Monitoring and Mapping of Avian Resources over the Great Lakes to Support Management – Phase 3

This is the final report submitted to the U.S. Fish and Wildlife Service for the "Continued Monitoring and Mapping of Avian Resources over Selected Areas of the Great Lakes to Support Related Resource Management – Phase 3" project (Agreement #F15AP00922), covering the period September 1, 2015 through November 30, 2017.

Great Lakes Commission
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Preface

The Great Lakes Commission (GLC) and the U.S. Fish and Wildlife Service (USFWS) have coordinated aerial surveys of pelagic birds over selected areas of Lakes Michigan, Huron, and Erie (Figure 1) during the fall of 2012 and spring of 2013 migration seasons (agreement #F12AC00699 funded in fiscal year (FY) 2012, referred to herein as Phase 1) and the fall of 2013 through the spring of 2014 migration and overwintering seasons (agreement #F12AC00699 funded in FY 2013, referred to herein as Phase 2).

This report is the final deliverable for Phase 3, entitled "Continued Monitoring and Mapping of Avian Resources Over Selected Areas of the Great Lakes to Support Related Resource Management – Phase 3" agreement #F15AP00922, which took place between September 1, 2015 and November 30, 2017. Phase 3 focused on supporting the development of a data management system for over-lake survey data and the development of predictive models that could use that data – ideally, to inform management decisions. Because multiple years of data will allow for better understanding of these spatial and temporal distribution patterns, Phase 3 activities integrated Phase 1 and Phase 2 with data collected by other over-lake aerial surveys. Phase 3 also includes engagement with natural resource and wildlife managers in the Great Lakes region and a broader outreach effort to disseminate project results. The outreach component involved delivering presentations and sharing project materials at regional and national conferences, publishing project products online, and engagement (via workshops and webinars) with natural resource and wildlife managers to ensure that resource management decisions and conservation management questions are were addressed.

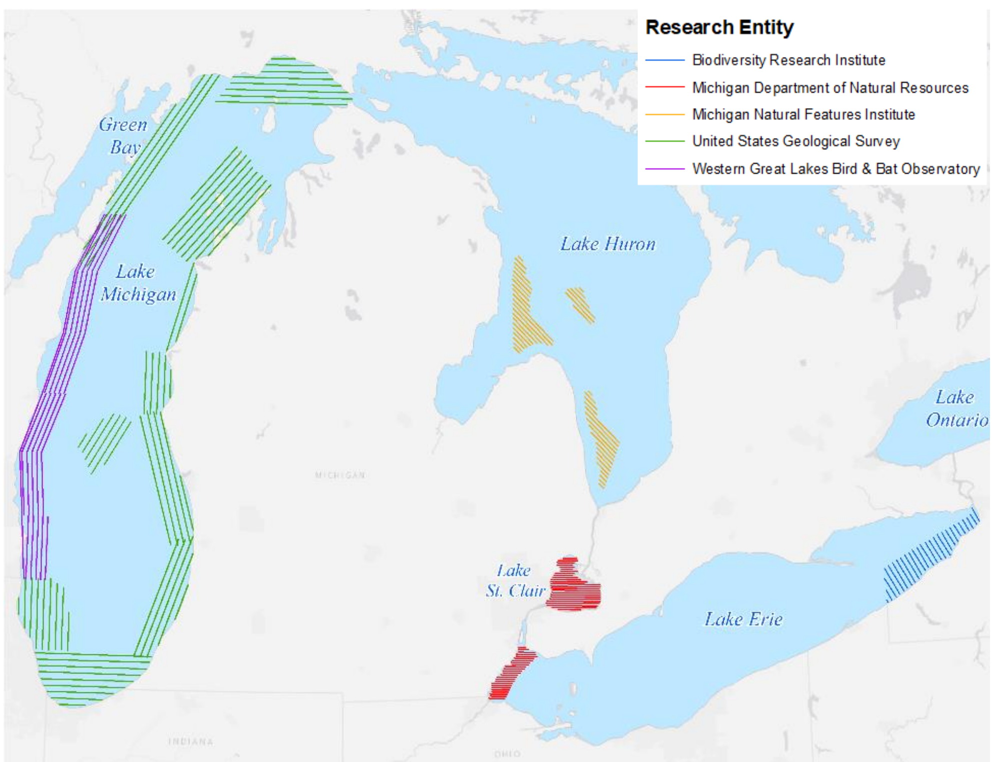

Figure 1: Aerial survey transects covered by Phases 1 and 2.

Project Rationale and Objectives

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles (including land and water), the Great Lakes region provides important breeding, feeding, and resting areas for many waterbirds. Many of the Great Lakes coastal aquatic and terrestrial landscapes that once supported migrating birds have been lost or degraded. Yet, the region supports hundreds of millions of migrants during both spring and fall migration. To assist in managing these bird populations and conserving the habitats that support them, the best information available on how these populations use the Great Lakes is needed. Armed with this knowledge, natural resource managers, conservationists, and other stakeholders can make better decisions for habitat restoration investments and identify important over-lake habitats that should be protected from human impacts.

This project was designed to answer the following research question: **How do birds use near-shore and open water areas of the Great Lakes, and how can this information be used to inform conservation and natural resource management decisions such as prioritizing areas for protection/restoration, evaluating the potential impact of proposed offshore wind-energy projects, and targeting conservation within the context of the full annual cycle?**

To answer this question, the project team executed a work plan to achieve the following five objectives:

1. Build a community of Great Lakes avian researchers under the Midwest Coordinated Bird Monitoring Partnership to share data and information, form data-sharing agreements where appropriate, identify information gaps and priorities, collaborate on future projects, and build upon the collective knowledge of bird use of the Great Lakes.
2. Inform Great Lakes conservation and management decisions by engaging natural resource and wildlife managers and subject experts in detailing needs for summarizing and using survey data within relevant decision frameworks.
3. Develop and promote the use of the Midwest Avian Data Center to manage, share, analyze, and distribute results from survey data and data collected by other research projects.
4. Develop predictive models of waterbird distributions and densities across the Great Lakes, to support decision making and conservation planning
5. Incorporate data and project results into briefing reports, the Great Lakes Wind Collaborative's Wind Atlas, the Great Lakes Information Network, the Midwest Avian Data Center, and relevant decision-making and conservation-planning tools and documents.

Methods

Regional Coordination

Regional Project Team and advisory group

The Regional Project Team (RPT) was created in September 2015. The RPT consists of: the data manager (Leo Salas, Point Blue Conservation Science); a modeling team (Evan Adams, Biodiversity Research Institute and University of Washington; Beth Gardner, University of Washington; Allison Sussman, Michigan State University; Kate Williams, Biodiversity Research Institute; Elise Zipkin, Michigan State University); a survey team (Kevin Kenow, U.S. Geological Survey; David Luukkonen, Michigan Department of Natural Resources; Michael Monfils, Michigan State University Extension; William Mueller, Western Great Lakes Bird and Bat Observatory), the U.S. Fish and Wildlife Service (USFWS), and the project manager—the Great Lakes Commission (GLC). See Appendix 1 for the final roster. An advisory group was created in October 2015 (Appendix 2), but the RPT didn't see the importance of having regular meetings of this group. Rather, members of the advisory group were asked to respond to an online survey used to identify needs (see page 12 details). Several members of the advisory group also attended the March 2016 workshop in Ann Arbor, Michigan (see page 13for details).

Subcontracts and Data Sharing Agreements

A subcontract was awarded to Point Blue Conservation Science (PBCS) for data management and integration (data management subcontractor). Subcontracts were also awarded to the Biodiversity Research Institute (BRI), Michigan State University (MSU) and University of Washington (UW) to help with data integration and to develop predictive models. In September 2017, after a change of leadership at the GLC, contracts were reviewed to include a detailed workplan, reporting form, and timeline for each subcontractor. Tasks and deadlines were not modified by the contract amendments; only the reporting requirements were modified to ensure a consistent format for each subcontractor.

Data sharing agreements were established between the Midwest Avian Data Center (MWADC) and the data providers (surveyors from Phases 1 and 2). Figure 2 provides a screenshot of the MWADC. The agreements are an important statement for data owners sharing data through MWADC, as they describe the terms under which the data should be properly used by third parties. For example, the agreement states that if data are openly shared, the user must acknowledge the provenance and intellectual property of the data in any document or manuscript stemming from it.

During the second year of the project, some of the tasks from the PBCS had fallen behind. Furthermore, because of the data issues (see page 10 for details), the modeling team had concerns about delivering the expected product by the agreed upon deadline. To rectify this situation, the GLC started to have regular conference calls with the contractors to ensure better supervision and achievement of the established goals. This allowed the project to get back on track, resolve issues with the data, and ensure the data management products would be completed on time. Once the project got back on track, we provided personalized follow-ups with team members as necessary.

Data Management

Leo Salas was the primary point of contact at PBCS. Data management was divided in several subtasks, all of which were completed by the end of the project. For each task that resulted in a tool developed by the PBCS team, feedback from the project management team (when appropriate) was requested, but minimal feedback was provided.

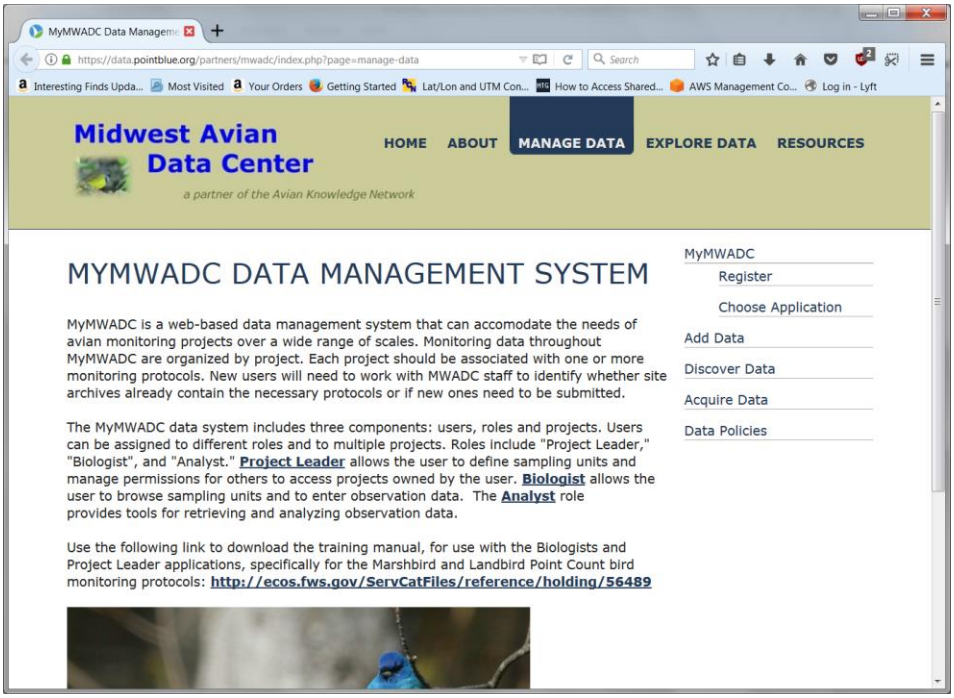

Figure 2: MWADC data management system.

Create a data warehouse

A single data table was created to aggregate the data from all surveyors in one location. This table (or warehouse) was designed to provide rapid access to the data, permit some general visualizations for reporting, and facilitate data discovery by third parties. The survey teams collected data using six different protocols and employed four different methodologies to record survey site conditions. This resulted in 11 combinations of methodologies used to collect all the data. Some of these used similar descriptions for many of the fields and for some of the fields, the definitions, metrics, and codes could be homogenized into a common definition. A single table (or warehouse) was created, housing all data from the 11 different ways in which they were collected and that can be interpreted automatically by machine-based analytical procedures and visualizations. That was achieved by using a more general interpretation of fields, with the caveat that the aggregated data would require knowledge of the individual survey protocols for imperfect-detection abundance/presence estimates. In the end, 133,945 observation records were compiled into a single table. More details are provided in the data integration section on page 10.

Table 1 below summarizes the amount of observations recorded per species for each surveyor and each year.

Table 1: Number of detections for each of the six taxa selected by the BRI/UW team, per survey protocol and year.

Survey	Year	Long-tailed Duck	Gulls	Goldeneyes	Loons	Mergansers	Scaup
WGLBBO	2012-13	399	2990	244	30	593	47
	2013-14	766	2378	646	90	463	131
USGS	2012-13	1458	707	183	949	1449	17
	2013-14	1230	1480	283	615	1076	266
MNFI	2012-13	1683	467	8	65	6	6
	2013-14	657	531	11	109	3	4
MDNR	2012-13	0	1419	0	1	3	1091
	2013-14	1	726	2	1	92	258
BRI	2013-14	10	853	17	251	424	5

Display data in multimap

The data warehouse was linked to the map tool of the MWADC to permit visualization of the aerial transect data from different types of survey protocols in that tool through a simple user interface. The locations of survey events are shown on an interactive map and the user is able to click on a location or draw a polygon to select a set of locations. The request triggers the generation of a simple summary including taxa detected and their count. The interface permits filtering by type of survey protocol, months of the year, and taxa. Several overlays of geopolitical boundaries permit querying by the following categories: state, bird conservation region, protected areas). Once a summary is generated, it can be further filtered by year. The most valuable uses of the tool are to generate quick summaries of the data and to permit others to discover data for their own uses. Figure 3 shows a screenshot of how map tool enables data visualization and discovery. The tool can be found at:
http://data.pointblue.org/partners/mwadc/index.php?page=map

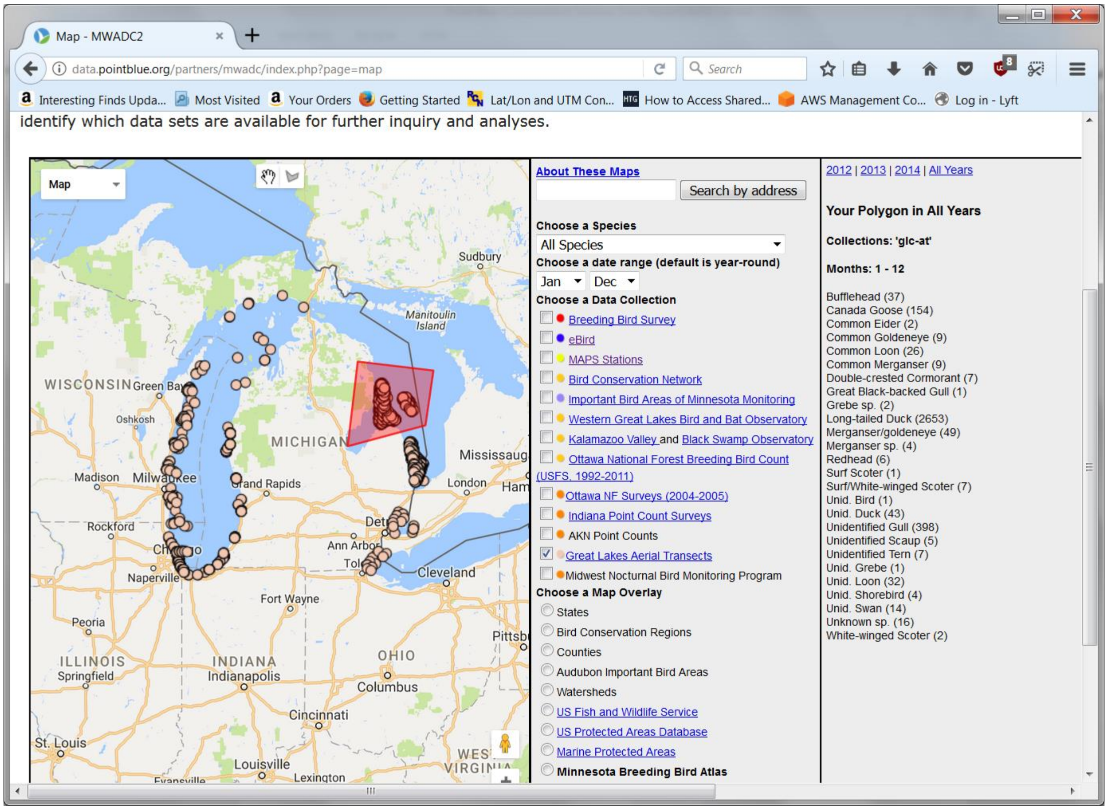

Figure 3: The Great Lakes Commission aerial transect data displayed in the map tool, selecting data within a polygon to display a summary of detections.

Create a data entry user interface for transect data

A data entry interface was created, that incorporate all the aerial survey data into the MWADC and permit the data contributors to manage their data through the data center. This required collecting the necessary descriptors of the project including persons responsible for managing the data, for entering data, and descriptors for the data itself. With those descriptors and data at hand, the necessary infrastructure was created and data was imported. Every data provider from Phases 1 and 2 was assigned its own project in the data center with project administration privileges which included defining how, where, and when data were collected; who has access to enter or update the data; who may conduct analyses or download data.

The Project Leaders tool was created in the MWADC. It is a graphical user interface that enables users to input and manage the following settings for a project:

- Create, describe, edit/delete, and download data on sampling locations using the Biologist tool
- Review (i.e., approve data entered by survey biologists), publish (i.e., assign a data sharing level), and download observation and survey event data
- Assign survey protocols to projects (i.e., specify how data were collected)
- Allow user access to projects as biologists, analysts, or project leaders
- Add new researchers to the system

Create an analyst data visualization tool

Having created a data warehouse for the aerial transect data enabled the adaptation of the Analyst tool in the MWADC to provide simple visualizations of the data. The Analyst tool is a web interface for users to submit requests for visualizations to the analysis server of the Avian Knowledge Network, Ravian, a R-language server that links data requests to analysis scripts.

The use of the tool is largely self-explanatory. The user may select one of three visualization scripts created for the aerial transect data:

- General summary: visualization includes descriptions of survey events and overall characteristics of the data selected including taxa present; number of individuals per taxon and by survey event; and diversity indices.
- Abundance: visualization provides total numbers of individuals detected by taxa across survey events, plotted by date and separately for each taxon.
- Richness: visualization provides three diversity indices by year.

The user must also specify the spatial grouping to apply to the reports, i.e. analyses of richness for a particular project and protocol for a chosen range of dates. Results may be calculated (i.e., "grouped") at the project level or at the study-area level (sampling locations are grouped in study areas, which are indeed the regions for which inferences are made with the surveys) or most atomically at the transect level.

The Analyst tool also permits the user to download the data used in the visualizations. This feature requires that the users of the Analyst tool be approved by the project leader for that role to ensure that the access restrictions set by the project leader are maintained. The tool requires user authentication via unique login and password information. The Analyst user interface is accessible at: http://data.pointblue.org/apps/analyst/home.

Create a bulk uploader tool

The MWADC is one of several geographic nodes of the Avian Knowledge Network (AKN). Some of the technologies described above were initially developed for other nodes and then adapted for the MWADC and then again for the aerial transect data. The bulk uploader is an example of that process; it was developed for the National Node of the AKN with the intention to help describe and upload legacy data to AKN nodes and to help data contributors upload data collected with desktop applications like Microsoft Excel or Access.

This tool allows users to collect data in spreadsheets and upload them into the data center. Upon uploading, data quality checks are performed, empowering the user to decide if and how many records to upload. It also permits managing the uploaded data in batches; a set of records is uploaded with some not being accepted because of violations of quality checks – the user can then review and correct any errors and re-upload the batch. This feature enables the data providers to increase the quality of the data by repeatedly editing and importing batches.

As part of this project, the bulk uploader was trained to import an example batch dataset for one of the data providers, in this case, the Biodiversity Research Institute. Because of time constraints and hoping to improve functionality, a memo was sent seeking feedback from data contributors on the possibility of using a single and common set of distance-bin definitions.

Data Integration

An important outcome of this project was the integration of data from all five data providers for surveys from Phases 1 and 2 into a single dataset and making it available to the modeling team.

There were challenges regarding assumptions about data definitions. Although effort was made to aggregate the survey data into a common format, it was not made clear that field definitions must be shared across surveyors. For example, the field “start time” was interpreted to mean either the time when the flight started or the time when the transect survey started. Because of these discrepancies, each surveyor used the reporting sheet differently. Scripts were developed to properly format the data, conformity with the data center was inspected (e.g., surveyor names existed in the data center, taxa definitions existed in the data center, etc.), and there were communications with the surveyors to correct any mistakes. This process required several iterations of describing, checking and re-uploading.

There were challenges with the spatial attribution of the data in reference to the transects. All but two surveyors included proper geospatial description (or at least in one case the data for us to generate these) of the transects. Thus, when the data indicated that the observation occurred in transect A at a distance of 200m from the airplane’s flight path, the available geospatial descriptions of the transect and of the observation permitted the exact location of the record with respect to the transect. However, one surveyor provided geospatial data for the transect and observations, but no link of observations to transects. Another surveyor linked observations to transects and geospatial data for the observations, but no geospatial data for the transects. After many iterations and scripts, the missing metadata descriptions were successfully generated for the data from these providers.

Once the single dataset was created, it was shared with the modeling team. At the March 2016 workshop in Ann Arbor, Michigan, the modeling team discovered that some of the Phase 1 and 2 survey data were not included in the compiled dataset that was provided to them. After working with data providers, another iteration was delivered in August 2016. However, problems in the data were again discovered afterwards. The data management team worked closely with the modeling team and the surveyors to resolve any issues with the data. Several iterations of the dataset were delivered, and the final one was produced and delivered to the modeling team in February 2017.

Development of Predictive Models

The modeling team was created during the fall of 2015. The team was divided in two sub-teams that each focused on one aspect of modeling. The sub-team at Michigan State University (MSU) included Elise Zipkin, an assistant professor at MSU, and Allison Sussman, a graduate student at MSU. They focused on identifying hotspots for waterbirds. The Biodiversity Research Institute/University of Washington (BRI/UW) sub-team included Beth Gardner, an assistant professor at UW, Evan Adams, an ecological modeler at BRI and UW, and Kate Williams, wildlife and renewable energy program director with BRI. They looked at covariates that could explain waterbird distribution in the region.

Data selection and organization

Species or groups of species were selected by the modeling team because they exhibited a relatively even distribution across the study area and were identified by regional managers and stakeholders as species of interest (Table 2).

Table 2: List of species or group of species selected by each modeling team

Species/Species Group	MSU	BRI/UW
Long-tailed duck (*Clangula hyemalis*)	X	X
Common loon (*Gavia immer*)	X	
Gulls (*Laridae sp.*)	X	X
Mergansers (*Mergus sp.*)	X	X
Scaup (*Aythya sp.*)	X	X
Loons (*Gavia sp.*)	X	X
Diving/Sea ducks (*Aythya sp., Bucephala sp., Clangula hyemlais, Melanitta sp., Mergus sp., Oxyura jamaicensis*, *Somateria sp.*)	X	
Goldeneyes (*Bucephala sp.*)		X

For the environmental covariates analysis performed by BRI/UW, parameters were chosen according to the literature. See Table 3 for parameters chosen and their source.

Table 3: List of covariates selected by the BRI/UW team with their source

Type of covariate	Description of covariate	Source
Wind	Direction and speed	NOAA GLERL database http://www.glerl.noaa.gov/metdata
Wave	Periodicity (waves/sec)	NOAA GLERL database (see above for URL)
Cloud	% coverage	NOAA GLERL database (see above for URL)
Bathymetry	Depth	NOAA National Center for Environmental Information database http://www.ncei.noaa.gov/
Lake bottom substrate	Type: clay, hard, mud, rock, sand, silt, unknown	NOAA GLERL contribution to the National Ice Center database http://www.natice.noaa.gov/products/great_lakes.html
Ice coverage	% coverage	Great Lakes Aquatic Habitat Framework http://www.glahf.org
Time of year	Spring, fall or winter	n.a.

Modeling

Identification of hotspots

Hotspots were determined using four different modeling approaches: two spatial approaches (kernel density estimation, Getis-Ord Gi* hotspot analysis) and two non-spatial parametric approaches (gamma distribution and lognormal distribution, both conditional on presence of the species/group). Each of these methods define hotspots differently. After running the four models on each species and species group, the team compared the consistency across the methods both visually (i.e., through maps) and quantitatively (i.e., through a correlation analysis). Results indicate that formal hotspot analysis frameworks do not always lead to the same results. The two spatial methods yielded the most similar results across all species analyzed. Yet, they found that the spatial models can differ substantially from the non-spatial models, which were not consistently similar to one another. From the four approaches explored, two fundamentally different hotspot analysis models were selected for an integrative approach: one spatial non-parametric (G*) and one non-spatial GLM-based model (hotspots conditional on presence) which were then used to estimate hotspots for the seven species groups.

Prediction of abundance and influence of covariates

A hierarchical distance sampling model was developed to address variation in survey-protocol methodology that may influence detection probability while estimating abundance across the Great Lakes. The abundance models changed slightly among taxonomic groups due to data limitations. Only lake substrate categories with greater than 5 percent of the total detections of each taxonomic group were included. Model fit was assessed using a posterior predictive check of both the detection model and the abundance model.

The expected number of animals over the entire survey area was calculated using the posterior mean estimates of the parameters. As some covariates change over time in this analysis (e.g., season), modelers selected the period when the taxon was most abundant and assumed there was no ice anywhere on the lakes so they could provide one consistent map per taxonomic group. As lake ice was found to influence the abundance of many taxonomic groups, the expected abundance will vary as ice coverage varies over the study area. The predicted number of groups was multiplied by average group for each survey area to determine the expected abundance within the prediction grid. Group-size models were too inconsistent among protocols for most species to consider using them to correct for the effects of detection probability on group size in this application.

Engagement of Natural Resource and Wildlife Managers

Stakeholders Survey

An online survey was sent out mid-December 2015 and closed mid-January 2016. 24 people from a diverse group of stakeholders responded to the survey. Nearly 60 percent of the responders were from federal or state agencies; 29 percent were from wildlife conservation organizations; 4 percent were wind energy developers; and 8 percent didn't identify any affiliation. Most responders were from Michigan, Ohio, and Wisconsin, and a few were from

Canada. Results were presented at the *Informing Great Lakes Pelagic Bird Management Workshop* and are summarized in Appendix 3.

Stakeholders Workshop

The *Informing Great Lakes Pelagic Bird Management Workshop* was held in Ann Arbor, Michigan on March 22-23, 2016 (see Appendix 4 for agenda). Over 30 participants attended the workshop, representing federal and state agencies, local government, research entities, non-governmental organizations and tribal government.

There were four main objectives to the workshop:

1. Identify management needs for which open water bird data can inform decision making.
2. Innovate with conservation managers and the regional project team the best ways to apply the project's information to support their management activities.
3. Define user interface options for the analysis tools developed by the project that will be integrated into the Midwest Avian Data Center website.
4. Gauge the need for continued data collection, monitoring, and review of impacts of management actions.

The Regional Project Team worked in collaboration to draft, revise, finalize and publish the workshop summary. The document was also shared with stakeholders registered for the workshop, as well as other interested parties. The report is available on the website (see the Events page at www.glc.org/work/avian-resources/events) and in Appendix 5.

Results Dissemination and Outreach Products

Website

The project page is hosted on the GLC website at www.glc.org/work/avian-resources.

In 2016, the GLC launched a new website with a new template for each project, including this one. This gave the team the opportunity to review the project site and identify potential improvements. The Regional Project Team provided comments on how to improve the site. These changes, mostly minor structural and/or editorial edits, have been completed.

Outreach material and presentations

Fact Sheet

At the March 2016 workshop in Ann Arbor, Michigan, surveyors were asked to present the results of phases 1 and 2 and a factsheet was developed for each of the five groups. A fact sheet was also developed for Phase 3, with the help of the Regional Project Team. All fact sheets have been published on the website and are attached to the workshop summary in report Appendix 5.

Poster

Two iterations of a poster summarizing the project were prepared during phase 3. The first one, prepared in December 2016, introduced the project and expected deliverables; the updated version of the poster was prepared in September 2017 and included results from the modeling team. Both versions are available as Appendices 6 and 7.

The posters were presented at:

- First poster:
  - Restore America's Estuaries/The Coastal Society joint meeting, New Orleans, Louisiana in December 2016
- Updated poster:
  - Great Lakes Restoration Conference (HOW), Buffalo, New York in October 2017
  - Southern Wisconsin Conservation Summit, Port Washington, Wisconsin in November 2017
  - State of Lake Michigan Conference, Green Bay, Wisconsin in November 2017

Oral presentations

The project was introduced at the March 2016 workshop in Ann Arbor, Michigan. The project was also presented at the Great Lakes Sea Duck Symposium in Port Clinton, Ohio in July 2017. These two events targeted natural resources managers and conservationists, as well as individuals from academia.

Members of the modeling team discussed their methods and preliminary results at American Ornithology 2017 – the Joint Meeting of the American Ornithological Society and the Society of Canadian Ornithologists that was held in August 2017.

A webinar was held on November 15, 2017, to discuss products developed and results from the third phase. Over 90 people attended the webinar. The recording is available on the website at: www.glc.org/work/avian-resources/events.

After the webinar, presentations from all contractors were combined in a single Power Point presentation that is also available on the website. This presentation is also available for anyone from the project team who is interested in presenting the project and results.

Other outreach products

The MSU team prepared a journal article that was reviewed by the entire Regional Project Team. The article was submitted to "Methods in Ecology and Evolution" on November 6. The BRI/UW team is also working on a journal article that has yet to be submitted.

Significant Outcomes and Experiences

In this section, we discuss results from the modeling team and lessons learned from the whole project.

Key findings

Variation in Detection and Group Size across Protocols

Covariates influencing detection probability were generally significant but had variable effects across taxonomic groups (Table 4). Overall, east-west winds significantly affected detection for five taxa and north-south winds affected three. No consistent patterns were found between these two covariates across species, high direction winds appear to affect viewing conditions differently across species. Increased cloud cover negatively affected detection probability in four species and positively affected detection in one. Decreased light from increased cloud cover could make it difficult to see species on the water, though increased detectability in similar conditions could be benefit some species where detection is difficult due to glare. Increased wave periodicity (lower frequency of waves) negatively affected detection in three taxa and positively in one. Increased wave periodicity is correlated with calm sea states, so decreased detection probabilities under calm conditions seems unlikely despite our empirical evidence otherwise. Remotely sensed environmental conditions can be inaccurate and perhaps we are seeing some evidence of systemic bias in this covariate.

Table 4: Posterior means for detection parameters from the multi-protocol detection model.

	Long-tailed Duck	**Gulls**	**Goldeneyes**	**Loons**	**Mergansers**	**Scaup**
East-West Wind	0.03	0	-0.02	-0.08	0	0.04
North-South Wind	-0.06	0	0.05	-0.02	-0.03	0.01
Cloud Cover	-0.11	-0.01	-0.08	0.17	-0.11	0.01
Wave Periodicity	0.01	-0.02	-0.17	-0.12	0.14	0

Group size models also varied significantly between protocols and taxa. Negative trends (indicative of detection bias related to group size) were consistently seen in Long-tailed Ducks, but all other species showed a mix of both positive and negative trends across study areas. Positive trends in the relationship between detection probability and group size are indicative of underestimation of group size for distant observations. This relationship did not vary consistently by surveyor so there was little evidence that certain protocols consistently under- or over-estimated distant group sizes, just that surveys were inconsistent in their estimates of group size across taxa groups.

Hotspots and impact of environmental covariates

Table 5 summarizes the results for the hotspot analysis, and figure 4 shows the map of hotspots for the all-species-combined group. The top row shows the percent of all grid cells surveyed (out of 1767) within each lake. When comparing across the lakes, it is important to note percentages are relative to the number of grid cells surveyed within each lake. Bold font indicates that the percent values are greater than the proportion surveyed in that lake and indicate more hotspots than would be expected by chance for a particular species group in a particular lake.

Table 5: Percent hotspots within each lake for each species/group and the all-species-combined group.

Species	Lake Huron	Lake Michigan	Eastern Lake Erie	Western Lake Erie	Lake St. Clair
Percent of all cells	8.83%	79.12%	5.43%	2.38%	4.24%
All-species-combined	4.30%	65.38%	5.20%	**8.14%**	**16.97%**
Diving/Sea Ducks	6.79%	64.25%	3.62%	**8.37%**	**16.97%**
Gulls	1.58%	69.91%	**13.57%**	**7.24%**	**7.69%**
Long-tailed Duck	**18.33%**	**81.67%**	0.00%	0.00%	0.00%
Mergansers	1.13%	62.67%	**13.57%**	**7.69%**	**14.93%**
Scaup	7.22%	66.30%	4.81%	**7.78%**	**13.89%**
Loons	4.73%	79.05%	**15.99%**	0.23%	0.00%
Common Loon	3.39%	78.51%	**17.87%**	0.23%	0.00%

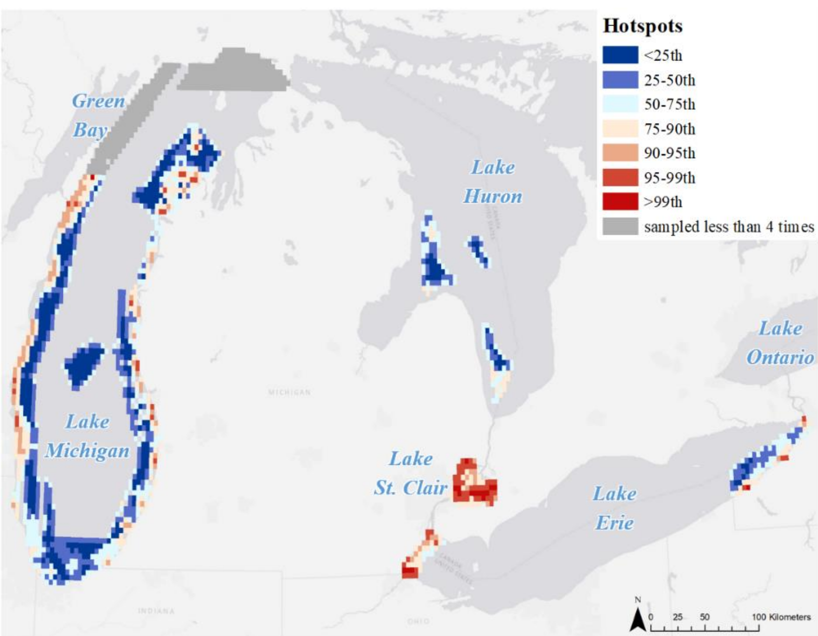

Figure 4: Potential hotspots across all sampled locations for all species combined. Grid cells sampled less than four times were excluded and shaded in grey. Individual species map available in Appendix 8.

Results of the covariates analysis are summarized in Table 6. Only the means are shown in this table. The complete table (including 95 percent CI) is available in Appendix 9.

Table 6: Analysis of covariates.

Response	Parameter	Long-tailed Duck	Gulls	Goldeneyes	Loons	Mergansers	Scaup
Zero-inflation	Intercept	1.1	0.3	-1.3	-0.5	-0.6	-1.3
	Longitude	1.1	-0.8	-1.1	0.1	-1.2	0.9
	Longitude^2	0	0.4	0.7	0.1	0.5	-0.5
	Ice Coverage (95%)	-1.1	-0.7	-1.8	0.6	-0.6	0.8
	Season -- Fall	-1.7	1.1	-2.3	0.2	-1.2	-0.1
	Season -- Winter	0.1	-0.4	0.9	-1.4	-0.4	-0.1
Abundance	Intercept	-2.4	-1.7	-3.5	-2.1	-2.4	-2.8
	Substrate -- Clay	1.5	0.6		0.3		
	Substrate -- Hard	1.7	0.6	1.9	0	1.8	1.1
	Substrate -- Mud		1.1		1.8		
	Substrate -- Sand	1.7	0.9	1.4	0.8	0.9	0.5
	Substrate -- Silt		0.3				
	Bathymetry	-1.3	-0.6	-2.4	-0.8	-2.1	-1.2
	Ice Coverage	0.2	0	0	-0.5	0.1	0

Bathymetry

The combined hotspot model shows that Lake St. Clair and western Lake Erie have more hotspots than could be expected relative to the number of grid cells surveyed in these two lakes. Therefore, they are critical locations for many waterbird species and should continue to be monitored and managed, especially when considering future conservation objectives. On average, these two lakes are the shallowest, even at their maximum depth, of all lakes in the Great Lakes region. Covariate analyses also showed that bathymetry and lake bottom substrate were important to estimating abundance for all species. Increasing water depth negatively affected abundance across all taxonomic groups (Figure 5), but there was significant variation in the negative relationship between water depth and abundance across taxa. Gulls and loons showed the smallest negative effect of increasing water depth while goldeneyes and mergansers had the largest effect. Long-tailed Ducks and Scaup appeared to fall in the middle of the other two groups. Increasing water depth has a negative effect across all groups, but there is ecologically important variance degree at which abundance decreased at higher water depths.

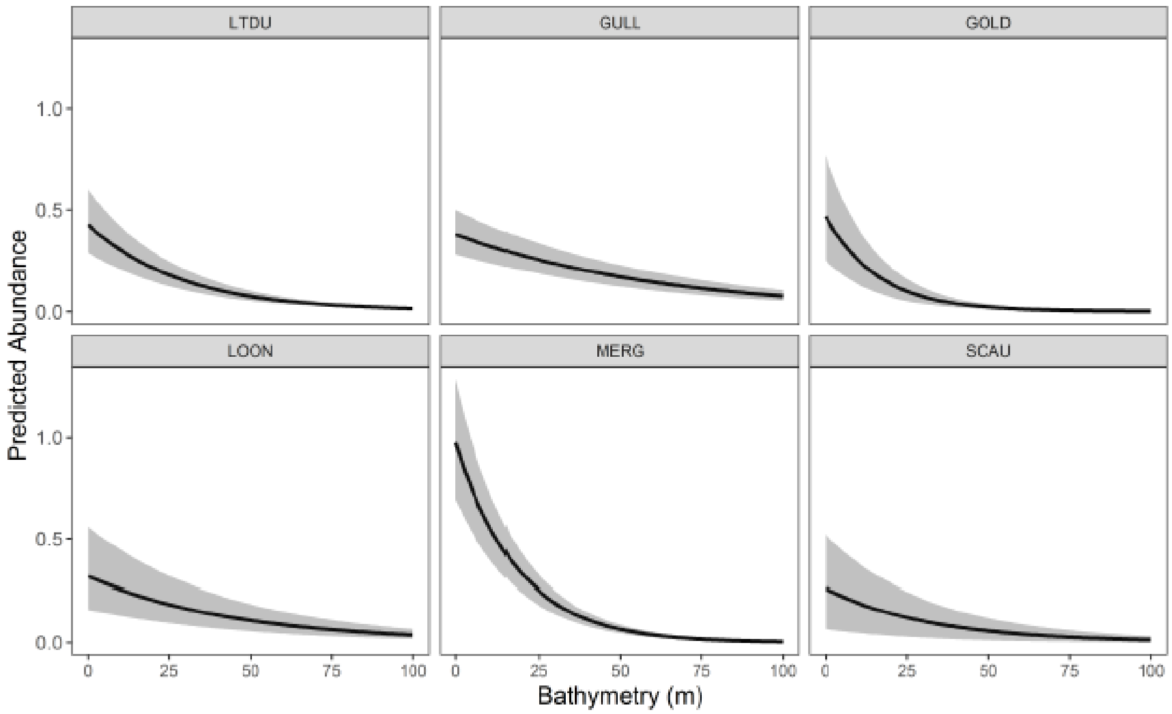

Figure 5: Relation between bathymetry and abundance

Higher amounts of food resources are often found in shallower waters so more groups in these habitats likely indicates a response to this pattern (Jones and Drobney 1986; Schummer *et al*. 2008). Increased water depth can limit accessibility for some waterbirds. Diving depth varies across species and benthic foragers need to be able to access the lake bottom substrate for successful foraging (Colwell and Taft 2000). The shallow water depths provide vital food and habitat resources for nesting colonial birds, migrating waterfowl and other waterbirds (Riffell *et al*. 2001; Monfils and Gehring 2011). For example, during the breeding season, female gulls have been shown to forage in nearshore and intertidal areas where prey species aggregate, resulting in less time spent traveling to and from the foraging area (Fox *et al.* 1990). By doing so, they can make more trips, and return to their young faster, leaving them unprotected less often than if they foraged further offshore. Taxa differences in their correlation to bathymetry represent a combination of foraging habitat preferences and water depth limitation.

Coastal wetlands have experienced increased degradation due to construction and development, destroying valuable habitat for wildlife, particularly waterfowl (U.S. Environmental Protection Agency 1995). Despite the urbanization along the coasts, many waterbird species are using the coastline by congregating in areas with remaining suitable habitat. Shallow areas nearshore provide more foraging opportunities and easier access to prey items than deeper offshore waters. Identifying locations of high-use along the coastline can help determine areas in need of protection from future development.

Substrate

Sediment type was also important to waterbird abundance (Figure 6). More widely distributed species had estimates of abundance for a larger number of categories, and the way to parameterize categories for each species led to most substrate types showing positive relationships with abundance. The substrate type described in almost all of these cases was found to be more important than that species' selection of miscellaneous substrate types. In terms of the habitat itself, sandy substrate was a consistently positive influence on abundance for all six species and hard bottoms were positive for abundance in all taxa except loons. It is likely that lake bottom substrate influences waterbird distributions for each group due to changes in macroinvertebrate abundance with substrate type (Stewart *et al*. 1998; Schummer *et al*. 2008). Benthic macroinvertebrates can still vary over small spatial scales and time across substrate type (Schummer *et al.* 2008), but results show the importance for benthic habitat in predicting large-scale patterns of presence or abundance.

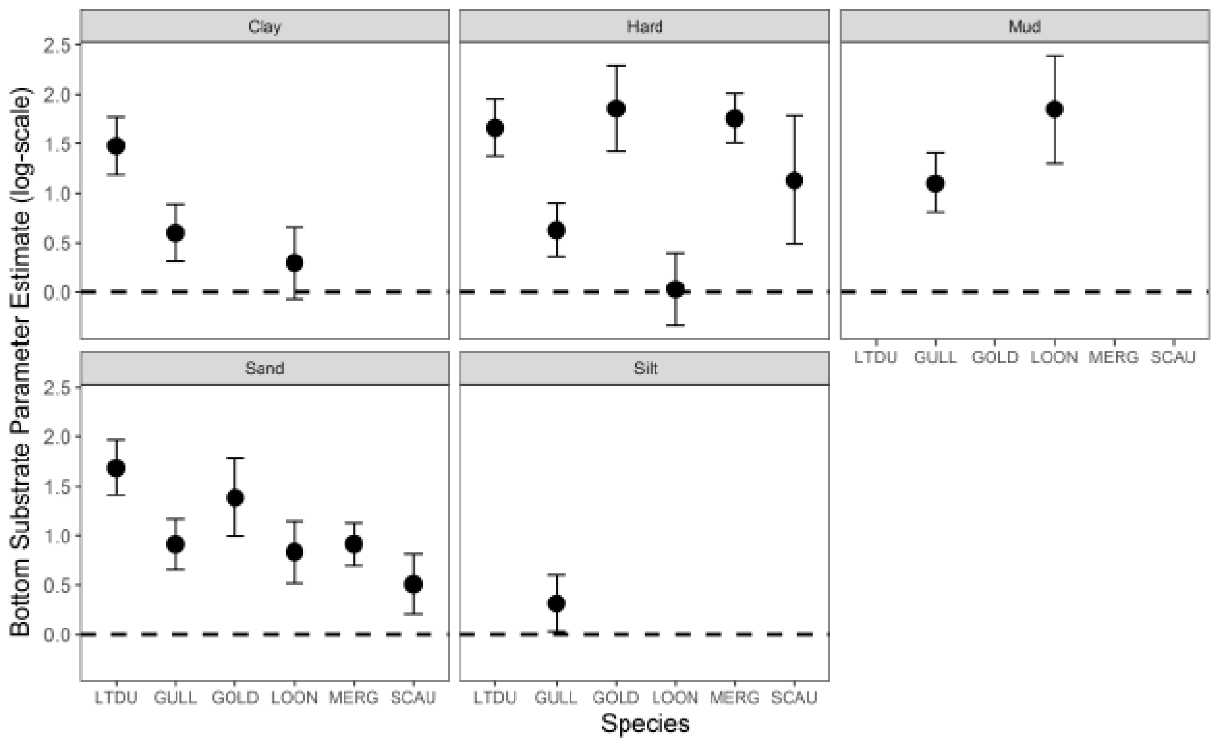

Figure 6: Relation between substrate and abundance

Ice coverage

Ice coverage was included as a variable that affected both probability of presence and abundance, so both must be considered when assessing the effect of this variable. When both parameters are considered, there is a non-linear affect for most species (Figure 7). There are a few general types of response to ice coverage: an increase with ice coverage until a decrease after completely frozen (Long-tailed Ducks), a decrease with ice coverage overall (loons), little to no effect of ice coverage until a decrease after completely frozen (gulls, goldeneyes, and mergansers), and little to no effect with a small increase after completely frozen (scaup). While statistical significance of both ice-related parameters varied among taxa, species with the largest ecological responses to ice were Long-tailed Ducks and loons, while most other species exhibited smaller or less consistent effect levels. One species, scaup, showed a relationship that indicated more birds were present after the area was completely frozen, and while this effect was relatively small it was statistically significant and could indicate inaccuracies in our estimates of ice coverage.

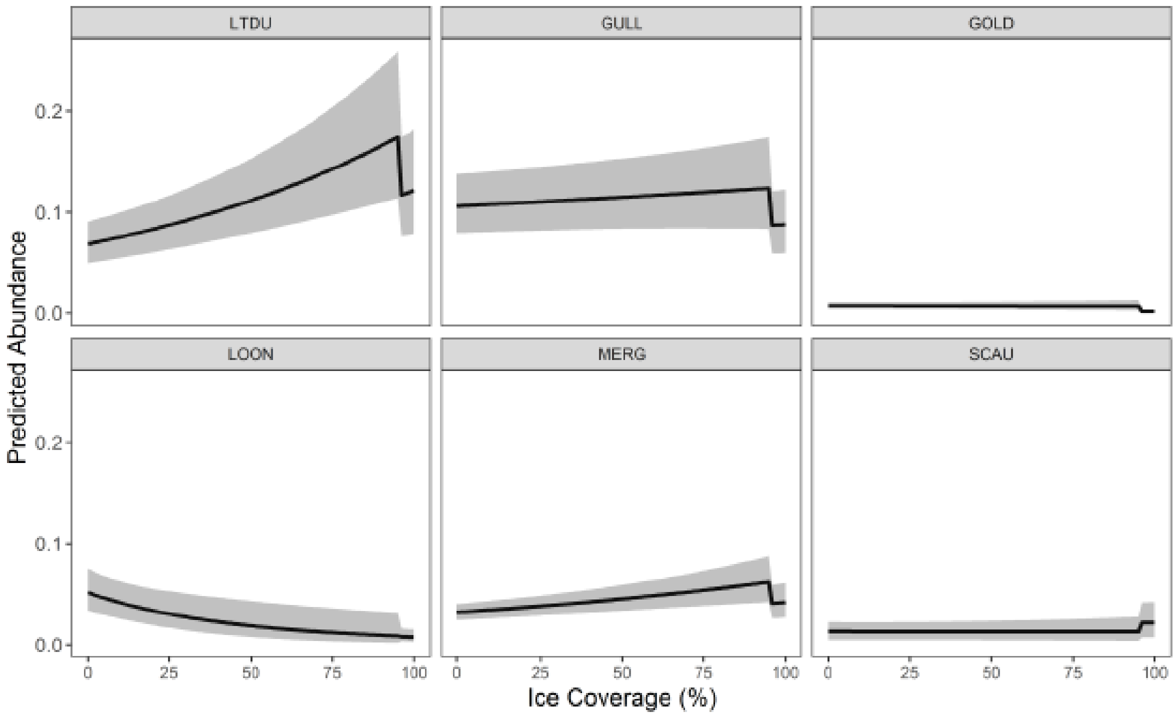

Figure 7: Relation between ice coverage and abundance.

Ice coverage is an important factor for predicting species abundance for five taxa groups based on the detection-naïve models. Ice coverage can reduce accessibility to benthic food resources for diving ducks which usually causes birds to move away from the site to find other food resources (Hamilton *et al*. 1994, Mitchell and Bailey 2000), and can cause large-scale population mortality events in extreme cases (Suter and van Eerden 1992). Similar processes are occurring in the Great Lakes where higher amounts of ice prevent access to benthic food resources and animals are moving away from these sites. Long-tailed Ducks and mergansers showed a non-linear relationship with ice coverage where they increased abundance with increasing coverage until the area was completely iced over and abundance decreased.

Complete ice coverage still negatively affects expected abundance but a positive trend with ice coverage suggested that a mixture of open water and ice could be preferred habitat in some cases (e.g., Gilchrist and Robertson 2000). Scaup populations showing an increase with >95 percent ice coverage could technically be possible (as 5 percent of the lake is available to them), but it is more likely that the estimates of ice coverage are spurious for this taxon. Ice coverage is estimated at the daily time scale and ice coverage could be changing at smaller time scales and increased ice coverage could be artificially increasing the number of groups by decreasing the available locations for animals to congregate. Despite these possibilities, the fact that there is a negative impact of ice coverage consistently affecting the number of groups across multiple taxa suggests that it is an important determinant for non-breeding distribution and abundance of Great Lakes waterbirds at a large spatial scale.

Time of the year

All taxonomic groups had many significant effects from the abundance model (Table 6). Gulls and loons were most likely to be present in fall; goldeneyes and Long-tailed Ducks were most common in winter; and mergansers and scaup are most common in spring. Dynamic environmental covariates like season and ice coverage can have an impact if animals are present to utilize the resources correlated with depth and lake bottom substrate. Most taxa groups can be present throughout the entire non-breeding season in Great Lakes waters with only loons and only during migration (Barr *et al*. 2000, Evers *et al*. 2010). Loons show the greatest decrease in the probability of presence during the winter season, so the models suggest a similar pattern. Still, even resident population sizes are expected to change throughout the non-breeding season as migratory populations of taxa groups pass through the study area and if animals move outside the study area in response to environmental conditions like changes in food availability. Gulls can use both onshore and offshore food resources, so their ability to move in and out of the study area is great; seasonal differences in year-round species are likely to produce changes in total population size due to seasonal migration and using other lake habitat that was not surveyed.

Lessons learned

Impacts of dataset problems

The original project workplan was developed under the premise that the data from phases 1-2 provided to the team would be ready to be used once integrated; this was not the case. The work of the modeling team was impacted by the issues with the dataset. The original dataset was delivered at the beginning of the project in the fall of 2015, but at the March 2016 workshop in Ann Arbor, Michigan, the modeling team realized some data was missing and they were working with incomplete information. A new iteration of the dataset was delivered to the team in August 2016, but there were still some issues (e.g., missing data, incorrect survey dates, wrong format for coordinates) and the data management team has had to revisit it several times since. An additional revision to the final database was released on February 18, 2017. While the data management team was putting a lot of effort into correcting the problems, the modeling team had to spend a considerable amount of time to review the dataset before being able to use it. Work that has been done while waiting for a revised dataset helped the modeling team making decisions about species and scale, but any change in the dataset had consequences on these efforts. Running a model can take several days and because of the issues encountered with the dataset, the modeling team had to redo some of the models several times. Working with incomplete data and the need for multiple iterations of the dataset resulted in the modeling team having to work significantly harder to be able to complete their respective modeling on time. To help cover the additional costs arising from these challenges, GLC amended subcontracts with the modeling team to provide some additional funding.

For future work, it would be ideal if the dataset was complete, accurate, and error-free before beginning the project. The issues with the dataset resulted in additional work (even duplicate or triplicate) that could have been avoided if quality control had been conducted before delivering the dataset. Furthermore, the data integration component of the project should have been scheduled prior to the beginning of the modeling phase, to ensure a better work flow.

Quantity of data

The data provided to the modeling team was the result of surveys from phases 1 and 2 which took place during the non-breading season in 2012-2013 and 2013-2014. Many individual observations were provided to the modeling team, but the overall amount of data available was lower than expected.

Ideally, hotspots should be identified for each species group by season, as distributions vary throughout the year. However, the quantity of data available can prevent the identification of seasonal hotspot patterns. The likelihood of detecting false hotspots, or failing to detect hotspots when they are actually present, decreases as the number of sampling events increases (Kinlan *et al*. 2012). While the data spans three seasons (fall, winter, and spring) over two years, there were not enough unique sampling events to break down the data into seasons. Zipkin *et al*. (2015) found that at least 40 sampling events are necessary to have adequate statistical power to detect species-specific seasonal hotspots for the most prevalent species and more than 100 sampling events for less common species. The sampling scheme in the analysis was uneven across the study region, ranging from one to 29 sampling events, and even the areas with the most surveys did not reach the minimum suggested number of sampling events. In the analysis, all surveyed grid cells were included, regardless of the number of sampling events. For covariate analysis, the multi-protocol model was not particularly robust compared to small sample sizes in some protocols. While having more than ten observations appeared to be a reasonable threshold, including protocols with less data could lead to spurious model results. There appeared to be identification problems with the model for surveys where very few birds were found. Specifically, the model was not able to resolve the reason for the low number of zeroes: whether detectability was very low or there were no animals present. The current model formulation used in this project is expected to perform well for integrating data from multiple protocols when at least ten observations are found in all protocols.

To utilize all available data, species were grouped at higher taxonomic levels and analyses were conducted by species group rather than being species-specific, meaning that more than 20 percent of all observations were not identified at the species-level. Results for species groups are useful, but for species-specific concerns and conservation and management decisions, the group level analysis may not be ideal. For example, the combined hotspot model demonstrates that long-tailed ducks do not exhibit the same pattern of aggregation as the diving/sea ducks within the Great Lakes region. Therefore, it is reasonable to believe that some species groups (e.g., diving and sea ducks) should probably be further split and analyzed separately as they exhibit different distributions (D. Luukkonen and M. Monfils, personal communication, 2017). Splitting the diving and sea ducks into two different species groups may result in drastically different patterns across the Great Lakes.

As mentioned above, the ideal scenario is to have at least 40 sampling events for a high-quality hotspot analysis (more than 100 for less common species) and a protocol with at least ten observations for the covariate analysis. Future modeling projects should include enough sampling events and observations to result in strong models that are representative of the distribution of waterbirds in the region and have an accurate description of factors that influence the distribution. Having a larger number of observations would also allow researchers to account for the differentiation of species in a group, which could result in a better species-specific description and analysis.

Using data from multiple sources

While aerial flights were designed with the goal of describing waterbird abundance, there were many differences among the methodologies, like different distance bins, transect strip lengths, flight height, and speed (Table 7).

Table 7: Difference in protocols

	USGS	**WGLBBO**	**MNFI**	**MDNR**	**BRI**
Transect spacing	4.8 km	3.2 km	5 km	3.2 km	5 km
Altitude of flights	61-76 m	100 m	91 m	91 m	61 m
Flight speed	200 km/hr	148 km/hr	130-200 km/hr	145 km/hr	145-169 km/hr

All surveys used two observers, but observers were not shared between organizations. Furthermore, some surveyors did not collect distance information in all years of the survey (though all collected it in at least one year), as changes to the protocol were implemented to allow for easier comparison between surveys after the first year of surveys.

The inconsistency in sampling across research entities demonstrates that although data collected by many different groups can be incorporated into a single analysis, it is necessary to consider how different protocols and survey methods may affect results. There are likely temporal biases in the data as some research entities selected survey periods to coincide with seasonal patterns and migration, focusing surveys around peaks of abundance for specific species. Such a sampling scheme can increase targeted species' abundances while decreasing abundances of non-targeted species. Targeted species sampling may also introduce observer bias, as observers may disregard species they are not specifically interested in surveying or only identify non-targeted species to family or genus level rather than to the lowest possible taxonomic rank (i.e., species).

The models also make assumptions about changes in spatial scale among survey protocols. Differences in spatial scales are explicitly accounted for in the abundance model; total area surveyed is used as an offset in the abundance model which allows the expected number of clusters to vary directly with survey area. However, this case assumes that the underlying ecological process relating survey area to abundance is similar at all spatial scales and there are situations where this assumption could be inappropriate. Spatial clustering can be significant in many non-breeding waterbirds and these patterns can be important to consider when predicting abundance (Miller *et al.* 2013). With high degrees of clustering of animals in a study area, subsamples of that area are less likely to be similar to the density of the entire area, particularly when these subsamples are small. Thus, in addition to larger survey areas having higher abundance (which is accounted for using a survey area offset), they are also less likely to be biased relative to the true density of animals in the study area. Survey protocols with larger survey area (e.g., MNFI or MDNR) are more likely to be accurate to the spatial distribution of waterbirds than surveys with smaller survey areas; we do not account for this potential source of bias.

This situation is to be expected when using data from different sources. And while the team was able to use the data and develop models, a lot of preliminary work was required to ensure there was a fair comparison between information from each survey area. As discussed in the memo sent to the surveyors by the data management team (see Appendix 10), adopting a single unified protocol would be desirable in future projects.

Area covered by this phase

The models developed for this project are useful for predicting large-scale changes in waterbird abundance within the survey area, but there are inferential limitations in the region. First, it is hard to extrapolate the results of this study to areas outside of the survey area. Given the clustering seen in the populations, it can be difficult to predict which areas are important without first surveying them or having a detailed survey of the food resources they rely on. The results are useful at scales larger than 5km, so small scale changes in abundance will not be detected. Second, using these results to predict future abundance in the areas that have been surveyed would also be difficult because we would need detailed information on the extent of ice coverage over the survey area. The extent of lake ice varies considerably from year (Assel *et al*. 2003), and spatially accurate forecasts of lake ice will be needed to accurately predict future non-breeding distributions of animals in this region. Additionally, extent of lake ice has been decreasing with climate change and further decreases could open previously inaccessible areas that are preferred by waterbirds over current open water habitat.

While this study describes the patterns seen in two non-breeding seasons it is difficult to predict how waterbirds will adapt to environmental changes in the future. The area covered by phases 1 and 2 were chosen because they represented areas of interest for potential offshore wind development projects at that time. Since then, the interest in offshore wind development has decreased and we tried to expand the research question to a larger conservation question. To have a better representation of the distribution of waterbirds in the region, the whole region should be covered by surveys and analyses, including Lake Ontario and other areas in Canada. While results of this project tend to show that combining data from several different protocols is not optimal, it might be the solution to cover a region as large as the Great Lakes region. The amount of data gathered by organizations, governmental agencies, and research institutions in the region is tremendous, and if this data can be made available for future modeling it would lead to the development of representative models that could not only explain the distribution of waterbirds, but also help conservationists and resource managers in making informed decisions for the region.

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Appendices

Appendix 1: Regional Project Team Members

Appendix 2: Advisory Group Members – Invited Advisors

Appendix 3: Management Data and Information Needs Assessment – Summary of Online Survey Results

Appendix 4: Workshop: Informing Great Lakes Open Water Bird Management – Agenda

Appendix 5: Informing Great Lakes Open Water Bird Management – Workshop Summary

Appendix 6: Project Poster – First Iteration (presentation of the project)

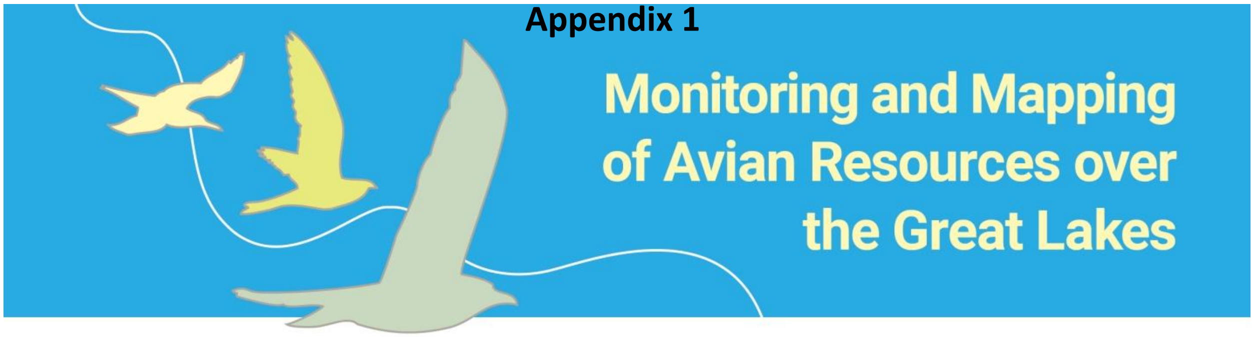
Appendix 7: Project Poster – Second Iteration (presentation of results)

Appendix 8: Potential hotspots across all sampled locations for all species and groups of species

Appendix 9: Posterior means of the abundance parameters for selected species and groups of species

Appendix 10: Memo to Regional Project Team – Unified Survey Protocol

Appendix 1



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Mgmt Data and Information Needs Assessment
Summary of Online Survey Results

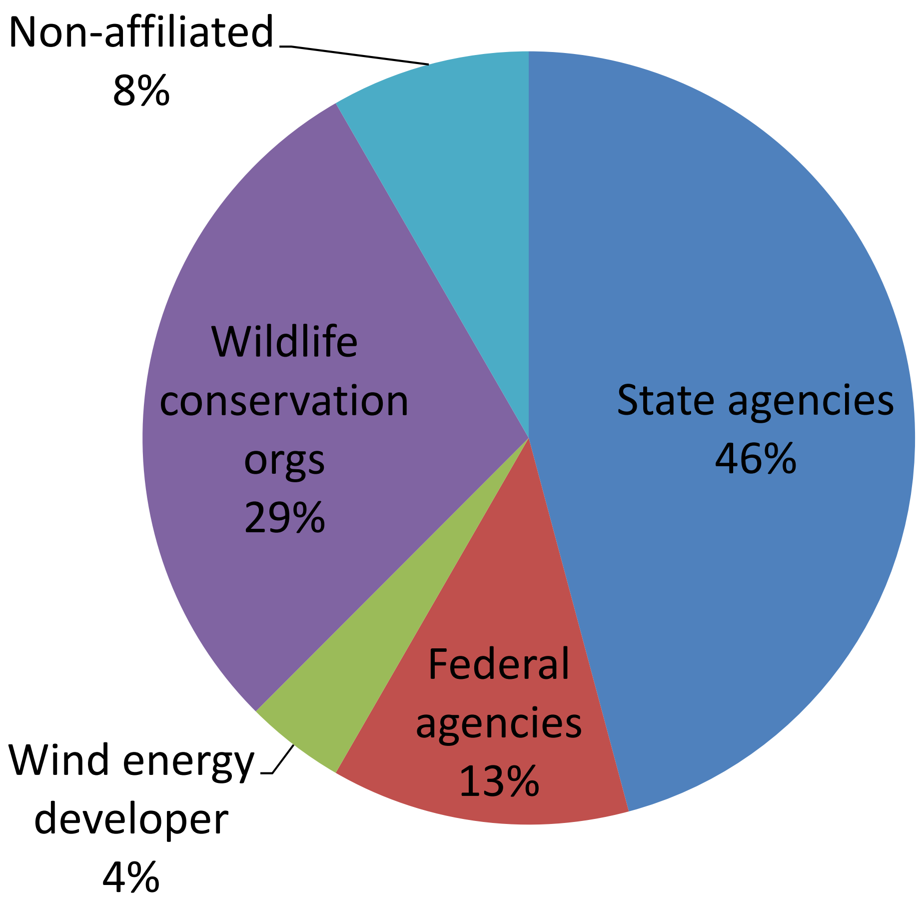
Why assess data & information needs?

Purpose: To ensure that the regional aerial survey results of open water birds inform management decisions in the Great Lakes region

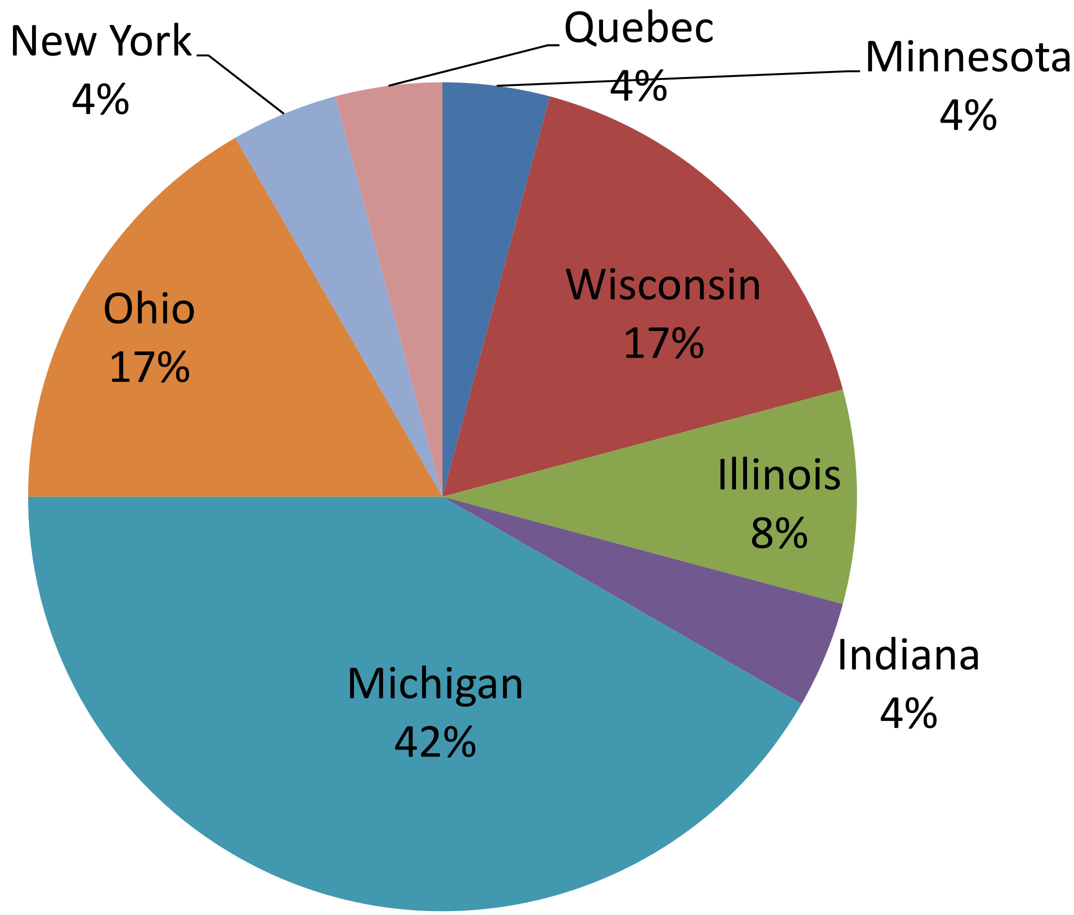
Who responded?

Canadian Wildlife Service
US Fish and Wildlife Service (2 responses)
MDNR, Wildlife Division (3 responses)
WDNR (2 responses)
NYSDEC
Indiana DNR, Division of Fish and Wildlife
Ohio DNR, Division of Wildlife (3 responses)
Wisconsin Coastal Management Program
Lake Erie Energy Development Corporation (LEEDCo)
Audubon Michigan
Copper Country Audubon
National Audubon Society - Chicago
Ducks Unlimited
Western Great Lakes Bird and Bat Observatory
The Nature Conservancy
Bird Conservation Network

Respondent Categories



Geographic Representation



What kind of activities, projects or initiatives do you work on that can be supported by bird data and information from the near-shore and open waters of the Great Lakes?

Answer Options	Response Percent	Response Count
Submerged lands permitting	13.0%	3
Marine spatial planning	4.3%	1
Coastal habitat conservation	60.9%	14
Open water conservation areas	39.1%	9
Designation of important birding areas (IBAs)	39.1%	9
Coastal restoration projects	43.5%	10
Wildlife conservation grants	56.5%	13
Natural heritage programs	21.7%	5
Coastal development planning	17.4%	4
Other	8.7%	2
Other (please specify)	47.8%	11
	answered question	23

Appendix 3

What type of data do you use for making management decisions for near-shore and open water resources?

Answer Options	Response Percent	Response Count
Expert opinion (colleagues, team of experts, your own	86.4%	19
Literature (scientific literature reports manuals)	86.4%	19
Regional conservation plans (state plans, JV plans)	72.7%	16
Unpublished monitoring data	90.9%	20
Publicly available data (BBS, eBird, Avian Knowledge	72.7%	16
Other (please specify)	9.1%	2
	answered question	22
	skipped question	2

How important are the following data and information to the decisions you make and questions you ask?

Answer Options	Very important	Important	Not important	Not important at all	Response Count
Bird hotspots/coldspots	16	5	1	0	22
Species richness	9	12	1	0	22
Areas where state and federal listed	10	11	1	0	22
Bird open water corridors or flyways	12	10	0	0	22
Other	1	0	0	0	1
Other (please specify)					1
				answered question	22
				skipped question	2

In an ideal world, what types of data and information would you likely use for management decisions for near-shore resources and avian fauna?

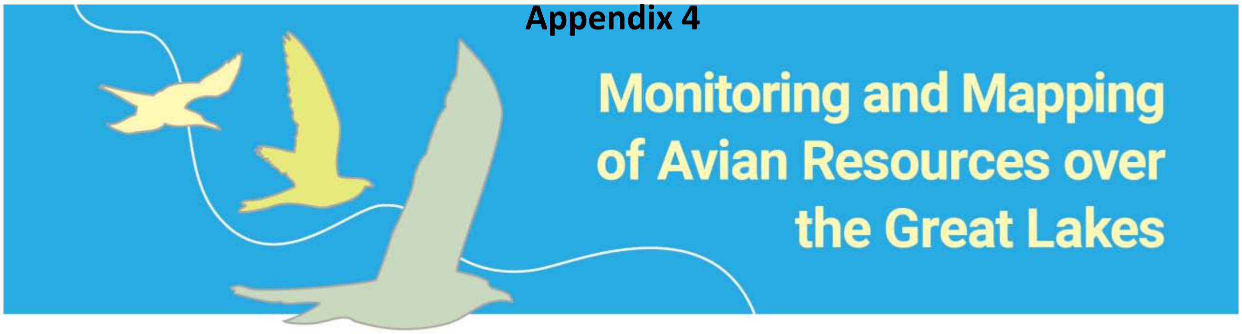
- Bird abundance/diversity
- Bird hotspots
  - federally/state listed species
  - species vulnerable to impacts to wind energy turbines
- Population trends in relationship to food sources

- Geo-referenced
- By and within season
- Trend by season and year
- Continued monitoring
- At least 8 miles offshore

How important is it for you to practice adaptive mgmt and what is the main challenge to practicing adaptive mgmt in your institution?

Adaptive mgmt is very important, but limited due to funding/staffing

Appendix 4



Workshop: Informing Great Lakes Open Water Bird Management

Agenda

March 22-23, 2016

Weber's Inn, 3050 Jackson Road
Ann Arbor, Michigan 48103

Objectives:

- Identify management needs for which open water bird data can inform decision making.
- Innovate with conservation managers and the regional project team the best ways to apply the project's information to support their management activities.
- Define user interface options for the analysis tools developed by the project that will be integrated into the Midwest Avian Data Center website.
- Gauge the need for continued data collection, monitoring and review of impacts of management actions.

March 22, 2016 – Day 1

8:30 a.m. – Welcome – Victoria Pebbles, Great Lakes Commission and Katie Koch, U.S. Fish and Wildlife Service

8:45 a.m. – Introductions

9:15 a.m. – Initial Great Lakes Open Water Bird Survey Results

- Monitoring the Distribution and Abundance of Migrating and Wintering Waterbirds on Lake Michigan – Kevin Kenow, U.S. Geological Survey
- Aerial Surveys in Eastern Lake Erie – Kate Williams, Biodiversity Research Institute
- Distribution and Abundance of Diving Ducks and Other Waterbirds on Lake St. Clair and Western Lake Erie – Dave Luukkonen, Michigan Department of Natural Resources
- Waterfowl and Waterbird Use of Lake Huron Wind Resource Areas – Mike Monfils, Michigan Natural Features Institute
- Great Lakes Open Water Survey Results, Western Lake Michigan – Bill Mueller, Western Great Lakes Bird and Bat Observatory

Each surveyor will briefly summarize the results from their 2012-2014 followed by a period for Q&A.

10:50 a.m. – Break

11:00 a.m. – Current Efforts to House, Curate and Translate Data into Information for Management Use– Becky Pearson, Great Lakes Commission

Review the major project elements: a) data and information needs assessment for management, b) modeling, and c) data management framework and associated products/outcomes from each of the elements.

11:30 a.m. – Lunch and Networking

12:45 p.m. – Great Lakes Research Highlights

Two researchers will present on current projects that may inform the Great Lakes Regional Project or other avian research projects in the Great Lakes.

- Waterbird and Waterfowl Monitoring on the Canadian Great Lakes – David Moore, Environment and Climate Change Canada
- Great Lakes Migratory Bird Stopover Habitat Portal – August Froehlich, The Nature Conservancy

2:00 p.m. – Break

2:10 p.m. – Midwest Avian Data Center – Developing a Data Management System for Great Lakes Researchers – Katie Koch and Leo Salas, Point Blue Conservation Science

The current plan for developing data management system will be presented. What is the purpose of the system? Who will use it? What services and products will be expected by the end of this project? A facilitated discussion will follow this presentation to solicit feedback on the user interface.

3:30 p.m. – Adjourn

4:00 p.m. - 6:00 p.m. Optional Field Trip – Birding Tour with Juliet Berger, ornithologist for the city of Ann Arbor, at Gallup Park, 3000 Fuller Rd, Ann Arbor, MI 48105

Dinner on your own.

March 23, 2016 – Day 2

8:30 a.m. – Summary of Day 1 and Day 2 Objectives – Becky Pearson

8:40 a.m. – Overview of Data and Information Needs Assessment and Presentation of Case Studies – Becky Pearson and Evan Adams, Biodiversity Research Institute

Brief presentation on the survey results followed by open discussion on data and information needs and overview of three management use case studies which will be further discussed during break out groups.

9:15 a.m. – Breakout Group Sessions: Management Use Case Study Development

- Long-tailed Duck Habitat Restoration Case Study – Evan Adams, Facilitator
- Siting Offshore Wind Development Case Study – Victoria Pebbles, Facilitator
- Monitoring Waterfowl Case Study – Leo Salas, Facilitator

11:15 a.m. – Breakout Groups Session Report-outs

Major findings from the breakout group discussions with be presented followed by a discussion in plenary. Major discussion points will provide input and direction on the regional project's modeling efforts, and help workshop organizers gauge the need for continued data collection and monitoring.

12:00 p.m. – Lunch and Networking

1:00 p.m. –Models to Inform Wildlife Management Decisions – Modeling Team

The model team will present the current plan for model development including expected products and outcomes. It will be followed by a facilitated discussion on how this modeling effort can best inform management activities. Suggestions on the ways the modelers can help in the management information needs may be raised such as frequency in time, resolution, etc.

- Models to Inform Wildlife Management Decisions – Allison Sussman, Michigan State University
- Standardizing and Integrating Aerial Surveys for Population Size Estimation across the Great Lakes – Evan Adams, Biodiversity Research Institute

2:45 p.m. – Wrap up – Becky Pearson

3:00 p.m. - Adjourn

Informing Great Lakes Open Water Bird Management

Workshop Summary

SUMMER 2016

A product of the Great Lakes Commission and the U.S. Fish & Wildlife Service based on the workshop held March 22-23, 2016, in Ann Arbor, Michigan.

Great Lakes Commission des Grands Lacs

U.S. Fish & Wildlife Service

Department of the Interior

Appendix 5

Appendix 5

Informing Open Water Bird Management - Workshop Summary -

Table of Contents

Appendix 5

Executive Summary

Organized by the Great Lakes Commission, the *Informing Great Lakes Open Water Bird Management Workshop* took place on March 22-23, 2016, in Ann Arbor, Michigan. Primary funding support for the workshop came from the U.S. Fish and Wildlife Service. Over thirty stakeholders, including avian researchers, federal and state resource managers and conservationists, met to achieve the following objectives:

1. Identify management needs for which data can inform decision-making.
2. Work with conservation managers and the regional project team to determine the best ways to apply the project's information to support their management activities.
3. Define user interface options for the analysis tools developed by the project that will be integrated into the Midwest Avian Data Center website.
4. Gauge the need for continued data collection, monitoring and review of impacts of management actions.

The main purpose of the workshop was to explore how the data collected from bird surveys that took place between September 2012 and June 2014 could be used to address conservation and management needs. This was done in part through breakout sessions that challenged small groups to consider how to apply the data to mock management scenarios. Case studies discussed were related to Long-tailed duck habitat restoration, offshore wind siting, and waterfowl monitoring.

Additionally, an update from the Monitoring and Mapping of Avian Resources over the Great Lakes project team was presented to workshop participants, with presentation from bird surveyors, data management team and the modeling team. Participants also had the opportunity to hear about other related research projects in the Great Lakes basin, including water bird and waterfowl monitoring on the Canadian Great Lakes, and the Great Lakes Migratory Bird Stopover Habitat Portal.

Appendix 5

Introduction

Wildlife agencies often lack adequate knowledge of pelagic (open water) bird migration patterns and non-breeding habitat use in the Great Lakes and may thus be less equipped to recommend measures to avoid and minimize development impacts and habitat loss. The Monitoring and Mapping of Avian Resources over the Great Lakes project is the first step in answering the question: how do birds use near-shore and offshore areas of the Great Lakes during the non-breeding season, and how can this information be used to evaluate the potential impact of offshore wind energy projects and other resource management decisions?

The goal of this cooperative research project led by the Great Lakes Commission and the U.S. Fish and Wildlife Service is to begin creating a comprehensive regional picture of nearshore and offshore bird concentrations and to assist decision makers in conservation planning and identifying suitable areas for proposed offshore wind energy development.

For two annual cycles (2012-2014) the Great Lakes Commission (GLC) coordinated aerial pelagic bird surveys in selected offshore areas of the Great Lakes. The project is now in its third phase, in which a team of researchers will be exploring modeling methods that will help generate meaningful data and information for nearshore spatial planning, conservation activities, and wildlife management. The survey data will also be used to inform siting and planning decisions for offshore wind energy development.

Recognizing that there are other ongoing avian research efforts throughout the Great Lakes basin, the GLC held a workshop, *Informing Great Lakes Open Water Bird Management,* on March 22-23, 2016 in Ann Arbor, Michigan to bring together the researchers. The workshop was designed to explore the state of the science in avian research and support offshore wind impact assessments and conservation management initiatives.

This document summarizes the discussions from that workshop. Primary funding support for the workshop came from the U.S. Fish and Wildlife Service. Over thirty stakeholders, comprised of avian researchers, federal and state resource managers and conservationists met to achieve the following objectives:

1. Identify management needs for which data can inform decision-making.
2. Work with conservation managers and the regional project team to determine the best ways to apply the project's information to support their management activities.
3. Define user interface options for the analysis tools developed by the project that will be integrated into the Midwest Avian Data Center website.
4. Gauge the need for continued data collection, monitoring and review of impacts of management actions.

During the workshop experts reviewed and discussed risk of offshore wind energy development to avian resources and researchers presented the preliminary results of their on-going avian studies. The workshop also featured small group discussions where participants assessed avian research needs, cause and effect relationships between offshore wind energy development and its effects on avian life, the latest research methods and technology, and conservation management initiatives that could be informed by completed and ongoing pelagic water bird survey efforts. The workshop was fairly successful in meeting the stated objectives.

Appendix 5

This workshop summary is organized into the following sections which reflect key topics discussed at the workshop:

1. Great Lakes open water bird survey results
2. Other avian research in the Great Lakes
3. Midwest Avian Data Center
4. Summary of the Phase 3 online data and information needs survey
5. Case study breakout outcomes
6. Models to inform management decision
7. Next steps

FEEDBACK REQUESTED!!! The Monitoring and Mapping of Avian Resources over the Great Lakes project team is seeking input from natural resources managers and others on how this data could be used to inform management decisions. The team would also like to know what are the data and modeling needs required for better decision-making. Please share your ideas by emailing Michele Leduc-Lapierre at michelel@glc.org. Contribution from all stakeholders will help improve the quality of the final product and help inform the next phase of the project.

Section 1: Initial Great Lakes Open Water Bird Survey Results

Overview of the 2012-2014 Great Lakes Open Water bird Surveys

The GLC and the USFWS coordinated aerial surveys of pelagic birds over selected areas of Lakes Michigan, Huron, and Erie during the fall 2012 and spring 2013 migration seasons (Phase 1) and the fall 2013 through the spring 2014 migration and overwintering seasons (Phase 2). A summary of these efforts was presented during the workshop. Please refer to Appendix A for detailed results from each group.

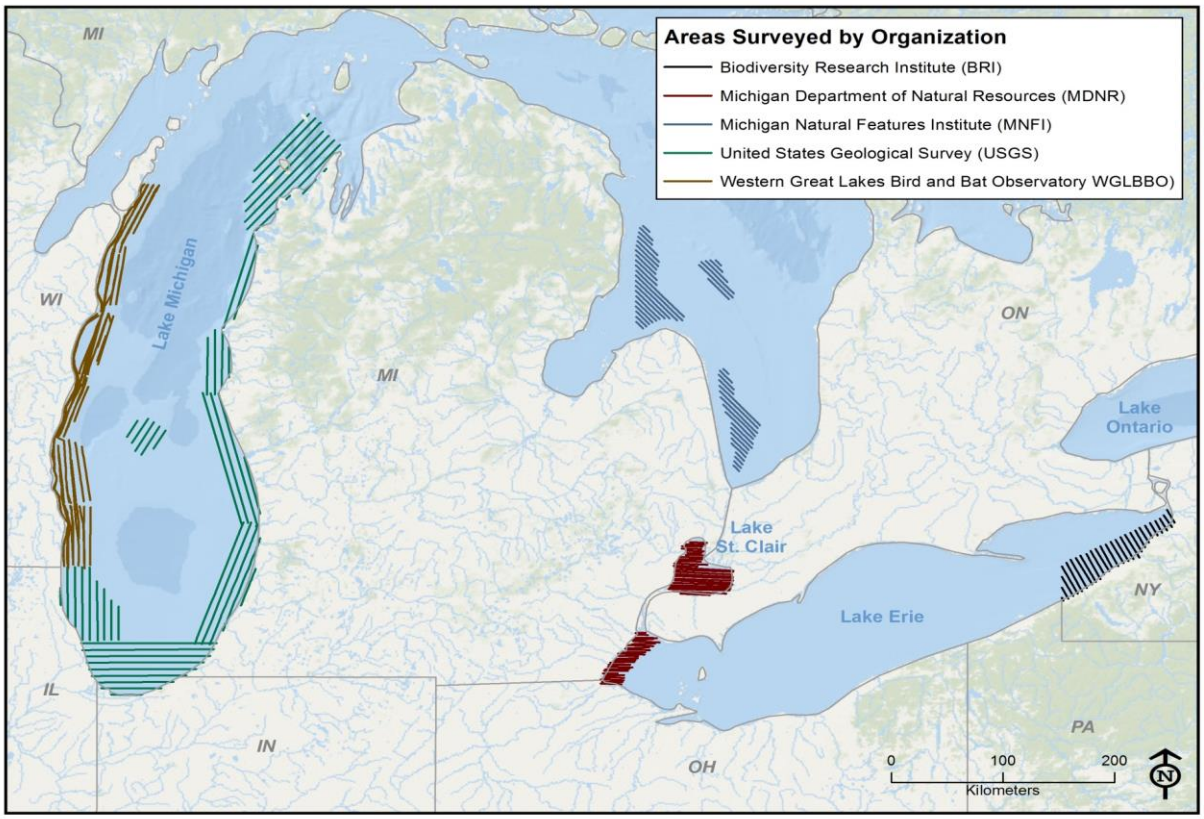


Figure 1. Map of the pelagic bird survey areas

Eastern and Southern Lake Michigan Surveys

Lead Surveyor: Kevin Kenow, U.S. Geological Survey Upper Midwest Environmental Science Center (USGS)

The survey area was broke down in eight survey areas and an area was added in the mid-lake plateau because of its potential for wind energy siting. The Manistee Bay area was added during Phase II. Because the surveys were weather dependant, there is a variation in the number of surveys for each area. Water bird distribution patterns were consistent for a number of species, including Long-tailed ducks, scoters, common loons and red-throated loons. These consistent patterns should be seen in the modeling efforts. Weather conditions have an impact on the distribution of birds as there was a shift in bird distribution relative to ice distribution. This factor will have to be considered in the modeling.

Appendix 5

Central Lake Huron Wind Resource Areas Surveys

Lead Surveyor: Michael Monfils, Michigan Natural Features Inventory (MNFI)

Surveys were made according to the locations identified as wind resources areas by the Michigan Great Lake Wind Council. The sampling effort in Phase I was a little greater than Phase II. This is partly explained by the fact that there was a lot of ice in spring of 2014, which had an impact on the conditions. Results show that there are not a lot of birds in the middle of Lake Huron. In general, birds were detected in small flocks of birds widely distributed on the survey area.

Lake St. Clair, Detroit River and Western Lake Erie Surveys

Lead Surveyor: David Luukkonen, Michigan Department of Natural Resources (MDNR)

Transects covered the totality of the water bodies for Lake St. Clair and Western Lake Erie. The Detroit River was flown over and observations were recorded, but no transects were done. Results show that diving ducks is the largest species group in the area and indicate that this is a significant area for duck migration. As it the case in all surveys efforts, there were some limitations in raw observations because of wind speed that create waves and glare. Surveyors also pointed out that night observations should be made to have a better idea of the situation, because we don’t have data from poor weather periods or at night, so developing a way to survey at night would allow us to develop a more complete picture of water bird distributions and habitat use. Bird distribution is likely influenced by water depth, plant species richness and boating activity.

Eastern Lake Erie Surveys

Lead Surveyor: Kate Williams, Biodiversity Research Institute (BRI)

BRI joined the survey efforts during Phase II of the project, so there is a more limited water bird dataset available for New York waters of Lake Erie than for other areas surveyed in Phases 1-2. The most common species groups across all surveys in 2013-2014 were mergansers, scaup, and gulls, which are somewhat different than the most common species reported by surveyors in some other areas of the Great Lakes. Large aggregations of water birds were consistently observed near the mouth of the Buffalo River. In general, more birds were observed in nearshore areas, although some groups, such as loons (which were observed during migration), were primarily observed farther offshore. Distribution patterns clearly varied with taxa, season, and other environmental variables such as ice coverage.

Western Lake Michigan Surveys

Lead Surveyor: William Mueller, Western Great Lakes Bird and Bat Observatory (WGLBBO)

This group flew survey transects parallel to the long axis of the lake, from one to ten miles offshore, and examined the potential correlation of avian numbers with bathymetry. They conducted a shoreline count from the Ozaukee County lakeshore as well. Variations were observed between each phase and each season, and migratory movements varied according to each species' timing of migration, and were influenced by changing weather conditions. Usually, birds observed during surveys were seen resting on the water, or in flight only a few meters above the water's surface, with some noteworthy exceptions (Tundra Swans and many individual gulls). Long-tailed ducks were often found far offshore in deeper water. The group reported that locations of concentrations of birds changed constantly, and that winter is challenging for finding and mapping waterfowl during times and in areas that have extensive ice coverage.

Discussion

Several surveyors suggested that pelagic water bird distributions in winter seemed to be influenced by ice coverage, and it was suggested that a similar avoidance could occur around wind farms. In Australia, some studies show that there can be changes in migration patterns to avoid wind farms, but it is species and location specific. These are the types of questions the work of the group could try to answer in the future. But before starting to use the data-based models to make important decisions, however, we need to develop these models further and understand the degree of uncertainty in model and predictions.

One of the objectives of Phase 3 of the project is to evaluate survey efforts, identify what additional data collection efforts may be needed, and determine how to gather the necessary data. It's always challenging to find long-term funding for monitoring, and support for future surveys will be dependent upon how well survey data can be used to address a range of management decisions. We need to address questions about methodology and approaches, take a step back, evaluate what has been done to date, and try to make recommendations to the different regions regarding what additional survey work may be needed and how limited funding could best be used to address data needs for resource management. Another consideration is the existence of new technologies, like drones, that can help reduce the cost of monitoring. Citizen science is another way we can help reduce the cost of gathering data and ensure long-term monitoring.

Originally, survey efforts were focused on wind development, but with climate change, bird patterns may also change. Moving forward, the work should not only focus on potential wind farms, but also on identifying impacts of climate change on various species.

Another question we should consider is what species of birds to focus on. The Migratory Bird Treaty Act and the Endangered Species Act help define species of focus due to the legal protections afforded by these laws. However, other species may be worth further examination to more fully inform management decisions related to conservation of the open waters of the Great Lakes. Great Lakes indicators may also help to focus this work.

Section 2: Other Great Lakes Research Highlights

Water bird and Waterfowl Monitoring on the Canadian Great Lakes

Presenter: David Moore, Canadian Wildlife Service, Environment Canada

The Binational Decadal Great Lakes Colonial Water bird Survey is a long-term population monitoring program for water birds in the Great Lakes that was initiated in 1976, with the most recent surveys in 2009. Results have allowed researchers to identify potential drivers of population change: changes in distribution and abundance of prey fish, effects of hyper-abundant species like cormorants and ring-billed gulls on other water bird populations, development and other anthropogenic activities, predation, and stressors outside of the Great Lakes region.

A second long-term monitoring program, the Migratory Waterfowl Surveys project, monitors abundance, distribution, and species composition of migrant waterfowl in the Ontario portion of the lower Great Lakes. This project also allowed for the evaluation of trends in abundance for areas of high historic use, and an examination of the degree to which species composition in these priority areas has changed over time (between 1968 and 2011). The results show that this area is important to waterfowl for staging and wintering. Spring and fall distribution are generally correlated, and the use is higher in the fall. Across time, the pattern in species composition is generally consistent. There is variation in abundance, but this does not seem to be a long-term trend.

Great Lakes Migratory Bird Stopover Habitat Portal

Presenter: August Froelich, The Nature Conservancy

The Great Lakes Migratory Bird Stopover Habitat Portal[1] is a website that can be used to learn about stopover sites in the Great Lakes region. It's also a tool that can be used to study stopover sites, apply models and download data. To predict migratory bird hotspots, attributes of stopover sites were identified and scored. Potential stopover habitats were mapped across the region (based on literature and available GIS layers), and rated by relative importance. It was very difficult to compare and rank habitats. Ranks were developed by combining land cover (habitat) values by species with geographic values (neighborhood values). Several different types of maps are available to users, and results can be downloaded in a choice of format. This was made possible by comparing information found in the literature with GIS analyses, and using case studies. In the future, they will improve the portal by updating models and adding case studies. It could also be interesting to find a way to incorporate this work with other projects such as the Midwest Data Center.

[1] Available at: http://glmigratorybirds.org/

Section 3: Midwest Avian Data Center – Developing a Data Management System for Great Lakes Researchers

The Midwest Avian Data Center – Bird Conservation through Data, Science, and Partnerships

Presenter: Katie Koch, U.S. Fish and Wildlife Service

The Midwest Avian Data Center[2] (MWADC) is a node – an interconnection of points – of the Avian Knowledge Network (AKN). The AKN is a partnership of people, institutions and government agencies supporting the conservation of birds and their habitats based on data, adaptive management and the best available science. Some of its functions are to serve as a tool to manage scientific data, foster meaningful data visualizations and coordinate partnerships around conservation questions. Through different levels of data availability, users of the MWADC can navigate through the database and visualize the information through different outputs. Data comes from different sources and there might duplication; eliminating these is something that is being worked on.

The Data Life Cycle in the Midwest Avian Data Center

Presenter: Leo Salas, Point Blue Conservation Science

There are seven steps to managing a project's data in MWADC. The first one is to register and create a project. Then, the user has to describe data collection protocols, researchers and their roles, and sampling location. Once these steps are complete, the user enters and edits data, and can finally visualize it. Several tools are available for visualization. The MWADC is partnering with GLC in the project to integrate data from phases 1 and 2 and allow visualization of the results.

[2] Available at: http://data.pointblue.org/partners/mwadc/index.php?page=home

Section 4: Summary of the Phase 3 Online Data and Information Needs Survey

Presenter: Rebecca Pearson, Great Lakes Commission

The purpose of this effort by the GLC was to assess data and information needs to ensure that data collected by the regional aerial survey efforts get used by managers and stakeholders in the region. The assessment began with a short online survey released in mid-December 2015, targeted at managers and stakeholders. Responses were received from a diverse group of stakeholders, including state agencies, federal agencies, wind energy developers and wildlife conservation organizations from across the Great Lakes region.

Question 1: What kind of activities, projects or initiatives do you work on that can be supported by bird data and information from the near-shore and open waters of the Great Lakes?

- ➔ The activities, projects or initiatives that can be supported by bird data and information from the near-shore and open waters of the Great Lakes that received the most responses were: coastal habitat conservation, wildlife conservation grants, and coastal restoration projects.

Question 2: What type of data do you use for making management decisions for near-shore and open water resources?

- ➔ The most popular types of data for making management decisions for near-shore and open water resources were: unpublished monitoring data, expert opinion and literature. This means managers generally use more than their own information stream to inform their decisions.

Question 3: How important are the following data [bird hotspots/coldspots, species richness, areas where state and federal listed birds, bird open water corridors or flyaways, other] and information to the decisions you make and questions you ask?

- ➔ When asked to pick, in order of importance for decision-making, the following data and information were ranked as the most important: bird hotspots/coldspots, bird open water corridors or flyways, and areas where state and federal listed birds.

Question 4: In an ideal world, what types of data and information would you likely use for management decisions for near-shore resources and avian fauna?

- ➔ Commons trends in responses to the open-ended question regarding the types of data and information that managers would likely use in an ideal world for management decisions for near-shore resources and avian fauna were: bird abundance and diversity, bird hotspots federally and state listed, species vulnerable to impacts to wind energy turbines, population trends in relationship to food source, geo-referenced, by and within season and year, continued monitoring, and at least 8 miles offshore.

Question 5: How important is it for you to practice adaptive management and what is the main challenge to practicing adaptive management in your institution?

- ➔ Most of the written responses to the question concerning adaptive management, and the main challenges to practicing it, mentioned that it was very important along with long-term monitoring efforts, but that securing funds and staffing were challenging.

Section 5: Case Study Breakout Outcomes

Overview of Management Use Case Studies

Three management case studies were identified to reflect the interests of the survey responders and promote communication amongst workshop participants. The first case study concerned Long-tailed ducks, a game species whose Great Lakes population is under the management of the Great Lakes Region and Upper Mississippi River Joint Ventures as well as individual states. As populations are currently in decline, this case study aimed to answer the following management question: *How should restoration activities be designed, implemented and evaluated to increase Long-tailed duck population size?* More specifically, given data on potential restoration location and estimated duck abundance in Lake St. Clair and Western Lake Erie during fall 2011, how can managers (1) select areas for restoration that are specifically useful to Long-tailed ducks and (2) evaluate the success of these restoration efforts at the scale of the restoration site as well as throughout the Great Lakes?

The second case study was to explore means to properly site offshore wind development by selecting areas of least biological conflict within Wind Resources Areas (WRAs) that were already defined by the Michigan Great Lakes Wind Council. This case study aimed to answer the following management question: *How can offshore wind development be sited within the three Central Lake Huron WRAs with the least impact to birds and bats?* The desired outcome of this case study was to ensure that the effort to meet domestic energy demands through wind power is conducted in an environmentally responsible manner that protects the health and safety of the environment and communities.

The third case study focused on the North American Waterfowl Management Program's primary goal. It aimed to answer the following management question: *How can we monitor waterfowl and habitat selection during the non-breeding season to ensure sustainable populations?* Recognized challenges and considerations – as a particular metric is developed – included food availability, human disturbance, time and geographic challenges, lack of protocol standardization for surveys and data collection, and climate change variation resulting in variability in environmental conditions and response from populations.

Breakout 1: Long-tailed duck Restoration

While some hypothetical restoration plans were proposed within the group, overall the group decided that there was not enough known about Long-tailed duck ecology to know what kind of restoration would be effective. Without the type of restoration defined, it was difficult to devise a monitoring plan that would be successful in quantifying the effects of the restoration action. Thus, the group decided to eliminate the word "restoration" from the main question. Instead, the group decided to focus more on understanding the factors that limit the populations of this species such that a plan for successful restoration could be considered.

Complicating matters further is that the declines seen in Long-tailed duck populations have been highly regional. This species is extremely common in parts of Lake Michigan but virtually unseen even in western Lake Erie. Thus, restoring the species from this decline is a regional issue where region-specific factors must be considered. The group came up with six limiting factors that could affect the non-breeding population. These factors have to be monitored to understand where the problems might be, and to see if there are differences in the Great Lakes population and the population from other regions. These factors are: control of ice water levels, harvest and bycatch, disturbance, food availability, contaminants and diseases. Aerial surveys to monitor Long-tailed duck populations that are similar to what has already occurred will be important in helping to: (1) determine the current status of the population, (2) determine how important some of these factors are for affecting duck populations, and (3) document the population-level responses to restoration activities.

Breakout 2: Siting Offshore Wind in Central Lake Huron Wind Resource Areas

The group discussed how offshore wind could be sited with the least impact to birds and bats. The discussion focused primarily on water birds and landbirds (including raptors), and on siting projects and measuring impacts, rather than on other mitigation approaches. Metrics needed to site offshore wind in such a way as to minimize impacts to these taxa include: locations and persistence of concentration of species of interest, presence of species of concern, timing of species presence or large aggregations relative to the timing of development activities, understanding of how abundance at a proposed development site compares to overall population size at some broader scale, and flight patterns (locations, timing, flight heights) of migratory birds and bats. In addition to identifying data gaps and needs, the group also discussed management actions or approaches required to site offshore wind projects to minimize wildlife impacts. Data collection requires funding, and participants suggested building the costs of monitoring into permits so that developers pay the costs to fill identified data gaps. It was also suggested that projects that develop or use a public resource (such as Great Lakes lake bottoms, which are held in trust by the states and the provinces) should be required to make all data publicly available. A broader planning effort to assess and weight available data, including biological data, was identified as an optimal approach for project siting, though determining how best to weight information from different sources can be difficult and this process could use additional development. While discussion focused on offshore wind, participants felt strongly that similar conditions should be imposed on all types of energy development, and that development decisions should be made within a broader context that incorporates a life cycle analysis of environmental impacts from different energy sources. Lastly, breakout session participants pointed out that while state wildlife agencies can identify areas that may be better or worse to develop, these agencies often do not actually have the authority to provide (or deny) a permit.

Breakout 3: Monitoring Waterfowl during the Non-breeding Season in the Great Lakes

The group worked on developing an index that would provide some information of the general spatial and temporal use of the Great Lakes by waterfowl and water birds in the non-breeding season. The purpose of the index would not be to provide numeric values of the total populations of waterfowl/water birds using the Great Lakes during fall and winter. Rather, the index would provide a relative measure of use of areas of the Great Lakes by comparing relative values across space and time. Information that could be gathered from the index includes: important locations, changes through time, and variance in space and time. These data would help guide research (triage), trigger other research questions, gap analyses (areas in need of better surveying, including at particular times of the year), provide a sense of the large-scale behavior of waterfowl and water birds in the Great Lakes during the non-breeding season, or simply provide indications of overall health. The team acknowledged the severe logistical constraints associated with data collection during the non-breeding season. Thus, strong bias may be present in the data due to limited sampling or sampling only from preferred locations. Users of the index could be warned about possible bias, for example by providing values of relative sampling effort, and statistical corrections through the use of simple models (e.g., smoothing and additive models). Bias may be reduced through the use of large datasets. Several types of data could be used, including: eBird, Christmas Bird Count, the Mid-winter Waterfowl Survey, and other sources that would be federated to the Midwest Avian Data Center. The group had discussion about the spatial, temporal and taxonomic resolutions of the index, and the amount of data was a factor to be considered. The team considered that temporal resolution at a monthly level could be possible. Spatial resolution would depend on the amount of data available, with the consideration to blank out areas with limited or no information rather than extrapolate to them from nearby areas. Taxonomic resolution may remain at guilds/functional ecological groups, as this would reduce issues with misidentifications. The target audience the team expected to profit from using the index would be agencies managing resources at large scales: state agencies, federal agencies, joint ventures and landscape conservation cooperatives, and conservation organizations.

Section 6: Models to Inform Wildlife Management Decisions

One of the objectives of the Monitoring and Mapping of Avian Resources over the Great Lakes project is to develop predictive models of water bird distributions and densities across the Great Lakes, in order to support decision-making and conservation planning. The broader goal of the predictive modeling is to examine water bird occurrences and abundances in near-shore and open water areas of the Great Lakes using survey data collected over 2012-2014. Approaches to attain this goal include the identification of “hotspot” and “coldspot” locations, identification of relationships between water bird occurrences and abundances and relevant environmental covariates, and standardization of data across differing sampling protocols. The desired outcomes of the modeling are to determine the sampling and modeling priorities for the next phases of the project, to inform current water bird conservation priorities, and to inform management decisions on wind energy development in the Great Lakes. The project’s modeling team includes Allison Sussman and Elise Zipkin (Michigan State University), Evan Adams (Biodiversity Research Institute and University of Washington), Beth Gardner (University of Washington) and Kate Williams (Biodiversity Research Institute). The Michigan State University team will focus on identification of “hotspot” and “coldspot” locations to determine which species and groups of species should be targeted for analysis as well as the appropriate scale. They will also identify meaningful definitions of hotspots and coldspots based on a combination of prevalence and abundance. The Biodiversity Research Institute and the University of Washington teams’ will focus on hierarchical distance sampling to help resolve the problems created by differences in survey methods across the Great Lakes. Developing a global distance model using a Bayesian framework that shares information across different surveys datasets should facilitate the creation of a unified abundance model for each species.

Exploring Open Water Bird Hotspots and Coldspots

Presenter: Allison Sussman, Michigan State University

The objective of this modeling effort was to explore open water bird “hotspots” and “coldspots” in the Great Lakes using a variety of approaches. A literature review was conducted on methods to identify hotspots and coldspots to evaluate the effectiveness of these methods for the current available data. The first method used was adapted from the Biodiversity Research Institute’s Mid-Atlantic Baseline Study.

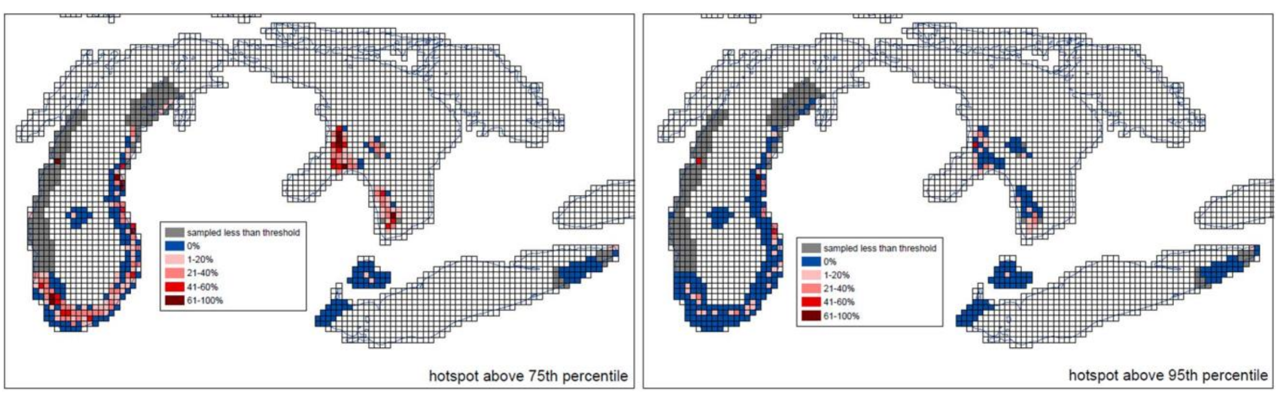


Figure 2. Map of Long-tailed duck hotspots, block sampled at least five times

As data were collected differently across the five Great Lakes surveys, data were first standardized to support the modeling analysis. Standardized data counts were then fit into a gamma distribution and each sampling event was assigned a probability. Two scenarios were explored to call a sampling event a hotspot: higher than 75th percentile and higher than 95th percentile. Using these scenarios and a threshold for the number of times a block was sampled (more than five and more than 10); maps (see figure 2 for an example) of persistent hotspot and coldspot locations across the Great Lakes were created for a test species (Long-tailed duck) and a test species group (gulls). Repeated sampling would be necessary to confirm these hotspots.

Standardizing and Integrating Aerial Surveys for Population Size Estimation across the Great Lakes

Presenter: Evan Adams, Biodiversity Research Institute

The objective of this approach was to find a way to combine data from aerial surveys together into a single modeling framework. The team also wanted to be able to correct for detection bias across all surveys and to be as accurate as possible when predicting locations of birds in the Great Lakes. Some of the challenges encountered included: different data collection methods, sparse data for some areas, skew in the counts and need for more flexible distributions or models to address large counts and zeroes, and correlation in the counts. The first part of this modeling effort looked at diversity in the surveys. As seen in Section 1 and Appendix 1 of this workshop summary, there were differences in methods used by each surveyor, resulting in different types of datasets that had to be standardized. Variables considered were the years surveyed, the transect spacing, the altitude of flights, the strip width (when no distance was provided), the distance bands and the species recorded. Having all surveys integrated within a unified dataset is important to being able to analyze the Great Lakes as a whole.

Discussion

Collaboration among modelers, but also with managers, is essential to ensure that the project survey and modeling work is supporting management decisions. This workshop was an initial effort to enable that collaboration. Future collaboration could help standardize survey designs, so that future surveys can be unified easily into one dataset. If surveys are not standardized, more details on different covariates – metadata – need to be gathered during surveys to facilitate the future integration of data into the model. Examples of important covariates to consider include: sea state, weather in general, wind, observers (single or double, for example), glare, etc. Modeling can also identify areas with potentially large aggregations of water birds that would need increased or new surveying. The integration of new technologies, such as georeferenced aerial photos, video surveys or drones could also guide the design of future surveys. Drones are currently being tested over Lake St. Clair, but those that can fly high enough for these types of surveys are relatively expensive. Nonetheless, these are tools that are worth exploring.

There can be a tension between the desire to have long-term monitoring data and the need to make immediate management decisions. Funding and resources for long-term monitoring are not necessarily available when needed. Models can expedite the delivery of information to help make these immediate decisions, so long as caveats are transparent and well-understood. As new data are made available and integrated in the models, model outputs will improve along with confidence to use those outputs in decision-making. Modeling can also help better design future short and long-term monitoring for different purposes, such as answering specific management questions, focusing on spatial data gaps or hot spots, for example. Monitoring and modeling therefore can improve in parallel and both be used as tools for management. These tools will be important as Great Lakes management needs evolve.

Section 7: Next Steps

One of the objectives of the Monitoring and Mapping of Avian Resources Over the Great Lakes project is to inform Great Lakes conservation and management decisions by engaging natural resource and wildlife managers and subject experts in detailing needs for summarizing and using survey data within relevant decision frameworks.

Moving forward, the project team will continue its data integration and modeling efforts and work on obtaining input on models from surveyors. The team will seek input from natural resources managers and others on how this data could be used to inform management decisions.

The team will also work on identifying gaps in how future surveys could be used to determine water bird distribution and abundance patterns across the Great Lakes. External input will also be sought to know what are the data and modeling needs required for better decision-making.

The work of the data integration and modeling team, as well as input from managers and other decisionmakers, will be essential to help identify management decisions that need this type of regionwide assessment.

Appendix 5

Appendices – Survey Effort Factsheets

Section 1 of this workshop summary summarized the 2012-2014 Great Lakes Open Water bird Surveys that were coordinated by the Great Lakes Commission and the U.S. Fish and Wildlife Service. For each surveyor, a fact sheet was developed and is included in this appendix.

Appendix A: Eastern and Southern Lake Michigan Surveys – U.S. Geological Survey

Appendix B: Central Lake Huron Wind Resource Areas Surveys – Michigan Natural Features Inventory

Appendix C: Lake St. Clair, Detroit River and Western Lake Erie Surveys – Michigan Department of Natural Resources

Appendix D: Eastern Lake Erie Surveys – Biodiversity Research Institute

Appendix E: Western Lake Michigan Surveys – Western Great Lakes Bird and Bat Observatory

Appendix A: Eastern and Southern Lake Michigan Surveys

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles, the Great Lakes region provides vital breeding, feeding, and resting areas for hundreds of millions of birds. To protect these birds and the habitats that support them, we need the best possible knowledge about their dependence on the Great Lakes. To that end, the Great Lakes Commission and partners conducted aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie over the course of two years during the non-breeding season (fall, winter and spring). Armed with the better knowledge gained from these surveys, we can help natural resource managers, conservationists, and other stakeholders make better decisions to protect avian habitats from human impacts. This is a summary of the aerial survey effort covering eastern and southern Lake Michigan.

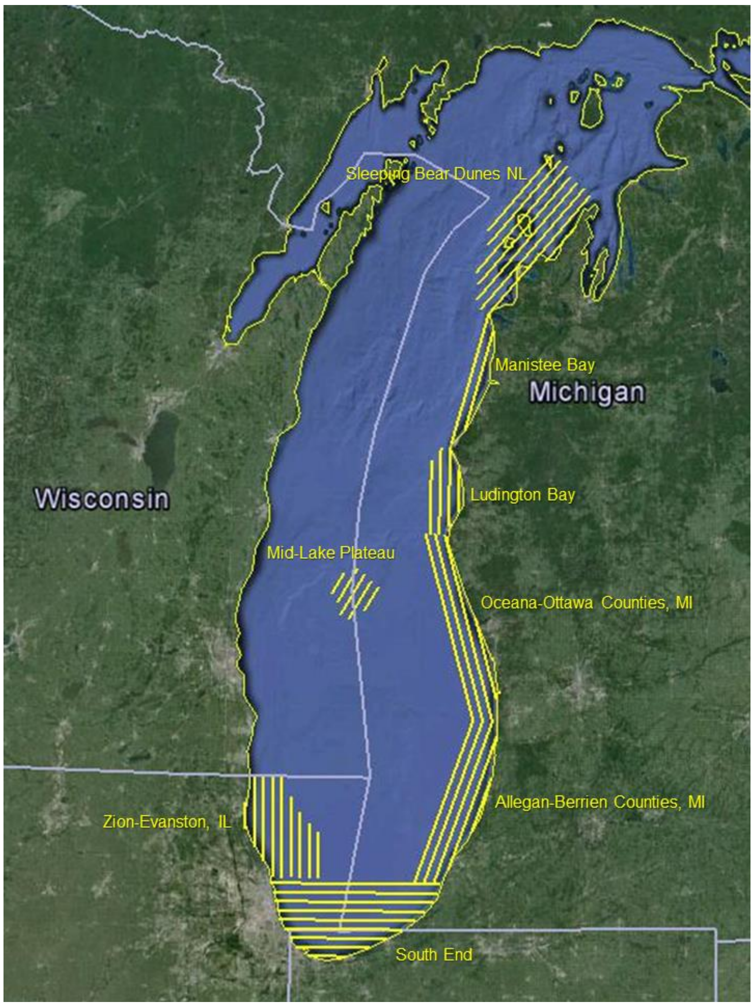


Figure 1. Survey Transects for Southern and Eastern Lake Michigan.

Lead Surveyor: Kevin Kenow, U.S. Geological Survey Upper Midwest Environmental Sciences Center, (608) 781-6278, kkenow@usgs.gov

Survey Area: 12,800 kilometer km^2

Total Length of Survey Transects: 14,761 km

Methods: Surveys were flown along fixed-width transects. Transects generally paralleled shorelines, were spaced at 4.8-km (3-mi) intervals, and extended up to 32 km (20 mi) offshore. Surveys were flown at an average air speed of about 200 km/h (125 mph) and at an altitude of about 61-76 m (200-250 ft) above the water using a U.S. Fish and Wildlife Service fixed-wing aircraft. Two observers, one on each side of the plane, identified and tallied waterbirds within 200 m-width (1/8 mi) strip transects on either side of the plane and categorized observations into one of two distance bands (observable portion of strip transect out to 100 m and 101-200 m). Distances were established using a clinometer, and the portion of the transect band beneath the plane that was not observable was estimated.

Appendix 5

Numbers of surveys and dates:

	Phase 1 **2012-2013 fall-spring seasons**	**Phase 2** **2013-2014 fall-spring seasons**	**Grand Total No. of Surveys**
Survey Dates	• September 25-27, 2012 • October 22-24, 2012 • November 26-29, 2012 • February 4-6, 2013 • February 24-25, 2013 • March 21-22, 2013 • April 3-5, 2013 • April 24-26, 2013	• September 18-26, 2013 • October 25-November 1, 2013 • November 19-20, 2013 • December 12-19, 2013 • January 8-9, 2014 • February 2-3, 2014 • March 24-26, 2014 • May 5-6, 2014	
Subtotal	8	8	16

Number of individual observations:

	Phase 1 **2012-2013 fall-spring seasons**	**Phase 2** **2013-2014 fall-spring seasons**	**Grand Total of No. Observation**
No. of Observations	67,563	95,218	162,781

Summary of Results:

Phase 1 - Long-tailed Ducks (59%) were the most abundant species over the fall- winter-spring survey period, followed by mergansers (17%), gulls (11%) and scoters (5%). The Sleeping Bear Dunes National Lakeshore, Allegan-Berrien Counties, Oceana-Ottawa Counties, and the southern end of Lake Michigan tended to have the highest concentrations of water birds during the survey period.

Phase 2 - Long-tailed Ducks were the most abundant species, representing 57 percent of all birds tallied during the eight month survey period (Figure 2). Mergansers, scaup, and scoters (primarily White-winged [*Melanitta deglandi*]) were also frequently observed along transects. Record ice coverage of Lake Michigan occurred during winter 2013–2014, with maximum coverage of 93 percent occurring on about 5 March 2014. Winter ice cover affected habitat availability.

Waterbird concentrations varied temporally and spatially within the areas of Lake Michigan that were surveyed. Overall water bird abundance during Phase 2 surveys ranked highest within the Sleeping Bear Dunes National Lakeshore, Oceana-Ottawa Counties, and the southern end of Lake Michigan.

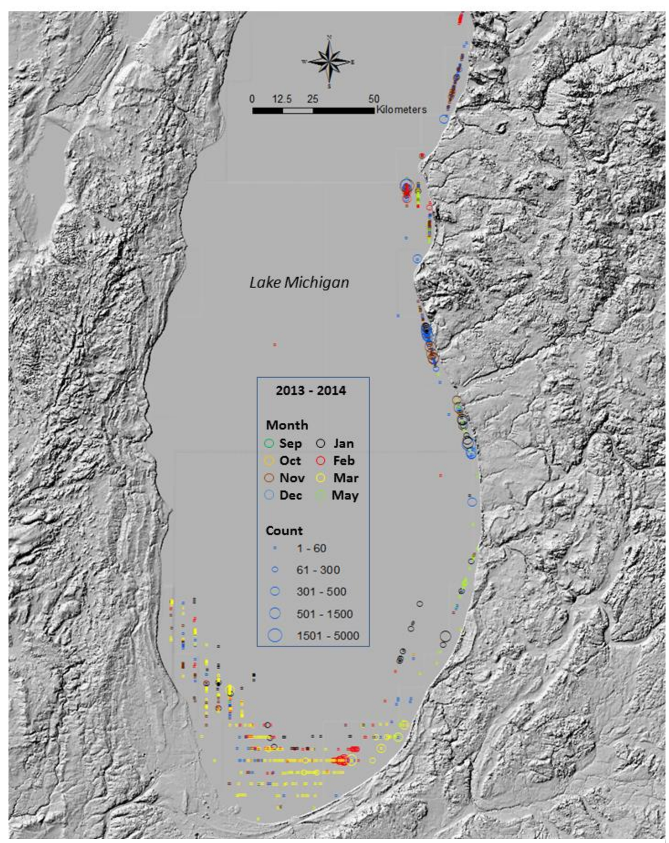


Figure 2. Long-tailed Duck observations from surveys conducted during Sept. 2013 through May 2014.

Appendix 5

Top Three Most Abundant Species by Fall and Spring Seasons:

Phase 1 2012-2013 fall-spring seasons				Phase 2 2013-2014 fall-spring seasons			
Fall 2012	**Species**	**Number**	**% of Total Observed**	**Fall 2013**	**Species**	**Number**	**% of Total Observed**
	Long-tailed Duck	8282	43.5		Long-tailed Duck	32400	51.1
	Gull	4099	16.0		Scaup	6423	10.1
	Merganser	2583	13.6		Gull	4967	7.8
Spring 2013	Long-tailed Duck	14351	58.9	**Spring 2014**	Long-tailed Duck	5411	60.5
	Merganser	3894	16.0		Merganser	1477	16.5
	Gull	2669	11.0		Gull	1214	13.6

Appendix B: Central Lake Huron Wind Resource Areas Surveys

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles, the Great Lakes region provides vital breeding, feeding, and resting areas for hundreds of millions of birds. To protect these birds and the habitats that support them, we need the best possible knowledge about their dependence on the Great Lakes. To that end, the Great Lakes Commission and partners conducted aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie over the course of two years during the non-breeding season (fall, winter and spring). Armed with the better knowledge gained from these surveys, we can help natural resource managers, conservationists, and other stakeholders make better decisions to protect avian habitats from human impacts. This is a summary of the aerial survey effort covering the Wind Resources Areas[3] in central Lake Huron.

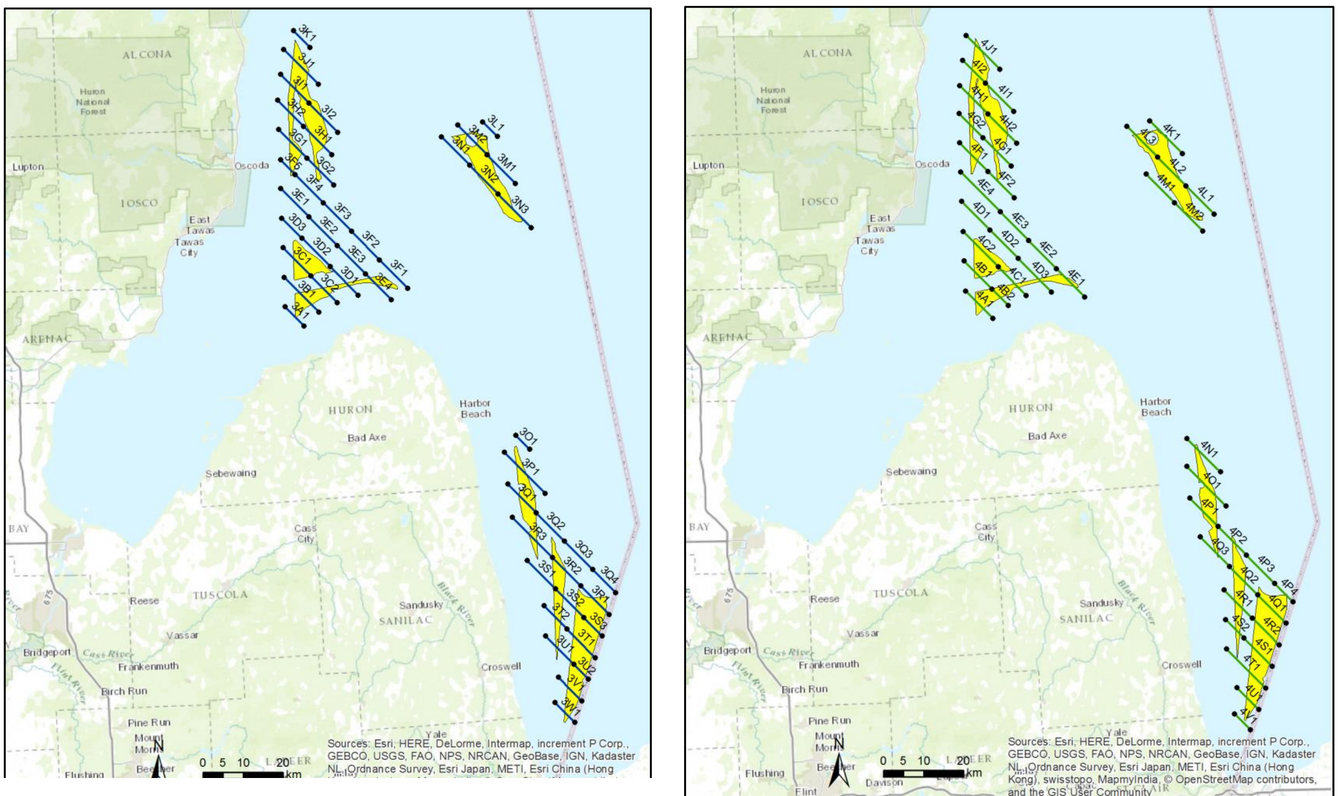


Figure 1. Locations of two sets of transects used for pelagic bird surveys of Lake Huron wind resource areas (yellow polygons) during Phases 1 and 2. One set of transects (i.e., blue – left graphic, or green – right graphic) was surveyed on a given day and the set covered was rotated every other survey. Transects were divided into approximately 10 km segments, with identifiers indicating transect set (number 3 [blue] or 4 [green]), transect (letter), and segment (number).

Lead Surveyor: Michael Monfils, Michigan Natural Features Inventory (MNFI), (517) 284-6205, monfilsm@msu.edu

Survey Area: 2,200 km^2

Total Length of Survey Transects: 881 km

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[3]Wind Resource areas were identified by the Michigan Great Lake Wind Council in 2010 to be most favorable to the development of offshore wind energy. The council developed a set of 22 criteria related to biological, cultural and other features and uses of the lakes to define these areas.

Appendix 5

Methods: Surveys were conducted along two sets of parallel transects traversing the Wind Resource Areas (Figure 1) and immediate vicinity. Transects within each set were 5 km apart, thus 2.5 km separated the full set of transects. MNFI used a Partenavia P68C twin-engine fixed-wing aircraft for all surveys. Surveys were flown at approximately 91 m above water level and speeds of 130-200 km/hr. Two observers conducted surveys (one on each side of the aircraft). For each flock or individual bird, MNFI recorded the species (or lowest taxonomic group), number observed, latitude and longitude (using GPS receiver), and the distance band in which it was first detected (0 – 100 m, 101 – 200 m, 201 – 300 m, 301 – 412 m, and >412 m).

Number of surveys and dates:

	Phase 1 **2012-2013 fall-spring seasons**	**Phase 2** **2013-2014 fall-spring seasons**	**Grand Total No. of Surveys**
Survey Dates	• October 26, 2012 • November 2 and 13, 2012 • December 6, 2012 • February 12 and 26, 2013 • March 1, 4 and 29, 2013 • April 17 and 30, 2013 • May 14, 2013	• October 25, 2013 • November 5 and 19, 2013, • December 19,2013 • April 18 and 24, 2015 • May 5 and 14, 2014	
Subtotal	12	8	20

Number of individual bird observations:

	Phase 1 **2012-2013 fall-spring seasons**	**Phase 2** **2013-2014 fall-spring seasons**	**Grand Total of No. Observation**
No. of Observations	12,402	7,143	19,545

Summary of Results: MNFI documented results from Phase 2 surveys that were largely consistent with the Phase 1 findings. Sea ducks and gulls dominated bird detections, with Long-tailed Duck being the most common species observed. Despite Canada Goose being rarely observed during Phase 1, MNFI commonly detected the species during spring 2014, which may have been a result of the late spring and/or later timing of surveys. None of the transect segments were devoid of birds and MNFI detected small flocks of birds widely distributed throughout the survey area. Although particular portions of the survey area had significantly greater bird densities, overall densities were low in both phases and seasonal differences were not observed.

Appendix 5

Top Three Most Abundant Species by Season:

Phase 1 2012-2013 fall-spring seasons				Phase 2 2013-2014 fall-spring seasons			
Fall 2012	**Species**	**Number**	**% of Total Observed**	**Fall 2013**	**Species**	**Number**	**% of Total Observed**
	Long-tailed Duck	2,087	86%		Long-tailed Duck	3,584	81%
	Large Gulls	146	6%		Large Gulls	420	9%
	Unidentified Loons	59	2%		Unidentified Sea Ducks	144	3%
Spring 2013	Long-tailed Duck	2,798	77%	**Spring 2014**	Long-tailed Duck	869	32%
	Large Gulls	432	12%		Canada Goose	818	30%
	Swans	153	4%		Large Gulls	430	16%

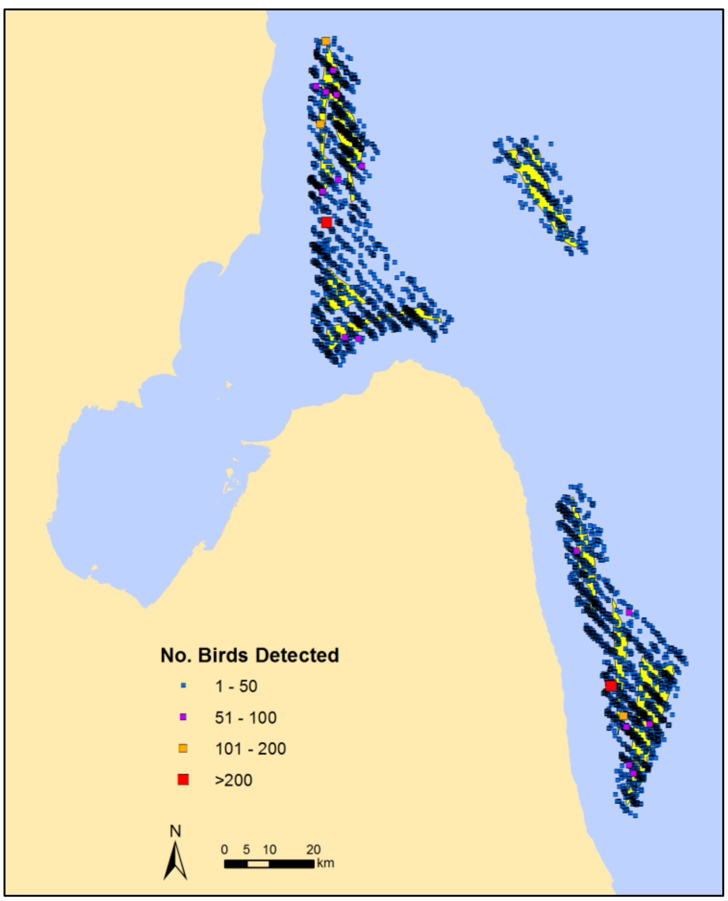


Figure 2 Approximate locations and relative abundances of all birds observed during aerial surveys conducted over central Lake Huron in 2012-2014. Lake Huron Wind Resource Areas as identified by the Great Lakes Wind Council are indicated by yellow shading.

Appendix C: Lake St. Clair, Detroit River, and Western Lake Erie Surveys

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles, the Great Lakes region provides vital breeding, feeding, and resting areas for hundreds of millions of birds. To protect these birds and the habitats that support them, we need the best possible knowledge about their dependence on the Great Lakes. To that end, the Great Lakes Commission and partners conducted aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie over the course of two years during the non-breeding season (fall, winter and spring). Armed with the better knowledge gained from these surveys, we can help natural resource managers, conservationists, and other stakeholders make better decisions to protect avian habitats from human impacts. This is a summary of the aerial survey effort covering eastern Lake Erie.

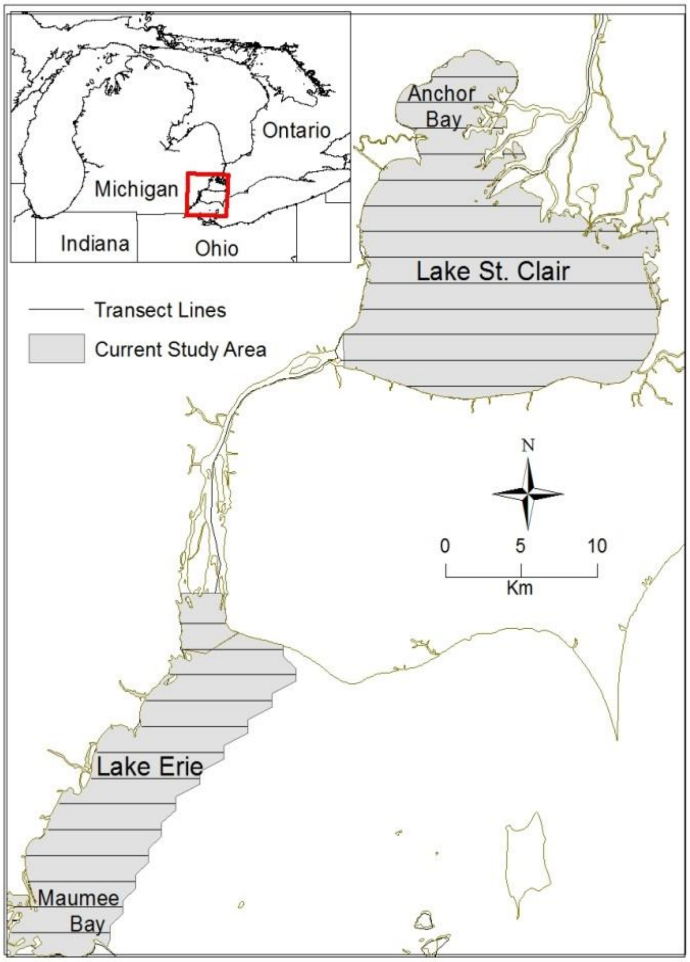


Figure 1. Map of Lake St. Clair and western Lake Erie diving duck survey area with east-west survey transects shown as solid lines

Lead Surveyor: David Luukkonen, Michigan Department of Natural Resources (MDNR), (517) 641-4903, ext. 250, luukkonend@michigan.gov

Survey Area: 1,770 km^2

Total Length of Survey Transects: ? km

Methods: Using Hawth's tools in ArcGIS, MDNR established 26 east-west transects spaced 3.2 km apart. MDNR recorded avian flocks in 5 distance categories extending out from the beginning of the visible portion (that area beyond the portion obscured by airplane floats - amphibious Cessna 185) of the transect line on each side of the airplane 0-50, 51-125, 126-225, 226-425, and >425 m. MDNR used a target flight altitude of 90 m and a clinometer to establish declinations from horizontal to associated distance bands and used 3 mm strips of masking tape to mark windows and 25 mm strips of masking tape to mark struts of the plane. Observers aligned window and strut marks when recording observations to prevent inaccurate distance measurements caused by a shift in the observer's line of sight. MDNR used two observers on each flight with each observer being responsible for one side of the plane. MDNR used data loggers with voice recording capabilities to record all observations for most flights.

Appendix 5

Number of surveys and dates:

	Phase 1 **2012-2013 fall-spring seasons**	**Phase 2** **2013-2014 fall-spring seasons**	**Grand Total No. of Surveys**
Survey Dates	• October 22 and 30, 2012 • November 5 and 20, 2012 • December 5 and 12, 2012 • January 8 and 23, 2013 • February 6 and 12, 2013 • March 7 and 22, 2013 • April 3, 21 and 26, 2013 • May 1 and 8, 2013	• October 22 and 30, 2013 • November 8 and 19, 2013 • December 12, 2013 • January 21, 2014 • February 13, 2014 • March 31, 2014 • April 9, 16 and 21, 2014 • May 6, 2014 • June 10, 2014	
Subtotal	17	13	30

Number of individual bird observations:

	Phase 1 **2012-2013 fall-spring seasons**	**Phase 2** **2013-2014 fall-spring seasons**	**Grand Total of No. Observation**
No. of Observations	1,172,832	534,069	1,706,901

Summary of Results:

Phase 1- In all 3 monitored seasons' canvasbacks were the bird species with the highest observed count (51% of fall 2012 observations, 54% winter 2013, 42% spring 2013), and canvasbacks, scaup, redhead, and swans were 4 of the 5 most abundant bird species observed during all 3 seasons. Based on our empirical count data, waterfowl (i.e., diving ducks, dabbling ducks, sea ducks, swans, and geese) were the most abundant avian group on Lake St. Clair, western Lake Erie, and lower Detroit River. MDNR also documented significant use of the study area by bald eagles, especially in winter (215 birds) when extensive ice coverage inland likely concentrated birds around remaining open water on Lake Erie and Lake St. Clair.

Phase 2 - Diving ducks were the most abundant species group and reached the highest densities of any bird group on the study area (peak diving duck estimate was 321,258 birds on November 2013-Figure 2). For all 4 major waterfowl groups (diving ducks, dabbling ducks, sea ducks, and swans) observed densities were highest during fall migration and lowest during winter migration. Conversely, densities for gulls were highest during spring migration and bald eagle densities peaked during the wintering period. Concentrations of diving ducks and sea ducks were often detected well offshore (> 5 miles) in comparison to dabbling ducks, swans, gulls, and bald eagles that often occurred at high densities in the near-shore waters of Lake St. Clair and western Lake Erie.

Appendix 5

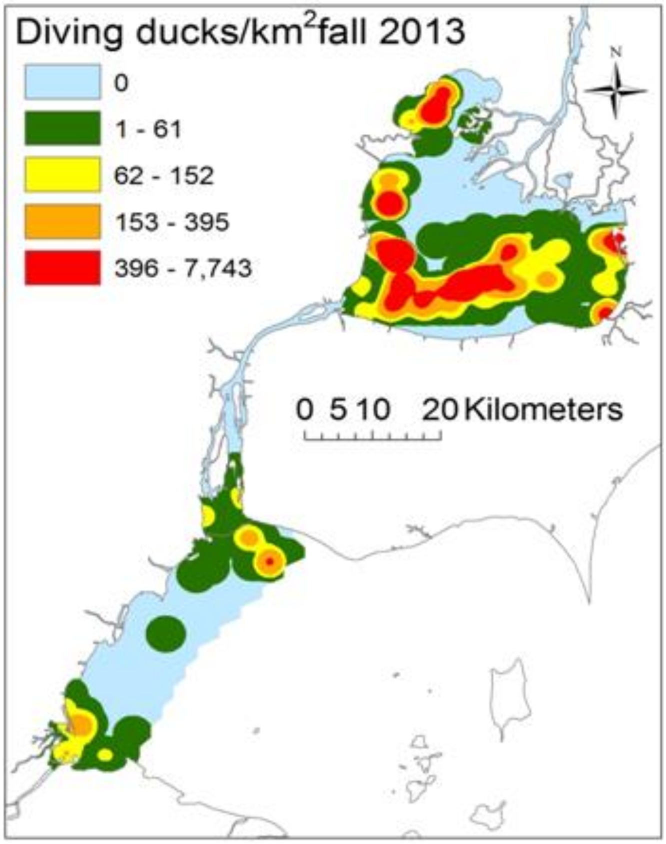


Figure 2. Kernel density map developed from MDNR aerial survey observations for diving ducks on Lake St. Clair, western Lake Erie and the Detroit River Fall 2013

Top Three Most Abundant Species by Fall and Spring Seasons:

Phase 1 2012-2013 fall-spring seasons				Phase 2 2013-2014 fall-spring seasons			
Fall 2012	**Species**	**Number**	**% of Total Observed**	**Fall 2013**	**Species**	**Number**	**% of Total Observed**
	Canvasback	393,245	48%		Canvasback	112,828	37%
	Scaup	178,628	22%		Scaup	87,943	29%
	Readhead	2,317	5%		Readhead	45,935	15%
Spring 2013	Canvasback	40,877	39%	**Spring 2014**	Scaup	59,066	41%
	Scaup	64,632	33%		Unknown diver	33,392	23%
	Readhead	11,428	11%		Canvasback	16,872	12%

Appendix D: Eastern Lake Erie Surveys

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles, the Great Lakes region provides vital breeding, feeding, and resting areas for hundreds of millions of birds. To protect these birds and the habitats that support them, we need the best possible knowledge about their dependence on the Great Lakes. To that end, the Great Lakes Commission and partners conducted aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie over the course of two years during the non-breeding season (fall, winter and spring). Armed with the better knowledge gained from these surveys, we can help natural resource managers, conservationists, and other stakeholders make better decisions to protect avian habitats from human impacts. This is a summary of the aerial survey effort covering eastern Lake Erie.

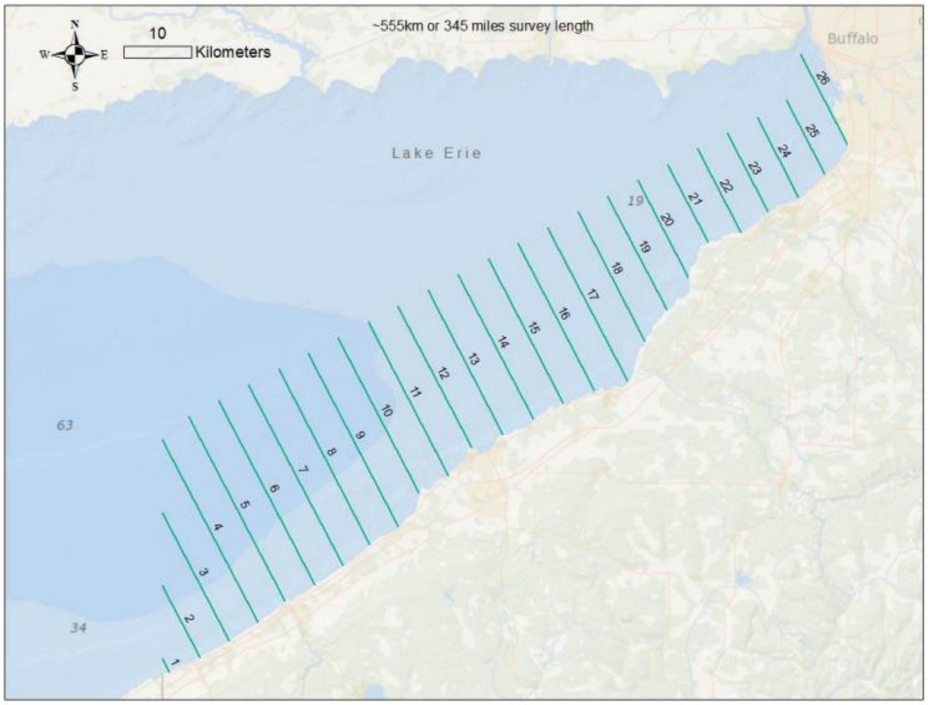


Figure 2. Map of the eastern Lake Erie survey area with survey transects shown as solid lines.

Lead Surveyor:
Kate Williams, Biodiversity Research Institute,
(207) 839-7600 x108,
kate.williams@briloon.org

Survey Area: 2786 km^2 (approximately 333 km^2 surveyed, assuming a 300m transect strip on either side of the plane)

Total Length of Survey Transects: 555km

Methods: Transects were spaced 5 km apart from each other and were flown perpendicularly to the coastline (Figure 1). A US Fish and Wildlife Service (FWS) pilot biologist served as an observer and recorded objects on the left side of the plane; the second observer from Biodiversity Research Institute (BRI) recorded objects on the right side of the plane. Survey protocols were based on breeding waterfowl surveys conducted by FWS pilots and recommendations for aerial surveys distributed by the Great Lakes Commission (GLC) in October 2013. A large portion of the survey area was iced over in winter, including during the February 2014 survey, and surveys were not initiated during a period in February-March 2014 when the survey area was almost entirely iced. Transects were flown at ground speeds of 90-105 mph (78-90 kts) and 200 feet (61 m) aboveground level (AGL). Reference marks were applied to the aircraft's wing struts to delineate transect widths of 100, 200, and 300 meters from the center of the aircraft for observations. All data were recorded into the voice/GPS survey program RECORD, developed by Jack Hodges (FWS).

Numbers of surveys and dates:

	Phase 2 **2013-2014 fall-spring seasons**
Survey Dates	• November 20-21, 2013 • February 8, 2014 • April 2, 2014 • May 5, 2014
Total No. of Surveys	4

Note: data from a January 2014 FWS midwinter waterfowl survey, using a different transect design, are included in Figure 2, but are otherwise excluded from the below summary

Appendix 5

Number of individual bird observations: 10,046

Summary of Results: The most common species groups across all surveys were mergansers, scaup, gulls (particularly Bonaparte's and Herring Gulls), Canada Geese, and Canvasbacks. Excluding the January FWS survey, which flew along the shoreline, most commonly observed species were mergansers, gulls, and scaup. Notable observations included several Bald Eagles, Common Terns, Caspian Terns, and an Iceland Gull. Figure 2 displays all observations from all surveys.

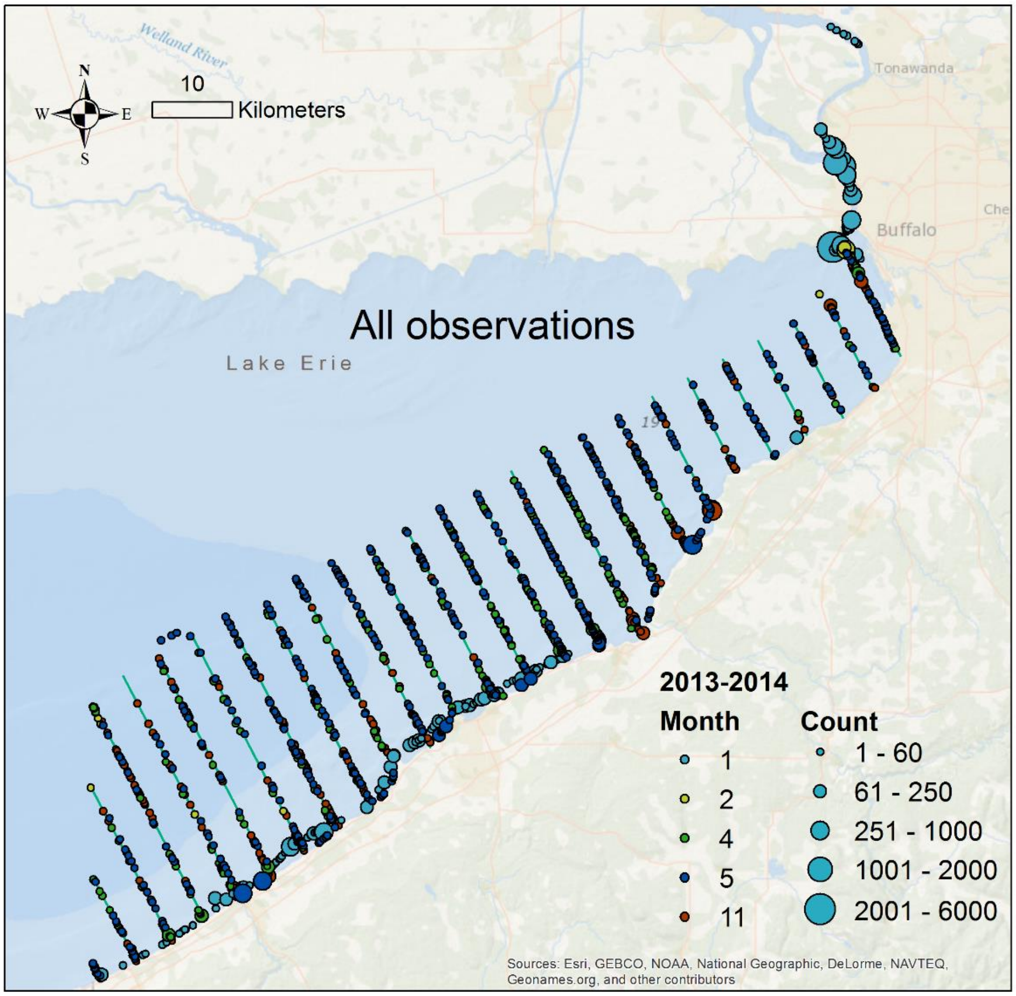


Figure 3. All observations, from all surveys. Colors indicate the month of survey (e.g., 1=January) and size indicates the size of the count (e.g., number of individuals observed).

Top Five Most Abundant Species or Species Groups, by Season (>500 individuals in the 4 BRI surveys):

Species group	Total Count	Fall	Winter	Spring	% of Fall Total	% of Winter Total	% of Spring Total
Red-breasted Merganser	**2197**	664	454	1079	25%	68%	16%
Bonaparte's Gull	**1594**	690	0	904	26%	0%	13%
Unidentified Gull	**1400**	146	47	1207	6%	7%	18%
Unidentified Merganser	**1248**	716	53	479	27%	8%	7%
Herring gull	**1067**	49	5	1013	2%	1%	15%

Appendix E: Western Lake Michigan Surveys

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles, the Great Lakes region provides vital breeding, feeding, and resting areas for hundreds of millions of birds. To protect these birds and the habitats that support them, we need the best possible knowledge about their dependence on the Great Lakes. To that end, the Great Lakes Commission and partners conducted aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie over the course of two years during the non-breeding season (fall, winter and spring). Armed with the better knowledge gained from these surveys, we can help natural resource managers, conservationists, and other stakeholders make better decisions to protect avian habitats from human impacts. This is a summary of the aerial survey effort covering western Lake Michigan.

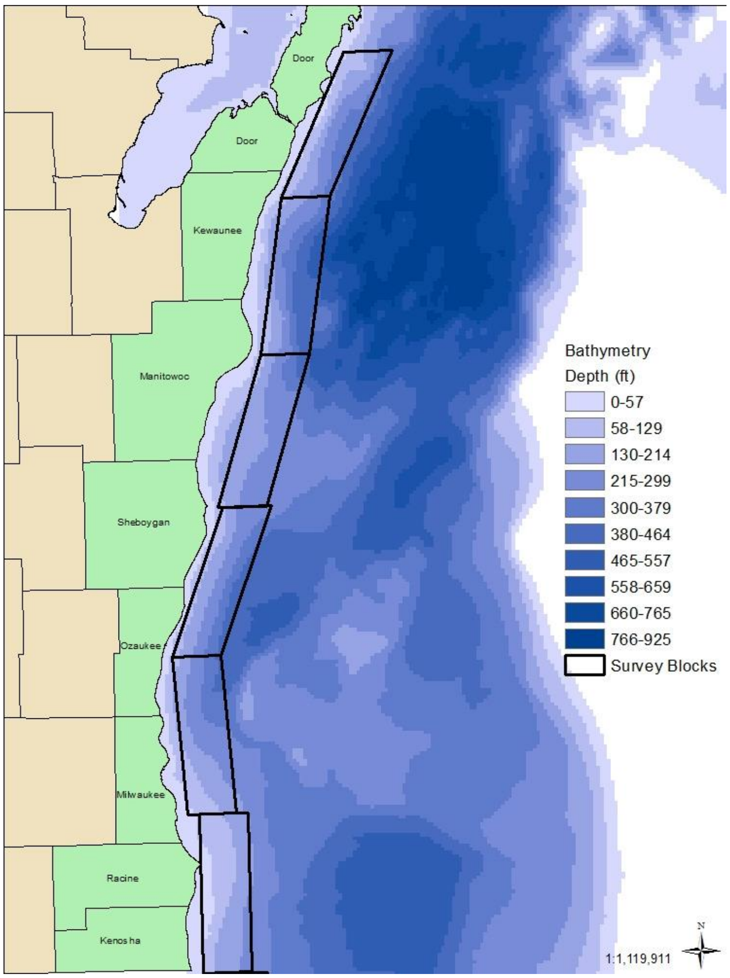


Figure 4. Map of the survey transects for western Lake Michigan

Lead Surveyor: William Mueller, Western Great Lakes Bird and Bat Observatory (WGLBBO), (414) 698-9108, wpmueller1947@gmail.com

Survey Area: 4194.6 km^2

Total Length of Survey Transects: 1738.1 km

Methods: WGLBBO flew parallel transects north and south along the west shore of Lake Michigan. Surveys were conducted along transects oriented north-south and spaced 3.2 km apart throughout the surveyed region, using a double-observer protocol. A fixed-wing aircraft flying at 148 km/h (92mph) followed the mapped transects in alternating directions, within a 48.28 kilometer-long (30 mile) transect block. Surveys were flown at a 100 m aircraft altitude level.

Bird concentrations outside of the survey blocks after a block was done were counted as part of an additional transect nearer the shore. These data are displayed on maps as records of birds nearer to shore than the one mile survey block boundary.

Appendix 5

Numbers of surveys and dates:

	Phase 1 2012-2013 fall-spring seasons	Phase 2 2013-2014 fall-spring seasons	Grand Total No. of Surveys
Survey Dates	• October 2, 16 and 19, 2012 • November 2, 9, 13, 27and 29, 2012 • December 4 and 14, 2012 • March 4, 8, 13, 14 and 22, 2013 • April 3, 16 and 24, 2013	• October 7, 17 and 242013 • November 5, 8, and 21, 2013 • December 2, 6 and 18, 2013 • March 24 and 26, 2014 • April 2, 7, 15, 18, and 22, 2014 • May 6, 2014	
Subtotal	18	19	**37**

Number of individual bird observations:

	Phase 1 2012-2013 fall-spring seasons	Phase 2 2013-2014 fall-spring seasons	Grand Total of No. Observation
No. of Observations	53,881	84,444	138,325

Summary of Results: Consistently, the survey blocks located offshore from the Door, Kewaunee, and Manitowoc County shoreline areas hold the highest numbers of waterfowl, especially Long-tailed Duck, the most abundant species. Other species however were consistently high in number depending on the month of each migratory season – especially Red-breasted Merganser and all gull species. These waterfowl and gulls were distributed all along Wisconsin's Lake Michigan shoreline, changing in number and location depending on the timing of migration within each season.

Top Three Most Abundant Species by Season:

Phase 1 2012-2013 fall-spring seasons				Phase 2 2013-2014 fall-spring seasons			
Fall 2012	**Species**	**Number**	**% of Total Observed**	**Fall 2013**	**Species**	**Number**	**% of Total Observed**
	Long-tailed Duck	29,152	60%		Long-tailed Duck	23,796	35%
	Red-breasted Merganser	8,721	18%		Merganser, species	16,731	24%
	Scaup, species	2,317	5%		Duck, species	12,105	18%
Spring 2013	Red-breasted Merganser	4,471	30%	**Spring 2014**	Long-tailed Duck	12,125	39%
	Long-tailed Duck	4,042	27%		Bonaparte's Gull	7,872	26%
	Common Goldeneye	1,693	11%		Scaup, species	2,358	8%

Appendix 5

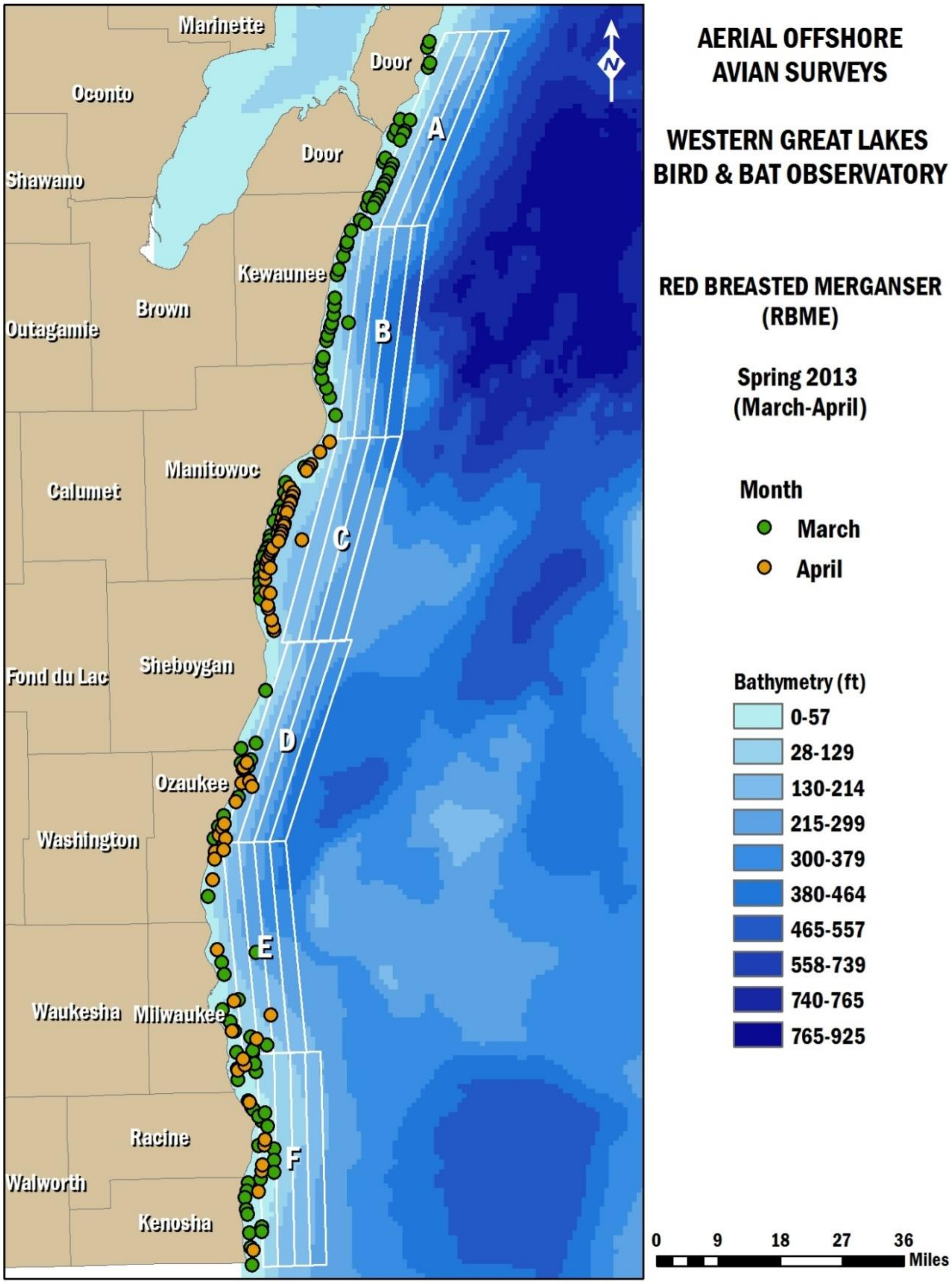


Figure 5 Distribution of the most common species, Red-breasted Merganser in the spring 2013

Appendix 6

Monitoring and Mapping of *Avian Resources* over the Great Lakes to Support Management

Goal

The main goal is to develop predictive models of water bird distributions and densities across the Great Lakes to support decision-making and conservation planning. The second goal is to establish a foundational data management system and that can foster a community of researchers that contribute data to the system beyond the life of the project.

Background

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles (including land and water), the Great Lakes region provides important breeding, feeding, and resting areas for many birds. Much of the Great Lakes coastal aquatic and terrestrial landscapes that once supported migrating birds have been lost or degraded, yet the region supports hundreds of millions of migrants during both spring and fall migration. To assist in managing these bird populations and conserving the habitats that support them, the best information available on how these populations use the Great Lakes is needed.

Informing Management and Conservation

This project makes significant contributions toward filling critical data gaps in our knowledge of avian distributions and abundances in the open waters of the Great Lakes. These data can be used to inform future management and conservation decisions related to activities that might affect waterbirds through their life cycles. The growing database can contribute to many management and conservation activities, including but not limited to:

- Increased understanding of the drivers of spatio-temporal use of Great Lakes by waterbirds
- Designing of the next generation of survey methodologies, and providing training and ground-truthing data for large-scale spatial models of bird abundance
- Addressing specific research and monitoring needs of the Upper Mississippi River and Great Lakes Region Joint Venture.
- Increased understanding of critical areas, habitats, resources, and times for waterbirds in the Great Lakes, including the identification of Important Birding Areas (IBAs), and enhancing state coastal and marine spatial planning efforts.

Armed with this knowledge, natural resource managers, conservationists, and other stakeholders can make better-informed decisions about habitat restoration investments and identify important over-lake habitats that should be protected from human impacts, closely monitored, and carefully managed.

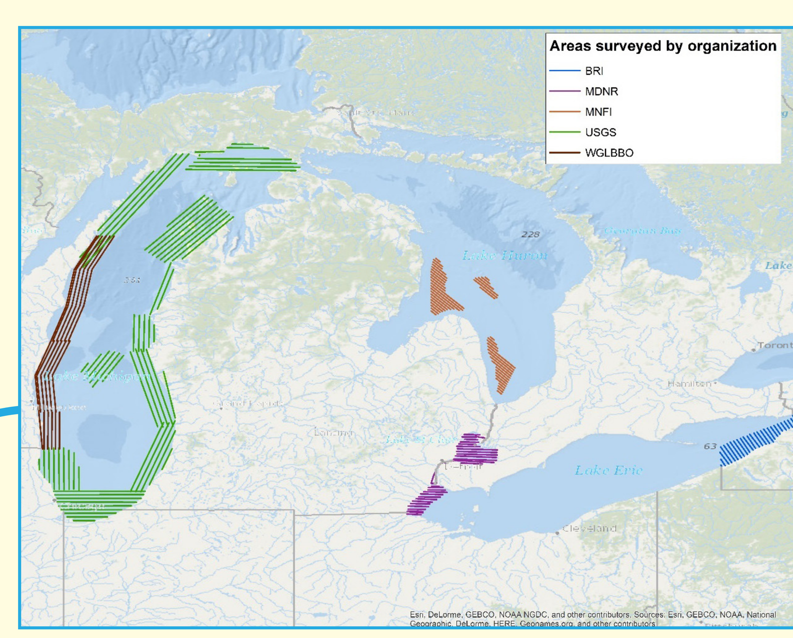


Figure 1. Aerial survey locations for the first two phases of the project (2012-2014). BRI: Biodiversity Research Institute, MDNR: Michigan Department of Natural Resources, MNFI Michigan Natural Features Inventory, USGS: U.S. Geological Survey, WGLBBO: Western Great Lakes Bats and Birds Observatory

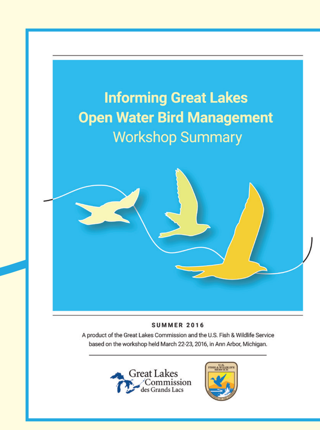
Developing Predictive Species Models

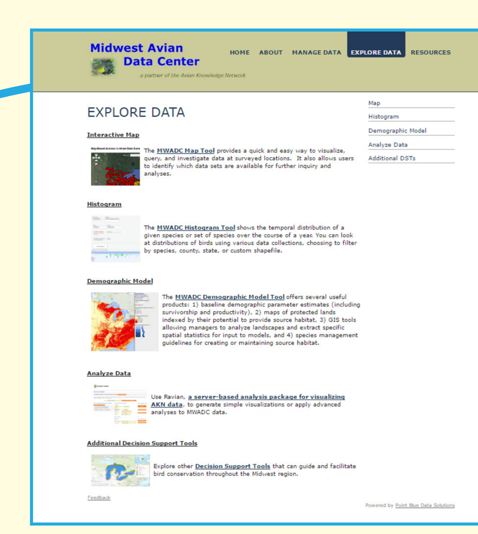
From 2012 to 2014, the Great Lakes Commission and the U.S. Fish and Wildlife Service coordinated five research entities to conduct aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie during the non-breeding season (see fig. 1). Building on the effort of these first two phases, a modeling team will develop predictive models to better serve and inform conservation and planning efforts through the collaborative work with natural resource managers and other stakeholders.

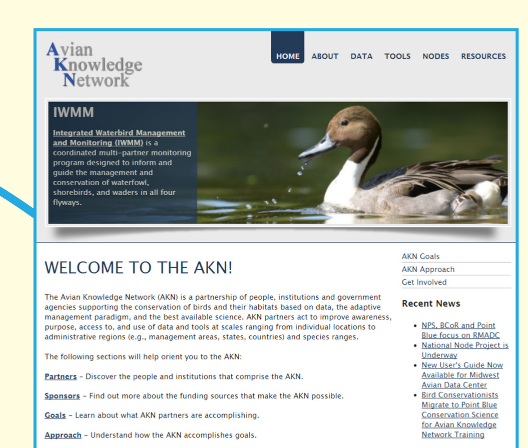
The desired outcomes of the modeling effort are to:

- Determine the sampling and modeling priorities for the next phases of the project
- Inform current water bird conservation priorities
- Inform management decisions on wind energy development in the Great Lakes

Approaches used include the identification of "hotspot" and "coldspot" locations, identification of relationships between water bird occurrences, abundances, and relevant environmental covariates, and integrating observation models across differing sampling protocols.







Developing a Data Management System for Great Lakes Researchers

The Midwest Avian Data Center (MWADC) is a node of the Avian Knowledge Network (AKN). The AKN supports a network of people, data, and technology to improve bird conservation, management, and research across organizational boundaries and spatial scales. The MWADC provides the platform to manage scientific data, foster meaningful data visualizations, and coordinate partnerships around conservation questions. MWADC users can manage point counts, aerial transects, area search and other types of data through on-line tools. By making the data discoverable, users can navigate through the database and visualize the information through different outputs.

Available at: http://data.pointblue.org/partners/mwadc/index.php

For more information on the project, visit: http://glc.org/projects/habitat/avian-resources

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1 Biodiversity Research Institute 2 University of Washington 3 U.S. Geological Survey 4 U.S. Fish and Wildlife Service 5 Great Lakes Commission 6 Michigan Department of Natural Resources 7 Michigan State University 8 Western Great Lakes Bird and Bat Observatory 9 Point Blue Conservation Science

Monitoring and Mapping of *Avian Resources* over the Great Lakes to Support Management

Goals

- Develop predictive models of water bird distributions and densities across the Great Lakes to support decision-making and conservation planning.
- Establish a foundational data management system that fosters a community of researchers contributing data beyond the life of the project, and that permits analyses and uses at multiple scales.

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Background

With 10,000 miles of shoreline and a watershed area of more than 300,000 square miles, the Great Lakes region provides important breeding, feeding, and resting areas for many birds. Much of the Great Lakes coastal aquatic and terrestrial landscapes that once supported migrating birds have been lost or degraded, yet the region supports hundreds of millions of migrants during both spring and fall migration. To assist in managing these bird populations and conserving the habitats that support them, the best information available on how these populations use the Great Lakes is needed.

Developing Predictive Species Models

From 2012 to 2014, the Great Lakes Commission and the U.S. Fish and Wildlife Service coordinated five research entities to conduct aerial surveys of selected areas of Lake Michigan, Lake Huron, Lake St. Clair, and Lake Erie during the non-breeding season (see fig. 1c).

Building on the survey, a team developed a modeling approach to better serve and inform conservation and planning efforts through the collaborative work with natural resource managers and other stakeholders.

Preliminary hotspot analyses (fig. 1) and environmental covariate analyses (table 1) were produced, but additional data will be necessary to have a clear understanding of the distribution of waterbirds in the entire Great Lakes region.

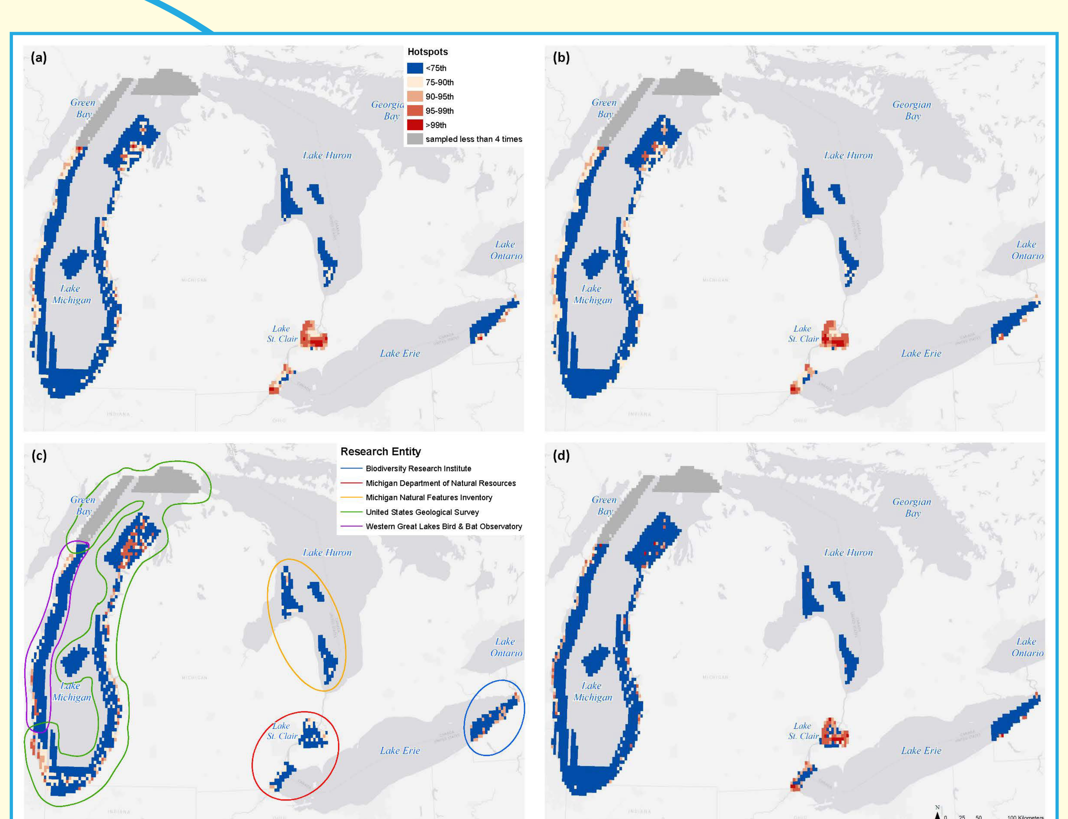


Figure 1. Potential hotspots (values above the 75th percentile within each method) for the all-species-combined species group as estimated with each of the four hotspot analysis approaches:

(a) kernel density estimation,
(b) Getis-Ord Gi*,
(c) hotspot persistence, and
(d) hotspots conditional on presence.

Grid cells sampled less than four times were excluded from the analysis and are shaded in gray. Note the survey regions are delineated for the hotspot persistence approach (c) because hotspots in this method are calculated relative to other grid cells within these specific regions. In this illustration, values below the 75th percentile are not considered hotspots.

Developing a Data Management System for Great Lakes Researchers

The Midwest Avian Data Center (MWADC, fig. 2) is a node of the Avian Knowledge Network (AKN). The AKN supports a network of people, data, and technology to improve bird conservation, management, and research across organizational boundaries and spatial scales. The MWADC provides the platform to manage scientific data, foster meaningful data visualizations, and coordinate partnerships around conservation questions.

MWADC users can manage point counts, aerial transects, area search and other types of data through on-line tools. By making the data discoverable, users can visualize and analyze information through different outputs, at multiple spatial scales.

Available at: http://data.pointblue.org/partners/mwadc/index.php

		Long-tailed Duck	*Gulls*	*Goldeneyes*	*Loons*	*Mergansers*	*Scaup*
Response	**Parameter**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**
Zero-inflation	Intercept	1.1 (0.8 , 1.5)	0.3 (0.1 , 0.5)	-1.3 (-1.7 , -0.8)	-0.5 (-0.9 , 0.1)	-0.6 (-0.8 , -0.3)	-1.3 (-1.9 , -0.6)
	Longitude	1.1 (0.9 , 1.4)	-0.8 (-1 , -0.7)	-1.1 (-1.4 , -0.8)	0.1 (-0.1 , 0.4)	-1.2 (-1.4 , -1.1)	0.9 (0.7 , 1.2)
	$Longitude^2$	0 (-0.2 , 0.2)	0.4 (0.3 , 0.5)	0.7 (0.5 , 1)	0.1 (0 , 0.2)	0.5 (0.5 , 0.6)	-0.5 (-0.8 , -0.3)
	Ice Coverage -- >95%	-1.1 (-1.5 , -0.7)	-0.7 (-1 , -0.4)	-1.8 (-2.6 , -0.9)	0.6 (-1.3 , 2.8)	-0.6 (-1 , -0.2)	0.8 (0.2 , 1.6)
	Season -- Fall	-1.7 (-1.9 , -1.4)	1.1 (0.9 , 1.4)	-2.3 (-2.6 , -1.9)	0.2 (0 , 0.5)	-1.2 (-1.4 , -0.9)	-0.1 (-0.4 , 0.1)
	Season -- Winter	0.1 (-0.2 , 0.4)	-0.4 (-0.6 , -0.2)	0.9 (0.5 , 1.5)	-1.4 (-1.8 , -1)	-0.4 (-0.8 , -0.1)	-0.1 (-0.5 , 0.2)
Abundance	Intercept	-2.4 (-2.7 , -2)	-1.7 (-2 , -1.4)	-3.5 (-4.1 , -2.9)	-2.1 (-2.8 , -1.5)	-2.4 (-2.7 , -2.1)	-2.8 (-4.2 , -1.9)
	Substrate -- Clay	1.5 (1.2 , 1.8)	0.6 (0.3 , 0.9)		0.3 (-0.1 , 0.7)		
	Substrate -- Hard	1.7 (1.4 , 2)	0.6 (0.4 , 0.9)	1.9 (1.4 , 2.3)	0 (-0.3 , 0.4)	1.8 (1.5 , 2)	1.1 (0.5 , 1.8)
	Substrate -- Mud		1.1 (0.8 , 1.4)		1.8 (1.3 , 2.4)		
	Substrate -- Sand	1.7 (1.4 , 2)	0.9 (0.7 , 1.2)	1.4 (1 , 1.8)	0.8 (0.5 , 1.1)	0.9 (0.7 , 1.1)	0.5 (0.2 , 0.8)
	Substrate -- Silt		0.3 (0 , 0.6)				
	Bathymetry	-1.3 (-1.5 , -1.2)	-0.6 (-0.7 , -0.6)	-2.4 (-2.7 , -2.1)	-0.8 (-1 , -0.7)	-2.1 (-2.3 , -1.9)	-1.2 (-1.5 , -0.9)
	Ice Coverage	0.2 (0.1 , 0.3)	0 (0 , 0.1)	0 (-0.2 , 0.1)	-0.5 (-0.8 , -0.1)	0.1 (0.1 , 0.2)	0 (-0.2 , 0.2)

Table 1. Posterior means of the abundance parameters for Long-tailed Duck, gulls, goldeneyes, loons, mergansers, and scaup. Covariates are shown for the zero-inflation component and the conditional upon presence abundance component of the model. 95% CI is the lower and upper 95% Credible Interval for each parameter estimate.

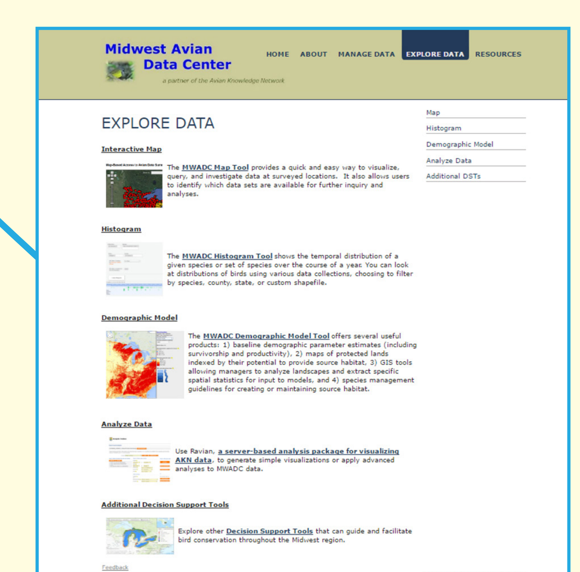
Informing Management and Conservation

This project makes significant contributions toward filling critical data gaps in our knowledge of avian distributions and abundances in the open waters of the Great Lakes. These data can be used to inform future management and conservation decisions related to activities that might affect waterbirds through their life cycles.

Armed with this knowledge, natural resource managers, conservationists, and other stakeholders can make better-informed decisions about habitat restoration investments and identify important over-lake habitats that should be protected from human impacts, closely monitored, and carefully managed.

For more information on the project, visit: http://glc.org/work/avian-resources

Figure 2. Home page of the MWADC.



AUTHORS

Evan Adams[1,2], Beth Gardner[2], Kevin Kenow[3], Katie Koch[4], Michèle Leduc-Lapierre[5], David Luukkonen[6], Michael Monfils[7], William Mueller[8], Victoria Pebbles[5], Allison Sussman[7], Leo Salas[9], Kate Williams[1], and Elise Zipkin[7].

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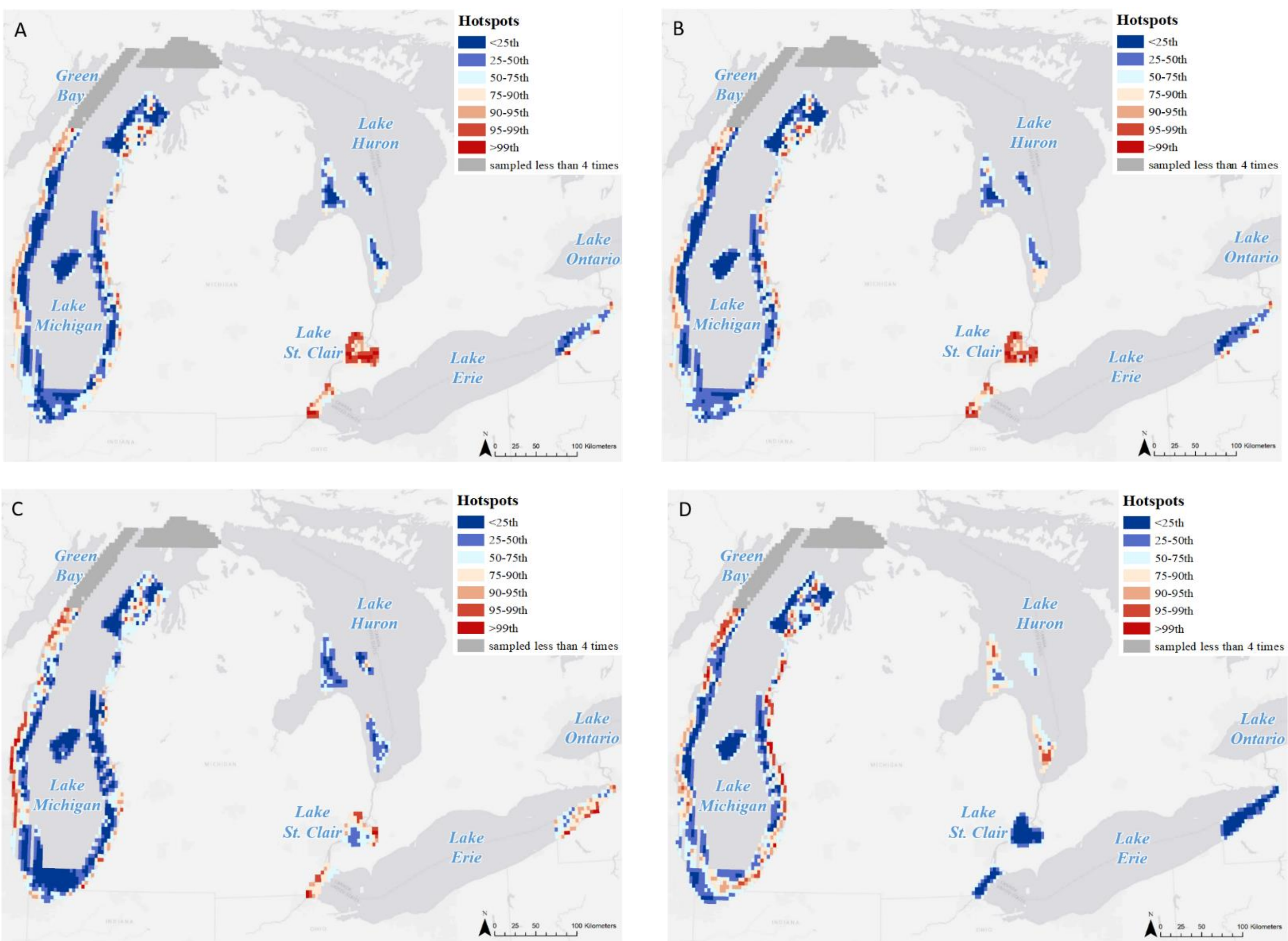
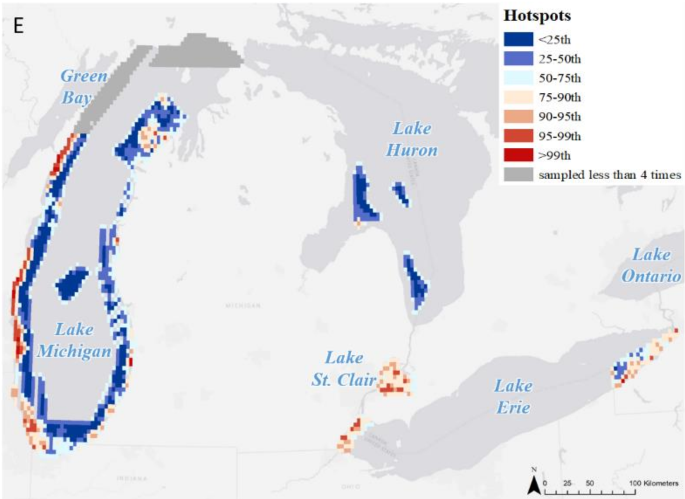
Appendix 8

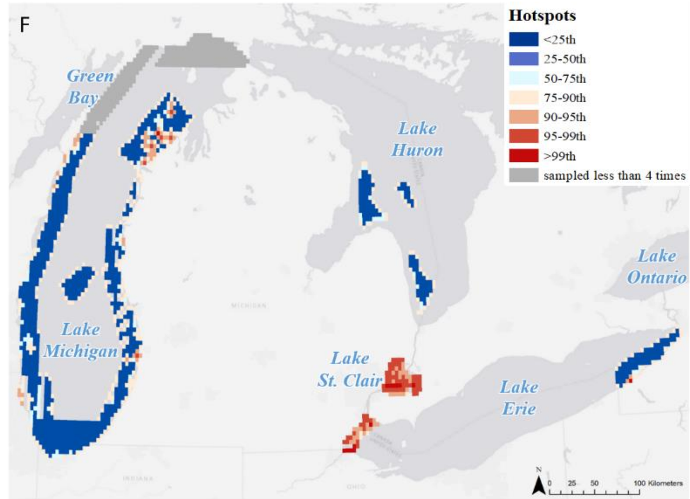
Potential hotspots (values above the 75% percentile) across all sampled locations for the specified species/group as averaged across one spatial, non-parametric approach (Getis-Ord G_i*) and one non-spatial, parametric approach (hotspots conditional on presence). Grid cells sampled less than four times were excluded from the analysis and are shaded in gray.

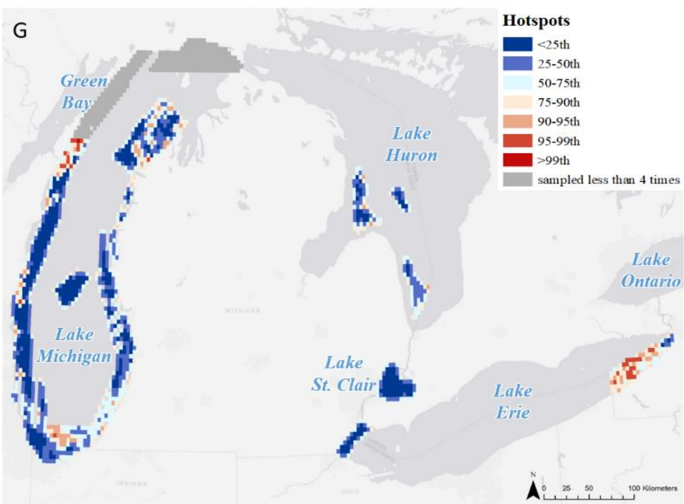
A. All-Species-Combined
B. Diving/Sea Ducks (includes: bufflehead, canvasback, common eider, long-tailed duck, redhead, ring-necked duck, ruddy duck, all eiders, all goldeneye, all mergansers, all scaup, all scoters, all unidentified diving ducks)
C. Gulls (includes: Bonaparte's gull, glaucous gull, great black-backed gull, herring gull, Iceland gull, mew gull, ring-billed gull, all unidentified gulls)
D. Long-tailed Duck *Clangula hyemalis*
E. Mergansers (includes: common merganser, hooded merganser, red-breasted merganser, all unidentified mergansers, all unidentified merganser/goldeneye)
F. Scaup (includes: greater scaup, lesser scaup, all unidentified scaup)
G. Loons (includes: common loon, red-throated loon, all unidentified loons)
H. Common Loon *Gavia immer*

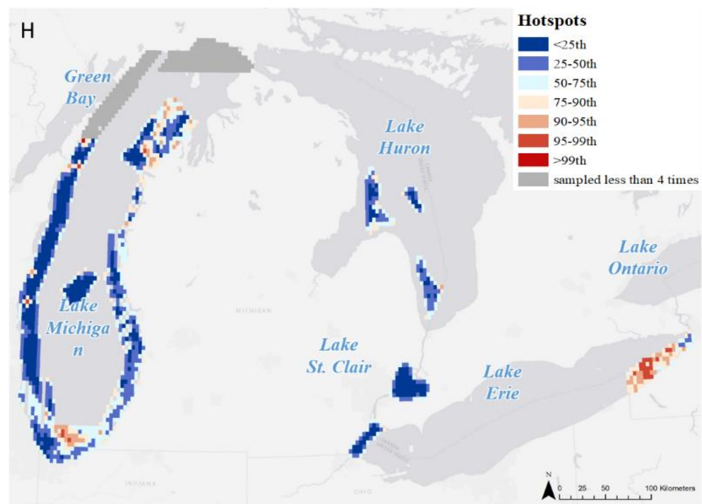


Appendix 8


E
Hotspots
<25th
25-50th
50-75th
75-90th
90-95th
95-99th
>99th
sampled less than 4 times
Green Bay
Lake Huron
Lake Ontario
Lake Michigan
Lake St. Clair
Lake Erie
100 Kilometers


F
Hotspots
<25th
25-50th
50-75th
75-90th
90-95th
95-99th
>99th
sampled less than 4 times
Green Bay
Lake Huron
Lake Ontario
Lake Michigan
Lake St. Clair
Lake Erie
100 Kilometers


G
Hotspots
<25th
25-50th
50-75th
75-90th
90-95th
95-99th
>99th
sampled less than 4 times
Green Bay
Lake Huron
Lake Ontario
Lake Michigan
Lake St. Clair
Lake Erie
100 Kilometers


H
Hotspots
<25th
25-50th
50-75th
75-90th
90-95th
95-99th
>99th
sampled less than 4 times
Green Bay
Lake Huron
Lake Ontario
Lake Michiga n
Lake St. Clair
Lake Erie
100 Kilometers

Appendix 9

Posterior means of the abundance parameters for Long-tailed Duck, gulls, goldeneyes, loons, mergansers, and scaup. Covariates are shown for the zero-inflation component and the conditional upon presence abundance component of the model. 95% CI is the lower and upper 95% Credible Interval for each parameter estimate.

		Long-tailed Duck	*Gulls*	*Goldeneyes*	*Loons*	*Mergansers*	*Scaup*
Response	**Parameter**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**	**mean (95% CI)**
	Intercept	1.1 (0.8 , 1.5)	0.3 (0.1 , 0.5)	-1.3 (-1.7 , -0.8)	-0.5 (-0.9 , 0.1)	-0.6 (-0.8 , -0.3)	-1.3 (-1.9 , -0.6)
	Longitude	1.1 (0.9 , 1.4)	-0.8 (-1 , -0.7)	-1.1 (-1.4 , -0.8)	0.1 (-0.1 , 0.4)	-1.2 (-1.4 , -1.1)	0.9 (0.7 , 1.2)
	Longitude^2	0 (-0.2 , 0.2)	0.4 (0.3 , 0.5)	0.7 (0.5 , 1)	0.1 (0 , 0.2)	0.5 (0.5 , 0.6)	-0.5 (-0.8 , -0.3)
Zero-inflation	Ice Coverage -- >95%	-1.1 (-1.5 , -0.7)	-0.7 (-1 , -0.4)	-1.8 (-2.6 , -0.9)	0.6 (-1.3 , 2.8)	-0.6 (-1 , -0.2)	0.8 (0.2 , 1.6)
	Season -- Fall	-1.7 (-1.9 , -1.4)	1.1 (0.9 , 1.4)	-2.3 (-2.6 , -1.9)	0.2 (0 , 0.5)	-1.2 (-1.4 , -0.9)	-0.1 (-0.4 , 0.1)
	Season -- Winter	0.1 (-0.2 , 0.4)	-0.4 (-0.6 , -0.2)	0.9 (0.5 , 1.5)	-1.4 (-1.8 , -1)	-0.4 (-0.8 , -0.1)	-0.1 (-0.5 , 0.2)
	Intercept	-2.4 (-2.7 , -2)	-1.7 (-2 , -1.4)	-3.5 (-4.1 , -2.9)	-2.1 (-2.8 , -1.5)	-2.4 (-2.7 , -2.1)	-2.8 (-4.2 , -1.9)
	Substrate -- Clay	1.5 (1.2 , 1.8)	0.6 (0.3 , 0.9)		0.3 (-0.1 , 0.7)		
	Substrate -- Hard	1.7 (1.4 , 2)	0.6 (0.4 , 0.9)	1.9 (1.4 , 2.3)	0 (-0.3 , 0.4)	1.8 (1.5 , 2)	1.1 (0.5 , 1.8)
Abundance	Substrate -- Mud		1.1 (0.8 , 1.4)		1.8 (1.3 , 2.4)		
	Substrate -- Sand	1.7 (1.4 , 2)	0.9 (0.7 , 1.2)	1.4 (1 , 1.8)	0.8 (0.5 , 1.1)	0.9 (0.7 , 1.1)	0.5 (0.2 , 0.8)
	Substrate -- Silt		0.3 (0 , 0.6)				
	Bathymetry	-1.3 (-1.5 , -1.2)	-0.6 (-0.7 , -0.6)	-2.4 (-2.7 , -2.1)	-0.8 (-1 , -0.7)	-2.1 (-2.3 , -1.9)	-1.2 (-1.5 , -0.9)
	Ice Coverage	0.2 (0.1 , 0.3)	0 (0 , 0.1)	0 (-0.2 , 0.1)	-0.5 (-0.8 , -0.1)	0.1 (0.1 , 0.2)	0 (-0.2 , 0.2)

Appendix 10

DATE: September 11, 2017

TO: Survey teams, Great Lakes Commission Aerial Transect Surveys

FROM: Data management team and Midwest Avian Data Center

RE: Unified survey protocol

Dear colleagues,

We are writing to share some thoughts toward developing a unified survey protocol for future aerial transect surveys. After all the amazing work you have completed, we thought it would help us all to look back to look for improvements on various field protocols employed to conduct transect surveys over the Great Lakes. Three main lessons were learned: First, although a common format was used to compile the data, the survey protocols were quite different. Note in the table below the varied the distance band definitions:

	BRI	*MIDNR*	*MIGOV*	*USGS*	*WGLBBO*
<50			x		
50-125			x		
<100	X	x		x	x
100-200	X	x		x	x
<200	X			x	x
125-225			x		
200-300	X	x			x
100-300					x
<300					x
200-400		x			
300-400		x			
225-450			x		
>300					x
>400		x			
450-800			x		
NR		x	x		

Second, as a consequence of this heterogeneity in distance bands, the analysis of the aggregate of data became more challenging and limited. Lastly, data descriptions and bulk import into the Avian Data Center became more onerous than we anticipated. In fact, we developed a format for bulk uploading the data, as an example, based on the BRI protocol. Rather than customizing the format to suit the individual protocols used, it would probably be best if a consensus was reached about the definitions for distance bins, and then develop a bulk uploading format for such consensus.

The simplest solution is to codify a protocol that includes all the above definitions, so each team would use those most suitable to them. However, this really does not solve the challenges of data aggregation and analysis. The ideal solution is a common set of distance bands. (Aside: As was the case with distance bands, each team used slightly different protocols for collecting survey conditions data. Fortunately, these are more homogeneous and can be redefined into a single protocol with minimal conflict).

We are fully aware that implementing a common protocol, one that differs from how you used to conduct surveys, implies a discontinuity in your data – you may no longer be able to easily aggregate data from prior years. On the upside, the change may permit data aggregation across institutions and, consequently, across larger areas. We want to encourage you to work toward a single format that all teams may use in the future. *This would be an important step toward implementing a regional network that fully integrates these monitoring programs into multi-scale bird conservation decision making throughout the Midwest.* The establishment of such a network is the primary goal of the Midwest Coordinated Bird Monitoring Partnership. Thus, we want to develop a discussion among all of us to move in this direction with the Great Lakes aerial transect surveys.

If you have any additional thoughts about this topic, or ideas about how to homogenize the protocols, please reply (to Michele and Leo). We will make sure your ideas are properly circulated, available, and fully considered by others when designing future aerial surveys.

Thank you for your help and insights.

Michele and Leo