IDENTIFYING MIGRANT WATERFOWL AND WATERBIRD STOPOVERS TO INFORM WIND ENERGY DEVELOPMENT SITING WITHIN SAGINAW BAY – YEAR 1 REPORT

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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 Saginaw Bay of Lake Huron in Michigan. Potential impacts could be direct, such as collisions with turbines, or indirect, such as displacement from critical migration stopover sites used for feeding/loafing and/or increased energy costs due to movement barriers in the form of strings of turbines. 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 September 2009, the Great Lakes Offshore Wind Council (GLOW Council) delineated almost the entire Saginaw Bay as areas of "Most Favorable" or "Conditional" offshore wind development, with few areas of "Categorical Exclusion". With water depths of ≤ 30 m, Saginaw Bay also provides for feasible and economical turbine construction (Mikinetics Consulting and Private Sector Consultants 2009). This information was provided to Governor Jennifer Granholm in part to help focus development efforts. Saginaw Bay has a combination of high winds, proximity to load centers (e.g., large urban areas) for interconnection, and water depths needed to construct turbine foundations tolerant of ice cover.

The shallow-water depths of Saginaw Bay also provide excellent 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). Lake Huron's Saginaw Bay contains a substantial concentration of Michigan's coastal marshes (about 2,500 ha; Bookhout et al. 1989), which occurs as a nearly continuous strip along the perimeter of the bay (Prince et al. 1992). Saginaw Bay was recognized as an Important Bird Area of global significance for several waterbird species (American Bird Conservancy 2003). Emergent wetlands and shallow open water zones of Saginaw Bay 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)

(Soulliere et al. 2007a,b, UMRGLR Joint Venture 2007). Several Species of Greatest Conservation Need identified in Michigan's Wildlife Action Plan (Eagle et al. 2005), such as American Black Duck (*Anas rubripes*) and Great Blue Heron (*Ardea herodias*), use Saginaw Bay coastal wetlands during migration. It is important that we better understand the potential impacts that wind turbine construction could have on migratory birds using Saginaw Bay and other parts of the Great Lakes.

Our research addresses priority monitoring needs within the Joint Venture. Soulliere et al. (2007a) recognized the need to develop a monitoring protocol to track priority populations of migrating and wintering waterfowl species within the Joint Venture. In addition, Soulliere et al. (2007b) identified the need for systematic surveys in near-shore and open waters of the Great Lakes to gather information on waterbird distribution, abundance, and migration chronology, which could be used to evaluate proposals for offshore wind power development. The Michigan Department of Natural Resources (DNR) is conducting a study of diving duck distribution and abundance on Lake St. Clair, the Detroit River, and western Lake Erie, which includes an estimation of diving duck detection probabilities and testing of a spring survey (D. Luukkonen, Michigan DNR, person. comm.). The data presented here will be available to augment both projects. By combining these efforts we are significantly increasing our knowledge of waterbird migration in the Great Lakes.

Although Michigan has conducted valuable annual spring waterfowl surveys throughout the inland areas since 1991 (Soulliere and Chadwick 2003), data collection on offshore bird use during migration has been limited. Similarly, we lack data on Great Lakes and North American offshore wind farm bird fatalities. Resource managers and researchers can not apply onshore data wind farm fatality rates to offshore situations. In addition, different species may be impacted in different offshore areas. Migrating songbirds may be more of a concern in the Gulf of Mexico than in offshore areas near Massachusetts, where waterbirds and waterfowl may be of greater concern (Arnett et al 2007). In the Great Lakes there is potential for impacts to a diversity of birds and bats species moving over these large water bodies.

Past research suggests that waterfowl is typically effective at avoiding offshore wind turbines and therefore collisions (Elsam Engineering and ENERGI E2 2005). However, displacement from and avoidance of important habitats and movement barriers are more of a concern. The Elsam radar study documented that 35% of the detected birds flew through the wind farm area before construction of the turbines and only 9% after construction (Elsam Engineering and ENERGI E2 2005). These effects, which would likely have cumulative effects, have not been quantitatively evaluated (Arnett 2007). The potential for waterbirds and waterfowl to avoid wind farms is not only a potential issue in offshore areas of the Great Lakes but nearshore as well. The Great Lakes area has already lost more than two-thirds of the natural wetlands due to filling and draining for farming, urbanization, shoreline development, recreation and resource extraction (e.g., peat mining) (GLIN 1998; GLWCAP 1994-2001). Additional avoidance of remaining wetlands due to wind farms would further this loss of habitat.

Before the potential impacts of wind energy development in Saginaw Bay 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 (United States 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 on Saginaw Bay. In 2009, the Michigan Natural Features Inventory (MNFI) proposed a project to improve our understanding of bird use of Saginaw Bay so that informed decisions can be made about future wind development. With approved funding from the Michigan Coastal Program, we began work in 2009 toward the following objectives: (1) evaluate existing data sources and make them more available to resource managers and agencies; (2) identify knowledge gaps in our understanding of waterfowl and waterbird use of Saginaw Bay and the Great Lakes; (3) conduct aerial surveys to fill knowledge gaps about bird use of Saginaw Bay; (4) incorporate our survey data into larger mapping efforts; and (4) provide map products to resource managers, agencies, and industry. The rapid increase in the discussion of offshore wind farms, especially in the Saginaw Bay, heightens the value and urgency of this research.

LITERATURE REVIEW

Generalized Findings of Complementary Surveys

Compared to our surveys, most efforts surveyed only in nearshore waters and not offshore. The Mid-winter Inventory (MWI) surveys are 0.5 km off shorelines in most areas of the lower Great Lakes except on the Canadian side of Lake Ontario where additional transects are added 2, 4, 10, 20 km offshore. "Results suggest that 83% to 100% of scaup (primarily Greater Scaup) spp, Bufflehead, Common Goldeneye, Common Merganser, and Red-breasted Merganser were counted on the shoreline transect, but all individuals of these species were accounted for by addition of the 2-km offshore transect. The shoreline transect contained 57% of the Long-tailed Ducks and 48% of scoter spp. About an additional 30% of both Long-tailed Duck (cumulative = 87%) and scoter spp. (cumulative = 76%) were counted on the 2-km transect, and more than 98% of individuals of each species observed were accounted for after inclusion of the 4-km transect." (Sea Duck Joint Venture 2007). "…an average of 50,214 Long-tailed Ducks were counted each January during the Lower Great Lakes January Waterfowl Survey, and > 90% of those birds were located on the Canadian side of Lake Ontario. Based on these survey results, the northern portions of Lake Ontario have been identified as the most important wintering area for Long-tailed Duck on the Lower Great Lakes. Possibly 100,000 to 200,000 Long-tailed Ducks (perhaps 10-20% of continental population) winter on the Great Lakes." This is believed to be correlated with the increase in zebra and quagga mussel availability (Sea Duck Joint Venture 2007).

Starting in 1974, the Michigan DNR has conducted annual November Canvasback surveys to track population trends and spatial distribution within the Great Lakes (Soulliere et al. 2000). This survey is conducted in coordination with the Ontario Ministry of Natural Resources, the U.S. Fish and Wildlife Service, the Canadian Wildlife Service, and several other state wildlife agencies (Soulliere et al. 2000). The most important areas for these ducks in Michigan include: 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 were in these 2 areas combined. Saginaw Bay was also highlighted as an important staging area in 1984 and 1985, with 18-20% of all Canvasbacks detected (Soulliere et al. 2000). Additional details are to follow in the Methods section of this report.

Ewert et al (2005) accumulated and summarized a significant amount of information regarding the qualities and characteristics of migratory bird stopover areas in the Western Lake Erie area. They state that the lower Great Lakes are considered by the North American Waterfowl Management Plan (NAWMP 2004) to be areas of continental significance. According to Prince et al. (1992) approximately 3 million birds of more than 30 species of waterfowl use Great Lakes coastal waters and wetlands at some time during the year (Great Lakes Basin Commission 1975). Some of the highest migratory waterfowl concentrations have occurred in the central basin and southwestern Lake Erie, Lake St. Clair, and the Detroit River (Dennis and Chandler 1974, Prince et al. 1992). The main species detected in the lower Great Lakes region include: Canvasback, Lesser Scaup, Redhead, Mallard, Green-winged Teal, Blue-winged Teal, American Wigeon, Wood Duck, Bufflehead, mergansers, and Tundra Swans.

Ewert et al (2005) provides a temporal framework for the timing of waterfowl species migration through the Great Lakes. However, they state that the "spring waterfowl inventories of coastal areas in the region have not been systematic so assessments of spring stopover sites remain inadequate."

Ewert et al (2005) summarized some of the habitat preferences for waterfowl in the lower Great Lakes. They state that, "most diving ducks require deeper water sites for feeding and loafing. Although Redheads may feed in <10 cm (<4 inches) of water and Lesser Scaups commonly use sites with water depths of 3-6 m (10-25 ft) (Bellrose 1980), most feeding sites used by diving ducks are in 2-5 m (6-15 ft) of water. Diving ducks using Lake Erie and Lake St. Clair have varied diets, with scaups and Common Goldeneyes consuming mollusks (80-99%) and Redheads and Canvasbacks eating primarily plants (50-99%) during fall and spring (Custer and Custer 1996). Zebra mussels have been a primary mollusk food source on Lakes Erie and St. Clair since their invasion, accounting for a majority of the mussels eaten by diving ducks (Hamilton and Ankney 1994, Custer and Custer 1996)."

Garthe et al (2009) studied the relationship between seabird use of their south North Sea study area and season, hydrographic variables, and meteorological variables. Between 1990 and 2007 they counted seabirds on 407 days and compared the data to archived data for two hydrographic and five meteorological parameters. The birds had different seasonal behaviors with some occurring year-round and others present only seasonally. Despite the seasonal changes the five meteorological and two hydrographic parameters significantly influenced the abundance of birds present. Wind field, sea surface temperature anomaly, sea surface salinity anomaly and air pressure change were most closely correlated with bird presence and absence. These data could be used to suggest the times with the most risk of avian collisions in offshore wind farm areas.

Dennis and Chandler (1974) suggested that in addition to quality habitat waterfowl needed areas with low human disturbance (e.g., low boat traffic). This may be more important during migration when feeding needs and energetic risks are higher. Knapton et al. (2000) found that diving ducks appeared more tolerant of boat traffic and often returned to feeding sites post disturbance. This response was more common in the spring than in the fall. Knapton et al. (2000) suggested that a 300 m (990 ft) buffer be placed around important feeding areas in order to reduce disturbance to these migrating birds.

Saginaw Bay has also been listed as an Important Bird Area for its importance to Great Blue Herons, Great Egrets, Black-crowned Night Herons, Least Bitterns, American Bitterns, Virginia Rails, Sora, Common Moorhens, Forster’s Terns, Black Terns, Common Terns, and Caspian Terns.

Similarly to their summary of waterfowl, Ewert et al (2005) summarized information on waterbirds in the same focal area of Lake Erie. According to Wires and Cuthbert (2001) islands in the western Lake Erie basin and Saginaw Bay are important to nesting egrets in the Great Lakes region. Campbell (1968) states that migrant Soras used dry grassy fields to wetlands of all sizes while migrant Black Terns used open water >3 ha and sandbars/ beaches lacking in human disturbance for roosting (Knutson et al. 2001). Gulls, terns, and cormorants have been found to use areas with concentrations of small (<15 cm) fish in wetlands, river mouths, or nearshore waters. Bonaparte’s Gulls, for example, have been found to feed on gizzard shad (Anderson et al. 2002) and emerald shiners during fall migration (Campbell 1968). Stepanian and Waite (2003) found that Ring-billed Gulls and Bonaparte’s Gulls spent equivalent amounts of time in four aquatic habitats: immediately offshore of refuges, developed shorelines, open water >10 m deep, and reefs and shoals of 3-6 m water depth. When compared to Double-crested Cormorants which were found less frequently over open water compared to other habitats, Herring Gulls frequently used areas 0.5-0.8 km offshore of refuges. 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. 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).

Wind Energy, Waterfowl, and Waterbirds

Exo et al. (2003) expressed the following concerns regarding how offshore wind turbines could effect birds: collision risk, short-term habitat loss and disturbance during construction of the wind farm, more 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 that these issues be considered in an integrated manner but suggested a lack of useful data to make this possible (Exo et al 2003). We currently have more information regarding onshore wind farms than offshore but as previously mentioned, onshore wind energy impacts can not always be directly compared to offshore wind energy impacts. However, some similarities are present. With both onshore and offshore turbines, many studies have determined that bird fatalities are more 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 (2008) found that some bird (and bat) fatalities increased after older turbines were replaced with more contemporary turbines. For waterbirds detected (Pied-billed Grebe, Gull spp., and Mallard) these changes in fatalities were not statistically significant ($p > 0.05$). In a larger analysis Barclay et al. (2007) found that while 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.

With waterfowl, most researchers suggest that displacement from habitats and movement barriers is more of a concern than actual bird collisions with turbines (Fox and Nilsson 2005).

Eriksson and Petersson (2005) concluded that the fatality risk to seabirds passing through or near to offshore wind farms was only one in 100,000. Desholm (2006) studied offshore wind farms in Denmark. Using thermal imaging and modeling he estimated a collisions rate of 1.4 Common Eiders per turbine per year. These birds also 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 the 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. He stated that this fatality rate is relatively low compared to the approximate 70,000 Common Eiders shot and killed by Danish hunters every year. Desholm (2006) used avoidance behavior rates and built stochastic model framework to estimate duck fatality rates. He suggested that this be incorporated into standard management procedures for estimating risk to birds and bats at both onshore and offshore wind farm sites.

Identifying those species most vulnerable to wind farm collisions is a challenge as it includes many biological variables such as the 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 will help resource managers to prioritize management and mitigation efforts. Specifically Desholm (2006) developed an Environmental Vulnerability Index (EVI). The EVI includes an abundance and demographic vulnerability indicator. These two indicators are thought to capture the vulnerability of migrating birds to wind farm related mortality. Desholm (2006) uses the Nysted offshore wind farm as a case-study. In general the large-bodied and long-lived species tend to be the most vulnerable of the species.

Similarly, Chamberlain et al (2006) conducted a sensitivity analyses on the variables that affect overall fatality rates. They examined many variables including but not limited to the size and speed of the turbine, the size and 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. Avoidance rates should be generated in 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. The authors suggest that this needs to change for more accurate estimates and subsequent management decisions (Chamberlain et al. 2006). Collision rates would likely be more of an issue for long-lived species with low reproductive rates, the wind farm related deaths would more likely be additive instead of compensatory.

The subject of avoidance and displacement has been the focus of several studies. Winkleman (1990) found that birds were more hesitant to approach turbines in the dark and estimated that 1 of 76 birds passing through the turbines at night suffers a collision. Winkleman (1992) suggested that because the turbines of the edges of wind farms are more likely to cause collisions that the turbines be clustered to minimize the edge effect. This is also consistent with the Winklemen (1994) finding of a 95% reduction in bird numbers within 250-500 m of the nearest turbine. Similarly, he found that 13% of migrating flocks of birds showed a turbine-related change in flight behavior (Winkleman 1985). Stewart et al. (2007) evaluated existing data for bird abundance declines in relation to the construction of onshore wind farms. They found that, although populations in different locations varied, the family Anseriformes (ducks and geese) had the greatest declines with Charadriiformes (gulls, shorebirds, waterbirds) the second greatest declines. This could be linked to displacement of birds away from wind farms. Abundance declines increased over time since wind farm construction, but the turbine number and turbine size (correlated with the author’s use of the word “power”) had little to no effect on the 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. Similarly, Benitez-Lopez et al. (2010) used met-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 was 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 fly <50 m from turbines with some flight 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 to fly close enough to the turbines to be at risk (Figure 1)

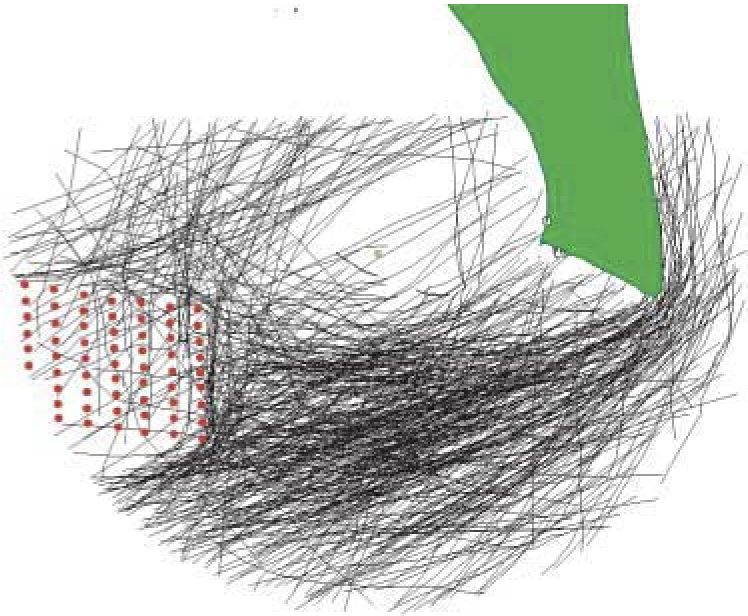

Figure 1**.** Radar registrations from the Nysted offshore wind farm applied on a GIS-platform. Red dots indicate individual wind turbines, green area the land, green dot the siting of the radar, and black lines migrating waterbird flocks determined visually at the Nysted offshore wind farm. (from Kahlert *et al.* 2004 in Desholm and Kahlert 2005)

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.

Most studies have found low fatality rates for waterfowl in general but relatively high avoidance rates of wind turbines (Winkelman 1995, Erickson et al. 2002). Jain (2005) studied the response of Canada Geese to the presence of wind turbines in their onshore foraging habitats. Whilst he found no collision fatalities of geese he also found minimal avoidance of the feeding 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 2 seasons. Jain (2005) suggested 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 this research, 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 actually be drawn into the turbines for foraging or perching. Petersen et al. (2004) documented an increase in Herring Gull (*Larus argentatus*) and tern use in offshore wind farm areas and cormorants (*Phalacrocorax carbo*) used the maintenance platforms for loafing (Kahlert et al. 2004). 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.

Modeling has been used at times to estimate impacts and prioritize conservation efforts. For example, Carrette 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 Hupop (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 potential offshore wind energy development. They 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, the authors determined that nearshore areas were more vulnerable than offshore areas. They suggest that this be applied at a large scale to help guide resource managers and decision makers in the early stages of wind farm planning.

More land-use focused, Eichhorn and Drechsler (2010) proposed using Pareto-optimal land use scenarios (the so-called efficiency frontier: e.g., Polasky et al. 2008) to determine prime locations for turbines that minimized negative impacts on humans and wildlife. These variables are considered to be at opposite ends of the spectrum as humans want turbines located away from their settlements and these more remote areas are often important to wildlife. 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 (2008). 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 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), sensitive times of the day (nights), or during high-risk weather conditions (foggy/low visibility). These options include potentially significant impacts to the energy production of the wind farm and hence to the financial profit. Therefore, these techniques may not be readily adopted nor supported by the wind energy industry. Appropriate micro-siting can also be helpful in reducing wildlife fatalities.

Placing turbines as close to one another as possible may encourage wildlife to go around the wind farm instead of through it (Winkleman 1992a). Incorporating travel corridors through the wind farms may funnel wildlife through safe pathways. Whilst the 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. They recommended several things to help mitigate the 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 km wide between the separate wind farms. Forth, avoid placing wind farms between bird feeding sites and bird roosting site; this should minimize the collision risk. Fifth, monitor weather conditions and maintain the ability to feather the blades if the level of risk to birds is dramatically higher 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

“Although areas where birds migrate through or concentrate seasonal activities are generally known, the specific timing, routes, and altitudes of movement within and between resting and foraging areas and altitudes that migrants use are poorly known, and such information is needed to conduct assessments of the potential risk to birds from offshore wind developments.” (Arnett et al 2007). 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.

Desholm et al. (2006) review 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 (2006) suggests that most current methods of estimating fatality rates would be more accurate and useful if the variable of avoidance was included. While estimating an individual's ability to avoid turbines requires intense research at the species level, Desholm (2006) still emphasizes its necessity.

In addition to collecting data via surveys and observations, Camphuysen (2004) suggested that "using spatial and temporal modeling techniques to estimate bird density over certain areas of open sea offers the best method for statistically detecting differences in the distribution and abundance of these birds before, during and post-construction of offshore wind farms."

Future research also needs to consider quantification of the effects of stopover habitat loss and movement barriers at a species level. In addition, we need to understand how the frequent motorized traffic to and from the offshore wind site might affect waterbirds. It may be possible to develop and use individuals-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 the 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 fight height) and overall abundance of the wildlife populations. Specifically the avoidance and displacement behaviors, 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 the 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 that are 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. 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 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). The authors suggest a before/after control/impact comparative study design for studies for more accurate interpretations. Our study includes some of the initial steps to building these models. Additionally Fox et al (2006) suggests that research use standardized methods for better comparisons among studies, experience and data sharing as much as possible for both pre-construction and post-construction, and testing of our 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.

METHODS

Existing Waterfowl and Waterbird Data

We examined data from existing sources to inform potential future wind development on Saginaw Bay. The Michigan Department of Natural Resources (MDNR) conducts several surveys on an annual basis: (1) fall weekly waterfowl surveys at wildlife areas managed for waterfowl; (2) Coordinated November Canvasback (*Aythya valisineria*) Inventory; and (3) Midwinter Waterfowl Survey. Fall weekly surveys are conducted at wildlife areas managed intensively for waterfowl, with Fish Point and Nayanquing Point being the only areas surveyed on Saginaw Bay. The Coordinated November Canvasback Inventory is a cooperative North American survey conducted by the U.S. Fish and Wildlife Service (FWS), Canadian Wildlife Service, and state agencies since 1974 (Cordts 2010). Surveys in Michigan are done using fixed-wing aircraft. Although detailed locations of the Saginaw Bay survey route are not available, surveys tend to be focused near the shoreline. The Midwinter Waterfowl Survey is an annual survey conducted by state agencies and the FWS since 1935. Surveys are conducted during the first week of January and the methods used vary across the County, but Michigan typically uses ground surveys.

In addition to surveys completed by the MDNR, we summarized data from aerial surveys conducted by the MNFI in 2006-2007 for a study of diked and undiked coastal wetlands (Figure 2; Monfils 2009). We compiled data from the MNFI surveys into the following taxonomic groups, due to similarities in habitat usage, food resources, and foraging strategies: (1) swans (genus *Cygnus*); (2) geese (genera *Anser*, *Chen*, and *Branta*); (3) dabbling ducks (genus *Anas* and Wood Duck [*Aix sponsa*]); (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 (Great Blue Heron, Great Egret [*Ardea alba*], Double-crested cormorant [*Phalacrocorax auritus*], and American Coot [*Fulica americana*]). 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.

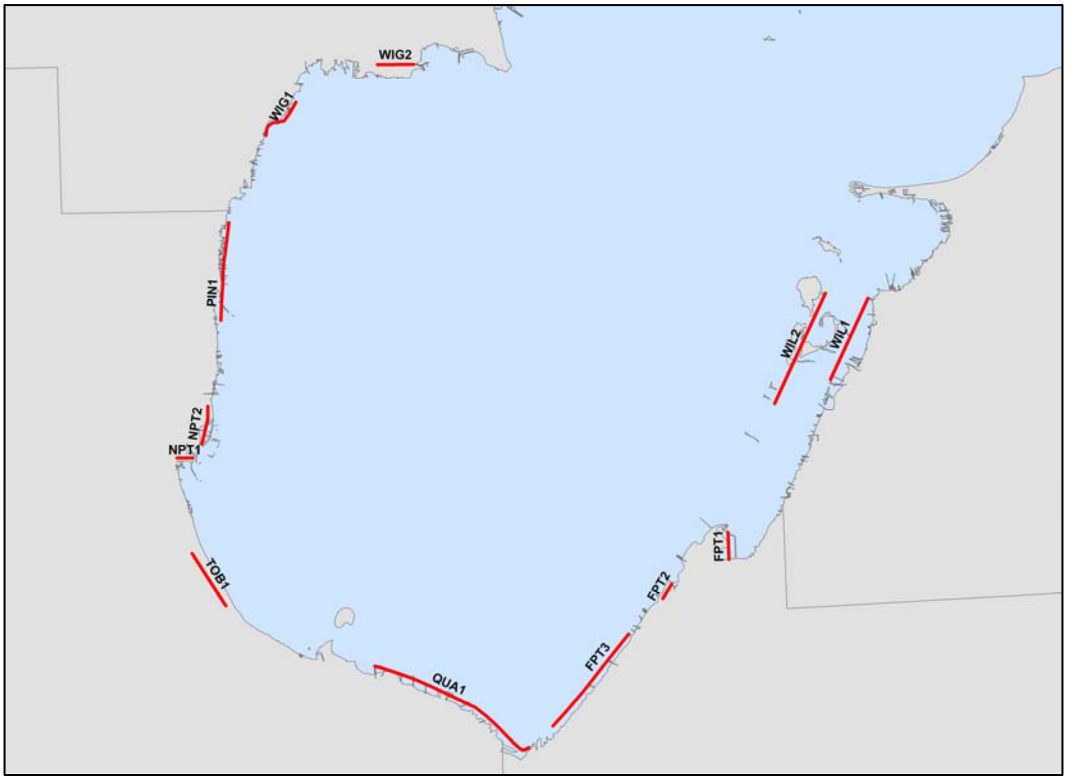

Figure 2. Transects used during aerial waterfowl and waterbird surveys conducted by the Michigan Natural Features Inventory on Saginaw Bay, Lake Huron in 2006 and 2007. Abbreviations indicate the general location (FPT = Fish Point; NPT = Nayanquing Point; PIN = Pinconning; TOB = Tobico Marsh; WIG = Wigwam Bay; and WIL = Wildfowl Bay) and transect number.

2010-2011 Aerial Surveys

We conducted low-level aerial waterfowl surveys in fall 2010 and spring 2011 along a system of parallel transects placed systematically across Saginaw Bay with a random starting point. We alternated between two sets of 12 transects each (transects A-L and M-X; Figure 3) during surveys to maximize coverage of Saginaw Bay and minimize the chance of double-counting birds. For example, during the first survey we used transects A-L, then transects M-X during survey two, back to transects A-L for the third survey, and so on. Transects within a given set were 5 km apart, thus 2.5 km separated the full set of 24 transects (Figure 3). Camphuysen et al. (2004) recommended transects for seabird surveys be separated by at least 2 km to avoid double counting.

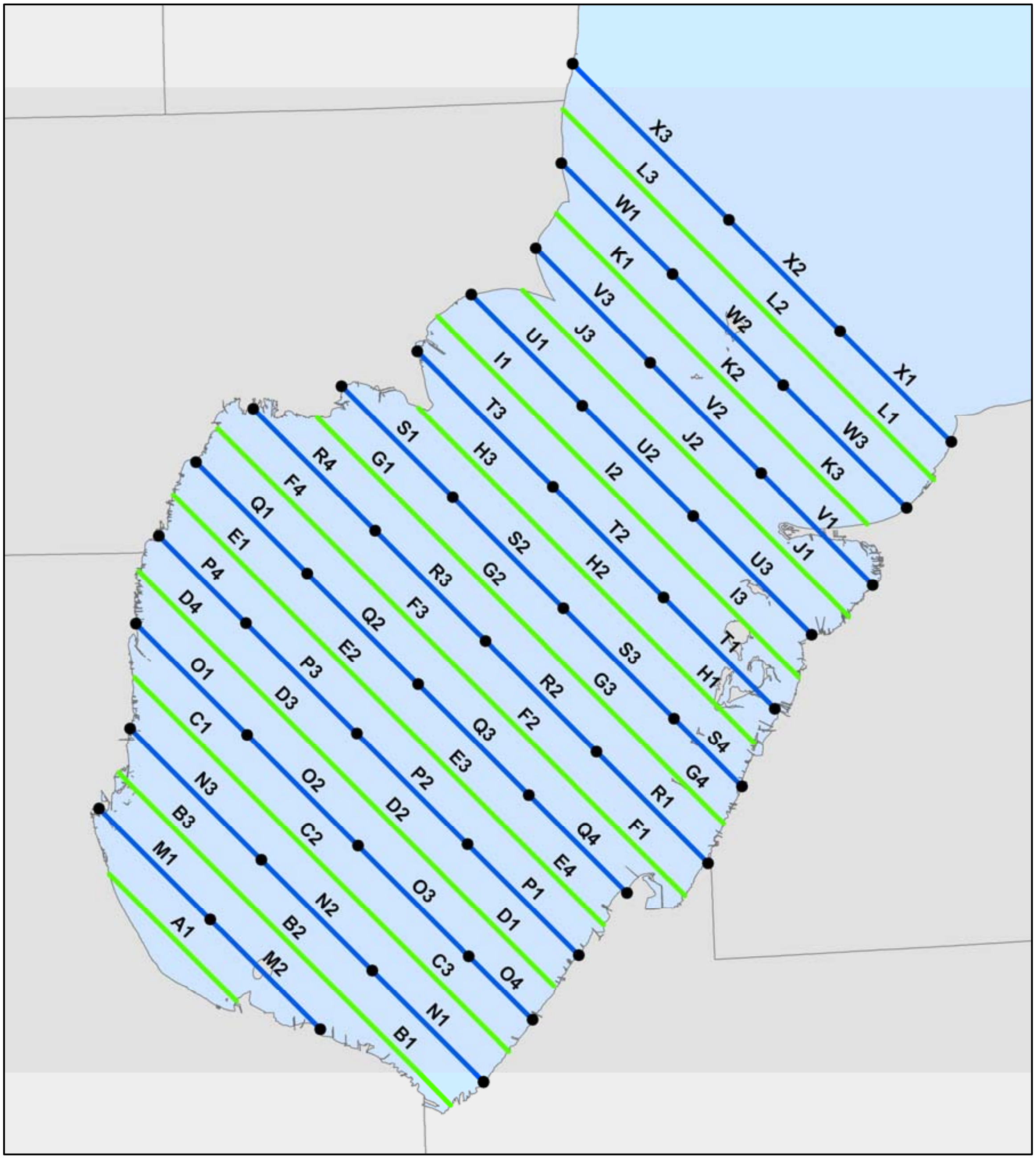

Figure 3. Study design used during aerial waterfowl and waterbird surveys conducted by the Michigan Natural Features Inventory on Saginaw Bay, Lake Huron in 2010 and 2011. Identifiers indicate transect (letter) and segment number. One set of transects (A – L or M – X) was covered during a given survey and we rotated between sets each survey.

Because there is substantial variation in migrant waterfowl and waterbird numbers across a given season, our goal was to conduct a minimum of three surveys during the peak of the fall (mid October – mid November) and spring (early March – late April) migration periods. We conducted four fall surveys between late October and early December and two spring surveys in April. We were only able to complete two spring surveys due to late thawing of Saginaw Bay and poor weather conditions.

We conducted surveys in the morning using a Partenavia P68C twin-engine fixed-wing aircraft. Surveys were flown at approximately 91 m (300 ft) at speeds of 130-200 km/hr (80-125 mph). We used four distance bands to estimate perpendicular distances of bird groups from the transects: two 100-m bands, a 200-m band, and an open-ended outer band (Figure 4). These distances were used to approximate bird group locations and create GIS data layers and could be used to estimate bird densities that incorporate imperfect detection (Buckland et al. 2001). We marked the boundaries of the distance bands on the aircraft windows using a clinometer and appropriate angles for our elevation. 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 data were recorded using a TDS Nomad handheld computer and Garmin 10 GPS receiver. Voice data were collected with Nomad units or digital voice recorders.

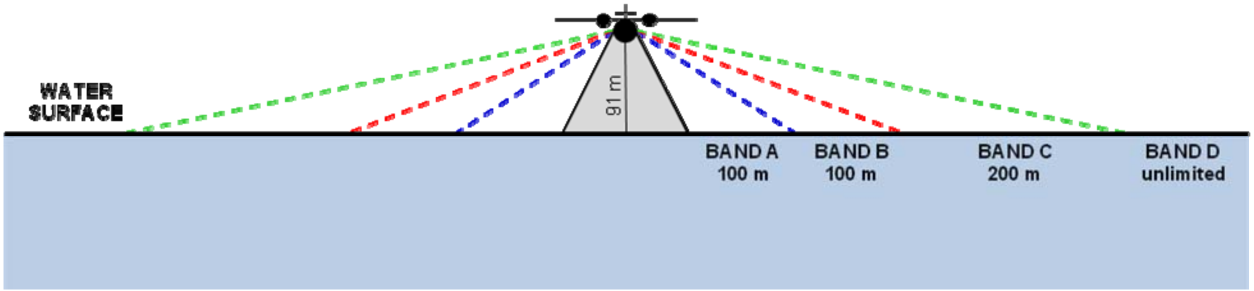

Figure 4. Distance bands used to estimate perpendicular distances of bird groups from transects during 2010-2011 aerial surveys conducted on Saginaw Bay, Lake Huron by the Michigan Natural Features Inventory.

We summarized data from our 2010-2011 aerial surveys using the same groups used for the 2006-2007 MNFI surveys, except that we combined geese and swans due to similar habitat usage. We also counted all waterbirds observed, including herons, egrets, American Coot, gulls, and terns. We estimated approximate densities (birds per ha) within each segment assuming a maximum survey distance of 1250 m on either side of the transect. We hope to refine these density estimates at a later date using distance sampling (Buckland et al. 2001) to account for decreasing probability of detection as distance increases. We approximated geographic locations of bird observations using latitude and longitude coordinates recorded using GPS 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 4), 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

Existing Waterfowl and Waterbird Data

We compiled data from previous surveys conducted by the MDNR and MNFI. The MDNR conducts weekly waterfowl surveys at state wildlife areas intensively managed for waterfowl. Data are available for two areas on Saginaw Bay: Fish Point State Wildlife Area and Nayanquing Point State Wildlife Area. We summarized data from the 2009-2010 and 2010-2011 seasons. These data provide useful information on waterfowl use of these areas and migration timing (Figure 5). These surveys provide data for all waterfowl species on a weekly basis throughout the hunting season and are available online (http://www.michigan.gov/dnr/0,4570,7-153-10363_10859-151581--,00.html).

The Coordinated November Canvasback Inventory is an aerial survey conducted annually by the MDNR in early November as part of the cooperative North American survey. This survey provides one-day counts of Canvasbacks (*Aythya valisineria*) and any other waterfowl species observed at or near traditional stopover sites. Surveys on Saginaw Bay are typically focused near Wildfowl Bay, Fish Point, Tobico Marsh, and Wigwam Bay. In 2010, 69,282 ducks, geese,

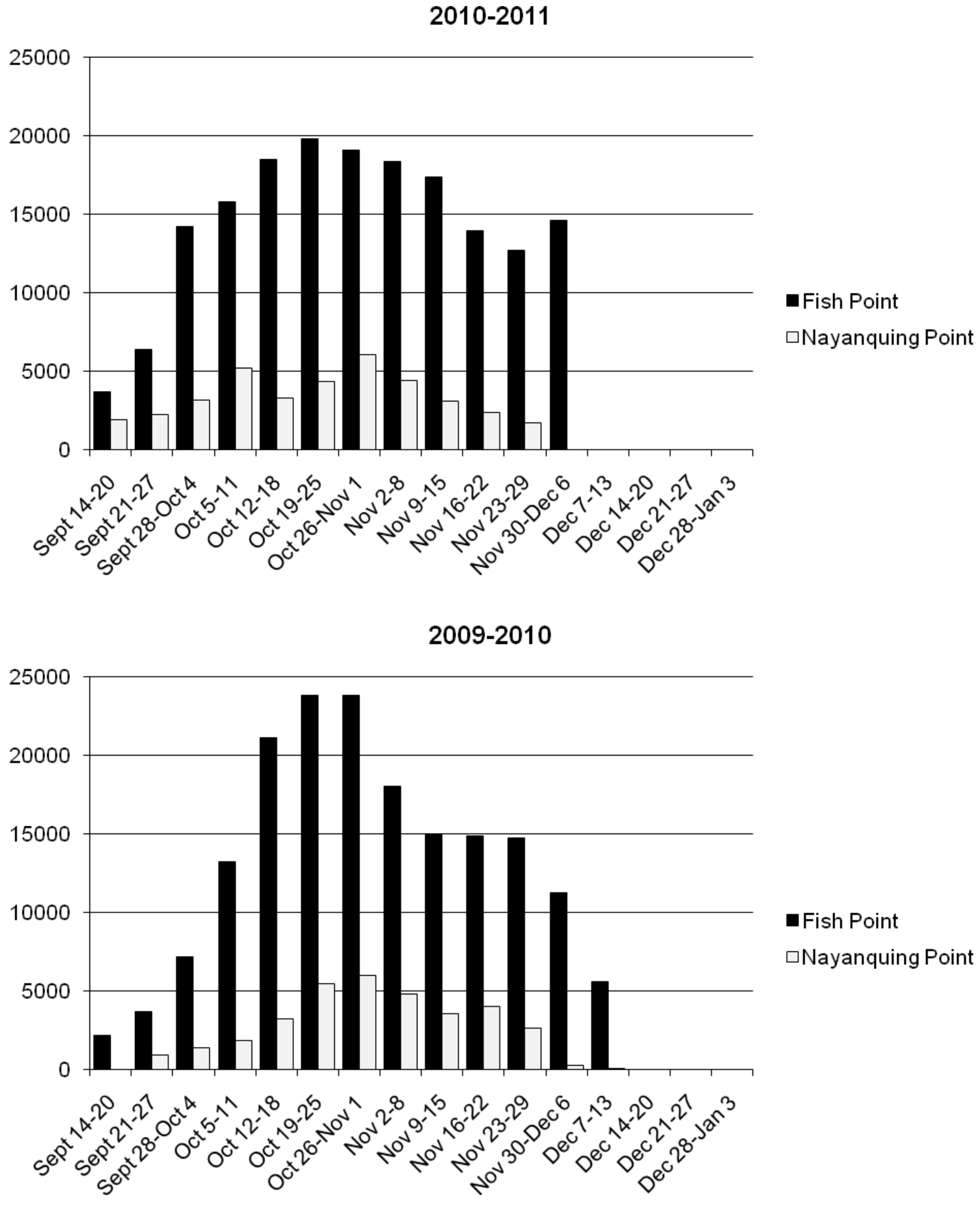

Figure 6. Total number of waterfowl observed during weekly surveys conducted by the Michigan Department of Natural Resources at Fish Point and Nayanquing Point State Wildlife Areas during the 2010-2011 and 2009-2010 fall seasons.

and swans were observed during the Canvasback survey, of which were 41.6% Mallards (*Anas platyrhynchos*), 22.5% Redheads (*Aythya americana*), 10.1% scaup (Lesser Scaup [*Aythya affinis*] and Greater Scaup [*A. marila*] combined), 7.4% Canada Geese (*Branta canadensis*), and 5.8% Canvasbacks. All other species observed made up 5% or less of the total.

We examined data from the Midwinter Waterfowl Survey for 2010 and 2011, but little data were available for Saginaw Bay. The Midwinter Survey is typically conducted in January and February. For Saginaw Bay, surveys were conducted on the ground and were limited to sites with open water, such as ponds at D.E. Karn/J.C. Weadock Power Generating Plant located at the mouth of the Saginaw River on portions of Saginaw Bay. A total of 605 birds were observed in 2011, consisting of 425 Mallards, 50 American Black Duck (*Anas rubripes*), 50 Canada geese, 50 Common Mergansers (*Mergus merganser*), and 30 Common Goldeneyes (*Bucephala clangula*). In 2010, 4,925 birds were recorded at the power plant and in open water near the Middle Grounds (Wildfowl Bay). The total consisted of 3,075 unidentified ducks, 1,000 Common Goldeneyes, 650 Mallards, 75 Canada Geese, 55 Mute Swans (*Cygnus olor*), 30 Common Mergansers, 25 American Black Ducks, and 15 Red-breasted Mergansers (*Mergus serrator*). Although this survey provides information on waterfowl wintering use of the Bay, the data are probably of limited value to offshore wind development planning.

Aerial surveys conducted by the MNFI in 2006-2007 provide additional information on waterfowl and waterbird use of the Saginaw Bay shoreline during spring, late summer, and early fall (Table 1). Transects covered several undiked marshes along the shoreline and adjacent diked wetlands located primarily within state wildlife areas (Figure 2; see Monfils 2009 for detailed descriptions of study areas). Dabbling ducks were the most abundant bird group observed during surveys across all survey periods (Table 1; Monfils 2009). Canada goose was the next most common taxa observed during spring and early fall surveys, whereas waterbirds was the second most common bird group detected during late summer surveys. Fall surveys ended before numbers of diving and sea ducks typically peak. Along with fall surveys conducted by the MDNR, the MNFI data provide information on nearshore waterfowl and waterbird use on Saginaw Bay and highlight the lack of data on offshore bird use.

Table 1. Summary results of aerial surveys conducted by the Michigan Natural Features Inventory on Saginaw Bay, Lake Huron, in 2006 and 2007 by transect and survey period.

		Spring (n = 5)			Late Summer (n = 5)			Early Fall (n = 3)		
Bird Variable	Transect[1]	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density
Total Waterfowl	FPT1	74	347	2.19	52	537	2.33	83	580	5.45
	FPT2	687	2416	4.54	86	340	0.64	42	230	0.38
	FPT3	30	196	2.23	3	152	1.31	2	49	0.49
	NPT1	60	266	3.35	1	21	0.21	10	164	1.71
	NPT2	88	322	1.58	3	44	0.18	0	19	0.09
	PIN1	236	705	1.69	8	196	0.35	282	562	1.59
	QUA1	393	1906	2.33	37	388	0.31	695	1834	2.46
	TOB1	140	568	1.96	67	130	0.55	424	688	3.44
	WIG1	101	643	3.24	5	124	0.59	37	88	0.44
	WIG2	41	190	1.14	1	9	0.03	5	44	0.20
	WIL1	573	2029	5.51	10	1008	1.84	411	1015	3.25
	WIL2	136	1931	2.10	23	194	0.43	59	148	0.35
Swans	FPT1	0	6	0.03	0	3	0.01	0	5	0.03
	FPT2	0	17	0.01	0	0	0.00	0	0	0.00
	FPT3	0	4	0.05	0	2	0.01	0	0	0.00
	NPT1	3	10	0.16	0	12	0.09	0	6	0.06
	NPT2	1	26	0.12	0	15	0.06	0	10	0.05
	PIN1	0	30	0.04	0	0	0.00	0	0	0.00
	QUA1	0	35	0.01	0	0	0.00	0	0	0.00
	TOB1	13	154	0.32	32	68	0.31	53	74	0.39
	WIG1	0	2	0.00	0	0	0.00	0	6	0.02
	WIG2	0	8	0.03	0	0	0.00	0	0	0.00
	WIL1	66	732	1.05	0	0	0.00	0	0	0.00
	WIL2	0	250	0.20	0	0	0.00	0	0	0.00

Table 1. Continued.

		Spring (n = 5)			Late Summer (n = 5)			Early Fall (n = 3)		
Bird Variable	Transect[1]	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density
Canada Goose	FPT1	7	17	0.18	0	3	0.01	0	297	2.79
	FPT2	603	1591	3.40	0	85	0.12	0	32	0.03
	FPT3	14	24	0.43	0	0	0.00	0	0	0.00
	NPT1	9	43	0.62	0	0	0.00	0	0	0.00
	NPT2	8	79	0.34	0	0	0.00	0	0	0.00
	PIN1	0	176	0.32	0	0	0.00	140	400	1.04
	QUA1	110	1252	1.09	0	278	0.13	186	378	0.56
	TOB1	2	209	0.39	0	15	0.03	0	71	0.15
	WIG1	21	450	1.93	0	31	0.05	0	2	0.01
	WIG2	5	62	0.35	0	0	0.00	0	15	0.07
	WIL1	81	1000	2.25	0	0	0.00	0	10	0.01
	WIL2	11	1362	1.15	0	0	0.00	0	30	0.03
Dabbling Ducks	FPT1	7	320	1.39	34	525	2.15	75	280	2.53
	FPT2	53	806	1.12	2	324	0.52	42	198	0.35
	FPT3	4	174	1.51	2	150	1.21	0	49	0.38
	NPT1	4	57	0.69	0	17	0.10	0	149	1.51
	NPT2	39	104	0.67	0	37	0.10	0	9	0.04
	PIN1	77	200	0.58	8	193	0.32	111	142	0.51
	QUA1	152	1063	1.19	37	187	0.18	509	1456	1.90
	TOB1	4	108	0.21	9	54	0.17	280	608	2.79
	WIG1	20	386	1.10	5	116	0.52	28	85	0.39
	WIG2	4	106	0.31	0	6	0.02	3	26	0.12
	WIL1	169	544	1.46	7	1003	1.83	399	1014	3.23
	WIL2	87	449	0.62	23	191	0.43	29	146	0.31

Table 1. Continued.

		Spring (n = 5)			Late Summer (n = 5)			Early Fall (n = 3)		
Bird Variable	Transect[1]	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density
Diving Ducks	FPT1	2	109	0.45	0	0	0.00	0	15	0.07
	FPT2	0	2	0.00	0	0	0.00	0	0	0.00
	FPT3	0	35	0.23	0	0	0.00	0	0	0.00
	NPT1	6	125	1.40	0	0	0.00	0	13	0.10
	NPT2	0	220	0.44	0	0	0.00	0	0	0.00
	PIN1	48	447	0.61	0	0	0.00	0	0	0.00
	QUA1	0	28	0.02	0	0	0.00	0	0	0.00
	TOB1	42	214	0.73	0	0	0.00	0	0	0.00
	WIG1	0	36	0.12	0	0	0.00	0	8	0.02
	WIG2	10	55	0.35	0	0	0.00	0	3	0.01
	WIL1	11	552	0.66	0	0	0.00	0	0	0.00
	WIL2	0	92	0.08	0	0	0.00	0	0	0.00
Sea Ducks	FPT1	0	18	0.10	0	0	0.00	0	0	0.00
	FPT2	0	10	0.01	0	0	0.00	0	0	0.00
	FPT3	0	4	0.02	0	0	0.00	0	0	0.00
	NPT1	0	31	0.40	0	0	0.00	0	0	0.00
	NPT2	0	0	0.00	0	0	0.00	0	0	0.00
	PIN1	9	55	0.11	0	0	0.00	0	0	0.00
	QUA1	0	17	0.01	0	0	0.00	0	0	0.00
	TOB1	37	62	0.31	0	0	0.00	0	15	0.03
	WIG1	2	11	0.05	0	1	0.00	0	0	0.00
	WIG2	1	10	0.08	0	0	0.00	0	0	0.00
	WIL1	0	30	0.06	0	0	0.00	0	0	0.00
	WIL2	0	16	0.02	0	0	0.00	0	0	0.00

Table 1. Continued.

		Spring (n = 5)			Late Summer (n = 5)			Early Fall (n = 3)		
Bird Variable	Transect[1]	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density	Min. Count	Max. Count	Mean Density
Total Waterbirds	FPT1	0	20	0.07	9	43	0.37	22	42	0.47
	FPT2	0	3	0.00	4	56	0.06	18	145	0.24
	FPT3	0	3	0.02	0	43	0.28	13	29	0.44
	NPT1	0	75	0.75	4	34	0.37	0	27	0.23
	NPT2	0	14	0.03	1	22	0.08	1	24	0.12
	PIN1	0	0	0.00	3	77	0.09	3	39	0.09
	QUA1	0	6	0.00	53	617	0.43	110	145	0.28
	TOB1	0	30	0.06	3	7	0.04	7	10	0.06
	WIG1	0	2	0.00	16	62	0.32	3	21	0.11
	WIG2	0	1	0.00	0	2	0.01	0	4	0.02
	WIL1	0	100	0.12	8	25	0.06	35	44	0.17
	WIL2	0	20	0.01	3	17	0.03	3	23	0.03

[1] Abbreviations indicate the general location (FPT = Fish Point; NPT = Nayanquing Point; PIN = Pinconning; TOB = Tobico Marsh; WIG = Wigwam Bay; and WIL = Wildfowl Bay) and transect number (see Figure 2).

2010-2011 Aerial Surveys

We conducted six aerial surveys over Saginaw Bay, of which four occurred during fall (between October 29 and December 3, 2010) and two during spring (April 13 and 21, 2011). We recorded a total of 76,293 waterfowl and waterbirds during the six surveys (mean 12,716 per survey). Our greatest single survey total was 25,891 birds on November 11, 2010. Diving ducks made up the greatest percentage (36.2%) of the total birds observed, with scaup (Lesser and Greater combined) accounting for the greatest proportion (59.6%) of the diving ducks recorded. Redhead and Canvasback were the second and third most common diving ducks, representing 22.1% and 10.3% of the total, respectively. Sea ducks accounted for 17.0% of the total waterfowl observed. Diving and sea ducks are especially difficult to identify at a distance. Because we attempted to identify all waterfowl we could see, 16.6% of the total were recorded as unknown diving/sea ducks. Thus, the proportion of the total made up by diving ducks and sea ducks was greater than those reported above. Long-tailed Duck made up the greatest proportion of the sea ducks seen (51.6%), followed by Bufflehead (*Bucephala albeola*; 28.4%) and Common Goldeneye (14.0%). Canada Goose accounted for 10.3% of the total birds recorded during surveys. Dabbling ducks constituted 7.6% of the total birds recorded. Mallard was the most common dabbling duck species making up 76.2% of the total observed, followed by American Black Duck (9.2%) and Wood Duck (*Aix sponsa*; 3.7%). Because most of the survey time is spent away from the shoreline, it is not surprising that dabbling ducks made up a small proportion of the waterfowl observed. We also timed surveys during the period when numbers of diving and sea ducks on Saginaw Bay were likely to peak, which precluded us from surveying species that tend to migrate earlier in the fall (e.g., Blue-winged Teal [*Anas discors*]). Dabbling ducks were the most common taxa observed along the shoreline of Saginaw Bay during 2006-2007 aerial surveys conducted in spring, late summer and early fall by MNFI (Table 1; Monfils 2009). Swans represented only 2.6% of the total birds observed.

Waterbirds made up only 7.9% of the total birds recorded during aerial surveys. Gulls were the most commonly observed waterbirds, making up 89.4% of the waterbirds counted. Although we did not attempt to identify all gulls to species, Ring-billed Gull (*Larus delawarensis*) and Herring Gull (*L. argentatus*) were the most common species observed. Double-crested Cormorant was the next most common species seen (7.7%) followed by Great Egret (1.3%). 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). Previous surveys conducted by MNFI in 2006-2007 indicate that waterbirds, such as Great Blue Heron and Great Egret, are common near the shoreline of Saginaw Bay (Table 1; Monfils 2009).

We estimated geospatial locations for 40,122 birds or 52.6% of the total waterfowl and waterbirds detected during surveys. Specific locations were not obtained for the remaining bird observations due to equipment malfunctions or poor GPS fixes; however, we also recorded information by transect segment, so these data were included in density estimates produced for individual segments. When data for all waterfowl taxonomic groups are combined, waterfowl locations were generally scattered throughout Saginaw Bay (Figure 6). Swans, Canada Geese, and dabbling ducks tended to be located closer to shore (Figures 7 and 8) compared to other waterfowl taxa. There appeared to be a tendency for densities of swans, Canada Geese, and dabbling ducks to be greater near the shoreline; however, densities were low for these throughout the Bay. Diving duck observations appeared to be more concentrated near the shoreline (Figure 9) when compared to sea duck locations (Figure 10). Diving ducks were often recorded further from shore compared to dabbling ducks, swans, and Canada Geese; however, they were observed more frequently overall. We regularly observed sea ducks throughout Saginaw Bay (Figure 10) and recorded them more frequently on transects located closer to Lake Huron proper than other waterfowl taxa. We recorded waterbirds in small numbers at many locations scattered across the Bay (Figure 11). Larger concentrations of gulls were observed near the Saginaw River Confined Disposal Facility (Figure 11). Patterns in use of Saginaw Bay by the various bird groups may become more apparent as more data are collected during year two of the study.

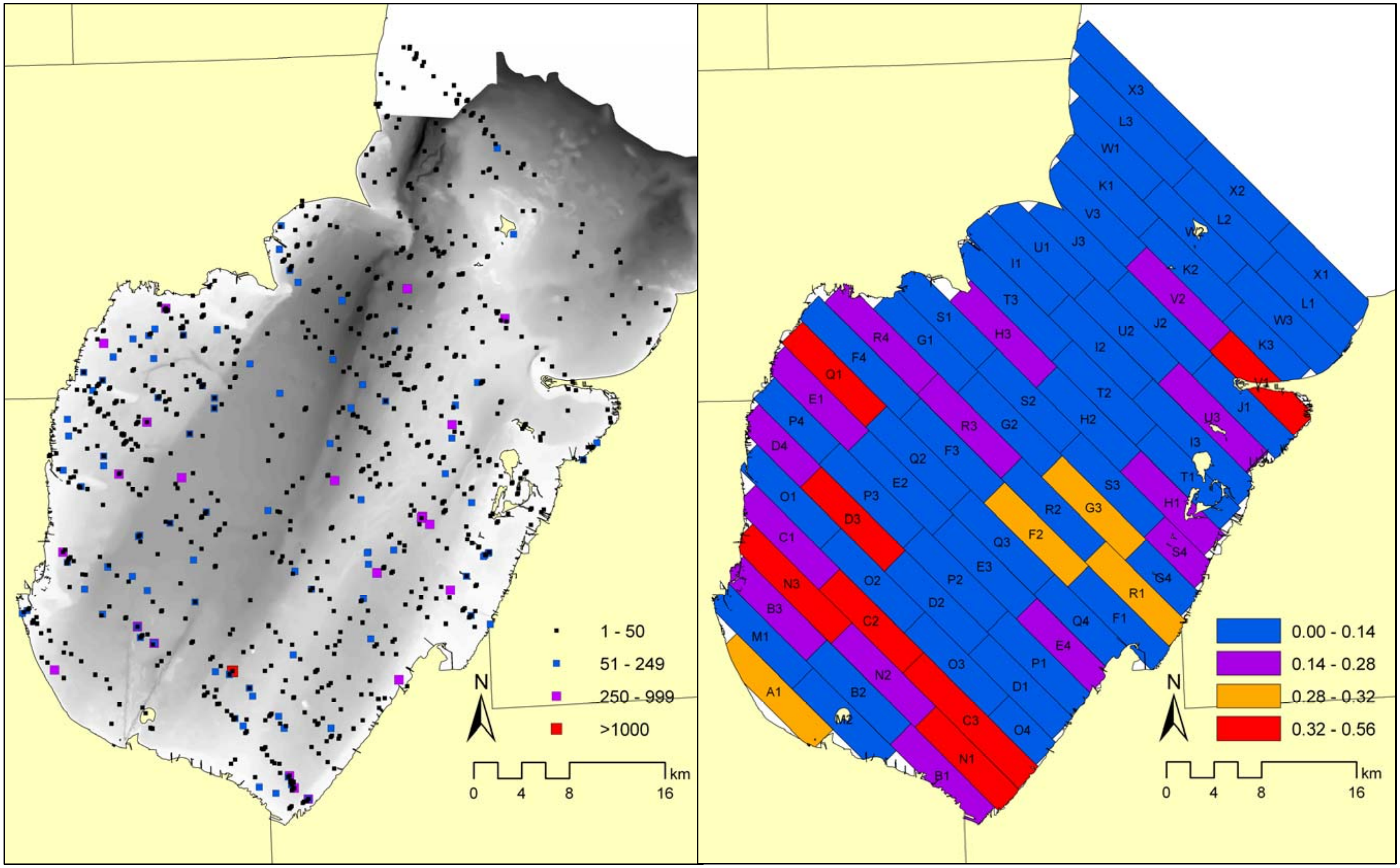

Figure 7. Approximate locations and relative abundance (left) and estimated density (birds per ha) by transect segment (right) for all waterfowl observed during aerial surveys conducted on Saginaw Bay, Lake Huron during fall 2010 and spring 2011 migration. Saginaw Bay basin contours (15 m digital elevation model) are provided on the left (darker areas indicate deeper water depths).

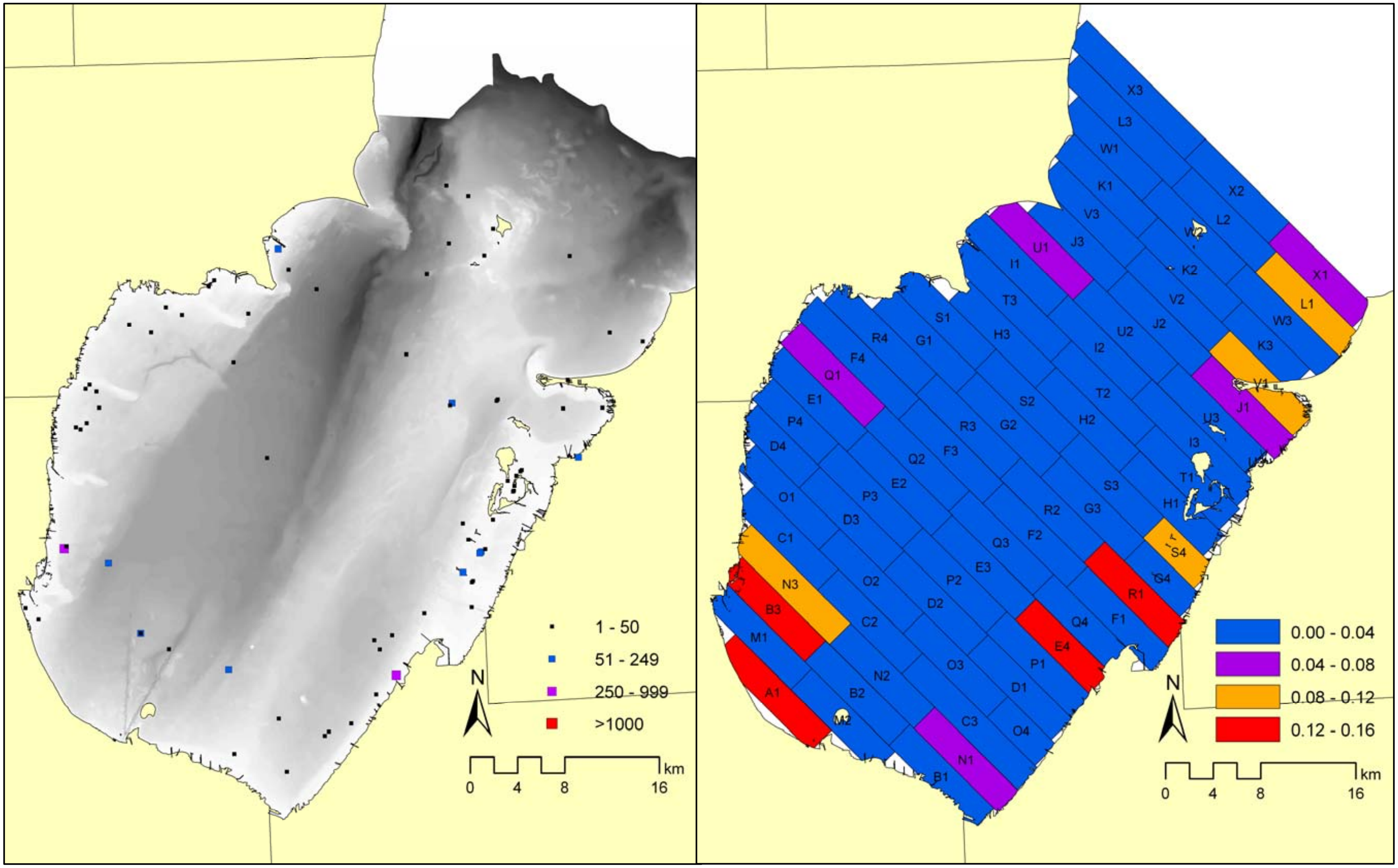

Figure 8. Approximate locations and relative abundance (left) and estimated density (birds per ha) by transect segment (right) for swans and geese observed during aerial surveys conducted on Saginaw Bay, Lake Huron during fall 2010 and spring 2011 migration. Saginaw Bay basin contours (15 m digital elevation model) are provided on the left (darker areas indicate deeper water depths).

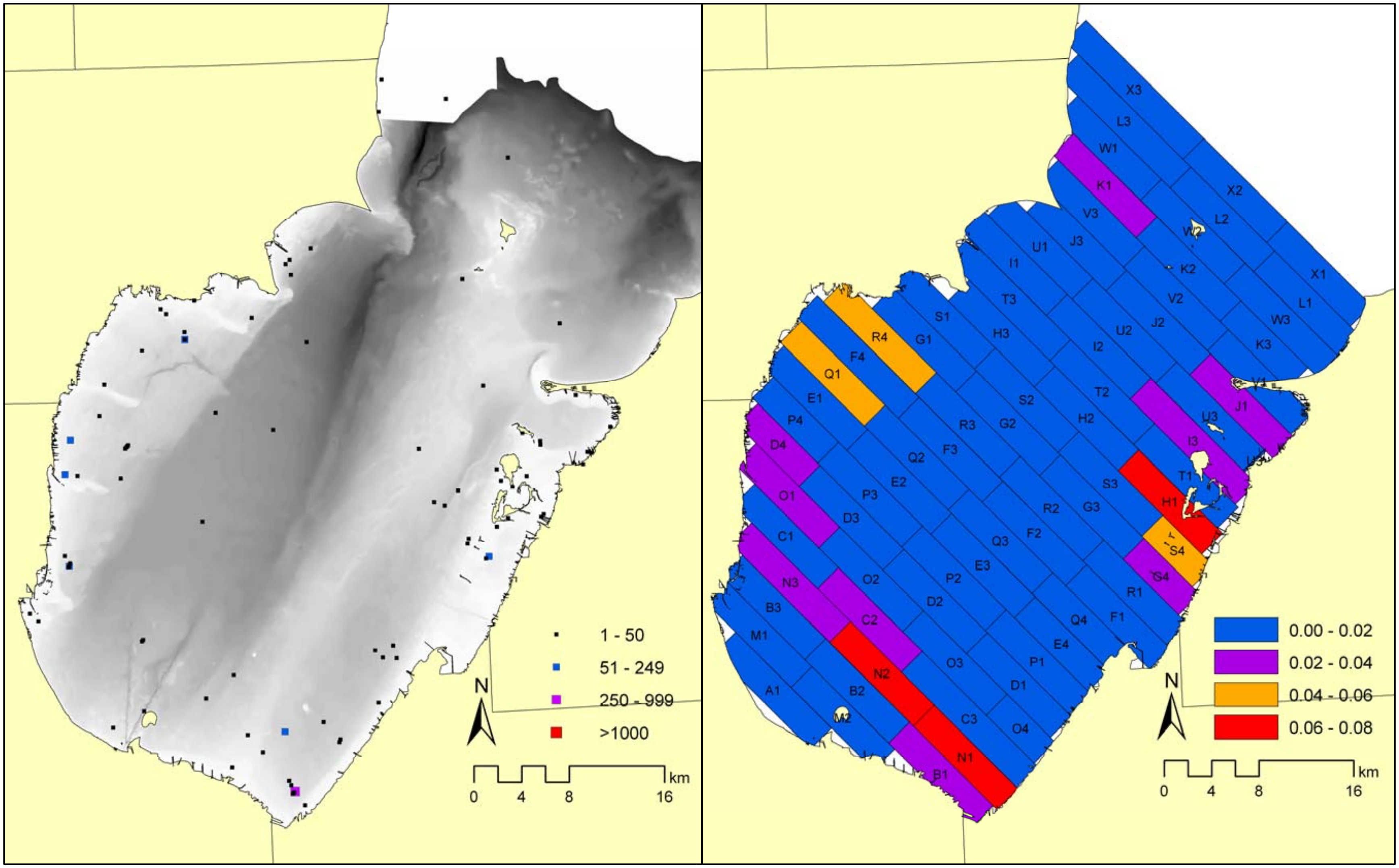

Figure 9. Approximate locations and relative abundance (left) and estimated density (birds per ha) by transect segment (right) for all dabbling ducks observed during aerial surveys conducted on Saginaw Bay, Lake Huron during fall 2010 and spring 2011 migration. Saginaw Bay basin contours (15 m digital elevation model) are provided on the left (darker areas indicate deeper water depths).

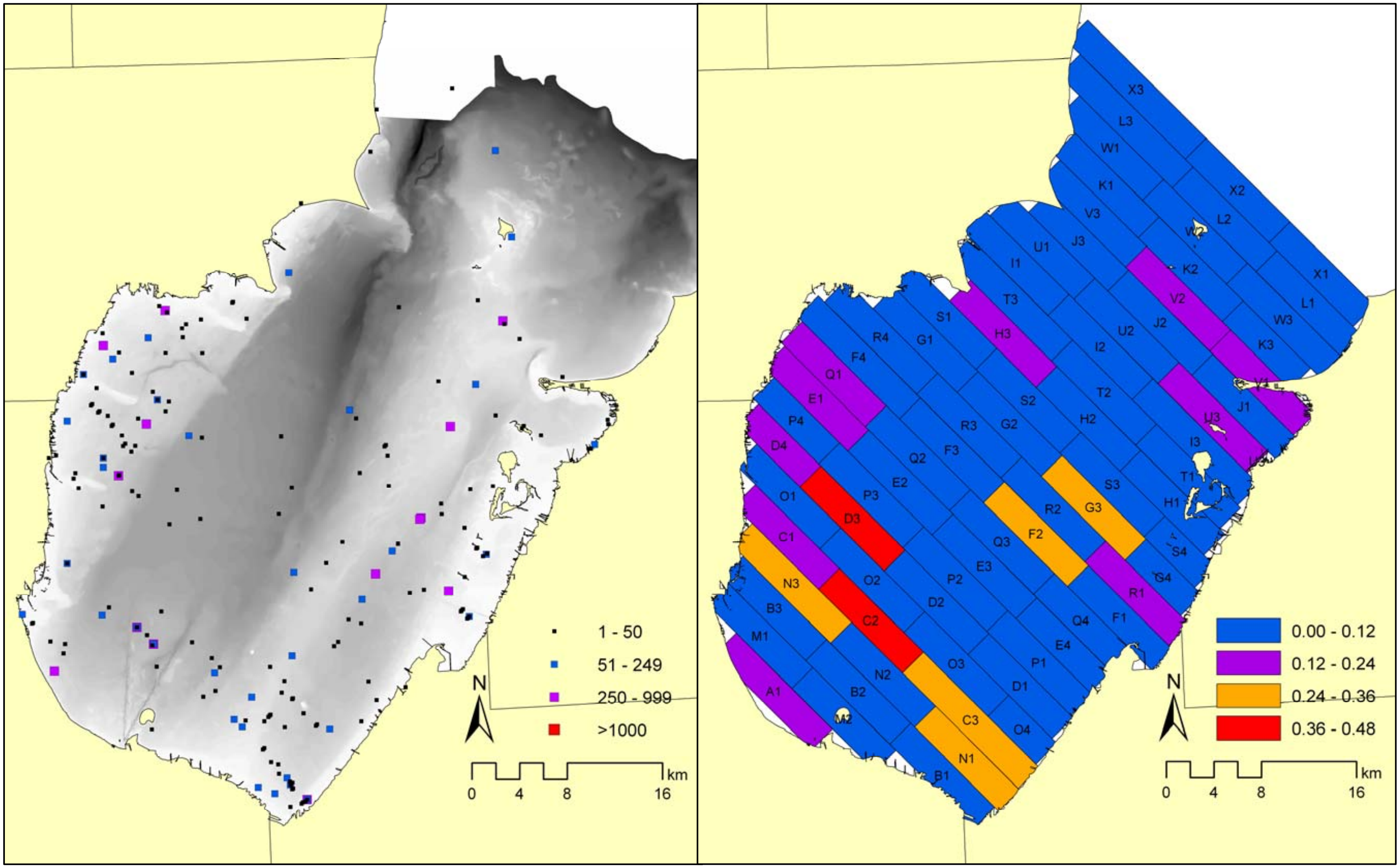

Figure 10. Approximate locations and relative abundance (left) and estimated density (birds per ha) by transect segment (right) for all diving ducks observed during aerial surveys conducted on Saginaw Bay, Lake Huron during fall 2010 and spring 2011 migration. Saginaw Bay basin contours (15 m digital elevation model) are provided on the left (darker areas indicate deeper water depths).

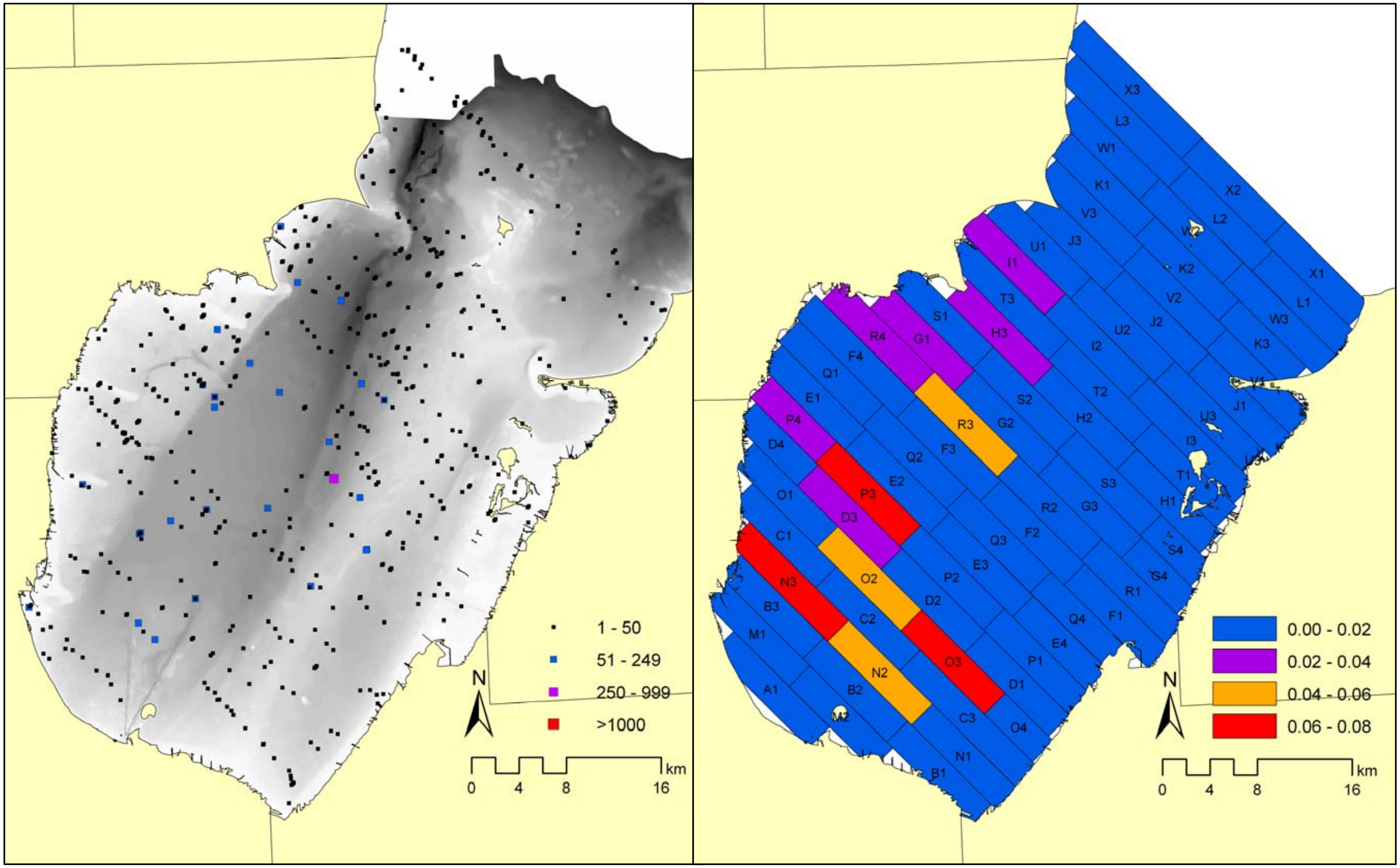

Figure 11. Approximate locations and relative abundance (left) and estimated density (birds per ha) by transect segment (right) for all sea ducks observed during aerial surveys conducted on Saginaw Bay, Lake Huron during fall 2010 and spring 2011 migration. Saginaw Bay basin contours (15 m digital elevation model) are provided on the left (darker areas indicate deeper water depths).

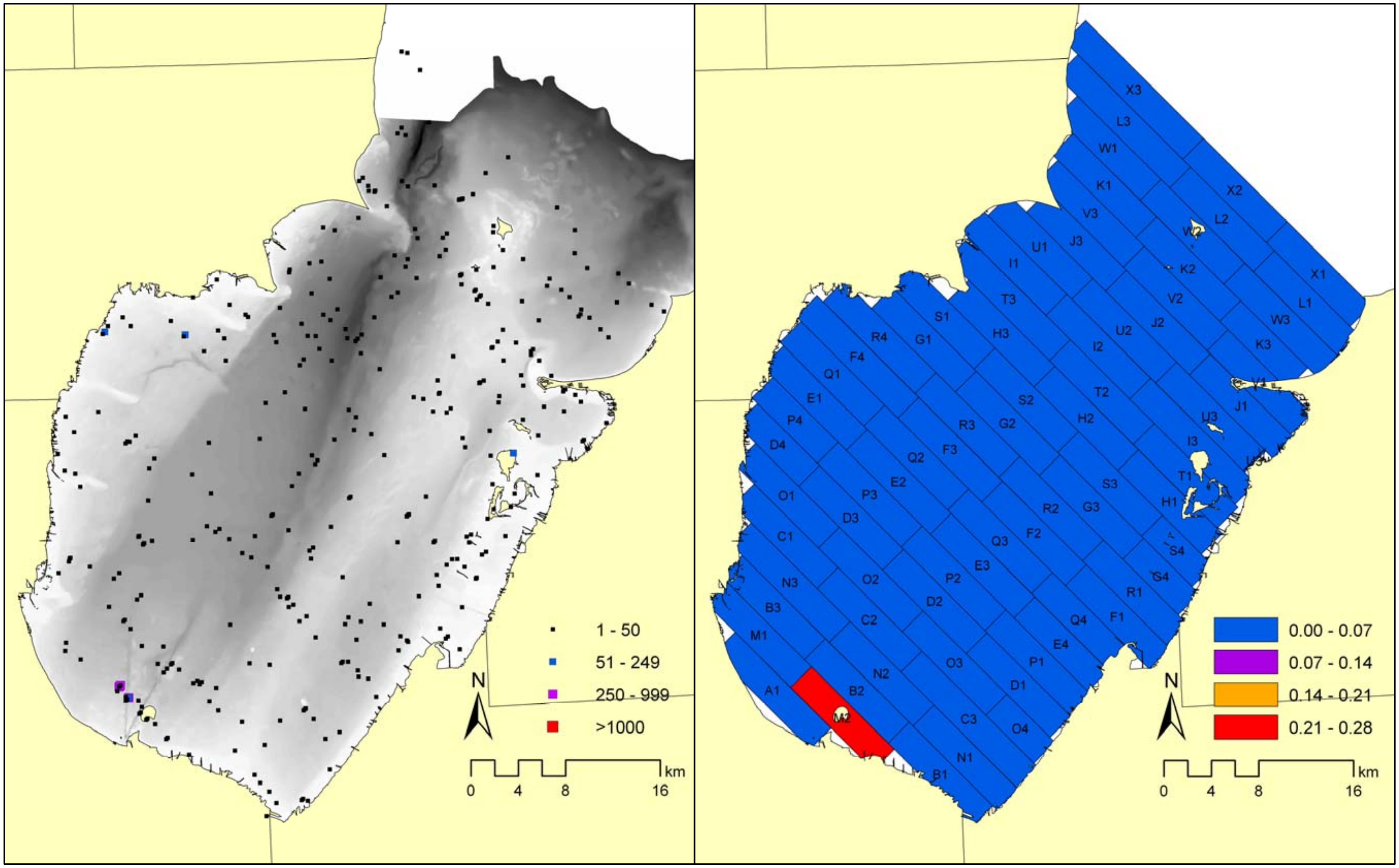

Figure 12. Approximate locations and relative abundance (left) and estimated density (birds per ha) by transect segment (right) for all waterbirds observed during aerial surveys conducted on Saginaw Bay, Lake Huron during fall 2010 and spring 2011 migration. Saginaw Bay basin contours (15 m digital elevation model) are provided on the left (darker areas indicate deeper water depths).

NEXT STEPS

During year two of this study, we plan to conduct additional fall and spring aerial surveys. These surveys will provide additional data to examine patterns of waterfowl and waterbird use of Saginaw Bay and better estimate average densities along transect segments. We will also compare use by the various bird groups between fall and spring migration periods. Because we encountered problems with our GPS equipment during our year one surveys, we will be testing a GPS data logger (Columbus V-900) to record geospatial and voice data beginning in fall 2011. This data logger has been used by others conducting similar surveys (D. L. Luukkonen, MDNR, personal communication). After completion of year two surveys, we will prepare final map products and GIS datasets incorporating both years of data.

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