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MIGRATION PATTERNS, HABITAT USE, PREY ITEMS, AND HUNTER HARVEST OF LONG-TAILED DUCKS (Clangula hyemalis) THAT OVERWINTER ON LAKE MICHIGAN

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By

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A Thesis
Submitted in Partial Fulfillment of the Requirements for the
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MAJOR PROFESSOR: Dr. Michael W. Eichholz

The long-tailed duck (*Clangula hyemalis*; hereafter LTDU) breeds on the arctic tundra across Alaska and Canada and winters south of the ice edge along the Pacific and Atlantic coasts, as well as on the Great Lakes. Data suggest that LTDU populations are in decline and, as a result, efforts have been made to better understand their population distributions through satellite telemetry studies. Radio-marked LTDUs from previous studies have shown very little use of Lake Michigan, even though aerial surveys indicate that large concentrations of this species overwinter there. LTDUs using Lake Michigan face a host of conservation issues, such as risk of exposure to type E botulism, bycatch in fishing gear, wind energy development, and a changing ecosystem.

Using satellite telemetry, I documented migratory routes and habitat use of LTDUs wintering on Lake Michigan. LTDUs on Lake Michigan were captured via night-lighting and 10 LTDUs were surgically implanted with Telonics platform transmitter terminals (PTTs). Six (60%) radio-marked LTDUs provided information on Lake Michigan habitat use, while only 3 (30%) provided information on migratory routes. The average distance from shore of individual radio-marked LTDUs on Lake Michigan varied from 1.4-7.8 km and average water depths at these locations varied from 16.8-27.7 m during daylight hours. At night, radio-marked LTDUs were located further offshore (averaging 7.3-16.5 km) and at deeper water depths (averaging 59.6-74.8 m). LTDUs tended to move south on Lake Michigan as winter progressed, and then

relocated to the north basin before spring migration. James Bay and Hudson Bay were the primary stopover sites during spring and fall migration, and the province of Nunavut, Canada was used during the breeding season. After breeding, radio-marked LTDUs traveled north to waters near Adelaide Peninsula, Nunavut, Canada. Only one radio-marked LTDU provided information for a full migration cycle and it returned to winter on Lake Michigan.

Two methods, ocular and molecular examination of the alimentary canal, were used to determine the diets of LTDUs on Lake Michigan. A total of 16 LTDU carcasses were donated by hunters for diet determination. An esophageal, small intestine, and cloacal swab were collected from each carcass for molecular determination of prey species through qPCR analysis. The esophagus of each carcass was then removed and prey items determined to lowest taxonomic level using a dissection microscope (10X Ocular). Molecular methods detected more prey species (4) than ocular methods (1), so molecular methods show promise as a non-lethal means to determine LTDU diets. Quagga mussel (*Dreissena rostriformis bugensis*) was the primary prey item with 100% occurrence. *Diporeia* spp., yellow perch (*Perca flavescens*), and alewife (*Alosa pseudoharengus*) were also detected, suggesting that LTDUs are opportunistic feeders.

An in-person hunter harvest survey was conducted at Two Rivers, Wisconsin, to determine how environmental variables influenced harvest, to estimate harvest rates, and to gather hunter input regarding hunting regulations on Lake Michigan. Results indicate that LTDUs made up 97% of the total harvest, and that hunters averaged 3.8 LTDUs per day. Harvest of LTDUs was positively correlated with hunter numbers, and wave height was the most influential environmental variable affecting hunter numbers. Results suggest that few hunters go out when wave heights exceed 1.5 m. Hunters indicated that they would prefer a later or longer season on Lake Michigan, and that they were concerned about LTDU populations.

Information from this study aids resource managers and scientists as they seek to determine basic information regarding LTDUs that winter on Lake Michigan. Migratory data is important in determining if the eastern population of North American LTDUs should be managed based on wintering and/or breeding distribution, while habitat use information will aid in mitigating impacts from fishing bycatch and future wind energy development. Habitat use and diet data will benefit resource managers and scientists seeking to determine where and how LTDUs may become exposed to avian botulism type E. Diet data will also aid in determining how LTDU diets are changing due to the altered ecosystem in Lake Michigan from introduced and invasive species. Moreover, results from the diet portion of this study suggest that molecular methods, that can be used non-lethally or in combination with lethal methods, show promise for determining LTDU prey items. Information on harvest rates can be used in determining harvest impacts, while hunter perceptions may aid resource managers as they make decisions regarding season structure and limits for LTDUs on Lake Michigan.

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CHAPTER 1

MIGRATION PATTERNS AND HABITAT USE OF LONG-TAILED DUCKS OVERWINTERING ON LAKE MICHIGAN

1.1 INTRODUCTION

The long-tailed duck (*Clangula hyemalis*; hereafter LTDU) breeds on the arctic tundra across Alaska and Canada and winters south of the ice edge along the Pacific and Atlantic coasts, as well as on the Great Lakes (Baldassarre 2014). Data suggest that LTDU populations are in decline, but causes are unknown (Caithamer et al. 2000, Silverman et al. 2013, Sea Duck Joint Venture 2007). As a result, efforts have been made to better understand those populations through telemetry studies addressing basic questions such as determining breeding and molting locations, locating important wintering and staging areas, documenting annual variability in migration patterns, determining site fidelity to breeding, molting and wintering areas, and developing better surveys to assess and monitor populations (Sea Duck Joint Venture 2015). From 2007-2013, 150 LTDUs along the Atlantic Coast and Lake Ontario were radio-marked with implantable satellite platform transmitter terminals (PTTs) to address those questions for populations wintering in eastern North America; however, LTDUs marked in those locations have shown very little use of Lake Michigan (Mallory et al. 2006, Sea Duck Joint Venture 2015), even though large concentrations of LTDUs overwinter there (Kumlien and Hollister 1903, Robbins 1991, Chartier and Ziarno 2004, Kenow et al. 2013, Kenow et al. 2015). Therefore, radio-marking LTDUs on Lake Michigan could provide a more geographically representative sample of LTDUs that winter in the Great Lakes region and provide supplemental information about the habitats they use.

Lake Michigan provides a variety of resources to migrating waterfowl (Prince et al. 1992) but also poses risks. According to Prince et al. (1992), major coastal wetlands along Lake

Michigan make up about one-quarter of the important waterfowl habitat areas among the Great Lakes. However, LTDUs using Lake Michigan face a host of conservation issues, such as risk of exposure to type E botulism (Brand et al. 1983, Skerratt et al. 2005, Chipault et al. 2015), bycatch in fishing gear (Schorger 1947, Peterson and Ellarson 1977, Peterson and Ellarson 1978, Peterson and Ellarson 1979), and wind energy development (Klepinger and Public Sector Consultants Inc. 2010). Resource managers attempting to address these issues would benefit from a better understanding of the spatial and temporal use patterns of LTDUs.

Outbreaks of type E botulism have resulted in die-offs of waterbirds, including LTDUs, in the Great Lakes since the 1960s, but outbreaks have become more common and widespread since 1999, particularly in Lakes Michigan, Huron, and Erie (Riley et al. 2008, Lafrancois et al. 2011). Since the 1960s, type E botulism has likely been responsible for nearly 100,000 avian mortalities in the Great Lakes (Chipault et al. 2015). According to Chipault et al. (2015), LTDUs ranked in the top five species of carcasses detected during shoreline surveys in three of four years from 2010-2013, with over 577 LTDU carcasses detected. It currently is not known where in Lake Michigan LTDUs and other waterbirds are exposed to the botulism toxin, although evidence for common loons (*Gavia immer*) points to exposure through ingestion of round gobies (Essian et al. 2016, Kenow et al. 2018). Understanding the habitats that LTDUs use, as well as their foraging habits, is central to determining the pathways of botulism exposure on Lake Michigan.

Historical bycatch of LTDUs is well-documented on Lake Michigan. Cottam (1939) stated that more than 1,500 LTDUs were collected in one haul from a gill net in 1934 and Ellarson (1956) estimated that 15,539 LTDUs were taken in gill nets in 1951-52 and 19,562 in 1952-53. He considered these estimates to be low and estimated that bycatch may have reached

100,000 LTDUs during years with high fishing pressure (see also Baldassarre 2014). The commercial fishery on Lake Michigan has since declined, but gill netting is still permitted in the Wisconsin waters of Green Bay and open waters of Lake Michigan north of Bailey's Harbor, Wisconsin; the open waters south of Bailey's Harbor have been closed to gill netting since 1970 (Wisconsin Department of Natural Resources 2017). Since 1974, large and small mesh gillnets have been banned in Michigan waters, but tribal members are still allowed to use gillnets (Michigan Department of Natural Resources 2018). Available data on the bycatch that occurs on Lake Michigan is well outdated, perhaps due to a substantial reduction in gill netting and commercial fishing (Wisconsin Department of Natural Resources 2017).

According to U.S. Department of Energy, National Renewable Energy Laboratory estimates (Schwartz et al. 2010), the Great Lakes offer tremendous offshore wind potential. The use of wind energy is being accelerated at a rapid rate, as national and state policies support cleaner and more secure energy resources (Great Lakes Wind Collaborative 2011). The Great Lakes Wind Collaborative acknowledges that crucial environmental data are absent and needed to inform siting of wind energy resources throughout the Great Lakes region; such data includes avian flight patterns under different weather conditions, as well as migration behaviors and routes (Great Lake Wind Collaborative 2011). Data on LTDU seasonal and diel movements, coupled with core use areas, would be useful to assess the environmental impact of turbine placement and provide a means to identify and recommend alternative windfarm sites.

To address the aforementioned needs, we captured and implanted PTTs into 10 LTDUs from fall to spring 2015-2016 and 2016-2017 to determine migratory routes and habitat use of LTDUs wintering on Lake Michigan. The specific objectives of this project were to characterize the temporal and spatial patterns of migration, breeding ground affiliations, and site fidelity of LTDUs wintering on Lake Michigan.

1.2 STUDY AREA

Capture took place on Lake Michigan offshore from Two Rivers, Wisconsin, and Seul Choix Point, Michigan (Figure1.1). The Seagull Marina boat launch in Two Rivers, Wisconsin, is located at the confluence of the East and West Twin Rivers and provides easy access to Lake Michigan. This site was selected based on LTDU distribution data collected during aerial surveys over the Wisconsin offshore waters of Lake Michigan, and anecdotal information provided by waterfowl guide services and conservation officers. Aerial surveys indicated that thousands of LTDUs use the offshore waters near Two Rivers during fall, winter, and spring (B. Mueller, personal communication, 10 July 2017).

The Seul Choix Point boat launch is located on the southern tip of Seul Choix Point, Michigan, and provides direct access to Lake Michigan. This site was selected based on aerial surveys in the spring of 2016, when low concentrations of LTDUs were being observed in the Two Rivers, Wisconsin area. Aerial surveys indicated that a few thousand LTDUs were using the offshore waters near Seul Choix Point, and a single capture attempt was made in April of 2016. All other captures sessions took place at Two Rivers, Wisconsin. Movements of radio-marked LTDUs covered a large expanse of North America and encompassed the Lake Michigan wintering area, subsequent stopover sites in James Bay, Hudson Bay, Queen Maud Gulf, Victoria Strait, and James Ross Strait and the potential breeding area in Nunavut, Canada (Figure 1.1).

1.3 MATERIALS AND METHODS

1.3.1 Capture, Handling, Radio-marking and Duty Cycles

LTDUs were captured using night-lighting techniques summarized by Perry (unpublished report; http://www.pwrc.usgs.gov/resshow/perry/scoters/CaptureTechniques.cfm) from November 2015 to April 2016 and October 2016 to March 2017. All captured birds were transferred to a pet crate equipped with a raised mesh platform, where they were held until being processed on shore. LTDUs were aged as after second year (ASY), second year (SY), and hatch year (HY) following guidelines summarized by the Sea Duck Joint Venture (2015). A combination of bursa depth and plumage was used for age determination of females, while plumage and the presence of a sheathed penis were used for males. Each individual was banded with a Federally issued numeric bird band. Blood and feather samples were collected (in accordance with the Sea Duck Joint Venture protocol [Sea Duck Joint Venture 2010]) and archived, body mass measured using a UWE HS-3000 hanging scale (± 0.002 kg), structural characteristics measured per Baldwin (1931), and a cloaca swabbed for future diet analysis. Telonics PTTs (model IMPTAV-2635, Telonics Inc., Mesa, AZ) were surgically implanted intracoelomically by Dr. Scott Ford, Avian Specialty Veterinary Services, Milwaukee, Wisconsin, following the technique of Korschgen et al. (1996). The PTTs were wrapped in a sterile mesh to promote additional surface area for adhesion to the body wall and provide additional anchoring points to stabilize the PTT within the bird. LTDUs selected for radio-marking were taken to a suitable surgery location (i.e., veterinary clinic, residence, etc.) for implantation. Following surgery, birds were monitored until they returned to an alert state. Radio-marked LTDUs were released from the harbor nearest their capture site. Capture, handling, and surgical procedures were conducted under the approval of the Animal Care and

Use Committee of the Upper Midwest Environmental Sciences Center (project number: WE-15-FPP3J), and complied with the Animal Welfare Act (Public Law 99-198 and 9 CFR Parts 1, 2, and 3).

Five PTTs were programmed to transmit at noon and midnight (2 hrs on: 10 hrs off), to provide information on diel movements and guide future capture efforts. These transmitters had an expected life of 185 days and provided movement information only on Lake Michigan. A second set of five PTTs were programmed to transmit every three days (3 hrs on: 72 hrs off) to provide information on migrations, breeding locations, and site fidelity to Lake Michigan. Expected life of these transmitters was two years.

1.3.2 Monitoring Movements, Habitat Use, and Mapping

Argos location data were processed and disseminated through Collecte Localisation Satellites (CLS) America. PTT signals were received by equipment on polar-orbiting National Oceanic and Atmospheric Administration and MetOp satellites. Data was transferred to the CLS America processing center in Lanham, Maryland, where locations were estimated from the Doppler shift in the PTTs carrier frequency. Location estimates were acquired with Argos Standard Service Processing (Argos Location Classes [LC] 3, 2, 1, and 0) and Auxiliary Location Processing (service for wildlife researchers; LC A, B, and Z). One standard deviation of nominal accuracy for location estimates with LC 3, 2, 1, and 0 were <250, 250-500, 500-1,500, and >1,500 m, respectively (Argos 2016). Estimates of accuracy were not provided for LC A, B, and Z locations and users must determine the feasibility of these locations. One location per 2 or 3-hour transmission period, depending on PTT duty cycle, was selected to describe the location of each individual. This selection of the single "best" location per transmission period was premised on a superior Argos precision index, plausibility of location (e.g., land vs. water) or in the event of a tie, the location derived from the most received transmissions (Kenow et al. 2002, Douglas 2012, Douglas et al. 2012).

LTDU location coordinates were downloaded and saved in Microsoft Excel (Microsoft Office Home and Student 2013, Version 15.0.5023.1000) spreadsheets, and then categorized by location (e.g., Lake Michigan, Green Bay, James Bay). Locations on Lake Michigan were further categorized as day or night, based upon the time the location was received. Night was defined as the time between two hours after sunset to two hours before sunrise. Day was defined as two hours after sunrise to two hours before sunset. The four hours around sunset and sunrise were removed to eliminate locations when birds may have been transitioning from a daytime to nighttime location or vice versa, and were removed only when analyzing day versus night locations. All high quality locations (LC≥1) were used when describing migratory routes.

Excel files were then imported into ArcGIS and converted to an ESRI shapefile of LTDU locations in ArcMap 10.3.2 (ESRI 2015) and projected in NAD_1983_UTM_Zone_16N. A bathymetric layer (National Geophysical Data Center 1996) of the open waters of Lake Michigan was used to estimate the distance and depth of each LTDU location, using ArcGIS software (ESRI 2015).

Winter ranges for radio-marked LTDUs were calculated using the Geospatial Modeling Environment (Beyer 2015), which has dependencies on Arc 10.3.2 and program R 3.4.0 (R Core Team 2017). Calculations included the minimum convex polygon, standard deviational ellipse of two deviations and fixed kernel (Worton 1989) methods. Fixed kernel home ranges were calculated using the least-square cross validation calculation of a smoothing parameter (Silverman 1986). The 95% utilization distribution probability contour was used to define the kernel home range and 50% contour used to define core use areas. Summary statistics were calculated for the intersections of each home range with areas of water depth >0 (home range calculations do not include terrestrial areas). Relative density estimates from all radio-marked LTDUs were also calculated from combined monthly locations to show hotspots of LTDU use each month.

1.4 RESULTS

1.4.1 Capture, Radio-marking, PTT performance

Two LTDUs were captured and implanted with PTTs between March and April 2016, seven PTTs were deployed in LTDUs during October to November 2016, and an additional PTT was deployed in March 2017 (Table 1.1). Spring migratory routes to breeding ground locations in Nunavut, Canada were documented for three female LTDUs (PTT-IDs 146126, 158804, 158806; Figures 1.2-1.4). Two LTDUs (PTT-IDs 146126 and 158804) provided locations post breeding, but only one (PTT-ID 146126) provided subsequent fall migration information. Three additional LTDUs (PTT-IDs 146128, 146131 and 146132) provided detailed information on wintering movements and habitat use for Lake Michigan (Figures 1.5-1.7). Of the four remaining radio-marked LTDUs, two died (PTT-IDs 158806-1 and 146129) and transmissions were lost from two (PTT-IDs 146127 and 158807) within the first 17 days of PTT implantation (Table 1.1).

A total of 2,762 transmissions were received from the 10 radio-marked LTDUs, of which 1,383 (50%) were high quality locations (defined as Argos Location Class 1-3, accurate to <1,500 m; Table 1.2). There were a total of 451 useable transmissions for mapping migratory routes and habitat use on Lake Michigan, after selecting the best location for each transmission period, and excluding the two LTDUs that died and two that lost transmissions.

1.4.2 Spring Migration, Breeding Grounds, and Fall Migration

Three radio-marked LTDUs, all females (PTT-IDs 146126, 158804 and 158806) provided information on spring migration and potential breeding ground affiliations, but only one bird (PTT-ID 146126) provided fall migration data (Table 1.3; Figures 1.2-1.4). Spring departure from Lake Michigan for the three radio-marked LTDUs occurred between 11 and 21 May. PTT transmissions were intermittent or of poor quality (LC≤0) from 16 May to 26 June 2017 for an ASY female (PTT-ID 158806), thus no migratory stopover information was provided before transmissions were lost while on its potential breeding grounds in Nunavut, Canada, on 27 June 2017 (Table 1.3; Figure 1.4).

A second ASY female (PTT-ID 158804) was in flight over Ontario, Canada on 21 May 2017 and stopped in Hudson Bay before reaching its potential breeding grounds in Nunavut, Canada on 2 June 2017 (Table 1.3; Figure 1.3). Following the breeding time period, this LTDU traveled north to Adelaide Peninsula, Nunavut, Canada, where transmissions were lost on 29 July 2017. The only bird to provide information for a full annual migration was a SY female (PTT-ID 146126) radio-marked in 2016. In spring, she made stops in James Bay and Hudson Bay, before settling on a breeding area in Nunavut, Canada. Following the breeding time period she traveled north, making stops at Queen Maud Gulf, Storis Passage, Victoria Strait, and James Ross Strait, before heading south to Hudson Bay, James Bay, and returning to Lake Michigan in late October 2017 (Table 1.3; Figure 1.2).

1.4.3 Movements and Habitat Use on Lake Michigan

Six LTDUs (PTT-IDs 146126, 146128, 146131, 146132, 158804 and 158806) provided movement and habitat use information while wintering on Lake Michigan (Table 1.4; Figures 1.2-1.7). A SY female LTDU radio-marked in April 2016 (PTT-ID 146126) near Seul Choix

Point, Michigan, provided spring use data from 29 April through 11 May 2016. During this time, she remained near Schoolcraft and Mackinac Counties in Michigan waters, before departing presumably to breeding grounds. She returned to Lake Michigan on 27 October 2016 and was located near Manistee, Michigan. On 30 October 2016, she traveled to an area near Two Rivers, Wisconsin where she remained until transmissions were lost on 2 November 2016 (Table 1.3; Figure 1.2). All other radio-marked LTDUs (PTT-IDs 158804, 158806, 146128, 146131, and 146132) provided data from fall 2016 until spring migration (PTT-IDs 158804 and 158806) or battery depletion (146128, 146131, and 146132).

Three LTDUs that were radio-marked in October and November 2016 (PTT-IDs 158806, 146128 and 146131) moved north within five days of being released from the capture site in Two Rivers, Wisconsin. An ASY female (PTT-ID 158806) moved to Little Bay de Noc in Delta County, Michigan where she remained until 6 December 2016. By 9 December 2016, she had relocated to Leelanau County, near Leland, Michigan. She was still near Leland, Michigan, on 15 May 2017, but did not provide another usable location ($LC \geq 1$) until on her presumptive breeding grounds (Table 1.3; Figure 1.4). An ASY male (PTT-ID 146128) moved to the tip of Door County, Wisconsin, where it remained until 18 November 2016. He relocated before 20 November 2016 to an area north of Manistee, Michigan. From 22 November through 1 December 2016, it made small movements down the Michigan coastline, with stops occurring near Manistee, Ludington, Pentwater and final location near Whitehall, Michigan. It made extensive use of the Michigan coastline along Muskegon, Ottawa, Allegan and Van Buren Counties from 1 December through 9 March 2017. On 10 March 2017, he had traveled to Cook County, Illinois where he remained until 26 March 2017. He moved back into Michigan waters on 27 March 2017 and was located near New Buffalo, Michigan. From 28 March through 10

April 2017, he traveled north along the Michigan coastline stopping near Benton Harbor, Michigan and returning to an area near Holland, Michigan on 10 April 2017, when transmissions were lost (Figure 1.4). Intermittent transmissions were provided throughout the life of PTT-ID 146131, which was implanted in an ASY male. After release, he traveled to Green Bay and remained near Chambers Island, Wisconsin through 30 November 2016. On 9 December 2016, he was located near Ludington, Michigan. He traveled south from Ludington, Michigan and was along the Michigan shoreline of Muskegon and Ottawa Counties from 27 December 2016 through 24 January 2017. From 6-9 March 2017, he was located near Washington Island, Wisconsin. He then traveled south to waters near Manitowoc, Wisconsin before relocating to Green Bay, near Peshtigo, Wisconsin by 4 April 2017. He then traveled to the lower portion of Green Bay, near Pensaukee, Wisconsin by 18 April 2017, where he remained until transmissions were lost on 29 April 2017 (Figure 1.6).

Two radio-marked LTDUs (PTT-IDs 158804 and 146132) remained near the Two Rivers, Wisconsin capture site for ≥ one week, before traveling to other areas of Lake Michigan. An ASY female (PTT-ID 158804) moved east to Michigan waters one week after capture and was located near Whitehall, Michigan on 14 November 2016. She stayed near Muskegon and Ottawa Counties through 28 December 2016. On 3 January 2017, she was located near Cedar Grove, Wisconsin. She then moved south and was along the Wisconsin shoreline of Racine and Kenosha Counties from 6-9 January 2017. She then traveled southeast and was along the Michigan shoreline of Berrien County on 12 January 2017. From 19 January through 19 February 2017, she remained in Michigan waters along Muskegon, Ottawa, and Allegan Counties. By 28 February, she had relocated to an area near Wind Point, Wisconsin, but traveled back to Michigan waters by 3 March 2017. She remained in the Michigan waters of Muskegon, Ottawa, and Allegan Counties through 19 March 2017. By 22 March 2017, she had moved north and was along Michigan's Upper Peninsula. She remained in this area, along Schoolcraft and Mackinac Counties through 11 May 2017. On 21 May 17, she was migrating over the province of Ontario, Canada. She provided migratory information to her presumptive breeding location in Nunavut, Canada, and post-breeding period movements before transmissions were lost on 29 July 2017 (Figure 1.3). An ASY male (PTT-ID 146132) radio-marked on 5 November 2016, remained near Two Rivers, Wisconsin for 10 days. Within a 12-hour window (1:37 to 13:12) on 15 November 2017, he traveled 100 km (62.3 mi) to a location off the Michigan coastline in Oceana County. He remained near the Michigan coastline of Oceana, Muskegon, and Ottawa Counties through 5 December 2017. On 8 December 2017, he was located along Lake and Cook Counties, Illinois. He remained in this area through 28 February 2017. By 2 March 2017, he had moved east to an area near Benton Harbor, Michigan and on 3 March 2017, he was near Holland, Michigan. He then traveled west and was again along Lake and Cook Counties, Illinois from 5-30 March 2017. By 3 April 2017, he had relocated to Green Bay and was near Chambers Island, Wisconsin, where he remained through 12 April 2017. He then traveled northeast and was near Washington Island, Wisconsin on 13 April 2017, near Garden Island, Michigan on 14 April 2017, and near Mackinaw City, Michigan on 15 April 2017. He remained in this area of the Mackinaw straits until 1 May 2017, when transmissions became poor ($LC \leq 1$) and intermittent (Figure 1.7).

A large majority (95%) of daytime wintering locations, excluding Green Bay, were on the open waters of Lake Michigan within 13.3 km of the shoreline (50% were within 3.3 km). The average distance from shore of individual radio-marked LTDUs varied from 1.4-7.8 km and average water depths at these locations varied from 16.8-27.7 m during daylight hours (Table

1.4). At night, radio-marked LTDUs were located further offshore (averaging 7.3-16.5 km) and at deeper water depths (averaging 59.6-74.8 m; Table 1.4). This shift from nearshore and shallow water during the day to further offshore and deeper water at night was well-represented by PTT-ID 146128, around Door County, Wisconsin and along the Michigan shoreline of Muskegon, Ottawa, and Allegan Counties (Figure 1.5); PTT-ID 146132 also showed these shifts near Two Rivers, Wisconsin, as well as Lake and Cook Counties, Illinois (Figure 1.7), when good locations ($LC \geq 1$) were being received every 10 hours. Combined daytime and nighttime locations of all LTDUs show that this offshore movement at night occurs throughout the open waters of Lake Michigan (Figure 1.8). Relative density estimates from radio-marked individuals indicate the areas around Manitowoc, Kewaunee, and Door counties in Wisconsin, as well as Oceana and Muskegon counties in Michigan are important areas throughout November, while in December important areas are near Leelanau, Ottawa, and Allegan counties in Michigan, as well as Lake and Cook counties in Illinois. Relative density estimates from January, February, and March indicate similar high use areas to those found in December but with varying density estimates. In April, the lower portion of Green Bay in Wisconsin and open waters northeast of Leelanau County, Michigan are highlighted as high use areas (Figure 1.9).

Winter range size for individual LTDUs ranged from 11,106.0 km^2 to 44,466.0 km^2 using the minimum convex polygon method. Using fixed kernel 95% utilization distribution probability averaged 31,922.4 km^2 (range = 8,129.5 to 51,816.6 km^2) and core use areas (50% fixed kernel contour) averaged 6,657.7 km^2 (range = 1,309.4 to 11,236.8 km^2; Table 1.5).

1.5 DISCUSSION

1.5.1 Satellite telemetry and LTDUs

Of the 10 PTTs deployed, six (60%) provided information necessary to meet study objectives of documenting habitat use on Lake Michigan and three (30%) in documenting migratory routes and breeding ground affiliations. Two (20%) radio-marked LTDUs died and two (20%) lost transmissions within 17 days of PTT implantation. Combined mortality or transmitter failure (40%) for this study was slightly lower than that of other satellite transmitter studies with LTDUs, which experienced 45-55% mortality or transmitter failure within 60 days of the surgical procedure (Mallory et al. 2006, Sea Duck Joint Venture 2015).

Surviving LTDUs implanted with PTTs may also experience effects from the additional weight of the PTT, and thus may not represent the population of LTDUs. A number of studies have shown that implantable transmitters can negatively impact the individual (Hupp et al. 2006, Latty et al. 2010, Fast et al. 2011) but less negatively than other types of external markers (Rotella et al. 1993, Dzus and Clark 1996, White et al. 2013). As of now, implantable transmitters remain the best method of determining migratory routes for sea ducks (Sea Duck Joint Venture 2015). Therefore, one should interpret the results, particularly of long distance movements, resting bouts, and timing of migration, with caution.

1.5.2 Migration and Breeding Grounds

Radio-marked LTDUs from this study departed Lake Michigan between 11 and 21 May, which was similar to those departing Lake Ontario (median departure date of 17 May; Sea Duck Joint Venture 2015) but later than those departing the Atlantic Coast (late March or early April; Sea Duck Joint Venture 2015). After departing Lake Michigan, radio-marked LTDUs tended to make a direct flight to James Bay or Hudson Bay, whereas radio-marked LTDUs from Lake

Ontario used a variety of routes (Mallory et al. 2006, Sea Duck Joint Venture 2015). Extra stopover sites, as exhibited by LTDUs radio-marked on Lake Ontario, could explain the large variation observed in their departure dates (9 April to 5 June; Sea Duck Joint Venture 2015), as opposed to the relatively similar departure dates of LTDUs radio-marked on Lake Michigan. Migration data from LTDUs radio-marked on Lake Michigan suggest that James Bay and Hudson Bay may provide important stopover and/or staging sites during spring and fall migration; the western shore of James Bay, and waters around Akimiski Island seem to be important, along with the Belcher Islands, waters south of South Hampton Island, Chesterfield Inlet, and Whale Cove areas of Hudson Bay. The Sea Duck Joint Venture (2015) highlights these and other areas as key migratory sites during migration, with the only notable exceptions being the western shore of James Bay and waters south of South Hampton Island. Mallory et al. (2006) found that LTDUs radio-marked on Lake Ontario circumnavigated Hudson Bay throughout their annual migration. In my study, only one radio-marked LTDU from Lake Michigan provided data for a full migration cycle. That individual duck traveled only a little further east during fall migration and followed a similar trajectory south back to Lake Michigan, as it did north. Habitat used during spring migration may be limited by sea ice, whereas fall migration is likely driven by where birds are able to gather food (Mallory et al. 2006).

The three female LTDUs radio-marked in this study spent the breeding period in Nunavut, Canada. However, this study has an extremely small sample size and does not mean that all LTDUs wintering on Lake Michigan breed in Nunavut, Canada. According to the Sea Duck Joint Venture (2015), radio-marked LTDUs from the Atlantic coast and Lake Ontario nested in the provinces of Manitoba, Northwest Territories, Nunavut, and Quebec, with all locations occurring east of Bathurst Inlet, Nunavut, Canada. I observed that female radio-marked LTDUs from Lake Michigan spent the breeding period within this area, suggesting that the breeding area is shared by the various eastern wintering populations of LTDUs.

Arrival time to the breeding grounds did not seem to be severely impacted by transmitter implantation. It is difficult to determine if arrival of radio-marked LTDUs from Lake Michigan was associated with ice deterioration on inland lakes, but their timing of arrival was similar to studies investigating unmarked individuals. Females radio-marked on Lake Michigan in my study arrived at traditional breeding areas between 2-27 June. According to Alison (1975), breeding pairs of LTDUs arrived from 31 May to 23 June over the course of four years at his study site near Churchill, Manitoba. Additionally, the first arriving LTDUs to the breeding area near Sarcpa Lake, in the northern part of Melville Peninsula, Nunavut, Canada, occurred on 9 June 1981 and 16 June 1982 and occurred within two days of open-water leads being observed on inland lakes (Montgomerie et al. 1983).

1.5.3 Lake Michigan Habitat Use and Movements

LTDUs radio-marked on Lake Michigan stayed within the Lake Michigan basin throughout winter and utilized 54% of Lake Michigan (58,000 km^2) based on the average fixed kernel 95% utilization distribution probability. Core use areas (50% fixed kernel contour), on average, occupied about 12% of the surface area of Lake Michigan. This is likely an underestimate of the locations used, as captured LTDUs were already on Lake Michigan and likely north of our capture site prior to capture, similar to SY female PTT-ID 146126 (Figure 1.2). Radio-marked individuals tended to move south on Lake Michigan as winter progressed, before returning to the northern end of Lake Michigan before spring departure (Figure 1.9). The only exception to this was an ASY female (PTT-ID 158806) that remained on the north end of Lake Michigan throughout winter (Figure 1.4). Aerial surveys conducted over Lake Michigan indicate that large concentrations of LTDUs utilize similar areas throughout winter, including individuals that remain on the north end of Lake Michigan (Kenow et al. 2013, Kenow et al. 2015, B. Mueller, personal communication, 10 July 2017). Radio-marked LTDUs utilized areas of varying water depths and were closer to shore during daylight hours, however at night they moved to deeper waters and were further offshore. This shift to further offshore and deeper water was well-documented by radio-marked individuals (Table 1.4), as well as aerial thermal imagery collected by the USFWS (B. Lubinski, unpublished data).

Diel movements could be related to disturbance, either from humans (Davidson and Rothwell 1993, Schwemmer et al. 2011) or perceived predation risk (Behney et al. 2018). According to Schwemmer et al. (2011), LTDUs and other waterbirds altered their distributions due to shipping traffic during the day. Commercial shipping occurs 24 hours a day throughout Lake Michigan (Colautti et al. 2004), with most international shipping lanes paralleling the shoreline (Great Lakes Environmental Assessment and Mapping Project 2017). LTDUs could be attempting to avoid disturbance from shipping by moving further offshore at night, but I find this unlikely as nighttime distributions of LTDUs typically fell within the shipping lanes and commercial ships were routinely encountered and avoided during nighttime capture efforts. There is little variance around international shipping routes (Great Lakes Environmental Assessment and Mapping Project 2017), suggesting that LTDUs may be subjecting themselves to more disturbance by moving offshore at night. Perceived risk of predation (Behney et al. 2018) may also be a factor in LTDU movements offshore at night. Early detection of predators greatly reduces the risk of prey being killed (Lima 1987), thus LTDUs moving further offshore could be reducing their perceived risk of predation from avian predators. However, flight is energetically expensive and energetic costs would need to be compensated for by reducing risk associated with predation or through increased food intake (Davidson and Rothwell 1993). LTDUs are already quite far (1.4-7.8 km) from shore during the day, and benefits from moving further offshore (7.3-16.5 km) at night would have to out-weigh energetic costs associated with flight. Determining potential sources of disturbance to LTDUs utilizing Lake Michigan, when disturbance events are likely to occur, and impacts from disturbance could elucidate if nightly offshore movements are related to human or predator disturbance.

Alternatively, diel movements of LTDUs on Lake Michigan could be related to foraging and food resource availability (Tamisier 1985, McNeil et al. 1992). Peterson and Ellarson (1977) showed that Lake Michigan LTDUs foraged heavily on *Diporeia* spp (hereafter Diporeia), a small crustacean that was once abundant throughout Lake Michigan (Nalepa et al 2009). However, the population of Diporeia has since declined and occurred from shallower to deeper water, which is associated with the invasion of quagga mussels (*Dreissena rostriformis bugensis*), and zebra mussels (*Dreissena polymorpha*; Nalepa et al. 2009). Another potential food item for LTDUs is opossum shrimp (*Mysis relicta*; hereafter Mysis), which is present at greater depths (75-110 m) in Lake Michigan (Pothoven et al. 2004). The deeper waters to which LTDUs are moving at night would fall within the range of both Diporeia and Mysis distributions, suggesting that LTDUs may be targeting these prey species. In addition, both Diporeia and Mysis show a vertical migration at night (Hondorp et al. 2005), making them susceptible to planktivorous fish (Janssen and Brandt 1980, Hondorp et al. 2005) and possibly LTDU predation. However, further studies are needed to determine how LTDU diets have changed since the invasion of zebra and quagga mussels into Lake Michigan, as well as determining if LTDUs forage (i.e., dive) at night.

1.5.4 Management Implications

Although LTDUs are widespread on Lake Michigan (Kumlien and Hollister 1903, Robbins 1991, Chartier and Ziarno 2004, Kenow et al. 2013, Kenow et al. 2015), information on their highest use areas will provide a means to better assess where LTDUs may potentially be exposed to forage containing type E botulinum toxin, mitigate effects of fisheries bycatch, and provide a means to identify and recommend alternative windfarm sites. Relative density estimates from radio-marked individuals from November through April indicate high use areas in the lower portion of Green Bay, as well as the open waters of Lake Michigan around Manitowoc, Kewaunee, and Door counties in Wisconsin, Oceana, Muskegon, Leelanau, Ottawa, and Allegan counties in Michigan, and Lake and Cook counties in Illinois (Figure 1.9). Aerial surveys indicate high use areas are similar to those shown by radio-marked individuals, but highlight additional areas, like the open waters of Lake Michigan near the Garden Peninsula and Mason County, Michigan (Kenow et al. 2013, Kenow et al. 2015) and areas near Sheboygan and Milwaukee counties in Wisconsin (B. Mueller, personal communication, 10 July 2017). High use areas, as indicated through radio-marked LTDUs and aerial surveys, could inform decision making related to mitigating detrimental impacts of gillnetting and wind farm development.

Decisions regarding wind farm placement will also benefit from a better understanding of the travel routes and diel movements of LTDUs on Lake Michigan. Diel movements from this study indicate that LTDUs move from shallower water closer to shore during the day to deeper water and further offshore at night (Table 1.4). This travel is likely occurring during the low-light hours around sunrise and sunset and is congruent with previous observations and studies of LTDU movements (Johnsgard 1975, Jones 1979). Increased movements coupled with low-light level conditions that occur during dawn and dusk may make LTDUs more susceptible to collisions with wind turbines (Larsen and Clausen 2002, Drewitt and Langston 2006). Insight into travel routes between high use areas on Lake Michigan was provided by individually radio-marked LTDUs. However, this information only provides straight line movements and LTDUs could take other routes (e.g., travel across the lake and then along the shoreline to the desired destination). Location information from this study, with current transmission times focused on migratory patterns and diel movements, does not have the resolution to capture those flight paths between high use areas, but provides insight into where those routes might be and can be used to mitigate issues from wind farm development.

Managers and researchers can use habitat use information to better assess where LTDUs may potentially ingest prey items that contain botulinum neurotoxin type E. Similar work has been conducted with common loons on Lake Michigan (Kenow et al. 2018). Additionally, finding dietary links and overlapping habitats among other waterbirds at risk to type E botulism and LTDUs would provide insight into how the toxin moves through the food web (Chipault et al. 2015). For example, common loons likely forage primarily on benthic prey while using Lake Michigan (Kenow et al. 2018) and Essian et al. (2016) found round gobies (*Neogobius melanostomus*) to be an important component of common loon diets, particularly those succumbing to type E botulism. LTDUs continued to forage on amphipods, but also feed on zebra and quagga mussels, following the zebra and quagga mussel invasion on Lake Ontario (Schummer et al. 2008). Dietary differences among at-risk waterbird species suggests that type E botulism may be present in a variety of food web components (Chipault et al. 2015, Essian et al. 2016). Determining where common loon and LTDU distributions overlap may provide insight into where both species are ingesting the toxin.

1.5.5 Conclusion

Radio-marked LTDUs from Lake Michigan have provided useful data on migration, habitat use, and movements. However, one must use caution in interpreting the data, as impacts from transmitter implantation are likely, based on the high rate of mortality and/or transmitter failure seen by other studies (Mallory et al. 2006, Sea Duck Joint Venture 2015) and this study. However, secondary information provided through aerial surveys conducted on Lake Michigan (Kenow et al. 2013, Kenow et al. 2015, Kenow et al. 2018, B. Mueller, personal communication, 10 July 2017) and on the nesting grounds, (Alison 1975, Montgomerie et al. 1983) provide a means to verify that LTDUs surviving >60 days past transmitter implantation show similar patterns of habitat use and arrival dates as unmarked individuals. Information on diel and seasonal movements from radio-marked LTDUs on Lake Michigan will benefit resource managers as they deal with key conservation issues on the Great Lakes, such as gillnet bycatch and wind power development. In addition, it will aid researchers in their search to determine the food web links of avian botulism type E throughout the Great Lakes.

Table 1.1. Radio-transmitter identification (PTT-ID), sex, age, capture location, capture date, duty cycle, transmission duration, and outcome of 10 long-tailed ducks radio-marked from March 2016 through March 2017 on Lake Michigan.

PTT-ID	Sex	Age[a]	Capture Location	Capture Date	Duty cycle	Transmission duration (days)	Outcome
158806-1	Female	ASY	Two Rivers, WI	11-Mar-16	3 hrs on: 72 hrs off	4	Mortality signal 15-Mar-16; confirmed mortality; PTT recovered 17-Mar-16
146126	Female	SY	Seul Choix Point, MI	28-Apr-16	3 hrs on: 72 hrs off	188	Last transmission 2-Nov-16; possible PTT failure
146127	Male	ASY	Two Rivers, WI	29-Oct-16	2 hrs on: 10 hrs off	17	Last transmission 15-Nov-16; possible PTT failure
146128	Male	ASY	Two Rivers, WI	29-Oct-16	2 hrs on: 10 hrs off	184	Last transmission 1-May-17; battery likely depleted
146129	Male	HY	Two Rivers, WI	29-Oct-16	2 hrs on: 10 hrs off	13	Mortality signal 11-Nov-16; confirmed mortality; remains found; PTT not recovered
146131	Male	SY	Two Rivers, WI	29-Oct-16	2 hrs on: 10 hrs off	213	Last transmission 30-May-17; battery likely depleted
146132	Male	ASY	Two Rivers, WI	4-Nov-16	2 hrs on: 10 hrs off	219	Last transmission 11-Jun-17; battery likely depleted
158804	Female	ASY	Two Rivers, WI	4-Nov-16	3 hrs on: 72 hrs off	270	Last transmission 1-Aug-17; possible PTT failure
158806	Female	ASY	Two Rivers, WI	21-Nov-16	3 hrs on: 72 hrs off	225	Last transmission 4-Jul-17; possible PTT failure
158807	Male	ASY	Two Rivers, WI	16-Mar-17	3 hrs on: 72 hrs off	1	Last transmission 17-Mar-17; possible PTT failure

[a]HY = hatch year, SY = second year, and ASY = after second year, as determined by bursal measurement (females), presence of sheathed penis (males), and/or plumage characteristics.

Table 1.2. Radio-transmitter identification (PTT-ID), total number of transmissions, number of high quality transmissions (≥LC 1), and transmissions used in mapping analysis for 10 long-tailed ducks radio-marked on Lake Michigan from March 2016 through March 2017.

PTT-ID	Total No. of transmissions	No. of transmission ≥LC1	No. transmissions used in mapping/analysis
158806-1	37	21 (57%)	0
146126	438	246 (56%)	49
146127	59	37 (63%)	0
146128	601	296 (49%)	139
146129	64	41 (64%)	0
146131	239	62 (26%)	26
146132	615	323 (53%)	146
158804	431	211 (49%)	56
158806	256	133 (52%)	36
158807	22	13 (59%)	0
Total	2,762	1,383 (50%)	452

Table 1.3. Sequential dates and locations of three female long-tailed ducks radio-marked on Lake Michigan during April and November 2016.

PTT-ID	Wintering	Spring staging areas	Breeding	Fall staging areas	Following year winter areas
146126	29 Apr 16-11 May 16 (Lake Michigan [29 Apr-11 May 16])	18 May 16-05 Jun 16 (James Bay [18-21 May 16]; Hudson Bay [24 May-05 Jun 16])	12 Jun 16-16 Aug 16 (~60 km south southwest of Karrak Lake, Nunavut, Canada)	04 Sep 16-18 Oct 16 (Queen Maud Gulf [04-07 Sep 16]; Storis Passage [10-13 Sep 16]; Victoria Strait [17 Sept 16]; James Ross Strait [20-29 Sep 16]; Hudson Bay [02-05 Oct 16]; James Bay [08-18 Oct 16])	27 Oct 16-02 Nov 16 (Lake Michigan [27 Oct-02 Nov 16]; transmission lost)
158804	05 Nov 16-11 May 17 (Lake Michigan [05 Nov-11 May 17])	21 May 17-27 May 17 (Ontario [21 May 17] in flight; Hudson Bay [27 May 17])	02 Jun 17-16 Jul 17 (~175 km north northwest of Baker Lake, Nunavut, Canada)	25 Jul 17-29 Jul 17 (Adalaide Peninsula, Nunavut, Canada [25 -29 Jul 17]; transmission lost)	
158806	22 Nov 16-15 May 17 (Lake Michigan [22 Nov 16]; Green Bay [23 Nov-06 Dec 16]; Lake Michigan [09 Dec 16-15 May 17])		27 Jun 17 (~35 km south of Yathkyed Lake, Nunavut, Canada; transmission lost)		

Table 1.4. Daytime and nighttime habitat use information from six long-tailed ducks radio-marked on Lake Michigan from March 2016 to November 2016, for the open waters of Lake Michigan, excluding Green Bay. Daytime was defined as the time between two hours post sunrise to two hours pre sunset, and nighttime as two hours post sunset to two hours pre sunrise. All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

PTT-ID	No. of transmissions used for day and night analysis on Lake Michigan	No. of daytime transmissions on Lake Michigan	No. of nighttime transmissions on Lake Michigan	Average distance to nearest shore during daytime hours (km ± SD)	Average distance to nearest shore during nighttime hours (km ± SD)
146126	3	0 (0%)	3 (100%)	n/a	8.4 ± 4.8
146128	138	118 (86%)	20 (14%)	4.0 ± 4.9	14.3 ± 5.3
146131	10	10 (100%)	0 (0%)	3.6 ± 1.7	n/a
146132	138	118 (86%)	20 (14%)	7.8 ± 4.4	16.5 ± 8.4
158804	19	10 (53%)	9 (47%)	4.8 ± 3.6	16.2 ± 5.2
158806	16	7 (44%)	9 (56%)	1.4 ± 1.1	7.3 ± 2.1

Table 1.4. Extended.

PTT-ID	Average water depth during daytime hours (m ± SD)	Average water depth during nighttime hours (m ± SD)
146126	n/a	64.9 ± 47.2
146128	18.3 ± 7.7	74.8 ± 46.6
146131	24.5 ± 9.0	n/a
146132	27.7 ± 11.0	71.5 ± 30.7
158804	21.6 ± 6.7	66.9 ± 21.2
158806	16.8 ± 12.8	59.6 ± 38.3

Table 1.5. Winter range sizes (km^2) for the open waters of Lake Michigan, including Green Bay, of five long-tailed ducks radio-marked on Lake Michigan from March 2016 through November 2016.

PTT-ID	No. of locations used in analysis	No. of days on Lake Michigan	Minimum convex polygon (km^2)	50% fixed kernel (km^2)	95% fixed kernel (km^2)	95% ellipse (km^2)
146128	139	163	32,510.1	4,217.3	28,207.9	42,642.6
146131	26	182	14,792.5	6,420.1	27,259.6	31,171.5
146132	146	178	44,466.0	10,104.8	44,198.6	55,644.3
158804	40	188	38,062.4	11,236.8	51,816.6	55,950.1
158806	34	175	11,106.0	1,309.4	8,129.5	17,396.9

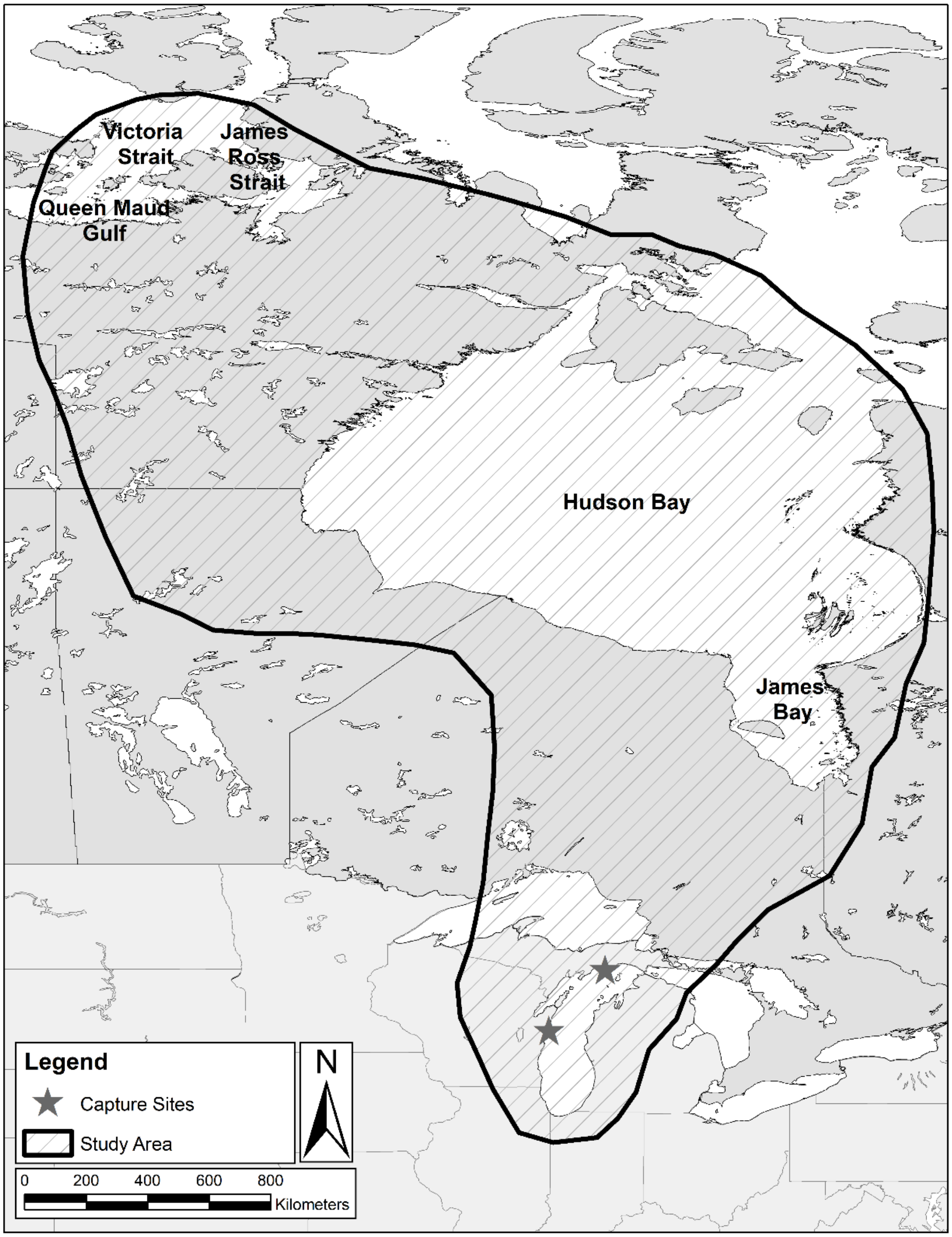

Figure 1.1. Geographical area (hashed) that encompassed all locations received from long-tailed ducks radio-marked on Lake Michigan, 2016-2017.

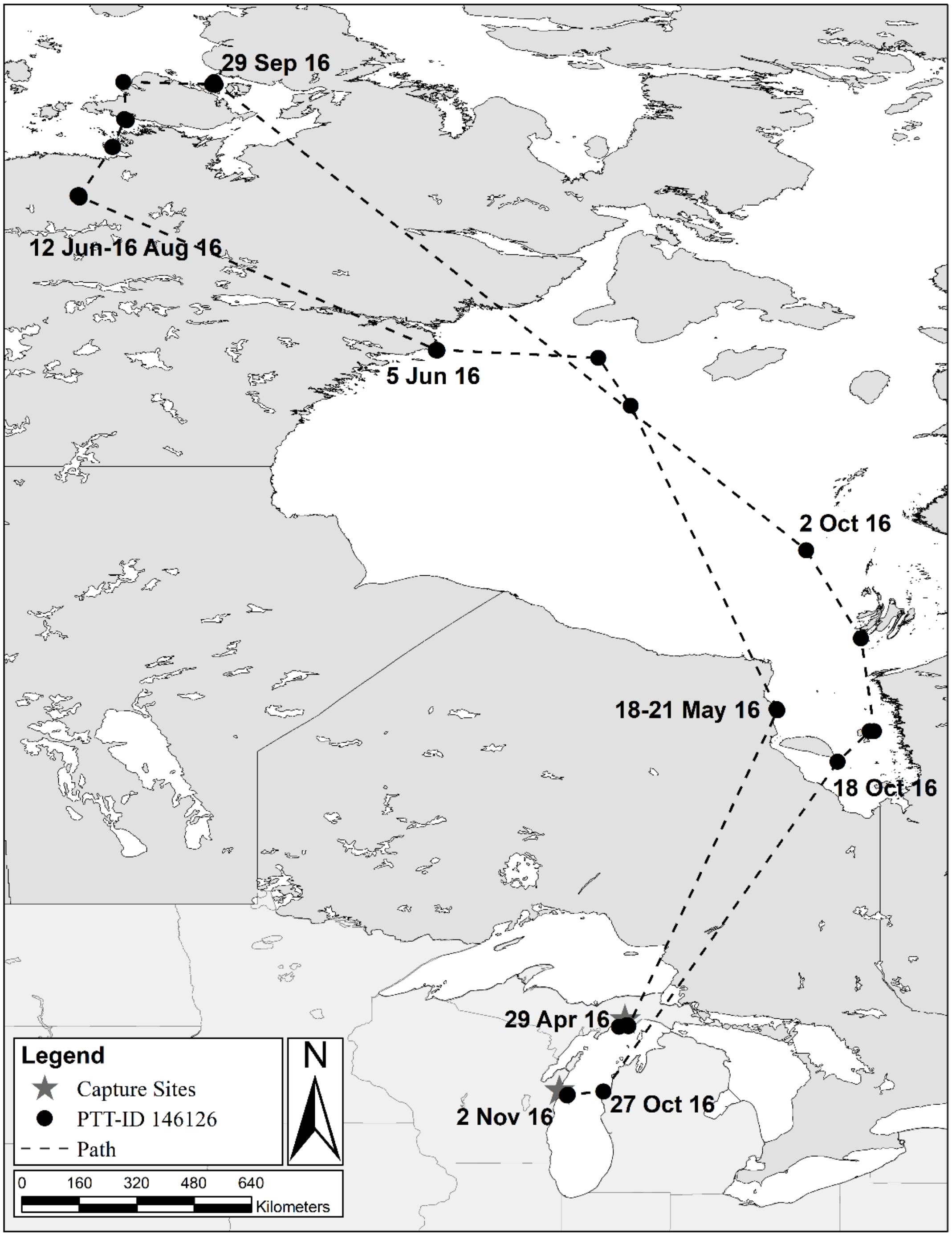

Figure 1.2. Migratory route of a second year female long-tailed duck (PTT-ID 146126) radio-marked on 29 April 2016. All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

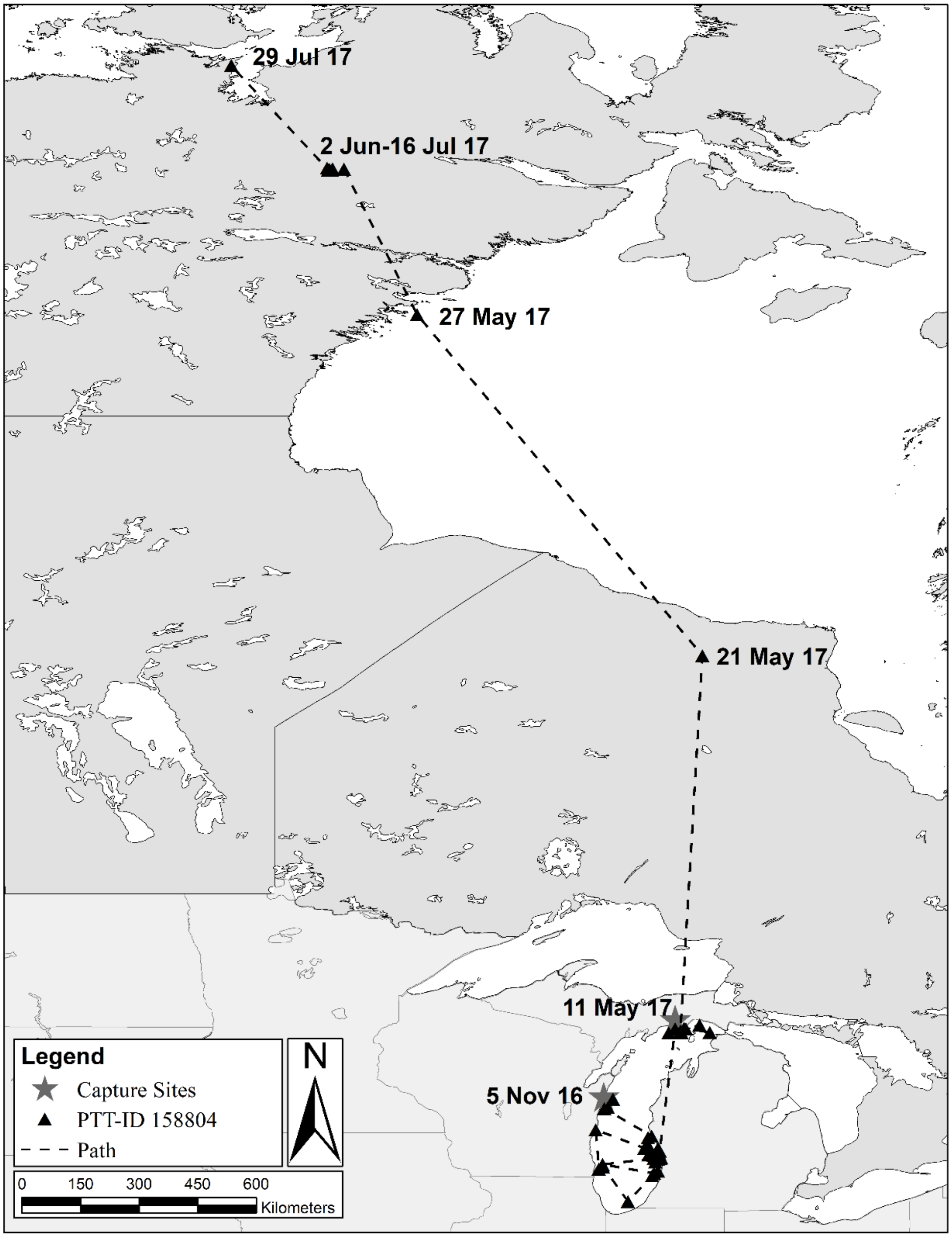

Figure 1.3. Winter movements and spring migratory route of an after second year female long-tailed duck (PTT-ID 158804) radio-marked on 05 November 2016. All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

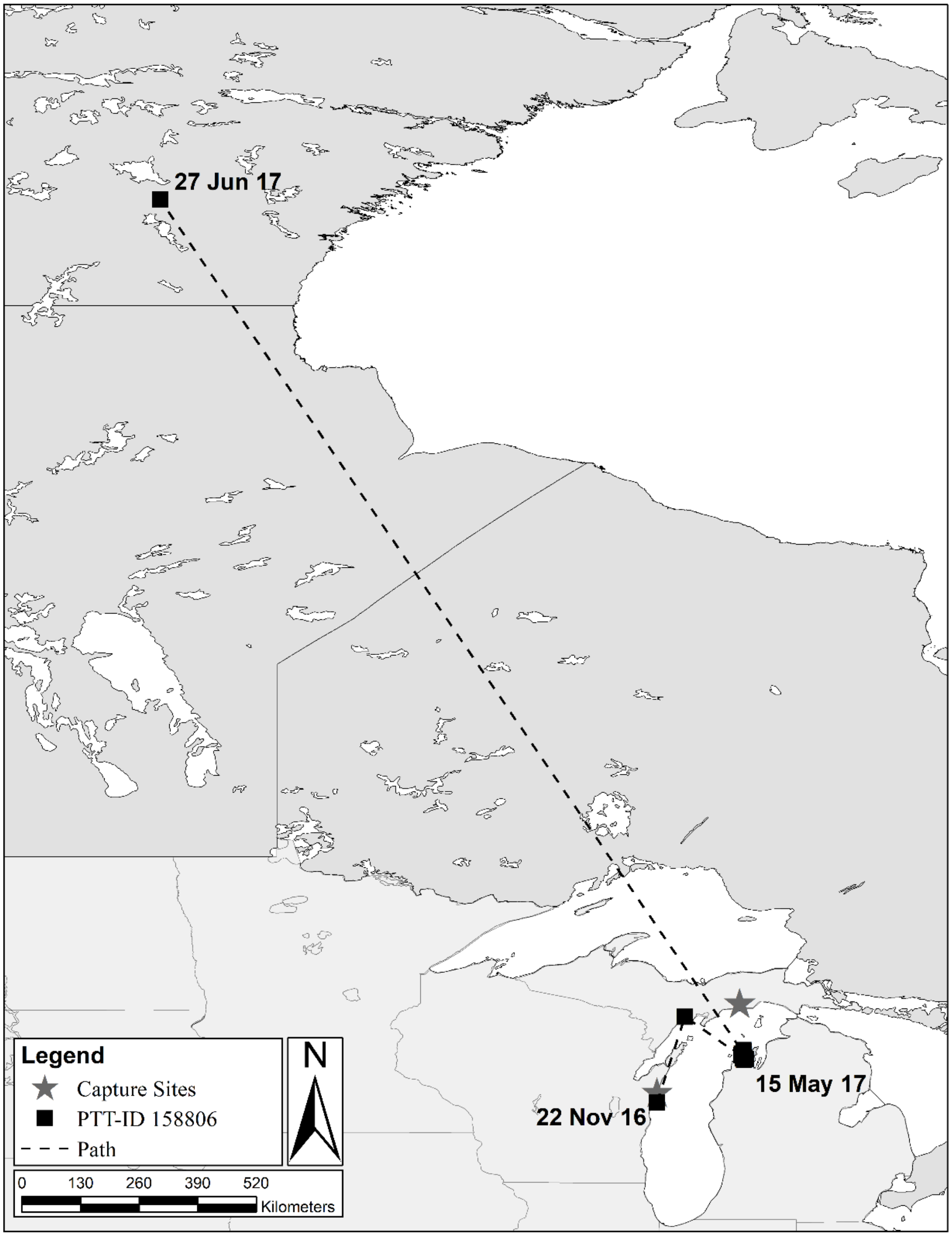

Figure 1.4. Winter movements and spring migratory route of an after second year female long-tailed duck (PTT-ID 158806) radio-marked on 22 November 2016 (intermittent transmissions since March 2017). All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

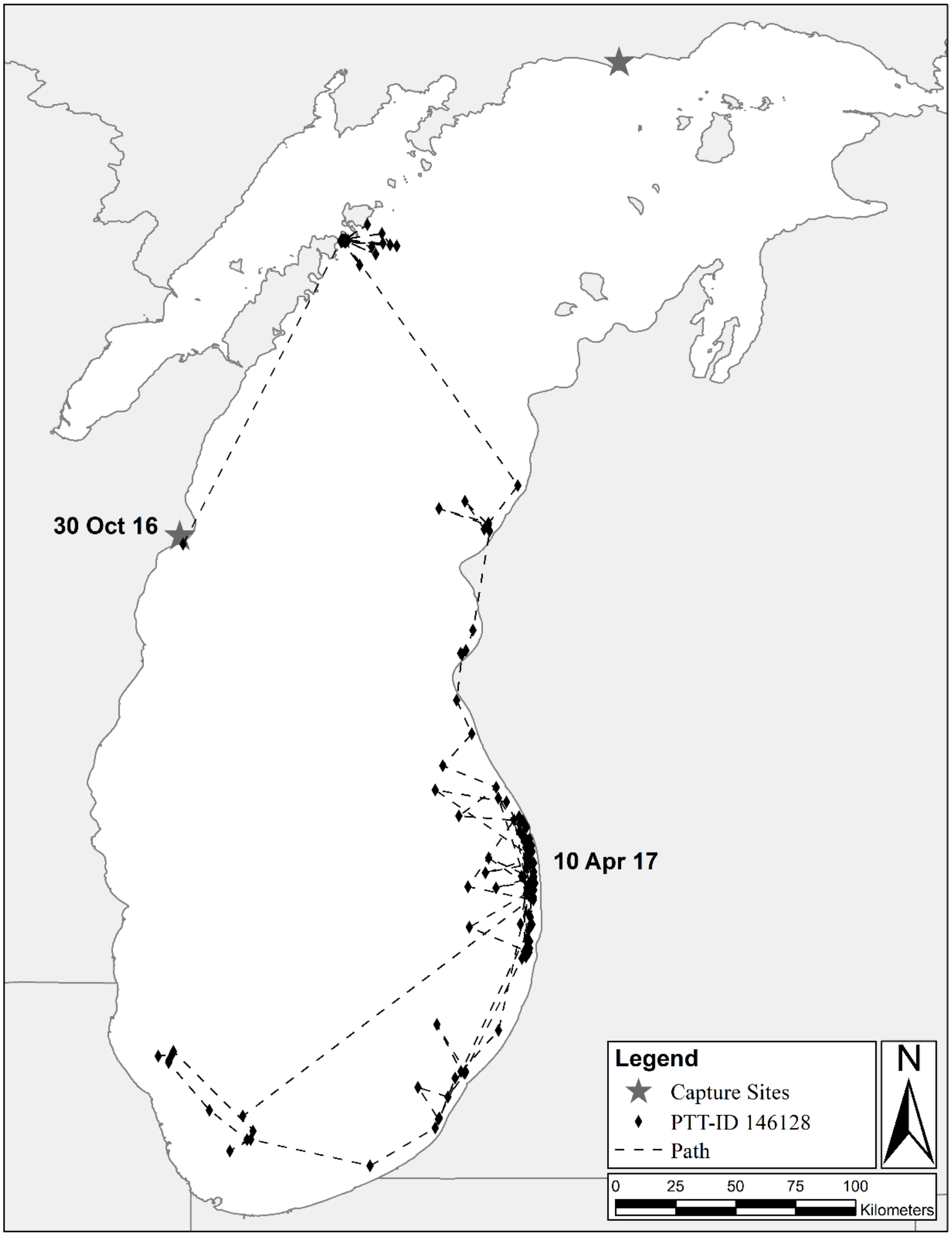

Figure 1.5. Winter movements of an after second year male long-tailed duck (PTT-ID 146128) radio-marked on 30 October 2016. All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

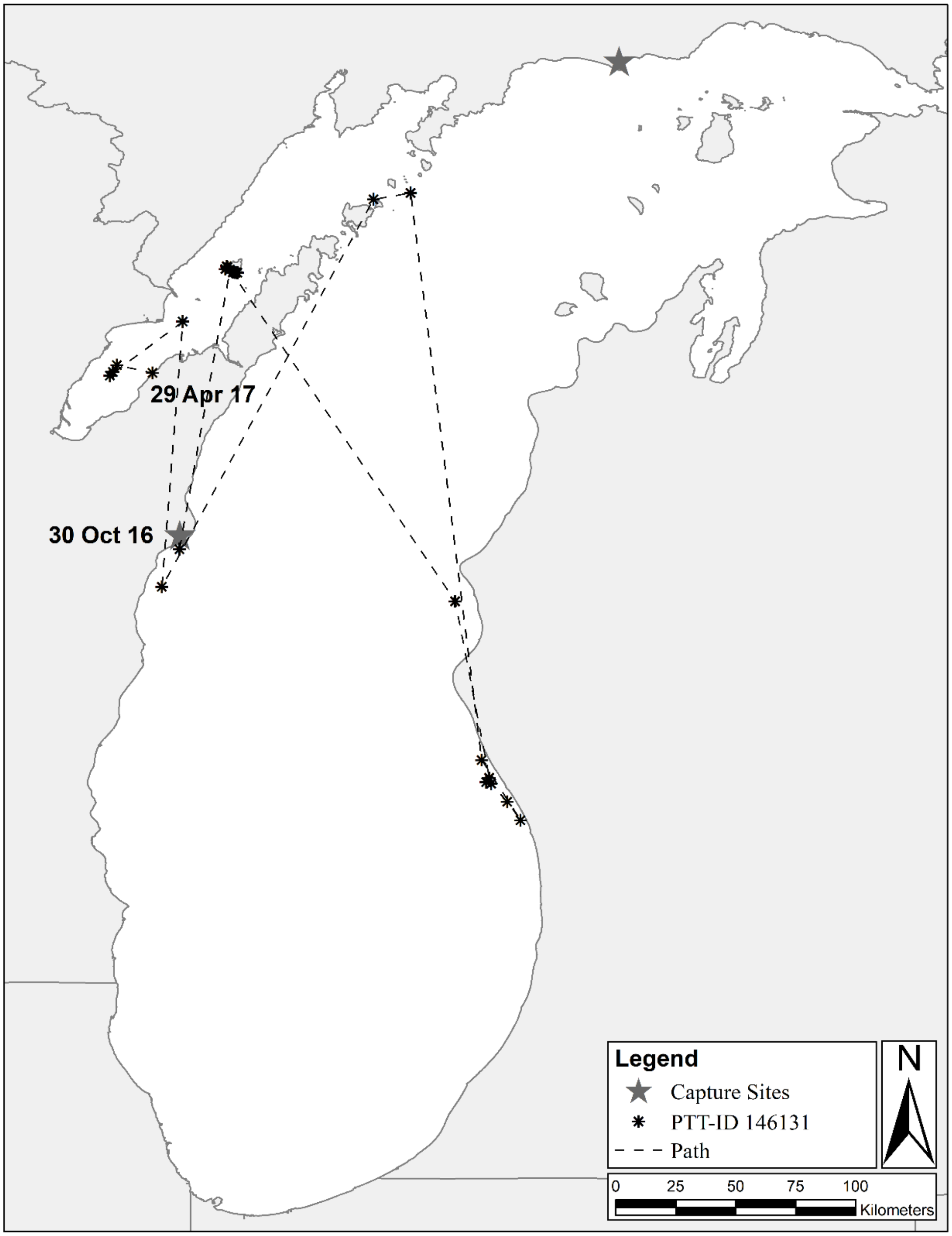

Figure 1.6. Winter movements of an after second year male long-tailed duck (PTT-ID 146131) radio-marked on 30 October 2016 (transmissions were intermittent throughout the life of the platform transmitter terminal). All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

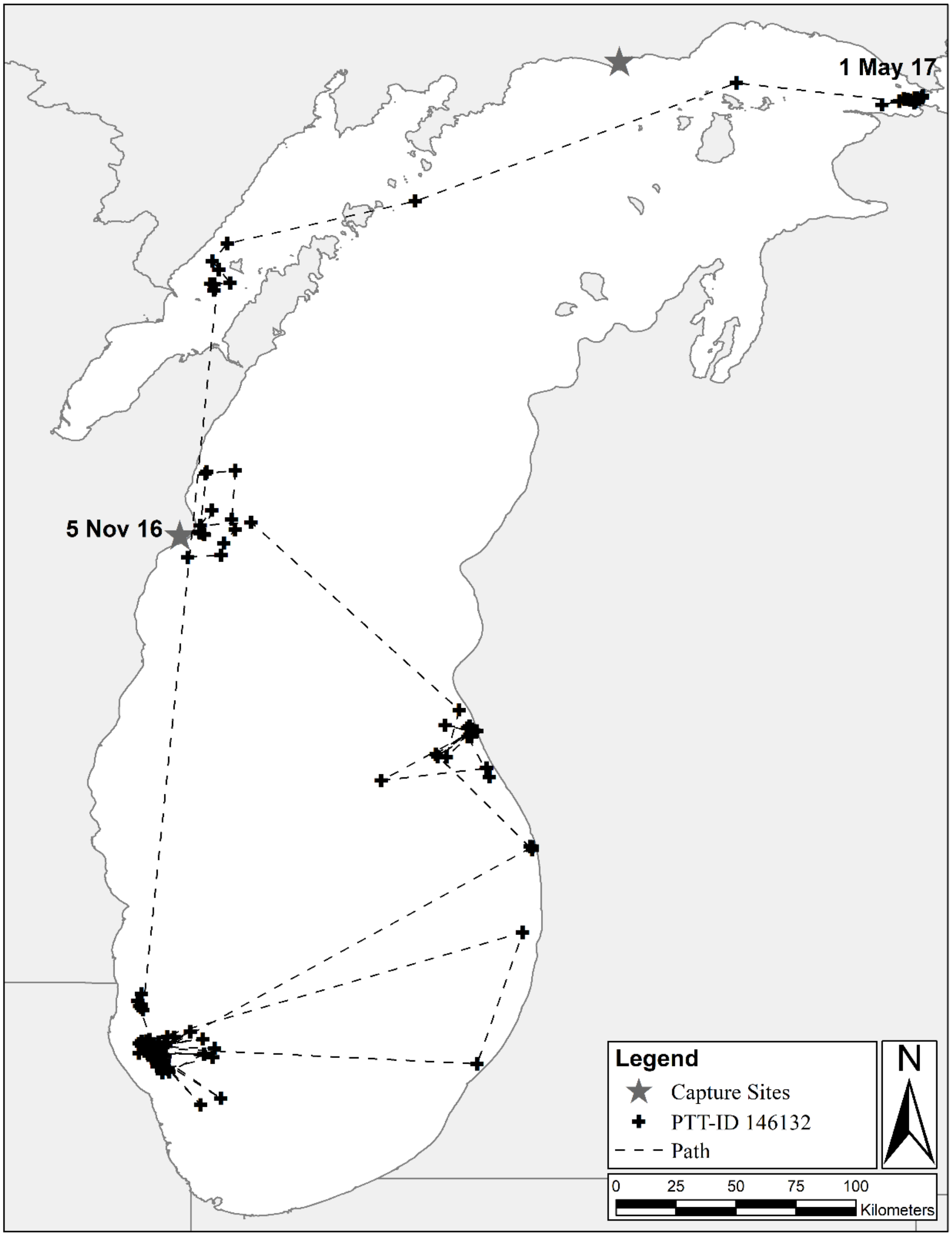

Figure 1.7. Winter movements of an after second year male long-tailed duck (PTT-ID 146132) radio-marked on 05 November 2016. All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

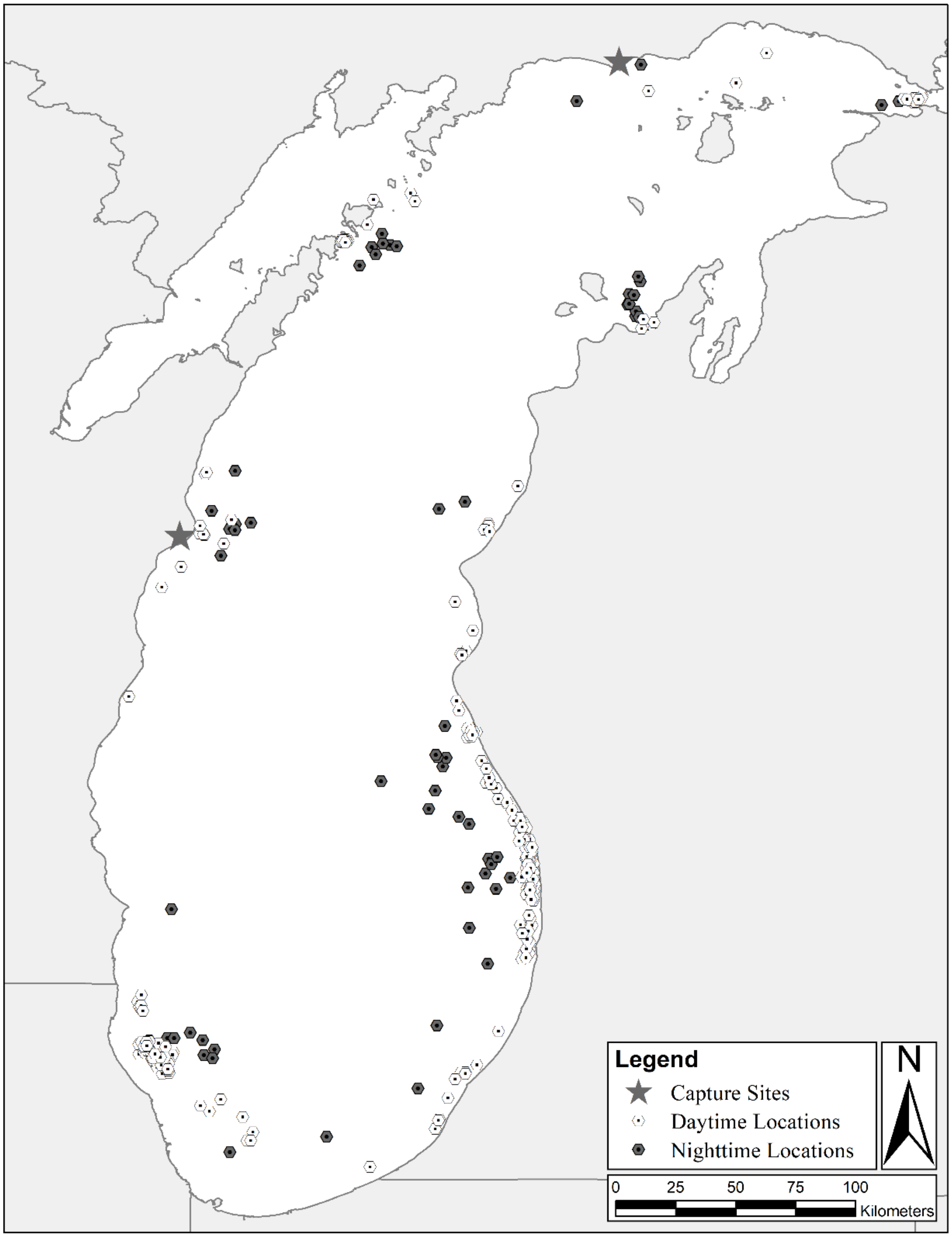

Figure 1.8. Daytime and nighttime locations of six long-tailed ducks radio-marked on Lake Michigan from April 2016 through November 2016, for the open waters of Lake Michigan excluding Green Bay. Daytime was defined as the time between two hours post sunrise to two hours pre sunset, and nighttime as two hours post sunset to two hours pre sunrise. All locations used had an Argos precision index location class greater than or equal to one (LC≥1).

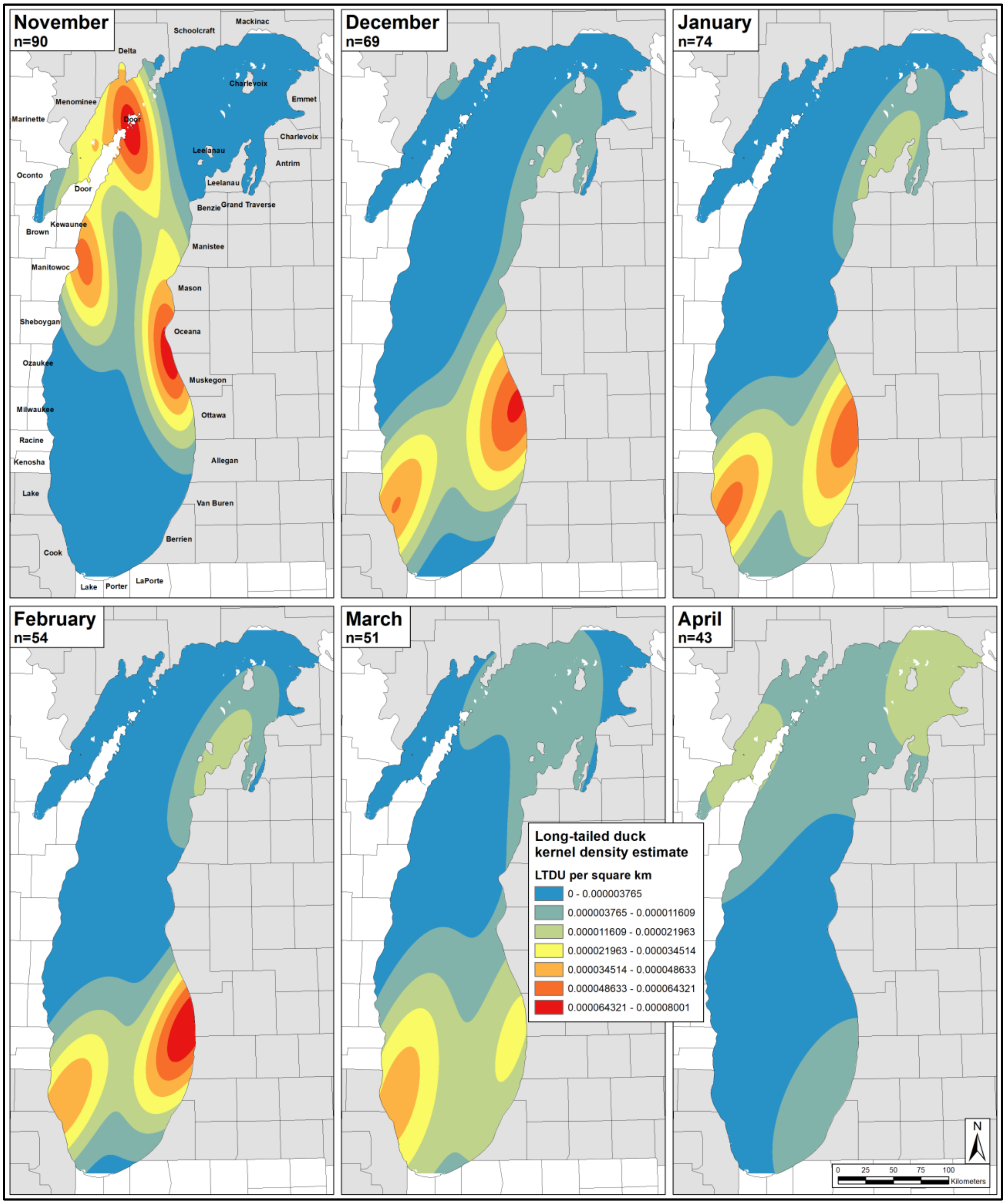

Figure 1.9. Monthly distribution and relative density estimated from cumulative satellite telemetry locations of six long-tailed ducks (LTDU) radio-marked on Lake Michigan from April 2016 through November 2016.

CHAPTER 2

A COMPARISON OF MOLECULAR AND OCULAR TECHNIQUES TO DETERMINE DIETS OF LONG-TAILED DUCKS WINTERING ON LAKE MICHIGAN

2.1 INTRODUCTION

Studies examining waterfowl diets have traditionally relied on lethal means (e.g., shooting live birds or carcass collection from fishing bycatch and disease) to determine prey items, through the examination of digestive tract contents (Dirschl 1969, Swanson and Bartonek 1970, Peterson and Ellarson 1977, Ross et. al. 2005, Schummer et al. 2008). This method has been widely used on a variety of waterfowl species (Dirschl 1969, Swanson and Bartonek 1970, Peterson and Ellarson 1977, Ross et. al. 2005, Schummer et al. 2008) and was corrected for bias associated with the location of prey contents in the digestive tract due to differential rates of digestibility (Swanson and Bartonek 1970). Since the Swanson and Bartonek (1970) paper, researchers have routinely examined esophageal contents when describing waterfowl diets to reduce bias associated with rates of digestibility (Peterson and Ellarson 1977, Ross et al. 2005, Schummer et al. 2008). Noninvasive genetic sampling techniques (Waits and Paetkau 2005) using fecal samples or alimentary canal swabs are now available, and provide a non-lethal means of determining the presence of prey species (Deagle et al. 2010, Yoccoz 2012). These molecular methods have been used to determine the diets of mammals (Clare et al. 2014), insects (Sint et al. 2014), reptiles (Brown et al. 2012), and more recently avian species (Deagle et al. 2010, Jedlicka et al. 2013, Oehm et al. 2016). The technique on avian species has proven useful in determining the presence of prey items but less useful in determining diet proportions (Deagle et al. 2010, Pompanon et al. 2012, Yoccoz 2012), hence a comparison of the former method, examining esophageal contents, to molecular methods is needed (Yoccoz 2012).

Lake Michigan provides a variety of resources to migrating waterfowl (Prince et al. 1992), but food resources have undergone extreme changes due to the introduction of invasive species (Nalepa et al. 2009, Mida et al. 2010), and altered food resources available to waterfowl (Ross et al. 2005, Schummer et al. 2008). Changes in food resources have been shown to create resource competition (Weins 1977, Schummer et al. 2008) and increase contaminant levels in waterbirds (Custer and Custer 2000, Schummer et al. 2010); both of which have been associated with decreased waterfowl survival (Owen and Black 1989, Esler et al. 2002) and reproduction (Heinz 1979, Fox 1993, Custer et al. 1999), potentially impacting waterfowl populations (Johnson et al 1992, Schmutz et al. 1997).

The long-tailed duck (*Clangula hyemalis*; hereafter LTDU) is a medium-sized duck (Robertson and Savard 2002, Baldassarre 2014) that winters from the ice edge south along the Pacific and Atlantic coasts, and on the Great Lakes (Baldassarre 2014). Population estimates for LTDUs overwintering on Lake Michigan are unknown, but LTDUs do overwinter there in great numbers (Ellarson 1956) and they were the most abundant species of waterbird observed during aerial surveys conducted during fall, winter, and spring (Kenow et al. 2013, Kenow et al. 2015, B. Mueller, personal communication, 10 July 2017). According to Lagler and Wienert (1948), LTDUs on Lake Michigan once fed primarily on bivalves (*Pisidium* sp.) and amphipods (*Pontoporeia* spp.), but Peterson and Ellarson (1977) considered LTDUs opportunistic feeders that ate a range of readily available animal matter. However, *Diporeia* spp. (formerly *Pontoporeia* spp.; hereafter Diporeia) constituted 82% of the total volume of animal matter in 151 gizzards examined by Peterson and Ellarson (1977). Diporeia were once the dominant benthic organism in Lake Michigan, but populations have declined dramatically due to the introduction of quagga mussels (*Dreissena rostriformis bugensis*) and zebra mussels (*Dreissena* *polymorpha*; hereafter collectively referred to as dreissenid mussels; Nalepa et al. 2009). Understanding how LTDU diets have changed within this changing ecosystem is important, especially as resource managers and researchers search for food web links associated with transfer of type-E botulism toxin to avian species on Lake Michigan (Essian et al. 2016, Kenow et al. 2018), which LTDUs are at-risk of exposure to (Chipault et al. 2015, Essian et al. 2016).

Objectives of this project were to describe the diets of LTDUs utilizing Lake Michigan by examining esophageal contents and utilizing molecular techniques to identify prey DNA in swab samples taken from the alimentary canal. Furthermore, I compared those methods to determine if ocular and molecular methods detected the same suite of prey species. If molecular techniques are able to describe the same or greater array of prey species as examining esophageal contents, it would provide a new, non-lethal, means of characterizing diet to researchers and resource managers.

2.2 Study Area

Carcass collection took place at Seagull Marina in Two Rivers, Wisconsin, while conducting hunter harvest surveys. The Seagull Marina boat launch provides easy access to western Lake Michigan waters and is located at the confluence of the East and West Twin Rivers. Hunters donating carcasses reported that the harvest of LTDUs occurred within a 23 km radius of Seagull Marina (Figure 3.1). The launch was selected based on information provided by guide services targeting LTDUs and conservation officers. Both groups stated that many hunters depart from this launch and that LTDU composes a majority of the hunters' bag.

2.3 MATERIALS AND METHODS

2.3.1 Carcass Collection

Hunter-harvested LTDUs were voluntarily submitted during an in-person hunter survey during 1 November through 4 December 2016. Carcasses were labeled with species, sex, age, harvest date, harvest location, and hunter information in accordance with state and federal regulations (50 CFR § 20.36 Tagging Requirement; 50 CFR § 20.37 Custody of Birds of Another; 50 CFR § 20.40 Gift of Migratory Game Birds) for donating harvested waterfowl species (Conservation Officer J. Lawrence, personal communication, 15 October 2016). LTDU carcasses were aged as after second year (ASY), second year (SY), and hatch year (HY) following guidelines summarized by the Sea Duck Joint Venture (2015). A combination of bursa depth and plumage was used for age determination of females, while plumage and the presence of a sheathed penis were used for males. All hunter interactions and survey protocols were approved under the Southern Illinois University – Carbondale Human Subjects Committee (Protocol Number: 15427). Carcasses were taken to a field house each day and frozen, until field work was completed. Upon completion of field work, carcasses were transported in coolers to the Upper Midwest Environmental Sciences Center, where digestive tracts were removed and DNA collected from carcasses.

2.3.2 Esophageal Contents Removal and DNA Collection

DNA swabs were taken from three locations of each carcass: (1) the esophagus, (2) lower segment of the small intestine, and (3) cloaca. Swabs taken from the esophagus followed protocols for the testing of avian influenza (United States Department of Agriculture – APHIS 2008), while swabs taken from the cloaca followed protocols outlined by Vo and Jedlicka (2014). Both methods represent field techniques that have been used on live birds (Dugan et al.

2008, United States Department of Agriculture – APHIS 2008, Daoust et al. 2011, Jedlicka et al. 2013, Vo and Jedlicka 2014). The small intestine swab was included to evaluate if detections were similar throughout the alimentary canal. Swab samples were frozen at -80°C, until DNA could be amplified and analyzed for prey species. After collecting swab samples, the esophageal contents were removed and examined under a dissection microscope (10X Ocular) and prey items identified to the lowest taxonomic level possible (Peterson and Ellarson 1977, Jamieson et al. 2001, Ross et al. 2005, White et al. 2009). Zebra and quagga mussels were identified as dreissenid mussels during ocular examinations, due to their high degree of morphological variation (May and Marsden 1992, Beggel et al. 2014) and that some esophageal contents only contained shell fragments.

2.3.3 DNA Analysis

Seven prey species were selected for DNA analysis based on a literature review of Great Lakes LTDU food habits studies, potential prey species currently available for consumption in Lake Michigan, and prey species with primers available for accurate identification. Species selected were quagga mussel, zebra mussel, round goby (*Neogobius melanostromus*), Diporeia, yellow perch (*Perca flavescens*), alewife (*Alosa pseudoharengus*), and spiny water flea (*Bythotrephes longimanus*). DNA was extracted from tissue samples using IBI Scientific gMax DNA Mini Kit with 100 µL final elution volume. Previously designed markers were used when available (round goby [Nathan et al. 2015], zebra mussel [Amberg and Merkes 2016]), while new assays were designed for quagga mussel, yellow perch, alewife, and Diporeia using IDT's PrimerQuest tool (https://www.idtdna.com/Primerquest/Home/Index, Integrated DNA Technologies, Inc. Coralville, IA) targeting the cytochrome oxidase I (COI) genes. GenBank accession numbers of the COI sequences used for marker development were: quagga mussel

(KP057252), Diporeia (EU761577), yellow perch (NC019572), spiny water flea (AF435122-AF435131), and alewife (AP009132). The qPCR markers were initially tested for the intended targets using the Basic Local Alignment Search Tool (BLAST; https://blast.ncbi.nlm.nih.gov/Blast.cgi), and specificity confirmed by testing each marker against a panel of genomic DNA from off-target organisms (round goby, bluegill [*Lepomis macrochirus*], paddlefish [*Polyodon spathula*], largemouth bass [*Micropterus salmoides*], mosquitofish [*Gambusia affinis*], spotfin shiner [*Cyprinella spiloptera*], rainbow trout [*Oncorhynchus mykiss*], brown trout [*Salmo trutta*], walleye [*Sander vitreus*], pallid sturgeon [*Scaphirhynchus albus*], brook trout [*Salvelinus fontinalis*], tilapia [*Oreochromis* spp.], channel catfish [*Ictalurus punctatus*], quagga mussel, and zebra mussel).

Each qPCR reaction consisted of 8µl molecular grade water, 10µl 2X QuantaBio PerfeCta qPCR Toughmix, 1µl primer/probe mix (final concentration=500nM primer and 250nM probe), and 1µl DNA template (=1ng for specificity testing vs off-target DNA). The qPCR thermal profiles differed among all species. Alewife had an initial denaturation of 30 seconds at 95°C, followed by 55 cycles at 95°C for 5 seconds, and 55 cycles at 60°C for 15 seconds. An initial denaturation of 2 minutes at 95°C, followed by 55 cycles at 95°C for 1 minute, followed by 55 cycles at 52°C for 30 seconds, and 55 cycles at 72°C for 30 seconds was used for zebra mussel, while quagga mussel had an initial denaturation of 30 seconds at 95°C, followed by 40 cycles at 95°C for 5 seconds, followed by 40 cycles at 61°C for 15 seconds and 40 cycles at 72°C for 10 seconds. An initial denaturation of 10 minutes at 95°C, followed by 50 cycles at 95°C for 15 seconds, and 50 cycles at 60°C for 1 minute was used for round goby. Spiny water flea had an initial denaturation of 3 minutes at 95°C, followed by 55 cycles at 95°C for 5 seconds, followed by 55 cycles at 60°C for 15 seconds, and 55 cycles at 72°C for 10 seconds.

Diporeia and yellow perch had the same thermal profiles, with an initial denaturation of 30 seconds at 95°C, followed by 55 cycles at 95°C for 5 seconds, and 55 cycles at 55°C for 15 seconds. No amplification was detected from genomic DNA of any off-target species, and all intended targets were successfully amplified. Each qPCR plate included a standard curve. We did a 10-fold serial dilution of gBlocks synthetic DNA fragments (Integrated DNA Technologies, Inc.; Coralville, IA) for each target diluted in 100ng/µl yeast tRNA. The concentrations used were 10^4, 10^3, 10^2, and 10^1 copies of the target molecule. All qPCR runs had R^2 values >0.98 and efficiencies between 95-105%. Copy numbers were reported for each sample based on the standard curve from the respective qPCR plate, and prey species were classified as being present or absent from each individual sample.

2.3.4 Statistical Analysis

I hypothesized that qPCR samples would detect more prey items than ocular examination of esophageal contents. A paired *t*-test was conducted on the differences between qPCR prey items found in the esophagus to prey items visually observed from the esophagus. Another paired *t*-test was conducted on the differences between qPCR prey items found in the cloaca to prey items visually observed from the esophagus. Due to the small sample size, a randomization test without replacement was also conducted on both datasets, with 10,000 Monte Carlo simulations of each dataset run. All calculations and simulations were conducted in program R 3.4.0 (R Core Team 2017).

2.4 RESULTS

2.4.1 Prey Items

Dreissenid mussels were the only prey observed using ocular methods, and were present in nine (56%) of the 16 esophagi examined. Results from qPCR methods indicated that four prey species were detected from the esophagus, two from the small intestine, and four from cloaca swab samples (Table 2.1). Dreissenid mussels were detected by qPCR in 16 (100%), 14 (88%), and 14 (88%) samples taken from the esophagus, small intestine, and cloaca, respectively. Results from qPCR methods were able to differentiate quagga and zebra mussels. However, a zebra mussel was only detected in one cloaca swab sample (Sample-ID 2016-029; Table 2.1). Diporeia was detected in one (6%) esophagus sample and five (31%) cloacal swab samples; it was not detected among small intestine swabs. Results from qPCR analysis indicate the presence of yellow perch in the esophagus, small intestine, and cloacal swab samples, with two (13%), one (6%), and three (19%) detections, respectively. Alewife was absent in samples taken from the small intestine and cloacal swabs, but was detected in one (6%) esophageal swab sample (Table 2.1). Round goby and spiny water flea were not detected in any of the samples. Quagga mussels occurred in the diet of all 16 (100%) LTDUs, followed by Diporeia in six (38%), yellow perch in five (31%), alewife in one (6%), and zebra mussel in one (6%), when ocular and molecular techniques were combined (Table 2.2).

2.4.2 Comparison of Methods

For both esophageal and cloacal swabs, the qPCR method detected more prey species than did visual examination of esophageal contents (both $t(15) \leq -3.22$, $p < 0.006$). Results of Monte Carlo simulations furthered my acceptance of the alternative hypothesis, that the qPCR method for both esophageal and cloacal swabs detected more prey species than examination of esophageal contents, as the two simulations showed similar results to their respective t-test with $p < 0.005$ in each case.

2.5 DISCUSSION

2.5.1 Diet Composition and Comparison of Methods

Diets of LTDUs in this study showed a high use of quagga mussels and to a lesser extent amphipods (*Diporeia* spp.) and yellow perch (Table 2.2), which is different from previous studies on the Great Lakes that showed a high use of amphipods followed by other species (Peterson and Ellarson 1977, Schummer et al. 2008). Causes of this dietary shift are likely due to changes in the benthic community of Lake Michigan, where quagga mussels have become the dominant species at depths ≤90 m (Nalepa et al. 2009), and according to Essian et al. (2016), no amphipod species were present in the gut contents of LTDUs that died from type E avian botulism. LTDUs radio-marked on Lake Michigan used open-water habitats during daylight hours that were about 16-28 m deep, and likely forage primarily on quagga mussels during that time. However, at night those same individuals tended to shift to waters with depths of about 59-74 m deep, where they could be foraging on Diporeia, as well as quagga mussels. According to Nalepa et al. (2009), Diporeia densities increased at depths >50 m, but did not exceed quagga mussel densities until >90 m. In addition, Diporeia tend to migrate vertically at night (Hondorp et al. 2005), making them susceptible to planktivorous fish (Janssen and Brandt 1980, Hondorp et al. 2005) and possibly LTDU predation. Alewife and zebra mussels were also found in the diets of LTDUs during this study, suggesting that LTDUs are opportunistic, which is congruent with other studies (Nilsson 1972, Peterson and Ellarson 1977, Jamieson et al. 2001, White et al. 2009).

Examination of esophageal contents from LTDUs on Lake Michigan revealed a less diverse prey base than qPCR methods (Table 2.1). Ocular methods indicated that dreissenid mussels were the only prey species, but field collection methods likely impacted those results.

Prey are subject to various digestion rates, with soft-bodied food items being digested quicker than hard-bodied food items (Swanson and Bartonek 1970, Swanson et al. 1974, Peterson and Ellarson 1977). Furthermore, digestion can occur even after mortality (Koersveld 1950, Swanson and Bartonek 1970), and studies examining diets have used methods to immediately stop digestion after mortality (Swanson and Bartonek 1970, Schummer et al. 2008). This study did not use those methods, as carcasses were donated by hunters and collected hours after being harvested, which may have resulted in soft bodied food items, such as Diporeia, being lost due to digestion. Food passage rates are also very fast for waterbird species capable of flight. According to Mayhew and Houston (1993), 95% of food passage in European wigeon (*Anas penelope*) occurred within 1.9 hours, while Mueller and van der Valk (2002) estimated seed passage in mallards at 7.6-11.1 hours, with most seeds being evacuated within 10 hours. In addition, the retention time of eight fish eating waterbirds for two trial diets ranged from 5.83 to 10.80 hours, with stomach retention time being a good predictor of total gut retention times (Hilton et al. 2000). As such, foods in the esophagus represent what has very recently been eaten, and most studies attempt to harvest individuals that are actively foraging (Swanson and Bartonek 1970, Schummer et al. 2008). Seven (44%) LTDUs harvested during this study did not contain prey items within their esophagus when examined ocularly (Table 2.1), which could be attributed to LTDUs being harvested while decoying and prior to actively foraging.

Molecular methods detected more prey species than ocular methods, but detection was not the same throughout the digestive tract. Quagga mussel, Diporeia, yellow perch, and alewife were detected in esophageal samples, while only quagga mussel and yellow perch were detected in the small intestine. Diversity of detected prey species increased at the end of the digestive tract, as quagga mussel, zebra mussel, Diporeia, and yellow perch were detected in the cloaca

(Table 2.1). Differences in species detection throughout the digestive tract are likely due to differences in digestive processes (Deagle et al. 2010, Oehm et al. 2016), DNA per gram of prey tissue, DNA purification, PCR amplification, and DNA sequencing (Deagle et al. 2010). Even so, molecular techniques have increased the prey spectrum detected in digestive tracts of various species (Oehm et al. 2016), including this study where 6 LTDUs contained no visible food items in their esophagi, but qPCR revealed prey species in various portions of the digestive tract.

Molecular methods, that could be used non-lethally, were able to detect more prey items than identifying prey species ocularly in this study, but it does not mean that molecular methods are better than ocular methods. One advantage of ocular methods is the ability to quantify prey species through dry weight or volume following ocular identification (Swanson et al. 1974). Quantifying food items using molecular methods has not yet been successful in avian species (Deagle et al. 2010, Pompanon et al. 2012, Yoccoz 2012) but was successful for Stellar sea lions (*Eumetopias jubatus*; Bowles et al. 2011). However, molecular methods are non-invasive (Waits and Paetkau 2005), allow for diet determination from live individuals (Deagle et al. 2010, Jedlicka et al. 2013), and allow for identification of prey items that are not detected using ocular methods (Oehm et al. 2016). Molecular methods are limited by primer availability for prey determination (Deagle et al. 2010). In this study, species specific primers, developed from specimens collected on Lake Michigan, were available for seven species, which represents a very small percentage of the variety of prey species available on Lake Michigan (Madenjian et al. 2002). Molecular and ocular methods could also be used in conjunction, to better describe the diet of an individual (Oehm et al. 2016). Determination of the best method(s) to use should be determined by the question being asked by the researcher or resource manager (Pompanon et al. 2012).

2.5.2 Diet Changes and Implications to Long-tailed Duck Health

LTDUs in this study appear to be foraging primarily on abundant dreissenid mussels, instead of amphipods, which is contradictory to previous studies conducted on the Great Lakes (Peterson and Ellarson 1977, Schummer et al. 2008). Dreissenid mussels are efficient filter feeders that accumulate contaminants more readily than native bivalves (Brieger and Hunter 1993), and contaminants are subsequently passed on to predatory waterfowl species (Petrie and Knapton 1999). Increased contaminants have been associated with decreased survival (White and Stickel 1975, Petrie and Knapton 1999) and/or nesting success (White and Stickel 1975, Heinz 1979, Custer et al. 1999), and can therefore impact populations (Petrie and Knapton 1999). In addition, the energy expenditure associated with ingestion and digestion of dreissenid shells, which constitute 80% of total dry mass for quagga mussels, is more difficult than Diporeia, which are high in energy and easy to ingest (Nalepa et al. 2009). Fish species in Lake Michigan that historically fed on Diporeia and subsequently switched to a dreissenid diet have shown a decrease in energy density and condition (Pothoven et al. 2001, Madenjian et al. 2006, Nalepa et al. 2009). LTDUs, similar to fish, could be suffering from the cost associated with the digestion of dreissenid mussels, but requires further investigation.

Identifying prey species of LTDUs is also important, as LTDUs are susceptible to type E avian botulism on Lake Michigan (Chipault et al. 2015, Essian et al. 2016). Outbreaks of type E avian botulism have become more common and widespread since 1999 (Riley et al. 2008, Lafrancois et al. 2011, Chipault et al. 2015), and according to Chipault et al. (2015), LTDUs ranked in the top five species of carcasses detected from shoreline surveys in three of four years from 2010-2013. Common loons (*Gavia immer*), a top level piscivore (Essian et al. 2016), constitute a large proportion of waterbird mortalities due to type E avian botulism (Brand et al.

1983, Chipault et al. 2015, Kenow et al. 2018), and determining dietary links between common loons and LTDUs would provide insight into how the toxin moves through the food web (Chipault et al. 2015). Loons forage primarily on benthic prey (Kenow et al. 2018) and Essian et al. (2016) found round gobies to be an important component of common loon diets, particularly those succumbing to avian botulism type E. Round goby was not detected in the digestive tract of LTDUs examined in this study, although Essian et al. (2016) found round goby in 50% of LTDUs that died from type E avian botulism. Dietary differences between the two species suggests that type E botulism may be present in a variety of food web components (Chipault et al. 2015, Essian et al. 2016). Determining the diets of healthy, sick, and dead birds susceptible to type E avian botulism and assessing their dietary overlap would benefit resource managers as they deal with type E botulism throughout the Great Lakes.

2.5.3 Conclusion

Results from this study suggest that molecular techniques provide a useful means of describing the diets of LTDUs using Lake Michigan and that field methods (e.g., esophageal or cloacal swabs) could be used to determine the diets of live birds. Use of molecular techniques combined with capture and marking of live birds could allow investigation of variation in seasonal diet, while gathering additional information from marked individuals (e.g., re-sighting/recapture of live animals or recovery information from harvested individuals). Additionally, molecular methods detected more prey species than ocular methods, but detections were not consistent throughout the digestive tract. Molecular techniques described four, two, and four species in the esophagus, small intestine, and cloaca, respectively, while ocular methods only described one species in the esophagus. Future researchers must acknowledge the biases associated with each method and consider them when developing research projects (Swanson and Bartonek 1970, Deagle et al. 2010). Future investigations comparing ocular and molecular methods are recommended (Yoccoz 2012), but may require additional primer development (Deagle et al. 2010).

Determining the diets of species in a changing ecosystem, such as Lake Michigan (Nalepa et al. 2009), is needed to assess potential impacts of dietary changes on individual condition and health (Pothoven et al. 2001, Madenjian et al. 2006, Nalepa et al. 2009), as well as susceptibility to disease (Essian et al. 2016). Molecular techniques provide a non-lethal means of accomplishing this with live individuals. In addition, molecular methods could be used in conjunction with ocular methods to increase information obtained from moribund or dead individuals (Oehm et al. 2016). Therefore, I recommend molecular methods be considered as a primary, alternative, or supplementary method to determine the diets of waterfowl, with use depending on the specific goals and objectives of the project.

Table 2.1. Comparison of prey items present (P) using ocular methods, of examining the esophageal contents, and qPCR molecular methods, throughout the digestive tract, of long-tailed ducks harvested from Two Rivers, Wisconsin during fall 2016.

				Prey Items Determined Visually in Esophageal Contents			
Sample-ID	Harvest Date	Sex	Age[a]	Dreissenid Mussels[b]	*Diporeia* spp.	Yellow Perch	Alewife
2016-013	16-Nov-16	Male	HY	P	-	-	-
2016-014	16-Nov-16	Male	HY	P	-	-	-
2016-016	16-Nov-16	Male	HY	P	-	-	-
2016-018	16-Nov-16	Female	HY	-	-	-	-
2016-019	25-Nov-16	Male	HY	P	-	-	-
2016-029	16-Nov-16	Female	ASY	-	-	-	-
2016-030	16-Nov-16	Female	HY	P	-	-	-
2016-033	15-Nov-16	Female	ASY	-	-	-	-
2016-037	15-Nov-16	Male	HY	-	-	-	-
2016-038	15-Nov-16	Male	ASY	P	-	-	-
2016-039	04-Dec-16	Female	HY	P	-	-	-
2016-040	15-Nov-16	Male	ASY	-	-	-	-
2016-041	15-Nov-16	Female	ASY	P	-	-	-
2016-042	03-Nov-16	Male	ASY	-	-	-	-
2016-047	03-Nov-16	Female	HY	-	-	-	-
2016-050	04-Nov-16	Male	HY	P	-	-	-

[a]HY = hatch year, SY = second year, and ASY = after second year, as determined by bursal measurement (females), presence of sheathed penis (males), and/or plumage characteristics.
[b]Quagga mussel and zebra mussel were combined, as dreissenid mussels, for ocular methods, but separated for molecular techniques.

Table 2.1. Extended.

	Prey Items Determined with Molecular Methods from the Esophagus				
	Dreissenid Mussels				
Sample-ID	Quagga	Zebra	*Diporeia* spp.	Yellow Perch	Alewife
2016-013	P	-	-	-	P
2016-014	P	-	-	-	-
2016-016	P	-	P	-	-
2016-018	P	-	-	P	-
2016-019	P	-	-	-	-
2016-029	P	-	-	-	-
2016-030	P	-	-	P	-
2016-033	P	-	-	-	-
2016-037	P	-	-	-	-
2016-038	P	-	-	-	-
2016-039	P	-	-	-	-
2016-040	P	-	-	-	-
2016-041	P	-	-	-	-
2016-042	P	-	-	-	-
2016-047	P	-	-	-	-
2016-050	P	-	-	-	-

Table 2.1. Extended.

	Prey Items Determined with Molecular Methods from the Small Intestine				
	Dreissenid Mussels				
Sample-ID	Quagga	Zebra	*Diporeia* spp.	Yellow Perch	Alewife
2016-013	P	-	-	-	-
2016-014	P	-	-	-	-
2016-016	P	-	-	-	-
2016-018	P	-	-	-	-
2016-019	P	-	-	-	-
2016-029	P	-	-	-	-
2016-030	P	-	-	-	-
2016-033	P	-	-	-	-
2016-037	P	-	-	-	-
2016-038	P	-	-	-	-
2016-039	-	-	-	-	-
2016-040	P	-	-	-	-
2016-041	P	-	-	P	-
2016-042	P	-	-	-	-
2016-047	P	-	-	-	-
2016-050	-	-	-	-	-

Table 2.1. Extended.

	Prey Items Determined with Molecular Methods from the Cloaca				
	Dreissenid Mussels				
Sample-ID	Quagga	Zebra	*Diporeia* spp.	Yellow Perch	Alewife
2016-013	P	-	P	-	-
2016-014	P	-	P	-	-
2016-016	P	-	-	-	-
2016-018	P	-	-	-	-
2016-019	P	-	P	P	-
2016-029	P	P	P	-	-
2016-030	P	-	-	P	-
2016-033	P	-	-	P	-
2016-037	P	-	-	-	-
2016-038	P	-	-	-	-
2016-039	-	-	-	-	-
2016-040	P	-	-	-	-
2016-041	P	-	-	-	-
2016-042	P	-	P	-	-
2016-047	P	-	-	-	-
2016-050	-	-	-	-	-

Table 2.2. Percent occurrence of prey species ingested, as determined using ocular and molecular methods, by long-tailed ducks (n=16) harvested from Two Rivers, Wisconsin in fall 2016.

Prey Species	Ocular	Molecular
Dreissena spp.	56%	100%
Quagga Mussel (*D. rostriformis burgensis*)	N/A[a]	100%
Zebra Mussel (*D. polymorpha*)	N/A[a]	6%
Diporeia spp.	0%	38%
Yellow Perch (*Perca flavescens*)	0%	31%
Alewife (*Alosa pseudoharengus*)	0%	6%
Round Goby (*Neogobius melanostomus*)	0%	0%
Spiny Water Flea (*Bythotrephes longimanus*)	0%	0%

[a]Ocular methods did not allow for differentiation of quagga and zebra mussels due to their high degree of similarity and morphological variation.

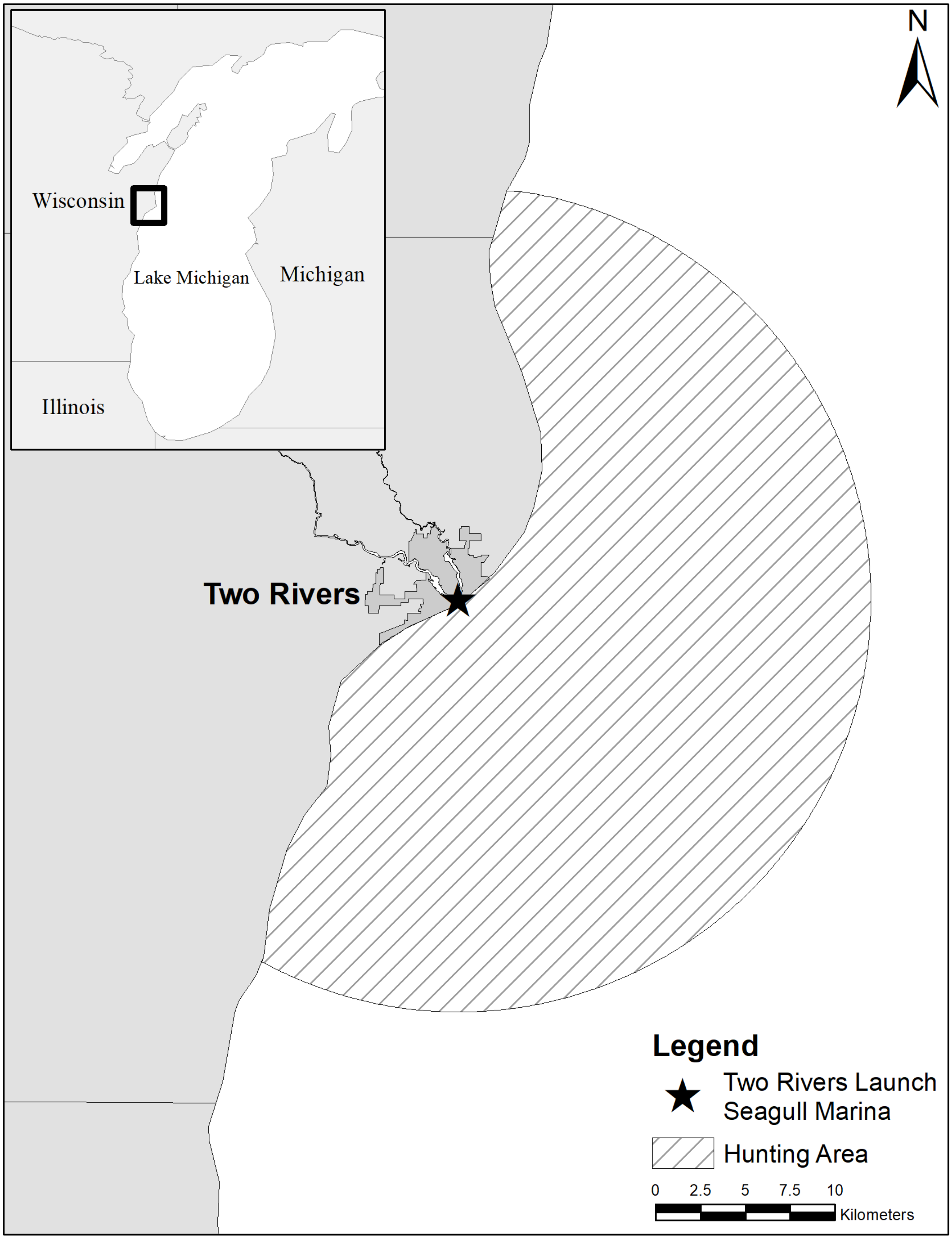

Figure 2.1. Location of Seagull Marina boat launch, in Two Rivers, Wisconsin where hunter collections took place and area (hashed) within which long-tailed harvest occurred in 2016.

CHAPTER 3

ENVIRONMENTAL VARIABLES AND HUNTER HARVEST OF LONG-TAILED DUCKS FROM A SELECT LOCATION ON LAKE MICHIGAN

3.1 INTRODUCTION

Hunter harvest statistics are an important component in monitoring/evaluating the dynamics of waterfowl populations and play a key role in adaptive harvest management (AHM), which is used to set duck hunting regulations in the United States (Johnson and Williams 1999, Nichols et al. 2007, U.S. Fish and Wildlife Service 2017). However, mallards (*Anas platyrhynchos)* are the only population of North American ducks with adequate data to populate the AHM model (Nichols et al. 2007, U.S. Fish and Wildlife Service 2017), thus mallard data are used to make harvest regulatory decisions for other species (U.S. Fish and Wildlife Service 2017). Species lacking necessary information to populate the AHM model, such as the long-tailed duck (*Clangula hyemalis*; hereafter LTDU), would benefit from an improved understanding of harvest and how it relates to specific management units (e.g., flyways and/or states and provinces; Rothe et al. 2015).

Lake Michigan provides a variety of habitats to migrating waterfowl (Prince et al. 1992). The LTDU uses the open-water habitats of Lake Michigan in great numbers, and they were the most abundant species of waterfowl observed during aerial surveys (Kenow et al. 2013, Kenow et al. 2015, B. Mueller, personal communication, 10 July 2017). Open-water hunting on the Great Lakes is the principle means by which hunters harvest LTDUs in the Midwest, but harvest typically remains low due to the unpredictable weather during fall hunting seasons affecting hunter access to the offshore, open-water habitats that LTDUs use (Ellarson 1956). However, according to the U.S. Fish and Wildlife Service (2018) the estimated harvest of LTDUs in

Wisconsin has increased since 2003, with estimates ranging from a low of 920 (2014) to a high of 9,700 (2016).

Weather is an unpredictable environmental factor (Johnson et al. 1997, Nichols et al. 2007, Johnson and Vrtiska 2014), and has been shown to influence hunter participation (Hansen et al. 1986), which correlates with harvest (Crawford 1982). Fall weather conditions on Lake Michigan are variable and are typically characterized by decreasing air and water temperatures, coupled with increasing winds, currents, and waves (Beletsky and Schwab 2001). One or more of these environmental variables may preclude hunters from hunting on a given day, and depending on prevailing conditions in any given year, may impact levels of annual harvest.

Objectives of this project were to summarize waterfowl harvest, determine what environmental variables are likely to impact harvest, and gather hunter opinions on waterfowl hunting regulations at a selected location on Lake Michigan. Survey results will aid managers by providing species specific harvest rates, as well as gathering input from hunters on current regulations, an objective of the North American Waterfowl Management Plan (North American Waterfowl Management Plan 2012).

3.2 STUDY AREA

Hunter surveys were conducted at Seagull Marina in Two Rivers, Wisconsin. The Seagull Marina boat launch provides easy access to Lake Michigan and is located at the confluence of the East and West Twin Rivers (Figure 3.1). The launch was selected based on information provided by guide services targeting LTDUs and conservation officers. Both groups stated that many hunters depart from this launch and LTDU harvest comprises a majority of the hunters' bag.

3.3 MATERIALS AND METHODS

3.3.1 Survey Design

An in-person survey was conducted from 1 November through 4 December 2016, the end of the Wisconsin southern zone duck hunting season. The survey was systematic and conducted on a five-day cycle, with surveys conducted on days one, three, and four, and skipped on days two and five. A random number generator was used to determine where to begin in the five-day cycle on 1 November 2016. Surveys were conducted on 21 (35%) of the possible 60 hunting days, but all surveyed days occurred within the final 34 days of the hunting season due to the survey start date. The survey start date was selected based on comments from guide services that stated they do not target LTDUs on Lake Michigan until after 01 November. The 2016 Wisconsin southern zone duck hunting season ran from 1-9 October and 15 October through 4 December; the time period from 10-14 October was closed to waterfowl hunting (Wisconsin Department of Natural Resources 2016). Surveyor(s) followed protocols outlined in the Protocol for Distributing Hunter Surveys at Seagull Marina, Two Rivers, Wisconsin (Appendix A). Surveyor(s) arrived at the launch at or before 08:00 and remained until 14:00. Upon arrival, during the survey, and at the completion of the survey, the surveyor(s) recorded information on the *Boat Launch Survey – Surveyor Datasheet – Seagull Marina, Two Rivers, WI*. Recorded information included name(s) of surveyor(s), date, survey start time, survey end time, number of vehicles with trailers at the start of the survey, number of attempts to survey hunting parties, number of successful surveys, number of vehicles with trailers at the end of the survey, and any comments the surveyor(s) had in regards to that specific day (Appendix B).

One hunter of ≥18 years of age, from each hunting party, was required to sign a consent form to participate in the hunter survey. Once a signature was acquired, results from all persons hunting in that party, including persons <18 years of age, could be recorded. Surveyor(s) conducted the hunter survey and recorded information on the *Hunter Harvest Record Sheet – 2016* (Appendix C). Information collected included: vessel or captain name, date, coordinates or rough location of hunting location, number of hunters in party, time hunting began, time hunting ended, species and sex of harvested birds, donations acquired, and a comments section where hunters could voice concerns regarding sea ducks on Lake Michigan. Hunter comments were summarized into nine categories based on similarity. Survey distribution and protocols were approved under the Southern Illinois University – Carbondale Human Subjects Committee (Protocol Number: 15427).

3.3.2 Environmental Variables

Environmental information was obtained from the Great Lakes Coastal Forecasting System Point Query Tool (Great Lakes Observing System 2018) for the yearly average distance from boat launch and water depth where hunting reportedly occurred. Environmental co-variates of significant wave height, ice concentration, and ice thickness were collected from the Nowcast 2D Model while wind velocity, cloud cover, and air temperature were collected from the Nowcast Input data (Great Lakes Observing System 2018). Daily precipitation totals were obtained for the Two Rivers, Wisconsin weather station from NOAA's National Centers for Environmental Information website (Department of Commerce 2018).

3.3.3 Statistical Analysis

Information from the *Boat Launch Survey – Surveyor Datasheet*, *Hunter Harvest Record Sheet – 2016*, and environmental variables were transcribed into Excel (Microsoft Office Home and Student 2013, Version 15.0.5023.1000) spreadsheets. Summary statistics, correlations, and multiple regressions were calculated in program R 3.4.0 (R Core Team 2017). Location information that had depth and distance from port was used as reported, but ArcMap 10.3.2 (ESRI 2015) was used to estimate depth and distance when geographic coordinates were reported, using Extract Points to Values and Near tools, respectively. Depth and distance information was dropped when either was not provided, or when two depths or distances were reported by the same group on the same day (e.g., hunters moved during the day). Correlations were conducted between the environmental variables and to determine if hunter numbers were correlated with waterfowl harvest, which would eliminate issues of collinearity within the multiple regression model. Variables were considered highly correlated if they had correlation coefficients > 0.60 ($r > 0.60$), coupled with a significant p value ($p < 0.05$). Correlation analysis of environmental variables (i.e., wave height, wind velocity, cloud cover, temperature, and 24 hour precipitation totals) showed weak relationships among all variables ($r \leq 0.60$, $p > 0.05$), except wave height and wind velocity, which were strongly positively correlated ($r = 0.76$, $p < 0.001$). Waterfowl harvested and hunter numbers were also strongly positively correlated ($r = 0.89$, $p < 0.001$). Because of their correlations, number of hunters, instead of harvest, and wave height, instead of wind velocity, were selected for multiple regression analysis. A multiple regression was conducted with number of hunters being dependent on the four environmental variables (i.e., wave height, cloud cover, temperature, and 24 hour precipitation). Number of hunters was log transformed to improve distribution normality.

3.4 RESULTS

3.4.1 Summary Statistics and Hunter Comments

Hunters were present on 15 (71%) of the 21 survey days. Response rate was 100% on the 127 attempted surveys, but 12 groups were missed due to high traffic or not falling within the survey time frame. The survey represented a total of 361 hunters from 62 hunting parties and a reported total harvest of 1,431 waterfowl. 1,392 (97%) were LTDUs and 31 (2%) were scoter species (24 white-winged scoters [*Melanitta fusca*] and seven black scoters [*Melanitta nigra*]). Other harvested species included red-breasted merganser (*Mergus serrator*; six) and bufflehead (*Bucephala albeola*; two). Hunters reported that 173 total birds were not recovered, accounting for a wounding loss [birds wounded and unable to retrieve / (birds wounded and unable to retrieve + birds killed and retrieved)] of 10.8%. Sex composition, as reported by hunters, of harvested LTDUs was 848 (61%) males and 544 (39%) females. Average depth of water at hunting locations (n=111) was 26.8 (*SD*=10.9 m; range 15.2-129.8 m) and average distance from Two Rivers launch (n=51) was 5.9 (*SD*=3.0 km; range 1.6-22.2 km). Total time hunting (n=127) averaged 247.1 (*SD*=75.3; range 60-420) minutes and hunter harvest of LTDUs (n = 127) averaged 3.8 (*SD* =2.1; range 0.0-6.0) LTDUs per hunter per day.

Of the 62 hunting parties, 45 (73%) provided 67 comments regarding sea duck harvest and regulations on Lake Michigan. From the 67 total comments, seven (10%) were removed; six from hunters reporting it as being their first-year hunting on Lake Michigan or that they lacked knowledge to provide useful input, and one that did not provide any information usable from a management perspective. Nine categories, based on similarity, were created from the remaining 60 comments (Figure 3.2). In general, hunter comments were related to LTDUs or hunting regulations on the open waters of Lake Michigan. Most comments, 24 (36%), were directed toward season start dates or length, with hunters indicating preference for a later start date or longer season on Lake Michigan. There were four (6%) comments related to concerns of overharvest and hunting pressure, 12 (18%) comments related to reducing the LTDU daily bag limit, and six (9%) comments on implementing a hen restriction for LTDUs. Hunter comments were five (7%) in favor of and two (3%) against implementing a special sea duck season (Figure 3.2).

3.4.2 Multiple Regression

The multiple regression model was highly significant (F = 8.941, df = 4, 16, $p < 0.001$), and tests of the individual regression coefficients indicated a negative and highly significant effect of wave height (T_s = -4.887, df = 16, $p < 0.001$) on hunter numbers (Table 3.1). Effects of cloud cover, temperature, and 24-hour precipitation were non-significant ($p > 0.05$). Linear regression analysis of wave height indicates that hunters are unlikely to go out when wave heights are >2 m and has good fit (R^2=0.603), while all other regressions showed poor fit (R^2<0.200; Figure 3.3)

3.5 DISCUSSION

3.5.1 Hunter Numbers, Harvest Rates, Wounding Loss, and Hunter Comments

Hunters partaking in open-water hunting and layout hunting make up a very small percentage of the total waterfowl hunters in Wisconsin, with only 23% and 7% responding that they sometimes, often, or always open-water hunt or hunt from a layout boat, respectively (Wisconsin Department of Natural Resources 2015). Even fewer hunters partake in open-water hunting on Lake Michigan, as only 3% of respondents reported hunting the open waters of Lake Michigan in the same survey (Wisconsin Department of Natural Resources 2015). Moreover, results from this study suggest that hunter numbers are greatly reduced when wave heights reach 1.5 m, and that hunters rarely go out when wave heights exceed 2 m (Table 3.1; Figure 3.3). Even though hunter numbers on Lake Michigan are small compared to the state-wide waterfowl hunting population, the rate of harvest, particularly on LTDUs (3.8 ±2.1 LTDUs/hunter/day), was high when hunters were able to hunt. This harvest rate was much higher than all species combined (0.95 ducks/hunter/day [interpolated as Total Duck Hunter Days Afield/Total Duck Harvest]) in Wisconsin during the 2016 hunting year (Raftovich et al. 2017). Wounding loss reported by hunters during this survey (10.8%), was less than those reported for sea ducks during annual harvest information program (HIP) surveys conducted throughout the United States (18.0%) from 1999-2003 (Padding et al. 2006, Moore et al. 2007, Rothe et al. 2015). However, wounding estimates should only be used as an index, as they are likely an underestimate of true wounding loss (Rothe et al. 2015). Total harvest of LTDUs from this survey (1,392) represented 14.4% of the 2016 state-wide HIP estimate (U.S. Fish and Wildlife Service 2018).

Harvest composition from Two Rivers, Wisconsin was primarily (97%) LTDUs and LTDUs were likely the main target of hunters. The high harvest of LTDUs could be due to the high abundance of LTDUs in the Two Rivers area, as LTDUs were the most abundant waterbird present during aerial surveys conducted along the Wisconsin shoreline from 2012-2014 (B. Mueller, personal communication, 10 July 2017). Sex composition of harvested LTDUs was reported as 61% males and 39% females. However, this is likely an over-estimate of females, as I observed many hunters were unable to differentiate immature males and females, and thereby categorized anything except adult males as females. Hunters are likely to have difficulty in sexing and ageing LTDUs as male and female juveniles are similar in appearance and plumage characteristics (Carney 1992, Baldassare 2014) and resemble adult females (Baldassare 2014). Sex ratios of LTDUs were not reported for the Mississippi flyway, but weighted age ratios were reported as 0.52 immatures per adult in 2016 (Raftovich et al. 2017). Harvest models would benefit from a more robust way of determining age and sex ratios for harvested birds, as well as the population available for harvest (Koneff et al. 2017).

Results from the hunter comments serve as means for federal and state managers to determine the needs and desires of people to help support conservation and management decisions (North American Waterfowl Management Plan 2012, Van Horn and Benton 2007). Comments from hunters in this survey indicate that they would prefer a later and/or longer season on the open waters of Lake Michigan. Extending the season is unlikely, as the federal framework only allows three regulatory alternatives for season length (U.S. Fish and Wildlife Service 2017), and Wisconsin has experienced the liberal (i.e., maximum) 60-day season since 1997 (Van Horn and Benton 2007). Starting the hunting season later is an option, but doing so would impact all hunters in the south zone (see U.S. Fish and Wildlife Service 2015 for boundary explanations) under the current zones offered (U.S. Fish and Wildlife Service 2015). Starting the south zone season later is unlikely as results from Wisconsin hunter survey in 2015 indicate that 17% of hunters thought the south zone opened too early, 56% thought that it was about right, and 7% thought it was too late (Wisconsin Department of Natural Resources 2015). In addition, only 42% of respondents to the Wisconsin survey said they would like the south zone to have a split, with most (38%) responding that the split should last five days and only 17% responding that the split should last >9 days (Wisconsin Department of Natural Resources 2015). Changing zone boundaries also does not seem likely based on the 2015 Wisconsin survey, as 63% of respondents said there should be no change to the current zone structure and only 19% preferred the creation of a fourth zone (i.e., Lake Michigan), but all four zones could not have splits (Wisconsin Department of Natural Resources 2015). Waterfowl hunters choosing to hunt Lake Michigan likely represent a very small percentage of Wisconsin waterfowl hunters, as only 3% of waterfowl hunters responded that they hunted on Lake Michigan during a 2015 hunter survey (Wisconsin Department of Natural Resources 2015). Therefore, hunters that do hunt on Lake Michigan likely have a very small voice when it comes to regulatory framework for the entire state.

While conducting my surveys, many hunters mentioned that environmental conditions are the main factor in determining when they hunt Lake Michigan and that in a typical year they don't get out often. Results from multiple regression analysis support those statements, and indicate that wave height may be the most influential environmental variable in that decision (Table 3.1; Figure 3.3). Hunters during my survey also appeared to be concerned about harvest impacts on LTDUs, with 22 (13%) comments focused on concerns of overharvest and implementing more conservative limits (e.g., reduced bag limit or implementing a hen restriction; Figure 3.2). Managers are also concerned about harvest impacts on LTDUs but better parameter estimates are needed to determine harvest impacts (Koneff et al. 2017). Hunting pressure on Lake Michigan may be increasing, as a 19% of respondents to a 2013 survey indicated that they sometimes, often, or always hunt open water (Wisconsin Department of Natural Resources 2013) and in a similar 2015 survey 23% responded that sometimes, often, or always hunt open water (Wisconsin Department of Natural Resources 2015). Those reporting that they sometimes, often, or always hunted from a layout boat remained the same (7%) in both survey years (Wisconsin Department of Natural Resources 2013, Wisconsin Department of Natural Resources 2015). Comments from my survey support the idea that hunting pressure is increasing, as six groups stated that it was their first-time hunting Lake Michigan. Hunters, regardless of time spent hunting on Lake Michigan, were concerned about maintaining the unique hunting opportunity and resources that Lake Michigan provides. This concern was of the utmost importance to all hunters and reflected in the high response rate (100%) received during my survey.

3.5.2 Management Concerns

The population dynamics of North American LTDUs is poorly understood, and remains one of the most poorly surveyed species of sea ducks in North America (Bowman et al. 2015). With a lack of information on populations, as well as a poor understanding of life history traits, there is concern that populations may be susceptible to overharvest (Koneff et al. 2017). Based on harvest simulations conducted by Koneff et al. (2017), LTDUs were at the highest risk of overharvest among North American sea ducks, but those estimates were conditional on the probability distributions used to characterize uncertainty in each demographic parameter, the assumptions and limitations of the deterministic framework, and assumed management objective of the model. The model by Koneff et al. (2017) was conducted at a continental level, but there should be concern at individual management units (e.g., flyways), as radio-marked LTDUs showed very little overlap among wintering areas (Sea Duck Joint Venture 2015) and have a high level of winter site philopatry (Robertson and Cooke 1999, Sea Duck Joint Venture 2015). A population estimate for LTDUs wintering on Lake Michigan, along with determining other locations where harvest is occurring and at what rates, would greatly benefit managers in determining the impacts due to harvest. It was difficult to ascertain what percentage of the hunter population was surveyed, especially regarding hunters that open-water hunt on Lake Michigan. Surveys covering a broader expanse of Lake Michigan or surveys that elicit how many hunters open-water hunt on Lake Michigan could provide a basis for determining how well this survey represents the total population of Lake Michigan waterfowl hunters.

3.5.3 Conclusion

With this survey, I was able to summarize waterfowl harvest, determine how environmental variables impact that harvest, and gather hunter opinions from Two Rivers, Wisconsin from 1 November through 4 December 2016. Survey results indicate that hunters, like managers, are concerned about the wintering population of LTDUs that use Lake Michigan. Additionally, many hunters suggested taking a conservative harvest strategy (i.e., reduction in daily bag limit or hen restriction) until we know more about the population and its dynamics. However, hunter feelings about harvest regulations and populations may not be the same across the Lake Michigan basin. Future surveys or studies could benefit from the findings of this survey, by targeting days when hunters are likely to be hunting the open waters of Lake Michigan, or following similar protocols. Following similar protocols would allow researchers to determine if hunters in other locations are influenced by environmental conditions in the same way and if hunter harvest rates and opinions regarding regulations are similar throughout the Lake Michigan basin. Further studies of harvest rates (Koneff et al. 2017) and hunter opinions (North American Waterfowl Management Plan 2012) are needed, but results from this survey provide a solid base for future projects studying hunter harvest and opinions of LTDUs on Lake Michigan.

Table 3.1. Summary table of multiple regression analysis for environmental variables predicting the number of hunters at Two Rivers, Wisconsin, 2016 (*n* =21).

	Number of Hunters				
Variable	*B*	*SE B*	*β*	*t*-statistic	*p-value*
(Intercept)	5.046	0.879		5.740	<0.001
Wave Height	-1.925	0.394	-0.853	-4.887	<0.001
Cloud Cover	-0.324	0.556	-0.094	-0.582	0.569
Temperature	-0.150	0.075	-0.324	-2.005	0.062
Precipitation	0.033	0.054	0.106	0.610	0.550
R^2		0.691			
Adjusted R^2		0.614			
F		8.941			<0.001

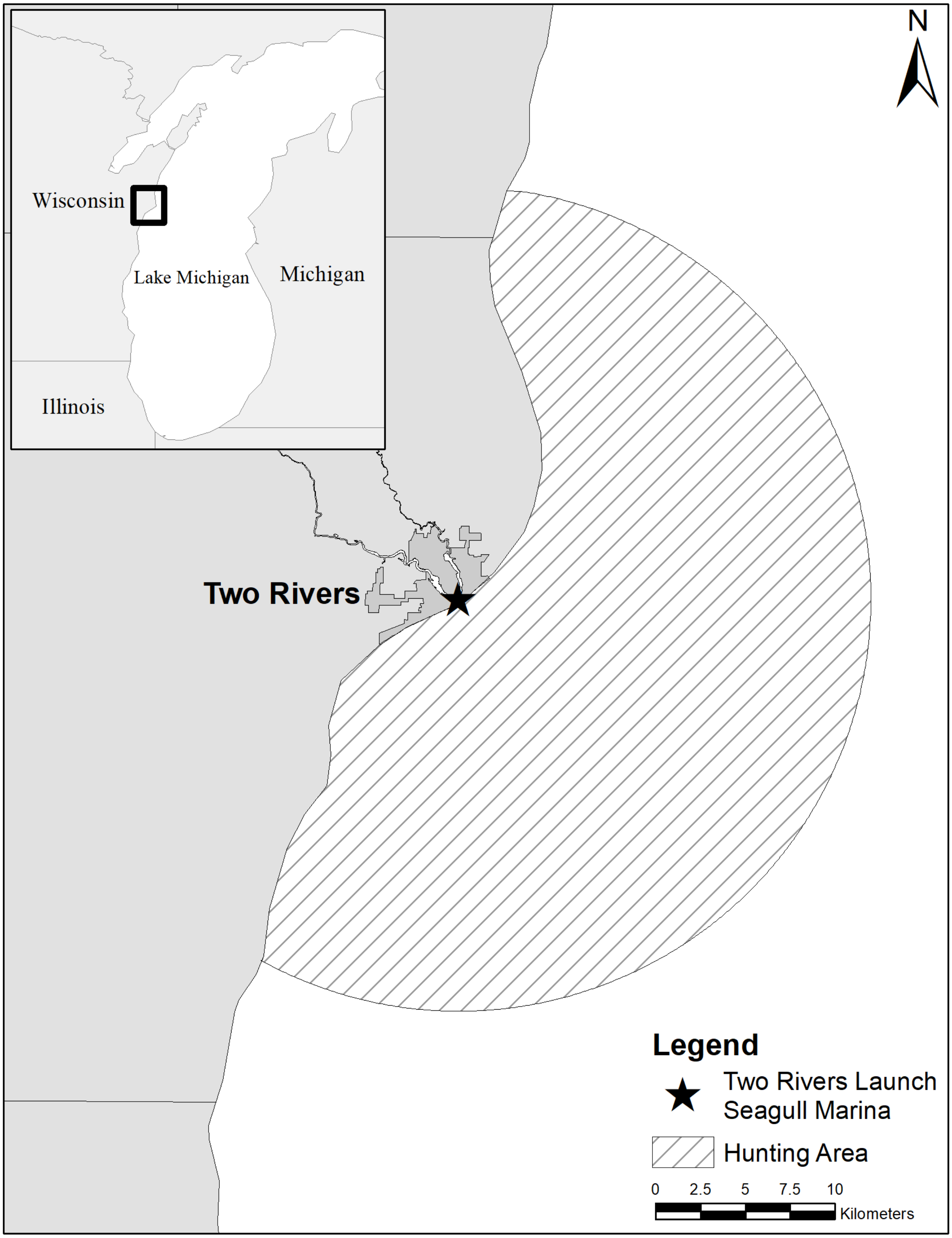

Figure 3.1. Location of Seagull Marina boat launch in Two Rivers, Wisconsin where hunter harvest surveys were conducted and area (hashed) within which hunters reported harvesting long-tailed ducks in 2016.

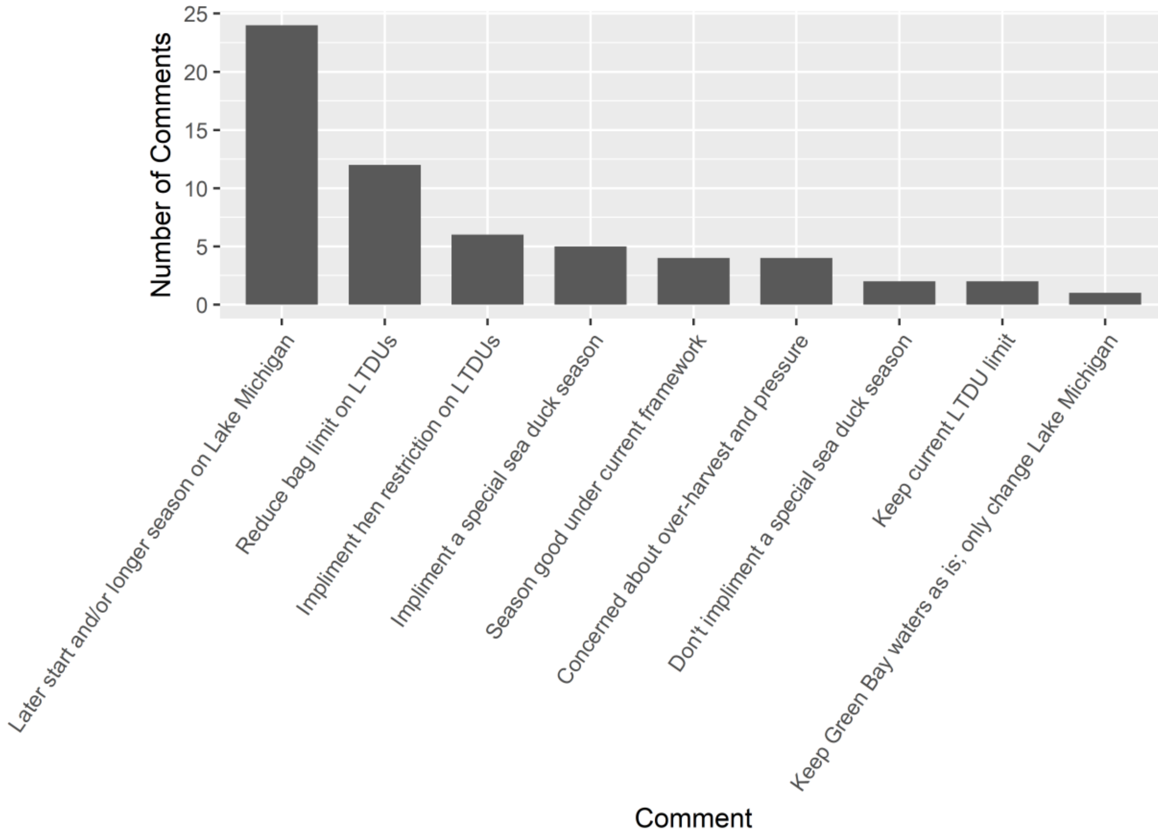

Figure 3.2. Comment type and number of each comment received from waterfowl hunters at Two Rivers, Wisconsin, 2016.

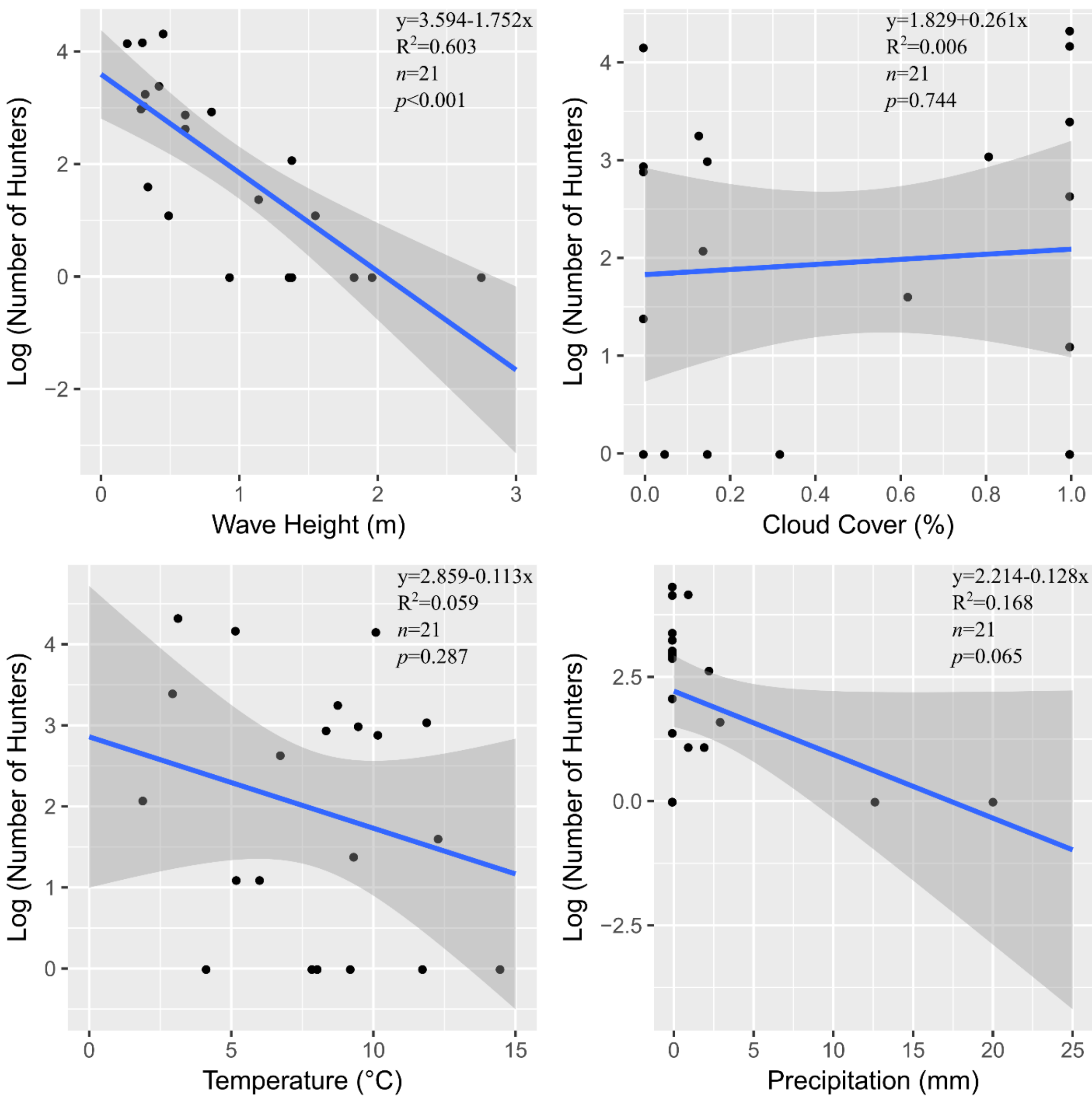

Figure 3.3. Linear regressions illustrating the association between environmental variables and hunter numbers from Two Rivers, Wisconsin, 2016. Number of hunters was Log_{10} transformed to improve normality.

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APPENDICES

APPENDIX A

PROTOCOL FOR DISTRIBUTING HUNTER SURVEYS AT SEAGULL MARINA, TWO RIVERS, WI

Arrive at launch, before or at 8:00 am on the day of the survey and remain at the launch until 2:00 pm. Upon arrival to the launch, you should start to fill out the BOAT LAUNCH SURVEY – SURVEYOR DATASHEET, surveys, and distribution protocols for the survey are listed below:

1) Fill in the BOAT LAUNCH SURVEY –SURVEYOR DATASHEET - Include your name(s), date, survey start time (should be 8:00 am), survey end time (should be 2:00 pm), number of vehicles present with trailers at start and end of survey (likely hunters or fisherman), survey attempts to hunting parties, number of successful surveys (surveys where a hunter completes the survey, or a fisherman tells you they were fishing-see below), and comments that you have. Comments can be anything from the weather, no boats present, which vehicles are present on a regular basis, etc. Comments are open, but realize I may contact you if I have a question about one. (If a group shows up while you are there, make a note as to if they look like they are hunting or fishing, in the event that they do not return before 2:00 pm, this can be done in the comments section.

2) Surveys Distribution – Please follow this protocol when distributing the survey:

a) Approach hunter, and introduce yourself - Preferably, we want to target the captain of the vessel, as we only need to complete one HUNTER HARVEST RECORD SHEET - 2016 for each hunting party.

If the hunter appears to be under 18, ask them their age. **If they are under the age of 18, then we can-not survey them**.

If individual is over 18, then ask if they would be interested in providing their harvest information to this study.

If answer is no, then reply: "Thank you for your time."

If the answer is yes, then proceed by having them sign the CONSENT FORM and filling out the HUNTER HARVEST RECORD SHEET – 2016. You can work through the datasheet with the hunters, or have them fill it out. Some may want to fill it out as they will be in a hurry. Hunters, and you as the surveyor, can make comments in the comments section of the HUNTER HARVEST RECORD SHEET – 2016, but please try to note which comments are from you and those that are from the hunter. **IMPORTANT - in the comments section of the HUNTER HARVEST RECORD SHEET – 2016, note if you personally observed the harvested birds, and verified the count, or if the hunter filled out the survey**. It is important to note this.

Feel free to provide hunters with the 1-page project description, which lists my contact information.

Please try to keep consent forms with their appropriate HUNTER HARVEST RECORD SHEET -2016, as we move along, we may notice that we are asking the same hunters that have already signed a CONSENT FORM. If this occurs, then we will just note that the hunter has already signed a previous CONSENT FORM (in the comments section), and ask that they use the same vessel or captain name on the HUNTER HARVEST RECORD SHEET – 2016.

b) Once the HUNTER HARVEST RECORD SHEET – 2016 is complete, ask them if they would like to donate any harvested long-tailed ducks for the diet analysis component of the study.

If no, then say "thank you", and move on to c.

If yes, then have them fill out a Hunter Donation Card (inside packet). **Carcasses need to be left whole, please do not collect them if they are going to remove the breasts, as that is illegal.** Collect the carcasses, and place them in a garbage bag. On the HUNTER HARVEST RECORD SHEET – 2016, there is a section to mark the number of birds donated. **Please, only collect long-tailed ducks, as I am not authorized to receive any other species.**

There are cards on the right and left hand side of the packets, but each is unique. The cards on right have a hole punched, and should be zip-tied to the outside of the seconds bag. The other (left side) does not have a hole punched and should be placed between the first and second garbage bag. This means that carcasses will be double bagged, and have two tags.

Keep carcasses separate from other carcasses collected that day. The number of donated birds (written on the card) should match up with what is in the bag.

*As a note, I can only collect 65 carcasses total for the year, so please don't take 20 in one day. Ideally we want to spread them out over the season. Therefore, we will shot to get 10 carcasses per week, and try to distribute them from up and down the coast. Don't hesitate to call me if you have questions on if you should collect carcasses or not.

c) Lastly, ask the hunter if they wish to be acknowledged for participating in the study (**there is a check box for this on the consent from, but we want to double check their answer**). Also state that if they wish to be acknowledged, that their name or business name, whichever they prefer, will be used at the end of all presentations and reports.

If no, then say thank you for your time and the survey is over.

If yes, then collect what information the hunter wants to be used for acknowledgment (i.e. name, business name, etc. and this can be recorded in the comments section of the HUNTER HARVEST RECORD SHEET - 2016). Thank them for their time, and the survey is over.

Reminders on Survey - Remember to be cordial and that the hunter is doing this voluntarily, we cannot force them to give us their harvest information. Once the survey is complete, hunters may ask you how other hunters are doing. It is fine to be modest, but please do not tell them other hunter's names or provide other harvest reports to them. If there is something interesting to note, then do so in the comments section of the HUNTER HARVEST RECORD SHEET – 2016. Please try to get as many hunters as possible on a survey day.

Notes –

-We will treat every vehicle with a boat trailer as a potential hunter. Some may be fishing, but a trailer will constitute a "hunting vehicle" for our purposes. We can also note hunters from fishers when conducting surveys (see next bullet point).

-With the above bullet point, we want to note if a group was hunting or fishing. In order to do so, wehave to treat them all the same. Therefore, if you are conducting a survey please fill out HUNTER HARVEST RECORD SHEET – 2016 for fisherman as well. In this case, when asking the first question "if they wish to partake in this survey…" if they respond "no, I was fishing not hunting," then we can just fill out a HUNTER HARVEST RECORD SHEET – 2016 for them. If this occurs, just date the form, use "Fisherman" as the vessel name, and in the comments note that the vessel was fishing and not hunting.

APPENDIX B

BOAT LAUNCH SURVEY – SURVEYOR DATASHEET - SEAGULL MARINA, TWO RIVERS, WI

Boat Launch Survey - Surveyor Datasheet - Seagull Marina, Two Rivers, WI

Surveyor(s) Name:	Date:	Survey Start Time:	Survey End Time:	Number of Hunting Parties/Vehicles Present at Start:	Number of Hunting Parties/Vehicles Present at End:	Survey Information		Comments:
						Survey Attempts to Hunting Parties	# of Successful Surveys	

APPENDIX C

HUNTER HARVEST RECORD SHEET – 2016

Hunter Harvest Record Sheet - 2016

Main Vessel and/or Captain: ____________________________________ **Date:** _____/_____/_____
Month/Day/Year

Coordinates where Hunted: Latitude: ________________ **Longitude:**________________

If you do not wish to disclose exact location, please describe location from the port of departure (example - 8 miles ESE of Gull Marina, Sheboygan, WI. In approximately 100 feet of water)**:**

____

Number of Hunters in Party (include captain, only if hunting)**:** __________

Time Hunting Began: __________ **Time Hunting Ended:** _________

		Harvest Record		Donation of Harvested Birds
Species		Number Harvested	Number Unrecovered/crippled	Please label specimens with date of harvest, and if shot from a flock, or as an individual
Long-tailed Duck	Male			Number donated:
	Female			Number donated:
White-winged Scoter	Male			Number donated:
	Female			Number donated:
Common Scoter	Male			Number donated:
	Female			Number donated:
Surf Scoter	Male			Number donated:
	Female			Number donated:
Red Breasted Merganser	Male			Number donated:
	Female			Number donated:
Common Merganser	Male			Number donated:
	Female			Number donated:
Other - Species and number harvested - example: (Bufflehead - 3)				

Additional Comments:____
____
____

VITA

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University of Wisconsin – Stevens Point
Bachelor of Science, Wildlife Ecology Research and Management, May 2008

SPECIAL HONORS AND AWARDS:

Student Scholarship, Wisconsin Waterfowl Hunters Conference, 2016, $1,500.

Donation, Wisconsin Waterfowl Association - Lakeshore Chapter, 2016, $200.

Student Grant, Delta Waterfowl, 2016, $1,000.

Runner-up, Biological Sciences – SIU 2016 Graduate Student Creative Activities and Research Forum, poster session, 2016.

Student Scholarship, Bill Cook Chapter of the Izaak Walton League of America, 2016, $1,000.

Student Scholarship, Wisconsin Division of the Izaak Walton League of America, 2016, $1,000.

Student Scholarship, Wisconsin Waterfowl Hunters Conference, 2017, $1,000.

Student Travel Award, 6th International Sea Duck Conference, 2017, $500.

Grant, Wisconsin Division of the Izaak Walton League of America - Endowment Trust, 2017, $3,000.

Student Scholarship, Illinois Federation for Outdoor Resources, 2017, $1,000

THESIS TITLE:

Migration patterns, habitat use, prey items, and hunter harvest of long-tailed ducks (*Clangula hyemalis*) that overwinter on Lake Michigan

MAJOR PROFESSOR: Michael W. Eichholz

PUBLICATIONS:

Fara, L. J., N. Docken, B. Schmidt, and J. Schultz. 2008. Use of Artificial Nest Boxes by Wood Ducks (*Aix sponsa*) and Hooded Mergansers (*Lophodytes cucullatus*) in Wisconsin. The Passenger Pigeon 70:301-306.

Kenow, K. P., S. C. Houdek, L. J. Fara, B. R. Gray, B. R. Lubinski, D. J. Heard, M. W. Meyer, T. J. Fox, and R. J. Kratt. 2018. Distribution and Foraging Patterns of Common Loons on Lake Michigan With Implications for Exposure to Type E Avian Botulism. Journal of Great Lakes Research. Available online at: https://doi.org/10.1016/j.jglr.2018.02.004.

Kenow, K. P., Z. Ge, L. J. Fara, S. C. Houdek, and B. R. Lubinski. 2016. Identifying the Origin of Waterbird Carcasses in Lake Michigan Using a Neural Network Source Tracking Model. Journal of Great Lakes Research 42:637-648. Available online at: https://doi.org/10.1016/j.jglr.2016.02.2014.