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Pelagic Bird Survey on Lake Ontario Following Hurricane Isabel, September 2003: Observations and Remarks on Methodology

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ABSTRACT. *The abundance and dispersion of pelagic waterbirds was measured on Lake Ontario during the aftermath of the storm system generated by Hurricane Isabel, September 2003. The purpose of this study was to determine whether standard shipboard methodologies developed for surveying pelagic seabirds from ships on the ocean are applicable on the Laurentian Great Lakes, and if so whether such surveys may provide information that cannot be acquired from shore-based surveys. The abundance of waterbirds was low in offshore Lake Ontario, but similar to oligotrophic ocean environments. Our results suggest that bird surveys are easy to conduct from Great Lakes research vessels, and are likely to provide information useful for monitoring ecosystem health in the Lakes.*

INDEX WORDS: *Birds, census methodology, ecological indicator species, Lake Ontario.*

INTRODUCTION

Pelagic waterbirds, those that search for food far offshore on large bodies of water, are considered to be important indicators of the environmental health of the Laurentian Great Lakes (Hebert and Sprules 2002). Abundances of pelagic waterbirds are estimated by annual censuses at breeding colonies (many are colonial breeders) and by shore-based counts of birds on a lake (e.g., Gebauer *et al.* 1992, Weseloh and Pekarik 1999). A few studies have used offshore radio-telemetry of a small number of individuals to estimate the spatial dispersion of particular waterbird species on the Great Lakes (e.g., double-crested cormorants *Phalacrocorax auritus* on the western basin of Lake Erie, Stapanian *et al.* 2002). Doppler radar has also been used in counting birds, but has mainly proven useful for estimating the timing and abundance of migrating landbirds that fly across or around the Great Lakes (Diehl *et al.* 2003).

In the world's oceans, the abundance and dispersion of pelagic seabirds are estimated by censuses from ships, using standard, reliable survey methods (Tasker *et al.* 1984, Gould and Forsell 1989, Bibby *et al.* 2000). A very few studies have attempted to measure the dispersion of waterbirds on the Great Lakes from boats; the most notable surveyed western Lake Erie offshore regions within 10 km of the mainland or islands (Stapanian and Bur 2002, Stapanian and Waite 2003). We have searched the archives of the three principal North American ornithological journals (*Auk*, *Condor*, *Wilson Bulletin*); the species profiles of the principal Great Lakes pelagic species in the recent, authoritative *Birds of North America* series; the *Journal of Great Lakes Research*, and other relevant reference sources, and have failed to locate any published papers that directly estimate the abundance and dis-

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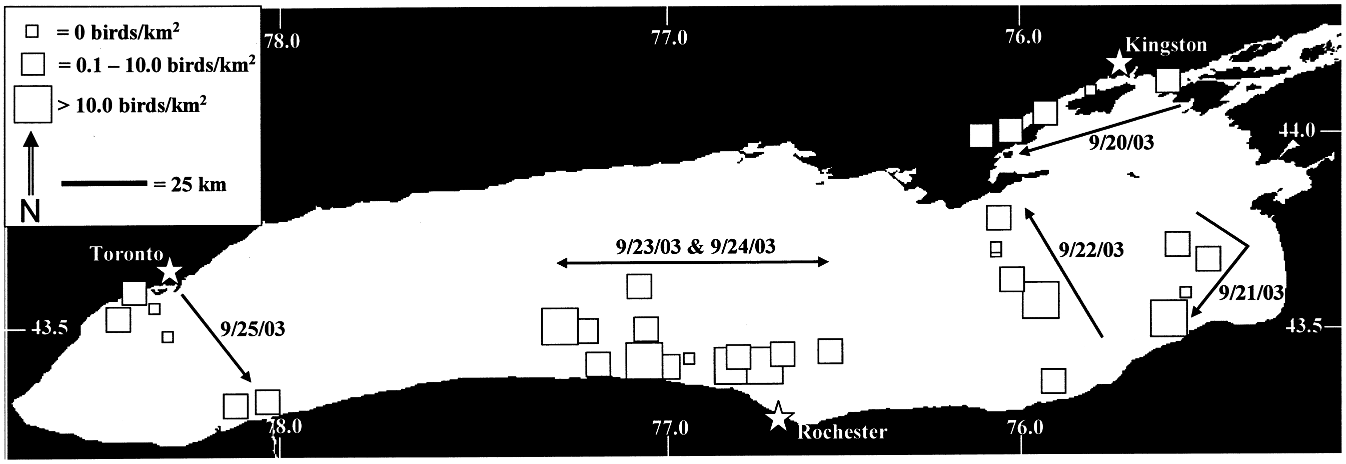

FIG. 1. The location of bird survey transects on Lake Ontario, 20–25 September 2003. The estimated local abundance of pelagic waterbirds is indicated for each point.

persion of pelagic waterbirds in the far offshore region (> 10 km from the mainland or islands) of any Laurentian Great Lake.

The abundance and dispersion of pelagic waterbirds can indicate spatial patterns of productivity (Haney and Solow 1992, Stapanian *et al.* 2002), and some species have abundances high enough to potentially alter food web dynamics, but controversy remains about the impact of pelagic waterbirds on the abundances of prey and on nutrient cycling in lakes (Bedard *et al.* 1980, Mills *et al.* 2003, Kalff 2003). Information on the abundance and dispersion of waterbirds on the Great Lakes would also be quite helpful for understanding where these birds become exposed to pathogens and chemical contaminants. For example, annually since 1999 large numbers of dead pelagic waterbirds have washed up on the shores of Lake Erie and Lake Ontario, having died from Type E botulism (Domske 2003). The birds are likely to have acquired the toxin by ingesting infected food; it would be helpful to know where these birds are feeding to understand how they are becoming diseased (D. Adams, New York Department of Environmental Conservation Wildlife Pathology Unit, personal comm.).

As a module of a 1-week field practicum course onboard the R/V *Lake Guardian* in Lake Ontario, we conducted the first ever survey of pelagic waterbird abundance and dispersion in the offshore environment of Lake Ontario, during September 2003 (for details on the course, see Twiss *et al.* 2005). The purpose was to evaluate whether the standard methodology for surveys on the ocean is appropriate for Lake Ontario and other Laurentian Great Lakes, and also to compare pelagic waterbird abundances to spatial patterns of lake primary productivity. Moreover, the start of our study happened to coincide with the passing of the intense tropical depression that was the remnant of Hurricane Isabel, and thus also provides a record of an extraordinary period on Lake Ontario.

METHODS

This bird survey was conducted on the USEPA ship R/V *Lake Guardian*, 20–25 September 2003. This survey was conducted after post-breeding dispersal of colonial waterbirds, and during the autumn migration period of pelagic waterbird species in the lower Great Lakes (Levine 1998). The bird transect counts were made opportunistically while the ship traveled between water-quality sampling stations. The survey route generally consisted of several parallel north-south crossings of Lake Ontario, starting at the east end of the lake near the St. Lawrence River headwaters. Counts were made between stations on this route, and also while the ship traveled east–west to reach the next survey route (Fig. 1). A number of modifications to the planned cruise track had to be made because of the unsettled weather conditions caused by the passing of the remnants of Hurricane Isabel. On 19 September 2003, the sustained wind speed was up to 55 km/h, with gusts to 67 km/h, and the mean wave height was 2.9 m (data from the NOAA Station 45012 weather buoy located in the central region of Lake Ontario). During bird survey transects (20–25 September 2003), mean ± sd windspeed = 27 ± 11.9 km/h, range 2.4–50.0 km/h; wave height = 0.3 ± 0.23 m, range 0–0.8 m (data recorded from instruments onboard the R/V *Lake Guardian*). Bird survey transects were between 0.3–32.8 km distance from the nearest land, over lake depths of 5–191 m. Survey periods occurred throughout the day, from 0.5 hours after sunrise to 1.5 hours before sunset (all surveys between 7:30 AM–5:40 PM, Eastern Standard Time).

The survey methodology was similar to the standard methods described in Tasker *et al.* (1984), Gould and Forsell (1989), and Bibby *et al.* (2000). Three surveyors stood on the foredeck, including two students and the instructor (Langen). One person was a recorder and timer, and the others were observers. The instructor was always one of the two observers; he was familiar with all of the species encountered on Lake Ontario, and had experience surveying birds from ships. Between some transects, inter-observer reliability at detecting birds was measured, and was found to be very high.

Before the start of a survey period, data on the ship's location, speed, and local weather conditions were transcribed from the ship's navigation instruments. To begin a survey, the recorder declared "start" and began timing, without having first scanned the lake for birds. This was done to avoid inflating abundance estimates by waiting to initiate transect counts until a countable bird was present. Observers identified and counted all birds within an imaginary 300 m × 300 m box, one side oriented in a straight line starting at the prow of the ship, and the perpendicular side headed away from the ship (90° viewing arc). The 300 m box moved with the forward progress of the ship, in the form of a strip transect (mean ship speed = 22 ± SE 0.2 km/hr). To avoid an inflated abundance estimate of flying birds, caused by the flux of birds moving in and out of the transect strip, we used the Tasker *et al.* (1984) method of instantaneous scans of each consecutive 300m block in the transect strip. Counts continued for 10.0 min. The mean (± SE) transect length was 3.6 ± 0.04 km; mean area surveyed in each strip transect = 1.2 ± 0.01 km^2 for a total area surveyed = 42.5 km^2 among 36 transect counts. After completion of each transect, we waited a minimum of 15 minutes to initiate the next. We alternated port and starboard surveys.

To accurately measure 300 m while on the lake, we used a method similar to Heinemann (1981). Knowing the height of our eyes above the water (7.5 m), we calculated the angle from where we stood, and relative to the horizon, that resulted in a distance of 300 m. We used a circular protractor, modified with a sighting tube, to find the angle relative to the horizon that aimed the sighting tube at a point 300 m from where we stood. In practice, it was easy to judge whether a bird was in or out of our transect area.

To determine whether we had conducted enough transects to accurately characterize the composition of waterbird species present on the lake during the cruise, we constructed a species accumulation curve (or rarefaction curve), which shows the relationship between cumulative number of species observed and cumulative sampling effort (Krebs 1999).

To statistically analyze the transect data, we classified transects in the following ways to pool data into biological meaningful categories while minimizing degrees of freedom. The dates of transects were divided into three 2-day categories: 20–21 September, n = 9 transects; 22–23 September, n = 15; and 24–25 September, n = 12. Clock time of transects was divided into three classes: Morning (7:00 AM–10:59 AM Eastern Standard Time, n = 8 transects), Mid-day (11:00 AM–2:59 PM, n = 8), and Afternoon (3:00 PM–6:00 PM, n = 20). The location of transects within Lake Ontario was classified into three categories: Eastern basin (east of 77.1 longitude, n = 15 transects), Central basin (77.7° to 78.25°, n = 15), and Western basin (west of 79.0°, n = 6). The location, in terms of distance from any land (including islands), was divided into three categories: Near (under 5.0 km, n = 11 transects), Medium (5.0–14.9 km, n = 13), and Far (at least 15.0 km from any land, n = 12).

To quantify the degree of aggregation of birds among transects, we calculated the index of dispersion I, also called the variance to mean ratio, which equals the product of the variance in abundance across transects divided by the mean abundance (Krebs 1999). Values of $I > 1$ indicate a clumped dispersion, whereas $I < 1$ indicates an even dispersion, and I = 1 is a random dispersion; we used a statistical test described in Krebs (1999) to test whether observed values of I were significantly different from 1.0.

To examine the association between lake primary productivity and bird abundance, we used measurements of chlorophyll *a* concentration at 5 m depth that were collected at each water sampling station by our class (Gouvêa *et al.* unpublished manuscript). For this analysis, we use data from the sampling station located closest to a bird transect, as

TABLE 1. Total counts of each species observed during transect counts, at three distances from shore. Abbreviations: **Mass** *= body mass (grams);* **Guild** *= method of feeding: SS = surface scavenger, PSD = piscivorous surface diver, SG = surface gleaner, PPD = piscivorous plunge diver.*

Species	Mass	Guild	Near	Medium	Far
Ring-billed Gull (*Larus delawarensis*)	570	SS	42	43	39
Herring Gull (*Larus argentatus*)	1,150	SS	11	27	21
Common Loon (*Gavia immer*)	5,460	PSD	3	9	5
Double-crested Cormorant (*Phalacrocorax auritus*)	2,090	PSD	7	3	1
Great Black-backed Gull (*Larus marinus*)	1,750	SS	4		
Bonaparte's Gull (*Larus philadelphia*)	220	SG		2	
Common Tern (*Sterna hirundo*)	120	PPD			1
Black Tern (*Chlidonias niger*)	60	SG	1		
Horned Grebe (*Podicips auritus*)	460	PSD	1		
Storm Petrel species	45	SG			1

indicated by a spatial map produced using ArcGIS 8.2 (ESRI, Redlands CA).

RESULTS

A total of ten pelagic waterbird species was tallied during the transect counts (Table 1). The species accumulation curve indicates that we had observed most of the species present in pelagic Lake Ontario during the sampling period (Fig. 2). Indeed, only two additional pelagic waterbird species were observed at any time during the trip: parasitic jaeger (*Stercorarius parasiticus)* and surf scoter (*Melanitta perspicillata*). However, several species of waterbirds that we never observed were reported by shore-based birder-watchers during the period of the cruise (e.g., D'Anna 2004, regional reports in *Kingbird* (2004) 52 (1)); these species were apparently either very rare or were restricted to nearshore during our study.

Eighty-six percent of the 221 birds recorded in the 36 transect counts were gulls, mainly herring gulls (*Larus argentatus)* and ring-billed gulls (*L. delawarensis*). The species observed within the transects ranged in size from 0.5 to 5.5 kg, and included members of four foraging guilds: surface scavengers, which feed opportunistically on floating detritus and small animals that can be collected from the surface; piscivorous surface divers, which capture fish by swimming pursuit; piscivorous plunge divers, which capture fish by aerial diving into the water; and surface gleaners, which collect small fish and invertebrates at the surface (Table 1). The most unusual species observed was a storm-petrel (possibly Leach's storm-petrel *Oceanodroma leucorhoa*), which was located at 26 km distance from land, and probably had been transported by Hurricane Isabel. Storm petrels are oceanic species that have only been seen on the shores of Lake Ontario in the aftermath of hurricanes (Levine 1998).

The number of birds per transect varied markedly among the 36 transects (Table 2). Despite the fact that our bird survey began the day after the passing of the Hurricane Isabel storm system, the abundance and diversity of birds per transect count did not vary predictably across the 6-day survey period (Kruskal-Wallis test, abundance: $H = 1.1$, df = 2, $P = 0.6$; species richness: $H = 0.8$, df = 2, $P = 0.7$). Time of day of the transect also did not matter during our survey (Kruskal-Wallis test, abundance: $H = 1.0$, df = 2, $P = 0.6$; species richness: $H = 1.7$, df = 2, $P = 0.4$).

The abundance and species richness of birds did not vary significantly with distance from land

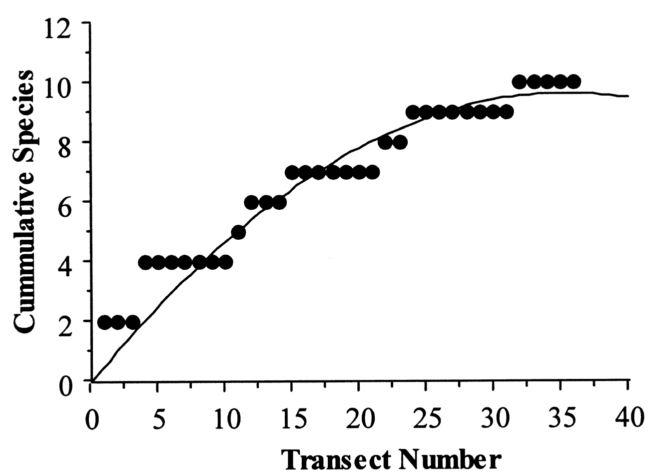

FIG. 2. The cumulative number of species observed in the transect counts compared to sample effort.

TABLE 2. Summary of the transect counts at three distances from shore. Abbreviations: N = number of transects;* Area Surveyed *= cumulative area surveyed (km^2);* Zero Count *= percentage of transects no birds were observed;* Median (max) *= median and maximum density of birds per transect (number / km2);* Number *= cumulative number of individual birds;* I *= index of dispersion;* Species Richness *= median (maximum) species per transect. Starred values of* I *indicate significantly (*P *< 0.05) aggregated dispersion.

Distance	N	Area Surveyed	Zero Count	Total Median (max)	Total Number	Total I	Species Richness
Near	11	13.1	9%	3.4 (12.3)	69	3.19*	2 (4)
Medium	13	15.6	38%	3.3 (23.8)	84	11.51*	1 (4)
Far	12	13.8	17%	2.5 (21.1)	68	7.95*	2 (3)
Total	36	42.5	22%	3.3 (23.8)	221	7.46*	2 (4)

TABLE 3. Summary of the transect counts of birds flying over the water, and birds sitting on the water, at three distances from shore. Abbreviations:* Median (max) *= median and maximum birds per transect (number / km^2);* Number *= cumulative number of individual birds;* I *= index of dispersion. Starred values of* I *indicate significantly (*P *< 0.05) aggregated dispersion.

Distance	Flying Median (max)	Flying Number	Flying I	Sitting Median (max)	Sitting Number	Sitting I
Near	1.8 (11.0)	45	4.31*	0.9 (8.4)	24	3.08*
Medium	0.8 (4.2)	25	1.88*	0.0 (23.8)	59	15.37*
Far	1.7 (4.9)	27	1.57	0.4 (21.1)	41	12.21*
Total	1.7 (11.0)	97	2.99*	0.8 (23.8)	124	11.68*

(Table 2; Kruskal-Wallis test, abundance: $H = 0.8$, df = 2, $P = 0.7$; species richness: $H = 3.6$, df = 2, $P = 0.2$), nor did median density flying or sitting on the water per transect vary with distance from land (Table 3; Both H's < 1.3, P's > 0.5). However, when the counts of all birds per distance class were summed, in the nearshore relatively more birds were detected flying across transects than sitting on the water, whereas at the two more distant categories relatively more birds were detected sitting on the water than flying through transects (Table 3; contingency test: $\chi^2 = 20.0$, df = 2, $P < 0.0001$). This suggests that more pelagic waterbirds were feeding at distances greater than 5.0 km offshore than the nearshore during the period of our survey (assuming that sitting birds feed in the area sighted), and inshore observations included many birds that were in transit between roosting sites on land and foraging sites offshore. In our survey, the dispersion of birds was significantly aggregated, at any distance category (Table 2, Table 3).

We examined the relative abundance of the most common species nearshore versus the two farther distance classes, the latter pooled to increase statistical power (i.e., less than 5 km from land versus minimum 5 km from land). Comparing the two most abundant surface scavengers, herring gulls were relatively more abundant offshore and ring-billed gulls were more common nearshore (Table 1; Fisher's exact test: $P = 0.04$). Both species were significantly aggregated among transects (ring-billed gull $I = 9.5$, herring gull $I = 5.0$, both P's < 0.05). Comparing the two most abundant piscivorous surface divers, cormorants were relatively more abundant nearshore, whereas common loons were most abundant offshore (Table 1; Fisher's exact test: $P = 0.02$). The dispersion of cormorants among transects was significantly aggregated ($I = 1.6$, $P < 0.05$), whereas the dispersion of loons was not significantly different from random ($I = 1.4$, $P > 0.05$); this was not surprising given the natural history of these two species (McIntyre and Barr 1997, Hatch and Weseloh 1999).

The concentration of chlorophyll *a* at 5 m depth, our measure of surface water primary productivity, was generally low but varied markedly among the regions of Lake Ontario where we conducted the bird transect counts (mean ± sd = 2.8 ± 2.24 μg/L, range 0.8–11.6 µg/L, Gouvêa *et al.* unpublished manuscript). The concentration of chlorophyll *a* was not associated with bird abundance (Spearman $r = 0.06$, $p = 0.7$).

DISCUSSION

This study provides some evidence that significant numbers of pelagic waterbirds forage in the far offshore region of Lake Ontario, well beyond the zone visible from shore. Indeed, the highest densities of some important species, such as the common loon, are not visible from shore. Abundances of pelagic waterbirds appear low in Lake Ontario, but may be similar to many offshore oceanic regions. For example, in the oligotrophic South Atlantic Bight off the Southeastern United States, pelagic seabird species richness is higher than Lake Ontario (23 species) but density is similar, ranging from 0.1 birds per km^2 to 8.2 birds per km^2, depending on the offshore environment (Haney 1986). Lake Ontario, during our survey, had a higher abundance of common loons (mean = 0.5 per km^2) than on marine wintering sites off the southeastern United States (mean = 0.35 per km^2, Haney 1990).

Stapanian and Waite (2003) provide the one study conducted on a Laurentian Great Lake that is comparable to ours. Those authors used a similar survey methodology to our study, but observations were made from a lower height above water in a smaller watercraft. Their transect widths were narrower (200 m) to account for lower observation height, and for close proximity to shore in some transects. The surveys were conducted in western Lake Erie, within a productive region characterized by many islands and shoals. Transect locations were repeatedly resampled during spring and summer, survey time was limited to the morning hours, and all transects were within 9 km of some landfall (mainland or island). Bird abundance in open water habitat was higher in their study than ours, but this appears to be mainly due to much higher abundances of Bonaparte's gull in their study. In nearshore areas, cormorants and other birds were far more abundant in Stapanian and Waite (2003) than in our study; this may reflect higher fish productivity or closer proximity to bird breeding colonies in the region of Lake Erie that they surveyed than in our Lake Ontario study.

In Stapanian and Waite's (2003) study, birds were far more abundant nearshore than offshore, and the species composition was similar between nearshore and offshore habitat. They concluded that land-based surveys or nearshore surveys from small boats are adequate for monitoring Great Lakes waterbirds, if the western basin of Lake Erie that they surveyed is representative of the Great Lakes as a whole. Our results indicate that their survey area may not be representative; on Lake Ontario, although some important birds such as double-crested cormorants may be adequately surveyed from the vicinity of land, other important species such as the common loon may only be adequately surveyed by going far offshore.

Hurricanes transport ocean birds inland to the Great Lakes (Levine 1998). While we were conducting these surveys on the R/V *Lake Guardian*, large numbers of bird watchers scanned the shoreline of Lake Ontario for unusual birds, and a number were reported including at least five marine pelagic species: the black-capped petrel (*Pterodroma hasitata*), Wilson's storm-petrel (*Oceanites oceanicus*), Sabine's gull (*Xema sabini*), sooty tern (*Sterna fuscata*), and bridled tern (*Sterna anaethetus*) (D'Anna 2004). We only detected one "rarity" during the survey (a possible storm-petrel), indicating the abundance of unusual birds associated with the passage of the hurricane was very low.

Anecdotally, a party of bird watchers on shore at one location identified our ship, which was stationed about 1.2 km offshore while collecting samples. We were contacted and asked if we could confirm their detailed observations of a storm-petrel that had been circling the ship. We informed them that the bird in question had been carefully observed by us at close range, and was actually a greater yellowlegs (*Tringa melanoleuca*), a common shorebird.

During our study, we failed to identify any environmental predictors of bird abundance. Given the extreme weather conditions at the time of our study, this was hardly surprising; high winds such as those during our survey period can affect the distribution of pelagic waterbirds (Blomqvist and Peterz 1984, Haney and Lee 1994).

Pelagic waterbirds tended to appear in aggregations, but it was usually unclear why birds were aggregated at particular locations. Our measure of primary productivity, lake water concentration of chlorophyll *a*, may have been measured at too coarse-grained a scale to detect the hotspots of productivity that birds track. One of the largest aggregations of pelagic waterbirds that we observed during the cruise was aligned along a "slick," a convergence of currents due to upwelling (a common feature in Lake Ontario) which results in a localized linear strip of flotsam and plankton. Many pelagic waterbirds, most notably Bonaparte's gull among the species we observed (Burger and Gochfeld 2002), are known to concentrate foraging activities at slicks, upwellings, and other localized areas of high productivity (Haney and Solow 1992).

Our experience demonstrates that a survey of the abundance and dispersion of pelagic waterbirds aboard a Great Lakes research vessel, using the standard methods developed for oceanic seabird surveys, is relatively easy to conduct and can provide valuable information for researchers and resource managers. Surveys can be performed by one observer, if that person is experienced at spotting and identifying birds from ships, but a two-person team is ideal. The upper foredeck of a research vessel such as the R/V *Lake Guardian* is an excellent platform for spotting birds. Hull speed should be 8–12 knots (15–22 km/h) since higher velocity will hinder identification and substantially increase the chance of missing birds. Access to data from the ship's navigation instrumentation is necessary if a surveyor lacks a GPS. To analyze spatial patterns in the survey data, geographic information systems (GIS) software is essential.

Although there has been some controversy in the ornithological literature about the utility of standardized survey methods for pelagic waterbirds (Tasker *et al.* 1984, 1985; Haney 1985; Gaston *et al.* 1987), we found the Tasker *et al.* (1984) methodology easy to use, and likely to provide valid estimates of absolute abundance of waterbirds in the offshore Great Lakes. We recommend that agencies and research teams involved in shipboard Great Lakes research activities encourage and support small projects focused on mapping the abundance and dispersion of pelagic waterbirds, because these studies may improve our understanding of food web dynamics and the environmental health of the lakes (a point also made by Stapanian and Waite 2003).

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REFERENCES

Bedard, J.J., Therriault, J.C., and Berube, J. 1980. Assessment of the importance of nutrient recycling by seabirds in the St. Lawrence estuary. *Can. J. Fish. Aquat. Sci.* 37:583–588.

Bibby, C.J., Burgess, N.D., Hill, D.A., and Simon, S.H. 2000. *Bird Census Techniques, 2nd Edition.* Academic Press.

Blomqvist, S., and Peterz, M. 1984. Cyclones and pelagic seabird movements. *Mar. Ecol. Prog. Ser.* 20:85–92.

Burger J., and Gochfeld, M. 2002. Bonaparte's Gull *(Larus philadelphia). Birds of North America* 634.

D'Anna, W. 2004. Hurricane Isabel (September 2003) in New York. *Kingbird* 54:14–19.

Diehl, R.H., Larkin, R.P., and Black, J.E. 2003. Bird migration around the Great Lakes on Doppler radar: implications for habitat conservation. *Auk* 120:278–290.

Domske, H.M. 2003. *Botulism in Lake Erie Workshop Proceedings*. Available at http://www.seagrant.sunysb.edu/botulism/Botulism-Proc03.pdf.

Gaston, A.J., Collins, B.L., and Diamond, A.W. 1987. The "snapshot" count for estimating densities of flying seabirds during boat transects: A cautionary comment. *Auk* 104:336–338.

Gebauer, M.B., Dobos, R.Z., and Weseloh, D.V. 1992. Waterbird surveys at Hamilton Harbour, Lake Ontario, 1985–1988. *J. Great Lakes Res.* 18:420–439.

Gould, P.J., and Forsell, D.J. 1989. *Techniques for shipboard surveys of marine birds.* U.S. Fish Wildl. Serv., Fish Wildl. Tech. Rep. 25.

Haney, J.C.1985. Counting seabirds at sea from ships: Comments on interstudy comparisons and methodological standardization. *Auk* 102:897–898.

_____. 1986. Seabird patchiness in tropical oceanic waters: the influence of *Sargassum* reefs. *Auk* 103:141–151.

_____. 1990. Winter habitat of common loons on the continental shelf of the southeastern United States. *Wilson Bull.* 102:253–263.

_____, and Lee, D.S. 1994. Air-sea heat flux, ocean wind fields, and offshore dispersal of gulls. *Auk* 11:427–444.

_____, and Solow, R.W. 1992. Analyzing quantitative relationships between seabirds and marine resource patches. *Curr. Ornithol.* 9:105–162.

Hatch, J.J., and Weseloh, D.V. 1999. Double-crested Cormorant *(Phalacrocorax auritus). Birds of North America* 441.

Heinemann, D. 1981. A range finder for pelagic bird censusing. *J. Wildlife Manage.* 42:489–493.

Hebert, C.E., and Sprules, W.G. 2002. The relevance of seabird ecology to Great Lakes management. *J. Great Lakes Res.* 28:91–103.

Kalff, J. 2003. *Limnology: Inland Water Ecosystems*, *2nd Edition.* Prentice-Hall.

Krebs, C.J. 1999. *Ecological Methodology, 2nd Edition*. Benjamin Cummings.

Levine, E. 1998. *Bull's Birds of New York State*. Cornell University Press.

McIntyre, J.W., and Barr, J.F. 1997. Common Loon *(Gavia immer). Birds of North America* 313.

Mills, E.L., Casselman, J.M., Dermott, R., Fitzsimons, J.D., Gal, G., Holeck, K.T., Hoyle, J.A., Johannsson, O.E., Lantry, B.F., Makarewicz, J.C., Millard, E.S., Munawar, I.F., Munawar, M., O'Gorman, R., Owens, R.W., Rudstam, L.G., Schaner, T., and Stewart, T.J. 2003. Lake Ontario: food web dynamics in a changing ecosystem (1970–2000). *Can. J. Fish. Aquat. Sci.* 60:1–20.

Stapanian, M.A., and Bur, M.T. 2002. Overlap in offshore habitat use by double-crested cormorants and boaters in western Lake Erie. *J. Great Lakes Res.* 28:172–181.

_____, and Waite, T.A. 2003. Species density of waterbirds in offshore habitats in western Lake Erie. *J. Field Ornith.* 74:381–391.

_____, Bur, M.T., Tyson, J.T., Seamans, T.W., and Blackwell, B.F. 2002. Foraging locations of double-crested cormorants on western Lake Erie: site characteristics and spatial associations with prey fish densities. *J. Great Lakes Res.* 28:155–171.

Tasker, M.L., Hope Jones, P., Dixon, T., and Blake, B.F. 1984. Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardized approach. *Auk* 101:567–577.

_____, Hope Jones, P., Blake, B.F., and Dixon, T.J. 1985. Response to J.C. Haney. *Auk* 102:899–900.

Twiss, M.R., Langen, T.A., Bullerjahn, G.S., Wilhelm, S.W., and Rockwell, D.C. 2005. The Lake Ontario Great Lakes Science Practicum: A model for training limnology students on how to conduct shipboard research in the Great Lakes. *J. Great Lakes Res.* 31:236–242.

Weseloh, D.V.C., and Pekarik, C. 1999. Declining contaminant levels in herring gull eggs from Toronto Harbour, Lake Ontario, 1974–1998. *Great Lakes Res. Rev.* 4:23–27.

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