Final Project Summary

Oct 1, 2020 – May 31, 2022

Project Title: Monitoring of Non-breeding Sea Ducks on the Great Lakes, Project 161

Principal Investigators:

Beth E. Ross, U.S. Fish and Wildlife Service, Science Applications, beth_ross@fws.gov

Auriel M. V. Fournier, Forbes Biological Station, Illinois Natural History Survey, Prairie Research Institute, University of Illinois Urbana-Champaign, 20003 N CR 1770E Havana, Il 62644; auriel@illinois.edu

Michael L. Schummer, Department of Environmental and Forest Biology, SUNY-ESF College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, NY 13210; mlschumm@esf.edu

Jacob N. Straub, Department of Environmental Science and Ecology,, State University of New York-Brockport, 350 New Campus Drive, Brockport, NY 14420; jstraub@brockport.edu

Shannon Badzinski, Environment and Climate Change Canada, Canadian Wildlife Service, 335 River Road, Ottawa, Ontario K1A 0H3; shannon.badzinski@ec.gc.ca

Douglas C. Tozer, Long Point Waterfowl and Wetlands Research Program, Birds Canada, P.O. Box 160 (Courier: 115 Front Road), Port Rowan, ON N0E 1M0; dtozer@birdscanada.org

Introduction

Sea ducks frequently encounter habitat changes due to global threats such as wind energy development, toxins, and climate heating in both terrestrial and marine environments (Zipkin et al. 2010, Loring et al. 2014). While such disturbances occur throughout the annual cycle, negative effects of these disturbances during the non-breeding period, including migration and wintering, can have disproportionate effects on the population growth rates of sea ducks (Savard and Peterson, 2015). As climate (Zipkin et al. 2010) and anthropogenic change (Loring et al. 2014) may affect non-breeding sea ducks, understanding habitat use during the non-breeding period can better inform potential conservation and management actions moving forward. At the same time, documenting disturbance effects and designing conservation and restoration measures to improve habitat quality during non-breeding can often be more challenging, as individuals are more broadly distributed in the marine environment than on terrestrial breeding sites.

A key area of importance for sea ducks during migration and winter is the Lower Great Lakes region (lakes St. Clair, Erie, and Ontario, Figure 1; Lamb et al. 2019). The Lower Great Lakes region plays a critical role in providing prey for sea duck during winter and migration (Ross et al. 2005, Schummer et al. 2012) While several studies have described habitat use of sea ducks wintering along the Atlantic Coast of the U.S. and Canada (e.g., Silverman et al. 2013), data are scarce for the Great Lakes region. Habitat used by sea ducks on the Great Lakes differ from the Atlantic Coast (Lamb et al. 2020). Additionally, with the introduction of zebra (*Dreissena polymorpha*) and quagga mussels (*D. bugensis*), there has been an increase in sea duck use on the Lower Great Lakes during migration and winter (Petrie and Schummer 2002, Shirkey 2012), but there is still limited information about sea duck relative abundance and habitat use in this region (Straub and Schummer 2018). Global climate change will cause large shifts in habitat and conditions in the Great Lakes region resulting in increased temperatures, precipitation, and extreme weather events (Winkler et al. 2012, Notaro et al. 2013, Zobel et al. 2017). Environmental conditions such as ice cover, water temperature, and extreme precipitation events likely all affect sea ducks on the Great Lakes and will impact them further in the future (Schummer et al. 2012, Notaro et al. 2013, Zobel et al. 2017, Lamb et al. 2020). Through modeling responses of sea ducks to current and historic environmental conditions, we can then better forecast changes in abundance of sea ducks on the Lower Great Lakes in the future.

Given considerable uncertainty about the current status of sea ducks populations, additional monitoring and research is critical for informing management actions (Koneff et al. 2017). However, because there are many unknowns about the life cycle of sea ducks, targeted information on priorities can help optimize decision making. Structured Decision Making (SDM) is a set of techniques within the broader field of decision science that make the problem, and the objectives (how we value solutions to that problem), explicit and more transparent. The goal of SDM is to ensure the process addresses the problem and explores a wider suite of options than might be typically considered (Conroy and Peterson 2013). The incorporation of an SDM approach to better prioritize information needs for sea ducks, and inform future monitoring efforts, would allow for the development of quantitative metrics that allow us to assess tradeoffs among alternative monitoring efforts relative to the needs of managers (Lyons et al. 2008).

To help inform management and conservation of sea ducks on the Lower Great Lakes, we propose developing a model to quantify population responses to environmental conditions from 1980 to present. Using this model, we will be able to identify key habitats and areas of high use for sea ducks, likely by species or species group (e.g., scoters), on the Lower Great Lakes. Count data will be linked to environmental covariates of importance (e.g., ice cover, temperature) to estimate relationships and make predictions. Once developed, we use the model to predict future population abundance and areas of importance under various scenarios of climate change. Based on input from stakeholders through an SDM approach, we then use model predictions to develop future monitoring scenarios.

Methods

Survey Methodology

We gathered midwinter waterfowl survey data from the Canadian Wildlife Service (CWS), Long Point Waterfowl (LPW), and Ontario Waterfowl Survey (OWS). Aerial surveys were completed along the Canadian shores of lakes St. Clair, Erie, and Ontario, as well as the Detroit, Niagara, and St. Lawrence rivers, and split across 87 segments (Figure 1). Surveys were completed during the months of January or February in 1971, 1972, 1975, 1977, 1978, 1984-2020. Survey data were in presence-only format, with no specific observer or observation covariate information available across all years (e.g. wind speed, time of day, distance to shore, etc.). Data used in the model were from CWS, but we were able to collect other aerial data, many of which were replicated in the CWS dataset (Table 1; see ECCC 2016 for data from 1971-2004).

We collected ice cover data from the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory (NOAA GLERL, Yang et al. 2020). Average percent ice cover was estimated for each year of the survey for lakes Erie and Ontario. Ice cover estimates were the average of percent ice cover in the 30 days prior to the survey within each specific year. In years where there were multiple aerial surveys completed, percent ice cover was estimated based on the first survey occurrence. We also gathered temperature data from multiple weather stations (Environment and Climate Change Canada 2022; Table 2). Similar to ice cover, we used average minimum air temperature (°C) in the 30 days prior to the survey within each specific year. We averaged temperature data by region: Eastern and Western Lake Erie, Eastern and Western Lake Ontario, Lake St. Claire, and the Detroit, Niagara, and St. Lawrence Rivers.

Habitat Model

We used a Negative Binomial Zero-Inflated Generalized Linear Mixed Model on the LTDU count data to determine how LTDU counts might be affected by sea ice cover and temperature across the Lower Great Lakes shoreline over a 42-year time period. We incorporated Year due to variation in survey length and inherent variation across years not associated with changes in Ice and minimum Temperature. We also included Site (transect segment) as a random effect. The Global Model:

$$\text{Count} \sim \text{Ice} + \text{Temperature} + \text{Ice*Temperature} + \text{Year} + (1|\text{Site})$$

We used the *glmmTMB* package (Brooks et al. 2017) to run our model and the *DHARMa* package (Hastig 2022) for post-analysis diagnostics. We used *broom.mixed* (Bolker and Robinson 2022), *dotwhisker* (Solt and Hu 2021), *ggeffects* (Lüdecke 2018), *ggplot2* (Wickham 2016), and *ggthemes* (Arnold 2021) for data visualization. We scaled covariate data using the 'scale' function within R. All data analyses were completed using R v. 4.2.1 (R core team 2022). All mapping was completed in ArcGIS Pro v. 2.8.0.

Structured Decision Making

We conducted targeted interviews to better understand the objectives of stakeholders in relation to Great Lakes sea ducks, and how they are currently using monitoring data and whether in their opinion they would make different decisions if they had better information on Great Lakes sea ducks. We sent out invitations to 12 individuals representing a range of state, provincial, federal (US and Canada), joint venture and nonprofit stakeholders within the region; we were able to set up meetings with 6 of them, including two state agencies, two joint ventures, one US federal agency, and one Canadian federal agency.

We asked a standard set of 5 questions, and then provided time at the end for participants to discuss anything they believed we had not covered, but that we should be aware of in relation to how they think about sea ducks in the Great Lakes.

Results

Summary Statistics

A total of 42 aerial surveys were completed between 1971 and 2020. From 1971 to 2020, average ice cover within the previous 30 days was greater than 20% in 11 years at 32 survey sites located along Lake Erie, Lake St. Claire, and the Detroit River. From 1971 to 2020, average temperatures across the Great Lakes ranged between -20.3 and 1.5°C during midwinter surveys. The St. Lawrence river averaged -11.3°C (range: -20.3 – -3.4°C), while the Detroit River averaged -5.0°C (range: -13.2 – 0°C). Eastern and Western Lake Ontario averaged -5.4°C (range: -13.3– 1.1°C) and -3.5°C (range: -9.6–2.4°C), respectively. Eastern and Western Lake Erie averaged -5.2°C (range:-13.1 – 0.6°C) and -4.5°C (range:-13.2 – 0.4°C). Lake St. Clair averaged -4.8°C (range: -13.2 – 1.5°C). Nine species of sea duck were detected, with over 4,249 observations (Table 3). Long-tailed Ducks (LTDU) were observed at least once during 38 surveys, with a total of 591 observations across the 87 sections (Figure 2). Counts ranged from 1 to 37,236, but count estimates were most frequently fewer than 500 LTDU. LTDUs were most commonly observed using Lake Ontario, with 80 total observations in Lake Erie (n=38), Lake St. Clair (n=1), the St. Lawrence River (n=7), the Niagara River (n=29), and the Detroit River (n=5).

Habitat Model

Relative abundance of LTDUs increased through the duration of our study (Figure 3). There was a strong interactive effect between Ice Cover and Minimum Temperature on LTDU presence across years (β=-0.996; SE=0.366) (Figure 3). When minimum temperature was lower, predicted relative abundance of LTDUs was highest at sites with higher percent ice cover, though this relationship had large uncertainty and was likely driven by only a few observations (Figures 4 & 5). When minimum temperature was higher, predicted relative abundance of LTDUs was highest at sites with less ice cover (Figure 5).

Structured Decision Making

Overall Summary

With the exception of the Sea Duck Joint Venture, sea ducks are not the highest priority for any agency we spoke to, though there is interest among many in better understanding the distribution/abundance and survival of sea ducks in their specific borders, and across the region more broadly.

The stakeholder organizations objectives focused on two primary areas, understanding habitat use by sea ducks to inform future habitat conservation work, especially in the context of wind energy development, and understanding the impacts of hunting on sea duck survival, to inform future regulations and management of hunting. When asked about additional science needs or information we should consider (Question 5, Table 5), several stakeholders mentioned the need for future monitoring efforts, if they were to occur, based on a coordinated effort across the Great Lakes. Information needs related to population vital rates of sea ducks on the Great Lakes was also mentioned by multiple stakeholders.

While there was interest in coordinated monitoring across the Great Lakes, limitations such as cost, staffing, lack of institution will, and safety for pilots/observers in aerial surveys, would potentially prevent additional monitoring work from happening without specific priority needs. Data sets such as eBird and the Christmas Bird Count were mentioned as potential sources of data that could be explored to assess their utility for studying sea ducks, especially given the recent success some states have had in using eBird to study other waterfowl species.

States

States were the primary group where regulation of hunting was discussed, since they are often making those decisions. Minnesota expressed that on the Great Lakes they have very limited sea duck harvest in part due to restrictions on hunting on open water on swaths of Lake Superior. Michigan talked about an increase in sea duck harvest as a percent of waterfowl harvest in the state, but uncertainty around what impact that harvest is having on Great Lakes sea ducks as a whole.

Budgets and safety were big potential limitations for expanding or changing sea duck monitoring in the future. While there was clear value in having better information, without a specific high priority need driving things, they did not see it being a funding/staffing priority.

Joint Ventures

The joint venture staff we spoke to talked a lot about habitat planning, and the need to better understand sea duck habitat needs, especially in the face of current threats like climate change, and wind energy development where understanding what habitats the birds need, could help avoid high conflict development.

Harvest was discussed, though the joint ventures do not play a role in harvest regulation setting, but they recognized that the uncertainty about the impacts of harvest is another major concern in the region. Bycatch of sea ducks in long line fishing was also brought up as a potential source of mortality that is not well understood whether it impacts the population as a whole.

Canadian and US Federal

Agencies from both nations are focused on a wide range of issues, of which sea ducks is only one, and they saw additional future monitoring as needing to be driven by a specific need, not collecting information for an unknown future purpose.

The USFWS highlighted that sea duck regulations along the Atlantic coast have been changed recently, and that knowledge gaps in the Great Lakes prevent us from being able to assess whether those changes are needed in this geography. Canada mentioned that sea duck harvest on the Great Lakes appears to be relatively low and fairly localized, particularly for priority species such as LTDU and scoters.

Wind energy development, as well as broader need to understand habitat were also mentioned.

Discussion

Our results indicate that LTDUs on the Lower Great Lakes are using areas with different ice cover as temperature changes. However, there was more uncertainty associated with habitat use in areas with high ice cover during lower temperatures. Most LTDUs used water habitats with < 20% ice cover, and large flocks only occurred in areas with lower ice cover regardless of temperature. Given the largest uncertainty in our estimates was related to water use under the coldest conditions, future surveys could improve the estimates of habitat associations with surveys conducted during coldest days across a range of ice cover; however, our discussions with stakeholders indicated that additional aerial surveys may not largely influence how LTDUs are managed.

Our results indicate that LTDUs on the Great Lakes primarily use habitat with limited sea ice cover (< 20%) with high to moderate temperatures during winter (> -5°C). A few individuals were observed using habitats with high ice cover (> 60%) with low temperatures, though only two observations likely drove this relationship resulting in high uncertainty in habitat use during periods with low temperatures. While the Great Lakes are predicted to have years of high ice cover in the future, forecasted climate change in the region is likely to decrease ice cover and increase air temperatures in general (Mason et al. 2016). As these forecast changes would result in additional habitat for LTDUs, it is likely that the increase in relative abundance of LTDUs we estimated during the study period will continue into the future.

We found similar results to Straub and Schumer (2018) in terms of knowledge gaps and stakeholder needs for Great Lakes sea ducks. There continue to be knowledge gaps around sea duck habitat use in the Great Lakes, and knowledge gaps around the impacts of sea duck harvest were emphasized in our interviews as well. In Michigan, sea ducks are increasing in the percent of ducks harvested in the state, though the harvest of waterfowl overall is declining. An increased interest in sea duck harvest, particularly LTDUs, was mentioned by several other stakeholders, though none were certain on what impact current harvest is having on survival of sea ducks in the Great Lakes, which limits their ability to make informed choices about sea duck regulation.

During Straub and Schummer (2018)'s workshops there was limited discussion of citizen science data (eBird or Christmas Bird Count), and our interviews highlighted that in just a few years the utility of these tools to applied research and conservation work has greatly increased. Straub and Schummer (2018)'s workshop also mostly discussed wind energy as an upcoming information need, while we heard stakeholders describing it as a current need in 2022, showing how the threat landscape has shifted in just a few years.

Sea duck distribution and abundance may change within the Great Lakes in coming years, though uncertainty remains that prevents us from making strong predictions about those changes. The Great Lakes themselves will change in the coming years, in terms of temperature and ice cover, and with ongoing wind energy development and possible increased interest in sea ducks by hunters, having a tool to predict and monitor sea duck abundance, distribution, and survival would assist stakeholders from state and federal agencies to make more informed regulatory and habitat conservation decisions. Future work could bring in additional ice cover data, perhaps at a finer scale, and could work to incorporate other covariates, such as precipitation, shoreline development, wind energy development, and changes in temperature. Our work focused on LTDUs, but future work would likely benefit from incorporating other species or species groups, such as mergansers, which may be impacted by these changes differently given their diet and natural history. The Great Lakes have the potential to support more sea ducks of several species in the future, and by using existing aerial survey datasets, along with newer products like those coming out of eBird, a richer understanding of sea duck abundance and distribution may be possible without new surveys being implemented, though for questions around the impacts of survival, additional work is likely required.

Literature Cited

Arnold, J. 2021. ggthemes: Extra Themes, Scales and Geoms for 'ggplot2'. R package version 4.2.4. https://CRAN.R-project.org/package=ggthemes

Bolker, B.M., and Robinson, D. 2022. broom.mixed: Tidying Methods for Mixed Models. R package version 0.2.9.4, https://CRAN.R-project.org/package=broom.mixed

Brooks, M.E., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Maechler, M., and Bolker, B.M. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal 9:378-400.

Conroy MJ, Peterson JT. 2013. Decision Making in Natural Resource Management: A Structured, Adaptive Approach. Wiley.

Environment and Climate Change Canada and ClimateData.ca. 2022. Webiste: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html [Accessed 21 June 2022].

Environment and Climate Change Canada. 2016. Great Lakes Migrant Waterfowl Survey. Website: https://open.canada.ca/data/en/dataset/b188cade-c51a-406a-ac43-8103622cc389 [Accessed 21 June 2022]

Hartig, F. 2022. DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models. R package version 0.4.5. https://CRAN.R-project.org/package=DHARMa.

Koneff, M. D., G. S. Zimmerman, C. P. Dwyer, K. K. Fleming, P. I. Padding, P. K. Devers, F. A. Johnson, M. C. Runge, and A. J. Roberts. 2017. Evaluation of harvest and information needs for North American sea ducks. PLoS One 12:e0175411.

Lamb, J. S., P. W. C. Paton, J. E. Osenkowski, S. S. Badzinski, A. M. Berlin, T. Bowman, C. Dwyer, L. J. Fara, S. G. Gilliland, K. Kenow, C. Lepage, M. L. Mallory, G. H. Olsen, M. C. Perry, S. A. Petrie, J. P. L. Savard, L. Savoy, M. Schummer, C. S. Spiegel, and S. R. McWilliams. 2020. Assessing year-round habitat use by migratory sea ducks in a multi-species context reveals seasonal variation in habitat selection and partitioning. Ecography 43:1842-1858.

Lamb, J. S., P. W. C. Paton, J. E. Osenkowski, S. S. Badzinski, A. M. Berlin, T. Bowman, C. Dwyer, L. J. Fara, S. G. Gilliland, K. P. Kenow, C. Lepage, M. L. Mallory, G. H. Olsen, M. C. Perry, S. A. Petrie, J.-P. L. Savard, L. Savoy, M. L. Schummer, C. S. Spiegel, and S. R. McWilliams. 2019. Spatially explicit network analysis reveals multi-species annual cycle movement patterns of sea ducks. Ecological Applications 29:e01919.

Loring, P. H., P. W. C. Paton, J. E. Osenkowski, S. G. Gilliland, J.-P. L. Savard, and S. R. McWilliams. 2014. Habitat use and selection of black scoters in southern New England and siting of offshore wind energy facilities. Journal of Wildlife Management 78:645-656.

Lüdecke, D. 2018. ggeffects: Tidy Data Frames of Marginal Effects from Regression Models. Journal of Open Source Software, 3:772. doi:10.21105/joss.00772

Lyons JE, Runge MC, Laskowski HP, Kendall WL. 2008. Monitoring in the Context of Structured Decision-Making and Adaptive Management. Journal of Wildlife Management 72:1683–1692.

Mason, L.A., Riseng, C.M., Gronewold, A.D. *et al.* 2016. Fine-scale spatial variation in ice cover and surface temperature trends across the surface of the Laurentian Great Lakes. Climatic Change 138:71–83.

Notaro M, Zarrin A, Vavrus S, Bennington V. 2013. Simulation of heavy lake-effect snowstorms across the Great Lakes Basin by RegCM4: Synoptic climatology and variability. Monthly Weather Review 141:1990-2014.

Petrie, S. Schummer, M.L. 2002. Waterfowl Responses to Zebra Mussels on the Lower Great Lakes. Birding August 2002:346-351.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. URL https://www.R-project.org/.

Ross, R. K., S. A. Petrie, S. S. Badzinski, and A. Mullie. 2005. Autumn diet of greater scaup, lesser scaup, and long-tailed ducks on eastern Lake Ontario prior to zebra mussel invasion. Wildlife Society Bulletin 33:81-91.

Savard, J.P. L., and M. R. Peterson. 2015. Remigial molt of sea ducks. Pages 305-335 in J.-P. L. Savard, D. V. Derksen, D. Esler, and J. M. Eadie, editor. Ecology and conservation of North American Sea Ducks. CRC Press, New York, New York, USA.

Schummer ML, Petrie SA, Bailey RC, Badzinski SS. 2012. Factors affecting lipid reserves and foraging activity of Buffleheads, Common Goldeneyes, and Long-tailed Ducks during winter at Lake Ontario. Condor 114: 62-74.

Silverman, E. D., D. T. Saalfeld, J. B. Leirness, and M. D. Koneff. 2013. Wintering Sea Duck Distribution Along the Atlantic Coast of the United States. Journal of Fish and Wildlife Management 4:178-198.

Solt, F., Hu, Y. 2021. dotwhisker: Dot-and-Whisker Plots of Regression Results. R package version 0.7.4. https://CRAN.R-project.org/package=dotwhisker.

Straub JN and Schummer ML. 2018. Population monitoring and information needs for management and conservation of sea ducks on the Great Lakes. Upper Mississippi River/Great Lakes Joint Venture Technical Report No. 2018-1.

Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Winkler JA, Arritt RW, Pryor SC. 2012. Climate projections for the Midwest: Availability, Interpretation, and Synthesis. In J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown (coordinators) US National Climate Assessment Midwest Technical Input Report. Available from the Great Lakes Integrated Sciences and Assessment (GLISA) Center, http://glisa.msu.edu/docs/NCA/MTIT_Future.pdf.

Yang, T.-Y., J. Kessler, L. Mason, P. Y. Chu, and J. Wang. 2020. A consistent Great Lakes ice cover digital data set for winters 1973-2019. Scientific Data 7:259.

Zipkin, E. F., B. Gardner, A. T. Gilbert, A. F. O'Connell, Jr., J. A. Royle, and E. D. Silverman. 2010. Distribution patterns of wintering sea ducks in relation to the North Atlantic Oscillation and local environmental characteristics. Oecologia 163:893-902.

Zobel Z, Wang J, Wuebbles DJ, Kotamarthi VR. 2018. Evaluations of high-resolution dynamically downscaled ensembles over the contiguous United States. Climate Dynamics, 50:1-22.

Tables

Table 1. Short descriptions of datasets collected from various agencies. Data were only available along the Canadian shores of Lakes Ontario, Erie, St. Clair, and the St. Lawrence, Niagara, and Detroit Rivers. Multiple waterbird species and groups were present in each dataset.

Data Origin	Seasons	Years Covered	Short Description
Canadian Wildlife Service and Ontario Waterfowl Survey	Midwinter Survey	1968-2020	Aerial Survey Count Data (presence-only)
Canadian Wildlife Service	Midwinter Survey	2012-2020	Counts of various species from 2012-2020 with specific latitude and longitude information and distance from shore
Canadian Wildlife Service	Spring, Summer, and Fall	1968-1972, 1974-2011, 2019, 2020	Aerial Survey Count Data (presence-only)
Long Point Waterfowl	Midwinter Survey	2002-2015	Aerial Survey Count Data (presence-only)

Table 2. Weather stations associated with the temperature data used in our GLMM.

Weather Stations	Waterbody
Fort Erie, Kingsville, Long Point, Point Pelee, Port Colborne, Port Crewe, Port Dover, Port Stanley, Southeast Shoal	Lake Erie
Cressy, Frenchmans Bay, Point Weller, Point Petre, St. Catherines, Toronto Headland, Wellington, Wolfe Island, Vineland Station	Lake Ontario
Belle River, Chatham, Windor Riverside	Lake St. Clair
Amherstburg, Windsor Ford Plant	Detroit River
Niagara Falls Chippewa, Niagara Falls NPCSH, Niagara on the Lake Golf Course	Niagara River
Berthierville, LAC St. Pierre, Vercheres	St. Lawerence River

Table 3. Sea Duck species, frequency of observations, and maximum estimated count during Midwinter Waterfowl Surveys along the Canadian Lower Great Lakes (Ontario, Erie, St. Clair) and associated rivers (St. Lawrence, Niagara, and Detroit) from 42 surveys completed between 1971 and 2020.

Species	# of Observations	Max Count
Black Scoter	82	7102
Bufflehead	746	2707
Common Goldeneye	1351	6327
Common Merganser	816	17640
Hooded Merganser	20	50
King Eider	1	1
Long-tailed Duck	591	37236
Red-Breasted Merganser	449	19670
Surf Scoter	12	75
White-winged Scoter	181	8500

Table 4: Stakeholders contacted and interviewed about sea ducks on the Great Lakes.

Agency	Participated in Interview?
Minnesota Dept. of Natural Resources	Yes
Michigan Dept. of Natural Resources	Yes
Upper Mississippi/Great Lakes Joint Venture	Yes
Sea Duck Joint Venture	Yes
Canadian Wildlife Service	Yes
U.S. Fish and Wildlife Service	Yes

Table 5: Interview questions for stakeholders about sea ducks on the Great Lakes.

1. How do sea ducks in the Great Lakes fit into your job position? Regulatory, conservation planning, etc.?
2. Is current monitoring meeting your needs or do you have a need for additional monitoring?
3. Are there other pieces of information about sea ducks that your organization would find useful?
4. If sea duck monitoring in the Great Lakes were to change, what would most affect that?
5. Anything else about sea duck monitoring or science in the Great Lakes we should hear about?

Figures

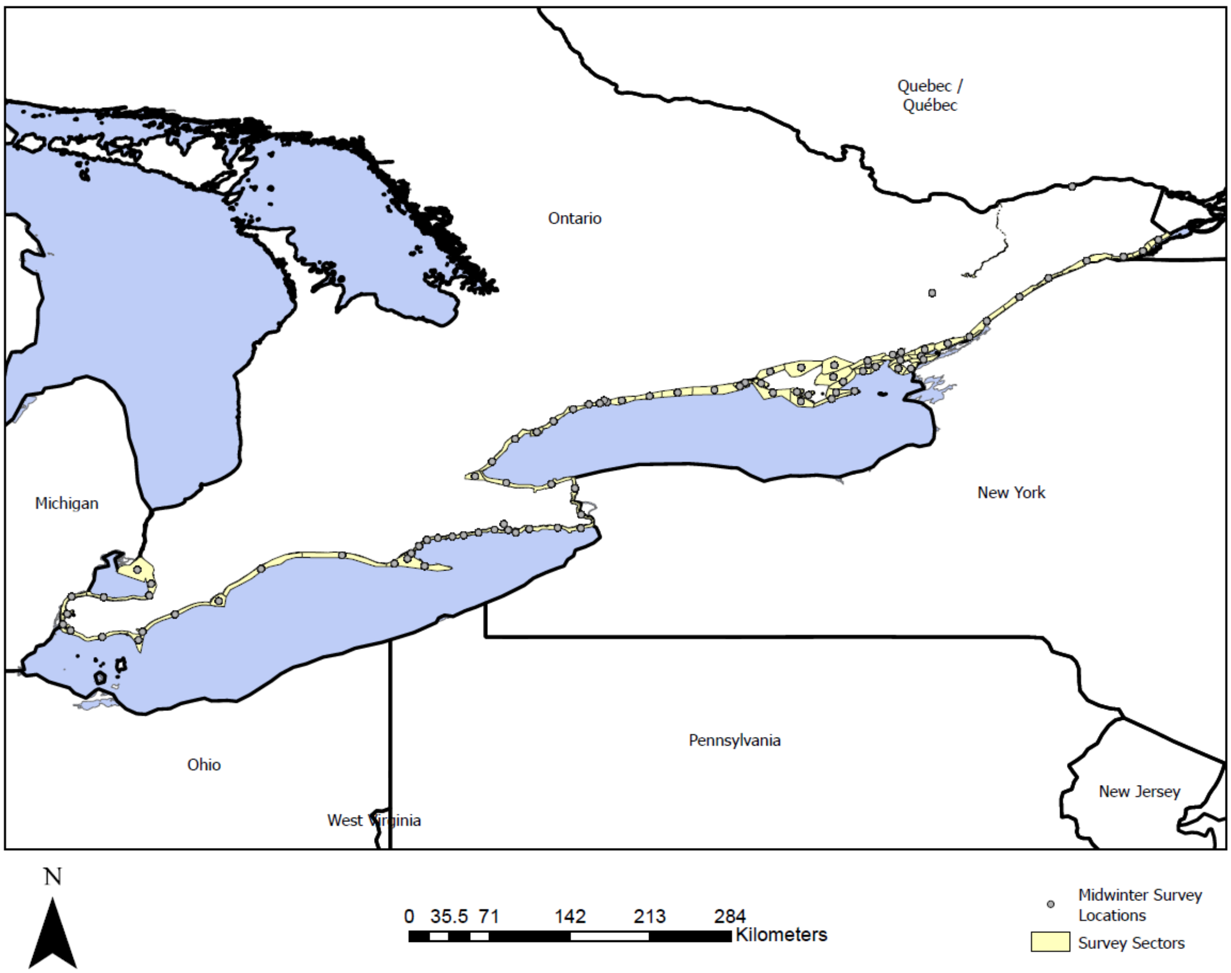

Figure 1. Map of areas surveyed during the Midwinter Waterfowl Survey (1971-2020).

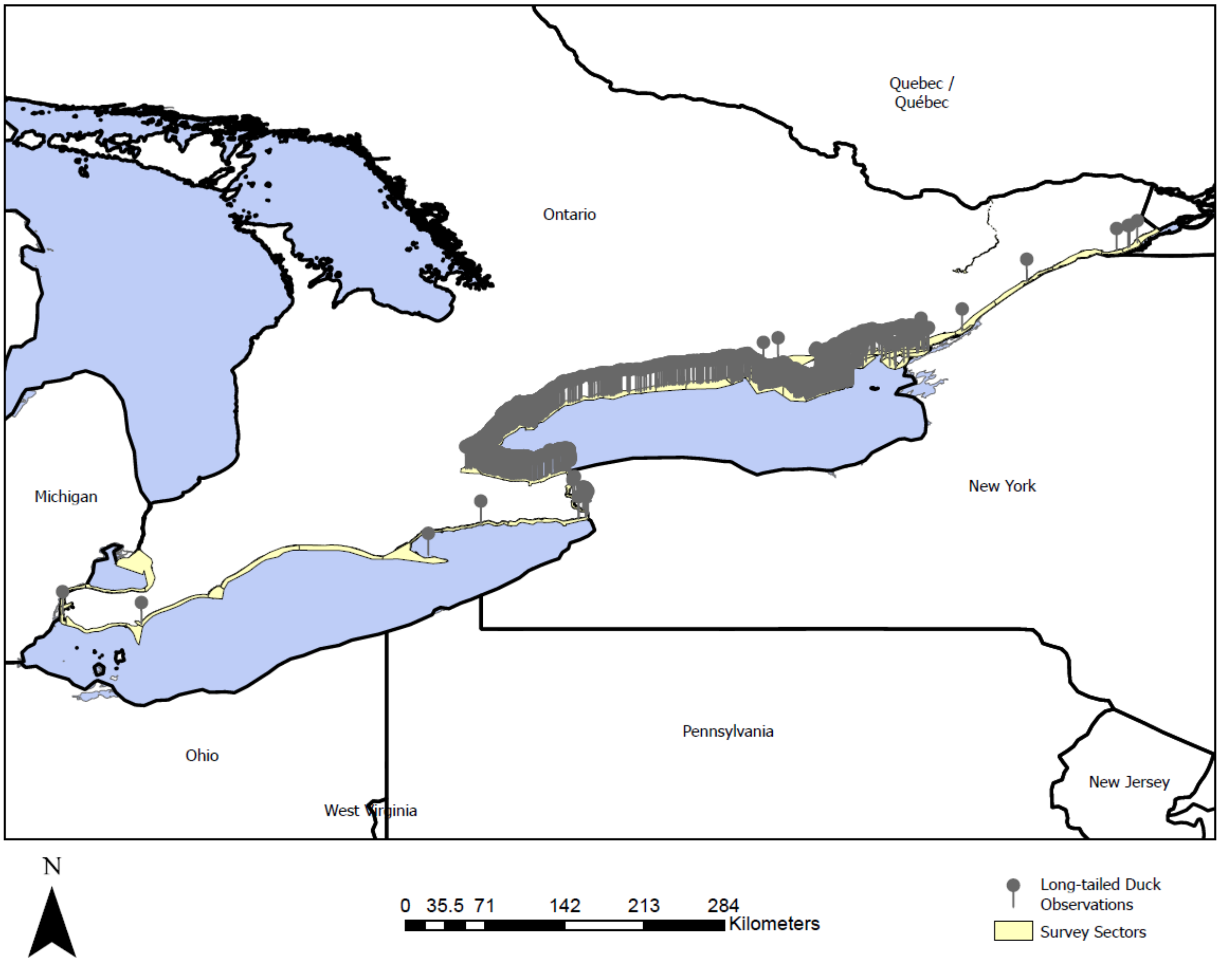

Figure 2. Long-tailed Duck observation locations during the Midwinter Waterfowl Survey from 1971 to 2020.

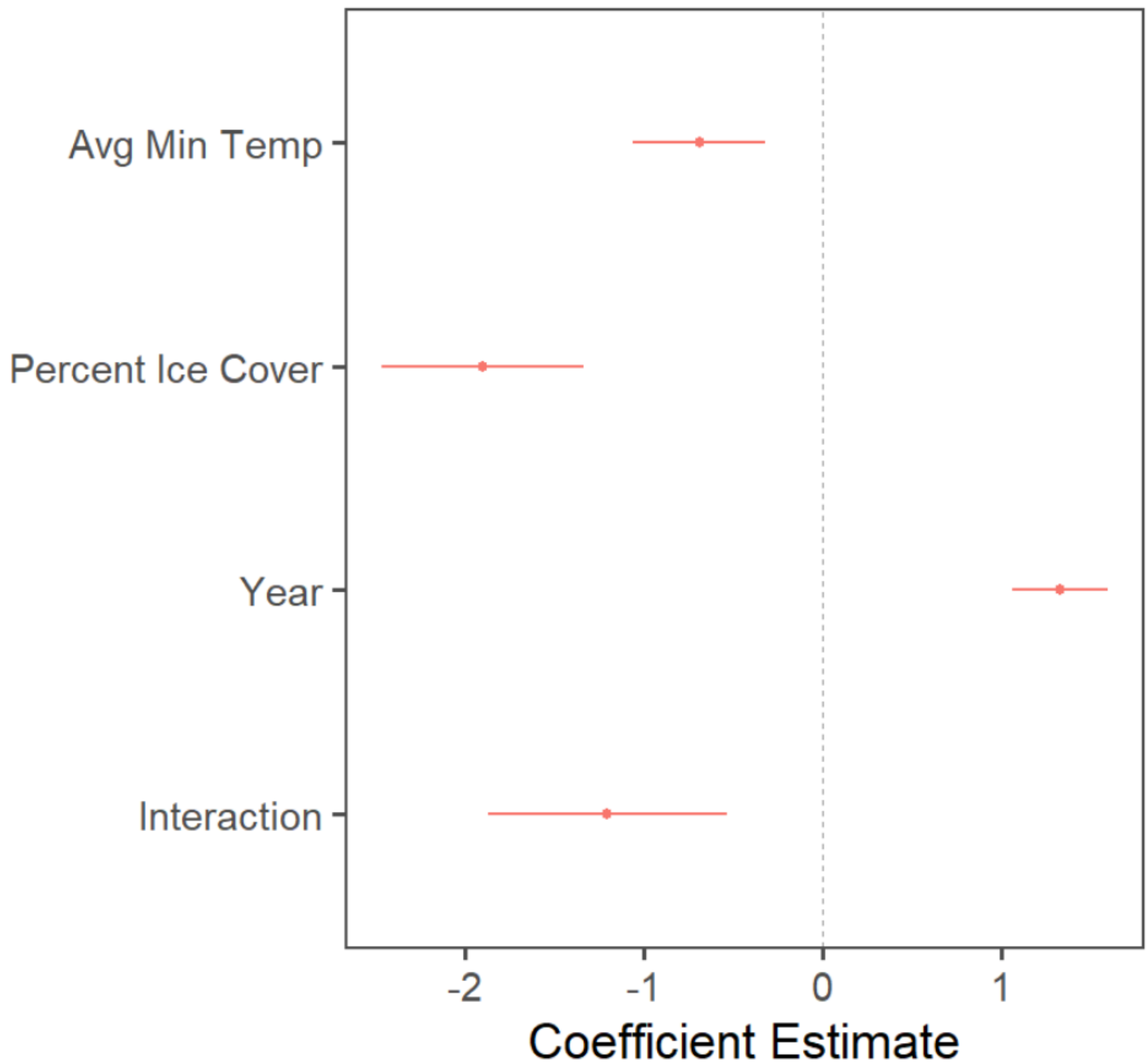

Figure 3. Model coefficient estimates for the global model evaluating the effects of average percent ice cover, average minimum temperature, year of the survey, and an interaction between percent ice cover and minimum temperature on Long-tailed Duck count data in the Lower Great Lakes Region of Canada. All covariates were scaled using the scale() function in R. Point represents the mean and whiskers the 95% confidence intervals. Values above 0 indicate a positive response to the covariate and values < 0 indicate a negative response.

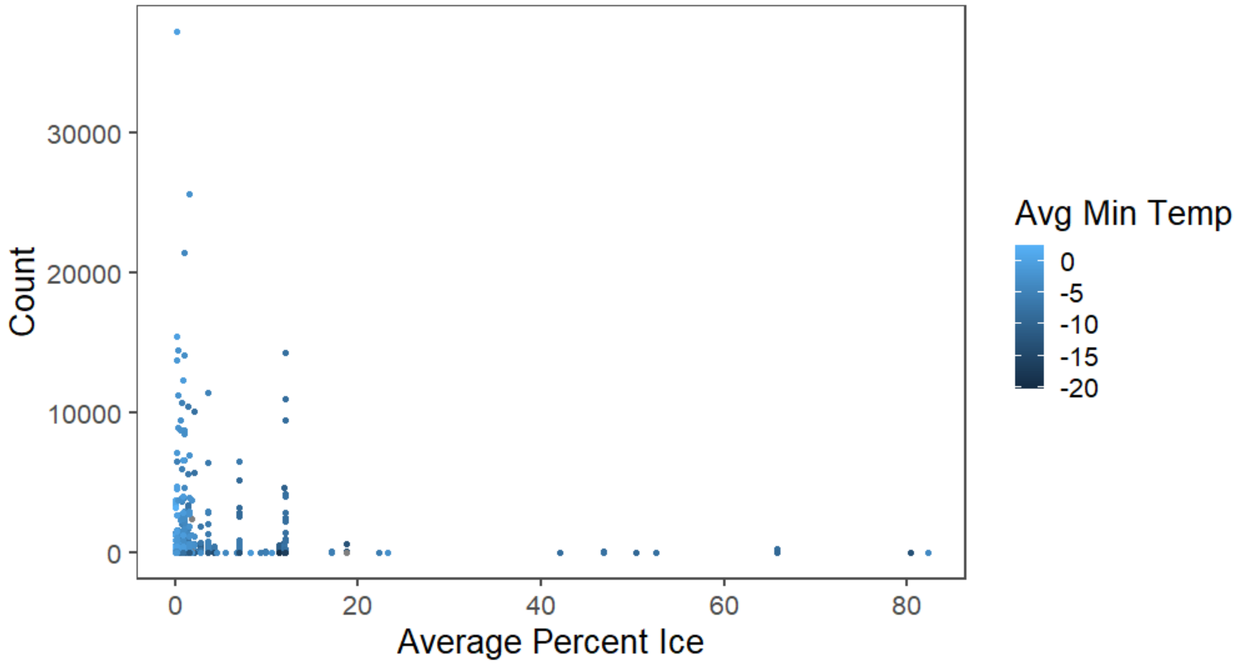

Figure 4: Raw data for observations of Long-tailed Duck counts based on percent ice and average minimum temperatures along the Canadian shores of Lakes Erie, Ontario, and St. Clair, and the Detroit, Niagara, and St. Lawrence Rivers (1971-2020).

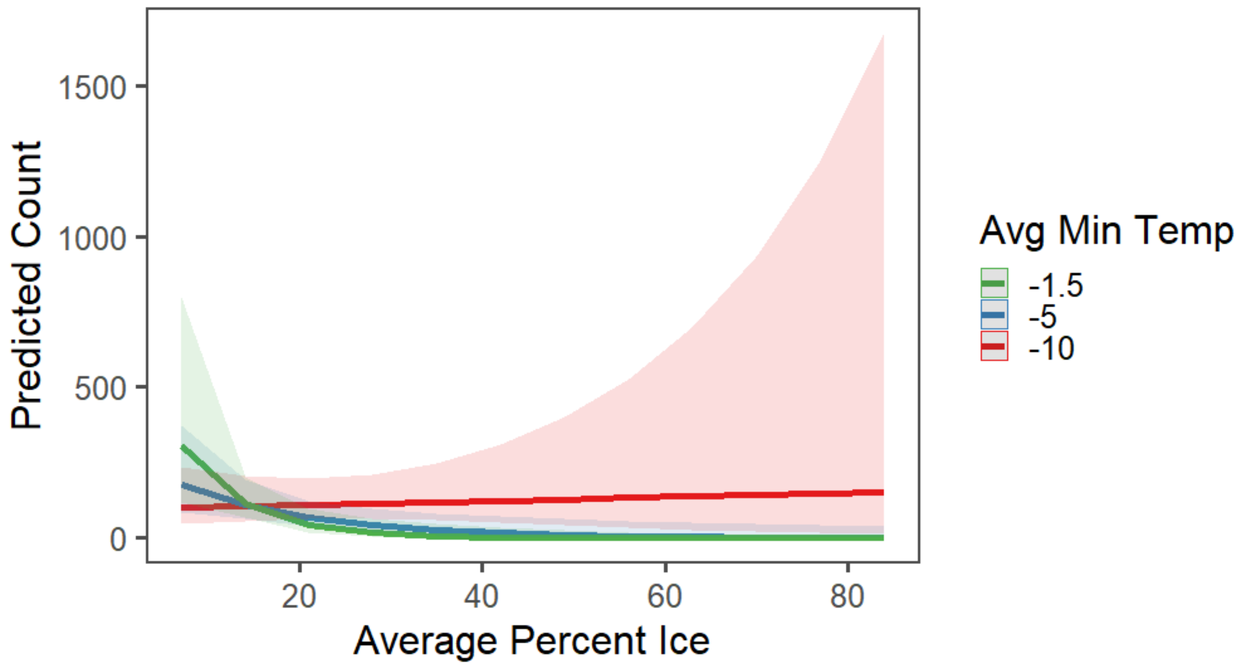

Figure 5. Predictions of Long-tailed Duck counts based on average percent ice cover and average minimum temperature (°C) within the previous 30 days along the Canadian shores of Lakes Erie, Ontario, and St. Clair, and the Detroit, Niagara, and St. Lawrence Rivers. Values of temperature correspond to the 2.75% (red), 50% (blue), and 97.5% (green) quantiles of temperature.

Project Funding Sources (US$).

SDJV (USFWS) Contribution	Other U.S. federal contributions	U.S. non-federal contributions	Canadian federal contributions	Canadian non-federal contributions	Source of funding (name of agency or organization)
		$25,209.41			Match (U of I, SUNY-ESF)
$79,042.75					

Total Expenditures by Category (SDJV plus all partner contributions; US$). Complete only if project was funded by SDJV in FY22; total dollar amounts should match those in previous table.

ACTIVITY	BREEDING	MOLTING	MIGRATION	WINTERING	TOTAL
Banding (include only if this was a major element of study)					
Surveys (include only if this was a major element of study)					
Research				**$79,042.75**	