# IDENTIFYING MIGRANT WATERFOWL AND WATERBIRD STOPOVERS TO INFORM OFFSHORE WIND ENERGY DEVELOPMENT IN THE EASTERN UPPER PENINSULA

# PROJECT NUMBER 12-309-04



Prepared By: Michael J. Monfils and Joelle L. Gehring Michigan Natural Features Inventory Michigan State University Extension P.O. Box 30444 Lansing, MI 48909-7944

Prepared For: Michigan Department of Environmental Quality Office of the Great Lakes Coastal Management Program

MNFI Report Number 2013-14

October 10, 2013









Financial assistance for this project was provided, in part, by the Michigan Coastal Management Program, Michigan Department of Environment Quality (MDEQ), through a grant from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions, and recommendations in this report are those of the Michigan Natural Features Inventory and do not necessarily reflect the views of the MDEQ and the NOAA.

### Suggested Citation:

Monfils, M. J., and J. L. Gehring. 2013. Identifying migrant waterfowl and waterbird stopovers to inform offshore wind energy development in the eastern Upper Peninsula. Michigan Natural Features Inventory, Report Number 2013-14, Lansing, MI.

Copyright 2013 Michigan State University Board of Trustees.

Michigan State University Extension programs and materials are open to all without regard to race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, marital status, or family status.

Cover photograph by Joelle Gehring.

INTRODUCTION	1
METHODS	2
Literature Review	
Existing Waterfowl and Waterbird Data	
Aerial Surveys	3
RESULTS AND DISCUSSION	6
Literature Review	6
Complementary Surveys	6
Migration Stopover Identification	
Potential Effects of Wind Energy	
Mitigation of Impacts	
Research Needs	
Existing Waterfowl and Waterbird Data	
Aerial Surveys	
ACKNOWLEDGEMENTS	
LITERATURE CITED	

# **TABLE OF CONTENTS**

## LIST OF TABLES

Table		Page
1	Average, minimum, and maximum flock sizes recorded for waterfowl and waterbird species observed during stationary ground surveys conducted by Richard Wolinski along the Bois Blanc Island, Michigan, shoreline, 1995-2008	21
2	Total number of birds observed by taxon during aerial surveys conducted during 2012-2013 over northern Lake Huron, Michigan	23

# LIST OF FIGURES

	Page
Study design used during aerial waterfowl and waterbird surveys conducted by the Michigan Natural Features Inventory on northern Lake Huron, Michigan,	4
1	Study design used during aerial waterfowl and waterbird surveys conducted by the Michigan Natural Features Inventory on northern Lake Huron, Michigan, during 2012-2013.

# Figure

2	Distance bands used to estimate perpendicular distances of bird groups from transects during 2012-2013 aerial surveys conducted on northern Lake Huron, Michigan
3	Radar registrations from the Nysted offshore wind farm applied on a GIS-platform
4	Approximate locations and relative abundance of waterfowl observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
5	Estimated raw waterfowl density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
6	Approximate locations and relative abundance of Canada Geese and swans observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
7	Estimated raw Canada Goose and swan density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
8	Approximate locations and relative abundance of dabbling ducks observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
9	Estimated raw dabbling duck density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
10	Approximate locations and relative abundance of diving ducks observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
11	Estimated raw diving duck density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
12	Approximate locations and relative abundance of sea ducks observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration

# Figure

13	Estimated raw sea duck density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
14	Approximate locations of sea ducks within two species groupings during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
15	Approximate locations and relative abundance of waterbirds observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
16	Estimated raw waterbird density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration
17	Approximate locations of waterbirds within several species groupings during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration

#### INTRODUCTION

There are many issues affecting migratory bird species, including habitat alterations to breeding, migration, and wintering sites. Little is known about the potential impacts of nearshore and offshore wind energy development on migrating waterfowl and waterbirds using the Great Lakes. Potential impacts could be direct, such as collisions with turbines, or indirect, such as displacement from critical migration stopover sites used for feeding and loafing. Tax credits, renewable energy mandates, and a strong desire for non-polluting energy sources have increased the use and development of wind energy world-wide. According to the Michigan Department of Energy, Labor, and Economic Growth, the Great Lakes and their coasts are specifically targeted for increases in wind farm development due to their propensity for high, steady winds (http://www.michigan.gov/cis/0,1607,7-154-25676\_25774-101765--,00.html). In October 2010, the Great Lakes Offshore Wind Council (GLOW Council) identified much of northern Lake Huron as "Conditional" for offshore wind development, with few areas of "Categorical Exclusion". With many areas having water depths of  $\leq 45$  m, parts of northern Lake Huron may have the high winds and water depths needed to construct turbine foundations tolerant of ice cover (Mikinetics Consulting and Private Sector Consultants 2009).

Northern Lake Huron provides food sources and habitat for migrating waterfowl and waterbirds. Approximately three million swans, geese, and ducks travel along migration corridors that cross the Great Lakes region (Great Lakes Basin Commission 1975, Bellrose 1980). Large numbers of diving, sea, and dabbling ducks, Canada Geese (*Branta canadensis*), Tundra Swans (*Cygnus columbianus*), and American Coots (*Fulica americana*) pass through the region during spring and fall migration (Bookhout et al. 1989). The region contains State Important Bird Areas for breeding common terns and migrant Redhead (*Aythya americana*; National Audubon Society 2013). Emergent wetlands and open water zones of the Straits of Mackinac, northern Lake Huron, and the St. Mary's River have been identified as priority areas for waterfowl and waterbird conservation in the Upper Mississippi River and Great Lakes Region Joint Venture (hereafter Joint Venture) area (Soulliere et al. 2007a,b, UMRGLR Joint Venture 2007). Soulliere et al. (2007a) analyzed county level fall waterfowl harvest data and indicated that some nearshore and offshore areas of Chippewa and Mackinac counties within the proposed project area are important to non-breeding waterfowl and of greater priority for protection compared to

other parts of the northern Great Lakes. Several Species of Greatest Conservation Need identified in Michigan's Wildlife Action Plan (Eagle et al. 2005), such as American Black Duck (*Anas rubripes*), Common Loon (*Gavia immer*), and Great Blue Heron (*Ardea herodias*), use coastal wetlands along the eastern Upper Peninsula during migration. It is important that we better understand the potential impacts that wind turbine construction could have on migratory birds using the Great Lakes.

Before the potential impacts of wind energy development in northern Lake Huron can be assessed or avoided, we need to better delineate those areas utilized by migratory birds. The numbers of avian fatalities are directly related to the placement of wind farms on the landscape (U.S. Fish and Wildlife Service 2003). Carefully planned siting of wind farms is thought to be one of the most important variables when attempting to minimize ecological impacts. Resource managers currently have few data available to them on the location of waterfowl and waterbird concentration areas in northern Lake Huron. In 2011, the Michigan Natural Features Inventory (MNFI) proposed a project to improve our understanding of bird use of northern Lake Huron so informed decisions can be made about future wind development. With approved funding from the Michigan Department of Environmental Quality Coastal Program, we began work in 2012 to synthesize existing literature regarding potential effects of wind development on waterfowl and waterbirds, evaluate the status of existing data sources, identify data gaps for the project area, conduct aerial surveys to address those gaps, develop map products to be used by resource managers, agencies, and industry, and make our data available to larger mapping efforts. The rapid increase in the discussion of offshore wind farms in the Great Lakes region heightens the value and urgency of this research.

#### METHODS

## Literature Review

We searched for relevant literature using the Web of Science search engine. During our literature search, we included all possible dates and used 18 three-word combinations of the following 10 key words: wind, power, development, turbine, offshore, nearshore, impact, waterfowl, waterbird, and bird. We also incorporated into our review additional published or "gray" literature used during proposal preparation or cited in other publications.

#### Existing Waterfowl and Waterbird Data

We contacted the Michigan Department of Natural Resources (MDNR) to determine if any data were available for the project area from recent surveys (e.g., Coordinated November Canvasback Inventory, Midwinter Waterfowl Survey). No MDNR data were available on near-shore or offshore migrant bird use of the project area. We obtained information from independent bird surveys conducted by Richard Wolinski along the shoreline of Bois Blanc Island. He conducted surveys on the island across multiple years (1995-2008) and all four seasons. Ground surveys of nearshore areas of Lake Huron were conducted from stationary points on Bo Lo Drive, Northshore Drive, and Lime Kiln Point (R. Wolinski, Michigan Department of Transportation, personal communication). Survey time at each point ranged from 15 min to 2 hr, depending on the number of bird species and individuals present.

#### Aerial Surveys

We conducted low-level aerial bird surveys in spring 2012, fall 2012, and spring 2013 along a series of parallel transects placed systematically across the study area with a random starting point. We focused surveys over waters having water depths up to 45 m, which is the maximum depth currently deemed technologically feasible for wind turbine development (Mikinetics Consulting and Private Sector Consultants 2010). The survey area covered approximately 2,322 km<sup>2</sup>. We alternated between two sets of 16 transects (transects 1A-1P and 2A-2P; Figure 1) during surveys to maximize coverage and minimize the chance of double-counting birds. For example, during the first survey we used transects 1A-1P, then transects 2A-2P during survey two, back to transects 1A-1P for the third survey, and so on. Transects within a given set were 5 km apart and the two sets of transects were offset by 2.5 km (Figure 1). Camphuysen et al. (2004) recommended transects for seabird surveys be separated by at least 2 km to avoid double counting. Each transect was broken into segments approximately 10 km in length to facilitate georeferencing of audio recordings and collection of environmental data (e.g., weather, sea conditions). We modified some transects and segments slightly after the first 2 surveys to better accommodate aircraft turning and avoid overlap between adjacent segments. Because there is substantial variation in migrant waterfowl and waterbird numbers across a given season, our goal was to conduct at least three surveys during the fall (mid-October - early December) and spring (mid-March – early May) migration periods.



Figure 1. Study design used during aerial waterfowl and waterbird surveys conducted by the Michigan Natural Features Inventory on northern Lake Huron, Michigan, during 2012-2013. Identifiers indicate transect set (number 1 or 2), transect (letter), and segment (number). One set of transects (set 1 -green, set 2 -blue) was covered during a given survey and we rotated between sets each survey.

We conducted surveys in the morning and early afternoon using a Partenavia P68C twin-engine fixed-wing aircraft. Surveys were flown at approximately 91 m (300 ft) above water level at speeds of 130-200 km/hr (80-125 mph). We used four distance bands to estimate perpendicular distances of bird groups from transects: two 100-m bands, a 200-m band, and an open-ended outer band (Figure 2). These distances were used to approximate bird group locations and create GIS data layers, but could also be used to estimate bird densities that account for decreasing detection probabilities with increasing distance from the observer (Buckland et al. 2001). We marked the boundaries of the distance bands on aircraft windows using a clinometer and appropriate angles for our survey altitude. For each flock or individual bird, we recorded the species, number observed, latitude and longitude (using GPS equipment), and the distance band in which it occurred. We also recorded the locations of hunting parties and fishing vessels (both sport and commercial) for future analyses, because human activities are likely to influence the locations of birds. Geospatial and voice data were recorded using a Columbus V-900 GPS data logger.



Figure 2. Distance bands used to estimate perpendicular distances of bird groups from transects during 2012-2013 aerial surveys conducted on northern Lake Huron, Michigan.

We compiled data from aerial surveys into the following groups, based on taxonomic classification, habitat usage, food resources, and foraging strategies: (1) swans (genus *Cygnus*) and Canada Goose; (2) dabbling ducks (genus *Anas* and Wood Duck); (3) diving ducks (genus *Aythya* and Ruddy Duck [*Oxyura jamaicensis*]); (4) sea ducks (eiders, scoters, mergansers, goldeneyes, and Long-tailed Duck [*Clangula hyemalis*]); and (5) waterbirds (gulls, terns, herons, Double-crested cormorant [*Phalacrocorax auritus*], and American Coot). Although Ruddy Duck is a member of the stiff-tail duck subfamily Oxyurinae, we combined it with the diving duck group because it often uses similar habitats. We estimated raw, unadjusted bird densities (bird

detections per ha) within each segment assuming a maximum survey distance of 1,250 m on either side of the transect. We approximated geographic locations of bird observations using latitude and longitude coordinates recorded with GPS units in the aircraft that were adjusted using the midpoints of the recorded distance bands. We used 860 m on either side of the aircraft as the approximate midpoint of the unlimited distance band D (Figure 3), which was calculated by using the midpoint between adjacent transects (i.e., 1,250 m perpendicular from either side of the transect line) as the outer edge of the band.

#### **RESULTS AND DISCUSSION**

#### Literature Review

#### Complementary Surveys

Most waterfowl surveys conducted in the Great Lakes region have focused on nearshore rather than offshore waters. Since 1974 the MDNR has participated in the annual Coordinated November Canvasback Inventory to track population trends and spatial distribution within the Great Lakes (Soulliere et al. 2000). This continental survey is coordinated by the U.S. Fish and Wildlife Service and conducted in partnership with the Ontario Ministry of Natural Resources, Canadian Wildlife Service, and several other state wildlife agencies (Soulliere et al. 2000). Soulliere et al. (2000) identified the most important areas for Canvasbacks (Aythya valisineria) in Michigan as Lake St. Clair (a mean of 88% of all Canvasbacks detected in Michigan) and the lower Detroit River/Lake Erie complex. Ninety-five percent of all Canvasbacks detected between 1974 and 1999 occurred in these two areas (Soulliere et al. 2000). Saginaw Bay was highlighted as an important staging area in 1984 and 1985, accounting for 18-20% of all Canvasbacks detected (Soulliere et al. 2000). The MDNR also conducted aerial surveys of the U.S. portion of Lake St. Clair during fall migration periods from 1983 through 2008. Shirkey et al. (2012) analyzed these data and observed an increase in Canvasback and Scaup (Lesser [Aythya affinis] and Greater Scaup [A. marila] combined) abundance, whereas Redhead remained about the same during the survey period. Canvasback and Scaup also shifted from shallow (<2 m) to intermediate water depths (Shirkey et al. 2012), whereas Redhead were observed in shallow waters throughout the survey period. Shirkey et al. (2012) suggested changes in Canvasback and Scaup abundance and distribution may have resulted from the dreissenid mussel invasion of Lake St. Clair that began in the mid-1980s. Custer and Custer

(1996) documented consumption of dreissenid mussels by Scaup in Lake St. Clair. Griffiths (1993) described a two-fold increase in water clarity and increased growth of aquatic plants in Lake St. Clair after the dreissenid mussel invasion. The increased submersed plant growth may have provided additional food resources for Canvasbacks and Redheads (Shirkey et al. 2012).

The Mid-winter Waterfowl Survey (MWS) has been conducted in portions of the U.S. and Canada since 1955 and provides the only large-scale information on waterfowl distribution and population trends during mid-winter (Soulliere et al. in press). However, the value of the MWS has been questioned because of inconsistent sample designs, survey methodologies, and effort (Eggeman and Johnson 1989). In the Great Lakes region, the MWS is conducted using both ground and aerial surveys. Aerial surveys conducted in the lower Great Lakes are typically done within nearshore habitats using transects parallel to the shoreline and located 0.5 km offshore, except on the Canadian side of Lake Ontario, where additional transects were added 2, 4, 10, and 20 km offshore in 2006 (Sea Duck Joint Venture 2007). An average of 50,214 Long-tailed Ducks was counted each January and over 90% were located on the Canadian side of Lake Ontario (Sea Duck Joint Venture 2007). The northern portions of Lake Ontario have been identified as the most important wintering area for Long-tailed Ducks in the lower Great Lakes, with an estimated total of 100,000 to 200,000 Long-tailed Ducks wintering on the Great Lakes (Sea Duck Joint Venture 2007). Wintering diving and sea duck use of the lower Great Lakes has increased since the late 1980s/early 1990s concurrent with the expansion of invasive zebra (Dreissena polymorpha) and quagga mussel (Dreissena rostriformis bugensis) populations and milder winters (Sea Duck Joint Venture 2007).

In recent years, researchers have initiated studies to better understand waterfowl and waterbird use of offshore portions of the Great Lakes to inform potential wind power development and conservation actions. Monfils and Gehring (2012) completed a two-year study of waterfowl and waterbird use of Saginaw Bay, Lake Huron. They observed widespread use of the bay by sea ducks and gulls, with swans, geese, and dabbling ducks concentrated near the shoreline. Diving ducks were also more abundant near shore compared to sea ducks, but often occurred further from shore than swans, geese, and dabbling ducks. Mueller et al. (2011) conducted aerial bird surveys of western Lake Michigan. Long-tailed Ducks were the most frequently detected

species, followed by Red-breasted Mergansers (Mergus serrator), and Common Goldeneyes (Bucephala clangula). Long-tailed Ducks were detected in high numbers (32,714 total) but were present predominantly in the fall, whereas Red-breasted Mergansers were detected throughout fall and spring survey periods. The authors planned to conduct additional analysis to investigate relationships between water depths and waterfowl concentrations. The U.S. Geological Survey (USGS) has also been conducting aerial surveys of Lake Michigan since 2009 to meet several objectives: (1) determine the fall distribution and foraging patterns of waterbirds at risk to type-E botulism; (2) investigate the distribution, abundance, and temporal patterns of waterbirds during fall, winter, and spring to assess impacts of potential wind energy development; and (3) characterize the distribution and abundance of wintering sea ducks (K. Kenow, USGS, personal communication). Lott et al. (2011) conducted aerial bird surveys over the Ohio portion of Lake Erie. They suggested gulls were widespread and detected miles from the shoreline, but dabbling ducks were only detected along shoreline areas after the freezing of inland waters. Diving ducks were found in deeper water than dabbling ducks and tended to concentrate at the mouth of the Maumee River and near islands. Long-tailed Ducks congregated along Long Point. Lott et al. (2011) suggested geese and swans concentrated their activities along the shoreline, especially during inclement weather. Loons and Grebes were typically detected more than 1 mile from the shoreline. Mergansers were detected less than 5 miles from the shorelines and appeared sensitive to the presence of the aircraft, suggesting that they may also be sensitive to the activity related to turbine construction and maintenance. Overall, Lott et al. (2011) states that no area of the Lake was devoid of birds, but there were decreasing numbers of waterfowl and waterbirds with increased distance from the shoreline. A similar conclusion was reached by Peterson (2011), who found almost no birds beyond 60 km from the North Carolina shoreline. The MDNR recently completed a study of diving duck use of Lake St. Clair, the Detroit River, and portions of western Lake Erie, which included analysis of historical data on the U.S. portion of Lake St. Clair and new aerial surveys of the entire study area (Shirkey 2012, Shirkey et al. 2012).

In 2012, the Great Lakes Commission initiated a regional effort to better understand bird use of offshore portions of the Great Lakes so informed decisions can be made regarding potential offshore wind energy development. Along with compiling existing data sets, the GLC has worked with several partners to continue or expand aerial surveys of portions of the Great Lakes.

This project has facilitated continued surveys of Lake Michigan (USGS, Western Great Lakes Bird and Bat Observatory), Lake St. Clair, Detroit River, and western Lake Erie (MDNR), and new surveys of Wind Resource Areas of Lake Huron (MNFI). Project partners plan to continue surveys through spring of 2014, after which time the regional data set will be compiled and analyzed.

### Migration Stopover Identification

The Great Lakes contains stopover areas of continental significance (North American Waterfowl Management Plan 2004), with approximately 3 million birds of more than 30 waterfowl species using Great Lakes coastal waters and wetlands annually (Great Lakes Basin Commission 1975, Prince et al. 1992). Several authors have compiled information regarding waterfowl use of the Great Lakes to identify concentration areas during breeding, migration, and wintering periods (Dennis and Chandler 1974, Bookhout et al. 1989, Prince et al. 1992). Bookhout et al. (1989) summarized data on wetland area and waterfowl abundance for each Great Lake basin and highlighted habitats of importance to waterfowl during migration and winter. Prince et al. (1992) synthesized data on waterfowl use of the Great Lakes during breeding, migration, and wintering. They identified 15 waterfowl habitat complexes at which the greatest number of species and individuals concentrate during spring and fall migration, which included emergent and open water wetlands associated with the St. Mary's River.

Ewert et al. (2006) summarized information regarding the qualities and characteristics of migratory bird stopovers in western Lake Erie and outlined a system for ranking the relative conservation importance of stopovers within the region. The following waterfowl stopover site attributes were assigned "very high" or "high" scores by Ewert et al. (2006): mixed emergent wetlands (ephemeral and permanent) >16 ha with >1 ha of open water, open water/mixed emergent wetlands >1 ha and <120 m from another wetland >1 ha, ephemeral wetlands (mixed emergent) >1 ha, and known diving duck concentration areas (>1000 individuals each migration season). Building upon the synopses of stopover attributes developed for western Lake Erie (Ewert et al. 2006), The Nature Conservancy recently developed Geographic Information System (GIS) models to identify migration stopovers for various bird groups in the Great Lakes coastal zone that incorporate land cover data, information from published literature, and expert opinion

(Ewert et al. 2012). Models developed by Ewert et al. (2012) indicated waterfowl stopover habitats occurred in bays of the Great Lakes, protected areas of eastern Lake Ontario, and connecting waters of the Great Lakes, including the St. Mary's River. Ewert et al. (2012) noted substantial overlap in the distributions of predicted stopover habitats for shorebirds and waterfowl, especially in the corridor from western Lake Erie to Saginaw Bay, Lake Huron, and land between Lake Ontario and Lake Erie.

Ewert et al. (2006) also examined the attributes associated with waterbird stopovers in the western Lake Erie basin. They noted that information on waterbird habitat use during migration is limited, but waterbird habitat preferences appear to be intermediate between or overlapping with shorebirds and waterfowl. Because of the lack of data regarding waterbird stopovers, Ewert et al. (2006) did not identify priority stopover attributes. However, they suggested conservation efforts include the extensive wetlands and nearshore open waters of Lake Erie, Lake Erie islands, and nearby inland wetlands with at least some emergent vegetation. Ewert et al. (2006) also indicated that areas with ample food and low human disturbance appear important to waterbirds. Given the lack of knowledge about migration habitat use by many waterbird species (Soulliere et al. 2007b, Wires et al. 2010), Ewert et al. (2012) did not build stopover models for waterbirds in the Great Lakes region, but suggested the criteria used for waterfowl and shorebirds might also indicate priority sites for many waterbird species.

Some authors have noted the influence of habitat factors and food resources on waterbird use of the Great Lakes and oceans. Stapanian and Waite (2003) examined waterbird use of four offshore habitats (offshore of bird refuges, offshore of developed beaches, reefs and shoals, and open water) in western Lake Erie during the breeding and immediate post-breeding periods. They observed greater species density (i.e., no. aquatic species/km<sup>2</sup>) offshore of refuges compared to open water, and Herring Gull (*Larus argentatus*) and Double-crested Cormorant densities were greater offshore of refuges than any other habitat. Ewert et al. (2006) suggested that gulls, terns, and cormorants may congregate in portions of the western Lake Erie basin where small fish are abundant in wetlands, river mouths, or nearshore waters. Knutson et al. (2001) characterized migrant Black Tern (*Chlidonias niger*) habitat as open water areas of at least 3 ha and beaches and sand bars lacking human disturbance for roosting. When studying

waterbirds in the Mid-Atlantic island archipelago of Azores, Amorim et al. (2009) found Common Terns to be closer to islands and in more shallow waters than other habitats. Garthe et al. (2009) examined the relationships between seabird use of the southern North Sea and season, hydrographic variables, and meteorological factors. Birds exhibited seasonal patterns, with some occurring year-round and others present only seasonally. Wind field, sea surface temperature anomaly, sea surface salinity anomaly, and air pressure change were most closely correlated with bird presence and absence (Garthe et al. 2009). The authors suggested these data could be used to determine the times during which birds are most at risk of collision in offshore wind farms.

Along with having migration stopovers with the necessary habitat attributes and food resources, waterfowl and waterbirds, especially species using large expanses of open water, need areas with limited human disturbance (Ewert et al. 2006). Dennis and Chandler (1974) suggested that in addition to quality habitat, waterfowl need areas with low human disturbance (e.g., low boat traffic). This may be more important during migration when feeding needs and energetic risks are greater. Knapton et al. (2000) found that mixed-species flocks of diving ducks (*Aythya* spp.) were the most often disturbed waterfowl group on Long Point Bay, Lake Erie, and commercial fishing was the most common source of disturbance. Knapton et al. (2000) indicated that it may be desirable to develop one large or several smaller refuges for waterfowl in which all forms of boat traffic are prohibited during spring and fall migration. Due to a potential sensitivity to disturbance, Rodgers and Schwikert (2000) suggested the following buffers: approximately 250 m for airboat activity near cormorants and 100 m for other waterbirds (Rodgers and Smith 1997). They also suggested a 140-m buffer for gulls and terns when using personal watercraft and outboard motors (Rodgers and Schwikert 2000).

#### Potential Effects of Wind Energy

Exo et al. (2003) expressed the following concerns regarding how offshore wind turbines could affect birds: collision risk, short-term habitat loss and disturbance during construction of the wind farm, long-term habitat loss due to the presence of turbines and the related boating activities, migration and movement barriers, and fragmentation of use areas (e.g., roosting and feeding). They suggested these issues be considered in an integrated manner, but noted a lack of useful data to make this possible (Exo et al. 2003). In addition to the possible impacts listed by

Exo et al. (2003), Drewitt and Langston (2008a) noted that the effects of wind development to birds could be subtle changes to condition and breeding success. Drewitt and Langston (2008b) summarized research on the factors determining avian collision risk, such as location, structural attributes, weather, and bird morphology and behavior. We currently have more information regarding onshore than offshore wind farms, but onshore wind energy impacts cannot always be directly compared to offshore wind energy impacts. However, both onshore and offshore studies have indicated that bird fatalities are most related to the location of the turbine in relation to landscape features and the frequency of use of that area by birds (Barrios and Rodriguez 2004). Smallwood and Karas (2009) found that some bird and bat fatalities increased after older turbines were replaced with more contemporary turbines; however, for the waterfowl and waterbird species detected (Pied-billed Grebe [*Podilymbus podiceps*], gulls, and Mallard [*Anas platyrhynchos*]) the increases in fatalities were not statistically significant (p > 0.05). In a larger analysis, Barclay et al. (2007) found that although bat fatalities increased with taller turbines and larger rotor swept areas, bird fatalities did not. This supports that location may be a more important variable in determining the level of impact to bird populations.

Most researchers suggest that for waterfowl and waterbirds, displacement from habitats and barriers to movement are more of a concern than collisions with turbines (Fox et al. 2006). Desholm et al. (2006) studied offshore wind farms in Denmark using thermal imaging and modeling and estimated a collision rate of 1.4 Common Eiders (*Somateria mollissima*) per turbine per year. These birds demonstrated a high ability to avoid turbines, especially in clear weather. Of 235,136 migrating sea ducks, only 47 individuals were predicted to collide with turbine rotor-blades, an overall mean collision risk of approximately 0.02%. Sea ducks avoided wind farms in many ways, including avoiding the farm completely, flying between turbines, flying above turbines, and cutting through the edges of the wind farms, thereby minimizing time spent at risk of collision (Desholm et al. 2006). Desholm et al. (2006) stated their estimated fatality rate was relatively low compared to the approximate 70,000 Common Eiders harvested by Danish hunters annually. Desholm et al. (2006) used avoidance behavior rates and built a stochastic model framework to estimate duck fatality rates. They suggested these analyses be incorporated into standard management procedures for estimating risk to birds and bats at both onshore and offshore wind farms.

Identifying the species most vulnerable to wind farm collisions is a challenge as it includes many biological variables, such as local migration densities, population size, flight altitude, avoidance behavior, and demographic vulnerability to wind farm related mortality. Desholm (2006) developed a general framework to categorize species according to their relative vulnerability to wind farm-related mortality. This categorization could be used by resource managers to prioritize management and mitigation efforts. Specifically, Desholm (2006) developed an Environmental Vulnerability Index (EVI), which consisted of an abundance indicator and a demographic vulnerability indicator. These two indicators are thought to capture the vulnerability of migrating birds to wind farm related mortality. Desholm (2006) used the Nysted offshore wind farm as a case-study and found, in general, large-bodied and long-lived species tended to be the most vulnerable.

Similarly, Chamberlain et al. (2006) conducted sensitivity analyses on the variables affecting overall fatality rates. They examined many variables, including but not limited to, size and speed of the turbine, and size, speed, and flight behavior of the bird, and found that the birds' avoidance rates were the most important variables. Small changes in avoidance rates can lead to large increases in the percent of birds suffering fatalities at wind farms. Chamberlain et al. (2006) suggested avoidance rates should be generated under a diversity of conditions (i.e., weather, season, temporal, and spatial). Currently, avoidance rates are rarely incorporated into estimates of fatality rates at proposed wind farms. Chamberlain et al. (2006) indicated that this needs to change to promote more accurate estimates and subsequent management decisions. Collision rates would likely be more of an issue for long-lived species with low reproductive rates, as wind farm related deaths would more likely be additive instead of compensatory (i.e., birds dying from collisions are in addition to birds that would have died naturally).

The subject of avoidance and displacement has been the focus of several studies. Winkelman (1990) found that birds were hesitant to approach turbines in the dark and estimated that 1 of 76 birds passing through the turbines at night suffered a collision. Winkelman (1992) suggested that because turbines on the edges of wind farms are more likely to cause collisions, turbines should be clustered to minimize the edge effect. This is also consistent with the Winkelman (1994) finding of a 95% reduction in bird numbers within 250-500 m of the nearest turbine.

Similarly, Winkelman (1985) found that 13% of migrating flocks of birds showed a turbinerelated change in flight behavior. Stewart et al. (2007) evaluated existing data for bird abundance declines in relation to the construction of onshore wind farms. Although populations in different locations varied, the family Anseriformes (ducks and geese) had the greatest declines and Charadriiformes (gulls, shorebirds, waterbirds) the second greatest declines (Stewart et al. 2007). This result could be attributed to displacement of birds away from wind farms. Abundance decreased with increasing time since wind farm construction, but the number and size of turbines had little to no effect on declines (Stewart et al. 2007). The fact that declines continued and increased over time suggests that Anseriformes and Charadriiformes do not adapt or habituate to the presence of turbines (Stewart et al. 2007). Similarly, Benitez-Lopez et al. (2010) used meta-analysis to examine the relationship between bird abundance and mammal abundance and road infrastructure. They found that bird populations were affected for approximately 1 km from the infrastructure and mammals were affected for approximately 5 km. Smallwood et al. (2009) determined that the majority of Mallards and gulls flew >50 m away from onshore turbines in the Altamont and were not documented flying through the rotor swept zone of turbines. However, Great Blue Herons flew <50 m from turbines, with some flights through the rotor swept zone.

Desholm and Kahlert (2005) found that Common Eiders changed their flight trajectory upon observation of the turbines at an average of 3 km away from the structures. This avoidance behavior was enough to prevent all but 1% of the ducks and geese from flying close enough to the turbines to be at risk (Figure 1). Similarly, Larsen and Guiilemette (2007) used sea duck decoys to study the response of Common Eiders to wind turbines that were moving and turbines that were stationary. They found that eiders avoided turbines and changed their flight paths regardless of whether the turbines were turning or stationary.



Figure 3. Radar registrations from the Nysted offshore wind farm applied on a GIS-platform. Red dots indicate individual wind turbines, green area the land, green dot the siting of the radar, and black lines migrating waterbird flocks determined visually at the Nysted offshore wind farm (from Kahlert *et al.* 2004 in Desholm and Kahlert 2005).

Masden et al. (2010) considered the energetics of waterfowl and waterbirds avoiding a wind farm and suggested that these types of estimates need to be addressed at a species level. For example, those species with high wing loading were more energetically challenged by avoiding wind farms than were low wing loading species (Masden et al. 2010). In addition, the frequent flights of terns made them a high risk species for negative energetic impacts due to avoidance of wind turbines (Masden et al. 2010). The specific biology of each species needs to be considered when estimating the impact of a wind farm.

Most studies have found low fatality rates for waterfowl in general, but relatively high avoidance rates of wind turbines (Winkelman 1994, Erickson et al. 2002). Jain (2005) studied the response of Canada Geese to the presence of wind turbines in their onshore foraging habitats. Although he found no collision fatalities of geese, he also observed minimal avoidance by feeding geese of fields with turbines. Geese were observed flying above and between the turbines, typically

avoiding them by 40-50 m. Jain (2005) suggested that avoidance may have been detected if the study had been continued for longer than two seasons. Jain (2005) indicated that turbines placed closer together formed more of a barrier to waterfowl than turbines placed farther apart from one another. He also suggested that habituation to the turbines could be taking place. Larsen and Madsen (2000) detected significant avoidance by Pink-footed Geese (*Anser brachyrhynchus*) of onshore foraging areas near turbines by at least 100 m. Upon revisiting sites studied by Larsen and Madsen (2000), Madsen and Boertmann (2008) determined that geese were habituating to the presence of the wind farm and were often 2 times as close to the structures than they had been almost a decade earlier.

Some birds may be attracted to wind turbines for foraging or resting. Petersen et al. (2004) documented an increase in Herring Gull and tern use in offshore wind farms in the North Sea and Kahlert et al. (2004) observed cormorants (*Phalacrocorax carbo*) using maintenance platforms for loafing in offshore wind farms located in the Baltic Sea. These piscivorous species could also be responding to an increase in fish populations related to the novel artificial reef structures of the turbines and related infrastructure.

## Mitigation of Impacts

Modeling has been used to estimate impacts and prioritize conservation efforts. For example, Carrete et al. (2009) used modeling to demonstrate that wind turbine related fatalities were negatively impacting populations of the endangered Egyptian vulture (*Neophron percnopterus*). Another landscape planning and modeling effort was undertaken by Garthe and Huppop (2004). The authors developed Wind Farm Sensitivity Indices (WSIs) that were based on accumulations of Species Sensitivity Indices (SSIs). The SSIs were determined for the seabirds expected to be found in the area of a potential offshore wind energy development. The SSIs were based on 9 factors: flight maneuverability, flight altitude, percentage of time flying, nocturnal flight behavior, sensitivity to ship and helicopter traffic, habitat plasticity, biogeographic population size, adult survival rate, and European threat and conservation status. Once the SSIs were applied to the landscape via the WSIs, Carrete et al. (2009) determined that nearshore areas were more vulnerable than offshore sites. They suggested these analyses be applied at a large scale to help guide resource managers and decision makers in the early stages of wind farm planning.

Eichhorn and Drechsler (2010) demonstrated using Pareto-optimal land use scenarios (the socalled efficiency frontier; e.g., Polasky et al. 2008) to analyze trade-offs between energy production and ecological impacts. Eichhorn and Drechsler (2010) found that increasing the minimum distance of wind turbines from settlements to minimize the impact on humans further intensifies the conflict between energy production and ecological protection, because sites located further away from humans often resulted in lower energy production and more ecological impacts. Many important variables were left out of the model, which significantly reduces its value; however, the framework may be valuable in the future.

Minimization of wildlife-turbine collisions and mitigation are summarized in Drewitt and Langston (2008a). They state that siting the location of the wind farm away from high use areas or away from sensitive species is the most important variable. Once a wind farm is constructed, they list blade feathering and turbine shut-downs as possible short-term methods of reducing collisions. These techniques can be automated to occur when radar detects large numbers of birds or bats flying through the area, during sensitive times of the year (migration), during sensitive times of the day (nights), or during high-risk weather conditions (fog/low visibility). However, these options include potentially significant impacts to the energy production of the wind farm and hence financial profit. Therefore, these techniques may not be readily adopted nor supported by the wind energy industry.

Placing turbines as close to one another as possible may encourage wildlife to go around the wind farm instead of through it (Winkelman 1992). Incorporating travel corridors through the wind farms may funnel wildlife through safe pathways. Although wind speed is often greater at the edge of outcroppings and cliffs, birds often use these strong winds for migration and hunting. Therefore, it may decrease collisions if turbines are set back from the edges of cliffs and outcroppings (Johnson et al. 2000, 2007). Decreasing the attraction to turbines via minimization of lighting (Gehring et al. 2009) and small mammal (i.e., prey) densities (Smallwood and Thelander 2004) is important and some have suggested increasing the visibility of the turbine blades using UV paint (Johnson et al. 2007).

Huppop et al. (2006) examined bird movement offshore of Germany. They used radar and thermal imaging to track the migration and movement paths of birds. They determined that the several million birds that cross these seas twice per year can be at risk of wind farm collisions as they are flying in what would be the rotor swept area if the wind farm is constructed. Huppop et al. (2006) provided seven recommendations to mitigate losses and reduce the risk to birds. First, refrain from building wind farms in areas with dense migration levels. Second, micro-siting of the wind farm should include plans to align the turbines in rows parallel to the migration directions. Third, ensure travel corridors several kilometers wide between separate wind farms. Forth, avoid placing wind farms between bird feeding and roosting sites to minimize collision risk. Fifth, monitor weather conditions and maintain the ability to feather the blades if the level of risk to birds is dramatically greater than normal. Sixth, minimize external lighting or light with only blinking lights. Seventh, make turbine blades more visible to birds but do not light and cause attraction to the site.

## Research Needs

Our understanding of waterbird migration timing, routes, and habitat use is limited. Ewert et al. (2006) suggested the timing, number, and location of waterbird species migrating through the western Lake Erie basin requires documentation. Soulliere et al. (2007b) listed the identification of critical migration staging areas, migration corridors, and migration timing for waterbird species of concern as a priority research need for the Joint Venture region. Furthermore, we need to determine habitat and landscape associations of waterbird groups during both breeding and migration periods (Soulliere et al. 2007b). Arnett et al. (2007) noted that although we generally understand the areas where birds migrate through or concentrate seasonal activities, the specific timing, routes, and altitudes of movements are poorly understood, and such information is needed to assess the potential risk of birds to offshore wind development. Similarly, the Sea Duck Joint Venture (2007) suggested that sea ducks are under monitored and similar data need to be collected. Camphuysen et al. (2004) suggested that the following variables be sought when collecting and analyzing seabird data in an effort to reduce fatalities from wind turbines: seabird abundance, migratory pathways, foraging areas, factors explaining seabird distribution and abundance, variability in spatial and temporal patterns (seasonal, diurnal, and spatial), and the evaluation of collision risks.

Drewitt and Langston (2008b) identified several priorities for future research: development of better methods of monitoring collision fatalities, research into the causes of collisions, design and testing of mitigation measures, and long-term population studies to assess the implications of collision mortality to vulnerable bird populations. Desholm et al. (2006) reviewed the different types of remote sensing data (radar, thermal imaging, etc.) that may be useful when studying the collision and avoidance rates of birds at offshore wind farms. Desholm (2009) suggested that most current methods of estimating fatality rates would be more accurate and useful if the variable of avoidance was included. Although estimating an individual's ability to avoid turbines requires intense research at the species level, Desholm (2009) still emphasized its necessity.

In addition to collecting data via surveys and observations, Camphuysen (2004) suggested that spatial and temporal modeling techniques offer the best method for statistically detecting differences in the distribution and abundance of seabirds before, during, and after offshore wind farm construction. Future research also needs to consider quantification of the effects of stopover habitat loss and movement barriers at the species level. In addition, we need to understand how the frequent motorized traffic to and from offshore wind sites might affect waterfowl and waterbirds. It may be possible to develop and use individual-based models to determine the effects of these issues (West and Caldow 2006).

When developing a site specific Environmental Impact Statement or when estimating the potential impacts of a specific wind farm (offshore or onshore), Fox et al. (2006) suggested several important variables to address relative to local wildlife populations. Specifically, the background information search should address the species present and how are they are distributed in the area temporally and spatially. It is also important to understand the behavior (including flight height) and overall abundance of wildlife populations. Avoidance and displacement behaviors should also be considered, as these can affect the energy budgets, life cycles, nest productivity and success, and habitat available to individuals and populations (Fox et al. 2006).

Maclean et al. (2007) evaluated the possibility of conducting population viability indices on waterfowl using areas near offshore wind farms in Denmark. They found that in most cases enough information was available to conduct the analysis, which would be helpful to determine potential impacts of offshore wind farms on their populations. Similar background work should be done for the species likely to be impacted by offshore wind energy development in the Great Lakes region.

In Europe, offshore wind farms expected to impact birds are required to complete a Strategic Environmental Assessment (SEA) and an Environmental Impact Assessment. The SEA involves mapping waterbird densities to determine important breeding and feeding areas that may be sensitive to wind development. Much of this can be done using radar ornithology, but more direct observation needs to be used for species identification and documentation of avoidance behavior (Fox et al. 2006). These data, combined with collision risk data and habitat loss, can be incorporated into models that estimate the cumulative impacts and energetic costs of offshore wind farms. Currently, we lack enough data to effectively build these models and emphasis should be placed on collecting those data (Fox et al. 2006). Fox et al. (2006) suggested a before/after control/impact comparative study design be used in studies to provide more accurate interpretations. Our study includes some of the initial steps required to build such models. Additionally, Fox et al. (2006) suggested that research use standardized methods for better comparisons among studies, share experience and data as much as possible for both preconstruction and post-construction studies, and test predictions using post-construction collision and displacement data. The steering group Collaborative Offshore Wind Research into the Environment (COWRIE) has initiatives to address most of these issues.

#### Existing Waterfowl and Waterbird Data

We found little existing data regarding waterfowl and waterbird use of the project area. Richard Wolinski (unpublished data) conducted an independent study of bird use of Bois Blanc Island spanning many years and seasons, which included ground surveys of Lake Huron nearshore areas during migration (Table 1). Results of our aerial surveys are consistent with his findings, with sea ducks dominating bird use of open waters during migration. However, we may have

underestimated used by grebes, which were difficult to observe and identify at the altitude at which we conducted surveys.

Table 1. Average, minimum, and maximum flock sizes recorded for waterfowl and waterbird species observed during stationary ground surveys conducted by Richard Wolinski along the Bois Blanc Island, Michigan, shoreline, 1995-2008.

			Flock Size	ck Size	
Species	Season	Average	Minimum	Maximum	
Surf Scoter	Spring	3.5	2	5	
White-winged Scoter	Spring	45.3	8	116	
	Fall	12.0	9	15	
Long-tailed Duck	Spring	624.1	14	2000	
	Fall	58.3	50	65	
	Winter	1.0	1	1	
Bufflehead	Spring	7.9	1	30	
	Fall	7.3	2	20	
Common Goldeneye	Spring	27.3	1	109	
-	Summer	22.8	1	67	
	Fall	60.6	1	350	
	Winter	14.1	1	79	
Hooded Merganser	Spring	1.5	1	2	
	Summer	1.5	1	2	
	Fall	1.0	1	1	
Common Merganser	Spring	5.2	1	14	
	Summer	4.6	1	25	
	Fall	6.8	1	34	
Red-breasted Merganser	Spring	8.9	2	30	
_	Summer	7.8	1	35	
	Fall	10.4	2	31	
	Winter	4.3	1	10	
Common Loon	Spring	9.6	1	36	
	Summer	1.6	1	3	
Horned Grebe	Spring	8.8	1	30	
	Fall	3.0	1	5	
Red-necked Grebe	Spring	6.0	2	14	
	Fall	10.8	1	39	

#### Aerial Surveys

We conducted 10 aerial surveys over northern Lake Huron, of which four occurred during spring 2012, four in fall 2012, and two in spring 2013. Fall surveys occurred between mid-October and mid-December and spring surveys were done between late March and early May. We recorded a total of 55,326 birds during the 10 surveys (mean 5,533 birds per survey; Table 2). Our greatest single survey total was 8,935 birds on 8 November 2012. Approximately 1.6% of the birds we observed were placed in the "unidentified bird" category because of poor visibility or faulty audio recordings. Waterfowl represented 88.2% of the total birds observed and we identified 79.4% of the waterfowl recorded to species, with the remainder categorized as unknown swan, unknown dabbling duck, unknown diving duck, unknown sea duck, or unknown duck. Sea ducks accounted for the greatest proportion (42.7%) of the total birds observed. Long-tailed Duck was the most common sea duck and represented 60.9% of all sea ducks recorded, followed by Common Goldeneye (17.4%) and Bufflehead (8.1%; Bucephala albeola). Similarly, Longtailed Ducks were the most common sea duck recorded during aerial surveys of western Lake Michigan (Mueller et al. 2011). Of the scoters identified to species, White-winged Scoter (Melanitta deglandi) was the most common species detected. Diving ducks represented 33.0% of the total birds observed. Redhead was the most common diving duck species, representing nearly three-quarters (74.3%) of all diving ducks recorded. Scaup (Lesser and Greater combined) and Ring-necked Duck (Aythya collaris) were the second and third most common diving ducks observed, but only accounted for 5.9% and 3.6% of all diving ducks, respectively. Swans made up 5.4% of the total birds observed. Although we often could not identify swans to species, most of the swans observed appeared to be Tundra Swans. Dabbling ducks only constituted 4.8% of the total birds recorded. Mallard was the most common dabbling duck species, representing 70.0% of all dabbling ducks observed, followed by American Black Duck (6.9%). Because most of the survey time was spent away from the shoreline, it was not surprising that dabbling ducks made up a small proportion of the total birds observed. We also conducted surveys during periods when numbers of diving and sea ducks were likely to peak, which precluded us from surveying species that migrate earlier in the fall (e.g., Blue-winged Teal [Anas discors]). Canada Goose accounted for less than one percent of the total birds recorded during surveys.

-	Spring 2012	Fall 2012	Spring 2012	
Bird Taxon	(n = 4)	(n = 4)	(n = 2)	Total
Canada Goose	194	181	20	395
Swans	508	2,040	458	3,006
Dabbling Ducks	366	2,178	92	2,636
Diving Ducks	4,415	11,711	2,118	18,244
Sea Ducks	10,441	4,789	8,387	23,617
Unknown Ducks	180	246	490	916
Waterbirds	1,435	1,080	3,011	5,526
Shorebirds	1	30	0	31
Unidentified Birds	759	48	88	895
Raptors	16	24	20	60
Total	18,315	22,327	14,684	55,326

Table 2. Total number of birds observed by taxon during aerial surveys conducted during 2012-2013 over northern Lake Huron, Michigan.

Waterbirds accounted for only 10.0% of the total birds recorded during aerial surveys. Gulls were the most commonly observed waterbirds, making up 79.5% of all waterbirds detected. Although we did not attempt to identify gulls to species, Ring-billed Gull (*Larus delawarensis*) and Herring Gull were the most common species observed. American Coot was the second most common waterbird detected and constituted 13.1% of the waterbirds recorded. Double-crested Cormorant was the next most common waterbird species seen (4.5%), followed by all loon species combined (2.2%). Low numbers of waterbirds were expected given most of our survey time was spent offshore and surveys were timed outside of periods when many waterbirds migrate (e.g., most herons and terns migrate in early fall or late spring).

We used geospatial data of bird observations to investigate patterns in usage of the project area by particular groups of waterfowl and waterbirds. We obtained geospatial locations for over 92% of the birds observed. Bird distributions and densities were similar between spring and fall seasons, so we combined the data in this report. We observed waterfowl throughout the project area (Figure 4), but raw densities of detections were small for many transect segments (Figure 5). Canada Geese and swans were usually recorded near shorelines (Figure 6) and we observed greatest densities on Munuscong Bay (Figure 7). We found the same pattern for dabbling ducks, with most observed near shorelines and greatest densities recorded in Munuscong Bay (Figures 8 and 9). Diving ducks were similarly concentrated near shorelines, but observations extended further from shore than those of geese, swans, and dabbling ducks (Figure 10). We recorded our greatest diving duck densities along segments over Munuscong Bay, Saint Martin Bay, and west of Round Island (Figure 11). We found sea ducks widely distributed in low numbers throughout the project area (Figure 12). Sea duck densities tended to be greater in Horseshoe and Saint Martin Bays and near Marquette, Mackinac, Round, and Bois Blanc Islands (Figure 13). Although the distributions of sea duck species overlapped within the project area, we observed Bufflehead, Common Goldeneye, and mergansers more often near the shoreline, whereas we regularly found Long-tailed Duck and scoters far offshore (Figure 14).

We observed a similar distribution of waterbirds in the project area as sea ducks, but waterbirds were much less abundant than waterfowl. Waterbirds occurred throughout the project area in low numbers (Figure 15). We observed little pattern in waterbird densities, with densities generally being low throughout the project area and only a few shoreline segments having slightly greater densities (Figure 16). Terns and Double-crested Cormorants were usually recorded near the shoreline, whereas gulls and loons were observed throughout the project area (Figure 17).



Figure 4. Approximate locations and relative abundance of waterfowl observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 5. Estimated raw waterfowl density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration.



Figure 6. Approximate locations and relative abundance of Canada Geese and swans observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 7. Estimated raw Canada Goose and swan density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration.



Figure 8. Approximate locations and relative abundance of dabbling ducks observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 9. Estimated raw dabbling duck density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration.



Figure 10. Approximate locations and relative abundance of diving ducks observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 11. Estimated raw diving duck density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration.



Figure 12. Approximate locations and relative abundance of sea ducks observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 13. Estimated raw sea duck density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration.



Figure 14. Approximate locations of sea ducks within two species groupings during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 15. Approximate locations and relative abundance of waterbirds observed during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).



Figure 16. Estimated raw waterbird density (bird detections per ha) by transect segment during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration.



Figure 17. Approximate locations of waterbirds within several species groupings during aerial surveys conducted over northern Lake Huron, Michigan, during spring (2012 and 2013) and fall (2012) migration. Transect locations (inset) and Lake Huron basin contours (15 m digital elevation model) are provided (darker areas indicate deeper water depths).

Our observations were consistent with the results of similar surveys conducted over portions of the Great Lakes. During aerial surveys conducted by MNFI over the Saginaw Bay of Lake Huron, Monfils and Gehring (2012) similarly observed widespread use of the bay by sea ducks and gulls, with swans, geese, and dabbling ducks concentrated near the shoreline. Diving ducks were also more abundant near shore compared to sea ducks, but often occurred further from shore than swans, geese, and dabbling ducks (Monfils and Gehring 2012). Sea ducks were most common during surveys of western Lake Michigan, with Long-tailed Ducks being the most frequently detected species, followed by Red-breasted Mergansers, and Common Goldeneyes (Mueller et al. 2011). Lott et al. (2011) noted that gulls were widespread and detected miles from the shoreline during their surveys of western Lake Erie, whereas dabbling ducks, swans, and geese were typically concentrated along the shoreline. Diving ducks were found in deeper water than dabbling ducks and tended to concentrate at the mouth of the Maumee River and near islands (Lott et al. 2011). Lott et al. (2011) suggested that no area of the Lake was devoid of birds, but there were decreasing numbers of waterfowl and waterbirds with increasing distance from the shoreline.

In 2006 as part of the Lower Great Lakes January Waterfowl Survey, the Long Point Waterfowl and Wetlands Research Fund and Canadian Wildlife Service expanded surveys of Lake Ontario beyond the typical nearshore transect (parallel to shoreline, 0.5 km offshore) to include additional transects located 2, 4, 10, and 20 km offshore. They observed 83% to 100% of the total Scaup (primarily Greater Scaup), Bufflehead, Common Goldeneye, Common Merganser (*Mergus merganser*), and Red-breasted Merganser on the shoreline transect and all individuals of these species were recorded with the addition of the 2-km offshore transect (Sea Duck Joint Venture 2007). The nearshore transect accounted for 57% of the total Long-tailed Ducks and 48% of scoter species, the 2-km offshore transect resulted in an additional 30% of both Long-tailed Duck (87% cumulative) and scoter species (76% cumulative), and over 98% of the total Long-tailed Ducks and scoters observed were accounted for after the addition of the 4-km offshore transect (Sea Duck Joint Venture 2007).

#### ACKNOWLEDGEMENTS

Financial assistance for this project was provided, in part, by the Michigan Coastal Management Program, MDEQ, through a grant from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. Matt Smar (MDEQ) provided support and feedback during the project. Richard Wolinski (Michigan Department of Transportation) provided summary data for surveys he conducted on Bois Blanc Island. David Luukkonen (Michigan Department of Natural Resources) and Brendan Shirkey (Michigan State University) provided useful information on the survey methods used for the MDNR diving duck study. Michael Sanders (MNFI) and Kristen Walter (MNFI) assisted with aerial surveys and Helen Enander (MNFI) provided GIS assistance.

#### LITERATURE CITED

- Amorim, P., M. Figueiredo, M. Machete, T. Morato, A. Martins, and R. Santos. 2009. Spatial variability of seabird distribution associated with environmental factors: a case study of marine Important Bird Areas in the Azores. Ices Journal of Marine Science 66:29-40.
- Arnett, E. B., D. B. Inkley, and D. H. Johnson. 2007. Impacts of wind energy facilities on wildlife and wildlife habitat. The Wildlife Society, Bethesda, Maryland, USA.
- Barclay, R., E. Baerwald, and J. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology-Revue Canadienne De Zoologie 85:381-387.
- Barrios, L., and A. Rodriguez. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology 41:72-81.
- Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.
- Benitez-Lopez, A., R. Alkemade, and P. Verweij. 2010. The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. Biological Conservation, 143:1307-1316.
- Bookhout, T. A., K. E. Bednarik, and R. W. Kroll. 1989. The Great Lakes marshes. Pages 131-156 in L.M. Smith, R.L. Pederson, and R.M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, USA.

- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas.
  2001. Introduction to distance sampling: estimating abundance of biological populations.
  Oxford University Press, Oxford, United Kingdom.
- Camphuysen, K., T. Fox, M. Leopold, and K. Petersen. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. Royal Netherlands Institute for Sea Research, report submitted to Collaborative Offshore Windfarm Research Into the Environment (BAM – 02-2002).
- Carrete, M., J. Sanchez-Zapata, J. Benitez, M. Lobon, and J. Donazar. 2009. Large scale riskassessment of wind-farms on population viability of a globally endangered long-lived raptor. Biological Conservation 142:2954-2961.
- Chamberlain, D. E., M. R. Rehfisch, A. D. Fox, M. Desholm, and S. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis 148:198-202.
- Custer, C. M. and T. W. Custer. 1996. Food habits of diving ducks in the Great Lakes after the zebra mussel invasion. Journal of Field Ornithology 67:86-99.
- Dennis, D. G., and R. E. Chandler. 1974. Waterfowl use of the Ontario shorelines of the southern Great Lakes during migration. Pages 58-65 *in* H. Boyd, editor. Canadian Wildlife Service waterfowl studies in eastern Canada, 1969-73. Canadian Wildlife Service Report Series No. 29.
- Desholm, M. 2006. Wind farm related mortality among avian migrants a remote sensing study and model analysis. Ph.D. Dissertation, University of Copenhagen, Denmark.
- Desholm, M., and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1: 296–298.
- Desholm, M., A. Fox, P. Beasley, and J. Kahlert. 2006. Remote techniques for counting and estimating the number of bird-wind turbine collisions at sea: a review. Ibis 148:76-89.
- Desholm, M. 2009. Avian sensitivity to mortality: prioritizing migratory bird species for assessment at proposed wind farms. Journal of Environmental Management 90:2672-2679.
- Drewitt, A. L, and R. H. W. Langston. 2008a. Assessing the impacts of wind farms on birds. Ibis 148:29-42.
- Drewitt, A., and R. Langston. 2008b. Collision effects of wind-power generators and other

obstacles on birds. Year in Ecology and Conservation Biology 1134:233-266.

- Eagle, A. C., E. M. Hay-Chmielewski, K. T. Cleveland, A. L. Derosier, M. E. Herbert, and R. A. Rustem, editors. 2005. Michigan's wildlife action plan. Michigan Department of Natural Resources. Lansing, USA. <a href="http://www.michigan.gov/dnrwildlifeactionplan">http://www.michigan.gov/dnrwildlifeactionplan</a>. Accessed 13 February 2009.
- Eggeman, D. R., and F. A. Johnson. 1989. Variation in effort and methodology for the Midwinter Waterfowl Inventory in the Atlantic Flyway. Wildlife Society Bulletin 17:227-233.
- Eichhorn, M., and M. Drechsler. 2010. Spatial trade-offs between wind power production and bird collision avoidance in agricultural landscapes. Ecology and Society 15. <a href="http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=GeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=FeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=FeneralSearch&qid=57&SID=2AOAbOPa6heG7IkIA5b&page=1&doc=1>">http://apps.isiknowledge.com.proxy2.cl.msu.edu/full\_record.do?product=WOS&search\_mode=FeneralSearch&qid=57&search\_mode=FeneralSearch&qid=57&sea
- Erickson, W. P., G. D. Johnson, D. P. Young, M. D. Strickland, R. E. Good, M. Bourassa, K.Bay, and K. Sernka. 2002. Synthesis and comparison of baseline avian and bat use,raptor nesting and mortality information from proposed and existing wind developments.West, Inc., Cheyenne, Wyoming.
- Ewert, D. N., P. J. Doran, K. R. Hall, A. Froehlich, J. Cannon, and J. B. Cole, and K. E. France.2012. On a wing and a (GIS) layer: prioritizing migratory bird stopover habitat alongGreat Lakes shorelines. Final report to the Upper Midwest/Great Lakes LandscapeConservation Cooperative.
- Ewert, D. N., G. J. Soulliere, R. D. Macleod, M. C. Shieldcastle, P. G. Rodewald, E. Fujimura, J. Shieldcastle, and R. J. Gates. 2006. Migratory bird stopover site attributes in the western Lake Erie basin. Final report to The George Gund Foundation.
- Exo, K. M., O. Hüppop, and S. Garthe. 2003. Birds and offshore wind facilities: a hot topic in marine ecology. Wader Study Group Bulletin 100:50–53.
- Fox, A., M. Desholm, J. Kahlert, T. Christensen, and I. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148:129-144.
- Garthe, S, and O. Huppop. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41:724-734.

- Garthe, S., N. Markones, O. Huppop, and S. Adler. 2009. Effects of hydrographic and meteorological factors on seasonal seabird abundance in the southern North Sea. Marine Ecology-Progress Series 391:243-255.
- Gehring, J. L., P. Kerlinger, and A. Manville. 2009. Communication towers, lights, and birds: successful methods of reducing the frequency of avian collisions. Ecological Applications 19:505-514.
- Great Lakes Basin Commission. 1975. Great Lakes Basin framework study. U.S. Department of Interior, Bureau of Sport Fisheries and Wildlife, Ann Arbor, Michigan, USA.
- Griffiths, R. W. 1993. Effects of zebra mussels (*Dreissena polymorpha*) on the benthic fauna of Lake St. Clair. Pages 415-437 in T. F. Nalepa and D. W. Schloesser, editors. Zebra mussels: biology, impacts, and control. Lewis Publishers/CRC Press, Boca Raton, Florida, USA.
- Hüppop, O., J. Dierschke, K. Exo, E. Fredrich, and R. Hill. 2006. Bird migration studies and potential collision risk with offshore wind turbines. Ibis 148:90-109.
- Jain, A. A. 2005. Bird and bat behavior and mortality at a northern Iowa windfarm. Thesis, Iowa State University, Ames, USA.
- Johnson, G. D., W. P. Erickson, and M. D. Strickland. 2000. Avian monitoring studies at the Buffalo Ridge Wind Resource Area, Minnesota: Results of a 4-year study. West Inc. Final report submitted to Northern States Power Co., Minneapolis, Minnesota, USA.
- Johnson et al. 2007. Use of data to develop mitigation measures for wind power development impacts to birds. Pages 241–257 in M. de Lucas, G.F.E. Janss, and M. Ferrer, editors. Birds and Wind Farms: Risk Assessment and Mitigation. Quercus, Madrid.
- Kahlert, J., I. K. Petersen, A. D. Fox, M. Desholm, and I. Clausager. 2004. Investigations of birds during construction and operation of Nysted Offshore Wind Farm at Rødsand, Annual Status Report 2003. National Environmental Research Institute Report Commissioned by Energi E2 A/S. Rønde: NERI.
  <a href="http://uk.nystedhavmoellepark.dk/upload/pdf/Birds2003.pdf">http://uk.nystedhavmoellepark.dk/upload/pdf/Birds2003.pdf</a>>.
- Knapton, R. W., S. A. Petrie, and G. Herring. 2000. Human disturbance of diving ducks on Long Point Bay, Lake Erie. Wildlife Society Bulletin 28:923-930.

Knutson, M. G., G. Butcher, J. Fitzgerald, and J. Shieldcastle. 2001. Partners in Flight bird

conservation plan for the upper Great Lakes Plain (Physiographic Area 16). U.S. Geological Service, Upper Midwest Environmental Sciences Center in cooperation with Partners in Flight, La Crosse, Wisconsin, USA.

- Larsen, J. K., and J. Madsen. 2000. Effects of wind turbines and other physical elements on field utilization by pink-footed geese (*Anser brachyrhynchus*): a landscape perspective. Landscape Ecology 15:755-764.
- Larsen, J., and M. Guillemette. 2007. Effects of wind turbines on flight behaviour of wintering common eiders: implications for habitat use and collision risk. Journal of Applied Ecology 44:516-522.
- Lott, K., M. Seymour, and R. Russell. 2011. Mapping pelagic bird distribution and abundance as a decision-making tool for offshore wind turbine development and conservation planning. Report to funders.
- Maclean, I. M. D., M. Frederiksen, and M. M. Rehfisch. 2007. Potential use of population viability analysis to assess the impact of offshore windfarms on bird populations. COWRIE PVA-03-07. <a href="http://www.offshorewind.co.uk/Assets/FINAL\_COWRIE\_PVA-03-07\_04.11.07.pdf">http://www.offshorewind.co.uk/Assets/FINAL\_COWRIE\_PVA-03-07\_04.11.07.pdf</a>>.
- Madsen, J., and D. Boertmann. 2008. Animal behavioral adaptation to changing landscapes: spring-staging geese habituate to wind farms. Landscape Ecology 23:1007-1011.
- Masden, E. A., D. T. Haydon, A. D. Fox, and R. W. Furness. 2010. Barriers to movement: modeling energetic costs of avoiding marine wind farms amongst breeding seabirds. Marine Pollution Bulletin 60:1085-1091.
- Mikinetics Consulting, LLC and Private Sector Consultants, Inc. 2009. Report of the Michigan Great Lakes Wind Council. Report to Gov. Granholm.

<http://www.michiganglowcouncil.org/GLOW%20Report%209-1-09\_FINAL.pdf>.

Mikinetics Consulting, LLC and Private Sector Consultants, Inc. 2010. Report of the Michigan Great Lakes Wind Council. Report to Gov. Granholm.

 $<\!\!http://www.michiganglowcouncil.org/GLOWreportOct2010\_with\%20 appendices.pdf\!>.$ 

Monfils, M. J., and J. L. Gehring. 2012. Identifying migrant waterfowl and waterbird stopovers to inform wind energy development siting within Saginaw Bay. Michigan Natural Features Inventory, Report Number 2012-19, Lansing, USA.

Mueller, W., N. Cutright, and N. Seefelt. 2011. Coordinated bird monitoring: aerial avian

surveys of western Lake Michigan 2010-2011. Report to funders.

- National Audubon Society. 2013. Michigan Important Bird Areas. <a href="http://web4.audubon.org/bird/iba/michigan/">http://web4.audubon.org/bird/iba/michigan/</a>>
- North American Waterfowl Management Plan. 2004. North American waterfowl management plan: strengthening the biological foundation (Implementation Framework).
  U.S. DOI, Fish and Wildlife Service and Environment Canada, Canadian Wildlife Service.
- Petersen, I. K., I. Clausager, and T. K. Christensen. 2004. Bird numbers and distribution in the Horns Rev Offshore Wind Farm Area. NERI report. Rønde: National Environmental Research Institute. <a href="http://www.hornsrev.dk/Miljoeforhold/miljoerapporter/">http://www.hornsrev.dk/Miljoeforhold/miljoerapporter/</a> Bird\_numbers\_2003%20status\_report.pdf>.
- Peterson, C. 2011. Risks to birds and wildlife from offshore wind farms: BOEMRE NC Task Force. <a href="http://www.boem.gov/Renewable-Energy-Program/State-Activities/RiskBirdsWildlife">http://www.boem.gov/Renewable-Energy-Program/State-Activities/RiskBirdsWildlife</a> Offshore.aspx>.
- Polasky, S., E. Nelson, J. Camm, B. Csuti, P. Fackler, E. Lonsdorf, C. Montgomery, D. White, J. Arthur, B. Graber-Yonts, R. Haight, J. Kagan, A. Starfield, and C. Tobalske. 2008.
  Where to put things? Spatial land management to sustain biodiversity and economic returns. Biological Conservation 141:1505–1524.
- Prince, H. H., P. I. Padding, and R. W. Knapton. 1992. Waterfowl use of the Laurentian Great Lakes. Journal Great Lakes Research 18:673-699.
- Rodgers, J. A. and H. T. Smith. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildlife Society Bulletin 25:139-145.
- Rodgers, J. A. and S. T. Schwikert. 2000. Buffer-zone distances to protect foraging and loafing waterbirds from disturbance by personal watercraft and outboard-powered boats. Conservation Biology 16:216-224.
- Sea Duck Joint Venture. 2007. Recommendations for monitoring distribution, abundance, and trends for North American Sea Ducks. Report produced by the Sea Duck Joint Venture. <a href="http://seaduckjv.org"></a>.
- Shirkey, B. T. 2012. Diving duck abundance and distribution on Lake St. Clair and western Lake Erie. Thesis, Michigan State University, East Lansing, USA.
- Shirkey, B. T., S. R. Winterstein, and D. R. Luukkonen. 2012. Developing spatially-explicit

models to guide conservation of diving ducks during migration. Pages 9-14 *in* S., Francoeur, L. Cargenellit, A. Cook, J. Hartig, J. Gannon, and G. Norwood, editors. State of the Strait: use of remote sensing and GIS to better manage the Huron-Erie Corridor. Great Lake Institute for Environmental Research, Occasional Publication No. 7, University of Windsor, Ontario, Canada.

- Smallwood, K. S., and B. Karas. 2009. Avian and bat fatality rates at old-generation and repowered wind turbines in California. Journal of Wildlife Management 73:1062-1071.
- Smallwood, K., L. Rugge, and M. Morrison. 2009. Influence of behavior on bird mortality in wind energy developments. Journal of Wildlife Management 73:1082-1098.
- Smallwood, K. S., and C. G. Thelander. 2004. Developing methods to reduce mortality in the Altamont Pass Wind Resource Area. Final report by BioResource Consultants to the California Energy Commission, Public Interest Energy Research 500-04-052.
- Stapanian, M. A. and T. A. Waite. 2003. Species density of waterbirds in offshore habitats in western Lake Erie. Journal of Field Ornithology 74:381-393.
- Stewart, G., A. Pullin, and C. Coles. 2007. Poor evidence-base for assessment of wind farm impacts on birds. Environmental Conservation 34:1-11.
- Soulliere, G. J., B. W. Loges, E. M. Dunton, D. R. Luukkonen, M. W. Eichholz, and K. E. Koch. In press. Monitoring waterfowl in the Midwest during the non-breeding period: challenges, priorities, and recommendations. Journal of Fish and Wildlife Management.
- Soulliere, G. J., T. E. Maples, and E. N. Kafcas. 2000. Twenty-five years of Canvasback inventory in Michigan. Michigan Department of Natural Resources, Wildlife Report No. 3322, Lansing, USA.
- Soulliere, G. J., B. A. Potter, J. M. Coluccy, R. C. Gatti, C. L. Roy, D. R. Luukkonen, P. W. Brown, and M. W. Eichholz. 2007a. Upper Mississippi River and Great Lakes Region Joint Venture waterfowl habitat conservation strategy. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, USA.
- Soulliere, G. J., B. A. Potter, D. J. Holm, D. A. Granfors, M. J. Monfils, S. J. Lewis, and W. E. Thogmartin. 2007b. Upper Mississippi River and Great Lakes Region Joint Venture waterbird habitat conservation strategy. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, USA.

Upper Mississippi River and Great Lakes Region Joint Venture. 2007. Upper Mississippi River

and Great Lakes Region Joint Venture implementation plan. G. J. Soulliere and B. A. Potter, compilers. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, USA.

- U.S. Fish and Wildlife Service. 2003. Draft interim guidelines to avoid and minimize wildlife impacts from wind turbines. U.S. Fish and Wildlife Service, Alexandria, VA, USA.
- West, A., and R. Caldow. 2006. The development and use of individuals-based models to predict the effects of habitat loss and disturbance on waders and waterfowl. Ibis 148:158-168.
- Winkelman, J. E. 1985. Vogelhinder door middlegrote windturbines -- ver vlieggedrag, slachtoffers en verstoring (Bird impact by middle-sized wind turbines - on flight behavior, victims, and disturbance.) Limosa 58:117–121.
- Winkelman, J. E. 1990. Nachtelijke aanvaringskansen voor vogels in de Sep-proefwindcentrale te Oosterbierum (Fr.) (Nocturnal collision risks for and behavior of birds approaching a rotor in operation in the experimental wind park near Oosterbierum, Friesland, The Netherlands; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 90/17.
- Winkelman, J. E. 1992. De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.) op vogels, 1. Aanvaringsslachtoffers (The impact of the Sep Wind Park near Oosterbierum [Fr.], The Netherlands, on birds, 1. Collision victims.) English summary only. Pages 69–71. DLO-Instituut voor Bos- en Natuuronderzoek, Arnhem, Netherlands. RIN-Rapport 92/2.
- Winkelman, J. E. 1994. Bird/wind turbine investigations in Europe. Pages 43–47. *In*Proceedings of the National Avian-Wind Power Planning Meeting, Lakewood, Colorado, 20–21 July 1994. Proceedings prepared by LGL Ltd., environmental research associates, King City, Ontario. Author's address: Birdlife/Vogelbescherming Nederland, Driebergweweg, The Netherlands.
- Wires, L.R., S. J. Lewis, G. J. Soulliere, S. W. Matteson, D. V. "Chip" Weseloh, R. P. Russell, and F. J. Cuthbert. 2010. Upper Mississippi Valley / Great Lakes Waterbird Conservation Plan. A plan associated with the Waterbird Conservation for the Americas Initiative. Final Report submitted to the U. S. Fish and Wildlife Service, Fort Snelling, MN.