2011

RELATIVE ABUNDANCE AND HABITAT ASSOCIATIONS OF LEAST BITTERNS (Ixobrychus exilis) AT LONG POINT, LAKE ERIE, ONTARIO

Nickolas D. Bartok

RELATIVE ABUNDANCE AND HABITAT ASSOCIATIONS OF LEAST BITTERNS (*Ixobrychus exilis*) AT LONG POINT, LAKE ERIE, ONTARIO

(Spine Title: Relative Abundance and Habitat Associations)

(Thesis Format: Monograph)

by

Nickolas D. Bartok

Graduate Program in Biology

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

School of Graduate and Postdoctoral Studies
The University of Western Ontario

THE UNIVERSITY OF WESTERN ONTARIO
SCHOOL OF GRADUATE AND POSTDOCTORAL STUDIES

CERTIFICATE OF EXAMINATION

Supervisor	Examiners
Dr. Scott Petrie	Dr. Brent Sinclair
Co-supervisor	Dr. Brian Branfireun
Dr. Hugh Henry	Dr. Jane Bowles
Supervisory Committee	
Dr. Chris Guglielmo	
Dr. Jane Bowles	

The thesis by

Nickolas D. Bartok

entitled:

Relative Abundance and Habitat Associations of Least Bitterns (*Ixobrychus exilis*) at Long Point, Lake Erie, Ontario

is accepted in partial fulfilment of the
requirements for the degree of
Master of Science

Date____________________

____
Chair of the Thesis Examination Board

ABSTRACT

The Least Bittern is a threatened species in Canada, with an estimated 1500 breeding pairs. I estimated relative abundance and determined habitat associations of Least Bitterns at Long Point, Lake Erie, Ontario. I conducted call-broadcast point counts during 2008 and 2009 with 96 and 197 individual Least Bitterns detected, respectively. I estimated 195 pairs of Least Bitterns at Long Point and 1434 pairs in coastal wetlands of the Canadian lower Great Lakes. Habitat assessments identified percent cover of Cattail and Bulrush, and number of dead Cattail stems as the best predictors of Least Bittern presence. Interspersion and percent cover of Cattail and Bulrush influenced relative abundance at the survey station scale. The estimated number of breeding pairs in Canada is potentially biased low. Point counts should be continued to increase our understanding of Least Bittern ecology. I recommend managing wetlands to increase the amount of Cattail and interspersion.

Keywords: Least Bittern, habitat, interspersion, Long Point, relative abundance

STATEMENT OF CO-AUTHORSHIP

As the first author I was in charge of literature review, study design, fund raising, data collection, analysis, and the monograph. I received draft edits of the monograph from: Benoît Jobin (CWS), Dr. Scott Petrie (LPW), Dr. Michael Schummer (LPW), Dr. Shannon Badzinski (CWS, formally LPW), Dr. Hugh Henry (UWO), and Dr. Chris Guglielmo (UWO).

This monograph will be broken down into two manuscripts for publication. Manuscript one will focus on abundance of Least Bitterns at Long Point, Lake Erie. It will be co-authored by: Dr. Scott Petrie, Dr. Michael Schummer, and Dr. Shannon Badzinski.

The second manuscript will focus on habitat use of Least Bitterns at Long Point, Lake Erie and will have the same authors as the first manuscript. I will be in charge of manuscript revisions and the publication process.

This thesis is dedicated to Ken Cox
A passionate wetland advocate
An uncle of grand proportions and wonderful role model
You are missed
Rest in Peace

ACKNOWLEDGEMENTS

Funding for this research project was provided by Long Point Waterfowl (LPW), Environment Canada (EC) – Canadian Wildlife Service – Ontario Region, Ontario Ministry of Natural Resources (OMNR), Bird Studies Canada (BSC), Nature Canada, Canada-Ontario Agreement, the World Wildlife Fund Canada, and S.C. Johnson and Son Ltd. and the Bluff's Hunt Club.

I would especially like to thank the federal, provincial and private wetland managers for allowing me access to the protected areas to conduct my research. Jeff Robinson and Danny Bernard, Environment Canada, for access to Long Point and Big Creek National Wildlife Areas, providing housing at the tip of Long Point and for the numerous boat rides and logistical support. Dave Richards and Rick Thompson, with the Ontario Ministry of Natural Resources, for access to the Crown Marsh, and Sandy Dobyn, John Marchington and Lyle Harper, with Ontario Parks, for access to Long Point Provincial Park. I would also like to thank Ray Ferris (Turkey Point Hunt Club), Emile Vandommele (Murray Marsh Hunt Club), Kim Brown (Lee Brown Wildlife Management Area) and David Walmsley (Long Point Company) for providing access to these private hunt clubs. Thanks also to Fin & Feather Marina for allowing me to launch canoes from their docks.

I would like to thank my advisor and friend Dr. Scott Petrie for providing support, encouragement, and trying to teach me to hunt turkeys; I have yet to bag one. I look forward to working and collaborating with Scott and LPW for many years to come. I would like to thank Dr. Shannon Badzinski for all of his statistical wizardry and wish him and his family much success in Ottawa. Much thanks to Dr. Michael Schummer for helping me through final revisions. I would also like to thank my scientific advisory committees at Long Point Waterfowl and the University of Western Ontario (UWO). Dr. Ken Abraham, Dr. Dave Ankney, Darrell Dennis, Dr. George Finney, Dr. Mark Gloutney, Shawn Meyer, and Rod Brook with LPW, and Dr. Hugh Henry, Dr. Chris Guglielmo and Dr. Jane Bowles at UWO. Thank you also to Dr. Bob Bailey for some early marsh bird discussions and improving my statistical abilities. Thanks to my fellow lab mates for all their tidbits of help: Rob Baden, Robin Churchill, Caroline Brady, Dave Messmer, Everett Hanna, Katie Stammler, and Sonja Teichert. Thanks to Carol Curtis at UWO for helping me keep my on campus school life organized.

I am forever grateful to all of my field technicians over the two field seasons; I would not have been able to accomplish any of this research without their help. I am especially glad to have the friendship and help of Lee Latramouille and Mike Seabert, who endured two summers with me tracking Least Bitterns and trudging the Long Point wetlands while trying to avoid ticks and thunder storms; you both know the stories! Also much thanks to Christina Kovacs, Magdalena Pilakowski, Amanda Richman, Jason Palframan, Ian Fife, Michelle Duong, and Sean Rapai. I would also like to thank volunteers Cara Adrain and Thierry Arsenault (a.k.a. Mr. T). I wish them all much success in their future endeavours. I would like to thank Bird Studies Canada for supplying Marsh Monitoring Program - Bird Surveys data, and all of the volunteer participants who gathered data for the project.

I received a lot of additional help, guidance and assistance from many people within LPW, BSC, OMNR, and EC. In order by organization: thanks to Ted Barney, Jim Cook (LPW); Stu MacKenzie, Yousif Attia, Ryan Archer, Kathy Jones, Dr. Phil Taylor, Anne Marie Ridout, Liane Varga, Andrew Couturier (BSC); Janice Gilbert, Kurt Olenburg, Silvia Strobl (OMNR); Andrew Taylor, Angela Darwin, Benoît Jobin, and Kim Laird (EC). Thanks also to Owen Steele for early guidance and discussions on waterfowl survey techniques and the possibilities of the relationship between waterfowl and Least Bittern habitat; it is now pretty safe to say there is!

Two people who really deserve a round of applause for all their assistance and guidance are: Jon McCracken and Laurie Maynard. Jon has been an inspiration, a wealth of knowledge and in a round-a-bout way, source of funding. Laurie gave me the ever so gentle nudge towards studying Least Bitterns and offered me work, which helped me to move back to Ontario; for this, my mum also thanks you. I am hugely indebted to the time and energy they put into this project and for all the long discussions on marsh birds, thank you!

I need to thank my fourth year honours undergraduate project advisor, Greg Michalenko. Without his encouragement to publish and present my thesis, I may not be in the situation I am in today; I wish him many fun adventures in his retirement. I would also like to thank Dr. Courtney Conway and Chris Nadeau of the University of Arizona, who put up with me for three fields seasons doing marsh bird point counts along the Colorado River and teaching me everything I know about identifying marsh birds.

I wish to thank all my friends and family for all their moral support and constant nagging for me to finish my thesis. Lastly, yet most importantly, I have to say thanks to my loving wife, of only 7 months, for allowing me to spend my summers away having fun chasing birds. She had to endure not seeing me for long periods of time and short phone calls during the summer months, all of which cut into her beach time, for this I apologize.

I will somehow try and make it up to you. I love you and look forward to growing old with you.

Table of contents

List of Tables

LIST OF FIGURES

LIST OF APPENDICIES

LIST OF ABBREVIATIONS

BBS	Breeding Bird Surveys
BSC	Bird Studies Canada
CLGL	Canadian Lower Great Lakes
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWS	Canadian Wildlife Service
EC	Environment Canada
LPW	Long Point Waterfowl
MMP	Marsh Monitoring Program
NLBSP	National Least Bittern Survey Protocol
NWA	National Wildlife Area
OMNR	Ontario Ministry of Natural Resources
PP	Provincial Park
SARA	Species at Risk Act
SWOOP	South Western Ontario Orthophotography Project
UWO	University of Western Ontario
WMA	Wildlife Management Area

1.0 Introduction

1.1 Least Bittern Life History

The Least Bittern (*Ixobrychus exilis*) is the world's smallest heron (Poole et al. 2009) and includes 6 subspecies. The body length and mass of a Least Bittern is between 28 – 36 cm and 36 g respectively (Poole et al. 2009). Males and females are similar in size, but are dimorphic in appearance; males having a contrasting black crown, nape, and back against the lighter coloured body. Use of large emergent wetlands by Least Bitterns and their brown and beige colours make them one of North America's most inconspicuous birds (Weller 1961). Food items used by Least Bitterns include: small fishes, amphibians, insects, small mammals, and vegetable matter (Poole et al. 2009). In Ontario, Least Bitterns arrive on breeding grounds at the end of April (*personal observation*) and begin calling for females using a distinctive "Coo-coo" call. Nests are built by bending live and dead vegetation around rigid plant stalks, usually 60 – 90 cm above water (Poole et al. 2009). On average Least Bitterns lay 6 eggs (Ontario range = 3 – 7 eggs, *personal observation)*. Least Bittern chicks leave the nest ≥ 6 days after hatch and fledge at 25 – 27 days (Bogner and Baldassarre 2002, Poole et al. 2009).

1.2 Least Bittern Population Status

Despite the fact that Least Bitterns occur throughout much of North America and many areas of South America (Figure 1.1), little is known about their population dynamics or habitat use. This lack of knowledge can largely be attributed to the secretive nature of Least Bitterns (Weller 1961; Bogner and Baldassarre 2002; Poole et al. 2009), apparent declines in populations throughout North America (James 1999; Poole et al.

2009), and limited monitoring efforts. Least Bittern population declines in Canada led to the species being listed as Special Concern in 1988 and subsequent listing as Threatened in 2001 (COSEWIC 2009). North American Breeding Bird Surveys (BBS) suggest that the North American population of Least Bitterns decreased by 43% during 1984-1993 (Price et al. 1995). Subsequent to that, data from the Great Lakes Marsh Monitoring Program (MMP) suggest annual population declines of 6.7%, 12.8% and 14.4 % for Lakes Ontario, Erie and Huron, respectively, from 1995-2004 (Timmermans et al. 2008). However, population trends for Least Bitterns, derived from BBS and MMP may not be reliable because many of the survey stations are located along roads or shorelines, which may not provide an adequate survey of Least Bittern habitat (Butcher 1989). Also, Least Bitterns are often not detected in large multi-species surveys of bird populations because of their secretive nature; hence data on population trends are contradictory and potentially unreliable (Poole et al. 2009). Based on population data deficiencies, there is limited information on Least Bittern populations and habitat use throughout their range and in particular, Canada.

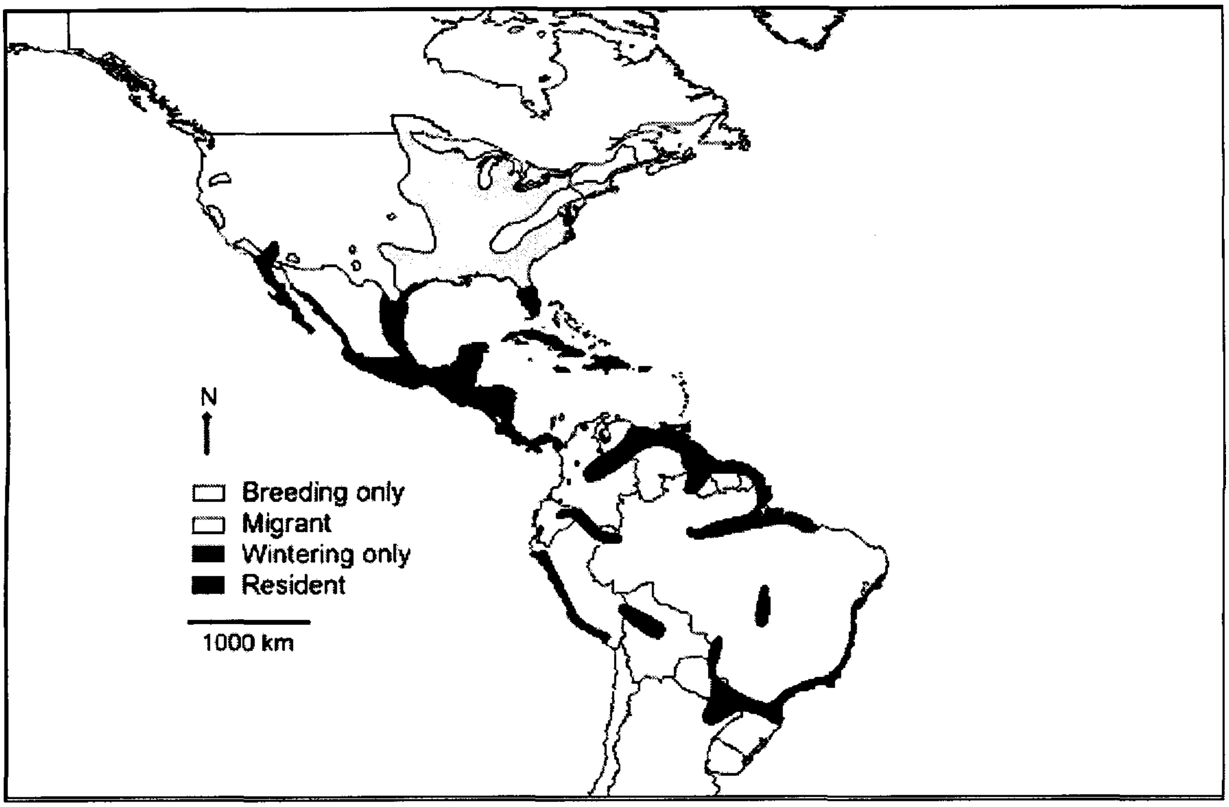


Figure 1.1 – Global range of Least Bitterns (Committee on the Status of Endangered Wildlife in Canada - COSEWIC 2009).

1.3 Least Bittern Canadian Status

The Canadian breeding range of Least Bitterns (Figure 1.2) is limited to southern Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia. The first Ontario Breeding Bird Atlas in the mid-1980s (Cadman et al. 1987) and the Ontario Rare Bird Breeding Program (Austen et al. 1994) suggested a provincial population estimate of 555 - 2360 breeding pairs. However, too few point counts were conducted during the second Ontario Breeding Bird Atlas (2001 - 2005) to provide a reliable abundance estimate of Least Bittern breeding pairs (Cadman et al. 2007), although frequency of occurrence was similar to the first atlas project (Woodliffe 2007). Based on limited knowledge of Least Bittern abundance, distribution, and the Species at Risk listing in Canada, a Least Bittern

Recovery Team was established in 2004, as a requirement of the Species at Risk Act (SARA), to identify and address recovery issues. Since 2004, surveys targeted at estimating Least Bittern abundance were conducted in Manitoba and Quebec using the methodology outlined in draft versions of the National Least Bittern Survey Protocol (NLBSP; Jobin et al. In press), but surveys did not begin in Ontario until 2007. Using abundance data from Breeding Bird Surveys (BBS), Marsh Monitoring Program (MMP), Provincial Atlas data, and targeted surveys, the Least Bittern Status Report (COSEWIC 2009) estimated the population of Least Bitterns in Canada at 1500 breeding pairs.

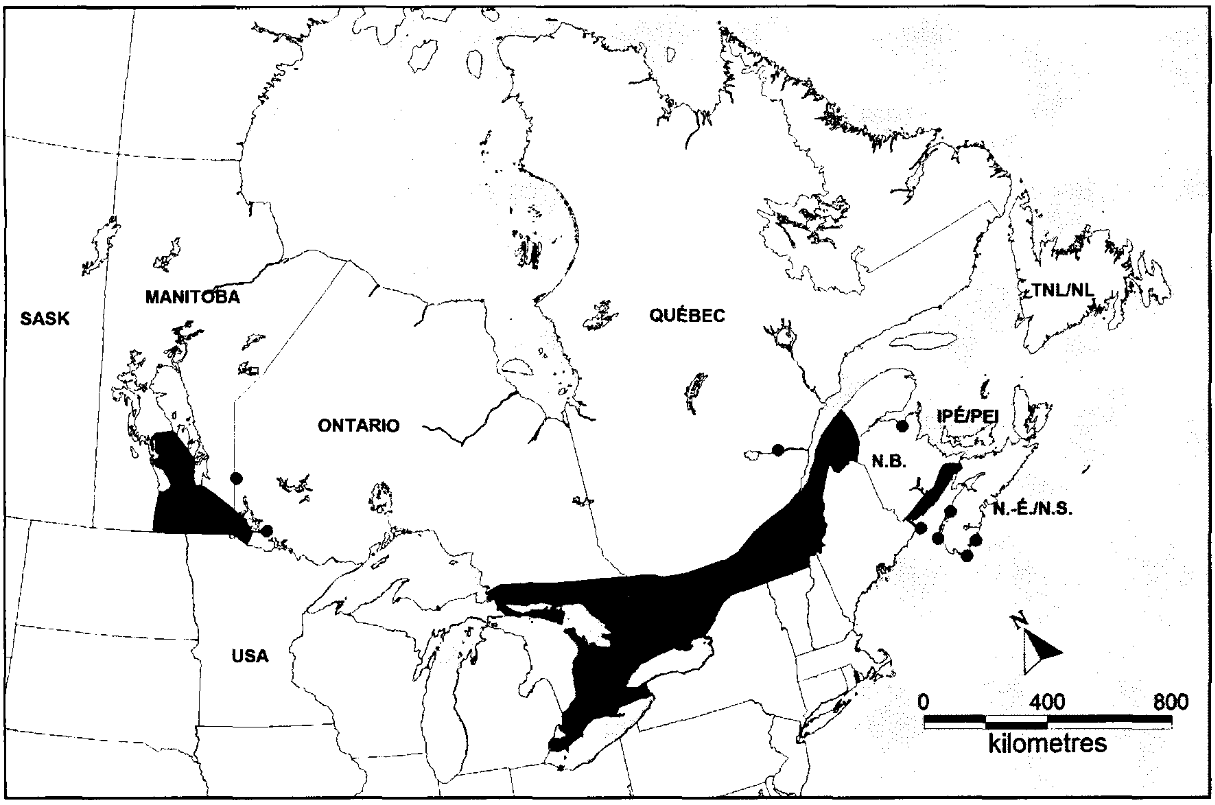


Figure 1.2 - Known distribution of the Least Bittern in Canada as of 2008; points indicate locations isolated from the known breeding range, where birds have been found during the breeding season (COSEWIC 2009).

1.4 Least Bittern Habitat

The Least Bittern is a migratory bird species listed under Schedule 1 of the federal Species at Risk Act because of its threatened status under COSEWIC, due to apparent historical declines throughout its Canadian range, potentially caused by the loss and degradation of wetland habitat. Least Bitterns require large patches of emergent wetland habitat (Poole et al. 2009), but many of these large wetlands have been drained or filled in the past century (Natural Resources Canada 2011; United States Environmental Protection Agency 2011). More than 90% of the original wetlands in southwestern Ontario are now gone (Ducks Unlimited Canada 2010) and less than 5% of western Lake Erie's original coastal wetlands remain (Herdendorf 1987). Anthropogenic influences are also impacting remaining wetland habitat in Ontario, including introduction of invasive species, channelization and water management, each with a myriad of effects that may or may not affect Least Bitterns.

Decreases in water levels in the lower Great Lakes are of concern because of potential wetland loss, degradation, and introduction of invasive species (Steen et al. 2006). Lake Erie in particular had a wide range of water level fluctuations from 1860 – 2010 and stable levels during this study; however, general declining water levels from 1995 - 2002 (National Oceanic and Atmospheric Administration 2011). Least Bittern annual abundance indices from 1995 - 2002 are positively correlated to water levels in Lake Erie (Timmermans et al. 2008). Recent research using general circulation models to couple climate change scenarios with Great Lakes hydrologic models predict continued water level declines (Swartz et al. 2004). Also, Great Lakes coastal wetlands experience frequent changes in vegetation composition from fluctuations in climate and water levels (Leahy et al. 2005). Based on predicted changes in wetland community composition, it is important to identify habitat used by Least Bitterns so researchers can predict how future changes could influence Least Bittern populations and habitat use.

Phragmites australis (Cav.) Trin. ex Steudel *americanus* and *Phragmites australis* subsp. *australis* (hereafter *Phragmites)* are tall cane-like perennial grasses that grow in aquatic, semi-aquatic, and terrestrial habitats (Marks et al. 1994), with the latter species being a non-native genotype. Although both species are similar in appearance and grow in the wetlands around Long Point, Ontario, *Phragmites* has expanded throughout many lower Great Lakes coastal wetlands (Catling and Carbyn 2006), including Long Point (Wilcox et al. 2003). The invasion of *Phragmites* is changing coastal wetland plant communities from diverse emergent marsh habitat to monotypic stands of *Phragmites* that may adversely affect waterbirds (Poole et al. 2009; Meyer et al. 2010). Therefore, wetland managers are concerned about *Phragmites* expansion and the effects it will have on waterbirds (Meyer et al. 2010).

Federal, provincial, and private agencies manage wetlands in an attempt to maintain a 'hemi-marsh' state to benefit a diversity of wildlife. Weller and Spatcher (1965) first described hemi-marsh as a wetland with an equal ratio (1:1) of emergent cover and open water (cover-to-water ratios) distributed in an "interspersed" pattern. Interspersion is defined as the amount of mixing that occurs between the wetland features of vegetation and water. Interspersion can be measured by the amount (m/ha) of interface between vegetation and water (Rehm and Baldassarre 2007). Vegetation management is occurring on some Lake Erie coastal wetlands, primarily in the form of channelization, which increases interspersion. This management to increase interspersion could benefit Least Bitterns, but has yet to be studied in Canada.

1.5 Overall Study Objectives and Predictions

The Least Bittern population has apparently declined in Canada with the loss and degradation of wetland habitat in the last century; however, the status of the population in Ontario is currently unknown (Cadman et al. 2007). My first objective was to use the NLBSP to estimate the distribution and relative abundance of Least Bitterns in several study wetlands at Long Point (Table 2.1), Lake Erie. A study in 2007 using the NLBSP at 83 survey stations estimated 47 individual Least Bitterns in Big Creek National Wildlife Area and the eastern portion Long Point National Wildlife Area (Environment Canada unpublished data). Because I conducted Least Bittern surveys on the same 83 stations as the 2007 study and added 268 stations for a total of 351 in 2009, I predicted that I would detect over 200 individual Least Bitterns using the new survey protocol.

There is a lack of specific information pertaining to habitat use and wetland selection by Least Bitterns, particularly in Ontario (Environment Canada 2010). Least Bitterns most commonly occur in emergent wetlands with open water where "hemi-marsh" conditions exist and the dominant vegetation is Cattail (*Typha latifolia*; *T. angustifolia*; DesGranges *et al.* 2006; Budd 2007; Rehm and Baldassarre 2007; Poole et al. 2009). However, Least Bittern associations with specific plant community composition, percent cover or height of emergent vegetation, and interspersion values, are unknown. Wetland managers and conservationists need basic information on habitat use and association by wetland obligate wildlife to manage wetlands properly so that they support, maintain, and increase species diversity. My second objective was to determine habitat associations of Least Bitterns. I predicted that Least Bitterns would mainly use Cattail dominated habitats, because Cattail is the dominant emergent vegetation at Long Point and is commonly used by Least Bitterns (Weller 1961; Post and Seals 1993; Rodgers and Schwikert 1999; Bogner 2001). I also predicted locations used by Least Bitterns would be 50% Cattail and 50% open water (Hay 2006). I predicted Least Bitterns would use habitat with an equal mix of live and dead Cattail stems and a water depth of 20-80 cm (Weller 1961; Reid 1989; Post and Seals 1993; Bogner 2001). I predicted a negative relationship between relative abundance of Least Bitterns during the breeding season and *Phragmites* (Meyer et al 2010), as Least Bitterns do not typically associate with this invasive species. I also predicted that relative abundance of Least Bitterns would be related with interspersion at the wetland and survey station scales as Least Bitterns may be responding to interspersion at different scales (*sensu* Rehm and Baldassarre 2007). Results from this project will be used to identify Best Management Practices and help meet two of the priorities in the National Least Bittern Recovery Strategy: 1) estimate distribution and relative abundance of Least Bitterns in Long Point area wetlands and 2) identify habitat associations of Least Bitterns (Environment Canada 2010).

2.0 Methods and Experimental Design

2.1 Study Area

The Long Point region of northern Lake Erie (Figure 2.1) has been designated a World Biosphere Reserve, an Important Bird Area, and a Provincially Significant Wetland complex. The Long Point region comprises 26,250 ha of coastal wetlands and is an example of a Great Lakes coastal ecosystem with several habitats, including long uninterrupted beaches, undisturbed sand dunes, grass ridges, wet meadows, woods, emergent wetlands and ponds, cold water streams, and the shallow Inner Bay.

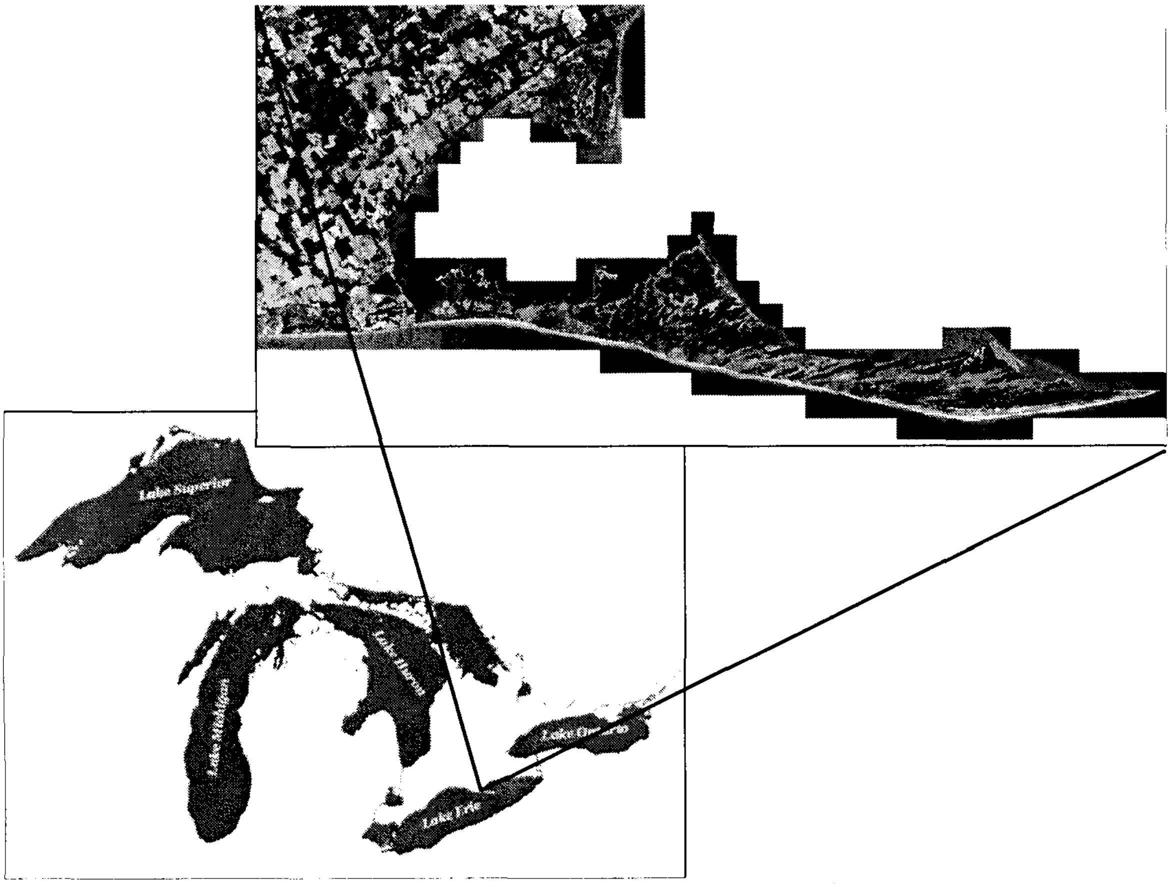


Figure 2.1 – Map of the Great Lakes Region (lower) and the Long Point Region (upper - Ontario Ministry of Natural Resources 2006) of Lake Erie, Ontario, Canada.

I sampled emergent wetlands within 6 independently managed properties in the Long Point Region for Least Bitterns in 2008 and 8 in 2009 (Figure 2.2, Table 2.1) and performed point counts at 193 and 351 survey stations in 2008 and 2009, respectively. The study wetlands are protected by federal, provincial, or private entities, which have resulted in limited overall loss of wetland size and function; however, levels and types of management vary by wetland (See Appendices 1 – 8). Wetlands surveyed in 2008 included Turkey Point, Murray Marsh, Long Point Company (only a small portion, approximately 4%, of Long Point Company Marsh was surveyed due to limited access), Crown Marsh, Long Point Provincial Park and Long Point National Wildlife Area. In 2009, I added two study sites in the Big Creek National Wildlife Area, the Lee Brown Waterfowl Management Area and 4 additional study sites in Long Point National Wildlife Area to increase area surveyed. All of the surveyed wetlands have historical evidence of Least Bittern activity and/or breeding (Woodliffe 2007). Wetland size was approximated using air photos imported into ArcGIS (ESRI 2011). Air photos were taken as part of the South Western Ontario Orthophotography Project (SWOOP; Ontario Ministry of Natural Resources 2006).

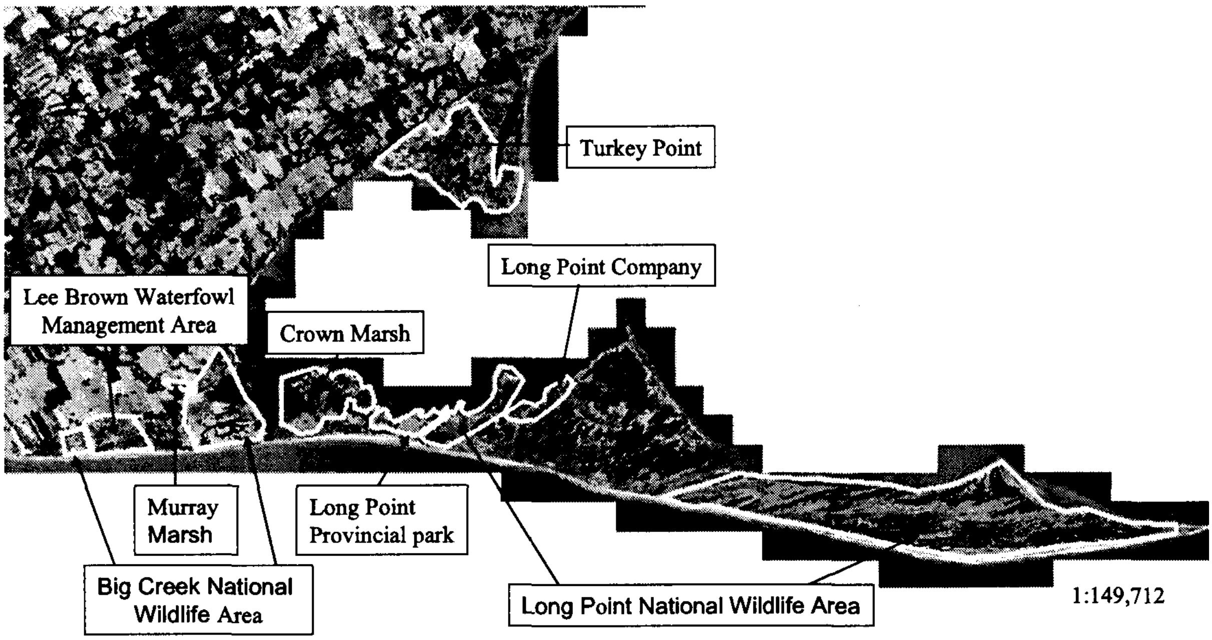


Figure 2.2 – Map of Long Point region showing the eight independently managed properties. The non-bordered area in the centre of the Figure is also part of Long Point Company; I only had access to a small northwest portion.

Table 2.1 - Number of survey stations, number of routes, and size of the study wetlands in the Long Point Region of northern Lake Erie, Ontario, Canada.

	# of Stations 2008	# of Stations 2009	# of Routes	Area Surveyed (ha)[d]
Big Creek NWA[a]	N/A	38	5	665
Crown Marsh	54	55	6	518
Lee Brown WMA[b]	N/A	31	3	221
Long Point NWA	32	102	11	1013
Long Point PP[c]	15	15	2	111
Long Point Company	9	9	1	90[e]
Murray Marsh	12	12	1	22
Turkey Point	71	89	9	924

Notes

[a]NWA = National Wildlife Area
[b]WMA = Wildlife Management Area
[c]PP = Provincial Park
[d]Size is an approximation based on mapping used for interspersion analysis
[e]Long Point Company encompases roughly 2300 ha; I only had access to a small portion

2.2 Survey Station Setup and Call-broadcast

I visually inspected satellite images (Google Earth) and air photos (SWOOP data) to obtain information on wetland characteristics (i.e. channels and site access) and confirmed these characteristics by visiting wetlands. I established survey stations in each wetland at 250 m intervals (Jobin et al. In Press). Survey stations were positioned along routes, with a maximum of 12 stations per route, the number of survey stations that could be completed in one morning between 30 min prior to sunrise and 1000 hrs. One to nine survey routes were established depending on wetland size resulting in 20 and 38 routes during 2008 and 2009, respectively. Survey stations and routes were visited prior to conducting surveys to validate access and identify potential problems with station positioning. Survey stations and routes were positioned along wetland-open water interfaces and within stands of emergent vegetation (e.g. Cattail and *Phragmites*). If coverage of habitats could not be obtained using wetland-open water interfaces, survey stations were established and accessed by walking through wetland habitat (for example in the middle of a *Phragmites* stand). In some cases there were relatively large distances between survey stations (see Appendices 1 - 8), where non-emergent habitat (e.g. Grass and Sedge) allowed for detection of Least Bitterns at greater distances (Ribic et al. 1999). Survey stations were located using a Garmin Rhino® 130 handheld GPS unit with accuracy of 3-5 m. The number of survey stations per wetland also was dependent on the size of the wetland (range = 6 – 89 stations). Co-ordinates were recorded for each survey station and stations were marked with flagging tape to ensure survey locations were standard among visits. Maps showing survey stations were created in Google Earth to assist surveyors with locating stations and accessing sites. Survey routes were travelled by foot, canoe, and motorized boat.

Call broadcasts following the NLBSP were conducted at each survey station and were full circular plots. Call broadcasts were unlimited-radius point counts (i.e. all Least Bitterns heard or seen, regardless of distance, were recorded), utilizing call response broadcasts to elicit responses from Least Bitterns. I provided pre-season training of survey protocol methods to technicians. Surveys were conducted from 5 June to 15 July 2008 and 20 May to 22 July 2009. A minimum of 2 visits were made to each survey station in 2008 (47 of 193 survey stations were completed three times), and 3 visits were made to each station in 2009. At least 3 surveys are needed to confirm with 90% certainty seasonal presence/absence of some wetland birds (Gibbs and Melvin 1993). Visits were ≥10 days apart to decrease frequency of disturbance to nesting birds. Surveys were not conducted in rain, fog, extreme heat (>35 degrees Celsius) or winds exceeding 15 km/h (Conway 2009). Wind and temperature were measured using a Kestrel 2500 meter (Nielsen-Kellerman, Inc., Boothwyn, PA, USA).

Surveys were 13 min in length and consisted of 5 min of passive listening, 5 min of call broadcast (each minute included 30 sec of the Least Bittern 'Coo' call and 30 sec of silence), and 3 minutes of passive listening (Jobin et al. In Press). Least Bittern calls were broadcast at a sound pressure of 90 decibels measured with a portable sound meter at 1 m in front of the speakers and were played at or just above water level from a portable MP3 player and 'clam' speakers. Surveyors worked in pairs to increase the likelihood of Least Bittern detection (Conway 2009). Because call types have been suggested as a way to differentiate among mate attraction ('Coo' call), mate communication/alarm ('Kak' call); and alarm ('Ert' call; Conway 2009) surveyors noted calls heard during survey broadcasts and type of call.

2.3 Habitat Assessments and Interspersion

2.3.1 Circular Plots (Macrohabitat)

In 2009, at each survey station (n = 351), I visually estimated percent cover of 8 vegetation types and 3 non-vegetative features within 50 m of the centre of the survey station (i.e. 100 m diameter plots). I designated the 8 dominant vegetation types as Cattails (*Typha* spp.), Sedges and Grasses (*Carex* spp.; Poaceae), Burreeds (*Sparganium* spp.), Bulrushes (*Scirpus* spp.), Common Reeds (*Phragmites* spp.), Shrubs and Trees, Floating Vegetation and Other species. The dominant shrub encountered was Alder (*Alnus* spp.), the dominant tree was Willow (*Salix* spp.), and the dominant floating vegetation was Yellow Pond Lily (*Nuphar lutea*) and White Water Lily (*Nymphaea odorata*). The 3 non-vegetative features were Bare Soil, Open Water, and Man-made Structure. I estimated percent cover of habitat features (Conway and Sulzman 2007) for areas with boat access by standing on the bow of a boat. For land based survey stations, I estimated percent cover of habitat features by standing at the middle of the survey station or from a nearby elevated location (i.e. walking up a hill or standing on a car).

2.3.2 Quadrats and Water Depth (Microhabitat)

In 2009, microhabitat and water depth assessments were conducted at all survey stations where one or more Least Bitterns were detected within 50 m of the survey station and one additional randomly selected survey station where a bittern was not detected in the same study wetland. I also assessed microhabitat and water depths at 2 randomly selected survey stations along survey routes with no Least Bittern detections.

I assessed habitat along four 50 m transects at each selected survey station. I selected a random transect direction for each quarter of a circle, for a total of 4 transects per circle (i.e. 0-90, 91-180 181-270, and 271-360 degrees). I measured water depth every 10 m (0, 10, 20, 30, 40 and 50 m) along transects ($n = 21$ water depths per habitat assessment). I placed a 1 m^2 quadrat randomly at 1-25 m and another at 26-50 m along each transect ($n = 9$ quadrats per habitat assessment). I counted the number of stems and maximum stem height of all live and dead vegetation types within each quadrat.

2.3.3 Interspersion

Air photos were acquired from SWOOP, which flew air photo transects in 2006 to produce 1 km^2 tiles for all of southwestern Ontario with a 0.3 m × 0.3 m resolution. To acquire a measure of interspersion at the wetland scale I created an air photo mosaic or orthophoto for each study site using PCI Geomatica 10 (PCI Geomatics Enterprises Inc. 2007). I extracted the study sites from the orthophotos using the ArcMap 9.3 extract function and performed a supervised image classification by setting training sites for water and vegetation using PCI Geomatica 10. To test the accuracy of the image classification I performed a post-classification analysis by selecting 200 random pixels and determined whether each pixel was classified correctly. Lastly, I filtered the image in IDRISI Kilimanjaro (Eastman 2003) to remove scattering of individually associated water or vegetation pixels and used the PERIM function to get a measure of edge length (m).

To determine interspersion at the survey station scale, I first imported the survey stations into ArcMap 9.3 and converted them from vector to raster format. Second, I created a uniquely identified 50 m buffer around each survey station. Third, I combined (or overlaid) the resulting buffer image and the classified wetland scale image. Lastly, I used the PERIM function to get a measure of edge length (m) for each survey station in each wetland. At the survey station scale, I used IDRISI Kilimanjaro to obtain edge length (m) for each survey station. Interspersion values are expressed as m / ha (Rehm and Baldassarre 2007).

2.4 Data Analysis

2.4.1 Relative Abundance of Least Bitterns

Relative abundance of Least Bitterns at the wetlands scale was determined as the maximum number of Least Bitterns detected for each survey route across the 3 route visits and summing all routes within a wetland (Ralph et al. 1995). Relative abundance is presented as the number of Least Bitterns per survey station (birds / survey station). I chose this method of estimating relative abundance because it takes into account temporal variation in detection and ensures 90% confidence in abundance estimates (Gibbs and Melvin 1993). Detection of bitterns may not have been independent among stations (i.e. the same individual Least Bittern may be detected at multiple survey stations); thus, surveyors used directional spot mapping to identify when detections of Least Bittern were likely unique (Conway 2009). Estimated relative abundance was determined for the survey station scale as the maximum number of Least Bitterns detected within 50 m for each survey station for each visit.

To estimate the number of Least Bittern pairs at Long Point, Lake Erie and in the CLGL coastal wetlands, I first used the maximum number of detections using the 'Coo' call for each survey station and summed all the stations. Second, I assumed each male detected had a mate, giving a number of pairs / ha in wetlands surveyed. Thirdly, I determined how much wetland habitat at Long Point was not surveyed during this study and extrapolated to provide an estimate of pairs at Long Point. Lastly, I used the number of Least Bittern pairs / ha at Long Point, assumed Least Bittern densities at Long Point were representative of all CLGL coastal wetlands, and extrapolated to an estimated number of pairs in all CLGL coastal wetlands. I estimated the Least Bittern population in the CLGL using 2009 data only, as greater area was surveyed and was surveyed more thoroughly (n = 3 visits per station; *sensu* Gibbs and Melvin 1993).

2.4.2 Presence / Absence Macrohabitat

I used stepwise binary logistic regression to identify vegetation types influencing Least Bittern presence within macrohabitat circular plots. I designated Least Bittern presence or absence as my response variable and the percent cover of the 11 vegetation and non-vegetation features were the explanatory variables. All 11 vegetation and non-vegetation independent variables were included in initial models and removed in a stepwise manner until only significant variables remained ($\alpha = 0.10$; SPSS 18.0). Second, I used independent sample t-tests to compare the percent coverage by each vegetation type or non-vegetative feature between stations at which we detected Least Bitterns and those lacking Least Bitterns ($\alpha = 0.10$; SPSS 18.0).

2.4.3 Presence / Absence Microhabitat

To determine if presence / absence of Least Bitterns was influenced by microhabitat features I first averaged the results of the 9 quadrats and 21 water depth measurements for each 50 m radius habitat assessment. I removed inter-correlated habitat variables prior to the stepwise binary logistic regression process by inspecting pair-wise scatterplots and correlation matrices. Where habitat variables were correlated ($r > 0.6$), I kept the variable with the greatest correlation to the response variable (Green 1979). I then subjected microhabitat variables associated with vegetation types retained in the macrohabitat analysis to a stepwise binary logistic regression ($\alpha = 0.10$; SPSS 18.0). Each vegetation variable had 5 associated explanatory variables: percent cover, number of stems live, number of stems dead, maximum height of live stems and maximum height of dead stems. Whether a Least Bittern was detected or not (within 50 m of the survey station) was the response variable.

2.4.4 Relative Abundance, Macrohabitat, and Interspersion

To analyze the relationship between relative abundance of Least Bitterns and interspersion at the wetland scale, I performed a linear regression ($\alpha = 0.10$; SPSS 18.0), using interspersion of the study wetland as the response variable and relative abundance of Least Bitterns as the explanatory variable. Outliers were determined by creating a box plot in SPSS 18.0.

At the survey station scale, I applied generalized linear mixed models to relative abundance data, incorporating habitat variables identified as influencing presence of Least Bitterns and interspersion (PROC GLIMMIX; SAS Institute Inc. 2008) Because data were skewed, I modeled the data as a Poisson distribution function using the Log Link function. I blocked by wetland (random effect) and designated habitat variables as fixed effects. My initial model included linear and quadratic relationships, interspersion, and the interaction between habitat variables and interspersion. Type 3 sum of squares were evaluated and the initial models were reduced using backwards elimination ($\alpha = 0.10$). I assessed over dispersion using the ratio of the generalized chi-square statistic and its degrees of freedom (SAS Institute Inc. 2008). A ratio close to 1 indicates variability in data has been properly modeled and little residual over dispersion (Schabenberger 2007). To ensure no statistical redundancy, I inspected correlation matrices before running models.

3.0 Results

3.1 Relative Abundance

In 2008, I conducted 433 point count surveys at 193 survey stations within 6 individually managed properties and detected Least Bitterns on 272 occasions. I estimated that 96 unique Least Bitterns were detected. The Turkey Point Marsh had the greatest relative abundance (0.62 birds / survey station), whereas the Murray Marsh had the least (0 birds / survey station - Figure 3.1). Mean relative abundance in 2008 for all study wetlands was 0.51 birds / survey station.

In 2009, I conducted 1026 point count surveys at 351 survey stations in 8 individually managed properties and recorded 712 detections of Least Bitterns. I estimate that 197 unique Least Bitterns were detected of which 118 or 61% were detected by the 'Coo' call, 32 were detected by the 'Kak' call (16%), 22 by the 'Ert' call (11%) and 24 by sight only (12%). The Crown Marsh had the greatest relative abundance (0.98 birds / survey station), whereas the Lee Brown Waterfowl Management Area had the least (0.07 birds / survey station – Figure 3.1). Mean relative abundance in 2009 for all study wetlands was 0.58 birds / survey station.

Using the estimated number of male Least Bitterns detected (using the 'Coo' call and not including birds detected by sight only) and assuming a mate accompanied each male, I estimate 118 pairs in the Long Point study wetlands in 2009. Because I only surveyed 90 of the available 2300 ha in Long Point Company, and assuming that the 3 male Least Bitterns detected at the 9 survey stations in 2009 in Long Point Company were representative of the entire wetland, I estimate 77 males (or pairs) within the Long Point Company. Thus, the Long Point Region contains 195 pairs of Least Bitterns or

13% (195 of 1500) of the COSEWIC estimated Canadian population. Extrapolating from the 195 pairs of Least Bitterns in the Long Point Region, I estimate that the 42259 ha of coastal wetland (Environment Canada 2003) in the CLGL may contain 1434 pairs of Least Bitterns.

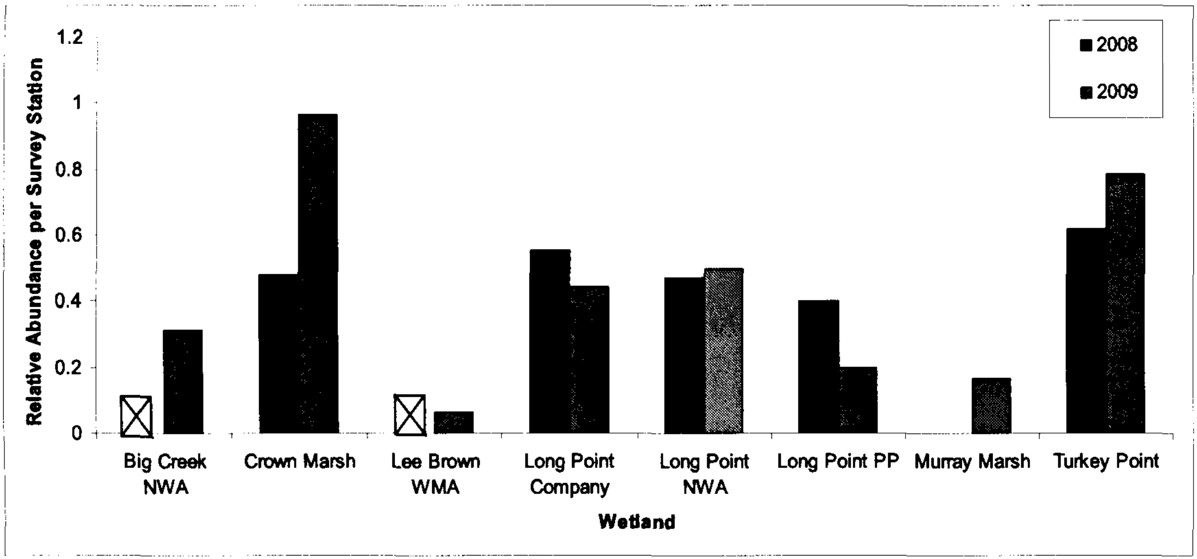


Figure 3.1 – Estimated relative abundance per survey station of Least Bittern by wetland and year. Big Creek National Wildlife Area (NWA) and Lee Brown Waterfowl Management Area were not surveyed in 2008 – denoted by a box with an X. Least Bitterns were not detected in Murray Marsh in 2008.

3.2 Presence / Absence Macrohabitat

I conducted 1053 point counts and recorded 712 detections (sight or aural) of Least Bitterns of which 197 were determined to be unique individuals. I assessed macrohabitat percent cover at 351 survey stations using a 50 m radius circular plot buffer. I used 344 50 m radius circular plots in analyses because 7 plots contained areas where not all habitat types could be determined because they were not visible. Probability of detecting a Least Bittern varied positively with Cattail (Table 3.1), Bulrush and Open Water. For each 10% increase in Cattail cover from 10 – 70%, the average predicted likelihood of detecting a Least Bittern increased by 10.2% (Figure 3.2), assuming mean percent cover values for Bulrush ($\bar{x} = 2.6\%$) and Open Water ($\bar{x} = 24.2\%$). Survey stations where I detected Least Bitterns within 50 m differed in vegetation composition compared to survey stations where I did not (Table 3.2).

Table 3.1 – Results of the stepwise binary logistic regression of the 50 m circular plot macrohabitat percent cover data. Least Bittern presence or absence was the response variable and the percent cover of the 11 vegetation and non-vegetation features were the explanatory variables ($n = 344$).

Effect	Estimate	Error	DF	*P*	X^2	Lower CI	Upper CI
Intercept	-2.653	0.467	1	<0.001	32.205		
Cattail	2.887	0.663	1	<0.001	18.970	0.780	1.727
Bulrush	4.291	1.897	1	0.024	5.117	0.509	3.219
Open Water	1.371	0.686	1	0.046	3.988	0.105	1.085

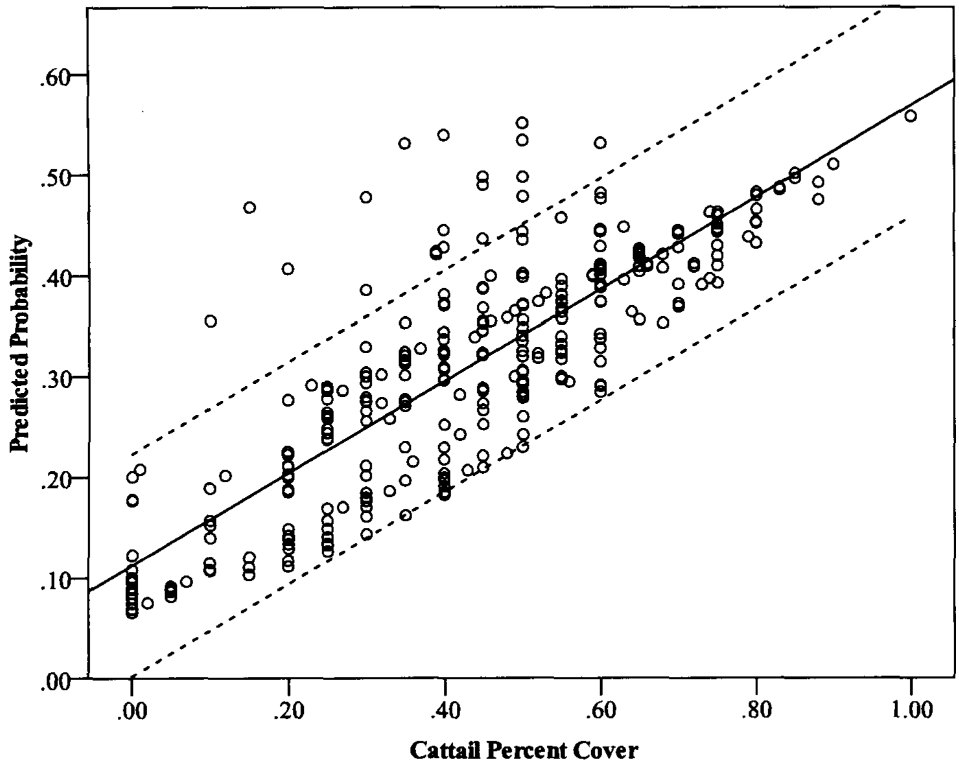


Figure 3.2 – Relationship between the predicted probability of Least Bittern presence and the observed proportion of Cattail percent cover (n = 344, u = 49.2%) using the 50 m Circular Plot data. Confidence intervals (90%) represented by dashed lines.

Table 3.2 – Results of the independent sample t-test of the 50 m circular plot data showing mean percent cover compared to presence / absence of Least Bitterns within 50 m of the survey station using 11 explanatory variables (n = 344).

All Stations		Survey Stations with Least Bitterns n = 105					Survey Stations without Least Bitterns n = 239						
					Range (%)					Range (%)			
Cover Type	Cover (%)	Cover (%)		SE	Low	High	Cover (%)		SE	Low	High	t	*P*
Cattail	42.1	49.2	±	2.0	0.0	100.0	39.1	±	1.4	0.0	88.0	4.085	<0.001
Trees and Shrubs	3.9	1.9	±	0.5	0.0	25.0	4.8	±	0.7	0.0	60.0	3.533	<0.001
Sedge and Grass	6.0	3.3	±	0.9	0.0	50.0	7.2	±	1.0	0.0	75.0	2.903	0.004
Phragmites	9.2	6.1	±	1.2	0.0	65.0	10.6	±	1.1	0.0	75.0	2.726	0.007
Other	0.8	0.4	±	0.1	0.0	10.0	1.0	±	0.3	0.0	29.0	2.072	0.039
Floating Vegetation	4.4	3.4	±	0.6	0.0	28.0	4.9	±	0.5	0.0	45.0	1.939	0.054
Bulrush	2.6	3.3	±	0.7	0.0	35.0	2.3	±	0.4	0.0	30.0	1.258	0.210
Open Water	24.2	25.7	±	2.2	0.0	76.0	23.6	±	1.5	0.0	75.0	1.079	0.281
Man-made Structure	0.3	0.2	±	0.1	0.0	10.0	0.4	±	0.1	0.0	20.0	0.800	0.424
Burreed	0.3	0.3	±	0.2	0.0	10.0	0.3	±	0.1	0.0	10.0	0.379	0.705
Bare Ground	0.3	0.3	±	0.2	0.0	13.0	0.3	±	0.1	0.0	25.0	0.198	0.843

3.3 Presence / Absence Microhabitat

I conducted 211 habitat assessments using quadrats and measured water depth at survey stations where at least one Least Bittern was detected (n = 97) and where none were detected (n = 114). The range of mean water depths at survey stations where Least Bitterns were detected was 2.96 – 107.83 cm ($\bar{x}$ = 54.4 cm), and mean water depths at stations were bitterns were not detected ranged from 3.92 – 111.17 cm ($\bar{x}$ = 49.3 cm). I analyzed Cattail and Bulrush microhabitat variables because they were retained in the macrohabitat assessment of Least Bittern presence / absence (See Section 3.2). Height of dead Cattail was removed due to high correlation with number of dead Cattail stems. The number of dead Cattail stems (Table 3.3, Figure 3.3) was retained in the analysis. Probability of detecting a Least Bittern varied positively with the number of dead Cattail stems (Table 3.3).

Table 3.3 – Results of the stepwise binary logistic regression of the 50 m circular plot microhabitat quadrat data. Least Bittern presence or absence was the response variable and the measurements of the 10 vegetation features were the explanatory variables (n = 211).

Effect	Estimate	Error	DF	P	X^2	Lower CI	Upper CI
Dead Cattail Stems	0.022	0.007	1	0.001	11.398	0.005	0.014
Intercept	-0.849	0.247	1	0.001	11.857		

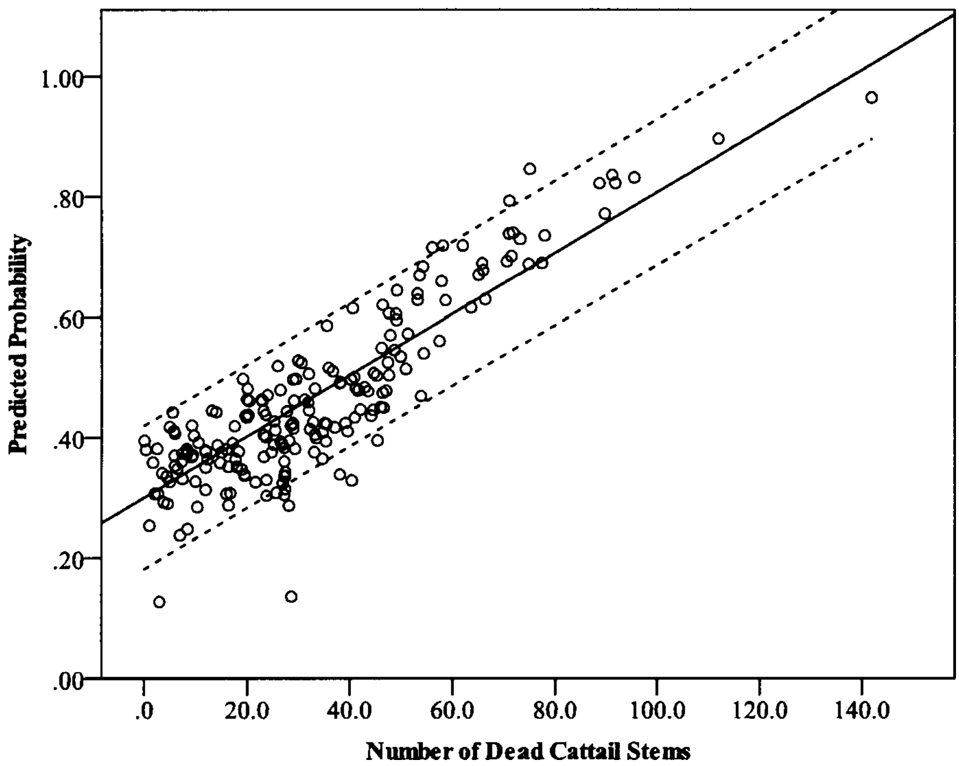


Figure 3.3 – Relationship between the predicted probability of Least Bittern presence and the observed number of dead Cattail stems (n = 211, u = 31.33, SD = 23.82) using microhabitat quadrat data. Confidence intervals (90%) represented by dashed lines.

3.4 Relative Abundance, Macrohabitat, and Interspersion

3.4.1 Wetland Scale

I determined interspersion values (m / ha) for 12 study sites within the 8 individually managed properties at the wetland scale (Table 3.4). I did not assess interspersion for the eastern portion of Long Point National Wildlife Area due to difficulty in differentiating between wetland area and terrestrial habitats using air photos. There was no influence of interspersion on relative abundance of Least Bitterns at the wetland scale ($P = 0.80$). To determine if an outlier (Big Creek NWA – Table 3.4) skewed the results, I removed the outlier from the analysis but the results remained non-significant ($P = 0.31$).

Table 3.4 – Individually managed properties and study sites indicating relative abundance in 2009 (birds / survey station), size and interspersion values.

Sites/Wetlands	Relative Abundance	Size (ha)	Interspersion (m / ha)
Crown Marsh	0.96	518.4	1658.7
Long Point NWA - Gravelly Land[a]	0.83	36.6	745.4
Turkey Point	0.79	924.3	1729.6
Long Point NWA - Squires Land	0.67	25.0	575.5
Long Point NWA - Thoroughfare Point	0.48	427.2	422.6
Long Point Company	0.44	90.1	804.2
Big Creek NWA	0.35	597.7	4010.5
Long Point NWA - Eastern Portion	0.33	481.8	N/A[b]
Long Point PP[c]	0.20	111.4	1690.7
Murray Marsh	0.17	22.3	1031.3
Big Creek NWA - The Hahn	0.17	67.3	532.6
Long Point NWA - Squires Cabin	0.10	42.7	659.4
Lee Brown WMA[d]	0.07	221.3	756.0

Notes

[a]NWA = National Wildlife Area

[b]Not Determined

[c]PP = Provincial Park

[d]WMA = Wildlife Management Area

3.4.2 Survey Station Scale

At the survey station scale, I determined relative abundance and macrohabitat percent cover data at all survey stations (n = 351). I removed survey stations from analysis due to missing macrohabitat data, pond dredging near a survey station after air photos were taken, mapping errors, and indiscernible interspersion values (Crown Marsh n = 4, Lee Brown WMA n = 3, Turkey Point n = 1, Long Point NWA – Squire Cabin n = 2, and Long Point NWA – Eastern Portion n = 42). Thus, I was able to determine interspersion values (m / ha) and conduct analyses using 299 survey stations. I analyzed Cattail and Bulrush macrohabitat variables because they were retained in the macrohabitat assessment of Least Bittern presence / absence. Percent cover of Cattail and Bulrush, and interspersion were retained in the analysis (Table 3.5). Relative abundance of Least Bitterns varied positively with percent cover of Cattail (range = 0 – 90%) and Bulrush (range = 0 – 35%), as well as interspersion (range = 0 - 12208 m / ha). An increase of 0.68 Least Bitterns / station is predicted by the model when Cattail is increased from 0 to 90% with Bulrush ($\bar{x}$ = 2.6%) and interspersion ($\bar{x}$ = 1667.1 m / ha) are held constant. When interspersion is varied from 0 to 12208 and Cattail ($\bar{x}$ = 42.1%) and Bulrush are held constant an increase of 0.64 least bitterns / station is predicted. However, if cattail and interspersion are both maximized (i.e. 90% and 12208 m / ha, respectively) the model predicts an increase of 2.15 least bitterns / station from mean conditions (i.e. 42.1% cattail and 1667.1 m / ha interspersion).

Table 3.5 – Results of the Generalized Linear Mixed Model of Relative Abundance, Cattail, Bulrush, and Interspersion. Data modeled as a Poisson distribution function using the Log Link function of Proc GLIMMIX in SAS 9.2. Wetland was blocked as a random effect and all other variables as fixed. The initial model included linear and quadratic relationships and the interaction between habitat variables and interspersion. Type 3 sum of squares were evaluated and the initial models were reduced using backwards elimination ($\alpha = 0.10$).

Effect	Estimate	Error	DF	*P*	Lower CI	Upper CI
Intercept	-2.363	0.3449	9	<0.001	-2.407	-2.318
Cattail	2.101	0.4967	286	<0.001	2.039	2.164
Bulrush	3.247	1.4960	286	0.031	3.058	3.435
Interspersion	0.000	0.0001	286	0.096	0.000	0.000

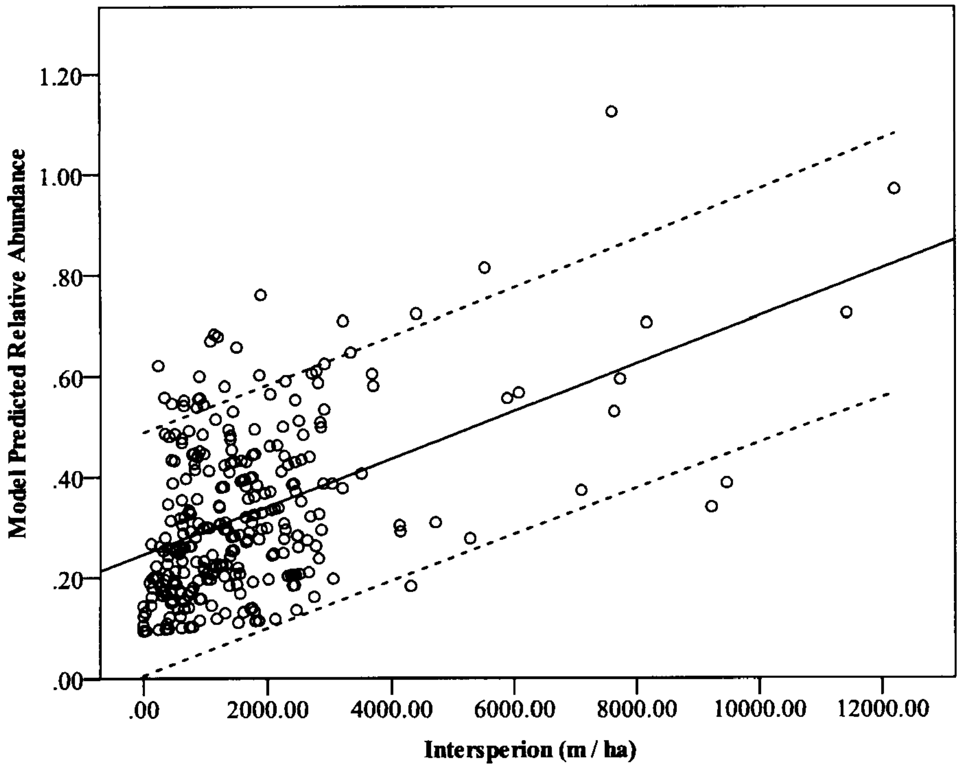


Figure 3.5 – Relationship between the model predicted relative abundance of Least Bittern and the calculated interspersion value (n = 299, u = 1667.10). Confidence intervals (90%) represented by dashed lines.

4.0 Discussion

4.1 Relative Abundance and Population

Historical surveys for Least Bitterns (i.e. BBS and MMP) do not provide reliable estimates of abundance, because they do not adequately survey Least Bittern habitat (Butcher 1989; Tozer 2007). Greater understanding of Least Bittern distribution and abundance would facilitate well-informed SARA policy and species designation decisions. In addition to information on distribution and abundance, an understanding of wetland habitat-Least Bittern associations would facilitate effective management of wetlands for Least Bitterns breeding in Canada. The NLBSP was created to increase precision of distribution and abundance estimates for Least Bitterns. In this study I used the NLBSP at Long Point, Lake Erie and demonstrated that use of the survey protocol resulted in substantial increases in detection when compared to MMP, which also conducted surveys at Long Point in 2008 and 2009 (0.12 birds / station and 0.08 birds / station in 2008 and 2009 respectively; Bird Studies Canada 2008). Results from my study supports previous suggestions that detections of Least Bitterns using the MMP may have been biased low because MMP does not survey appropriate Least Bittern habitat (Butcher 1989) and uses a different call broadcast technique from the NLBSP. The NLBSP protocol is designed to target Least Bitterns and increase detection probability compared to traditional methods such as passive listening (i.e. BBS) and multi-species call broadcasts (i.e. MMP) . For example, Least Bitterns may remain undetected with use of call-broadcasts < 30 sec, even if pairs of these birds nested within 25 m of call-broadcast locations (Tozer et al. 2007). The NLBSP methodology appears useful in detecting a greater number of Least Bitterns and should provide more accurate estimates of Least Bittern abundance.

The estimated population of Least Bitterns in Canada was recently increased from 1000 pairs to 1500 pairs based on additional abundance data from use of the NLBSP (COSEWIC 2009). Data from the 2001-2005 Breeding Bird Atlas suggests there were 555 – 2360 pairs in Ontario (Cadman et al. 2007). My estimated pair value within the CLGL (n = 1434) is within the range of the most recent Breeding Bird Atlas (Cadman et al. 2007); however, my pair estimate of Least Bitterns does not consider inland wetlands or other provinces. Therefore, the estimate of 1500 pairs of Least Bitterns used in SARA designation in Canada is potentially an underestimate. Additional surveys using the NLBSP throughout the Canadian breeding range of Least Bitterns may increase the accuracy of the estimated breeding population of these birds in Canada and in other countries; thus, increased use of the NLBSP is recommended. I also recommend assessing the ability of the NLBSP to detect Least Bitterns by directly comparing it to other marsh bird monitoring protocols such as the MMP or the Standardized North American Marsh Bird Survey Protocol (Conway 2009). Use of several survey methods at the same survey stations would provide a comparison of methodologies, which would help determine the effectiveness and efficiency of using a multi-species approach to surveying Least Bitterns compared to targeted species approaches. A protocol comparison study would help assess the survey intensity needed to monitor Least Bitterns and other wetland obligate species, which would be beneficial to conservationists in terms of budgeting and time constraints.

I detected relatively clumped distributions of Least Bitterns in certain wetland areas (Figure 4.1 and 4.2). Although the term 'semi-colonialism' is not defined clearly in the literature (Meyer and Friis 2008), previous studies in Ontario (Meyer and Friis 2008) and Florida (Kushlan 1973) have suggested that Least Bitterns may nest semi-colonially. Least Bitterns appeared concentrated in central areas of The Crown Marsh and Turkey Point Marsh and seemed to avoid coastal edges, in particular at Turkey Point Marsh (Figure 4.2). These high concentrations may suggest semi-colonialism at Long Point, Lake Erie. Nesting semi-colonially may provide selective advantages for Least Bitterns, such as minimizing predation risk (Burger 1981). Alternatively, clumped distributions of breeding pairs may be facilitated by greater interspersion in habitats selected by Least

Bitterns (Rehm and Baldassarre 2007). Increased interspersion may increase visual barriers leading to smaller; more closely associated and therefore clumped territories. Further study is necessary to determine if clumped distributions confer increased recruitment (i.e. selective advantage) or if the distributions we observed were a product of habitat selection and interspersion.

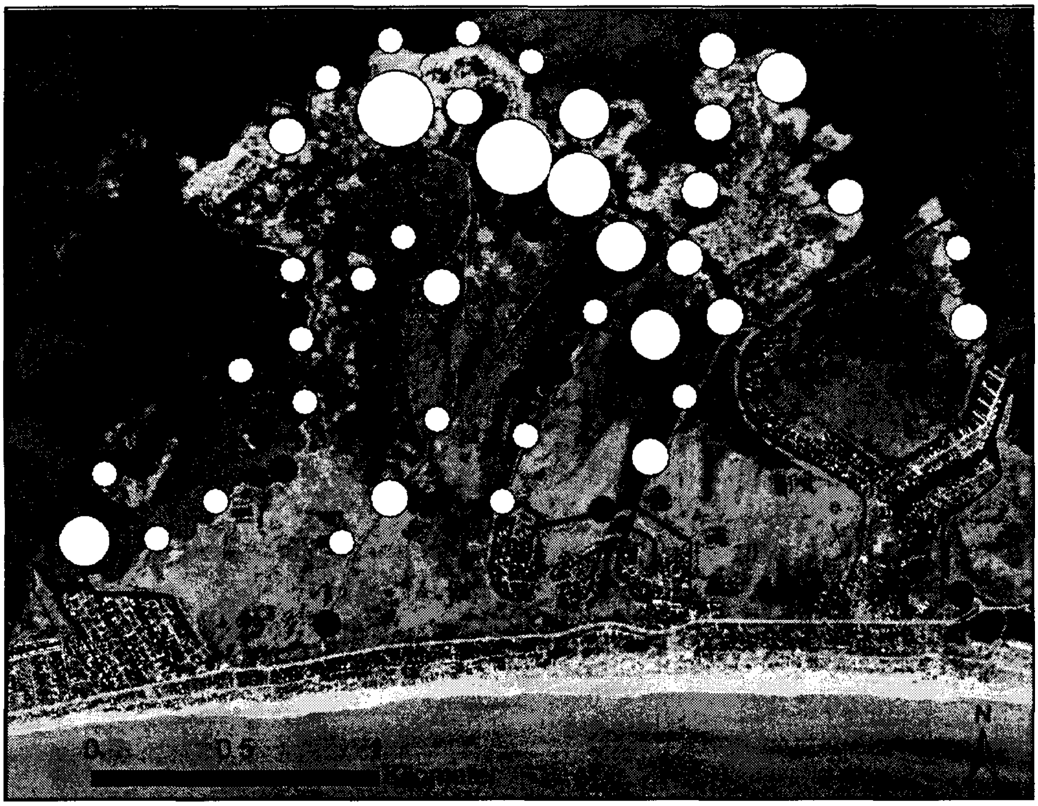


Figure 4.1 - Maximum relative abundance of Least Bitterns in the Crown Marsh by survey station, 2009; white circles represent the number of Least Bitterns detected at a survey station, range 1 (small) to 5 (large), black circles represent no detections.

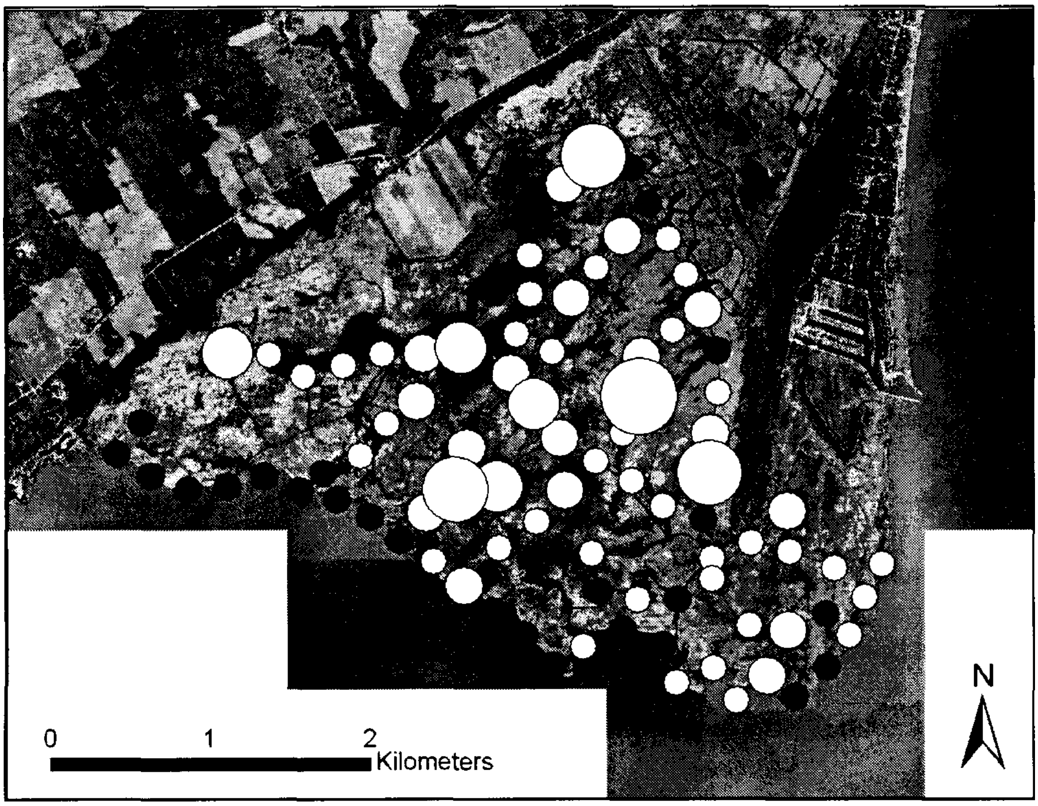


Figure 4.2 - Maximum relative abundance of Least Bitterns in the Turkey Point Marsh by survey station, 2009; white circles represent the number of Least Bitterns detected at a survey station, range 1 (small) to 5 (large), black circles represent no detections.

Survey methods that improve detection of avian species help increase accuracy of population estimates but also may provide a greater understanding of avian-habitat associations (Ralph et al. 1995; Carter et al. 2000). Determining habitat use by Least Bitterns in the CLGL may help increase accuracy of population estimate of these birds. In addition, determining Least Bittern habitat preferences would provide habitat management guidance to conservationists attempting to increase habitat suitability and availability for these secretive marsh birds.

4.2 Habitat Associations

Traditional monitoring programs such as BBS and MMP do not survey Least Bitterns effectively because many of the survey stations are located along roads or shorelines, which may not provide an adequate survey of Least Bittern habitat (Butcher 1989). Thus, determinations of habitat associations of Least Bitterns were previously not possible and knowledge on habitat use and selection by these secretive birds was lacking (Poole et al. 2009). Identifying habitat requirements in Canada is one of the objectives listed in the Recovery Strategy for Least Bitterns (Environment Canada 2010). In this study I identified habitat variables that influenced the presence and relative abundance of Least Bitterns in coastal wetlands at Long Point, Lake Erie. Historical and continued loss and degradation of wetland habitat is thought to be the most severe threat to Least Bitterns (Sandilands and Campbell 1988; James 1999; Poole et al. 2009) with most loss and degradation due to anthropogenic causes (COSEWIC 2009). However, it is possible that current wetland management techniques, such as increasing interspersion (primarily for waterfowl), are beneficial to Least Bitterns on the CLGL. My results could be used to guide protection and management of remaining wetland habitat in Great Lakes coastal habitats to maximize the efficiency and effectiveness of these conservation efforts.

Use and selection of wetlands by Least Bitterns is often associated with presence and abundance of dense, tall stands of emergent vegetation (primarily Cattail and Bulrush; Weller 1961; Post and Seals 1993; Rodgers and Schwikert 1999; Bogner 2001). Similarly, Least Bittern presence and relative abundance in this study were positively influenced by percent cover of Cattail and Bulrush at Long Point. Additionally, my investigation of microhabitat features determined that Least Bitterns were associated with an increased abundance of dead Cattail stems. As far as I am aware, this study is the first to assess specific microhabitat features associated with the presence of Least Bitterns and the first to identify dead Cattail as influencing the presence of Least Bitterns during the breeding season. As dead Cattail is the dominant habitat feature when Least Bitterns return to breeding sites at Long Point, I hypothesize that greater relative abundance of Least Bitterns in areas with dead Cattail was related to rigid stems that they use as habitat cues for nest site selection, settling, and support of a relatively large nest (Poole et al. 2009).

Least Bittern presence has also been associated with dense, tall growths of aquatic vegetation (particularly Cattail and Bulrush and to a lesser extent *Carex* and *Sagittaria*) interspersed with clumps of vegetation and open water (Poole et al. 2009). In this study, Bulrush was associated with Least Bittern presence; however, Bulrush was generally associated with Open Water (i.e. emerging through Open Water areas; *personal observation*; Pearson Correlation = 0.76). Least Bittern nests have been found in Bulrush (Weller 1961); however, Bulrush was not the dominant vegetation type at Long Point, nor were there any Least Bittern nests found in Bulrush in this study (*personal observation*). My results suggest that Cattail is the best predictor of Least Bittern presence and relative abundance, but management of wetlands for increased wetland diversity which includes areas of Bulrush and Open Water may provide habitat for Least Bitterns.

Within the family Ardeidae, species that depend on marsh habitat for breeding, such as Least Bittern, are often associated with sites characterized by interspersion of open water and vegetation (Crewe et al. 2006; Rehm and Baldassarre 2007). In my study, interspersion was not an important predictor of relative abundance of Least Bitterns at the wetland scale but was found to be influential at the survey station scale (i.e. within 50 m of a survey station). Therefore, breeding Least Bitterns likely respond to interspersion within their home range rather than that of the entire wetland. Alternatively, a lack of relationship between relative abundance and interspersion at the wetland scale may be related to reduced statistical power (Coefficient of Variation = 0.81), partially resulting from my small sample of study wetlands (n = 12). Least Bittern response to interspersion at the survey station scale may suggest that interspersion and associated visual barriers facilitates a greater number of territories and foraging areas. It is probable that Least Bitterns select habitat based on both interspersion and vegetation composition as these attributes influence foraging availability and nesting habitat quality (Poole et al. 2009).

Trees, Shrubs, Grass, Sedge, and *Phragmites* were underrepresented in areas occupied by Least Bitterns, but I did not detect an influence of these habitat features on presence of Least Bitterns. In other studies, Least Bittern nests have been found in stands of *Phragmites* (Bent 1926; Dillon 1959; Jobin et al. In press). Least Bitterns may use *Phragmites* for nesting because of similarity in form and rigidness to dead Cattail, but, at Long Point, lack of positive association between *Phragmites* and Least Bittern presence and relative abundance suggests that *Phragmites* is not a functional replacement for Cattail (Meyer et al. 2010). Further, selection for Cattail relative to *Phragmites* may result from the relative availability of these two habitat types, whereby Cattail is selected when available in abundance and *Phragmites* is used secondarily. Nonetheless, encroachment by Trees and Shrubs, as well as rapid expansion of *Phragmites* may reduce availability of Cattail habitat and reduce wetland interspersion (Wilcox et al. 2003). My results suggest that reductions in Cattail coverage and interspersion would negatively influence the relative abundance of Least Bitterns at Long Point coastal wetlands. *Phragmites* may not be a functional replacement for Cattail by Least Bitterns and, given rapid expansion of *Phragmites* in lower Great Lakes coastal wetlands, active control of *Phragmites* would likely benefit Least Bitterns through maintenance of quality habitat (i.e. Cattail and interspersion). Future studies could use radio-telemetry to track habitat use and selection by Least Bitterns and determine nest success of these secretive birds among different habitat types (e.g. Cattail, *Phragmites*).

4.3 Sampling Errors and Assumptions

Results of this study may have been skewed by sampling and mapping errors, limitations or assumptions. Similar to many studies of wetland obligate bird species, Least Bitterns are usually detected aurally instead of visually, which limits the ability to effectively document relative abundance, establish what habitat the birds are using (including water depth), or estimate distance. Gibbs and Melvin (1993) report that marsh bird presence and absence can be determined within 90% accuracy after 3 surveys have been conducted during the breeding season. In this study, I completed 3 surveys on each survey route and used detections of Least Bitterns within the 50 m buffer around survey stations for presence / absence analyzes. I did this to increase the detection probability, as the further away a Least Bittern is from the survey station the less likely it is to be detected (*personal observation*). Additionally, habitat information (i.e. percent cover) was collected by 6 different people and in some cases not all the habitat features were visible when conducting the 50 m buffer percent cover plots. Plots where any amount of area was determined as 'Not Visible' (i.e. habitat could not be seen) were removed from the analysis to eliminate ambiguity in the data.

To estimate the number of Least Bittern pairs in the CLGL I had to make three assumptions: 1) every Least Bittern detected with the 'Coo' call was a male (Conway 2009), 2) each detected male had a mate, and 3) the number of males detected on one route at Long Point Company was representative of the entire wetland property. As access was only provided to the shoreline of the northwestern portion of Long Point Company, constituting one route, I assumed the route habitat was representative to the entire property; however, Figure 4.1 and 4.2 suggest that Least Bittern relative abundance is quite low along coastal edges. With fewer Least Bitterns found at the coastal edges, it is likely that my estimate for Long Point Company and for Long Point is in fact a conservative estimate.

The methodology of determining interspersion likely provided a low estimate of interspersion due to filtering of the classified wetland images. Filtering was performed to remove independent 0.3 x 0.3 m classified pixels to produce a cleaner image and remove tiny pockets of open water which were deemed as classification errors or were too small to provide Least Bittern habitat. Keeping these pixels within the image would have greatly increased the interspersion value, but likely decreased accuracy of the classified pixels.

5.0 Management Implications

Preservation, protection, and enhancement of wetland habitats, particularly large (>10 ha), shallow wetlands with dense growth of robust, emergent vegetation (particularly Cattail), is the most urgent conservation need for Least Bitterns (Poole et al. 2009). The wetlands used in this study were large, shallow, and emergent wetlands known to have breeding Least Bitterns (Cadman et al. 2007); however, I had poor Least Bittern detection in some of these wetlands (See Chapter 2). Limited detection of Least Bitterns was likely the result of poor habitat quality, habitat characteristics not assessed in this study, or other biological factors (i.e. food availability).

A recently published study on bird use of *Phragmites* at Long Point found that *Phragmites* provides suitable habitat for a diversity of landbirds but only limited habitat for many marsh-nesting birds (Meyer et al. 2010). Other studies (Benoit and Askins 1999; Meyer 2003) also found negative correlations between *Phragmites* and marsh bird obligate species (e.g. *Raillidae*). The majority of *Phragmites* at Long Point is the non-native genotype and has become increasingly abundant in the CLGL over the past three decades (Lynch and Saltonstall 2002; Wilcox et al. 2003; Catling and Carbyn 2006; Frieswyk and Zedler 2007). Survey stations where Least Bitterns were detected had a lower percent cover of *Phragmites* than those where Least Bitterns were not detected; however, I did not detect an influence of *Phragmites* on relative abundance. As *Phragmites* is increasing exponentially in Lake Erie wetlands (Wilcox et al. 2003) by replacing Cattail, which appears to be the most important emergent vegetation for breeding Least Bitterns. There is concern about *Phragmites* reducing interspersion and habitat quality for Least Bitterns and other marsh obligate species; therefore, removal of *Phragmites* to increase interspersion and promote growth of Cattail should provide habitat for Least Bitterns and may benefit other species (Kaminski and Prince 1981; Rehm and Baldassarre 2007; Meyer et al. 2010). Interspersion and Cattail were both habitat features that influenced presence and relative abundance of Least Bitterns in my study.

Active management within Crown Marsh (Appendix 2) in the fall of 2008, between my two field seasons, entailed dredging of 3 ponds ≤ 5 ha. Reasons for dredging included, increasing the amount of open water and the removal of *Phragmites*. I detected nearly double the relative abundance of Least Bitterns at Crown Marsh in 2009 than in 2008 (Figure 3.1). The change in relative abundance between 2008 and 2009 may be directly related to habitat modifications, considering the other study wetlands had similar relative abundance between years (Figure 3.1).

Many marsh-nesting obligates (e.g. herons and bitterns) require openings within stands of emergent vegetation, as this provides access to nesting and foraging habitats (Manci and Rusch 1988; Gibbs et al. 1991; Benoit and Askins 1999). Openings in stands of Cattail may be created naturally by muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*) activities (Edwards and Otis 1999; Rehm and Baldassarre 2007) or through active management for open water habitats and boat channels in Great Lakes coastal wetlands. Management agencies and private land managers, such as hunt clubs, dredge openings in monotypic stands of Cattail and *Phragmites* to maintain or manage wetlands in a 'hemi-marsh' state to benefit a diversity of wildlife (Murkin et al. 2000) and allow access to wetlands for waterfowl hunting. These natural and anthropogenic openings increase interspersion and thus, benefit Least Bittern populations by providing necessary habitat for breeding and foraging. Interspersion was the best predictor of abundance for Least Bitterns in New York (Rehm and Baldassarre 2007) and was also a good predictor in this study. Therefore, coastal Great Lakes wetlands should be managed to increase interspersion. 'Hemi-marsh' conditions provide the necessary water openings and stands of vegetation that support Least Bitterns so long as the interspersion or edge density (m / ha) remains high. High interspersion in a 'hemi-marsh' could be achieved by creating many long sinuous channels through wetland habitat, thus providing wetland access and habitat for Least Bitterns, while still maintaining habitat for other marsh species. I strongly recommend managing coastal Great Lakes wetlands by increasing the amount of interspersion.

The Least Bittern is among the most inconspicuous of North American bird species (Poole et al. 2009). Studying Least Bitterns and other secretive marsh birds can be challenging as these birds are rarely seen. However, use of the NLBSP to study habitat use of Least Bitterns should continue and expand in future years, as traditional survey methods may not adequately survey Least Bitterns habitat. Results from this study will help wetland conservationists create, maintain, and manage wetland habitat to benefit Least Bitterns.

6.0 Future Research and Recommendations

My study addressed the lack of knowledge about the relative abundance of Least Bitterns in the Long Point region of Lake Erie; a priority described in the most recent draft of The Least Bittern Recovery Strategy (Environment Canada 2010). My study provided baseline data on relative abundance of Least Bitterns at Long Point for use in assessment of population trends. I encourage use of the NLBSP to assess the distribution, relative abundance and population trends of Least Bitterns throughout Canada. Long-term monitoring programs of breeding populations of Least Bitterns (i.e. NLBSP) are needed to determine trends in populations of these birds with precision.

The NLBSP not only provides data on distribution and relative abundance of Least Bitterns, but for other bird species as well. A knowledge gap not identified in the Recovery Strategy is to assess bird species relationships. For example, are Least Bitterns more commonly found in areas with high Marsh Wren (*Cistothorus palustris*) density? A study in northern Illinois compared the presence / abundance of other marsh birds in relation to Least Bitterns and found an association with Mute Swans (*Cygnus olor*) and Sora (*Porzana Carolina* - Ward et al. 2010). As part of the NLBSP, surveyors record detections and abundances of other marsh birds; therefore, the data are already available for analysis. If relationships can be identified between Least Bitterns and other marsh bird species, this may be an indicator of suitable habitat for Least Bitterns, regardless of if they are present in a wetland or not. Therefore, I recommend studying the habitat relationships of Least Bitterns to other marsh bird species in Canada. This information will provide land managers with an indicator as to whether a wetland is suitable for Least Bitterns.

It also would be valuable to undertake habitat modeling to determine the extent and amount of suitable habitat for Least Bitterns throughout Canada and elsewhere. There now may be enough existing information on habitat use in Canada [this study (2009), Ontario; Hay (2006), Manitoba; and, Jobin (2009), Quebec] to develop habitat models for Least Bitterns. After developing a reliable habitat model it could be combined with remote sensing of Canadian wetlands to assess available habitat in Canada for Least Bitterns. These models could also be applied to wetlands in other countries.

7.0 Best Management Practices for Least Bitterns in Southern Ontario Wetlands

Best Management Practices (BMP) are defined as "approaches based on known science that, if followed, should allow the client to meet the required standard(s) or achieve the desired objective(s)" (Ministry of the Environment 2011). I outline two BMP's that are necessary to monitor and maintain or increase the population of Least Bitterns in Southern Ontario.

BMP #1 *- Protect, create, maintain, and restore wetlands to promote growth of Cattail and increase interspersion*

- Remove stands of *Phragmites* to promote growth and expansion of Cattail.
- Dredge or channelize wetlands sinuously on an annual basis to promote increased interspersion of open water and emergent vegetation.

BMP #2 *– Assess distribution, relative abundance and population trends*

- Continue and expand use of the National Least Bittern Survey Protocol.
- Conduct long-term monitoring to assess population trends.

8.0 Conclusion

In conclusion, the results of this study supported some but not all of my predictions. I predicted that I would detect over 200 individual Least Bitterns, which was nearly the case in 2009 with 197 unique individuals detected (96 in 2008). Secondly, I predicted that the probability of detecting a Least Bittern would be greatest in areas with live and dead Cattail stems equal in number, a water depth of 20-80 cm and low percent cover of *Phragmites*, and that interspersion would influence relative abundance. My prediction of finding Least Bitterns in areas with an equal number of live and dead Cattail stems was not supported. The number of Cattail dead stems was a significant variable in the probability Least Bittern presence. My prediction of finding Least Bitterns in areas where the range in water depth was 20-80 cm was similar. My prediction of finding Least Bitterns in areas with lower percent cover of *Phragmites* was correct. There was significant difference in the percent cover of *Phragmites* between survey stations where Least Bitterns were present compared to stations where they were not present. My prediction that interspersion at the wetland and survey station scales would be correlated with Least Bittern relative abundance was not correct; there was only a relationship between relative abundance and interspersion at the survey station scale.

Overall, in 2008 (n = 193 survey stations), I recorded 272 Least Bittern detections of which 96 were estimated to be unique (0.49 birds/ survey station), whereas in 2009 (n = 351 survey stations) I had 712 detections estimated as 197 unique Least Bitterns (0.56 birds / survey station). Relative abundance differed substantially among surveyed wetlands and between years with a range of 0 – 0.62 birds / survey station in 2008 and 0 – 0.98 birds / survey station in 2009. Based on detections of Least Bitterns responding to the survey protocol with the 'Coo' call (n = 118) in 2009, wetland area not surveyed, and total area of coastal wetland, I estimate 195 pairs of Least Bitterns at Long Point, Lake Erie and 1434 pairs in coastal wetlands of the CLGL. Thus, the breeding population of Least Bitterns in Canada (n = 1500) is potentially biased low. Use of the

NLBSP should be continued and expanded to increase our understanding of Least Bittern distribution, relative abundance, and habitat use for effective wetland management and species-listing policy. Macrohabitat assessments determined percent cover of Cattail to be the best predictor of Least Bittern presence. Microhabitat assessments determined number of dead Cattail stems as the best predictors of Least Bittern presence. Interspersion of the study wetlands was significant at the survey station scale, but not at the wetland scale. Current wetland management at Long Point (primarily for waterfowl) appears to be beneficial to Least Bitterns. I recommend managing wetlands by increasing interspersion, maintaining the percent cover and density of cattail in wetlands, and minimizing the percent cover of *Phragmites*.

9.0 References

Austen, M. J. W., M. D. Cadman, and R. D. James. 1994. Ontario Birds at Risk: Status and Conservation Needs. Federation of Ontario Naturalists and Long Point Bird Observatory, Toronto and Port Rowan, Ontario, Canada. 165 pp.

Benoit, L. K. and R. A. Askins. 1999. Impact of the spread of *Phragmites* on the distribution of birds in Connecticut tidal marshes. Wetlands. 19:194-208.

Bent, A. C. 1926. Life Histories of North American Marsh Birds. Dover Publications, Inc., New York, New York, USA. 392 pp.

Bird Studies Canada. 2008. Marsh Monitoring Program - Bird Surveys. Data accessed from NatureCounts, a node of the Avian Knowledge Network, Bird Studies Canada. Available at: http://www.naturecounts.ca/. Last visited February 2011.

Bogner, H. E. 2001. Breeding biology of Least Bittern (*Ixobrychus exilis*) in western New York. M.Sc. Thesis, State University of New York, Syracuse, New York, USA. 78 pp.

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.

Budd, M. J. 2007. Status, distribution, and habitat selection of secretive marsh birds in the delta of Arkansas. M.Sc. Thesis, University of Arkansas, Fayetteville, Arkansas, USA. 110 pp.

Burger, J. 1981. A model for the evolution of mixed-species colonies of Ciconiiformes. The Quarterly Review of Biology. 56:143-167.

Butcher, G. 1989. Bird conservation: establishing priorities. Birdscope. 3:1-3.

Cadman, M. D., P. F. J. Eagles, and F. M. Helleiner. 1987. Atlas of the Breeding Birds of Ontario. University of Waterloo Press, Waterloo, Ontario, Canada. 611 pp.

Cadman, M. D., D. A. Sutherland, G. G. Beck, D. Lepage, and A. R. Couturier (eds.). 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, Ontario, Canada. 706 pp.

Carter, M. F., W. C. Hunter, D. N. Pashley, and K. V. Rosenberg. 2000. Setting conservation priorities for landbirds in the United States: The Partners in Flight approach. Auk. 117:541–548.

Catling, P. M. and Carbyn, S. 2006. Recent invasion, current status and invasion pathway of European Common Reed, *Phragmites australis* subspecies *australis*, in the southern Ottawa district. Canadian Field Naturalist. 120:207–312.

Connor, K. J. and S. Gabor. 2006. Breeding waterbird wetland habitat availability and response to water-level management in Saint John River floodplain wetlands, New Brunswick. Hydrobiologia. 567:169-181.

Conway, C. J. 2009. Standardized North American Marsh Bird Monitoring Protocols, version 2009-2. Wildlife Research Report #2009-02. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, AZ, USA. 57 pp.

Conway, C. J. and C. Sulzman. 2007. Status and habitat use of the California Black Rail in the southwestern USA. Wetlands. 27:987-998.

Cornell Lab of Ornithology. 2003. Range Map of Least Bittern, *Ixobrychus exilis*. Available at: http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Least_Bittern_dtl.html. Last visited April 2011.

COSEWIC. 2009. COSEWIC Assessment and Update Status Report on the Least Bittern *Ixobrychus exilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario, Canada. 36 pp.

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. Bird Studies Canada in cooperation with Environment Canada. 28 pp.

Crewe, T. L. and S. T. A. Timmermans. 2005. Assessing Biological Integrity of Great Lakes Coastal Wetlands Using Marsh Bird and Amphibian Communities. Technical report # WETLANDS – EPA-01, prepared for Great Lakes Commission. 88 pp.

DesGranges, J. L., J. Ingram, B. Drolet, C. Savage, J. Morin, and D. Borcard. 2006. Modelling wetland bird response to water level changes in the Lake Ontario - St. Lawrence River hydrosystem. (Special Issue: Canada's Ecosystem Initiatives). Environmental Monitoring and Assessment. 113:329-365.

Dillon, S. T. 1959. Breeding of the least bittern in Manitoba. Auk. 76:524-525.

Ducks Unlimited Canada. 2010. Southern Ontario Wetland Conversion Analysis. Final Report. Ducks Unlimited Canada-Ontario Office, Barrie, Ontario, Canada. 51 pp.

Eastman, J. R. 2003. IDRISI Kilimanjaro – Guide to GIS and Image Processing. Clark Labs, Worcester, Massachusetts, USA. 328 pp.

Edwards, N. T. and D. L. Otis. 1999. Avian communities and habitat relationships in South Carolina piedmont beaver ponds. The American Midland Naturalist. 141:158-171.

Environment Canada and Ontario Ministry of Natural Resources. 2003. Ontario Great Lakes Coastal Wetlands Atlas: A Summary of Information (1983-1997). Canadian Wildlife Service and Natural Heritage Information Centre. 57 pp.

Environment Canada. 2010. Recovery Strategy for the Least Bittern (*Ixobrychus exilis*) in Canada (Draft). *Species at Risk Act* Recovery Strategy Series. Environment Canada. Ottawa, Canada. 33 pp.

ESRI (Environmental Systems Research Institute). 2011. ArcGIS Desktop Help 9.3. Available at: http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=welcome. Last accessed April 2011.

Friswyk, C. B. and J. B. Zedler. 2007. Vegetation change in Great Lakes coastal wetlands: deviations from the historical cycle. Journal of Great Lakes Research. 33:366-380.

G. G. Beck, D. Lepage, and A. R. Couturier (eds.). The Atlas of the Breeding Birds of Ontario. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, Ontario, Canada. 728 pp.

Gibbs, J. P., J. R. Longcore, D. G. McAuley, and J. K. Ringelman. 1991. Use of wetland habitats by selected nongame water birds in Maine. U.S. Fish and Wildlife Service, Fish and Wildlife Research Report 9, Washington, District of Columbia, USA. 57 pp.

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

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons, New York, USA. 257 pp.

Griffin, A. D., F. E. Durbian, D. A. Easterla, and R. L. Bell. 2009. Spatial ecology of breeding Least Bitterns in northwest Missouri. The Wilson Journal of Ornithology. 121:521-527.

Hay, S. 2006. Distribution and habitat of the Least Bittern and other marsh birds species in southern Manitoba. M. Sc. Thesis. University of Manitoba, Winnipeg, Manitoba, Canada. 91 pp.

Herdendorf, C. E. 1987. The ecology of the coastal marshes of western Lake Erie: A community profile. Rept. 85 (79) National Wetlands Research Center, Fish and Wildlife Service, United States Department of the Interior, Washington, District of Columbia, USA. 185 pp.

James, R. D. 1999. Update COSEWIC status report on the Least Bittern *Ixobrychus exilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario, Canada. 10 pp.

Jobin, B., L. Robillard, and C. Latendresse. 2009. Response of a Least Bittern (*Ixobrychus exilis*) population to interannual water level fluctuations. Waterbirds. 32:73-80.

Jobin, B., P. Fradette, and S. Labreque. In-press. Habitat use by Least Bitterns (*Ixobrychus exilis*) in Quebec. Waterbirds.

Jobin, B., R. Bazin, L. Maynard, A. McConnell, and J. Stewart. In Press. National Least Bittern Survey Protocol. Environment Canada, Canadian Wildlife Service. Québec Region. Waterbirds.

Kaminski, R. M. and H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management. 44:1-15.

Kushlan, J. A. 1973. Least Bittern nesting colonially. Auk. 90:685-686.

Leahy, M. G., M. Y. Jollineau, P. J. Howarth, and A. R. Gillespie. 2005. The use of Landsat data for investigating the long-term trends in wetland change at Long Point, Ontario. Canadian Journal of Remote Sensing. 31:240-254.

Lor, S. and R. A. Malecki. 2006. Breeding ecology and nesting habitat associations of five marsh bird species in western New York. Waterbirds. 29:427–436.

Lynch, E. A. and K. Saltonstall. 2002. Paleoecological and genetic analyses provide evidence for recent colonization of native *Phragmites australis* populations in a Lake Superior wetland. Wetlands. 22:637-646.

Manci, K. M. and D. H. Rusch. 1988. Indices to distribution and abundance of some inconspicuous waterbirds at Horicon Marsh. Journal of Field Ornithology. 59:67–75.

Marks, M., B. Lapin, and J. Randall. 1994. Element Stewardship Abstract. *Phragmites australis* (*P. communis*): Threats, Management, and Monitoring. Natural Areas Journal. 14:285-294.

Meyer, S. W. 2003. Comparative use of *Phragmites australis* and other Habitats by Birds, Amphibians, and Small Mammals at Long Point, Ontario. M. Sc. Thesis. University of Western Ontario, London, Ontario, Canada. 127 pp.

Meyer, S. W. and C. A. Friis. 2008. Occurrence and habitat of breeding Least Bitterns at St. Clair National Wildlife Area. Ontario Birds. 26:146-164.

Meyer, S. W., S. S. Badzinski, S. A. Petrie, and C. D. Ankney. 2010. Seasonal abundance and species richness of birds in common reed habitats in Lake Erie. Journal of Wildlife Management. 74:1559–1567.

Ministry of the Environment – British Columbia. 2011. Guidelines and Best Management Practices (BMP's). Available at: http://www.env.gov.bc.ca/wld/BMP/bmpintro.html. Last visited April 2011.

Murkin, H. R., A. G. Van der Valk, and E. D. Clark. 2000. Prairie wetland ecology. The contribution of the Marsh Ecology Research Program. Iowa State University Press, Ames, Iowa, USA. 413 pp.

National Oceanic and Atmospheric Administration. 2010. Lake Erie Hydrograph. Available at: http://www.glerl.noaa.gov/data/now/wlevels/lowlevels/plot/Erie.gif. Last visited April 2011.

Natural Resources Canada. 2011. The Atlas of Canada – Wetlands. Available at: http://atlas.nrcan.gc.ca/site/english/learningresources/theme_modules/wetlands/index.html. Last visited 21 February.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.7. NatureServe, Arlington, Virginia, USA. Available at: http://www.natureserve.org/explorer. Last visited November 2010.

Ontario Ministry of Natural Resources. 2006. South Western Ontario Orthophotography Project. First Base Solutions Inc. Markham, Ontario, Canada.

PCI Geomatics Enterprises Inc. 2007. Geomatica 10 – Geomatica OrthoEngine Course Guide Version 10.1. Richmond Hill, Ontario, Canada.

Poole, A. F., P. Lowther, J. P. Gibbs, F. A. Reid, and S. M. Melvin. 2009. Least Bittern (*Ixobrychus exilis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/017. Last visited April 2011.

Post, W. and C. A. Seals. 1993. Nesting associations of least bitterns and boat-tailed grackles. Condor. 95:139-144.

Price, J., S. Droege, and A. Price. 1995. The summer atlas of North American birds. Academic Press, New York, New York, USA. 364 pp.

Ralph, C. J., J. R. Sauer, and S. Droege, S. 1995. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, California. 187 pp.

Rehm, E. M. and G. A. Baldassarre. 2007. The influence of interspersion on marsh bird abundance in New York. The Wilson Journal of Ornithology. 119:648-654.

Reid, F. A. 1989. Differential habitat use by waterbirds in a managed wetland complex. Ph.D. Dissertation. University of Missouri, Columbia, Missouri, USA. 243 pp.

Ribic, C. A., S. Lewis, S. Melvin, J. Bart, and B. Peterjohn. 1999. Proceedings of the Marsh bird monitoring workshop. USFWS Region 3 Administrative Report, Fort Snelling, Minnesota, USA. 57 pp.

Rodgers, J. A., and S. T. Schwikert. 1999. Breeding ecology of the Least Bittern in central Florida. Florida Field Naturalist. 27:141-194.

Sandilands, A. P. and C. A. Campbell. 1988. Status Report on the Least Bittern (*Ixobrychus exilis*). COSEWIC. 40 pp.

SAS Institute Inc. 2008. SAS/STAT® 9.2 User's Guide – The GLIMMIX Procedure. Cary, North Carolina, USA. 380 pp.

Schabenberger, O. 2007. Growing Up Fast: SAS® 9.2 Enhancements to the GLIMMIX Procedure. SAS Global Forum, Paper 177. 20 pp.

Schwartz, R. C., P. J. Deadman, D. J. Scott, and L. D. Mortsch. 2004. Modeling the impacts of water level changes on a Great Lakes community. Journal of the American Water Resources Association. 40:647-662.

Smith, L. M., D. A. Haukos, and R. M. Prather. 2004. Avian response to vegetative pattern in playa wetlands during winter. Wildlife Society Bulletin. 32:474-480.

Steen, D. A., Gibbs, J. P., 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.

Timmermans, S. T. A., S. S. Badzinski, and J. W. Ingram. 2008. Associations between breeding marsh bird abundances and Great Lakes hydrology. Journal of Great Lakes Research. 34:351-364.

Tozer, D. C., K. F. Abraham, and E. Nol. 2007. Observations of nesting Least Bitterns in response to call broadcasts. Northeastern Naturalist. 14:637-642.

United States Environmental Protection Agency. 2011. Wetlands – Status and Trends. Available at: http://water.epa.gov/type/wetlands/vital_status.cfm. Last visited 21 February 2011.

Ward, M. P., T. J. Benson, B. Semel, and J. R. Herket. 2010. The use of social cues in habitat selection by wetland birds. The Condor. 112:245-251.

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

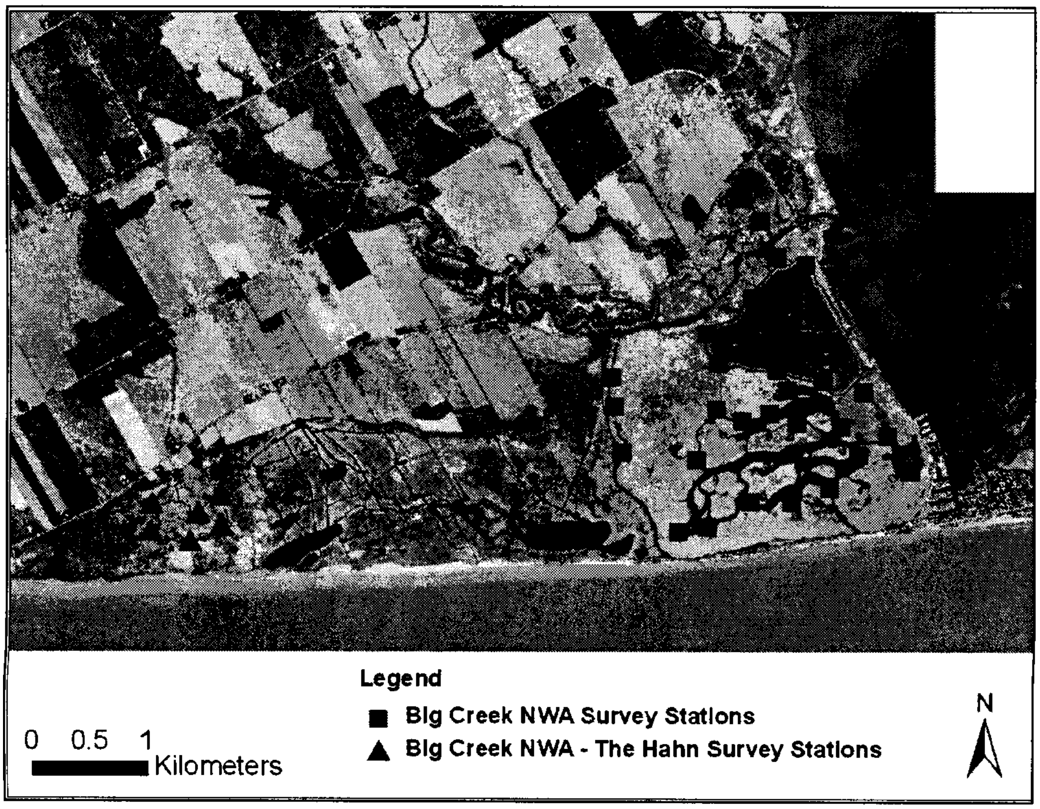
Weller, M. W. and C. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Special Report 43. Agricultural and Home Economics Experiment Station, Iowa State University, Ames, Iowa, USA. 31 pp.

Wilcox, D. A. and T. H. Whillans. 1999. Techniques for restoration of disturbed coastal wetlands of the Great Lakes. Wetlands. 19:835-857.

Wilcox, K. L., S. A. Petrie., L. A. Maynard, and S. W. Meyer. 2003. Historical distribution and abundance of *Phragmites australis* at Long Point, Lake Erie, Ontario. Journal of Great Lakes Research. 29:664-680.

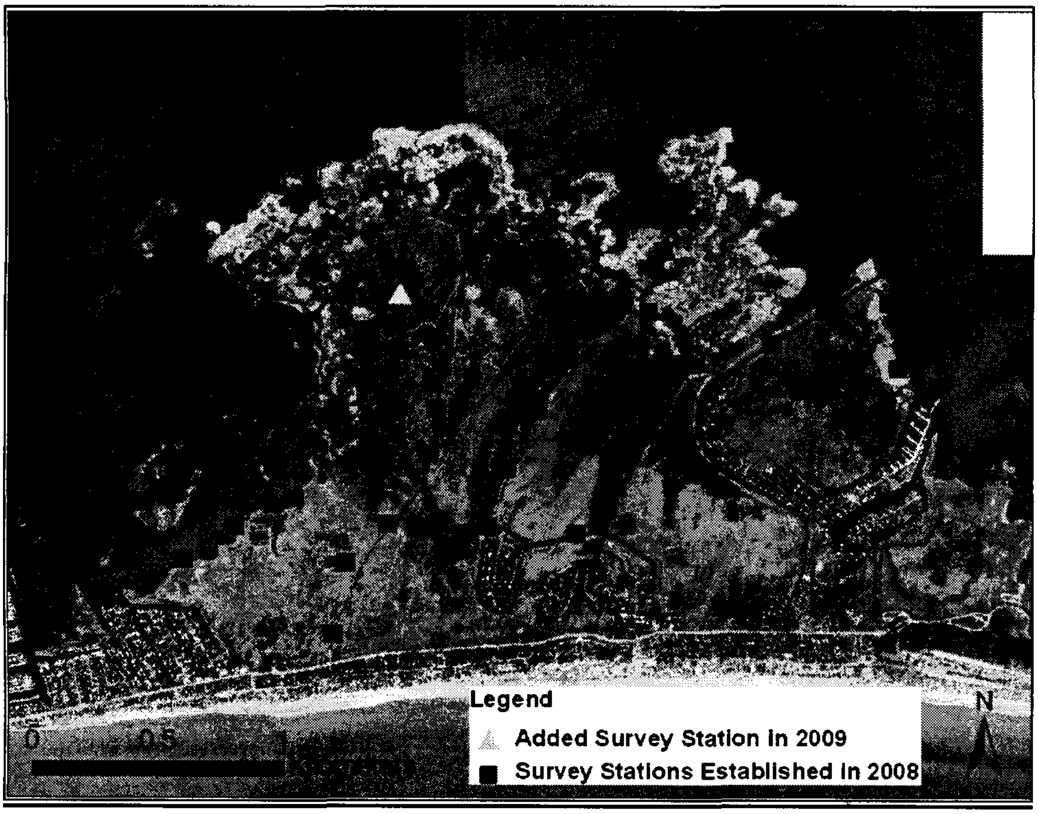
Woodliffe, P. A. 2007. Least Bittern. Pp. 156-157, in M. D. Cadman, D. A. Sutherland, G. G. Beck, D. Lepage, and A. R. Couturier (eds.). The Atlas of the Breeding Birds of Ontario. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, Ontario, Canada. 2 pp.

Appendix 1



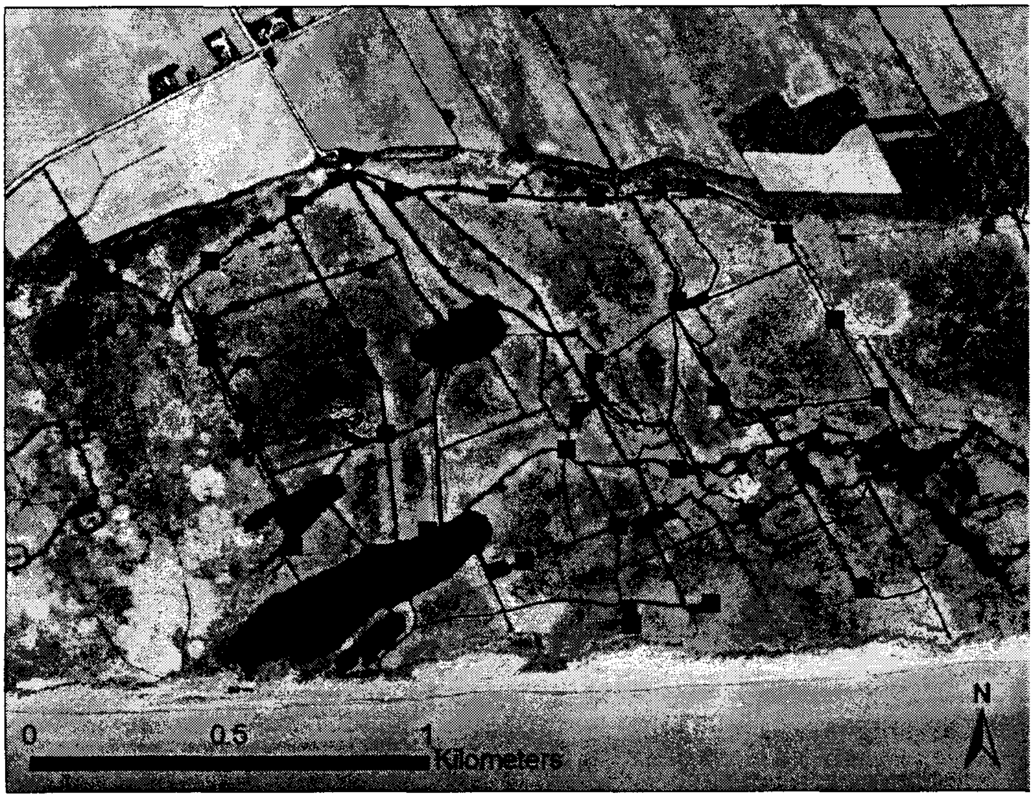
Big Creek National Wildlife Area (BCNWA) was established in 1973 and is comprised of two units. The east unit of BCNWA (598 ha) is situated to the northwest of the Town of Long Point and at the base of Long Point. It is bordered by Big Creek and agriculture in the north, the Inner Bay (Lake Erie) in the east, Lake Erie in the south and a private hunt club in the west. A secondary unit (The Hahn; 67 ha) is located west of the east unit and is bordered by agriculture to the north and west, Lee Brown Waterfowl Management Unit in the east, and Lake Erie to the south. I surveyed 38 stations on 5 routes in BCNWA, 2009. The routes surveyed in BCNWA were established in 2007 during previous Least Bittern research (Environment Canada unpublished data). The BCNWA is managed federally by the Canadian Wildlife Service – Environment Canada and historically was heavily dredged and channelized, but no physical manipulation of habitat has occurred in the past 5 years.

Appendix 2



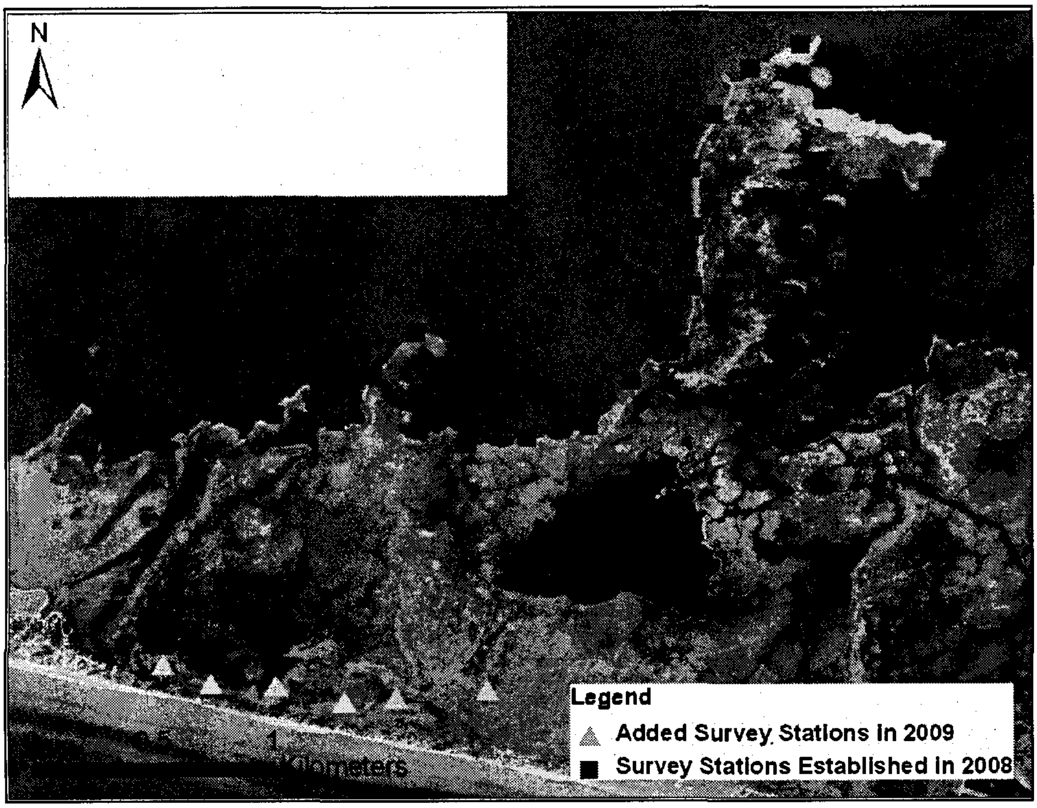
Crown Marsh (518 ha) is owned by the province of Ontario and managed by the Ontario Ministry of Natural Resources. Crown Marsh is located northeast of the Town of Long Point. I surveyed 54 stations on 6 routes in 2008 (one station was added in 2009 to increase area surveyed, thus making 55 survey stations) in the Crown Marsh. Crown Marsh is open to waterfowl hunting, September – January. The wetland receives periodic management to maintain boat channels for access to hunting locations. During autumn 2008 and 2009 the Ministry of Natural Resources dredged 12 ponds (range = <1 ha to 2 ha) to increase interspersion and remove patches of *Phragmites*. The figure does not show the 12 recently dredged ponds.

Appendix 3



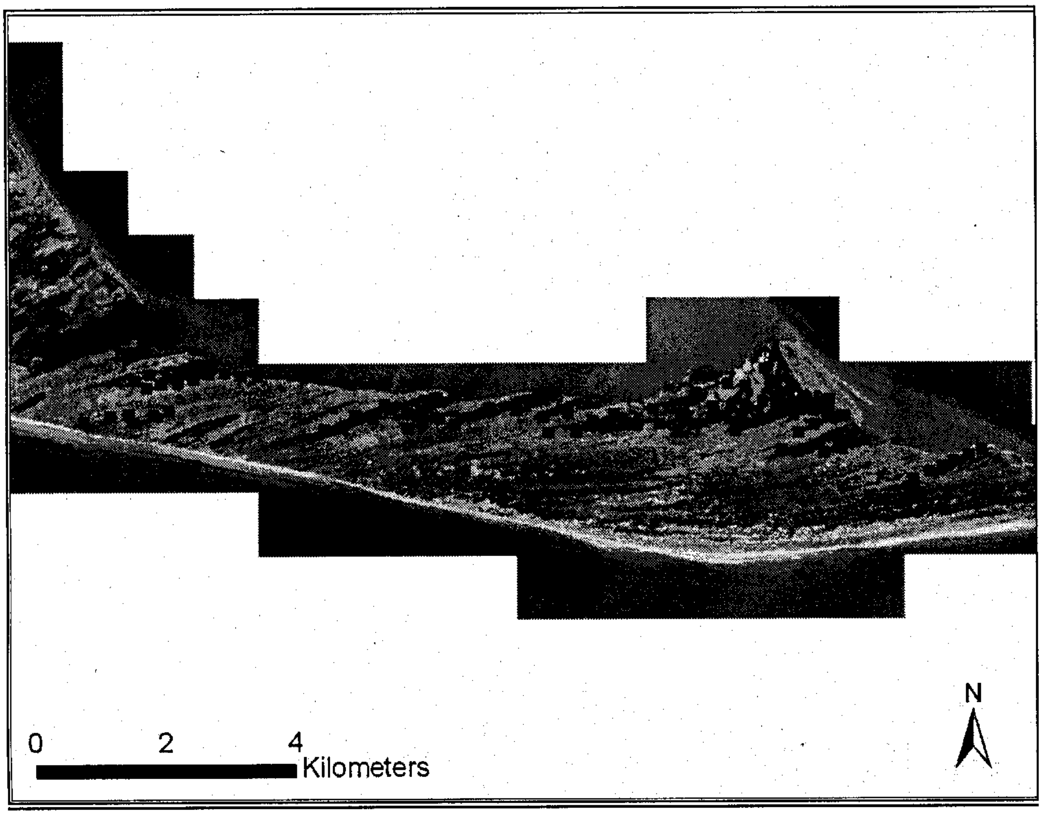
Lee Brown Waterfowl Management Area (221 ha) is managed by the local Conservation Authority and is bordered by a private hunt club in the west, agriculture in the south, The Hahn in the east and Lake Erie in the north. Surveys were conducted at LBWMA in 2009 at 31 survey stations along 3 routes. The boat channels are mechanically dredged each year and removed sediment is piled on the sides of the channels.

Appendix 4a

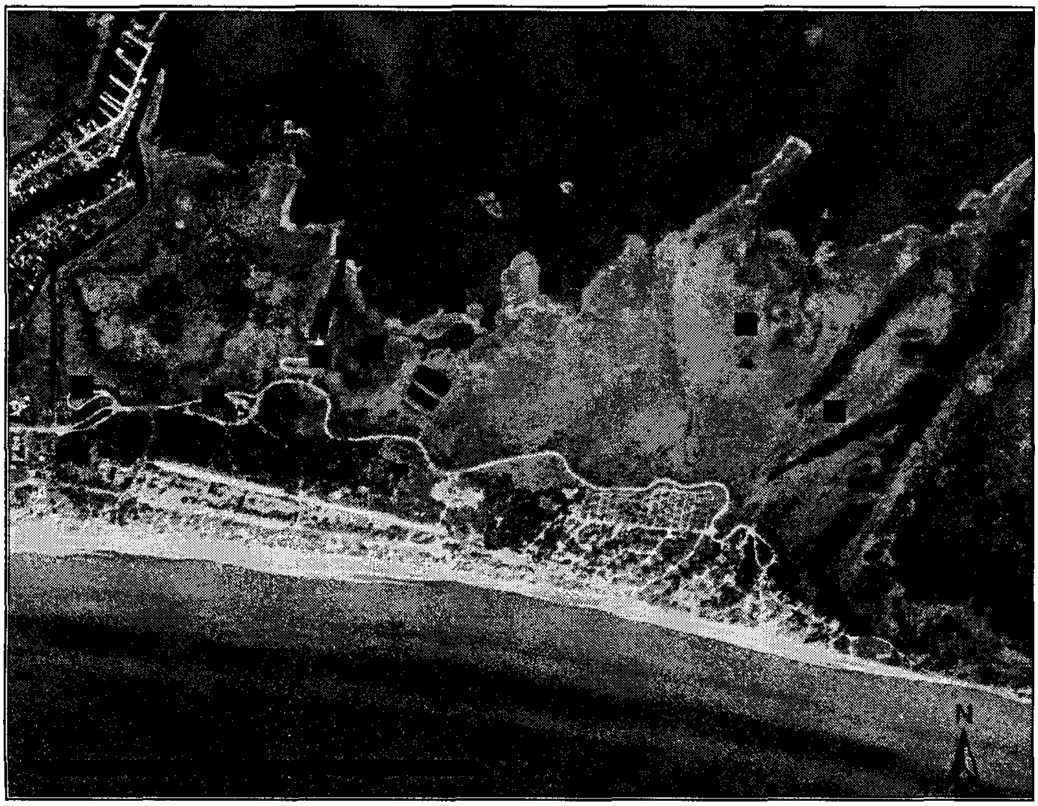


Long Point National Wildlife Area (LPNWA) is managed federally by the Canadian Wildlife Service – Environment Canada and is comprised of two units. The smaller unit (Thoroughfare Point) is located in the west central portion of Long Point and is bordered by Long Point Company in the east, Crown Marsh in the west and Lake Erie to the north and south. Thoroughfare Point (427 ha) and was surveyed in 2008 and 2009. In 2008, 32 stations were surveyed on 3 routes and I added 6 survey stations in 2009 for a total of 38 survey stations on 4 routes. The larger portion of LPNWA (586 ha – see Appendix 4b) was surveyed in 2009 with 64 survey stations on 7 routes. This site has not received active management in many years.

Appendix 4b

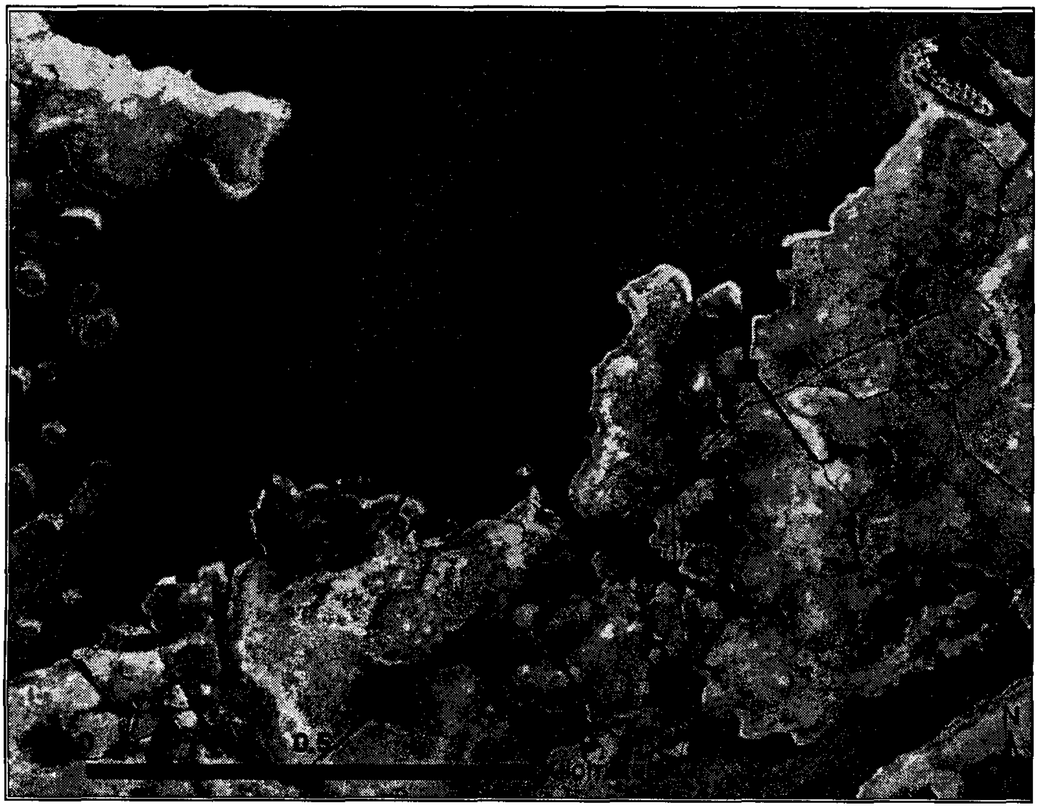


Appendix 5



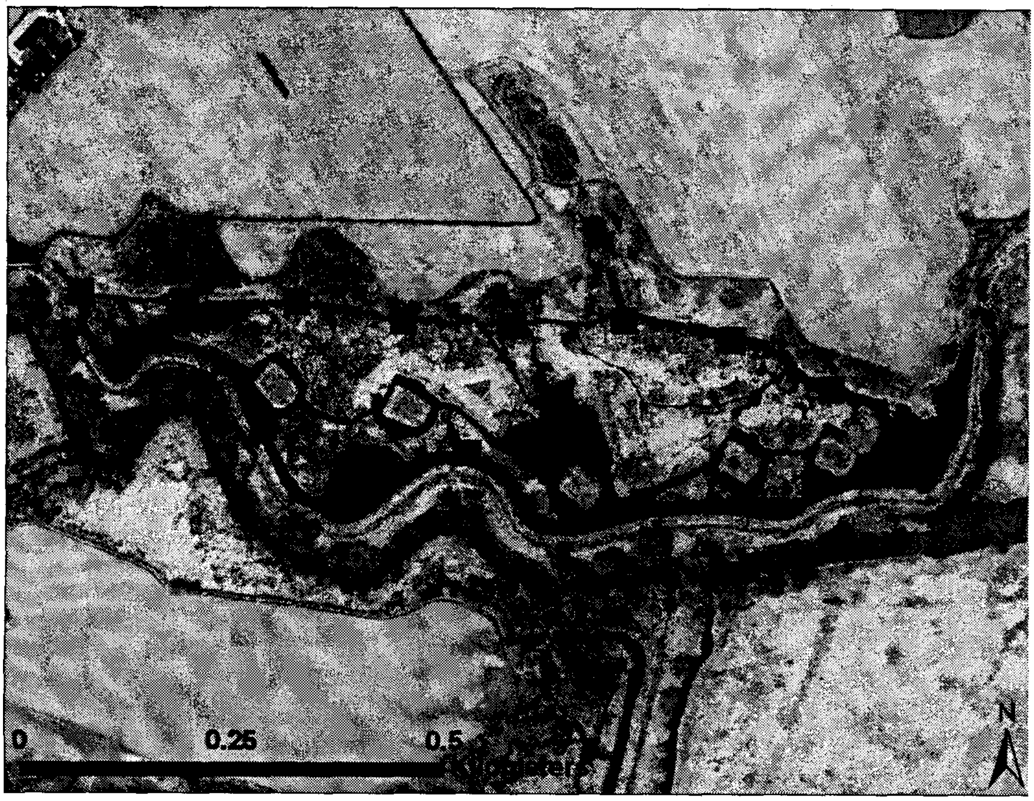
Long Point Provincial Park (LPPP) is managed provincially by Ontario Parks. The wetland portion of LPPP (111 ha) is bordered by Crown Marsh in the west, Thoroughfare Point in the east and Lake Erie in the north and south. Surveys were conducted in 2008 and 2009 at 15 survey stations along 2 routes. With the exception of a small pond dredged by OMNR in the fall of 2008, active management of hydrology and vegetation is limited. The figure does not show the small pond due to how recently the pond was dredged.

Appendix 6



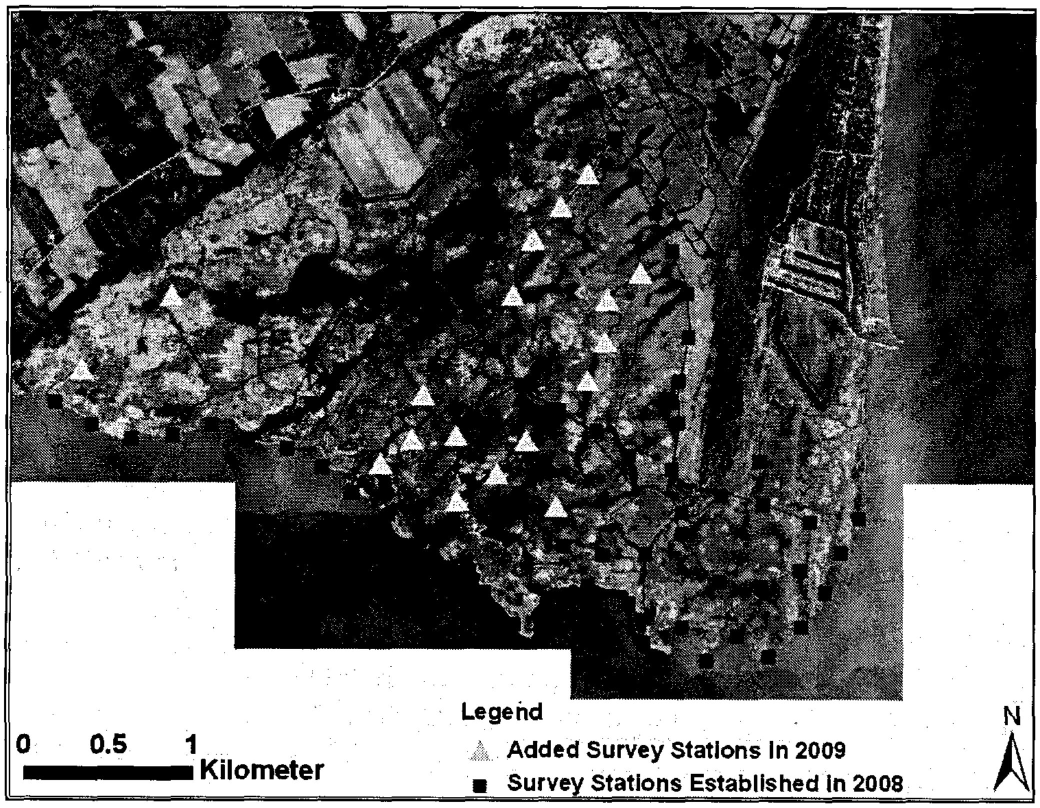
Long Point Company (LPC; 2300 ha) is a private hunt club located in the central portion of Long Point. LPC is bordered in the west by Thoroughfare Point, LPNWA in the east and Lake Erie to the north and south. Surveys were conducted in 2008 and 2009 at 9 survey stations on 1 route. Access to this site was limited and therefore only one route was established in approximately 90 ha. Boat channels are dredged annually.

Appendix 7



Murray Marsh (22 ha) is a private hunt club located southeast of the Town of Port Royal. Murray Marsh is bordered on all sides by agriculture except BCNWA to the southeast. Surveys were conducted in 2008 and 2009 at 12 survey stations on one survey route. Boat channels are dredged annually.

Appendix 8



Turkey Point (924 ha) is intensively managed by the Turkey Point Hunt Club with the exception of the northeast corner, which is managed by 3 smaller, separate hunt clubs, to which I did not have access. In 2008, surveys were conducted at 71 survey stations on 7 routes. In 2009, these same stations and routes were surveyed with the addition of 18 survey stations and 2 routes. Boat channels at Turkey Point are dredged annually.