

Abundance, Distribution, and Species Assemblages of Colonial Waterbirds in the Boreal Region of West-Central Manitoba and East-Central Saskatchewan

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Central and southern Manitoba contain some of the largest breeding populations of several colonial waterbird species in North America. Despite the value of this region for waterbirds, very little monitoring has been conducted on Lake Winnipeg, Lake Winnipegosis, or Lake Manitoba in the past three decades and little is known about the smaller boreal lakes in adjacent areas to the north. In June 2011, boat surveys were conducted on 11 boreal lakes in west-central Manitoba and east-central Saskatchewan to examine current abundance and distribution of colonial waterbirds in that region. Data from this survey were compared with abundance of colonial waterbirds on Lake Winnipegosis and Lake Manitoba from an aerial survey of these lakes in 2012. Waterbird colonies were located on 7 of the 11 lakes in 2011 and included Double-crested Cormorants (*Phalacrocorax auritus*) (2373 adults, 1134 pairs in 7 colonies), Common Terns (*Sterna hirundo*) (1367 adults, 772 pairs in 29 colonies), Forster's Terns (*Sterna forsteri*) (20 adults, 11 pairs in 1 colony), Herring Gulls (*Larus argentatus*) (876 adults, 568 pairs in 23 colonies), and Ring-billed Gulls (*Larus delawarensis*) (3752 adults, 16 colonies). Common Terns and Herring Gulls appeared to be predominantly breeders and pair abundance for both species increased in a sigmoidal fashion; lakes <100 km² in area had few breeding pairs. Numbers of Double-crested Cormorants and especially, Ring-billed Gulls, may have included a sizeable non-breeding component. Densities (pairs/lake area) of Common Terns and Herring Gulls were about 2 and 4 times higher, respectively, on these lakes than on Lake Winnipegosis and Lake Manitoba, while Double-crested Cormorant and Ring-billed Gull densities were higher on lakes Winnipegosis and Manitoba. Additional studies of productivity in relation to lake characteristics and connectivity among colonies throughout the region would further our understanding of the importance and sustainability of waterbird populations in this region of the boreal forest.

Key Words: abundance; boreal; colonial waterbird; Common Tern; *Sterna hirundo*; Herring Gull; *Larus argentatus*; Double-crested Cormorant; *Phalacrocorax auritus*; Ring-billed Gull; *Larus delawarensis*; Manitoba; Saskatchewan

Introduction

The North American boreal forest covers a vast region from Alaska through Newfoundland and Labrador (Brandt 2009), and it contains numerous lakes and large rivers that provide potential breeding habitat for colonial waterbirds. The central and southern region of Manitoba, in particular, is a major nesting area for Common Terns (*Sterna hirundo*) and Herring Gulls (*Larus argentatus*), both of which breed primarily within the boreal forest biome, as well as several other species whose breeding range extends more broadly to the south, e.g., Double-crested Cormorant (*Phalacrocorax auritus*), American White Pelican (*Pelecanus erythrorhynchos*), and Caspian Tern (*Hydroprogne caspia*) (Koonz and Rakowski 1985).

To date, there has been almost no work on the waterbird community that uses the many smaller boreal lakes north of approximately 54°N latitude (but see Vermeer 1973; Stelfox and Brewster 1979; Somers *et al.* 2010). From the 1960s through the 1980s, several studies reported on the abundance and distribution of colonial waterbirds on lakes Winnipeg, Winnipegosis, and Manitoba, south of the 54th parallel (Vermeer 1969, 1970; Koonz and Rakowski 1985; Hobson *et al.* 1989). No region-wide monitoring has taken place in central and southern Manitoba in over two decades despite ob-

served declines in the populations of some colonial species further east on the Great Lakes (Morris *et al.* 2010, 2011) and a number of regional threats to waterbirds, including persecution, flooding of colonies due to water level manipulation, and eutrophication of the lakes, which may subsequently impact breeding waterbirds (Hobson *et al.* 1989; Lindenschmidt *et al.* 2012; Schindler *et al.* 2012).

Updated information on the abundance and distribution of colonial waterbirds in Manitoba and Saskatchewan is needed for conservation planning at regional, national, and continental scales. To address this, surveys were conducted in 2011 and 2012 consisting of two components: 1) ground-based surveys in 2011 of several smaller lakes along the southern edge of the Boreal Shield ecozone/the northern edge of the Boreal Plains ecozone, north of 54°N and 2) aerial surveys in 2012 of Lake Winnipeg, Lake Winnipegosis, and Lake Manitoba to monitor all historical colonies and potential new breeding sites (Wilson *et al.* unpublished manuscript). The focus of the 2011 survey, reported on here, was to examine breeding densities and the distribution of colonial waterbirds on smaller boreal lakes north of Lake Winnipegosis. Information on abundance and long-term trends, based on the aerial surveys in 2012, will be presented elsewhere, but I use overall abundance

estimates from lakes Winnipegosis and Manitoba as a basis of comparison for the breeding densities of Double-crested Cormorants, Herring Gulls, Ring-billed Gulls (*Larus delawarensis*), and Common Terns on the smaller boreal lakes.

Methods

Surveys

Surveys were conducted by boat (16 ft Big Lakes model, Lund Boats Inc., Steinbach, Ontario) between 20 and 25 June 2011 (~40 hours of survey effort) on 11 lakes in The Pas–Flin Flon region of west-central Manitoba and east-central Saskatchewan (Figure 1 and Table 1). Lakes included in the survey were Amisk Lake in Saskatchewan and Athapapuskow Lake, Cormorant Lake, First Cranberry Lake, Second Cranberry Lake, Goose Lake, Rocky Lake, Otter Lake, Schist Lake, Simonhouse Lake, and White Lake in Manitoba. Lakes varied in size from 0.6 km² to 360 km². Surveys included the entirety of all lakes, with the exception of

Amisk Lake, where we were unable to survey Missi Bay and the narrow channel to the northwest of Crater Island, representing an estimated 11% of the lake area. Because colonies tend to be on sites surrounded by greater amounts of open water, it is likely that at most only small numbers of breeding birds were missed in this region. For all of the lakes, satellite imagery (Google Image Landsat 2013) was used to identify all potential islands that might contain breeding colonial species. In addition, visual scans of all other islands that were less suitable (e.g., entirely forested islands) were done during surveys of the lake basin.

Digital photographs were taken using a D700 Nikon camera (Nikon Canada Inc., Mississauga, Ontario) and a 400-mm zoom lens, with the magnification adjusted as needed, of the adults at all breeding colonies. Because adults would depart as the boat approached, photographs were taken when the boat was about 75 m away and at approximately 10-m intervals until the boat reached the shore. This was particularly helpful in the

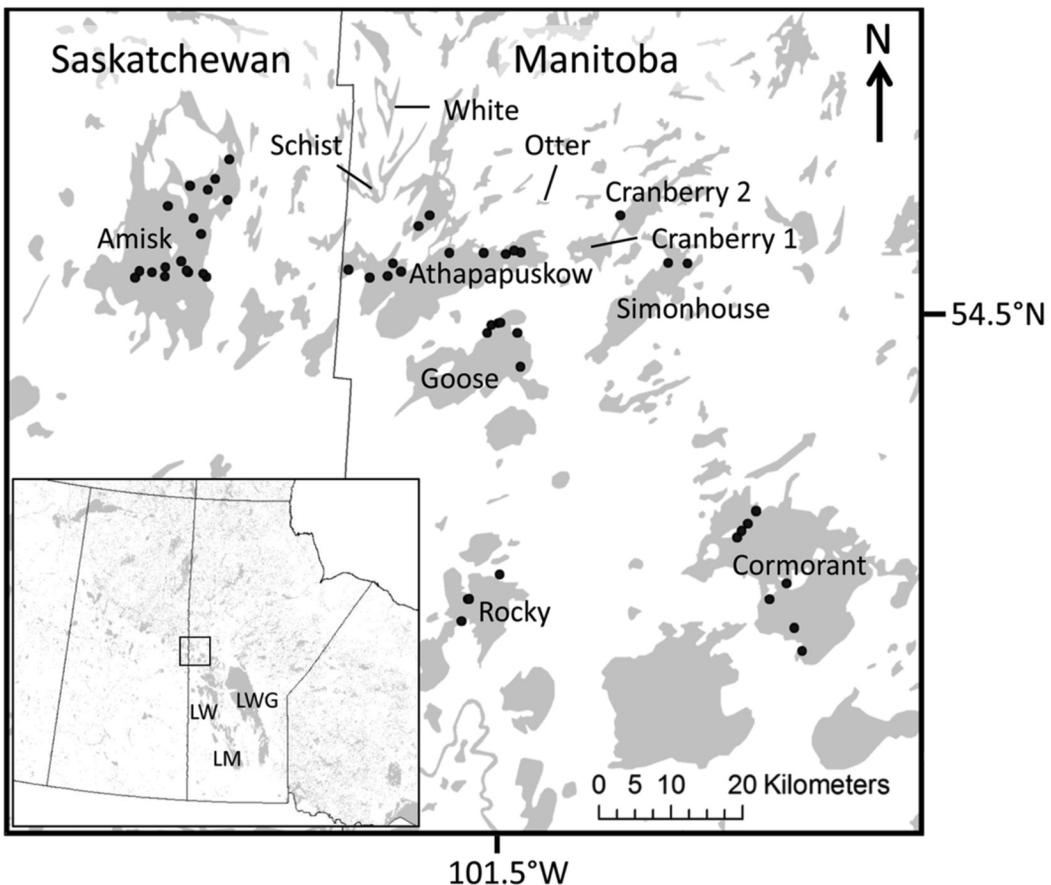


FIGURE 1. Map of the survey area showing boreal lakes that were included in the survey. Circles refer to the locations of waterbird colonies on each lake. Inset map shows Saskatchewan and Manitoba with the square indicating the survey area. The three large lakes surveyed in 2012 are also included; LW = Lake Winnipegosis, LM = Lake Manitoba, LWG = Lake Winnipeg.

TABLE 1. Numbers of adults, estimated breeding pairs, and colonies of four species of colonial waterbirds nesting on lakes in west-central Manitoba and east-central Saskatchewan. Surveys were conducted between 20 and 25 June 2011. Sites refers to locations where at least one species was observed breeding. The adult count for a lake includes individuals at breeding colonies and loafers observed at colonies of other species, but no attempt was made to survey individuals detected while travelling between colonies. Only adult counts are presented for Ring-billed Gulls because of uncertainty in the non-breeding component (see text).

Lake	Area (km ²)	Sites	Double-crested Cormorant			Common Tern			Herring Gull			Ring-billed Gull	
			Adults	Pairs	Colonies	Adults	Pairs	Colonies	Adults	Pairs	Colonies	Adults	Colonies
Amisk	360	18	446	165	4	341	186	10	183	120	8	956	6
Athapuskow	255	12	0	0	0	294	173	6	291	189	6	275	2
Cormorant	356	9	0	0	0	423	240	6	183	115	3	660	5
First Cranberry	21	0	0	0	0	0	0	0	0	0	0	0	0
Second Cranberry	25	1	0	0	0	26	15	1	0	0	0	0	0
Goose	136	6	1815	916	1	230	128	3	145	95	3	582	2
Otter	0.6	0	0	0	0	0	0	0	0	0	0	0	0
Rocky	111	4	2	0	0	52	31	3	58	39	1	1279	1
Schist	20	0	0	0	0	0	0	0	0	0	0	0	0
Simonhouse	85	2	110	53	2	1	0	0	16	10	2	0	0
White	2	0	0	0	0	0	0	0	0	0	0	0	0
Total	1371.6	52	2373	1134	7	1367	773	29	876	568	23	3752	16

case of Common Terns, which often take flight uniformly, and made it possible to capture an entire colony in a single frame. Photographs were taken in raw format and set for the maximum resolution (~34.5 megapixels per image).

Counts

Adult counts were conducted in Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, California) using the digital photographs. Photographs of each colony were first examined to identify the one that best captured the adults and then selected photographs were split into 54 grid cells of equal width. Adults were counted in each grid cell and then summed to produce a total count. At some colonies, multiple photographs were needed and landmarks such as vegetation, rocks, and the position of breeding birds were used to identify sections where photographs overlapped. A drawing tool was then used to exclude sections of one photograph that had been counted in another.

Whenever possible, nest counts were carried out on shore. An active nest was defined as a nest containing eggs or chicks. Nests were counted with a hand-held counter. For the larger colonies, flagging tape was used to section off parts of the colony to keep track of nests that had already been counted.

Estimates of breeding pairs

For sites where nests could be reliably counted, this count was used as the estimate of breeding pairs (one nest equal to one breeding pair). For any sites where it was not possible to go ashore, where chicks had hatched and left the nest, or where there was evidence of recent widespread nesting failure (a case for one Common Tern colony), the count of adults was used to estimate breeding pairs.

Accurate nest counts were possible for 5 of 7 Double-crested Cormorant colonies and 16 of 29 Common Tern colonies. Nest counts were possible for Herring Gulls at only a few sites because chicks had already hatched at most colonies, but the number of chicks observed was recorded and recently used nest structures were noted to confirm a breeding colony.

Breeding pair estimates based on the counts of adults are less certain, because it is not clear what fraction of breeding birds were at the colony during the count. To provide a stronger measure, I determined the ratio of adults to nests at all sites where both could be reliably counted and then applied this estimate to those sites where only adults could be counted. For Double-crested Cormorants, this ratio (scaled to colony size) was 2.19 ± 1.81 (mean \pm SE, $n = 5$), while for Common Terns it was 1.76 ± 0.07 ($n = 16$). The greater error in the ratio for Double-crested Cormorants results in greater uncertainty in the breeding pair estimate.

Based on a small number of Herring Gull colonies at either the egg stage or with chicks still in or beside the nest, the ratio of adult Herring Gulls to nests was 1.63 ± 0.29 ($n = 6$), suggesting ~82% of adult Herring

Gulls were at the colony on average during the incubation stage and early hatchling stages. Colony attendance tends to decrease from incubation through the chick-rearing period, and earlier studies on *Larus* spp. have shown a range of colony attendance of about 60 to 80% (Morris and Black 1980; Pierotti 1987). Surveys also included adults offshore but within the vicinity of the colony (<100 m), and I assumed that 75% of adults were present at colonies during the chick-rearing stages.

Some degree of error is expected in the pair count, and the numbers reported in this manuscript should be treated as a best estimate. The number of adult Ring-billed Gulls was often far higher than the nest count, and Ring-billed Gulls were frequently observed loafing at the colonies of other species (see Results). This potentially suggests a large non-breeding component and I therefore report only the number of adult Ring-billed Gulls without a breeding pair estimate.

Relationship between lake size and breeding abundance

For Common Terns and Herring Gulls, I examined the effects of lake size on breeding abundance by comparing support for a linear, quadratic, and cubic relationship (Kutner *et al.* 2005) between lake area and the estimated number of breeding pairs. Because of the small sample size, I did not consider higher order terms beyond a third-order polynomial. A generalized linear model with a Poisson distribution was used to test this relationship and was performed with program R (R Core Team 2013). Evaluation of support for the three model types was made using Akaike's Information Criterion for small samples (AIC_c), and all models within 2 units of the top model were considered to be supported by the data (Burnham and Anderson 2002). Measures of lake area were made using a Google area mapping tool (Daft Logic 2013). I restricted this analysis to Common Terns and Herring Gulls because Double-crested Cormorants were observed breeding on only three lakes and because of the uncertainty in the estimate of breeding pairs for Ring-billed Gulls.

Comparisons between this region and Lake Winnipegosis and Lake Manitoba were based on estimated densities of each species (pairs or adults per km² of lake area). A detailed description of the methods and results from the aerial survey will be presented elsewhere (Wilson *et al.*, unpublished manuscript), but a brief summary is included here. The survey took place on 13, 15, and 16 June, 2012 and was designed to include all historical and potential new colony sites for island-nesting colonial waterbirds on Lake Winnipeg, Lake Winnipegosis, Lake Manitoba, and the inter-lakes region between the three lakes. Colonies were surveyed by helicopter (13 June) and float plane (15 and 16 June), and high-resolution digital photographs were taken of all locations where any one of the six target colonial species (American White Pelican, Double-crested Cormorant, Ring-billed Gull, Herring Gull, Caspian Tern, and Common Tern) was observed breeding.

Colonial bird counts based on the photographs were conducted in Adobe Photoshop CS5 and included estimates of adults and nest abundance (based on incubating birds); these estimates were then used to estimate the number of breeding pairs at each colony. Calculation of area for Lake Winnipegosis and Lake Manitoba was done using the same method as described above for the small boreal lakes. It was not possible to survey the northeastern portion of Lake Winnipeg in 2012 and I therefore do not include abundance on Lake Winnipeg in the density comparison.

Results

Surveys located a total of 52 sites across the 11 lakes where at least one of the four species was observed breeding (Figure 1). Common Terns and Herring Gulls were breeding on six of the 11 lakes, Ring-billed Gulls on five, and Double-crested Cormorants on three (Table 1). Only two lakes (Amisk Lake and Goose Lake) had breeding activity by all four species, while Schist Lake, First Cranberry Lake, Otter Lake, and White Lake did not have any breeding colonies. Colony characteristics differed among the four species. Common Terns and Herring Gulls were present at a larger number of sites but with fewer pairs per colony: 29 colonies averaging 27 pairs per colony for Common Terns and 23 colonies averaging 25 pairs per colony for Herring Gulls (Table 1). Colony sizes tend to be positively skewed for these species and the median colony sizes were 20 pairs per colony for Common Terns and 17 pairs per colony for Herring Gulls.

The number of breeding pairs was low on small lakes but increased in a sigmoidal pattern with lake area (Figure 2). For both Common Terns and Herring Gulls, a cubic model relating breeding pair abundance to lake area had substantially more support than either the qua-

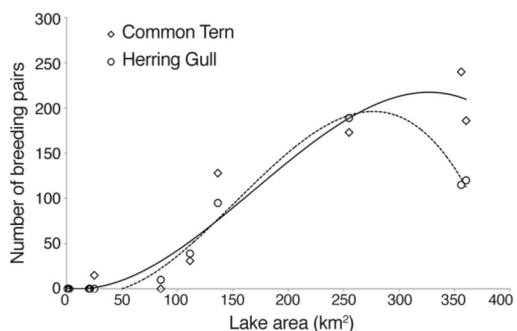


FIGURE 2. Number of breeding pairs in relation to lake area for Common Terns (*Sterna hirundo*) and Herring Gulls (*Larus argentatus*) on boreal lakes in west-central Manitoba and east-central Saskatchewan. Best fit lines for each species are based on a model with a cubic relationship between lake area and number of breeding pairs (solid line = Common Tern, dashed line = Herring Gull).

dratic or the linear model (Common Tern: AIC_c increase = 23.5 units for the quadratic model, 204 units for the linear model; Herring Gull: AIC_c increase = 37.9 units for the quadratic model, 360 units for the linear model). Predictions from the cubic model suggest that the number of Common Terns would increase beyond 10 pairs on lakes exceeding 60 km² and beyond 25 pairs on lakes exceeding 85 km². For Herring Gulls, those same predictions suggest in excess of 10 and 25 pairs on lakes that were greater than 85 km² and 100 km², respectively.

Double-crested Cormorants were breeding at fewer locations than Common Terns and Herring Gulls but had larger average colony sizes (mean = 162 pairs, median = 43 pairs). Eighty-one percent of breeding Double-crested Cormorants were observed at a single colony on Goose Lake with 916 pairs (Table 1). For comparison, the largest Herring Gull colony ($n = 111$ pairs), on Lake Athapapuskow, comprised 19.5% of the Herring Gull pairs on all lakes, while the largest Common Tern colony ($n = 100$ pairs), on Cormorant Lake, contained 12.9% of the Common Tern pairs on all lakes. Because of uncertainty concerning the non-breeding component of the Ring-billed Gull numbers, I only report adult abundance and observed 3752 adults and located 16 breeding colonies. The number of adult Ring-billed Gulls far exceeded nest counts at several colonies, and 11% of adults were observed at sites where only the other species were observed breeding.

Double-crested Cormorants were occasionally observed loafing at the colonies of other species (4.9% of adult observations), while Common Terns and Herring Gulls almost never were (0.004 and 0.006% of adults, respectively). A colony of 11 Forster's Terns (*Sterna forsteri*) was also observed on Cormorant Lake, where they were nesting sympatric to a colony of Common Terns. In this case, the Common Terns were nest-

ing on rocky substrate on the main part of the island, and the Forster's Terns were nesting in a patch of dense emergent vegetation along the periphery. Caspian Terns and American White Pelicans were observed on several lakes, but no breeding colonies were located.

Of the 52 sites, 29 had only one species breeding; of these 29 sites, 27 had either Common Terns or Herring Gulls (Table 2). Both species were typically breeding on small rocky islets, but, despite the large number of colonies for the two, they rarely nested on the same islands. Where Common Terns nested with other species, they were most commonly associated with Ring-billed Gulls; Herring Gulls were more often associated with Double-crested Cormorants. There were three cases where Herring Gulls and Ring-billed Gulls nested on the same island, in which case Ring-billed Gulls tended to nest in dense clusters in the centre of the island and Herring Gulls were scattered around the periphery. There were no sites where all four species were breeding together.

Densities of the four species showed different patterns between the boreal lakes and Lake Winnipegosis and Lake Manitoba. For Common Terns, breeding pair densities on the boreal lakes were about 2.2 times greater than on Lake Winnipegosis and 2.2 times greater than on Lake Manitoba (Table 3). For Herring Gulls, breeding pair densities on the boreal lakes were about 3.4 times greater than on Lake Winnipegosis and 4.1 times greater than on Lake Manitoba (Table 3). Double-crested Cormorants and Ring-billed Gulls showed the opposite pattern. Relative to the boreal lakes, pair densities of Double-crested Cormorants were about 4.6 times greater on Lake Winnipegosis and 3.0 times greater on Lake Manitoba (Table 3). Adult densities for Ring-billed Gulls were 1.5 times greater on Lake Winnipegosis and 1.6 times greater on Lake Manitoba.

TABLE 2. Species assemblages at 52 sites on islands in the boreal region of west-central Manitoba and east-central Saskatchewan. See Table 1 for the total number of sites for each species.

Combination	Cases	Percentage of sites
Double-crested Cormorants only	1	2
Common Terns only	14	27
Herring Gulls only	13	25
Ring-billed Gulls only	1	2
Double-crested Cormorants + Common Terns	0	0
Double-crested Cormorants + Ring-billed Gulls	0	0
Double-crested Cormorants + Herring Gulls	5	10
Common Terns + Herring Gulls	2	4
Common Terns + Ring-billed Gulls ¹	11	21
Herring Gulls + Ring-billed Gulls	3	6
Double-crested Cormorants + Common Terns + Herring Gulls	0	0
Double-crested Cormorants + Common Terns + Ring-billed Gulls	1	2
Common Terns + Herring Gulls + Ring-billed Gulls	1	2
All species	0	0

¹ Includes one colony with Forster's Terns.

TABLE 3. Comparison of adult and breeding pair densities on the boreal lakes in this study in 2011 and on Lake Winnipegosis and Lake Manitoba, surveyed in 2012. Only adult densities are provided for Ring-billed Gulls on the boreal lakes.

Species	Adults/km ² of lake area			Pairs/km ² of lake area		
	Boreal lakes	Lake Winnipegosis	Lake Manitoba	Boreal lakes	Lake Winnipegosis	Lake Manitoba
Double-crested Cormorant	1.73	6.91	3.72	0.83	3.79	2.53
Common Tern	1.00	0.43	0.44	0.56	0.25	0.25
Herring Gull	0.64	0.25	0.19	0.41	0.12	0.10
Ring-billed Gull	2.73	4.13	4.44	–	2.10	2.06

Discussion

Most previous monitoring of colonial waterbirds in Manitoba has focused on breeding populations on lakes Winnipeg, Winnipegosis, and Manitoba (Vermeer 1970, 1973; Koonz and Rakowski 1985; Hobson *et al.* 1989; Koonz 2000). The results reported here indicate that medium-sized lakes in adjacent regions to the north also support notable populations of some species. This is particularly true for Common Terns and Herring Gulls, whose densities were about 2 and 3–4 times higher, respectively, on smaller boreal lakes than on Lake Winnipegosis and Lake Manitoba. Similar levels of abundance were previously reported for these two species on Reindeer Lake, Saskatchewan, to the northwest of the survey area (Stelfox and Brewster 1979).

Densities of Ring-billed Gulls were about 50% higher on Lake Winnipegosis and Lake Manitoba, while densities of Double-crested Cormorants were 3 to 4 times higher on the two large lakes. Double-crested Cormorants are more prevalent in the Boreal Plains ecozone and have only recently expanded their range onto lakes in the Boreal Shield ecozone of Saskatchewan (Doucette *et al.* 2010). It is unknown whether this is an original expansion or the species historically bred further north in the Boreal Shield prior to the population declines of the mid-20th century (Doucette *et al.* 2010). Lake Winnipegosis has one of the largest breeding concentrations of Double-crested Cormorants in North America, with 35 181 and 36 497 pairs in 1987 and 1999, respectively (Hobson *et al.* 1987; Koonz 2000). Numbers appear to have declined since, with only 20 149 pairs observed in 2012 (Wilson *et al.*, unpublished manuscript). Forster's Tern, recorded breeding in this survey only at Cormorant Lake, is near the northern limit of the breeding range for this species in Manitoba.

Common Terns and Herring Gulls were rarely observed outside breeding colonies, and the adult to nest ratios at colonies were generally less than 2, suggesting that the population of the two species in this region in summer is primarily composed of breeding birds. Single individuals of both species were occasionally seen in flight or on the water away from a colony but only in low numbers. In contrast, large numbers of Ring-billed Gulls were observed at sites where they were not breeding (i.e., the colonies of other species). Even at breeding colonies, the ratio of adult Ring-billed

Gulls to nests was often high: in 5 colonies on Cormorant Lake, we observed 531 adult Ring-billed Gulls but only 40 nests. A lower ratio was found on Amisk Lake, where across 6 colonies 549 adult Ring-billed Gulls and 207 nests were observed. The generally high ratio of birds to nests could have been caused by late breeding. However, this is unlikely, because during the survey even Common Terns, which typically breed later than Ring-billed Gulls (Nisbet 2002; Pollet *et al.* 2012), were at the late incubation stage. Also, the large Ring-billed Gull colony on Rocky Lake contained primarily hatched chicks, and the probability that young would have hatched at some colonies while nesting had not yet been initiated at others seems remote.

There is a chance that some of the adult Ring-billed Gulls observed may have been breeding on nearby lakes that were not included in the survey. Baird (1976) found that Ring-billed Gulls foraged an average of 10.8 km from the breeding colony with a range of 2–31 km. Although the distance from other lakes that might support breeding colonies of Ring-billed Gulls in the study region is considerably greater than 31 km, monitoring of other lakes in the region would help examine this possibility further. Another possibility is that the adult Ring-billed Gulls observed had either forgone breeding in 2011 or had attempted to breed elsewhere and then moved into the study region after their nests failed. The densities of Ring-billed Gulls on the boreal lakes was lower than on Lake Winnipegosis and Lake Manitoba, and this suggests that the boreal lakes are a peripheral breeding area. This might explain the higher ratio of non-breeders to breeders in Ring-billed Gulls than in Common Terns and Herring Gulls.

The number of breeding pairs for Common Terns and Herring Gulls increased in a sigmoidal fashion with lake area, and there were only low numbers of breeding birds on lakes <100 km², suggesting a threshold of suitability. Even three of the smaller lakes in this study, Schist Lake, First Cranberry Lake, and Second Cranberry Lake, are large by comparison to the many other water bodies in the region. Schist Lake and First Cranberry Lake did not have any colonial waterbirds, while Second Cranberry Lake had a single colony of 15 Common Tern pairs. Thus, although a much larger number of small lakes in the 0.1–25 km² range exists in this region, they are unlikely to support populations of colonial waterbirds. Further monitoring across a latitudi-

nal gradient to the north and a greater range of lake sizes would be useful to confirm the relationship between abundance and lake size for different species.

Common Terns and Herring Gulls rarely utilized the same islands for nesting, and Common Terns were more likely to nest in association with Ring-billed Gulls. Studies elsewhere have indicated that Herring Gull predation on Common Tern nests can be substantial and is notably higher at sites where Herring Gulls also breed (O'Connell and Beck 2003). Encroachment of Herring Gulls into colonies of Common Terns has resulted in the latter selecting less favourable nesting sites (O'Connell and Beck 2003) and a general decline in abundance in colonies along the Atlantic coast (Burger and Shisler 1978). Herring Gulls can also inflict heavy losses on Ring-billed Gulls at breeding colonies (Quinn *et al.* 1996).

Studies comparing the effects of Ring-billed Gulls on Common Terns are mixed. Morris and Hunter (1976) reported that interactions were infrequent between the two species in the Great Lakes, and Courtney and Blokpoel (1980) found no significant effects of Ring-billed Gulls on incubation attentiveness or breeding success of Common Terns. However, evidence of predation by Ring-billed Gulls on eggs during panic flights by Common Terns was later reported at Great Lakes colonies (Morris *et al.* 1992). It seems likely that both larid species may be at least occasional predators of Common Tern eggs or chicks, but the segregation between Common Terns and Herring Gulls on boreal lakes in Manitoba suggests that Herring Gulls may be a greater perceived threat, leading to avoidance of the same sites by Common Terns. These surveys were not designed to examine hypotheses underlying interspecific patterns of colony site selection. Further study to provide a better understanding of how all species select breeding sites, as well as the potential implications of fluctuations in the abundance of species for interspecific interactions and breeding success, would be valuable.

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Literature Cited

- Baird, P. A.** 1976. Comparative ecology of California and Ring-billed Gulls (*Larus californicus* and *L. delawarensis*). Ph.D. thesis, University of Montana, Missoula, Montana.
- Brandt, J. P.** 2009. The extent of the North American boreal zone. *Environmental Reviews* 17: 101–161.
- Burger, J., and J. Shisler.** 1978. Nest site selection and competitive interactions of Herring and Laughing Gulls in New Jersey. *Auk* 95: 252–266.
- Burnham, K. P., and D. R. Anderson.** 2002. Model selection and multi-model inference: a practical information-theoretic approach. Second edition. Springer, New York, New York.
- Courtney, P. A., and H. Blokpoel.** 1980. Behavior of Common Terns nesting near Ring-billed Gulls. *Canadian Field-Naturalist* 94: 336–338.
- Daft Logic.** 2013. Google Maps Area Calculator, Version 6. <http://www.daftlogic.com>
- Doucette, J. L., A. Bugajski, and M. Duffy.** 2010. Double-crested cormorants expand their breeding range onto the Boreal Shield in Saskatchewan. *Blue Jay* 68: 71–74.
- Google Image Landsat.** 2013. Google Earth, version 7.1.1.1888. <http://www.earth.google.com>
- Hobson, K. A., R. W. Knapton, and W. Lysack.** 1989. Population, diet and reproductive success of Double-crested Cormorants breeding on Lake Winnipegosis, Manitoba. *Waterbirds* 12: 191–197.
- Koontz, W. H., and P. W. Rakowski.** 1985. Status of colonial nesting waterbirds in southern Manitoba. *Canadian Field-Naturalist* 99: 19–29.
- Koontz, W. H.** 2000. Some bird observations in Manitoba in 1999. *Blue Jay* 58: 65–66.
- Kutner, M. H., C. J. Nachtsheim, J. Neter, and W. Li.** 2005. Applied linear statistical models, 5th edition. McGraw-Hill Companies Inc., New York, New York. 1396 pages.
- Lindenschmidt, K. E., M. Sydor, and R. W. Carson.** 2012. Modelling ice cover formation of a lake-river system with exceptionally high flows (Lake St. Martin and Dauphin River, Manitoba). *Cold Regions Science and Technology* 82: 36–48.
- Morris, R. D., and J. E. Black.** 1980. Radiotelemetry and herring gull foraging patterns. *Journal of Field Ornithology* 51: 110–118.
- Morris, R. D., and R. A. Hunter.** 1976. Factors influencing desertion of colony sites by Common Terns (*Sterna hirundo*). *Canadian Field-Naturalist* 90: 137–143.
- Morris, R. D., H. Blokpoel, and G. D. Tessier.** 1992. Management efforts for the conservation of common tern *Sterna hirundo* colonies in the Great Lakes: two case histories. *Biological Conservation* 60: 7–14.
- Morris, R. D., D. V. Weseloh, F. J. Cuthbert, C. Pekarik, L. R. Wires, and L. Harper.** 2010. Distribution and abundance of nesting common and Caspian terns on the North American Great Lakes, 1976 to 1999. *Journal of Great Lakes Research* 36: 44–56.
- Morris, R. D., D. V. Weseloh, L. R. Wires, C. Pekarik, F. J. Cuthbert, and D. J. Moore.** 2011. Population trends of Ring-billed Gulls breeding on the North American Great Lakes, 1976 to 2009. *Waterbirds* 34: 202–212.
- Nisbet, I. C.** 2002. Common Tern (*Sterna hirundo*). No. 617 in *The Birds of North America Online*. Edited by A. Poole. Cornell Lab of Ornithology, Ithaca, New York. <http://bna.birds.cornell.edu/bna/species/618>.
- O'Connell T. J., and R. A. Beck.** 2003. Gull predation limits nesting success of terns and skimmers on the Virginia barrier islands. *Journal of Field Ornithology* 74: 66–73.
- Pierotti, R. J.** 1987. Behavioral consequences of habitat selection in the Herring Gull. *Studies in Avian Biology* 10: 119–128.
- Pollet, I. L., D. Shutler, J. Chardine, and J. P. Ryder.** 2012. Ring-billed Gull (*Larus delawarensis*). Revised. No. 33 in *The Birds of North America Online*. Edited by A. Poole. Cornell Lab of Ornithology, Ithaca, New York. <http://bna.birds.cornell.edu/bna/species/033>.
- Quinn, J. S., R. D. Morris, H. Blokpoel, D. V. Weseloh, and P. J. Erwin.** 1996. Design and management of bird nesting habitat: tactics for conserving colonial waterbird biodiversity on artificial islands in Hamilton Harbour, On-

- tario. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 45–57.
- R Core Team.** 2013. R Version 3.0.1. R Foundation for Statistical Computing, Vienna, Austria.
- Schindler, D. W., R. E. Heckey, and G. K. McCullough.** 2012. The rapid eutrophication of Lake Winnipeg: greening under global change. *Journal of Great Lakes Research* 38: 6–13.
- Somers, C. M., V. A. Kjoss, F. A. Leighton, and D. Fransden.** 2010. American White Pelicans and Double-crested Cormorants in Saskatchewan: population trends over five decades. *Blue Jay* 68: 75–86.
- Stelfox, H. A., and G. J. Brewster.** 1979. Colonial-nesting Herring Gulls and Common Terns in northeastern Saskatchewan. *Canadian Field-Naturalist* 93: 132–138.
- Vermeer, K.** 1969. The present status of Double-crested Cormorant colonies in Manitoba. *Blue Jay* 27: 217–220.
- Vermeer, K.** 1970. Large colonies of Caspian Terns on Lakes Winnipeg and Winnipegosis, 1970. *Blue Jay* 28: 117–118.
- Vermeer, K.** 1973. Food habits and breeding range of Herring Gulls in the Canadian prairie provinces. *Condor* 75: 478–480.

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