5.3 Developing Spatially-Explicit Models to Guide Conservation of Diving Ducks During Migration

Introduction

Historically, Lake St. Clair and western Lake Erie hosted an estimated 250,000 to 750,000 diving ducks during peak fall migration and is a location of continental significance to waterfowl as depicted in the North American Waterfowl Management Plan (NAWMP 2004; Bookhout et al. 1989; Soulliere et al. 2000). Prominent diving ducks during migration include canvasbacks (*Aythya valisineria*), lesser scaup (*A. affinis*), greater scaup (*A. marila*), and redheads (*A. americana*). Both canvasbacks and lesser scaup have been listed as species of priority by the Upper Mississippi River Great Lakes Region Joint Venture (UMRGLJV 2007).

Little research has been conducted on factors affecting distribution and abundance of diving ducks during migration, and understanding these factors for the Great Lakes region is important within the context of system-wide impacts of coastal wetland losses, reduced water quality, contaminant discharge, and invasions by exotic species. Poor water quality historically reduced abundance of submerged aquatic plants that were important foods for migrating diving ducks. Invasion by zebra (*Dreissena polymorpha*) and quagga mussels (*D. bugensis*) into Lake St. Clair during the 1980s created a new food source for some species of diving ducks and these invasions may have indirectly affected abundance of important diving duck plant foods as the filtering effects of mussels can improve water clarity. Also, Lake St. Clair is among the most heavily used areas of the Great Lakes by recreational boaters with over 200 marinas (Snider 1999) and this has implications for use by diving ducks as disturbance from boaters can displace birds from preferred feeding areas (Knapton et al. 2000). There is also concern that nearshore and offshore wind energy structures may displace diving ducks from important use areas if land use planners do not consider potential affects on diving ducks.

Feedback is a key component of adaptive conservation planning and the goal of our research is to address UMRGLJV and Michigan Department of Natural Resources (MDNR) needs related to monitoring priority waterfowl species during migration. We hope to improve conservation planning by identifying factors affecting temporal and spatial dynamics of diving duck populations during migration. To meet these information needs on our study area, we are analyzing data collected during historical aerial surveys conducted by MDNR. In addition, we are developing aerial survey protocols using distance sampling methodology that we hope will improve our understanding of diving duck distribution and abundance on Lake St. Clair and western Lake Erie.

Methods

Lake St. Clair and western Lake Erie are shallow, highly productive lake basins and our study area is dominated by open water less than ten meters deep. Lake St. Clair encompasses an area of 1150 km^2. The international border divides Lake St. Clair with the western third of the lake in the United States and the eastern two thirds in Canada. Historic diving duck surveys (1983–2008) included only the U.S. portion of Lake St. Clair while our contemporary surveys include transects across the entire lake;

in addition, we now survey portions of western Lake Erie extending southward from the lower Detroit River to Maumee Bay near Toledo, Ohio.

Historical Surveys

Historical surveys (1983–2008) were flown to monitor diving duck abundance within the U.S. waters of Lake St. Clair during fall migration. All surveys were flown on east-west transects spaced three kilometers apart. Pilots flew approximately 150 km/h at a height 100 m above the water. We estimated diving duck flock size by species, and recorded flock locations on paper maps of Lake St. Clair. During these surveys, no attempt was made to estimate detection probability of flocks, which was assumed to be near 1.0. In addition, we recorded locations of boats observed during aerial surveys as diving ducks are intolerant of boats in close proximity. We digitized flock and boat locations and georectified paper maps to a base Geographic Information System (GIS) layer using ArcGIS (ESRI 2006). All flocks were represented by a single point located at their center.

We used a bathymetric GIS layer with pixel resolution of 15 m by 15 m (NOAA 2011) to associate duck observations with water depth in four categories and adjusted estimated water depths at flock locations to account for deviations in Lake St. Clair water levels from the long-term average lake level. We modeled temporal changes in diving duck abundance by species using generalized linear models and implemented these analyses in SPSS (2009). We used the number of birds of each species counted on individual surveys as the response variable and broke the fall migration season into six weekly intervals for inclusion as a categorical explanatory variable. We also created a year categorical explanatory variable using three, 6-year intervals (1983–1988; 1989–1994, and 1995–2000) and one 8-year interval (2001–2008). We included number of boats counted during each survey as a covariate in our linear models to account for potential effects of disturbance on diving duck abundance. We estimated marginal means for effects of week and year using linear models fit to each diving duck species with the covariate for boat counts held at the mean over all surveys. We used ArcGIS to map distributions of diving ducks using the same 4-year periods used in our linear modeling. We fit kernel density models for each species and year interval and mapped model estimates using the spatial modeling feature in ArcGIS (ESRI 2006).

Current Surveys

Prior to our first fall field season we used ArcGIS to establish a systematic east-west oriented line transect survey with a random start point (ESRI 2006). Historic surveys were expanded to cover all of Lake St. Clair (1149 km^2) and parts of western Lake Erie (621 km^2). We established 26 transects from the northern end of Lake St. Clair to the southern shore of Lake Erie. We established five distance categories extending from the transect line out to 50, 125, 225, 425, and 825 m from the aircraft. We used our target flight altitude and a clinometer to establish declinations from horizontal to associated distance bands and placed visible markings on windows and struts of the airplane to allow observers to record ducks by distance categories. Observers aligned window and strut marks and recorded the appropriate distance category at the center of each flock. All distance data were analyzed using the software *Distance 6.0* (Thomas et al. 2010).

Each of two observers was responsible for recording birds on one side of the aircraft. All flights were conducted at a target altitude of 91 m using an amphibious DHC-DeHavilland Beaver. We recorded flock locations using a Global Positioning System (GPS) with audio recording capability. Due to GPS failures during the first field season, two different GPS systems were used. One observer used a Nomad unit connected to a Garmin 10.0 wireless GPS, while the other observer used a Columbus V-900 data logger. We recorded GPS locations of diving ducks, offshore boats, and hunting parties. Our research plan includes conducting five aerial surveys during both spring and fall migration for two-years, and we have completed the first year of aerial surveys. We plan to use the spatially explicit data collected during these surveys to evaluate variables predictive of diving duck abundance.

Results

Historical Surveys

MDNR staff completed 99 diving duck surveys of the U.S. portion of Lake St. Clair during fall migrations from 1983–2008. Linear models predicting diving duck abundance by species supported seasonal effects as well as an effect of boating traffic on abundance for all species (F-values > 6.0; p-values < 0.01). The only species for which linear models did not support year effects was the model predicting redhead abundance. Parameter estimates for the effect of boating activity indicated an expected 648, 178, and 312 fewer canvasbacks, redheads, and scaup observed for each additional boat counted during the surveys (95% confidence intervals: + 393, + 122, and + 202).

Lake St. Clair supported more diving duck use in recent years (i.e., after invasion by Dreissenid mussels) compared to the 1980s (Figure 1). For example, estimates of total annual fall use-days, with a use-day equal to one duck spending one day on the study area, by canvasbacks in U.S. waters increased from 500,550 use-days/year (95% confidence interval + 202,445) prior to 1989 to 1,048,972 use-days/year (95% confidence interval + 271,342) during 1989–2008. Total annual fall use-day estimates for scaup increased from 176,975 use-days/year (95% confidence interval + 54,235) prior to 1989 to 599,321 use-days/year (95% confidence interval + 133,381) during 1989–2008. In contrast, total annual fall use-day estimates for redheads in U.S. waters were relatively stable with 413,015 use-days/year (95% confidence interval + 113,500) prior to 1989 and 430,575 use-days/year (95% confidence interval + 95,371) during 1989–2008.

In addition to changes in abundance, we observed different spatial use patterns of Lake St. Clair by diving ducks among years. Canvasback distribution in U.S. waters of Lake St. Clair changed with a relatively broader distribution during the period 1989–2000 when canvasbacks were most abundant. Canvasbacks used the western side of Anchor Bay north of the mouth of the Clinton River extensively during 1983–2000, but this area received relatively less use during 2001–2008. Redhead distribution was relatively stable over time compared to changes in canvasback distribution. The near-shore waters along the western side of Anchor Bay were used extensively by redheads in all periods; however, there was a notable shift away from the shore after 1994. Changes in scaup distribution were similar to those of canvasbacks, except after 2000 when scaup use of offshore waters of Anchor Bay remained relatively high. Like canvasbacks, scaup used deeper waters later in the study, but change in water depth use was less dramatic after 2000 resulting from persistence of scaup in the relatively shallow Anchor Bay. Distributional shifts in canvasbacks and scaup resulted in increased use of intermediate water depths (2-4 and 4-6 m) and reduced use of shallow water depths (0-2 m) over time.

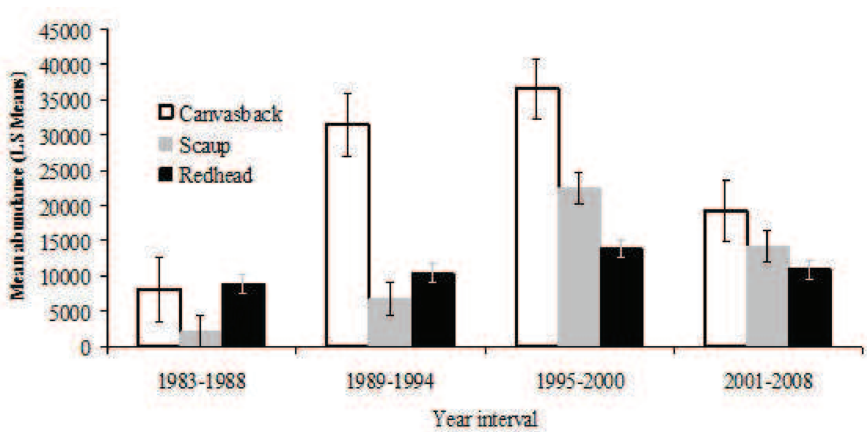

Figure 1. Mean (+ 1 SE) abundance of diving ducks on U.S. waters of Lake St. Clair by year interval, 1983-2008. Estimates are marginal means from species-specific linear models predicting abundance from week and year intervals and numbers of boats observed held at the mean over all surveys.

Current Surveys

We completed five surveys during fall of 2010 and five surveys during spring of 2011. The pilot flew a total of 531.5 km of transect on each survey. The total number of observed flocks on individual flights ranged from 65 to 204, and flock size ranged from a 1 to 45,000 birds. The total number of GPS-referenced flocks ranged from 43 to 97 (Table 1). The detection probability on individual surveys ranged from 20% to 28% and expected flock size ranged from a low of seven birds to a high of 536 (Table 1). The coefficient of variation (CV) ranged from 13% to 38% with CV's generally being higher during fall migration due to inherent variation in flock size (Table 1). Population estimates obtained with distance sampling methods were generally higher during fall migration than during spring with a peak estimate of 470,190 birds (Table 1).

Table 1. Summary statistics of current aerial diving duck surveys conducted using distance sampling techniques over Lake St. Clair and western Lake Erie.

Flight Date	Detection Probability	Expected Flock Size	Population Estimate	CV	Model Fit	Number of Flocks with GPS Location
10/29/2010	0.238	536	310,270	0.277	*<.05	na (GPS failures)*
11/08/2010	0.261	266	260,600	0.338	0.219	70
11/16/2010	0.196	319	470,190	0.379	* <.05	43*
12/03/2010	0.236	135	194,650	0.317	* <.05	78
03/25/2011	0.229	67	120,550	0.205	0.294	48*
04/01/2011	0.284	53	67,377	0.183	0.236	81
04/13/2011	0.216	17	23,424	0.154	0.571	97
04/21/2011	0.231	9	15,409	0.172	0.519	94
04/29/2011	0.201	7	26,263	0.132	0.386	94

Discussion

Historical analyses revealed an increase over the course of the study period in scaup and canvasback abundance while redhead abundance remained approximately the same. In addition, both canvasbacks and scaup had a shift in distribution from shallow water depths (0-2 m) to intermediate water depths, while redheads remained closely tied to shallow water throughout the study period. We also found that abundance of all three diving ducks species was inversely related to recreational boating pressure within U.S waters of Lake St. Clair.

We believe that increases in scaup and canvasback abundance, as well as distributional shifts to deeper water, may indicate increased food availability on Lake St. Clair. One possible explanation for increasing amounts of food during our study period could be the invasion of dreissenid mussels in the mid 1980s. Dreissenids became a new and abundant food source for the more carnivorous scaup as found by researchers who documented 80% of scaup on Lake St. Clair contained dreissenids (Custer and Custer 1996). In addition, dreissenids may have had indirect impacts on more herbivorous diving ducks like canvasbacks and redheads. Although not targeted as a new food resource, dreissenids were the likely cause of a two-fold increase in water clarity documented on Lake St. Clair from 1986–1994 (Nalepa et al. 1996). This two-fold increase in water clarity led a resurgence in submergent vegetation documented anecdotally by MDNR biologists, and subsequently may have resulted in more food distributed over a wider geographical range for canvasbacks and redheads (Ernie Kafcas pers. communication).

Current survey methodology has improved the quality of spatial data because we now are no longer dependent on paper maps and observer judgment to locate diving duck flocks. Instead, we are able to record GPS locations for all diving duck flocks allowing us to perform more rigorous spatial analyses of factors influencing diving duck distribution within our study area. In addition to obtaining spatially-explicit distribution data, it appears distance sampling is a viable survey option for open water scenarios although not commonly used for waterfowl surveys. Historical surveys focused solely on large flocks (>250 birds) and assumed a detection probability of near 1.0; however, during some surveys, large numbers of small flocks of birds may have gone undetected. Distance sampling allows us to more appropriately account for small groups and likely generates a more accurate measure of abundance. Our second year of distance sampling research will focus on determining the most appropriate means for analyzing extremely large flocks of ducks (>10,000 birds) that cover multiple distance bands within a distance sampling framework.

References

Bookhout, T. A., K. E. Bednarik, R. W. Kroll. 1989. The great lakes marshes. In *Habitat management for migrating and wintering waterfowl in North America*. ed. L.M. Smith, R. L. Pederson, and R.M. Kaminski, pp.131–156. Lubbock, TX: Texas Tech University Press.

Custer, C.M. and T. W. Custer. 1996. Food habits of diving ducks in the great lakes after the zebra mussel invasion. *Journal of Field Ornithology* 67:86–99.

ESRI 2006. ArcGIS Desktop: Release 9. Redlands, CA: Environmental Systems Research Institute.

Knapton, R. W., S. A. Petrie and G. Herring. 2000. Human disturbance of diving ducks on Long Point Bay, Lake Erie. Wildlife Society Bulletin 28:923–930.

Nalepa, T. F., D. J. Hartson, G. W. Gostenik, D. L. Fanslow, and G. A. Lang. 1996. Changes in the freshwater mussel community of Lake St. Clair: From Unionidae to *Dreissena polymorpha* in eight years. *Journal of Great Lakes Restoration* 22:354–369.

NAWMP 2004. North American Waterfowl Management Plan, Plan Committee. 2004.

North American Waterfowl Management Plan 2004. Implementation framework: Strengthening the biological foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales, 106 pp.

NOAA. 2011. National Oceanic and Atmospheric Administration. National Geophysical Data Center. Available online: http://www.ngdc.noaa.gov/.

Snider, V. W., Jr. 1999. The economic impact of boating in Wayne, St. Clair and Macomb Counties. In *Lake St. Clair: Its current state and future prospects*, 18.pp. Conference summary report, Port Huron, Michigan.

Soulliere, G. J., T. E. Maples, E. N. Kafcas. 2000. Twenty-five years of canvasback inventory in Michigan. Michigan DNR wildlife report 3322.

SPSS 2009. PASW STATISTICS 18.0 Command Syntax Reference. SPSS Inc., Chicago.

Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47: 5-14.

UMRGLRJV. 2007. Upper Mississippi River and Great Lakes Region Joint Venture Waterfowl Habitat Conservation Strategy. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, USA.

Contact Information

Brendan T. Shirkey, Michigan State University- Department of Fisheries and Wildlife
shirkeyb@msu.edu

Scott R. Winterstein, Michigan State University- Department of Fisheries and Wildlife
winterst@msu.edu

David R. Luukkonen, Michigan Department of Natural Resources
luukkonend@michigan.gov