Reducing the Adverse Effects of Offshore Wind Development on Waterbirds in the Great Lakes: A Proposed Four-Step Approach

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Executive Summary

The Biodiversity Research Institute (BRI) is assisting the Great Lakes Commission (GLC) in developing a research plan to understand waterbird populations in the Great Lakes and inform offshore wind energy siting and general conservation planning. We are following a four-step process in which we are developing 1) data on species presence, via GLC's Phase I and Phase II aerial surveys for waterbirds in the Great Lakes; 2) a process for determining species vulnerability (currently limited to select waterbird species observed during Phase I aerial surveys, but which could be expanded based on other survey datasets from the region); 3) focused study ideas for key species of interest, based on data gaps and species priorities identified in #2; and 4) potential mitigation approaches for waterbirds likely to interact with future offshore wind energy development (OWED) in the Great Lakes.

The vulnerability assessment process described in this report separately considers occurrence data from Phase I surveys; likelihood of each species' collision risk with OWED; likelihood of behavioral avoidance/disturbance from OWED; and conservation status (including global population size and other metrics). This is a preliminary assessment that primarily draws upon Phase I survey data and existing vulnerability analyses from Europe and the northwest Atlantic. It could, however, be easily expanded to include other species and to more specifically describe the Great Lakes through the inclusion of additional relevant literature. A more comprehensive analysis would also likely consider each of the Great Lakes separately in determining species vulnerability, as conditions and species composition varies widely between water bodies.

In the preliminary analysis, none of the 27 species examined were deemed to be "most vulnerable" (e.g., 75th percentile or above) in all four categories – occurrence, collision risk, displacement risk, and conservation status. However, a third of the species examined were estimated to be "most vulnerable" in at least two categories. The most common species observed during 2012-2013 aerial surveys were the diving duck species, Canvasback (*Aythya valisineria*), Scaup spp. (*A. affinis/marila*), and Redhead (*A. americana*), which together accounted for over 70% of total observations. The Redhead and Scaup spp. were also predicted to have high displacement risk (75% percentile).

Based on this preliminary vulnerability assessment, the published literature, and our informed opinions, we identify species present in the Great Lakes during spring/fall migration and during winter (nonbreeding season) that should be priorities for additional research. We briefly mention several species that breed in the Great Lakes as well, but as Phase I surveys were not designed to survey these species, they were underrepresented in the vulnerability assessment. We recommend development of a comprehensive vulnerability assessment that is more specifically tailored to Great Lakes species and behaviors; continued aerial surveys to gather species distribution and abundance data, performed according to standardized protocols so that the data can be effectively used in modeling efforts; and specific studies of bird movements and flight heights to reduce uncertainty in vulnerability assessments and help define species' habitat use. We propose several potential mitigation approaches, including efforts to avoid, minimize, or compensate for adverse effects from OWED on waterbirds in the Great Lakes.

Introduction

Project Summary

The Biodiversity Research Institute (BRI) is assisting the Great Lakes Commission (GLC) in developing a research plan to understand nearshore and offshore bird populations in the Great Lakes and inform offshore wind energy siting and general conservation planning.

It is extremely difficult to predict how offshore wind energy development (OWED) will affect bird populations, because it involves a complex interaction between how *vulnerable* species are to being *exposed* to the *hazards* of OWEDs (Fox et al. 2006). Bird vulnerability to OWED is related to how rare the species is and how sensitive the birds are to the related hazards (Furness et al. 2013). Birds will be exposed to the hazards posed by OWED primarily during the operation of the turbines. Fox et al. (2006) described three hazards to birds from OWED: direct collision mortality, behavioral response (avoidance and displacement), and physical habitat modification. Birds respond to these hazards on a spectrum in which some species, such as Red-throated Loons (*Gavia stellata*), consistently avoid OWEDs, while others, such as gulls and cormorants, are seemingly unaffected or even attracted to OWED facilities (Desholm and Kahlert 2005, Percival 2010, Lindeboom et al. 2011). Avoidance behaviors (e.g, veering to avoid a wind project during flight) has been shown to only marginally increase energy use for Common Eiders (*Somateria mollissima*) during migration in Europe (Masden et al. 2009). Though it is conceivable that cumulative avoidance effects from multiple OWED might reduce the fitness of individuals—or that repeated avoidance behaviors during daily foraging flights may be problematic for breeding seabirds (Masden et al. 2009)—this topic is not discussed further in this report. Rather, we focus instead on the behavioral phenomenon of displacement from regular habitat use areas (e.g., foraging or roosting areas) and subsequent effective habitat loss. Likewise, physical habitat modification is largely unaddressed in published vulnerability assessments to date, in large part because its effects on birds are poorly understood.

Recognizing the complexities involved, we propose the following four-stage process to assist decision makers in identifying areas for siting OWED with the least avian conflicts:

<u>Stage 1: Species presence</u>. We are determining which species are present and how they are distributed during the fall and spring in certain areas of the Great Lakes using existing data. We have provided recommendations on survey methods to improve the utility of data for this purpose.

<u>Stage 2: Species vulnerability</u>. Based on the species observed during 2012-2013 GLC surveys and existing vulnerability indices (e.g., Furness et al. 2013, Willmott et al. 2013), we have developed a vulnerability assessment process for waterbirds observed during Phase I survey flights. This process could be expanded and further developed to determine which species will be most at risk from the hazards of OWEDs in the Great Lakes region.

<u>Stage 3: Focused studies</u>. Based on the results of Stage 2, we developed ideas for focused studies on certain waterbird species. For example, loons are ranked highly in published

vulnerability analyses, and focused studies on their use of the Great Lakes during migration may be crucial in avoiding or minimizing adverse impacts.

Stage 4: Mitigation measures. Based on findings from Stages 1-3, we suggest potential methods of mitigating adverse effects on waterbird species in the Great Lakes.

Great Lakes ecology and waterbirds

The Great Lakes (Lakes Superior, Michigan, Huron, Erie, and Ontario) are effectively vast inland freshwater seas, with a combined surface area of over 244,000 km^2 (>94,000 sq miles). Collectively, they constitute the largest freshwater ecosystem on the planet, containing nearly one-fifth of the surface freshwater on Earth, and 90% of the freshwater in the United States. The Lakes themselves span more than 1,200 km (750 miles) from east west, and drain a watershed of more than 521,000 km^2 (200,000 sq. miles). This enormous area is divided by an international border, and includes portions of eight U.S. states and two Canadian provinces (Great Lake Information Network 2014). The Great Lakes also boast over 17,000 km (10,000 miles) of shoreline and over 35,000 islands, and the Great Lakes Basin includes another several thousand smaller lakes.

The Great Lakes watershed varies enormously in its geology, hydrology, geography, climate, and ecology (U.S. Environmental Protection Agency 2012)[1]. As well as open freshwater, surrounding habitats include coniferous and northern hardwood forests, marshes, wetlands, prairies, and beach/dune communities, as well as agricultural lands and urban areas. The watershed is home to over 35 million people, and the Great Lakes are known to be sensitive to anthropogenic pressures, particularly contaminants (U.S. Environmental Protection Agency 2013)[2]. A number of invasive species have been introduced due to trade and transportation, such as the zebra mussel (*Dreissena polymorpha*), threatening the region's native biodiversity.

Migratory waterbirds are a significant biological resource in the Great Lakes, and the rich habitats of the region draw in enormous numbers of breeding, staging, and wintering waterbirds. Breeding terns, gulls, and plovers nest on beaches, while herons, night-herons, egrets, and cormorants nest on nearshore trees and shrubs. Large numbers of dabbling ducks, grebes, and rails nest in the extensive marshes and wetlands. Many northern breeding waterbirds, such as loons, use the Great Lakes as critical stopover or staging areas where they build up essential reserves to get them through their long-distance migration. Many species of waterbirds, particularly diving ducks and sea ducks, remain in the open water habitat of the Lakes throughout the winter.

The area supports a number of distinct waterbird populations and species at risk. The most prominent of these is the Great Lakes breeding population of the Piping Plover (*Charadrius melodus*), which is listed as federally endangered under the US Endangered Species Act (US

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[1] http://www.epa.gov/greatlakes/basicinfo.html

[2] http://www.epa.gov/greatlakes/ecopage/index.html

Fish & Wildlife Service 2014).[3] Numerous other waterbird species are listed as endangered, threatened, or special concern in the surrounding individual states and provinces.

Offshore wind and birds in the Great Lakes

The Great Lakes region has the potential to produce 700 gigawatts (GW) of energy[4], and the wind development company LEEDCo has identified a long-term vision of developing one GW energy production by 2020.[5] The wind resource in the Great Lakes is highest in the interior of lakes Huron, Michigan, and Superior (Figure 1), but the shallow water (Figure 2) and the proximity to load centers may make development in Lake Erie more feasible in the short term (Lott et al. 2011). The proposed LEEDCo "Icebreaker" project would consist of nine three-megawatt (MW) turbines located seven miles northwest of Cleveland; installation is scheduled to begin in 2017.[6]

The proceedings from a workshop on the current knowledge of the ecological effects of wind energy in the Great Lakes region noted that fatalities related to land-based wind have been detected for raptors and passerines and that passerines have been observed flying within the rotor swept zone (RSZ) at land-based sites. Furthermore, while there are many unknowns and further research is needed, the summary noted that some migrants flying over Lake Erie are flying above or below the rotor-swept zone. For all species groups, however, the report recognized significant data gaps, particularly for migrants (GLWC 2011). The Great Lakes Wind Collaborative has also established best practices for sustainable wind energy development, which includes comprehensive environmental assessments, mapping of important bird areas, standardized surveys protocols, mitigation, and other considerations.[7]

NEXRAD (Next Generation Radar) radar has shown that birds cross the Great Lakes in large numbers during migration (Diehl et al. 2003), but it is unclear how these birds may interact with OWED. In 2009 and 2010, the Ohio Division of Wildlife, in coordination with the US Fish and Wildlife Service (USFWS), flew weekly surveys during spring and fall migration in the Ohio waters of Lake Erie. Overall they detected 458,522 individual birds representing 44 species. While they detected birds throughout the survey area, they found birds were generally at lower densities further from shore, with most birds concentrated within 2.5 miles of shore. Additionally, they found the highest concentrations of birds close to river mouths and islands (Lott et al. 2011). A 2013 report to the USFWS indicated that avian migration over eastern Lake Ontario is highly variable from year to year, and that migratory activity over open water (rather than circling around the lake) varies by season, with higher levels of activity over open water areas in spring (Williams et al. 2013).

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3 http://www.fws.gov/midwest/endangered/pipingplover/index.html
4 http://www1.eere.energy.gov/wind/pdfs/great_lakes_offshore_wind_energy_consortium_mou.pdf
5 http://www.leedco.org/about
6 http://www.leedco.org/icebreaker/vision-timeline
7 http://www.glc.org/files/docs/2011-wind-bp-toolkit.pdf

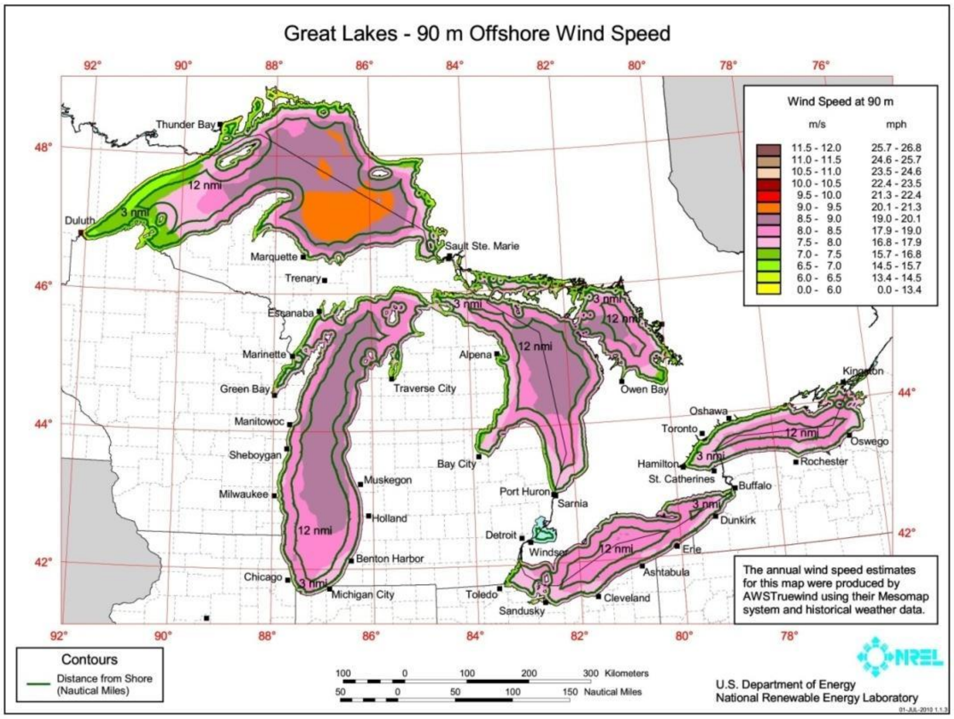

Figure 1. The wind resource of the Great Lakes.[8]

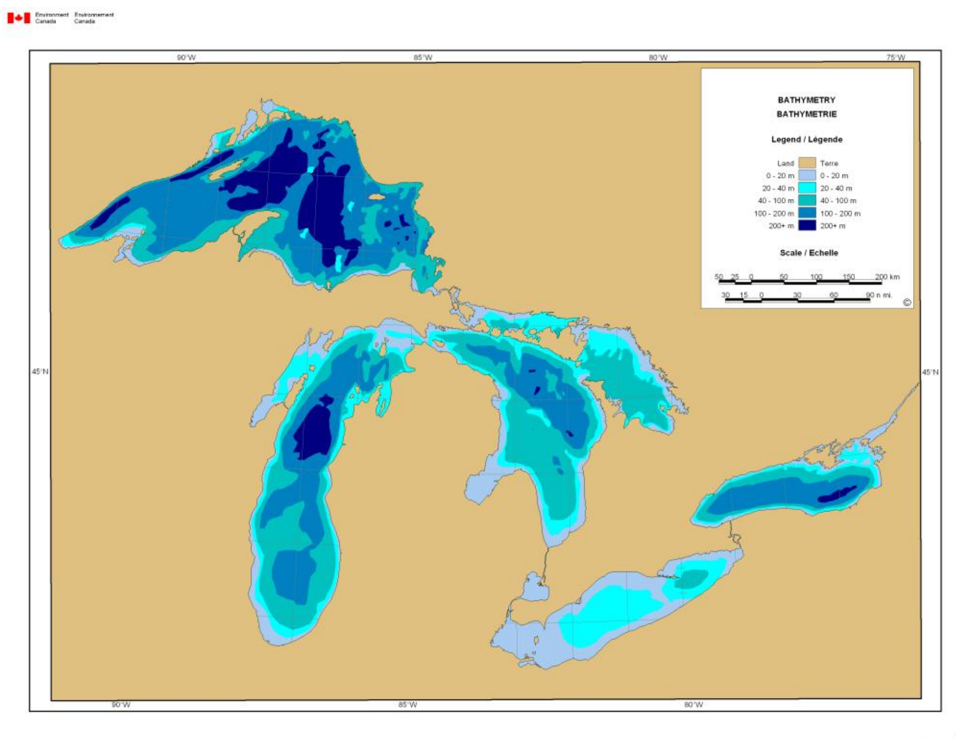

Figure 2. The bathymetry of the Great Lakes.[9]

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8 http://www1.eere.energy.gov/wind/pdfs/gl_mou_fact_sheet.pdf

9 http://ice-glaces.ec.gc.ca/IA_GLCA_SM/bathymetry_300dpi.gif

Avian research conducted at the LEEDCo project in Lake Erie included marine radar studies, boat surveys, and passive nocturnal passive acoustic studies for birds and bats. The report concludes that the species richness of the study area was low; they observed a total of 3,414 birds, the majority of which were gulls (Svedlow et al. 2012). In relation to the LEEDCo project, Curry and Kerlinger (*in* Driedger-Marschall et al. 2009) found that songbird and waterbirds migrated in large numbers over Lake Erie (mostly at night) and raptors in smaller numbers (during the day). They identified 11 species that were most likely to occur at the project site (Table 1). Based on European studies showing that Red-throated Loons avoid wind farms, they suggested that "habitat loss is only questionably indicated" for Common Loon (*Gavia immer*) and that, while unlikely, the project could act as a barrier to their movements. They also speculated that boat and helicopter traffic could cause temporary habitat loss for other species, such as Red-breasted Merganser (*Mergus serrator*). The report indicated that all waterbirds could be vulnerable to collision mortality, but that the exposure to the 27MW LEEDCo project off of Cleveland would be low and therefore collision risk would not cause population level effects (Driedger-Marschall et al. 2009).

Table 1. Species Likely Occurrence at LEEDCo Icebreaker Project Site (Curry and Kerlinger *in* Driedger-Marschall et al. 2009)

Species	Expected Occurrence at LEEDCo Project Site
Common Merganser	Small to moderate numbers in migration
Red-breasted Merganser	Potentially large numbers, particularly in fall migration
Common Loon	Small numbers in migration
Horned Grebe	Small numbers in migration
Double-crested Cormorant	Small numbers in summer, larger numbers in migration
Bonaparte's Gull	Potentially large numbers, particularly in fall migration
Ring-billed Gull	Small to moderate numbers, except in winter
Herring Gull	Small to moderate numbers, except in winter
Great Black-backed Gull	Small numbers, except in winter
Caspian Tern	Small numbers in migration
Common Tern	Small numbers mainly in fall migration

Individual and population level effects

It is important to consider the individual or per-capita risk versus the population risk of OWED to birds. When we examine avian vulnerability to OWED hazards, we must first consider the behavioral traits that put individuals at risk of direct and indirect effects, and then secondly consider the life history of a species within the context of their conservation status in order to understand how individual risk might scale up to population-level risk. In some cases a species could have a relatively high individual risk, but a small portion of their population is exposed to OWEDs, so the population-level risk would be low; in contrast, another species could have a moderate individual risk, but if their populations are already depleted, or a large portion of the population is exposed to OWED hazards, then population-level risk could be higher overall. While there are many data gaps that hinder a comprehensive individual and population-level vulnerability assessment, we start to identify which waterbirds observed during the 2013 GLC surveys may be most vulnerable to OWED and suggest targeted research to fill data gaps.

Methods

Stage 1: Species Presence

As a first step in determining waterbird species vulnerability to offshore wind energy development in the Great Lakes, BRI collated and summarized the data from pelagic bird surveys conducted for the Great Lakes Commission during the fall and winter of 2012 and spring of 2013 (Phase I of the project, "Monitoring and Mapping Avian Resources Over Selected Areas of the Great Lakes and Outreach to Support Related Resource Management"; Appendices 1-4).

Stage 2: Vulnerable species

Species Relative Abundance

"Unidentified" observations from the dataset described above were assigned to species based on relative frequency of species-level identification within the survey dataset. For example, all "unidentified swans" were assigned to be either Tundra Swans (*Cygnus columbianus*) or Mute Swans *(C. olor*) for the overall abundance calculations, based on the ratios of birds identified as each species. The exception is "unidentified" species that were not easily assigned to a specific species category (for example, there were no grebes identified to the species level in Phase 1 aerial surveys, so "unidentified grebe" records remained as such). This method of dealing with unidentified species has limitations—for example, some proportion of the unidentified swans are almost certainly Trumpeter Swans (*C. buccinator*) rather than Tundra or Mute Swans—but for the purposes of developing relative abundance estimates for this report, and given that the only data we were working with was the aerial survey Phase 1 data, this seemed to be a reasonable approach. For assessment of collision risk, displacement risk, and species of conservation concern, we included 27 species (all open-water waterbird species observed in the GLC Phase 1 aerial surveys, once unidentified species were assigned to the species level). This list excluded all raptors, passerines, shorebirds, and wading birds observed during surveys, as well as Mute Swan (an exotic species in North America) and grebes, which were never identified to the species level during surveys.

Collision Risk

Collision sensitivity was estimated using a similar approach to that of Willmott et al. (2013). Given that our occurrence data (e.g., species presence data) is based upon a single year of migration-season surveys (see above), however, we chose not to incorporate occurrence rank into our estimates as Willmott et al. did for their vulnerability assessment for bird species on the Atlantic Outer Continental Shelf. Thus, collision risk and displacement risk estimates are presented without the context of relative occurrence of these species in the Great Lakes region.

As a result, we calculated collision risk for each species according to the following formula:

$$\text{Collision Risk} = ((NFR+DFR)/RSZ)*MA*RT$$

Where NFR is a nocturnal flight rank, DFR is a diurnal flight rank, RSZ is the percentage of time spent at the rotor-swept zone, MA is macro-avoidance of turbines, and RT is residence time. NFR is the estimated percentage of the time that a species is flying over open water at night (1 = 0-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%). DFR is the estimated percentage of time that species is in flight over open water during the day (1 = 0-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%). RSZ is the percentage of a species' time spent in flight between 20 and 200m in altitude (1 = >20%, 3 = 5 to 20%, 5 = <5%). MA ranks a species' macro-avoidance behavior, or large-scale avoidance behavior occurring before species enters a wind farm (1 = >40% avoidance, 2 = 30 to 40% avoidance, 3 = 18 to 29% avoidance, 4 = 6 to 17% avoidance, 5 = 0 to 5% avoidance). RT ranks the number of seasons that each species spends in the Great Lakes region, where species are assigned a 0 or 1 score for presence during breeding, wintering, and migration seasons, and then the average of these scores is taken (for example, a species present during migration, but not during breeding or winter, would get an RT score of 0.33). Species presence during each season was assessed using information in *Birds of North America* accounts of species distributions (Poole 2005).

NFR, DFR, RSZ, and MA values were obtained from Willmott et al. (2013) in most cases. Due to a lack of species-specific data, scores for American White Pelicans (*Pelecanus erythrorhynchos*) were based on Brown Pelican (*P. occidentalis*) assessments and MA scores for some other species were estimated using group scores in Willmott et al. (2013). NFR, DFR, and RSZ scores for American Coot (*Fulica americana*) and Tundra Swan were developed based on information in the *Birds of North America* accounts for these species.

Displacement Risk

Displacement risk was assessed similarly to Willmott et al (2013) using the following formula:

$$\text{Displacement Risk} = ((DR+MA)/2)*HF*RT$$

Where DR is a rank of a species' visible disturbance by anthropogenic activity (primarily boats and helicopters; 0 = unaffected by boat and helicopter traffic; 2-4 = grades of behavior; 5 = strong escape/avoidance and large fleeing distance). HF is a metric of a species' habitat flexibility (1 = uses a wide range of habitats and broad prey base; 2-4 = grades of behavior; and 5 = has specific prey or habitat requirements and limited flexibility in diving depth or other behaviors). Most values were obtained from Willmott et al. (2013), though four DR and eight HF ranks were obtained from other sources for species where the Willmott et al. rank (developed for the Atlantic Outer Continental Shelf) was clearly inapplicable for the Great Lakes. MA and RT scores are as described above.

It should be noted that most collision risk and displacement risk ranks, as well as some conservation status ranks (below), were obtained from Willmott et al. (2013), which is the only avian vulnerability assessment for offshore wind currently published for the United

States. That report was focused on the Atlantic Outer Continental Shelf, however, and thus some of their estimated values may not be accurate for the same species in the Great Lakes. For the purposes of demonstrating this vulnerability assessment process for Great Lakes waterbirds, we simply used these rankings from the AOCS where it seemed appropriate; these values should be revisited, however, and estimated specifically for the Great Lakes region before vulnerability assessment values are relied upon and used for decision making in the region.

Conservation Status

Each species' conservation status was assessed using a similar protocol to that for "Population Sensitivity" in Willmott et al. (2013), though our development of the "threat ranking" metric and the ranks assigned to each species differed from their approach:

$$\text{Conservation Status} = (((\text{STR}+\text{CTR}+\text{GTR})/3)+\text{GPS}+\text{ASR})/3$$

STR, CTR and GTR and all metrics of species' conservation status, assessed at different geographic scales, and are averaged to develop a cumulative threat rank in this formula. More detail on these metrics is provided below. GPS is the global population size; we used GPS estimates from several sources, including Willmott et al. (2013) and (BirdLife International 2013). Our GPS metric used the same ranges as Garthe and Huppop (2004); 1 = >3 million individuals, 2 = 1–3 million individuals, 3 = >500,000 to <1 million individuals, 4 = 100,000–500,000 individuals, 5 = <100,000 individuals). ASR, or adult survival rank, is an estimate of annual adult survival rate following protocols in Garthe and Hüppop (1= <0.75, 2= 0.75 to 0.80, 3= >0.80 to 0.85, 4= >0.85 to 0.90, 5= >0.90); values are from Willmott et al. (2013) with the exception of American White Pelican, where the SR value was derived from the *Birds of North America* account. The cumulative threat ranking, GPS, and ASR are averaged to develop an estimate of each species' conservation status.

Estimates of cumulative threat rank were the most complicated to develop, in part because the threat ranks developed for the only published American vulnerability assessment to date (Willmott et al. 2013) were largely inapplicable for the Great Lakes region and/or for our species list. STR is the state threat ranking, where the state or provincial listing status for a species (0=not present in that state; 1=no listing; 2=species of special concern; 3=threatened; 4=endangered) is averaged across the nine Great Lakes states and provinces (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and Ontario). Although each state or province differs slightly in the specific ranking system they use, we determined that state species conservation ranks were similar enough to be combined as above in this report (this assumption should be revisited for a full-scale vulnerability analysis in future). CTR is the continental threat ranking; our assessment of continental-scale population trends was based on Breeding Bird Survey (BBS) and Christmas Bird Count (CBC) data from 1966-2012 (see below; 1=significantly increasing; 2=no statistically significant change; 3=significantly decreasing). GTR is the global threat ranking for a species, as assessed in the IUCN Red List of Threatened Species (http://www.iucnredlist.org/).

CTR estimates were developed in part based on the "Regional Trend Analysis" analytical tool on the BBS website, which is based on a hierarchical model for population change that produces annual abundance indices and compares the first and last annual indices for the time interval of interest (Sauer et al. 2012). To develop continental conservation status values for our species list, we chose the species of interest (for example, "Canada Goose,") and the region of interest (the United States and Canada; a regional-scale analysis could be conducted by assessing regional trends across the breeding range of each species, after Link and Sauer (2002) , but that was deemed to be beyond the scope of this initial analysis). The date range for trend analysis was chosen as the widest date range available (either 1966-2011 or 1967-2011). Annual indices of relative abundance and associated 2.5% and 97.5% confidence intervals were used to rank the population trajectory for the entire period as significantly increasing, significantly decreasing, or no statistically significant change.

For several species, model results were not available, presumably because there were not sufficient BBS data to analyze trends; in one case, the trends of a related species were used instead (Lesser Scaup substituted for Greater Scaup). In nine other cases, CBC data[10] were used instead of BBS data – Bonaparte's Gull (*Chroicocephalus philadelphia*), Tundra Swan, Surf Scoter (*Melanitta perspicillata*), Glaucous Gull (*Larus hyperboreus*), Red-throated Loon (*Gavia stellata*) , Great Cormorant (*Phalacrocorax carbo*), Common Eider (*Somateria mollissima*), Ring-necked Duck (*Aythya collaris*), and Long-tailed Duck (*Clangula hyemalis*). These data were not analyzed via the Sauer et al. (2002) hierarchical model nor bootstrapped as with the BBS data; instead, we conducted an ANOVA for the CBC data for these species to determine if observed populations appeared to increase, decrease, or remain stable (number observed per party hour) through time. Bonaparte's Gull significantly decreased ($p<0.001$) according to this assessment method, for example, while Long-tailed Duck counts increased, but not significantly ($p=0.73$). A bootstrapped, more reliable analysis is recommended for all species for future assessments of conservation status.

Highest priority species

We developed an overall priority species score for each of the above four vulnerability metrics by dividing species' end scores into quartiles (e.g., to provide each species with a 1-4 final score for each metric). This was done to eliminate small and likely insignificant differences between species' scores, which we felt provided a misleadingly precise estimate of their respective vulnerabilities. Stochastic processes such as weather, seasonality, and long-term population fluctuations may affect species' vulnerability over time; additionally, there may be variations between water bodies within the Great Lakes that entail differences in relative vulnerability of local populations. Traditional vulnerability assessments fail to capture such variations, due in part to a lack of data on species' distributions and behavior. As a result, in addition to using these final 1-4 scores, we also relied upon qualitative expert judgment to highlight several species that we believe require special consideration for focused studies.

[10] http://birds.audubon.org/data-research

Results/Discussion

Stage 1: Species Presence

Tables 2 and 3 list the taxonomic groups and species observed during Phase I aerial surveys in order of overall abundance (including unidentified species). Eight species constitute 95% of all the birds observed during the surveys (Tables 3 & 5). It is important to consider that these species would likely have a high level of potential exposure to the hazards posed by future OWED in the Great Lakes. The large population sizes and wide ranges of some of these species, such as Mallard (*Anas platyrhynchos*) and Canada Goose (*Branta canadensis*), however, may mean that even relatively severe direct and indirect effects within the Great Lakes region may not have population-level consequences.

Table 2. The number of birds observed in each taxonomic group during Phase I aerial surveys of the Great Lakes.

Row Labels	Total
Diving ducks	975,855
Dabbling ducks	84,919
Sea ducks	42,295
Swans	41,083
Unidentified gulls	21,123
Geese	13,616
Coots	9,143
Cormorants	1,587
Small gulls	552
Large gulls	486
Raptors	269
Passerines	262
Other waterbirds	242
Terns	150
Loons	114
Unidentified ducks	68
Shorebirds	46
Birds	4
Grebes	3
Pelicans	3

Table 3. Counts of birds in the Great Lakes in fall/winter 2012 and spring 2013 aerial surveys.

Common Name	Count
Canvasback	541,679
Unidentified Scaup	258,939
Redhead	138,941
Unidentified dabbling duck	84,862
Unidentified Swan	40,954
Ruddy Duck	29,950
Unidentified Goldeneye or Merganser	24,456
Unidentified Gull	21,123
Canada Goose	13,616
American Coot	9,143
Bufflehead	8,630
Long-tailed Duck	6,695
Red-breasted Merganser	4,527
Common Goldeneye	1,652
Double-crested Cormorant	1,581
Unidentified Merganser	1,240
Greater Scaup	801
Common Merganser	541
Bonaparte's Gull	272
Bonaparte's Gull	272
Herring gull	270
Bald Eagle	264
Unidentified Crow	210
Common Tern	150
Unidentified Large Gull	146
Great Blue Heron	137
Tundra Swan	128
Unidentified Egret	91
Unidentified Duck	68
Unidentified Loon	61
Mallard	57
American Goldfinch	52
Unidentified shorebird	46
Common Loon	44
Ring-billed Gull	42
Ring-necked Duck	38
Unidentified Diving/Sea Duck	31
Glaucous Gull	24

Common Name	Count
Unidentified Scoter	15
Great Egret	14
Surf Scoter	12
Red-throated Loon	9
Great Cormorant	6
Unidentified Bird	4
Unidentified small gull	4
Northern Harrier	4
Unidentified small gull	4
Common Eider	3
Unidentified Grebe	3
Great Black-backed Gull	3
American White Pelican	3
Great or Lesser Black-backed Gull	1
Red-tailed Hawk	1
Mute Swan	1
Total	1,191,820

Stage 2: Vulnerable species

Birds can be adversely affected by OWED directly through collision mortality and injury, and through displacement caused by disturbance (Drewitt and Langston 2006, Fox et al. 2006, Langston 2013). Birds avoid wind farms at macro, meso, and micro scales (Desholm and Kahlert 2005, Burger et al. 2011) and, for some species, the avoidance can lead to permanent or temporary displacement. Displacement by OWED has been documented in sea ducks and loons (Petersen et al. 2006, Percival 2010). However, in some instances, species may reenter a wind farm over time, seeking newly available food resources (Petersen and Fox 2007, Leonhard et al. 2013).

Birds' vulnerability to adverse effects is dictated by exposure (e.g., species presence and availability to be exposed to those hazards), by behavioral traits that increase their exposure (e.g., flying at rotor height), life history traits that increase the significance of the loss of an individual (e.g., population vital rates), and conservation status (e.g., species with small or declining populations; (Garthe and Huppop 2004, Desholm 2009, Furness et al. 2013, Willmott et al. 2013). Table 4 represents vulnerability ranks for 27 species in four categories: relative abundance (based on survey data from Phase 1); collision risk; displacement risk; and conservation status.

Table 4. The vulnerability of waterbird species of highest priority detected during Phase I aerial surveys. Vulnerability is represented by green (low), yellow (medium), orange (high), and red (extra high).

Common Name[2]	Scientific Name[2]	Relative Abundance	Collision Risk	Displacement Risk	Conservation Status
Ruddy Duck	*Oxyura jamaicensis*	Red	Red	Orange	Orange
Redhead	*Aythya americana*	Red	Orange	Red	Yellow
Great Black-backed Gull	*Larus marinus*	Yellow	Red	Orange	Red
Bufflehead	*Bucephala albeola*	Orange	Red	Red	Yellow
Herring Gull	*Larus argentatus*	Orange	Red	Green	Red
Tundra Swan	*Cygnus columbianus*	Red	Green	Orange	Red
Common Goldeneye	*Bucephala clangula*	Orange	Red	Red	Green
Red-breasted Merganser	*Mergus serrator*	Red	Orange	Yellow	Orange
Long-tailed Duck	*Clangula hyemalis*	Orange	Red	Red	Green
Scaup sp.	*Aythya affinis/marila*	Red	Orange	Red	Green
Bonaparte's Gull	*Chroicocephalus philadelphia*	Orange	Green	Orange	Red
Canada Goose	*Branta canadensis*	Orange	Orange	Orange	Yellow
Canvasback	*Aythya valisineria*	Red	Yellow	Yellow	Orange
Glaucous Gull	*Larus hyperboreus*	Yellow	Orange	Green	Red
Mallard	*Anas platyrhynchos*	Red	Orange	Yellow	Green
American Coot	*Fulica americana*	Orange	Yellow	Red	Green
Common Merganser	*Mergus merganser*	Yellow	Orange	Orange	Yellow
Common Loon	*Gavia immer*	Green	Green	Orange	Red
Surf Scoter	*Melanitta perspicillata*	Green	Green	Orange	Red
Ring-billed Gull	*Larus delawarensis*	Yellow	Red	Green	Yellow
Common Tern	*Sterna hirundo*	Yellow	Orange	Green	Orange
Ring-necked Duck	*Aythya collaris*	Green	Orange	Red	Green
Double-crested Cormorant	*Phalacrocorax auritus*	Yellow	Orange	Green	Orange
Red-throated Loon	*Gavia stellata*	Green	Green	Orange	Orange
Common Eider	*Somateria mollissima*	Green	Green	Orange	Orange
Great Cormorant	*Phalacrocorax carbo*	Green	Green	Yellow	Orange
American White Pelican	*Pelecanus erythrorhynchos*	Green	Yellow	Green	Orange

Relative Abundance

An important limitation of the vulnerability assessment approach described here is that it is only based upon Phase I surveys, primarily conducted during fall and spring; this survey is far from comprehensive and specifically does a poor job of capturing the presence of breeding birds, passerines, shorebirds, and raptors. These surveys were designed to specifically study migratory waterbirds, and the recommendations presented in this report are similarly limited. Surveys were also not optimized for all waterbird species; survey locations, frequency, transect density, altitude, and other methodologies may cause detection rates for different species to vary based on their visibility, grouping tendency, and other traits. For further information, please see "A Framework for Exploring and Understanding the Effects of Offshore Wind Energy Development on Migratory Waterfowl in the Great Lakes: Interim Report and Survey Recommendations" report submitted to GLC on 01/15/2014.

Relative abundance for 27 waterbird species observed in Phase I surveys was estimated by assigning unidentified observations to the species level, as described above. The resulting relative abundance estimates used in the vulnerability assessment are listed in Table 5.

Table 5.The relative abundance of waterbird species observed during Phase 1 aerial surveys, after unidentified species were assigned to the species level (see text). Percentage values are to two significant digits.

Species	% of observations
Canvasback	45.46%
Greater Scaup	21.79%
Redhead	11.66%
Mallard	7.13%
Tundra Swan	3.42%
Ruddy Duck	2.51%
Red-breasted Merganser	1.86%
Canada Goose	1.14%
Bonaparte's Gull	0.84%
Herring Gull	0.82%
American Coot	0.77%
Bufflehead	0.72%
Common Goldeneye	0.64%
Long-tailed Duck	0.56%
Common Merganser	0.22%
Double-crested Cormorant	0.13%
Ring-billed Gull	0.13%
Glaucous Gull	0.07%
Common Tern	0.01%
Great Black-backed Gull	0.01%
Common Loon	0.01%
Ring-necked Duck	0.00%
Surf Scoter	0.00%
Red-throated Loon	0.00%
Great Cormorant	0.00%
Common Eider	0.00%
American White Pelican	0.00%

Collision risk

As also described in the methods sections, it should be noted that most collision risk and displacement risk ranks were obtained from Willmott et al. (2013), which is the only avian vulnerability assessment for offshore wind currently published for the United States. That report, however, was focused on the Atlantic Outer Continental Shelf, and thus some estimated values may not be accurate for the same species in the Great Lakes. For the purposes of demonstrating this vulnerability assessment process for Great Lakes waterbirds, we simply used these rankings from the AOCS where it seemed appropriate; these values should be revisited, however, and estimated specifically for the Great Lakes region before vulnerability assessment values are relied upon and used for decision making in the region.

Table 6 shows the potential vulnerability to collision with OWED for the 27 species described above. It should be noted that these values are based upon several published estimates for other geographic locations, but in most cases are based on relatively little actual data. All values should be viewed with extreme caution and should not be used for decision-making purposes—a more intensive analysis would be required to develop a comprehensive vulnerability assessment for Great Lakes species. The assessment presented in this report is merely a demonstration of the methodology, with some ideas of how it could be refined to further reflect Great Lakes species compositions and vulnerabilities.

In European assessments, gulls rank highly for potential collision risk because of the large percentage of time they spend flying within the rotor-swept zone (30-35%; (Furness et al. 2013). Their attraction to some projects (Lindeboom et al. 2011), possibly due to reef effects (Linley et al. 2007, Inger et al. 2009, Boswell et al. 2010), may also be a risk factor. Willmott et al. (2013) also ranked some small duck species higher in collision risk, such as Ruddy Duck (*Oxyura jamaicensis*), Common Goldeneye (*Bucephala clangula*), and Bufflehead (*B. albeola*), due to their high nocturnal flight rankings, relatively low estimated rates of macro-avoidance, and particularly to the large percentage of the time that these species were estimated to spend in the rotor-swept zone. Our findings are mostly consistent with these results, with *Bucephala* and *Oxyura* duck species and Herring Gulls ranking highest for estimated collision rates. Canada Goose also ranked relatively highly for collision risk, although there is some evidence from Europe that most individuals of other geese and swan species fly above turbine height and have also been observed to increase flight altitude to avoid wind projects (Griffin et al. 2011, Plonczkier and Simms 2012).

Table 6. Collision risk.

Common Name[2]	Scientific Name[2]	Nocturnal Flight Rank	Diurnal Flight Rank	Rotor-Swept Zone	Macro-Avoidance	Residence Time	Collision Risk
Ruddy Duck	*Oxyura jamaicensis*	5	1	1	2	1.0	12.0
Ring-billed Gull	*Larus delawarensis*	3	3	1	2	1.0	12.0
Common Goldeneye	*Bucephala clangula*	3	2	1	2	1.0	10.0
Herring Gull	*Larus argentatus*	3	2	1	2	1.0	10.0
Great Black-backed Gull	*Larus marinus*	3	2	1	2	1.0	10.0
Bufflehead	*Bucephala albeola*	3	1	1	2	1.0	8.0
Long-tailed Duck	*Clangula hyemalis*	4	3	1	1	1.0	7.0
Glaucous Gull	*Larus hyperboreus*	3	2	1	2	0.7	6.7
Canada Goose	*Branta canadensis*	3	3	1	1	1.0	6.0
Redhead	*Aythya americana*	3	3	1	1	1.0	6.0
Greater Scaup	*Aythya marila*	5	2	1	1	0.7	4.7
Ring-necked Duck	*Aythya collaris*	5	1	1	1	0.7	4.0
Common Tern	*Sterna hirundo*	1	5	1	1	0.7	4.0
Double-crested Cormorant	*Phalacrocorax auritus*	1	5	3	3	0.7	4.0
Mallard	*Anas platyrhynchos*	1	3	1	1	1.0	4.0
Red-breasted Merganser	*Mergus serrator*	1	1	1	2	1.0	4.0
Common Merganser	*Mergus merganser*	1	1	1	2	1.0	4.0
Canvasback	*Aythya valisineria*	3	2	1	1	0.7	3.3
American White Pelican	*Pelecanus erythrorhynchos*	1	3	3	5	0.3	2.2
American Coot	*Fulica americana*	1	1	5	5	1.0	2.0
Surf Scoter	*Melanitta perspicillata*	3	2	1	1	0.3	1.7
Bonaparte's Gull	*Chroicocephalus philadelphia*	2	1	3	2	0.7	1.3
Great Cormorant	*Phalacrocorax carbo*	1	2	3	3	0.3	1.0
Common Loon	*Gavia immer*	1	2	3	1	0.7	0.7
Common Eider	*Somateria mollissima*	3	2	3	1	0.3	0.5
Red-throated Loon	*Gavia stellata*	1	2	3	1	0.3	0.3
Tundra Swan	*Cygnus columbianus*	1	1	5	1	0.7	0.3

Displacement risk

The results below are based upon values for different displacement parameters determined by Willmott et al. (2013) and are influenced by how the values were weighed in the analysis. In many cases the values have a high level of uncertainty due to significant data gaps on basic behavioral and natural history traits of many species (see methods for further details). Some ducks and loons have been shown in European studies to be susceptible to displacement effects, and many of these species likewise ranked high in potential displacement in this study (Table 7). While there is little to no information on how many of the ducks that frequent the Great Lakes will respond to OWED, it is reasonable to assume based on the available data (Percival 2010, Langston 2013) that there is a risk of displacement and effective loss of critical habitat for foraging, roosting, migratory staging, or other purposes.

Table 7. Displacement risk.

Common Name[2]	Scientific Name[2]	Displacement Rank	Macro-Avoidance	Habitat Flexibility	Residence Time	Displacement Risk
Common Goldeneye	*Bucephala clangula*	4	4	4	1.0	16.0
Long-tailed Duck	*Clangula hyemalis*	3	5	4	1.0	16.0
American Coot	*Fulica americana*	2	5	4	1.0	14.0
Redhead	*Aythya americana*	4	5	3	1.0	14.5
Bufflehead	*Bucephala albeola*	4	4	3	1.0	12.0
Scaup spp.	*Aythya marila*	4	5	4	0.7	12.0
Ring-necked Duck	*Aythya collaris*	4	5	4	0.7	12.0
Common Loon	*Gavia immer*	5	5	3	0.7	10.0
Ruddy Duck	*Oxyura jamaicensis*	4	4	2	1.0	8.0
Red-throated Loon	*Gavia stellata*	5	5	4	0.3	6.7
Surf Scoter	*Melanitta perspicillata*	5	5	4	0.3	6.7
Tundra Swan	*Cygnus columbianus*	5	5	2	0.7	6.7
Common Eider	*Somateria mollissima*	3	5	4	0.3	5.3
Bonaparte's Gull	*Chroicocephalus philadelphia*	2	4	2	0.7	4.0
Canada Goose	*Branta canadensis*	3	5	1	1.0	4.0
Common Merganser	*Mergus merganser*	4	4	1	1.0	4.0
Great Black-backed Gull	*Larus marinus*	2	2	2	1.0	4.0
Great Cormorant	*Phalacrocorax carbo*	4	3	3	0.3	3.5
Red-breasted Merganser	*Mergus serrator*	3	4	1	1.0	3.5
Canvasback	*Aythya valisineria*	4	5	1	0.7	3.0
Mallard	*Anas platyrhynchos*	1	5	1	1.0	3.0
Common Tern	*Sterna hirundo*	1	1	3	0.7	2.0
Double-crested Cormorant	*Phalacrocorax auritus*	3	3	1	0.7	2.0
Herring Gull	*Larus argentatus*	2	2	1	1.0	2.0
Ring-billed Gull	*Larus delawarensis*	1	2	1	1.0	1.5
American White Pelican	*Pelecanus erythrorhynchos*	3	5	1	0.3	1.3
Glaucous Gull	*Larus hyperboreus*	2	2	1	0.7	1.3

Species of high conservation concern

Based upon this analysis several species are potentially vulnerable because their populations are already marginalized due to other anthropogenic factors, they have naturally small population sizes, or they are k-selected species with low reproductive rates and high adult survival (meaning that adult mortalities would be more likely to have population-level impacts; Table 8). The most notable species within this group is the Tundra Swan. Swans are a species that are exposed to OWED in Europe (Griffin et al. 2011), and, while there is little evidence that they are at risk for either displacement or collision mortality, their populations are less resilient to potential effects from OWED than species that have large populations and lower adult survival rates, such as mallards. Herring Gull populations are larger than those of Tundra Swans but are decreasing across North America, and their high adult survival rates also make them vulnerable to adult mortalities. Bonaparte's Gull has a relatively small and decreasing global population, also making them a species of higher conservation concern.

Table 8. Conservation status.

Common Name	Scientific Name[2]	State TR (Threat Ranking)	Continental TR	Global TR*	Cumulative TR	Global Population Size	Adult Survival Rank	Conservation Status
Tundra Swan	*Cygnus columbianus*	1.0	1	1	1.0	4	5	3.3
Surf Scoter	*Melanitta perspicillata*	1.0	3	1	1.7	3	5	3.2
Common Loon	*Gavia immer*	1.3	2	1	1.4	3	5	3.1
Great Black-backed Gull	*Larus marinus*	1.0	2	1	1.3	3	5	3.1
Glaucous Gull	*Larus hyperboreus*	1.0	2	1	1.3	3	5	3.1
Bonaparte's Gull	*Chroicocephalus philadelphia*	1.0	3	1	1.7	4	3	2.9
Herring Gull	*Larus argentatus*	1.0	3	1	1.7	2	5	2.9
Common Tern	*Sterna hirundo*	3.0	2	1	2.0	2	4	2.7
Red-throated Loon	*Gavia stellata*	1.0	1	1	1.0	4	3	2.7
American White Pelican	*Pelecanus erythrorhynchos*	1.3	1	1	1.1	4	2	2.4
Great Cormorant	*Phalacrocorax carbo*	1.0	3	1	1.7	2	3	2.2
Red-breasted Merganser	*Mergus serrator*	1.0	3	1	1.7	3	2	2.2
Canvasback	*Aythya valisineria*	1.0	2	1	1.3	3	2	2.1
Common Eider	*Somateria mollissima*	1.0	2	1	1.3	1	4	2.1
Double-crested Cormorant	*Phalacrocorax auritus*	1.0	2	1	1.3	2	3	2.1
Ruddy Duck	*Oxyura jamaicensis*	1.0	2	1	1.3	3	2	2.1
Ring-billed Gull	*Larus delawarensis*	1.0	1	1	1.0	2	3	2.0
Redhead	*Aythya americana*	1.0	2	1	1.3	2	2	1.8
Bufflehead	*Bucephala albeola*	1.0	1	1	1.0	2	2	1.7
Canada Goose	*Branta canadensis*	1.0	1	1	1.0	1	3	1.7
Common Merganser	*Mergus merganser*	1.0	3	1	1.7	2	1	1.6
American Coot	*Fulica americana*	1.0	2	1	1.3	1	2	1.4
Common Goldeneye	*Bucephala clangula*	1.0	2	1	1.3	1	2	1.4
Scaup spp.	*Aythya marila*	1.0	2	1	1.3	2	1	1.4
Long-tailed Duck	*Clangula hyemalis*	1.0	2	3	2.0	1	1	1.3
Ring-necked Duck	*Aythya collaris*	1.0	1	1	1.0	2	1	1.3
Mallard	*Anas platyrhynchos*	1.0	2	1	1.3	1	1	1.1

Priority Species

We have highlighted several waterbird species, below, that were observed during the Phase 1 surveys and that may be considered higher priority for additional research. This is necessarily a somewhat subjective assessment, as many species could be considered high priority for various reasons, but we have attempted to use the results of the preliminary vulnerability assessment (above) with our own knowledge of species' behaviors and stressors to develop a suggested list of focal species. Such a list would likely need to be revisited with the development of a more comprehensive vulnerability assessment for the Great Lakes.

For species that winter in (as well as migrate through) the Great Lakes, we highlight Canvasbacks (*Aythya valisineria*), scaup spp. (*A. marila/A. affinis*), and Redheads (*A. americana*) because they were the most common species encountered during surveys, and large numbers will almost certainly be exposed to offshore wind energy development projects in the Great Lakes. We also highlight Long-tailed Ducks (*Clangula hyemalis*), a species of global conservation concern that occurs in large numbers in certain areas of the Great Lakes (particularly Lakes Michigan and Huron). Among species that are present in the Great Lakes primarily during migration, we highlight loons (*Gavia* spp.) because they rank highest for displacement vulnerability in European studies. Additionally, we highlight Red-breasted Merganser (*Mergus serrator*), which ranked relatively high in three vulnerability categories and may overall have a higher vulnerability. While breeding birds were beyond the scope of this study, we also mention Common Terns (*Sterna hirundo*) and Bald Eagles (*Haliaeetus leucocephalus*) which are two species of conservation priority that breed in the Great Lakes and may be a concern for potential collision mortality. Eagles are the one non-waterbird we have highlighted because of their special conservation status within the U.S. For each species we review their natural history and what is known about their potential vulnerability to offshore wind power.

Species that winter in the Great Lakes

Canvasbacks, Scaup spp., and Redheads represent 79% of the total individuals observed during Phase I surveys (Table 6). However, these are species that have not been well represented in existing OWED/bird studies. Consequently, there is little empirical evidence for these species to indicate whether they are specifically vulnerable to OWED. Research in Europe has demonstrated that waterbirds in general, and ducks in particular, can be displaced from OWED sites, leading to temporary or possibly permanent effective habitat loss. This suggests that these three species may be adversely affected by OWED that is sited within wintering (or migratory) concentration areas.

Canvasback

The Canvasback is a large diving omnivorous duck that feeds on both plants and benthic invertebrates in a variety of habitats, including shallow bays. They breed in the northwestern parts of the U.S. and the western half of Canada. They winter throughout the U.S., and in the Great Lakes are concentrated in Lake Erie and Lake Ontario, and the southern part of Lake Michigan. They generally migrate in small flocks of 10-40, but congregate into larger flocks in certain staging and wintering areas. Canvasback populations have fluctuated from 1955-2001, and the 2001 population estimate was 3% above the long-term trend, suggesting an overall stable population (Mowbray 2002).

Since the range of the Canvasback is limited to North America, there are no post-construction studies available to indicate how they will respond to OWED, and they have not been included in vulnerability assessments conducted in Europe. Our assessment (partially based on Willmott et al. 2013) suggests that they are at moderate risk of both collision and displacement (Tables 6 and 7). Thus, little is known about how this species will respond to OWED. Given the large numbers observed during Phase 1 surveys (and the extremely high level of variability in observed distributions), we suggest that this species should be a focus for additional research, particularly as they are also a species of some conservation concern for the region (Table 8).

Scaup spp.

The following natural history is for Greater Scaup, which have high wintering populations in the Great Lakes. Like the Canvasback, scaup are large diving omnivorous ducks that feeds on both plants and benthic invertebrates in shallow bays. While seasonally dependent, the birds generally forage in shallow water closer to shore (<5 m). They breed in northern Canada and Alaska, and winter in the Great Lakes, Atlantic Coast, and Pacific Coast. Often during migration and wintering they congregate in large flocks (1,500-3,000 individuals). Their overwintering populations in the Great Lakes, especially Lake Erie and Lake Ontario, have increased since the 1980's due to milder winters, heated water-exchange sites, and availability of zebra mussels. Wintering scaup populations as a whole have been significantly declining at a rate of over 21,000 individuals/year from 1975-1999 (Kessel et al. 2002). The declines may be due to contaminants, low female survivorship, and reduced recruitment due to changes in food resources (Austin et al. 2000).

A critical consideration with scaup is that it is often impossible to distinguish between the Greater and Lesser Scaup. According to Kessel et al. (2002) "...their similarity is a major challenge to waterfowl managers, who require accurate population information for each species to set harvest limits and develop management policies. Unfortunately, because of identification difficulties, the 2 species are combined during aerial (and most ground) population surveys, so changes in populations of either species are obscured—especially those of Greater Scaup, whose numbers are overwhelmed by the more abundant Lesser Scaup."

Existing vulnerability assessments suggest that scaup spp. are not at a high risk for collision mortality (Garthe and Huppop 2004, Furness et al. 2013). Furness et al. (2013) included scaup spp. in their vulnerability analysis and calculated a relatively low risk of collision. This was driven primarily by a low estimated percentage of time flying in the rotor-swept zone (3%, compared to 35% for Herring Gull). This calculation was repeated by Willmott et al. (2013). Relative to the other species observed during surveys, however, scaup ranked in the top 50% of the species we examined for collision risk, and ranked even more highly for potential displacement (Table 5). Furness et al. (2013) also ranked scaup high for disturbance and having low habitat flexibility. Scaup spp. are sensitive to disturbance by boats and aircraft (Kessel et al. 2002), suggesting that activities related to OWED during all operation phases could cause displacement and potentially chronic disturbance.

Redhead

Redheads are also large diving omnivorous ducks that feeds on both plants and benthic invertebrates in coastal lagoons and bays (12-30cm deep). They breed in the northwestern U.S. and western Canada, and winter throughout the continental U.S. In the Great Lakes, they winter in Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario. They migrate in small flocks, and the average flock size during winter is about 25. The North American population has not significantly changed from 1954 to 1994; from 1994-2002, however, there were large population fluctuations. Overall, there has been no long-term change in population trends (Woodin and Michot 2002).

Like the Canvasback, their species range is limited to North America and there is no direct information on how Redheads will respond to OWEDs. Our assessment, however, suggests that they are at medium-high collision risk and high displacement risk (Table 5). Given their relative abundance in the Great Lakes, these scores suggest that they may be a priority species for additional research.

Long-tailed Duck

Long-tailed Ducks are medium-sized omnivorous diving ducks that feed primarily on aquatic insects, fish, mollusks and crustaceans and can dive as deep as 60m, though the majority of feeding activity occurs within 9m of the water's surface (Robertson and Savard 2002). They spend a higher proportion of their foraging time underwater than any other diving duck. North American populations breed in arctic and subarctic wetlands from Alaska to Labrador, winter on large freshwater lakes or on the ocean (eastern populations winter in the northwest Atlantic and Great Lakes), and migrate and winter in large flocks (Robertson and Savard 2002). Populations are thought to be declining, although their offshore wintering habits and large breeding range make accurate censuses difficult.

Though they were not highly ranked in our Great Lakes-focused conservation status assessment, Long-tailed Ducks are a species of global conservation concern ("Vulnerable" on the IUCN Red List) due to presumed population declines. Long-tailed Ducks represented less than 1% of Phase I survey observations, but they are among the most common species observed in some areas of the Great Lakes (particularly Lakes Michigan and Huron; Appendices 3-4), and appear to be distributed farther from shore than many other species (Appendix 4), indicating high potential for exposure to OWED in these areas. Our preliminary assessment also suggests that they are at high risk of both collision and displacement relative to the other species we examined (the species ranked 7th in collision risk and 2nd in displacement risk).

Migratory species in the Great Lakes

Loons are a long-lived species with high adult survival and low annual productivity. Therefore, the loss of individuals or the chronic reduction of individual fitness has the potential to adversely affect populations. Red-throated Loons respond to OWED by avoiding them completely (see below for more details), which can lead to a *de facto* habitat loss. Such a loss of habitat could be an additional stressor for the loon populations that migrate through the Great Lakes. Loons in the Great Lakes also suffer from outbreaks of botulism; between 1963-1981 an estimated 7,400 loons died in Lake Michigan, and from 2000-2006 over 12,000 loons are estimated to have died in Lake Erie (Evers et al. 2010). Loss of habitat could potentially exacerbate the effects of botulism at migratory staging and/or stopover sites if the birds are forced into areas where botulism concentrates (D. Evers, personal communication 2014).

Red-throated Loon

Red-throated Loons are small loons that feed mainly on small fish, both near-shore and offshore. These loons have a circumpolar distribution and, in North America, they breed in coastal and northern Canada and Alaska, and winter along the east and west coasts of the U.S. (Barr et al. 2000). They pass through the Great Lakes, primarily during fall migration (Williams et al. 2014), in flocks of ~15 individuals (Barr et al. 2000). The birds are seen in the greatest numbers in Lake Ontario, where the peak period of migration is from mid-November to the beginning of December (Williams et al. 2014). While there is little information on population trends, the Alaska population declined by 53% from 1977-1993, and the Swedish population declined by 50% over the 50 years leading up to 1994; population trends vary in other countries (Barr et al. 2000). Red-throated loons have been identified as a priority species for the Atlantic coast of the US[11].

Red-throated loon/OWED interactions have been well studied in Europe. The primary response of the loons to OWEDs is displacement (Lindeboom et al. 2011, Leonhard et al. 2013); displacement at one site, for example, seemed to occur within a 500m buffer around a project, and the birds did not appear to habituate to the project (Percival 2010). The potential cumulative effects of this displacement has been modeled with Europe's current build-out scenario for OWED, and is predicted to reduce the species' overall available habitat by 5.42% (Busch et al. 2013). Red-throated loons have been ranked as the most vulnerable species to displacement (Garthe and Huppop 2004, Furness et al. 2013) and are considered to be one of the species that are at high risk of adverse effects (Langston 2010). While they were ranked as only medium-high for risk of displacement in our study, this was largely due to the fact that their residence time (RT score) was low, because they do not breed or winter on the Great Lakes. While Red-throated Loons may only be present in the Great Lakes for relatively short periods of the year, they are one of the species at highest risk of displacement from important migratory stopover locations during these periods. The consistent displacement effects observed in Europe, in addition to the large proportion of the east coast population that appears to migrate through the Great Lakes during fall migration (Williams et al. 2014), suggest that this should be a priority species for additional research.

Common Loon

Common Loons (*Gavia immer*) are large loons that feed on fish in relatively shallow water (<5m) within 50-150 meters of the shore. The Common Loon's range is primarily in North America and Iceland, with a few breeding records in northern Scotland. They use the Great

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11 http://www.acjv.org/resources.htm

Lakes as a critical stopover site and staging area for migration. Staging flocks can range from 5-50 birds. With a few exceptions they do not breed in the Great Lakes. Peak migration in the lower Great Lakes ranges from late October to late November. Overall, global populations are considered healthy, but recent declines are being detected in Canada, potentially due to the substantial die offs caused by botulism (Evers et al. 2010).

While there are few Common Loons in Europe, and, therefore, few direct observed interactions with OWED, they still rank at the top of vulnerability indices for displacement due to their genetic similarity to Red-throated Loons (Garthe and Huppop 2004, Langston 2010, Furness et al. 2013). Additionally, while there are currently no specific studies on collision risk, Common Loons can fly along the coast within the rotor-swept zone. Generally, they will fly higher over land than over the ocean (D. Evers, personal communication 2014). Their high conservation status rank (due to state species listings, a relatively small global population, and high adult survival) also contributes towards making them a priority species.

Red-breasted Merganser

The Red-breasted Merganser is a medium-sized 'sawbill' diving duck that feeds on small fish in shallow, weedy areas close to shore. This species exhibits a holarctic distribution across the Northern Hemisphere, breeding in fresh, brackish, or saltwater estuaries and bays, and wintering largely in secluded coastal bays or estuaries. Some use the Great Lakes as critical wintering and migration habitat, in groups of up to several thousand. Peak migrations in the lower Great Lakes occur from early March to early June, and again from late October to early December. Overall, global populations are considered to be stable, but declines were detected in the eastern U.S. and Canada between the 1960s and 1990s (Titman 1999, BirdLife International 2014).

While there has been little direct study on how Red-breasted Mergansers respond to offshore wind farms, our vulnerability scores show that they had extra high relative abundance, high collision risk, medium displacement risk, and high conservation score. Langston (2010) found that Red-breasted mergansers had an overall moderate risk, with the greatest concern being around the barrier effect and changes in habitat. This is corroborated by early findings at the Nysted wind farm in Denmark, which found that the mergansers avoided the project area (Energi 2002). Additionally, the birds may be sensitive to board traffic.[12]

Species that breed on the Great Lakes

This species group is beyond the scope of this study, as no Phase I surveys were conducted during breeding season. Data on species relative abundance needs to be compiled and the vulnerability of this group needs to be assessed, per Recommendation 1, below. We do mention a few notable species below, however, that are likely to be of interest due to their conservation status in the region.

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12 http://helcom.fi/Red%20List%20Species%20Information%20Sheet/HELCOM%20Red%20List%20Mergus%20serrator%20(wintering%20population).pdf

Common Tern

The Common Tern is a medium-sized tern that plunge-dives for small fish and invertebrates in fresh or coastal marine waters. This species exhibits a circumpolar distribution across the Northern Hemisphere. In North America, they breed along the Atlantic coast and inland east of the Rockies in dense colonies, generally on open, flat ground, and winter in the tropics of Central and South America. They breed around the Great Lakes in colonies of up to several hundred pairs, although their Great Lakes range has contracted and numbers have declined since the 1960s (Nisbet 2002, Cuthbert et al. 2003). Large numbers of Common Terns also use the Great Lakes as staging habitat post-breeding, and may remain in the region for up to 4 months. Birds generally leave the lower Great Lakes around October, returning again around April-May. Overall, global populations are considered to be stable, and, although trends are difficult to detect in the Great Lakes, this population may have stabilized in recent years (Cuthbert et al. 2003, BirdLife International 2014).

Several tern species in Europe has been shown to be adversely affected by OWED in various ways, although how consistent these effects are (or the root causes of them) are still not entirely clear. Little Terns (*Sternula albifrons*)in the United Kingdom suffered from reduced foraging success and productivity for years after construction of OWED near a colony, which was tentatively linked to reductions in their prey base of herring due to construction activities during the herring spawning period (Perrow et al. 2011). Terns make repeated daily foraging trips during breeding, which in one study led to them having the highest relative increase in predicted energetic costs due to turbine avoidance of nine species examined (Masden et al. 2010). Terns have also been found to be at collision risk if OWED is located between the colony and foraging areas (Everaert and Stienen 2007), and Common Terns have demonstrated reduced micro-avoidance behaviors around power lines as the breeding season progresses, leading to increased collisions (Henderson et al. 1996).

Bald Eagle

The Bald Eagle is federally protected under the Bald and Golden Eagle Protection Act, and is also a significant conservation success story. After becoming rare in much of the U.S. in the mid- to late 1900s, due to long-term persecution and the effects of contaminants, this species has rebounded dramatically in the last four decades, such that it was removed from the Endangered Species list in 2007 (Department of the Interior 2007). They are opportunistic feeders, but prefer to prey upon fish in fresh or coastal marine waters. Bald Eagles nest around the Great Lakes region, and some utilize the habitat on migration and during winter as well. As a top predator, Bald Eagles are recognized as good indicators of environmental contamination, especially organochlorine compounds, and ecosystem health in the Great Lakes region (Bowerman et al. 2002). Overall, continental populations are still rebounding from historical lows.

The number of collisions of Bald Eagles and other raptors at terrestrial wind developments has been hugely controversial. The Bald and Golden Eagle Protection Act specifically protects eagles from intentional killing, but in 2009, the federal government introduced a process for permitting incidental 'take' of eagles (Department of the Interior 2009). Little is known about the risk to Bald Eagles from OWED, although it would seem likely that eagles will interact with OWEDs in near-shore waters in areas where these raptors are present.

Stage 3: Recommended targeted studies

Recommendation 1: Comprehensive analysis of vulnerable species

A key limitation of the analysis within this report is that we have focused solely on waterbirds that were observed and identified to the species level during the Phase I migration aerial surveys. A complete analysis of all bird taxa that may be exposed to OWED, during all seasons, will be necessary to have a comprehensive understanding of the species and species groups that will be most vulnerable to OWED in the Great Lakes region. We recommend that a comprehensive effort be made to fully describe the major species groups that will be exposed to OWED during all phases of development. This would include gathering existing distribution, abundance, and seasonality data from a variety of sources on colonially breeding wading birds, seabirds, raptors, breeding and migratory shorebirds, and migratory passerines.

Such an assessment would also require a Great Lakes-centric re-analysis of certain vulnerability metrics, because bird behaviors and flight heights are known to differ between this region and the marine environments where previous vulnerability analyses were conducted. Moreover, as there are major differences in abundance and distributions of various pelagic waterbird species across the Great Lakes, a comprehensive vulnerability assessment may need to consider distinct areas of the Great Lakes rather than the region as a whole. Likewise, focal species for additional research may need to be identified by region (e.g., by lake). While this type of vulnerability assessment is inherently limited—for example, stochastic processes such as weather, seasonality, and long-term population fluctuations may affect species' vulnerability, and such variations may be difficult to incorporate into a generalized framework—such analyses can be very useful for identifying additional data gaps and research needs, as well as identifying the species likely to be most sensitive to future OWED development in the region.

Recommendation 2: Continue waterbird surveys

As discussed below, avoidance of key biological hotspots has been identified as the best method to mitigate the adverse effects OWED on birds (Drewitt and Langston 2006). Identification of these areas will require substantial data on avian abundance by season. While there will be inter-annual variation, survey data can help identify the areas most critical to vulnerable species. Additionally, these survey data could be used within National Environmental Policy Act (NEPA) analyses for proposed OWED.

We recommend that the current survey efforts being coordinated by the Great Lakes Commission should be continued for at least a total of three years, as frequently, and over as great a geographic area, as is financially feasible. Continuing surveys in small geographic areas, but over longer time periods, is an alternative approach; on the Atlantic Outer Continental Shelf, for instance, a database containing decades of small-scale or short-duration surveys has been used to develop powerful estimates of seasonal distributions for seabirds (O'Connell et al. 2009, Kinlan et al. 2012). Recognizing that there are many considerations that go into survey design, surveys should be replicated across seasonal and annual gradients, include effort data for each survey (see Recommendation 3 below), and be optimized for species that are most vulnerable or are otherwise considered to be high priority.

Survey optimization for particular species could include the use of specific survey methodologies related to survey frequency, flight height, transect spacing, or other considerations. For example, if a priority species is difficult to identify from the air (e.g., Tundra Swan vs. Mute Swan), then surveys may need to be conducted at a lower altitude to ensure accurate species identification and estimation of the target species' distribution and abundance. A highly clumped species with an irregular distribution, such as many sea ducks and diving ducks, may require more regular surveys or more closely spaced transects to develop accurate abundance estimates. And species that are not present year-round on the Great Lakes would require careful timing to ensure that surveys are occurring during peak occurrence times (for example, Red-throated and Common Loons, which migrate through the Great Lakes primarily in a short window during fall migration).

Recommendation 3: Modeling of waterbird abundance in relation to environmental covariates

A critical need in studies related to OWED and birds is to develop models that synthesize large datasets, display uncertainty, and describe biological hotspots. Waterbird distributions are largely driven by meteorological, climatological, ecological (e.g., food availability) and physical (e.g., bathymetry) factors. As we develop a better understanding of the relationships between bird abundance and environmental covariates, modeling efforts will be able to predict potential important bird areas in locations that have poor data. This type of modeling is essential for using survey data (which often provides coverage of only a small percentage of a study area) to predict patterns for the entire study area or water body. If observed patterns of waterbird distribution and abundance can be reliably linked to environmental factors such as chlorophyll a concentration, water temperature, bathymetry, or other factors, then remote sensing data for these parameters can be used to predict bird distributions across broad spatial gradients (e.g., Kinlan et al. 2012). Such relationships can also be used to predict future shifts in waterbird distributions in relation to development, climate change, or other factors.

This type of modeling is data-intensive, however, and requires reliable effort data as well as observation data. In addition to information on when and where birds were observed, it is just as essential to obtain information on when and where surveys were conducted and birds were *not* observed ("effort data"). Without this context, it is impossible to develop a reliable understanding of the relationships between bird distributions and environmental variables.

Recommendation 4: Satellite tracking of high priority species

Above we described why scaup spp., Canvasback, Redhead, Long-tailed Duck, Red-throated Loon, and Common Loon should be considered high priority species. These species will be observed in further survey efforts, but surveys are limited to describing the relative abundance of birds at a certain time and place. Individual tracking studies, in contrast, are able to provide detailed information on the daily movements of individual birds. Individual tracking can show how birds are using different habitat types during breeding, migration, and staging as well as show the connectivity between breeding and wintering sites. There have been several studies to date on high priority species using satellite telemetry (e.g., Williams et al. 2014).[13] While the sample size of these studies tends to be relatively small due to financial constraints (15-50 individuals), they provide a critical complement to survey data.

Recommendation 5: Flight height studies over the Great Lakes

Measurements of flight height, macro-avoidance, and percentage of time spent in the rotor-swept zone are key metrics in vulnerability assessments. We have very poor data on birds' flight behaviors offshore, however, and particularly over the Great Lakes. European approaches to this topic have included the use of marine radar (which provides fine-scale information on flight height, but no species-specific data) and observers posted on offshore platforms (which provides species information but limits observations to lower altitudes and diurnal time periods). Satellite transmitters can also be designed to provide flight height data, although there are technological limitations that prevent these data from being collected for most waterbirds or passerines. Perhaps the best approach, though similarly limited by current technology, is deployment of high definition cameras on offshore platforms to obtain more information on species' flight heights and macro, meso, and micro-avoidance behaviors. A recently funded study in Europe is using a combination of radar and high-resolution cameras to attempt to link flight height and species identification data for individual birds[14]; though such amalgamated technologies are still being developed, they hold promise for addressing this data gap in the Great Lakes.

Stage 4: Mitigation

Avoidance of adverse effects

The most effective way to mitigate the adverse effects of OWED on birds is to avoid areas where the birds concentrate, such as critical bird habitat, breeding colonies, and known migratory flyways (Drewitt and Langston 2006). To do so will require analysis of existing data, acquisition and standardization of relevant existing data sets, collection of new data on vulnerable species, and spatial modeling of the results. Examples of this type of analysis can been seen in Figures 3 and 4. Figure 3 should be considered as an example only and

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[13] Scaup- http://longpointwaterfowl.org/research/staff/current-staff-research/scaup-tracking/; Common Loon- http://www.umesc.usgs.gov/terrestrial/migratory_birds/loons/migrations.html; Red-throated Loons- http://www.briloon.org/research/research-centers/center-for-ecology-and-conservation-research/mabs/telemetry

[14]http://www.dhigroup.com/News/2014/04/23/WeWinAHighProfileBirdCollisionAvoidanceStudyInTheUnitedKingdom.aspx

should not be considered to represent bird use of Lake Erie. For illustrative purposed only BRI calculated the density of birds wintering along the western edge of Lake Erie using a Kernel Density Estimator (KDE) algorithm within ArcGIS 10.1. Bird count data were from transect-based aerial surveys conducted by the Michigan Department of Natural Resources between 10/22/2012 - 05/08/2013. A total of 16 flights yielded 2489 observations of birds with nearly 118,000 individuals counted. All observations were used to estimate density. For the KDE, default values for cell size and search radius were used.

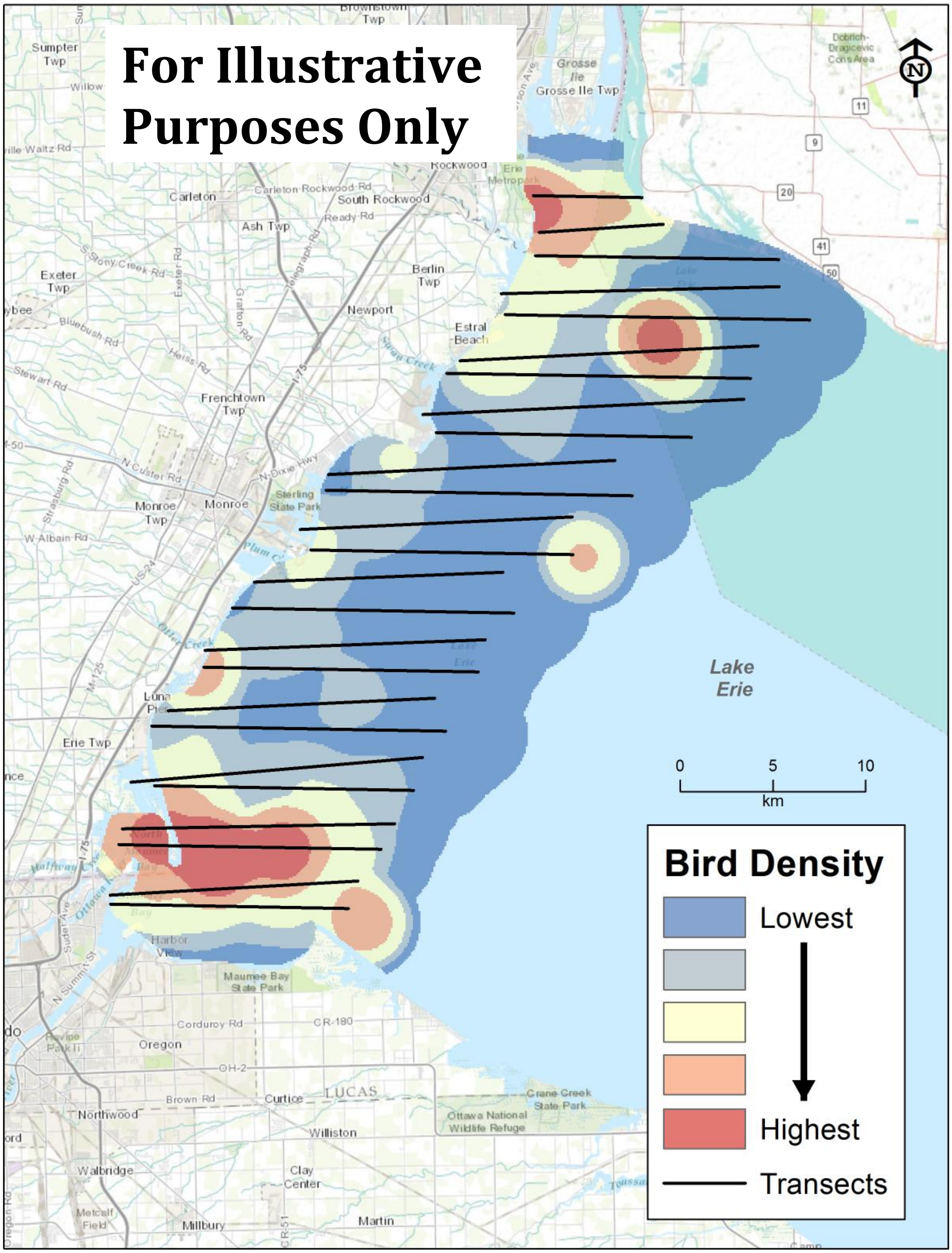

Figure 3. Example of quantitative spatial analysis (using Phase I survey data from eastern Lake Erie) that can help identify waterbird hotspots. Data are from Michigan Department of Natural Resources surveys conducted between 10/22/2012 - 05/08/2013. See appendices for greater detail on these surveys.

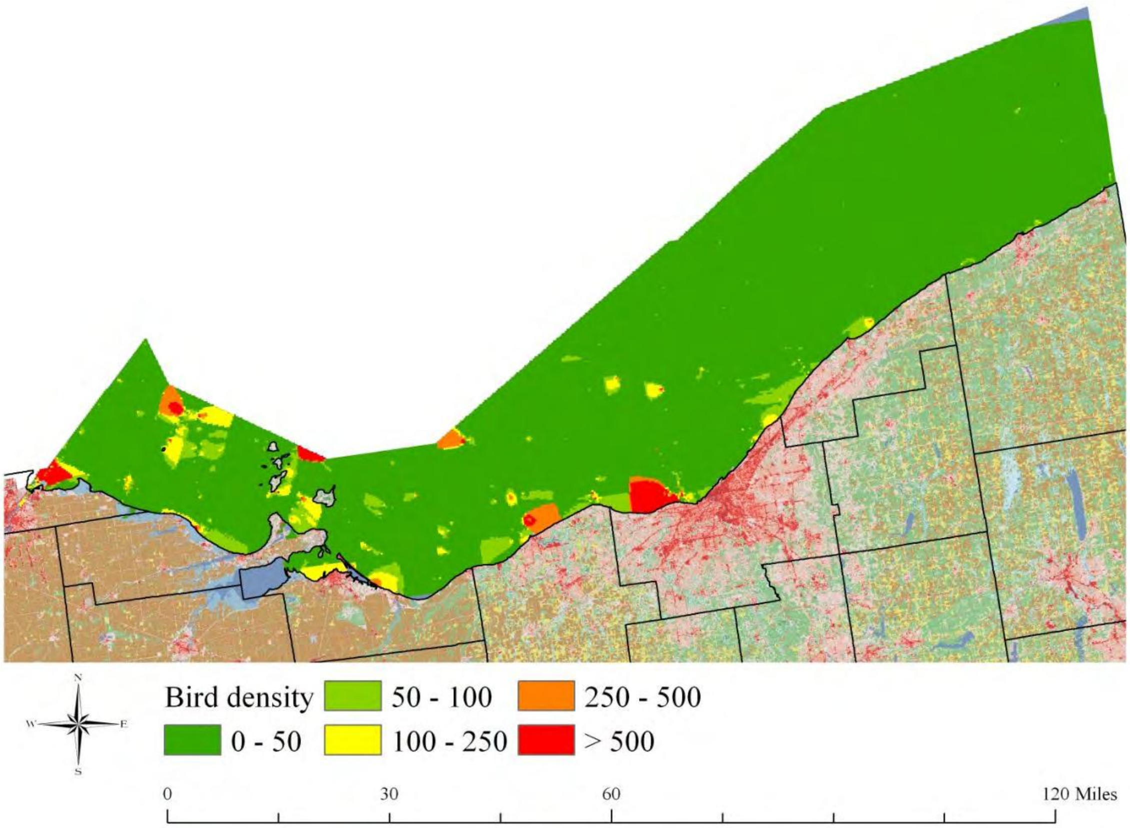

Figure 4. Number of birds per square mile grid cell in the vicinity of the LEEDCo Icebreaker site in lake Erie (*from* Lott et al. 2011)

Despite these efforts, it is likely in many cases that siting decisions will need to be made with imperfect information and high levels of uncertainty. Two resources could be used to aid in decision-making. The first would be to assemble a group of local bird experts (both professional and amateur) to assist in filling data gaps with local applied knowledge (for example, on major stopover areas along the shores of the Great Lakes). Second would be to develop a standing committee of professionals with extensive knowledge of the Great Lakes ecosystem as well as the adverse effects of OWED on birds to assess the pros and cons of OWED development in different areas of the Great Lakes. Quantitative assessments, local expert input, and standing committee input could be combined to identify areas deemed to have the highest and lowest potential for bird-OWED interactions.

Minimization of adverse effects

Despite avoidance efforts, individual birds will interact with OWED in the Great Lakes. Efforts can be made to reduce the potential for adverse effects, however. Lighting in the offshore environment can attract birds. At an offshore wind research station in Germany, for example, the platforms' bright white lights attracted thousands of birds (primarily passerines) during poor weather conditions, and many of these individuals died from collisions (Huppop et al. 2006). Every effort should be made to work with local officials, the

Federal Aviation Administration (FAA), and the U.S. Coast Guard to reduce operational lighting as much as possible and to use light colors that are less attractive to birds. Another method of minimization could be curtailing turbine operation during peak migration,[15] which may reduce effects on bats. While curtailment can be done during critical migration, there is the potential to also consider "smart" curtailment where resources such as NEXRAD, onsite radar, weather analysis, and expert opinion could be used to selectively curtail turbines during peak migration nights. For many species of birds the greatest risk of collision will be driven by stochastic weather events, such as poor weather followed by a short window of good weather when birds take flight, followed immediately by poor conditions that force birds lower in the aerosphere and cause them to be attracted to lights. Currently, the FAA is reviewing a terrestrial wind project in Maine that would use directional radar to detect when airplanes are in the vicinity of the project to trigger navigational lighting.[16] This is being considered as a mitigative action for adverse visual impacts, but this type of out-of-the-box thinking could also be applied to reduce the risk to birds—onsite directional radar could detect large-scale bird movements and curtail the turbines for a short time period. Additionally, curtailment may not need to occur for all the turbines in a project. Research in Spain has demonstrated that often a few turbines are responsible for the majority of avian mortalities at a wind farm facility (Barrios and Rodríguez 2004). For example, turbines that are closer to the shoreline may have greater number of bird mortalities and could be the focus of curtailment efforts.

Compensation for adverse effects

Despite all efforts to avoid and minimize potential adverse effects, some birds will be directly or indirectly adversely affected by a project. There will be a high degree of uncertainty on the exact number of birds that are directly affected through collision mortality and injury, and indirect effects such as increased energy expenditure through avoidance response will be even more difficult to quantify. Given this uncertainty, and the large costs associated with extensive post-construction studies, one approach could be to develop a mitigation fund based upon the size of the project and expected potential adverse effects. This mitigation fund could be used to enhance other factors that affect individual and population vital rates, such as long-term habitat protection, reduction of anthropogenic stressors that effect adult and juvenile survival such as lead poisoning, or enhancement of important breeding sites. This approach could help provide certainty for developers, successfully protect the resource, and ensure that funds go towards the research or conservation efforts of highest urgency. Such a scheme adheres closely to Department of the Interior mitigation guidelines released in 2014, which note that "Mitigation 'banking'… may be used where there might be economic efficiencies as well as better environmental results if compensatory mitigation actions are carried out in advance of foreseeable future projects, or if a single large mitigation action could compensate for the impacts of multiple future development projects" (Clement et al. 2014).

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15 http://www.maine.gov/dep/ftp/WindPowerProjectFiles/BowersMountain/review_comments/Maine%20Turbine%20Curtailment%20.pdf

16 http://www.firstwind.com/sites/default/files/Bingham%20Public%20Statement_FINAL_021814.pdf

Another compensation mechanism could be to support a research collaborative comprised of academics, NGOs, environmental consultants, and government agencies. This collaborative could start to develop a greater understanding of the cause/effect relationships between OWED and birds. The knowledge gained from an initiative of this type could then be disseminated through peer-review journals to help inform future siting and mitigation decisions.

Conclusion

This analysis has focused on birds that were observed during Phase I waterbird surveys in the Great Lakes. Many of these species have not been extensively studied in Europe, and we know relatively little about some basic aspects of their behavior (for example, how flight height is affected by weather conditions). Nonetheless, this analysis has identified several priority species for additional research. We also recommend that a comprehensive vulnerability assessment be conducted (including taxa not targeted during Phase I surveys), that waterbird surveys continue for at least a total of three years in the Great Lakes, that we pursue avenues for monitoring avian flight height and flight patterns, and that modeling efforts are developed that incorporate survey data into decision making tools. We suggest that the best mitigation method for avoiding adverse effects to waterbirds is to avoid biological hotspots and areas of high bird habitat use.

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Appendix 1: Lake St. Clair, western Lake Erie, and Detroit River Surveys

Spring 2013 Pelagic Bird Surveys: Lake St. Clair, western Lake Erie, and Detroit River

Brendan Shirkey and David Luukkonen
Michigan State University and Michigan Department of Natural Resources
May 13, 2013

Section A: Description of Survey Implementation

We completed 6 surveys during the Spring 2013 season beginning March 22, 2013 and finishing May 8, 2013. All surveys were completed in approximately 6 hours and under weather conditions deemed safe for flying (little precipitation, wind <25 mph, and visibility >5 miles). We surveyed Lake St. Clair and western Lake Erie using line transect techniques on all 6 survey dates, and we monitored the Detroit River on 3 of our 6 surveys. We also encountered significant stretches of poor weather that prevented us from completing surveys until the second week of May when most spring migrants were already through the study area.

Table 1. Date of completed aerial surveys (X) on Lake St. Clair, western Lake Erie and the Detroit River.

	Mar-22, 2013	Apr-3, 2013	Apr-21, 2013	Apr-26, 2013	May-1, 2013	May-8, 2013
Lake St Clair	X	X	X	X	X	X
Detroit River	X		X		X	
Lake Erie	X	X	X	X	X	X

Section B: Description of the Data Collected

We observed a total of 18 different bird species or taxonomic groups during Spring 2013 (Table 2). Based on raw counts uncorrected for detection probabilities, canvasbacks, scaup, and redheads were all prominent during early spring migration with canvasback being the most abundant bird counted on Mar-22 and Apr-3 and scaup being the most abundant bird counted on Apr-21, Apr-26, and May-1. Peak count of all combined bird species occurred on Mar-22 with a count of 51,741 birds (Table 2). As spring migration progressed observations of summer resident species such as gulls, common terns, double-crested cormorants, and mute swans began to dominate the data (Figure 1 a-f). We observed that most tundra swans left the study area by Apr-3, and most if not all canvasbacks and redheads left by Apr-26. Most bird species observed had highest abundances on Lake St. Clair with the exception of double-crested cormorants, which were often more abundant on western Lake Erie.

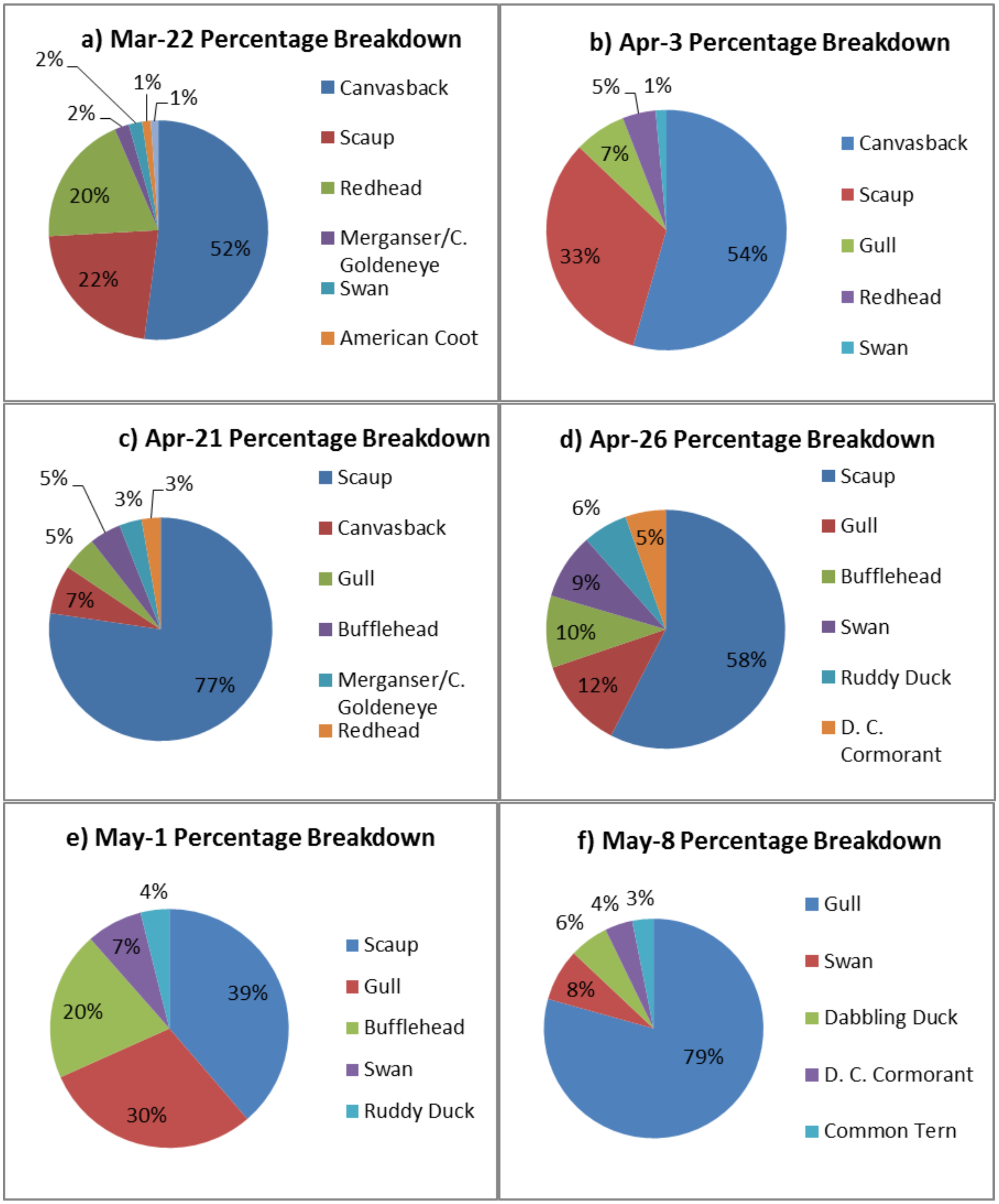


Figure 1. Percentage breakdown by species of pelagic bird observations on Lake St. Clair, western Lake Erie and the Detroit River (a) Mar-22, (b) Apr-3, (c) Apr-21, (d) Apr-26, (e) May-1, and (f) May-8.

Section C: Summarize Data

Table 2. Avian observations by flocks (n-flocks) and by individuals (n-indiv) for Spring 2013 aerial surveys conducted over Lake St. Clair, western Lake Erie, and the Detroit River

	Survey Date											
	Mar-22		Apr-3		Apr-21		Apr-26		May-1		May-8	
species or group	n-flocks	n-indiv	n-flocks	n-indiv	n-flocks	n-indiv	n-flocks	n-indiv	n-flocks	n-indiv	n-flocks	n-indiv
Bufflehead	16	63	26	192	38	719	72	359	74	599	9	40
Canvasback	85	26,624	374	13,140	37	1,113	0	0	0	0	0	0
Scaup	147	11,272	326	7,872	578	12,165	308	2,115	123	1,147	14	61
Redhead	29	9,915	34	1,079	34	434	0	0	0	0	0	0
D. C. Cormorant	3	7	2	101	42	153	54	201	19	42	46	150
Canada Goose	19	316	12	45	10	31	6	20	9	40	19	58
Northern Harrier	1	1	0	0	0	0	0	0	0	0	0	0
American Coot	2	650	1	200	1	250	2	151	0	0	0	0
Egret	0	0	0	0	2	18	4	16	4	7	8	10
Great Blue Heron	0	0	0	0	1	2	2	16	4	13	3	6
Common Loon	0	0	0	0	1	1	2	2	1	2	0	0

Ruddy Duck	0	0	0	0	27	388	33	223	9	116	2	4
Common Tern	0	0	0	0	4	8	5	7	5	15	34	115
Gull	110	182	90	1,681	104	793	204	450	101	879	128	2,910
Dabbling Duck	13	575	16	255	15	190	14	114	3	16	14	211
Swan	29	1,014	49	351	25	192	69	327	40	225	74	282
Merganser/C. Goldeneye	139	1,083	41	214	24	512	18	149	4	34	1	1
Bald eagle	9	39	1	1	2	3	1	3	0	0	0	0
totals	602	51,741	972	25,131	945	16,972	794	4,153	396	3,135	352	3,848

Section D: Other tasks

All flock locations have been organized by species and have an associated GPS waypoint that will allow for the creation of spatial data layers in ArcGIS. In addition, all data is being formatted in concordance with GLC requests for the required field attribute data associated with each bird observation. Furthermore, we plan to begin work on the final draft report for the GLC summarizing our first full year of field work shortly.

Appendix 2: Central Lake Huron and Southern Lake Huron Wind Resource Areas Surveys

Monitoring and Mapping Avian Resources in the Nearshore and Open Waters of Lakes Erie, Huron, Michigan, and St. Clair – Phase 1

Semiannual Report Template

Name: Michael J. Monfils
Affiliation: Michigan Natural Features Inventory, Michigan State University Extension
Submission Date: May 29, 2013

Section A: Description of Survey Implementation

1. **Survey time period**: Winter 2012-2013 and Spring 2013

2. **Number of surveys**: We conducted eight surveys (four winter, four spring) during this reporting period.

3. **Identify geographic areas surveyed and date of survey**: We surveyed the Central Lake Huron and Southern Lake Huron Wind Resource Areas. Winter surveys

occurred on February 12 and 26, and March 1 and 4, 2013. Spring surveys were conducted on March 29, April 17 and 30, and May 14, 2013.

4. **Describe any challenges encountered**: As with any aerial survey project, weather presented the greatest challenge to meeting survey goals. High winds, storms, and precipitation made finding suitable days for surveys difficult. We had to end the April 30 survey early due to dense fog cover, so only about half of transects were completed.

5. **Describe how will challenges impact the data**: We will take the partial survey into consideration as we summarize the data.

6. **Describe how you will overcome these challenges (if possible) during the next survey period**: Weather will always be an issue, but we will continue doing our best to conduct surveys on suitable days within identified survey windows.

Section B: Description of the Data Collected

1. **Quantify and identify the total number of bird species (or groups) observed during the survey period**:
2. **Describe the bird species or groups as a percentage of the total observations**:
3. **Note the date of Maximum Count and list number and species**:
4. **List the geographic area(s) with the most counts during survey period:**
5. **Describe any unique, observed bird activity**:

We are still transcribing data and checking geospatial coordinates. We have entered approximately 50% of the fall 2012 data and 25% of the winter 2013 data. We plan to have the fall and winter survey data entered and summarized in time for the September 2013 report and spring 2013 data compiled in time for the final report.

Section C: Summarize Data

See note under Section B.

Section D: Other tasks

1. **Status of Data analysis/GIS**: We are entering and reviewing data gathered during aerial surveys. As we process survey data, we also assign geospatial coordinates collected by the GPS data loggers to all bird observations. Once data entry and review is completed, spreadsheets will be converted into ArcMap shapefiles. Figures will be developed from the shapefiles and included in the final report. We will also provide the shapefiles in digital format with the final report.

2. **Status of upcoming surveys**: All planned surveys under Phase I of the project have been completed. We anticipate conducting four fall 2013 and four spring 2014 surveys under Phase II of the project.

Appendix 3: Lake Michigan Surveys

Monitoring and Mapping Avian Resources in the Nearshore and Open Waters of Lakes Erie, Huron, Michigan, and St. Clair – Phase 1

Semiannual Report

Name: Kevin Kenow
Affiliation: U.S. Geological Suvey
Submission Date: 30 July 2013

Section A: Description of Survey Implementation

7. **Survey time period**: [e.g., Winter-Spring 2013]
8. **Number of surveys**: 5
9. **Identify geographic areas surveyed and date of survey**: (see previous report for map of survey areas)

Table 1. Summary of Lake Michigan aerial waterbird surveys conducted during winter-spring 2013.

	4-6 Feb 2013	24-25 Feb 2013	21-22 Mar 2013	3-5 Apr 2013	24-26 Apr 2013
Ludington Bay	X	X	X	X	X
Mid-Lake Plateau	X		X		X
Oceana-Ottawa Counties, MI	X	X	X	X	X
Allegan-Berrien Counties, MI	X	X	X	X	X
Zion-Evanston, IL		X	X	X	X
South End		X	X	X	X
Sleeping Bear Dunes National Lakeshore				X	

10. **Describe any challenges encountered**: Weather/pilot availability precluded surveys in December 2012 and January 2013 (adjusted by conducting two surveys in February and two surveys in April.
11. **Describe how will challenges impact the data**: Do not have early winter distribution data.
12. **Describe how you will overcome these challenges (if possible) during the next survey period**: These challenges are expected to persist.

Section B: Description of the Data Collected

6. **Quantify and identify the total number of bird species (or groups) observed during the survey period**: 21 waterbird taxa were observed/tallied including long-tailed duck, white-winged scoter, black scoter, common merganser, red-breasted merganser, common loon, red-throated loon, red-necked grebe, horned grebe, common goldeneye, scaup (lesser vs. greater not differentiated), mallard, gadwall, double-crested cormorant, gull species, Canada goose, snow goose, canvasback, redhead, ring-necked duck, and bufflehead.

7. **Describe the bird species or groups as a percentage of the total observations**:

   Long-tailed ducks (65.3%), mergansers (18.0%), gulls (7.0%), scaup (2.5%), common goldeneye (2.3%), scoters (1.5%), loons (1.0%), grebes (0.6%), dabbling ducks (0.3%), double-crested cormorants (0.1%)

8. **Note the date of Maximum Count**: [Month/Day/Year] **and list number and species**:

Table 2. Maximum waterbird count by survey area and date.

Survey area	Date	Specifics
Ludington Bay	02/04/2013	3,450 total waterbirds, including 2,850 long-tailed ducks, 419 mergansers, 53 common goldeneye
Oceana-Ottawa Counties, MI	02/25/2013	4,316 total waterbirds, including 3,651 long-tailed ducks, 384 mergansers, 169 common goldeneye
Allegan-Berrien Counties, MI	04/03/2013	5,660 total waterbirds, including 4,852 long-tailed ducks, 512 scaup, 129 mergansers, 65 scoters, 42 loons
South End	04/03/2013	2,766 total waterbirds, including 2,022 long-tailed ducks, 281 mergansers, 227 gulls, 71 loons
Zion-Evanston, IL	02/24/2013	1,568 total waterbirds, including 823 mergansers, 547 long-tailed ducks, 116 common goldeneye, 75 gulls
Mid-Lake Plateau	02/04/2013	29 total waterbirds – all gulls
Sleeping Bear Dunes NL	04/05/2013[a]	3,012 total waterbirds, including 849 mergansers, 773 long-tailed ducks, 537 gulls, 278 common goldeneye

[a] Only one survey conducted during winter/spring 2013.

9. **List the geographic area(s) with the most counts during survey period:**

   The Ludington Bay, Oceana-Ottawa Counties, and Allegan-Berrien Counties survey areas tended to have the highest concentrations of waterbirds during the survey period.

10. **Describe any unique, observed bird activity**:

    None come to mind.

Section C: Summarize Data
(on following pages)

Table 3. Waterbird observations (count) by survey area and date during winter/spring 2013 aerial surveys of selected portions of Lake Michigan.

Survey Area	Dates	Transect Dist (km)	Number of individual waterbirds[1] tallied											
			LTDU	SCOT	MERG	LOON	GREBE	COGO	SCAUP	DABBL	DCCO	GULL	MISC	Total
Sleeping Bear Dunes NL	5-Apr-2013	668.4	773	56	849		175	278	164	50		537	130	3012
Ludington Bay	4-Feb-2013	205.6	2850	74	419		1	53				53		3450
Ludington Bay	25-Feb-2013	203.2	1743	115	6		6	21				23		1914
Ludington Bay	22-Mar-2013	158.3	263	2	146			4				52		467
Ludington Bay	4-Apr-2013	206.8	132		4							377	20	533
Ludington Bay	26-Apr-2013	157.1	10	1	28	14					4	40	1	98
Oceana-Ottawa Counties, MI	4-6-Feb-2013	355.9	2703	7	65	2		13	250			19		3059
Oceana-Ottawa Counties, MI	25-Feb-2013	357.0	3651	5	384	5		169				77	25	4316
Oceana-Ottawa Counties, MI	21-22-Mar-2013	353.8	2681	30	43	2	1	1				32		2790
Oceana-Ottawa Counties, MI	4-Apr-2013	354.9	589		28	3	7	18		8		10	6	669
Oceana-Ottawa Counties, MI	25-Apr-2013	354.8	157		47	8	2					92	14	320
Allegan-Berrien Counties, MI	6-Feb-2013	360.4	1699	15	1510	11		17				46	10	3308
Allegan-Berrien Counties, MI	24-25-Feb-2013	387.3	2984	37	731	13		116				181	7	4069

[1]LTDU = Long-tailed Duck
SCOT = White-winged, Surf, and Black Scoter
MERG = Common Merganser and Red-breasted Merganser
LOON = Common Loon and Red-throated Loon
GREBE = Red-necked Grebe, Horned Grebe, and unidentified grebe species
COGO = Common Goldeneye
SCAUP = Lesser Scaup and Greater Scaup
DABBL DUCKS = Dabbling Ducks include Mallard and Gadwall
DCCO = Double-crested Cormorant
GULL = Gull species
MISC = Canada Goose, Snow Goose, Canvasback, Redhead, Ring-necked Duck, Bufflehead, and unidentified waterbirds

Table 3 (continued). Waterbird observations (count) by survey area and date during winter/spiring 2013 aerial surveys of selected portions of Lake Michigan.

Survey Area	Dates	Transect Dist (km)	Number of individual waterbirds[1] tallied											
			LTDU	SCOT	MERG	LOON	GREBE	COGO	SCAUP	DABBL	DCCO	GULL	MISC	Total
Allegan-Berrien Counties, MI	21-22-Mar-2013	389.3	766	262	792	24		110		12		157		2123
Allegan-Berrien Counties, MI	3-4-Apr-2013	382.0	4852	65	129	42	1	20	512	6	2	21	10	5660
Allegan-Berrien Counties, MI	25-Apr-2013	387.5	565		83	37		14		5	3	119	38	864
South End	24-Feb-2013	509.8	1180	27	920	6		36				260	31	2460
South End	21-Mar-2013	584.9	744		394	27	42	22		21		455	127	1832
South End	3-Apr-2013	584.8	2022	29	281	71	35	27		41	17	227	16	2766
South End	24-Apr-2013	583.9	206		305	144	16	23			22	327	1	1044
Zion-Evanston, IL	24-25-Feb-2013	391.5	547	6	823	1		116				75		1568
Zion-Evanston, IL	21-Mar-2013	387.2	427	1	256	3	5	20	66			56	12	846
Zion-Evanston, IL	3-Apr-2013	388.0	153	2	281	16	19	39	215			27	128	880
Zion-Evanston, IL	24-25-Apr-2013	389.6	11		228	53	3	7			16	136	7	461
Mid-Lake Plateau	4-Feb-2013	172.0										29		29
Mid-Lake Plateau	22-Mar-2013	168.6										3		3
Mid-Lake Plateau	26-Apr-2013	185.3										1		1

[1]LTDU = Long-tailed Duck
SCOT = White-winged, Surf, and Black Scoter
MERG = Common Merganser and Red-breasted Merganser
LOON = Common Loon and Red-throated Loon
GREBE = Red-necked Grebe, Horned Grebe, and unidentified grebe species
COGO = Common Goldeneye
SCAUP = Lesser Scaup and Greater Scaup
DABBL DUCKS = Dabbling Ducks include Mallard and Gadwall
DCCO = Double-crested Cormorant
GULL = Gull species
MISC = Canada Goose, Snow Goose, Canvasback, Redhead, Ring-necked Duck, Bufflehead, and unidentified waterbirds

Section D: Other tasks

3. **Status of Data analysis/GIS**: Nothing to report. Awaiting guidance on final data format.
4. **Status of upcoming surveys**: Nothing to report.

Appendix 4: Western Great Lakes Surveys

Monitoring and Mapping Avian Resources in the Nearshore and Open Waters of Lakes Erie, Huron and Michigan – Phase 1

Quarterly Report

Pelagic Waterfowl/Waterbird Surveys – Western Lake Michigan
Western Great Lakes Bird and Bat Observatory
Spring 2013

Name: William P. Mueller
Affiliation: Western Great Lakes Bird and Bat Observatory (WGLBBO)
Submission Date: May 31, 2013
Section A: Description of Survey Implementation

1. **Survey time period**: Spring 2013

2. **Number of surveys**: 9

3. **Identify geographic areas surveyed and date of survey**:
    a. Western Lake Michigan offshore from Door County WI to WI/IL border, from 1 mile offshore to 10 miles offshore, in parallel transect survey blocks

4. **Describe any challenges encountered**: Weather was often too windy to safely conduct flights during the early part of the spring survey period. This provided significant challenges to doing surveys on a weekly basis. Secondly, the availability of our partner Wisconsin Department of Natural Resources (WIDNR) plane and pilot(s) occasionally proved to be challenging as well. WIDNR uses their plane and pilots for multiple purposes (fire observation,

other wildlife surveys) that sometimes take precedence over these offshore waterfowl and waterbird surveys.

5. **Describe how will challenges impact the data**: Fewer data were collected than would have been under optimum weather conditions.

6. **Describe how you will overcome these challenges (if possible) during the next survey period**: [Include any changes to survey methods.] There is no way to overcome weather issues.

7. *Survey Protocol:* WGLBBO conducted focused aircraft surveys utilizing twin-engine aircraft covering areas from 1.6 - 16 km offshore in western Lake Michigan from the Wisconsin-Illinois border to northern Door County, Wisconsin in spring of 2013. A double-observer protocol (Conant and Groves 2005) was utilized to eliminate potential detectability concerns potentially affecting survey results. Surveys were conducted along transects oriented north-south and spaced 3.2 km apart throughout the surveyed region. A fixed-wing aircraft flying at 148 km h^{-1} ground speed followed the mapped transects in alternating directions, within a 64 kilometer-long (40 mile) transect block. Surveys were flown at a 100 m aircraft altitude level. WGLBBO utilizes a plane and pilots from the WDNR flying out of Whitman Field in Oshkosh, WI. Location of transects, flights, and timing are coordinated with Kevin Kenow of USGS, who is conducting related ongoing research efforts in other geographic areas of Lake Michigan. Additional ongoing adjustments of the study area and protocol will be done in coordination with Kevin Kenow and USFWS Migratory Bird Program staff to build in efficiency and eliminate potential duplication of effort and expense.

<u>Section B: Description of the Data Collected</u>

8. **Quantify and identify the total number of bird species (or groups) observed during the survey period**: 18 different bird species or groups were observed, including gull species (those which are not identified to species), merganser species, Common Loon, Red-throated Loon, swan species, Mute Swan, Tundra Swan, Common Merganser, Red-breasted Merganser, Bufflehead, Long-tailed Duck, Common Goldeneye, American White Pelican, Bonaparte's Gull, Herring Gull, Ring-billed Gull, Great Black-backed Gull, and Glaucous Gull.

9. **Describe the bird species or groups as a percentage of the total observations**: [Red-breasted Merganser comprised 29.5% of the seasonal

total; Long-tailed Duck 26.7%; Common Goldeneye 11.2%; gull species (not identified to species)7.7%; merganser species (not identified to species) 7.7%; Greater Scaup 5.2%; Common Merganser 3.4%. All remaining species or taxa each comprised less than 1% of the total.

10. **Note the date of Maximum Count**: [Month/Day/Year] **and list number and species**: [ex: On 3/4/2013, a total of 3,316 individuals were found, including 630 Long-tailed Ducks, 719 merganser species, and 1,560 Red-breasted Mergansers, plus smaller numbers of other species. Autumn numbers for single dates have been considerably greater than single-day counts this spring.

11. **Identify geographic areas with the most counts during survey period:** As in previous years, blocks offshore from Door, Manitowoc and Kewaunee counties hold the majority of individuals. (See attached maps).

12. **Describe any unique, observed bird activity**: Nothing unusual observed this season.

13. **If possible, estimate the average height (in meters) above lake level that most flocks were flying.** Most flocks were either found resting/swimming on the surface of the water or less than 5 meters above the surface. Individual birds (primarily gulls) were occasionally observed within a band of distance from 0 to 80 meters above the water's surface. Among waterfowl, Tundra Swan flocks were occasionally observed at distances of 50-60 meters above the water. This species' migration takes them diagonally from somewhat south-southeast to west-northwest across Lake Michigan in late March and early April, within a relatively brief window of observed dates. Unlike most other waterfowl species noted on these surveys, Tundra Swan flocks are generally observed in flight, moving across the lake, and normaly are not seen resting on the lake's surface.

Section C: Summarize and Visually Display Data

MAPS - See included Maps 1 through 13, and Map 1A.]

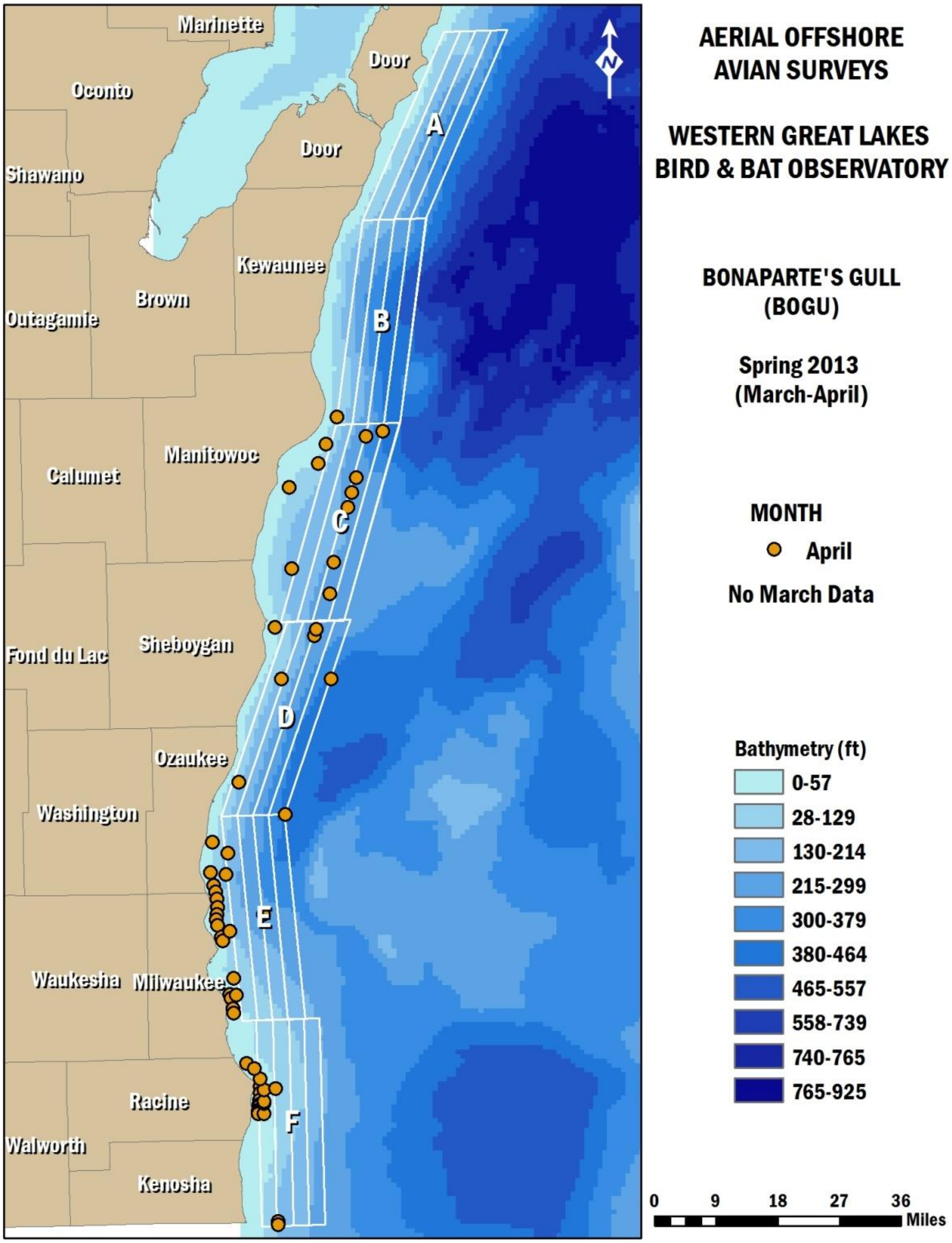
Table 2 –

Number of Individuals observed (species or species group) for most abundant species during spring aerial surveys - W. Lake Michigan, 2013

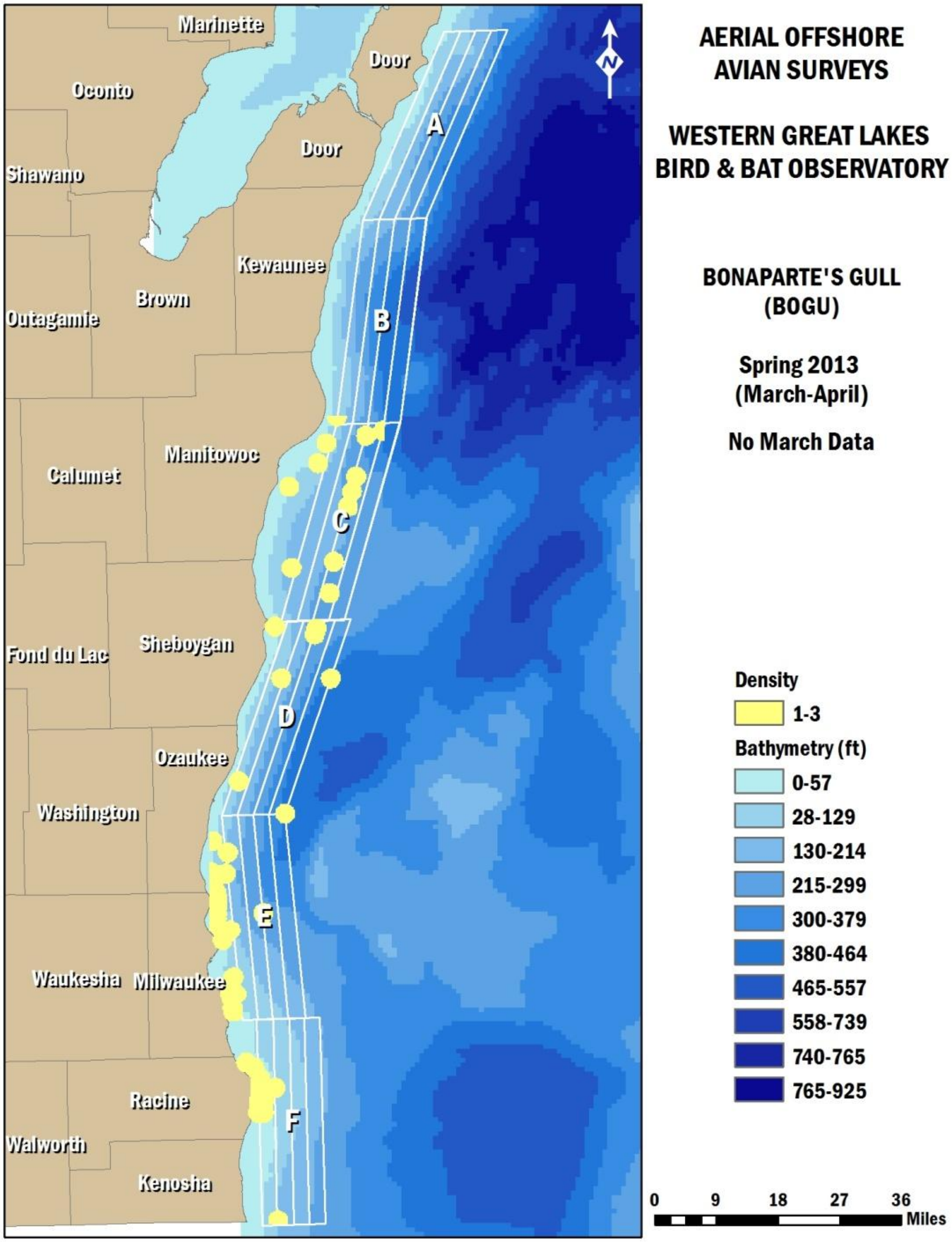
Species	Total from 6 March survey dates	Total from 3 April survey dates
American White Pelican	3	
Bonaparte's Gull		272
Bufflehead	54	25

Canada Goose	124	3
Common Goldeneye	885	808
Common Loon	1	2
Common Merganser	375	136
Great Black-backed Gull	3	
Glaucous Gull	21	3
Great Egret		4
gull species	1057	102
Greater Scaup	801	
Herring Gull	202	68
loon species	2	
Long-tailed Duck	3548	494
Mallard	52	
merganser species	1073	89
Ring-billed Gull	40	2
Red-breasted Merganser	3762	709
Red-throated Loon	1	
scaup species	230	8
scoter species	3	
swan species	2	
Tundra Swan	15	113
subtotals	12,254	2,838

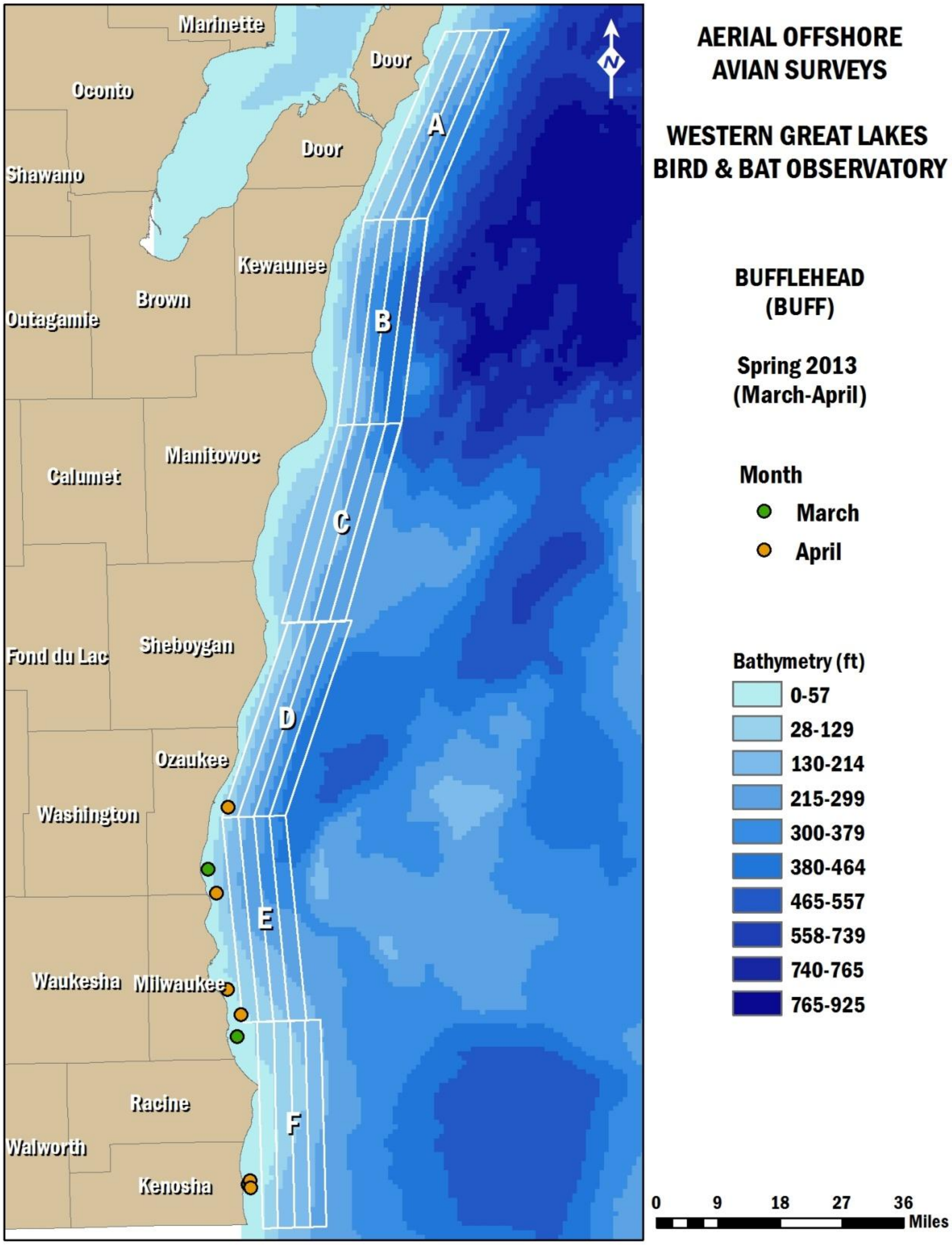
Maps 1-14



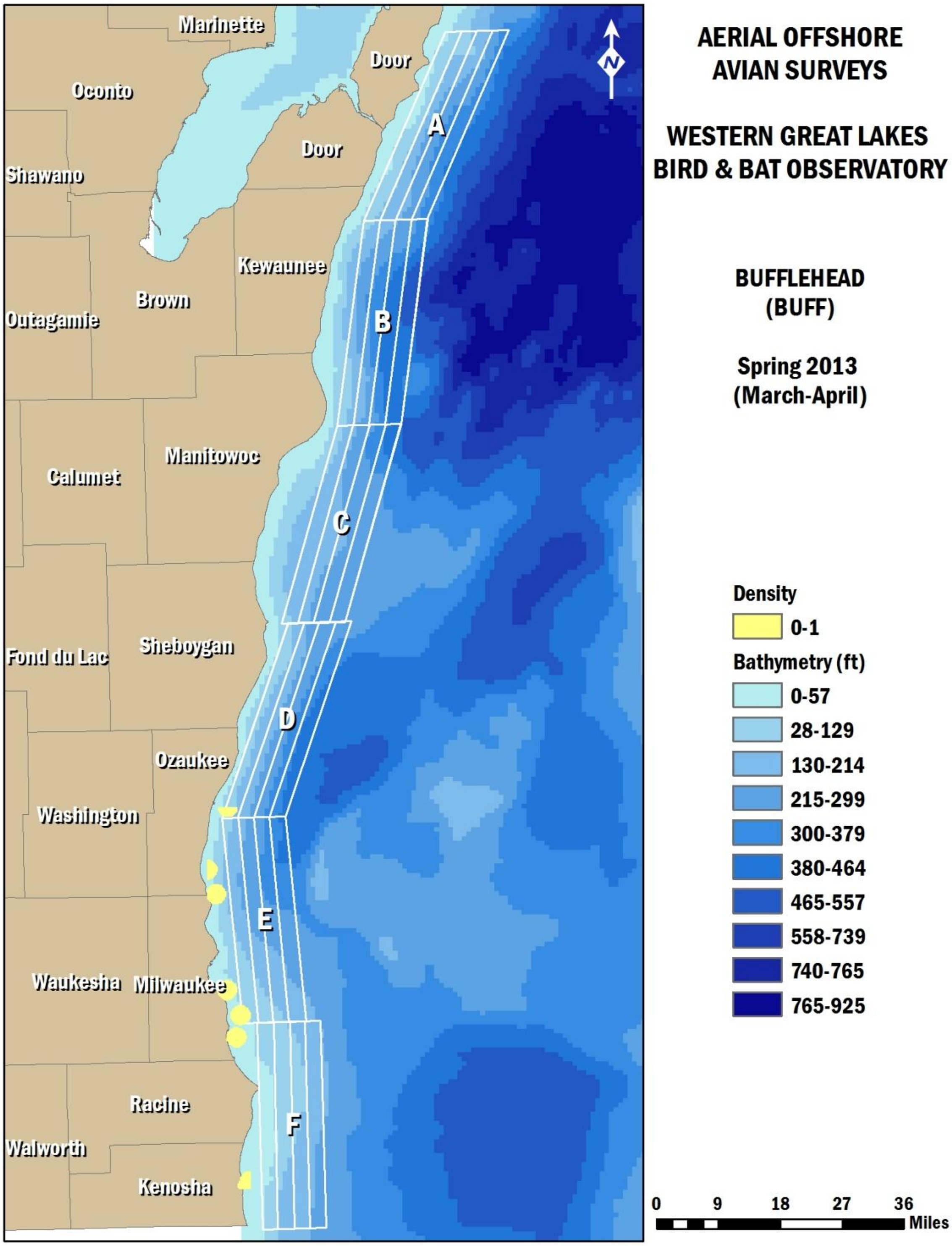
Map 1 –Bonaparte's Gull



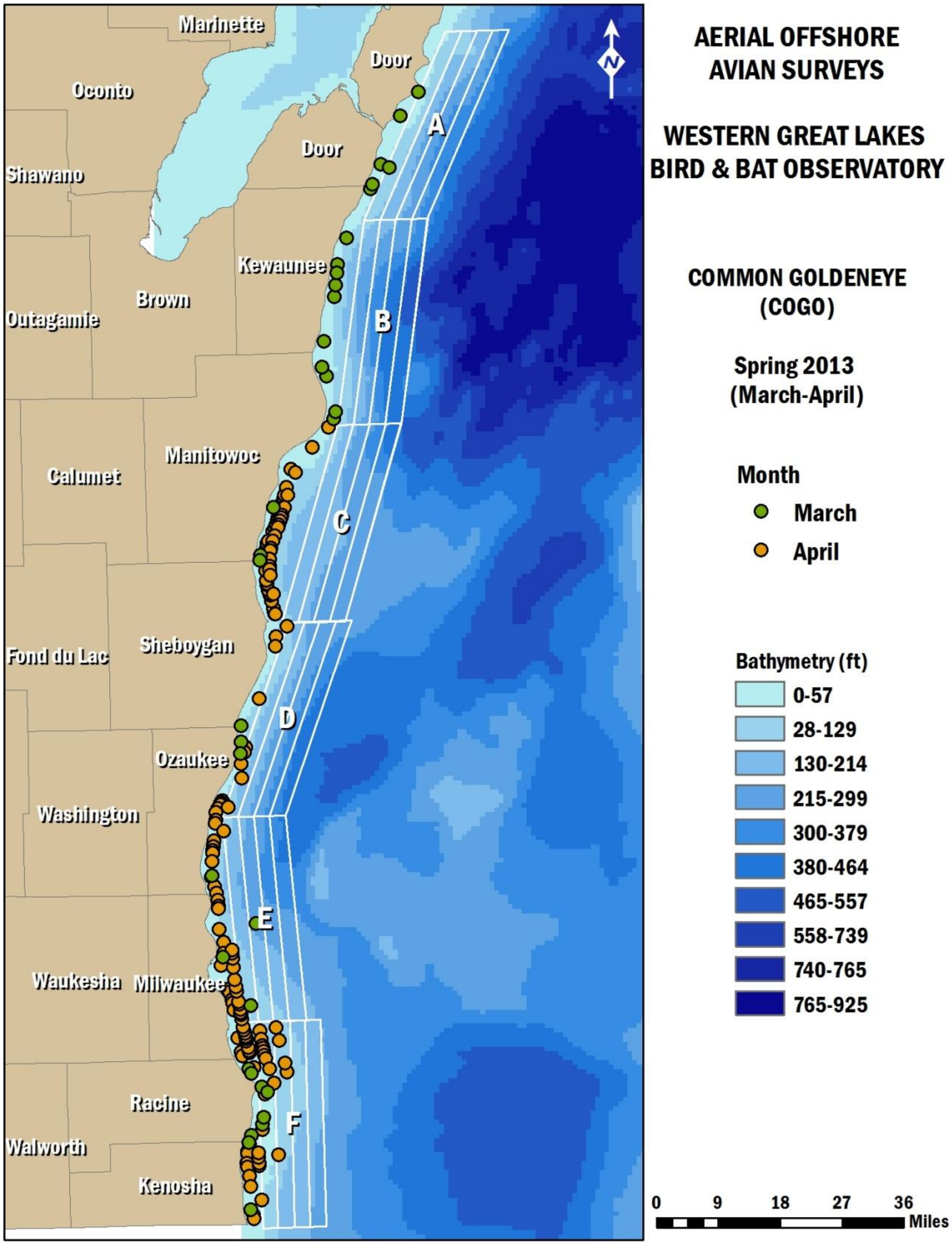
Map 2 Bonaparte's Gull – Density



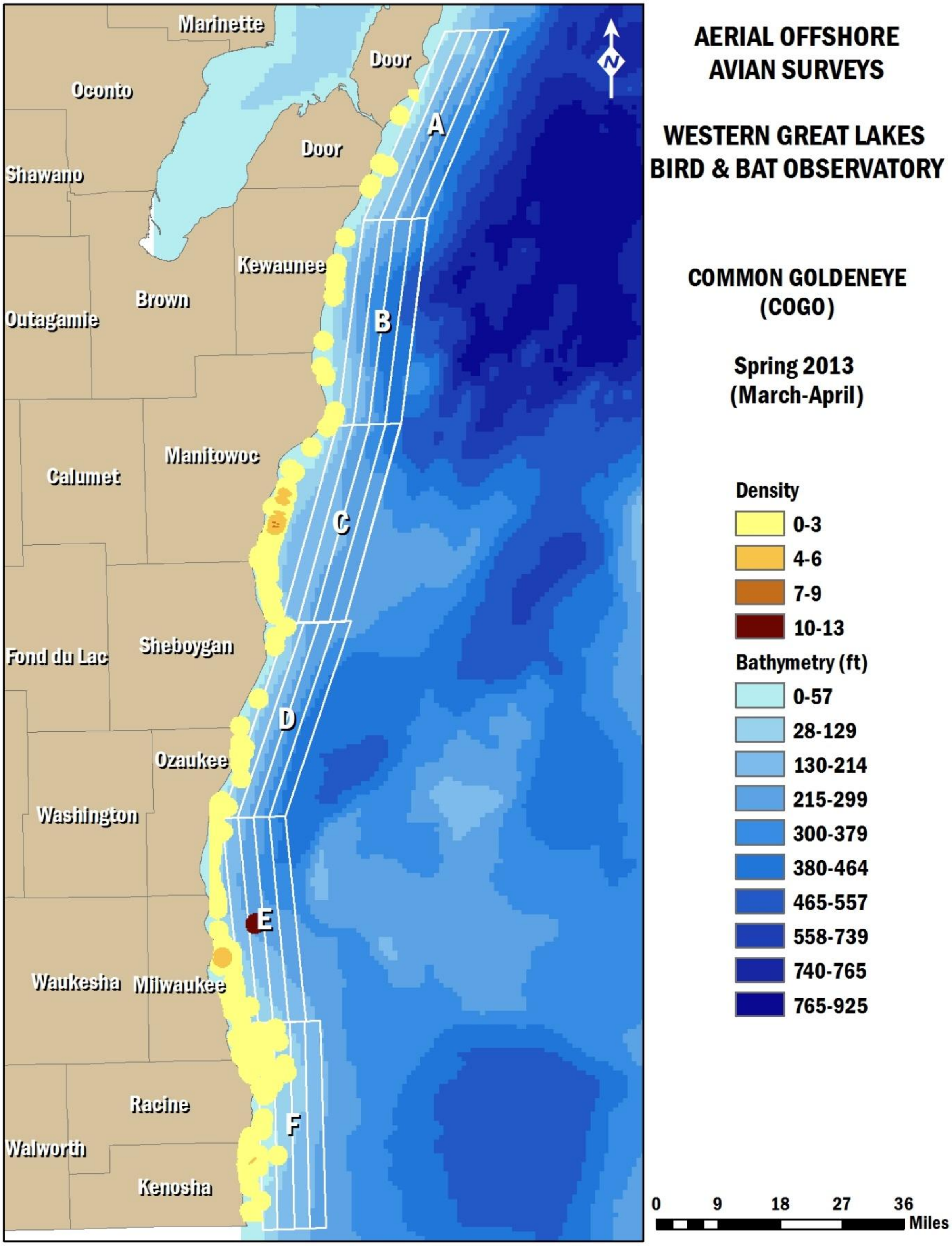
Map 3 – Bufflehead



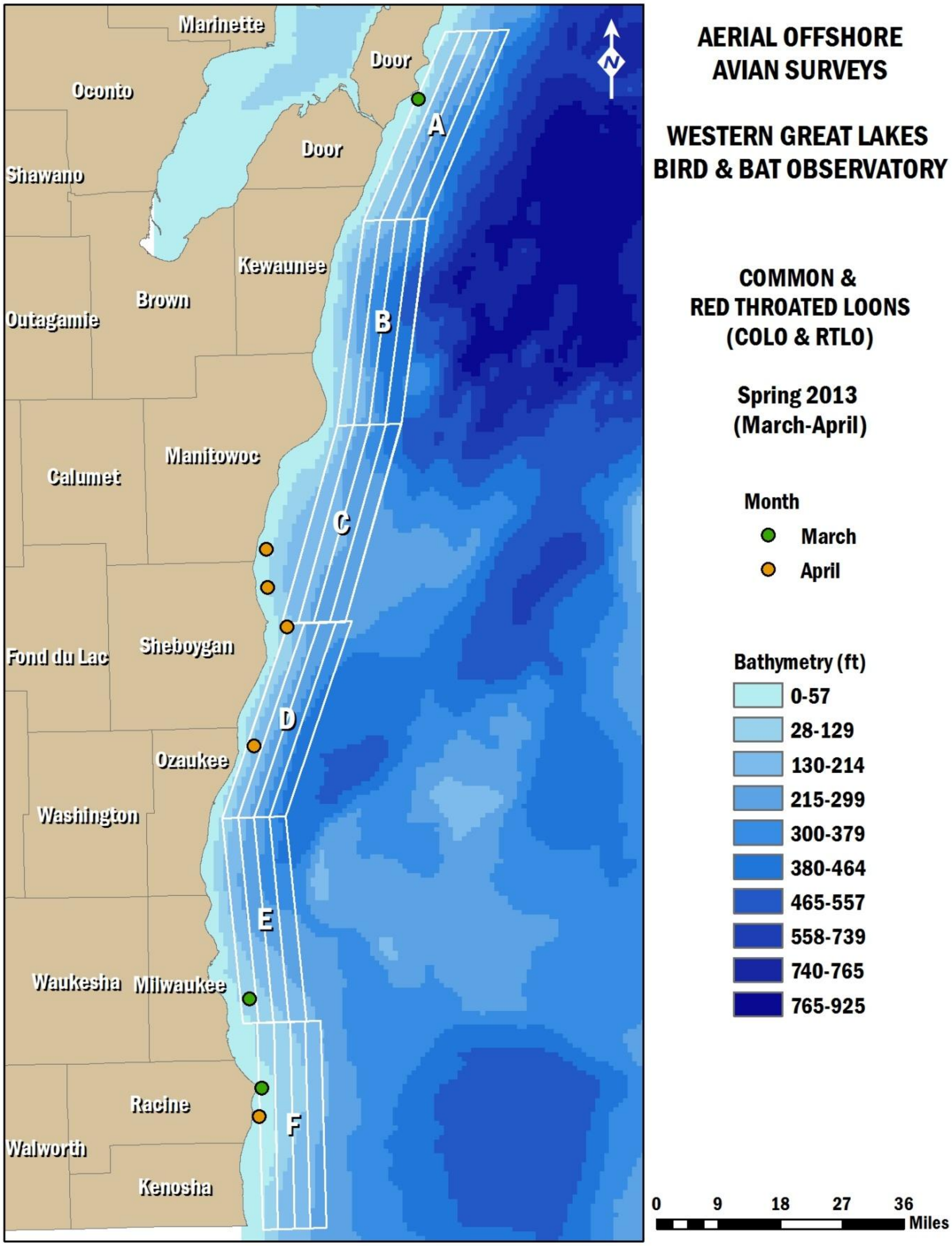
Map 4 – Bufflehead Density



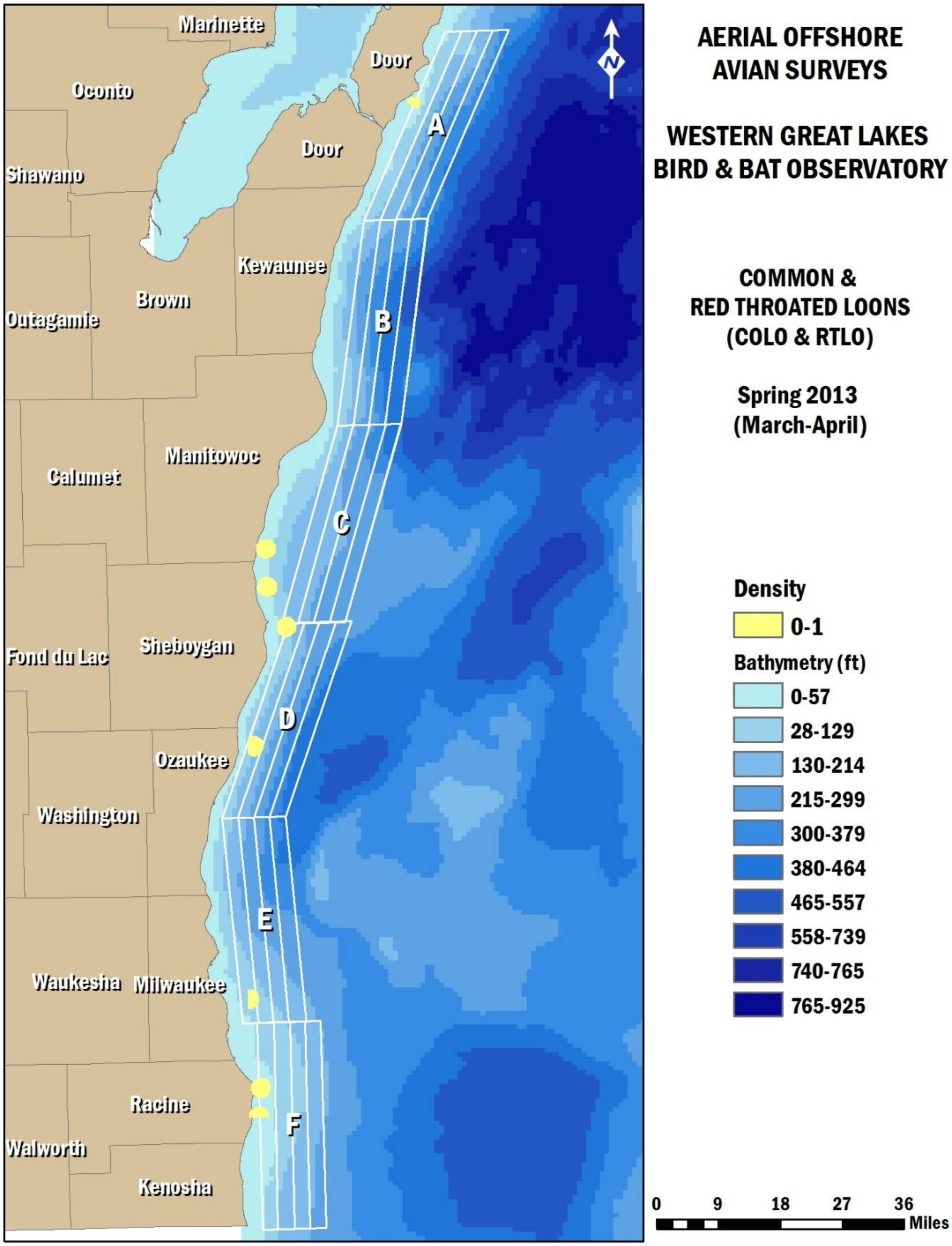
Map 5 – Common Goldeneye



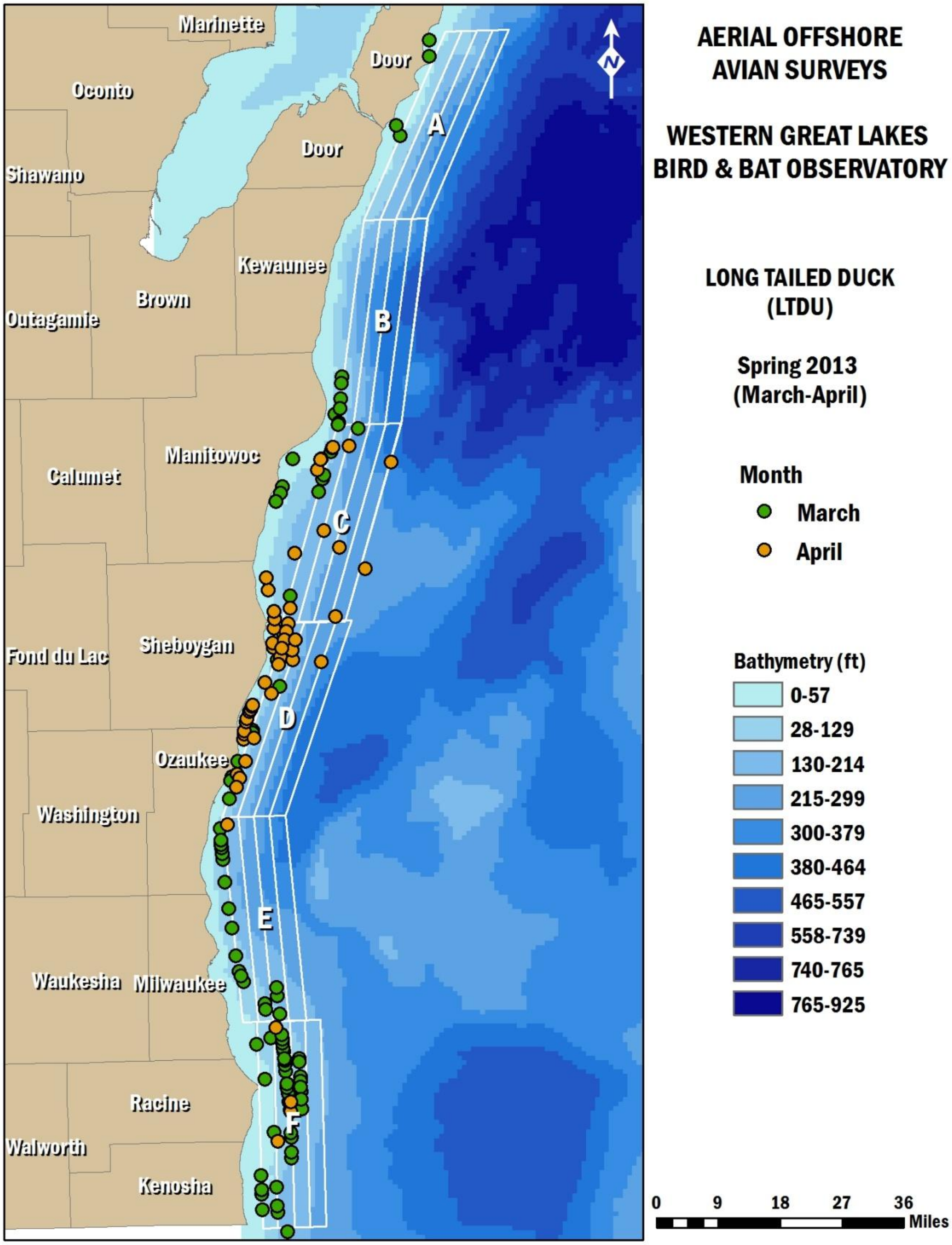
Map 6 – Common Goldeneye – Density


Marinette
Door
Oconto
Door
Shawano
Kewaunee
Brown
Outagamie
Manitowoc
Calumet
Fond du Lac
Sheboygan
Ozaukee
Washington
Waukesha
Milwaukee
Racine
Walworth
Kenosha
A
B
C
D
E
F
N
AERIAL OFFSHORE
AVIAN SURVEYS
WESTERN GREAT LAKES
BIRD & BAT OBSERVATORY
COMMON &
RED THROATED LOONS
(COLO & RTLO)
Spring 2013
(March-April)
Month
March
April
Bathymetry (ft)
0-57
28-129
130-214
215-299
300-379
380-464
465-557
558-739
740-765
765-925
0
9
18
27
36
Miles

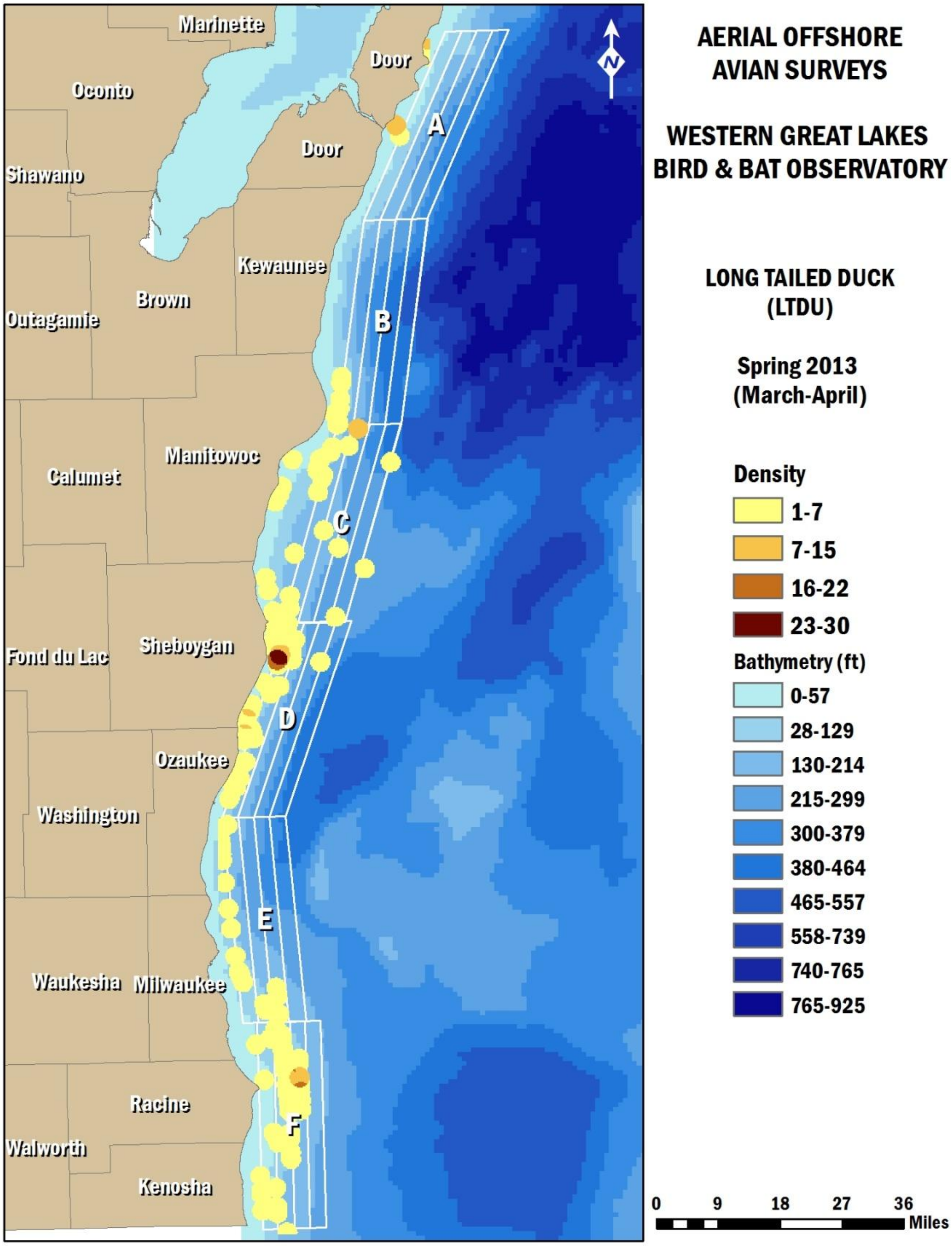
Map 7 – Loons



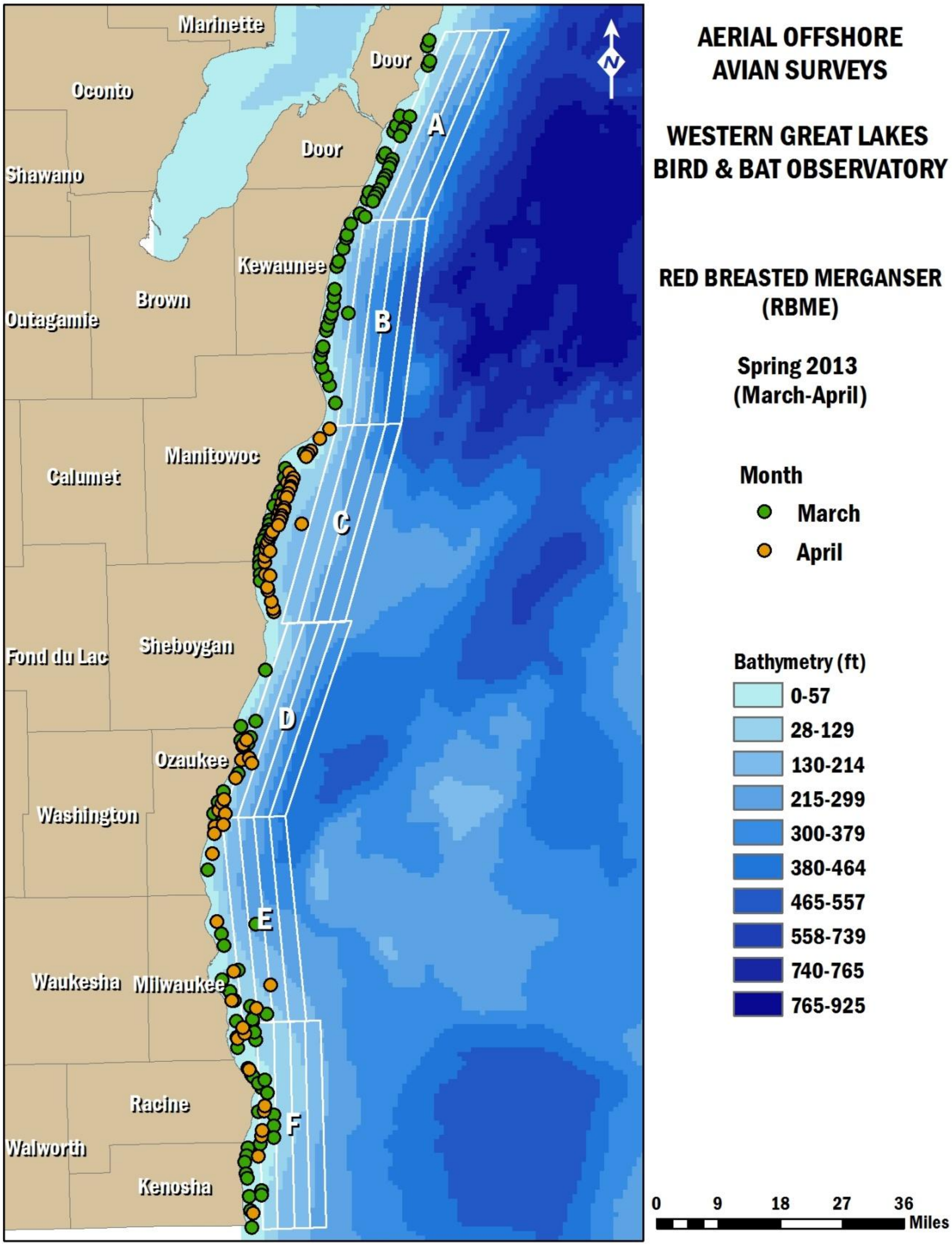
Map 8 – Loons – Density



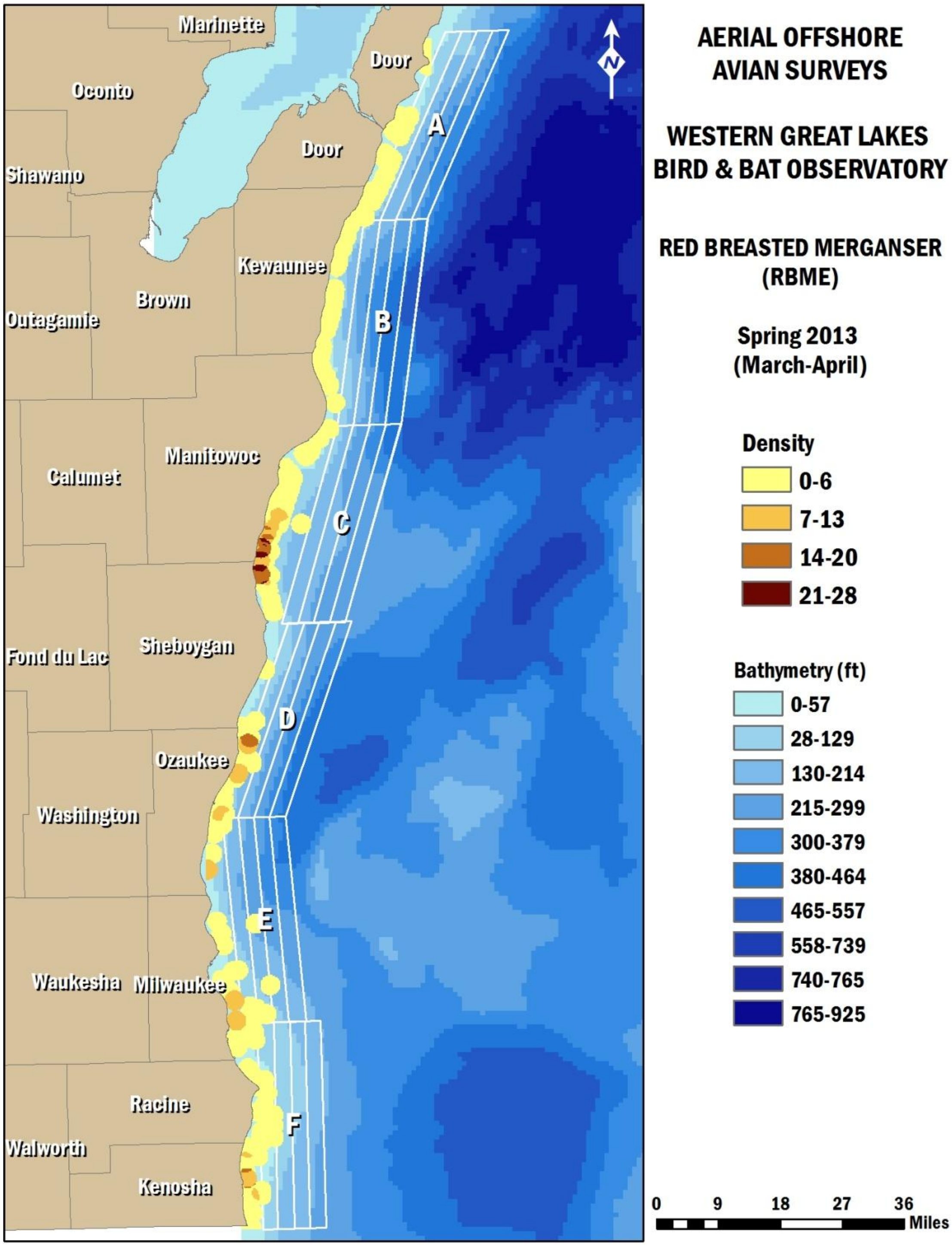
Map 9 – Long-tailed Duck



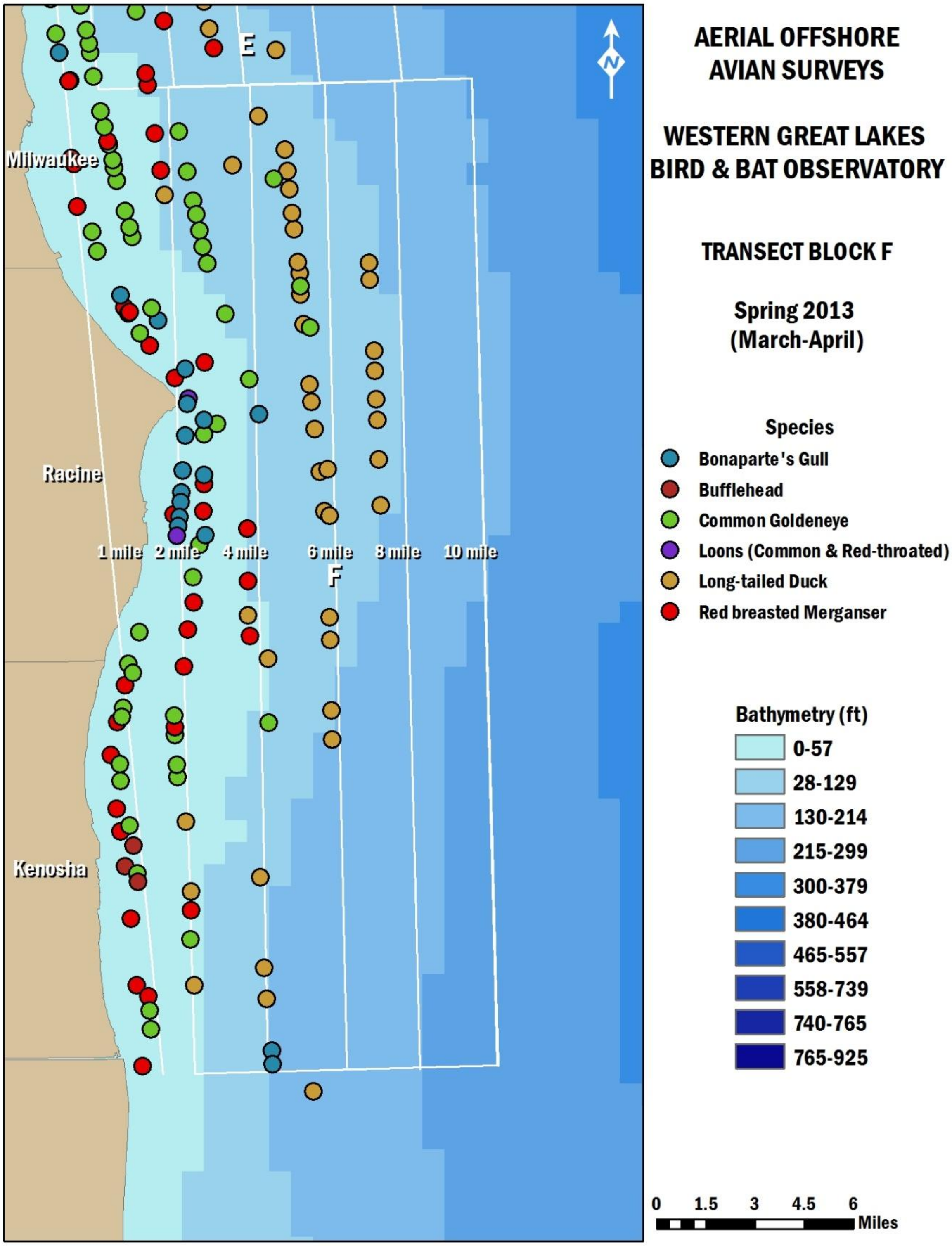
Map 10 – Long-tailed Duck – Density



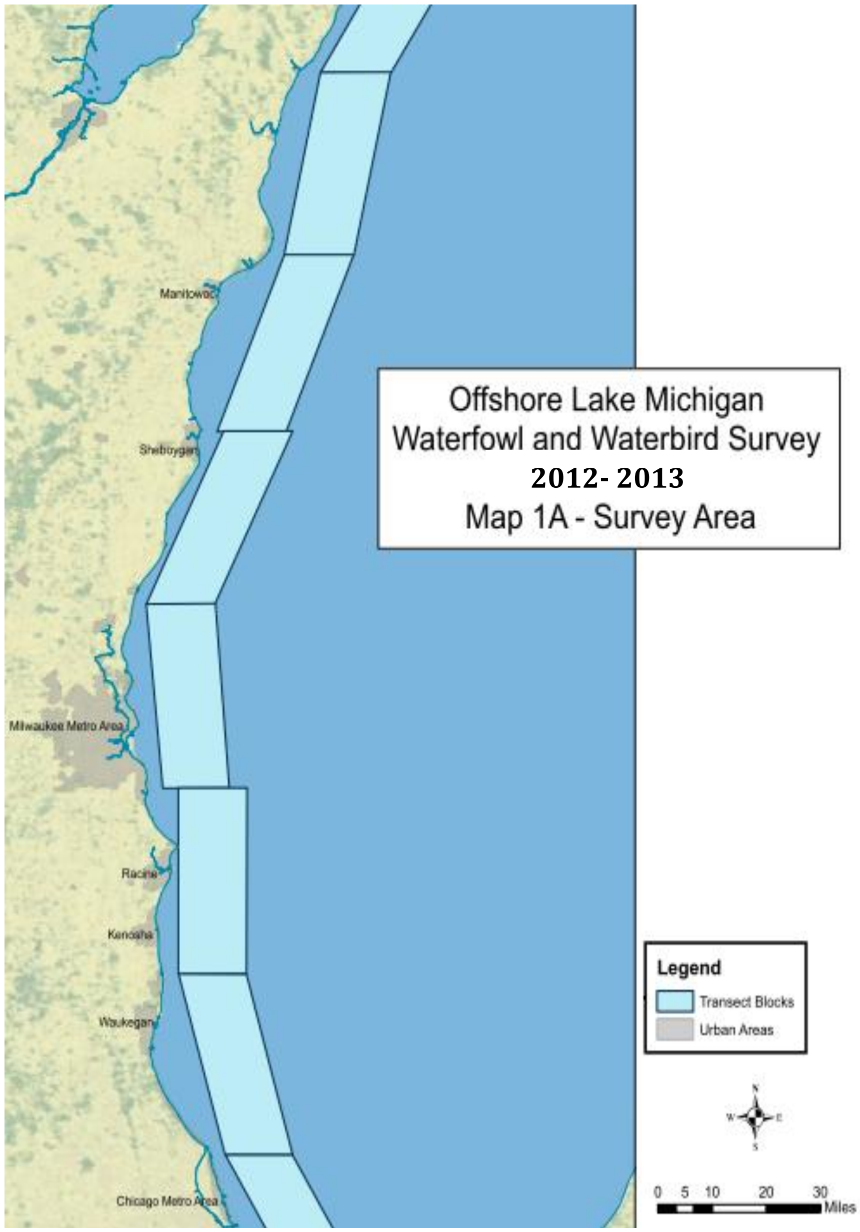
Map 11 – Red-breasted Merganser



Map 12 – Red-breasted Merganser – Density



Map 13 – Zoomed-in Multi-species by Transect – Southern Counties



Survey Blocks – Map 1A

Section D: Other tasks

5. **Status of Data analysis/GIS**: A series of maps now include density measures, as noted in map legends, for the most abundant species. (Ongoing GIS work is being done with our combined fall and spring data sets.) Abundance estimates are not yet complete.
6. **Status of upcoming surveys**: [Note status and report any anticipated challenges.] Continuing weather-related issues are expected, but no known strategy can assist in dealing with the vagaries of weather.