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Abundance and Trends of Colonial Waterbirds on the Large Lakes of Southern Manitoba

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Abstract.—Regular surveys of waterbird colonies are needed to identify changes in abundance and distribution. Consistent surveys have been maintained in some regions, but one area where updated surveys were needed was southern Manitoba, where Lakes Winnipeg, Winnipegosis and Manitoba had not been jointly surveyed since 1979. In mid-June, 2012, an aerial survey of the region was conducted using digital photography to estimate abundance of six colonial waterbird species that are regular breeders on these lakes. Breeding by at least one of the six species was confirmed at 131 locations. Double-crested Cormorant (*Phalacrocorax auritus*) was the most abundant breeder (43,388 pairs, 47 colonies), followed by Ring-billed Gull (*Larus delawarensis*, 41,819 pairs, 67 colonies), American White Pelican (*Pelecanus erythrorhynchos*, 12,680 pairs, 20 colonies), Common Tern (*Sterna hirundo*, 7,950 pairs, 31 colonies), Herring Gull (*L. argentatus*, 4,013 pairs, 90 colonies) and Caspian Tern (*Hydroprogne caspia*, 3,207 pairs, 14 colonies). Comparisons with earlier surveys in this region suggest that all six species have increased in abundance from the 1970s when populations were still recovering from earlier threats. However, Double-crested Cormorants, Caspian Terns and Common Terns show evidence of declines since the early 1990s. Standardized surveys of colonial waterbirds on these lakes should be maintained at 10-year intervals similar to the Great Lakes Monitoring Program. *Received 10 October 2013, accepted 6 March 2014.*

Key words.—aerial census, breeding populations, colonial waterbirds, Lake Manitoba, Lake Winnipeg, Lake Winnipegosis.

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Regular monitoring of colonial waterbirds is essential for assessing population trends and documenting shifts in abundance and distribution at various scales across their breeding ranges. While consistent monitoring is maintained in some parts of North America, such as the Great Lakes (Weseloh *et al.* 1995, 2002; Morris *et al.* 2010, 2011) and the Atlantic coast (Boyne *et al.* 2006; Brinker *et al.* 2007; Thomas *et al.* 2011), other regions have been neglected, leaving data gaps that limit our knowledge of regional trends and hinder conservation assessments at national and continental scales. One area where updated monitoring information is critically needed is southern Manitoba, Canada. Lakes Winnipeg, Winnipegosis and Manitoba have historically contained substantial breeding populations of several colonial waterbird species including Double-crested Cormorant (*Phalacrocorax auritus*), American White Pelican (*Peleca-*

nus erythrorhynchos), Ring-billed Gull (*Larus delawarensis*), Herring Gull (*L. argentatus*), Caspian Tern (*Hydroprogne caspia*) and Common Tern (*Sterna hirundo*). Despite the importance of this region, the last complete survey of all three lakes took place in 1979 (Koonz and Rakowski 1985), and only local surveys have been conducted since, mainly on Lake Winnipegosis (Hobson *et al.* 1989; Koonz 2000).

Many waterbird species, including those that breed in Manitoba, suffered severe declines at various periods from the late 19th century to about the mid-20th century related to overhunting, direct persecution, habitat loss or disturbance, and DDT pollution (Hatch 1995; King and Anderson 2005; Wires and Cuthbert 2006; Morris *et al.* 2011). As a result of conservation initiatives, including the prevention of unregulated take and banning of DDT, numbers for most species have increased throughout many regions of North America since the mid-20th century (e.g., Double-crested Cormorants, Wires and Cuthbert 2006; American White Pelicans, King and Anderson 2005; Caspian Terns, Wires and Cuthbert 2000). Trends among species have been more variable in recent decades. Double-crested Cormorants and Ring-billed Gulls are abundant in many regions and they may be actively managed, particularly where they are viewed as competing with fisheries in the case of Double-crested Cormorants or where they create problems in urban areas or near airports (Wires and Cuthbert 2006; U.S. Fish and Wildlife Service 2009; Pollet *et al.* 2012). In contrast, Common Terns are declining in some regions such as the Great Lakes, prompting conservation concern (Morris *et al.* 2012). These variable patterns highlight the importance of updated survey information from key breeding areas that do not receive regular monitoring but are essential for proper assessments of regional and continental abundance and trends. To address this gap in southern Manitoba, we conducted aerial surveys of waterbird colonies on Lakes Winnipeg, Winnipegosis and Manitoba and the inter-lakes region between the three lakes in June 2012. Here, we report on the results of this survey to provide a new baseline for abundance and distribution of the six species in this region and compare our results with historic surveys to examine change in abundance over the past 4 to 6 decades on these lakes.

METHODS

Survey Area

The survey area included the southern half of Manitoba, encompassing Lake Manitoba, Lake Winnipegosis and most of Lake Winnipeg as well as several of the larger lakes in the inter-lakes region, including Kaweenakumik Lake, Lake St. Martin, Dog Lake and Shoal Lake (Fig. 1). We also surveyed the northern half of Dauphin Lake to the west of Lake Manitoba, but there were no potential breeding sites. Due to logistical reasons, our surveys did not include the western shore of Shoal Lake and parts of Lake Winnipeg, including the very south end below 51.0° N and the region to the North of approximately 52.56° N and East of approximately 97.90° W. We did not survey several large lakes to the north and northwest of this region, including Pelican, Cedar and Moose Lakes, all of which contained breeding colonial waterbirds in the 1970s (Koonz and Rakowski 1985).

The study area is primarily situated within the Boreal Plains ecozone except for portions of the eastern shore of Lake Winnipeg, which lies within the Boreal Shield. Areas of the Boreal Plain typically have a flat or gently rolling topography with fewer but larger lakes as compared to the adjacent Boreal Shield (Wilken 1986). Islands used for breeding on lakes in the Boreal Plains often have a base of sand or loose rock and frequently contain vegetation at various stages of succession. In contrast, the Boreal Shield has a more variable topography with numerous lakes that are often deeper and less nutrient rich than those in the Boreal Plains. Islands used for breeding in the Boreal Shield are typically composed of bedrock often with minimal vegetative cover.

Aerial Surveys

Aerial surveys using digital photography were conducted on 13, 15 and 16 June 2012 and were targeted to the six colonial waterbird species noted above. Aerial surveys of colonial waterbirds based on visual counts alone may be inaccurate, and the use of photography provides a more reliable means of estimating adults and nests, although some degree of bias is still expected (Dolbeer *et al.* 1997; Frederick *et al.* 2003). Surveys on Lakes Winnipeg, St. Martin, Dog, Shoal and southern Lake Manitoba (south of 50.9° N) were conducted during 11 hr of flight time on 13 June using a Bell 206 Helicopter. Surveys of Lakes Winnipegosis and Kaweenakumik and northern Lake Manitoba (north of 50.9° N) were conducted during 7 hr of flight time on 15 and 16 June using a Quest Kodiak float plane.

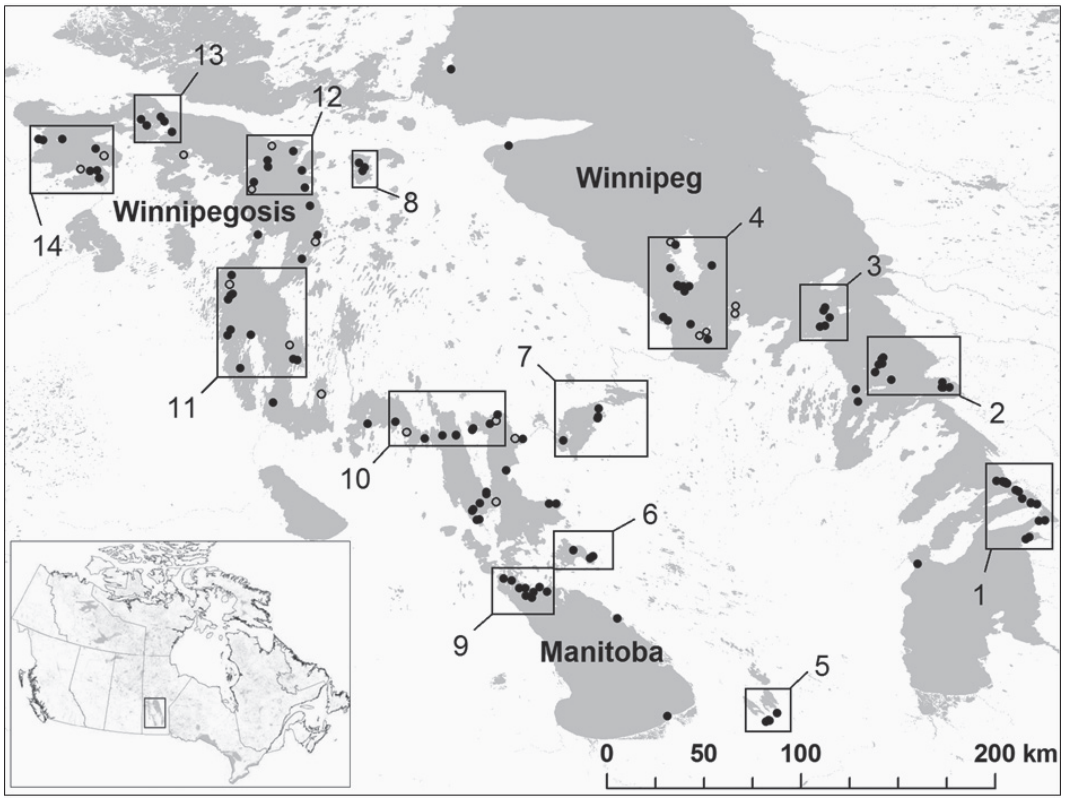

Figure 1. Location of waterbird colonies for the six focal species in southern Manitoba based on aerial surveys in mid-June 2012. Each filled circle indicates a breeding colony for at least one of the six species. Open circles are sites where one of the six species bred historically but where there was no evidence of breeding in 2012. The four lakes surveyed in the inter-lakes region include Shoal (Region 5), Dog (Region 6), St. Martin (Region 7) and Kaweenakumik (Region 8). Inset map shows the location of the survey area in Canada.

The routes covered during aerial surveys were designed to include all historic colony locations and potential new sites that contained suitable habitat for breeding colonial waterbirds. As such, our route took us directly from one site to another. Digital photos were taken of any location where one or more of the six target species was observed. Photos were taken through the rear right side window using a D700 Nikon camera and a 400 mm zoom lens with magnification adjusted as needed. We approached each colony so the photographer (SW) would have a clear view and could take a series of photos as the aircraft flew past. Flight speeds were highly variable during the helicopter survey with frequent hovering as needed to take photos. During float plane surveys, photos were taken at speeds of 135-175 kmph as the plane passed the colony. After photos were taken, we immediately checked their quality and if not sufficient for counts (blurred or poorly exposed), we made another pass of the colony. Our intent was to fly a single pass in order to minimize disturbance and a second pass was necessary in fewer than 20% of cases. We used two cameras during the float plane surveys on 15 and 16 June with the second set of photos taken as a back-up. Photos were taken in raw format and set for the highest possible resolution (usually 34.5 mexapixels per image). Two additional observers coordinated the route using GPS locations and recorded data such as time and photo numbers at each site.

Estimates of Colony and Regional Abundance

Colonial bird counts based on the photos were conducted in Adobe Photoshop CS5 (Adobe Systems, Inc. 2010). We took 2,074 photos of sites with colonial birds that were either nesting or loafing and from this base of photos we identified the best quality images for subsequent counting. The quality of each photo was determined from its resolution and its coverage of the breeding colony. We used various landmarks in photos, including rocks, woody debris, vegetation and the position of birds, to join photos of adjacent sections of the colony. We then used a drawing tool to exclude parts of one image that overlapped with a previously counted section of the colony in another photo. Once a section of the photo was identified for counting, it was split into 54 equal-image-width grid cells, each of which was counted separately and then summed for the entire

photo. In photos with a high density of birds, a single grid cell was often split into two to eight sub-grid cells.

For all grid cells in a photo, we first counted adult birds of the six focal colonial species and noted any other incidental species detected. The adult counts included non-incubating birds that were loafing along the edges of the colony or just offshore, but we did not attempt to count adults that were detected on the lakes while travelling between colony locations. We then estimated the number of nests at each colony based on counts of incubating birds (all six focal species) or nestlings in some cases (Double-crested Cormorants and American White Pelicans only). Double-crested Cormorants, Herring Gulls and Ring-billed Gulls were determined as nesting based on the presence of a nest structure and/or the posture of an incubating bird. American White Pelicans, Common Terns and Caspian Terns use only a nest scrape with occasional lining, and we determined nesting birds based on incubation posture and location within the nesting colony. The latter was most relevant for American White Pelicans and Caspian Terns, which typically nest in dense clusters. Nest counts were often difficult for Common Terns because: 1) they often flushed before we could approach close enough to take photos of incubating birds; and 2) their short legs and resting body position made it difficult to separate loafing from incubating birds. Incubating birds of the other five species rarely flushed from nests before photos were taken. Ground-based studies on these lakes in 2012 (J. M. Arnold, unpubl. data) and on small lakes to the north in 2011 (Wilson 2013) provided many opportunities to observe loafing and incubating birds from all species that aided subsequent estimation of nest abundance in photos. For every colony where we could estimate adults and nests, we calculated an adult-to-nest ratio and this was used to calculate an overall average and variance for the adult-to-nest ratio of each species weighted by colony size.

Nest counts, either direct or extrapolated from adult-to-nest ratios, were used to generate an estimate of breeding pairs at each colony. If we were unable to clearly identify incubating birds or nests in one section of a colony, we used photos from parts of the colony where we were able to generate an accurate count of nests and applied the adult-to-nest ratio to sections where we could count only adults. More frequently, we were unable to count nests for an entire colony. In those cases, we used the average adult-to-nest ratio from all colonies as an estimate of the number of nests at the colony. Difficulty in nest estimation was primarily an issue for Common Terns (we used the overall adult-to-nest ratio for 16 of 33 colonies) and was less commonly an issue for the other five species (< 20% of colonies). At the time of our surveys, some nests had hatched for Double-crested Cormorant, American White Pelican and Herring Gull. Because Double-crested Cormorants and American White Pelicans raise young that remain in the nest for 2-4 weeks after hatch, our ability to count their nests from the air was not affected. However, it was problematic for Herring Gulls because their young leave the nest soon after hatch. Because we were unable to conduct nest counts for Herring Gulls, we used the overall adult-to-nest ratio for Ring-billed Gulls as an estimate of Herring Gull breeding pair numbers.

RESULTS

Our surveys identified 131 locations within the three lakes and the inter-lakes region where at least one of the six focal species was observed breeding (Fig. 1). We estimated 113,057 breeding pairs of the six focal species at these sites. Double-crested Cormorant was the most abundant (38.4%), followed by Ring-billed Gull (37.0%), American White Pelican (11.2%), Common Tern (7.0%), Herring Gull (3.5%) and Caspian Tern (2.8%) (Table 1). Eighteen other historically-occupied sites had no evidence of breeding, but loafing birds were observed at 17 of these sites (Fig. 1).

Species Abundance and Distribution

Double-crested Cormorant. Double-crested Cormorants bred at 47 sites with 74,976 adults recorded (including loafers). From direct nest counts and extrapolation from adult-to-nest ratios at a few sites, we estimated 43,388 breeding pairs (Table 1). The median colony size across all lakes was 343 pairs. Nearly a third of all Double-crested Cormorants observed were in Dawson Bay on Lake Winnipegosis (32.4% of total abundance; Region 14 in Table 1; Fig. 1). Abundance was similar on Lakes Manitoba and Winnipeg, although the former held nearly twice as many colonies. Colonies of Double-crested Cormorants were distributed throughout Lake Manitoba with the largest numbers in the central region near the Sand Reef Islands and the Crane Narrows in the North (Regions 9 and 10, respectively, in Table 1; Fig. 1). On Lake Winnipeg, Double-crested Cormorant concentrations were highest in the St. Martin Islands (Region 4) with lower numbers along the eastern shore.

American White Pelican. American White Pelicans bred at 20 surveyed sites with 16,826 adults recorded at colonies and an additional 1,684 loafers at non-breeding sites (Table 1). Our best estimate of breeding abundance was 12,680 breeding pairs with a me-

Table 1. Estimated number of breeding pairs and colonies (in brackets) for breeding regions on Lakes Winnipeg, Winnipegosis and Manitoba and the inter-lakes area in southern Manitoba. Estimates where the region represented at least 20% of the total breeding pair abundance across the survey area are bolded. The bottom five rows indicate the totals for all colonies on each lake and the entire surveyed region. Inter-lakes refers to Shoal Lake, Dog Lake, Lake St. Martin and Kaweenakumik Lake.

Region	Lake	Double-crested Cormorant	American White Pelican	Ring-billed Gull	Herring Gull	Caspian Tern	Common Tern
1	Winnipeg	1,626 (5)	1,694 (3)	3,830 (9)	**1,309 (15)**	0	49 (3)
2	Winnipeg	1,559 (3)	1,309 (1)	2,631 (7)	531 (10)	364 (2)	**1,615 (2)**
3	Winnipeg	1,501 (1)	1,719 (1)	731 (2)	107 (3)	356 (1)	1,153 (2)
4	Winnipeg	3,758 (2)	**2,846 (3)**	2,993 (5)	377 (9)	**648 (3)**	**2,099 (5)**
5	Shoal	0	0	3,122 (2)	2 (1)	1 (1)	287 (2)
6	Dog	1 (1)	0	1,864 (3)	6 (1)	0	0
7	St. Martin	3,169 (3)	0	3,765 (2)	63 (3)	0	60 (1)
8	Kaweenakumik	663 (1)	902 (3)	548 (2)	72 (1)	0	0
9	Manitoba	3,535 (6)	481 (2)	6,436 (6)	217 (7)	**782 (1)**	988 (2)
10	Manitoba	2,747 (4)	567 (2)	2,563 (2)	128 (7)	0	30 (1)
11	Winnipegosis	2,076 (5)	508 (2)	3,374 (6)	193 (6)	407 (2)	538 (3)
12	Winnipegosis	0	0	3,198 (5)	67 (6)	260 (2)	0
13	Winnipegosis	3,841 (2)	2,373 (2)	1,123 (4)	127 (5)	389 (2)	325 (2)
14	Winnipegosis	**14,076 (2)**	0	3,858 (3)	184 (5)	0	66 (2)
	Lake Winnipeg	8,873 (11)	7,849 (9)	10,560 (26)	2,655 (38)	1,368 (6)	5,044 (15)
	Lake Manitoba	10,533 (20)	1,048 (4)	9,579 (11)	528 (21)	782 (1)	1,177 (6)
	Lake Winnipegosis	20,149 (11)	2,881 (4)	12,381 (21)	687 (25)	1,056 (6)	1,382 (8)
	Inter-lakes	3,833 (5)	902 (3)	9,299 (9)	143 (6)	1 (1)	347 (2)
	Regional	43,388 (47)	12,680 (20)	41,819 (67)	4,013 (90)	3,207 (14)	7,950 (31)

dian colony size of 376 pairs and a maximum of 2,062 pairs on North Long Island Reef in northern Lake Winnipegosis (Region 13 in Table 1; Fig. 1). Breeding abundance was highest on Lake Winnipeg (62% of pairs) with 23% and 8% of pairs on Lakes Winnipegosis and Manitoba, respectively. American White Pelicans and Double-crested Cormorants frequently nested in the same colonies with 16 of the 20 American White Pelicans colonies also containing breeding Double-crested Cormorants.

Ring-billed Gull. Ring-billed Gulls were observed breeding at 67 colonies with 76,038 adults recorded at breeding sites, and an additional 1,553 loafing birds were observed at non-breeding sites. Our total breeding abundance estimate was 41,819 breeding pairs. Numbers were equally distributed across all three lakes and the inter-lakes (Table 1) with a maximum colony size of 3,772 pairs (Region 14, Dog Island Reef, Dawson Bay, Lake Winnipegosis) and a median colony size of 301 pairs. Several sites across the survey area contained > 2,000 breeding pairs including the second largest colony on Lake St. Martin (3,075 pairs; Region 7 in Table 1; Fig. 1).

Herring Gull. We observed 7,174 Herring Gull adults at breeding sites, and an additional 141 loafers at non-breeding sites. Based on the adult-to-nest ratio observed for Ring-billed Gulls, we estimated 4,013 breeding pairs. Compared to the other five species, Herring Gull colonies were distributed across a larger number of sites (n = 90) but were smaller with a maximum colony size of 474 pairs at Pipestone Rocks, Lake Winnipeg, and a median colony size of 19 pairs. Herring Gulls were most common on Lake Winnipeg (66% of individuals), particularly along the eastern shore from Princess Harbour south to the Kasakeemeemisekak Islands (Regions 1 and 2 in Table 1; Fig. 1).

Caspian Tern. Caspian Terns were observed breeding at 14 colonies with 6,438 adults recorded, equivalent to 3,207 breeding pairs. The number of breeding Caspian Terns and colonies were similar between Lake Winnipeg and Lake Winnipegosis, while Lake Manitoba had only a single colony on the Sand Reef Islands (Region 9 in Table 1; Fig. 1). The median colony size for Caspian Terns was 198 pairs with a range from 1 to 782 pairs.

Common Tern. We observed 12,958 adult Common Terns at 31 breeding colonies and 66 individuals at non-breeding sites. Our best estimate of breeding abundance was 7,950 breeding pairs based on direct nest counts and extrapolations from adult-to-nest ratios (Table 2). The median colony size was 61 pairs (Range: 1-1,662 pairs). The distribution of Common Terns across the three lakes was similar to Herring Gulls with a greater proportion on Lake Winnipeg (64%) than Lake Manitoba (15%) or Lake Winnipegosis (17%). Four percent of Common Terns recorded were on Lake St. Martin and the Shoal Lakes in the inter-lakes region. Within Lake Winnipeg the vast majority of breeding birds were located in the central portion of the lake (Regions 2-4 in Table 1; Fig. 1), particularly on Mexico Island (1,662 pairs) in the St. Martin Island chain and the Egg Island chain approximately 80 km to the southeast (1,161 pairs).

Adult-to-Nest Ratios

Species differed in the ratio of adults to nests at colonies ranging from a low of 1.33

Table 2. Estimated ratios of adults-to-nests at breeding colonies containing at least 10 nests. Only those colonies for which adults and nests could be accurately counted across the entire colony were used. Herring Gull nests had already hatched at many sites when the survey was conducted; therefore, the adult-to-nest ratio for that species was not estimated.

Species	Mean Ratio (+ SE)	Colonies	Adults	Nests
Double-crested Cormorant	1.54 + 0.20	44	53,932	35,131
American White Pelican	1.33 + 0.07	19	15,091	11,373
Ring-billed Gull	1.81 + 0.12	45	65,045	35,917
Caspian Tern	1.73 + 0.29	10	5,050	2,921
Common Tern	1.65 + 0.10	7	1,922	1,166

adults per nest for American White Pelicans to 1.81 adults per nest for Ring-billed Gulls (excluding Herring Gull where hatching had occurred at many colonies) (Table 2). Based on these ratios, the proportion of non-incubating adults that were not in the vicinity of the colony when photos were taken would be: American White Pelican (0.67), Double-crested Cormorant (0.46), Ring-billed Gull (0.19), Caspian Tern (0.27) and Common Tern (0.35). These are minimum estimates that assume all adults recorded were members of a breeding pair without non-breeding adults present.

DISCUSSION

This survey provides the first regionwide coverage of colonial waterbird abundance and distribution on Lakes Winnipeg, Winnipegosis and Manitoba since 1979, providing a new baseline for the six species in southern Manitoba. Our regional totals should be viewed as minimum estimates because we were unable to survey the northeastern and southern regions of Lake Winnipeg. The southern region below 51° N holds few potential breeding locations and historically contained only small numbers (Koonz and Rakowksi 1985). The northeastern section also has few potential breeding sites with the exception of the George Island region and small rocky islets along the eastern shore. The George Island region historically contained large numbers of several waterbird species, including an estimated 1,800 pairs of Double-crested Cormorants and 2,400 pairs of American White Pelicans in 2004 (Canadian Wildlife Service, unpubl. data). Caspian Terns have consistently bred at this site with an estimated 900 adults (~520 pairs) in 2004, 1,500 pairs in 1986 (Manitoba Conservation Data Centre, unpubl. data) and 1,045 pairs in 1971 (Vermeer 1972). Common Terns were not observed breeding in the George Island region in 2004, but bred there previously with an estimated 700 pairs in 1970 and 1986 (Vermeer 1972; Manitoba Conservation Data Centre, unpubl. data).

Census-based counts of colonial waterbirds have several potential sources of error that need to be considered when estimating colony and regional abundance (Hutchinson 1979; Rodgers *et al.* 2005; Green *et al.* 2008). Whereas adults are easily counted in digital photos from the air, nest counts are more difficult because they require a determination of whether adults are incubating. This was primarily an issue for Common Terns as they only nest in a scrape, and it can be difficult to separate loafing and incubating birds. As a result, we often had to use the adult count combined with the average ratio of adults-to-nests across all sites to estimate pair abundance for this species. It is also possible that some nests were missed if they were under vegetation or were unattended during our survey. Cases for the latter were likely few in number because after egg-laying several species (e.g., American White Pelicans, Caspian Terns) attend nests almost continuously (Penland 1976; Knopf and Evans 2004), while others only leave nests unattended for short periods (e.g., 2% of the time for Herring Gulls (Drent 1970) and 1-6% for Ring-billed Gulls (Chardine and Morris 1983)).

If we failed to detect some colonies, we expect that they were most likely to have been of Common Terns and Herring Gulls. Both species nest in smaller colonies (e.g., see median colony sizes above), particularly along the eastern shore of Lake Winnipeg where there are numerous rocky islets. However, the number of missed breeding pairs is likely small relative to the total number we recorded across the region. Another potential source of error is whether all Common and Caspian terns had commenced breeding by 13 June when our surveys started. Vermeer (1972) reported that peak clutch initiation for Common Terns was 8-14 June, while for Caspian Terns it was more prolonged, lasting from 8 June to 28 June. For both species, egg-laying begins about 2 to 3 weeks after arrival (Cuthbert and Wires 1999; Nisbet 2002), and thus all breeding birds were likely visiting the colony by mid-June but some individuals may not have initiated nesting.

Reliably comparing abundance and distribution between surveys depends critically on any differences in methodology or data

quality. Monitoring of colonial waterbirds in southern Manitoba has included surveys of nests conducted on the ground (e.g., Vermeer 1970a, 1970b; Hobson *et al.* 1989; Koonz 2000), mixed aerial visual counts and ground nest counts (Koonz and Rakowski 1985) and aerial surveys with digital photography. Ground counts typically have low error (4-22%; Hutchinson 1979; Erwin 1980) and are usually based on nests, thus providing a more direct link to the number of breeding pairs at a colony. Adult counts are reliable from the air, but estimates of nests or incubating adults are less accurate, yielding estimates that differ from ground counts by up to 35% or more (Kadlec and Drury 1968; Morris *et al.* 2012). Both overestimation (Green *et al.* 2008) and underestimation (Rodgers *et al.* 2005) of colony size have been reported for visual counts from fixed-wing aircraft (Erwin 1982; Rodgers *et al.* 2005). The use of digital photography improves the accuracy of aerial counts, and Dolbeer *et al.* (1997) showed that aerial photos of Laughing Gull (*L. atricilla*) nests differed from the ground nest count by -9% to 1% (see also Frederick *et al.* 2003).

While acknowledging the potential bias in estimates of colonial bird abundance from different methods, it is still valuable to consider our results in comparison with past surveys. The extent of past coverage differs among species and lakes. The only estimates of abundance for all three lakes within a short period of 1-3 years occurred around 1970 (Vermeer 1969, 1970a, 1970b, 1972), in 1979 (Koonz and Rakowski 1985) and for our survey in 2012. A survey of Lake Winnipegosis for all species was conducted in 1999 (Koonz 2000), while monitoring specifically for Double-crested Cormorants occurred in 1945, 1950, 1951 (McLeod and Bondar 1953) and 1987 (Hobson *et al.* 1989). Thus, for Double-crested Cormorants, we have a 68-year time series on one of the most important breeding lakes for this species in North America. Those results for Lake Winnipegosis show an initial decline between 1945 (9,862 pairs; McLeod and Bondar 1953) and 1969 (1,602 pairs; Vermeer 1969) followed by a rapid increase to 35,181 pairs in 1987 (Hobson *et al.* 1989) and 36,497 pairs in 1999 (Koonz 2000). Our results suggest a decline from 1999 to 2012 when only 20,149 pairs were recorded. The extent to which this decline is due to a decrease in the demographic rates vs. a shift in distribution among lakes is not clear. The abundance across all three lakes in 1979 was 17,495 pairs (Koonz and Rakowski 1985) compared to 39,555 pairs in 2012 (both estimates after excluding abundance in the inter-lakes region).

On Lake Winnipegosis, Double-crested Cormorants have also shown a shift toward a greater concentration of breeders at fewer sites since the surveys in the late 1980s and 1990s. Hobson *et al.* (1989) reported 37 colonies with a median colony size of 543 pairs and a maximum colony size of 3,509 pairs. Koonz (2000) reported 35 colonies with a median size of 143 pairs and a maximum of 8,032 pairs. Our survey located only 11 colonies with a median size of 307 pairs and a maximum of 13,864 pairs. Indeed, 68.8% of Lake Winnipegosis pairs are now breeding on one island in Dawson Bay and such a high concentration at a single site is a concern given past cases of cormorant persecution in this region of Lake Winnipegosis (Hobson *et al.* 1989).

Comparisons of past and current abundance for the other five species are less clear, but two patterns are apparent. First, there has been a general increase in abundance for most species from the 1970s to the present. American White Pelican numbers increased rapidly from 4,449 pairs in 1969 (Vermeer 1970a) to 10,501 pairs in 1979 (Koonz and Rakowski 1985) with a slower but sustained growth to at least 12,680 pairs in 2012. This increasing trend for American White Pelicans in southern Manitoba is consistent with the general pattern for the species across North America over the same period (King and Anderson 2005). Concern has been raised over the effects of West Nile Virus at several large colonies of American White Pelicans in the northern Great Plains south of our survey area (Sovada *et al.* 2008), and potential impacts of West Nile Virus for this species and others should be evaluated further at colonies in southern Manitoba.

Comparisons of 2012 survey numbers with those from the 1979 survey of the same region by Koonz and Rakowski (1985) also show an increase in abundance for Ring-billed Gulls, Herring Gulls, Caspian Terns and Common Terns. The range and abundance of Ring-billed Gulls and Caspian Terns have expanded in many areas of North America since the mid-20th century (Wires and Cuthbert 2000; Suryan *et al.* 2004; Pollet *et al.* 2012), while Herring Gull and Common Tern abundance has been more variable (Pierotti and Good 1994; Nisbet 2002). The range of Herring Gulls has expanded south along the USA east coast (Andrews 1990), while declines have been observed at some sites further north (Hebert 1989). On the Great Lakes, Herring Gull abundance increased from the late 1970s to the late 1980s and then declined to the late 1990s (Morris *et al.* 2003). Common Tern numbers have generally increased since the 1970s (Nisbet 2002), but with recent declines in the Canadian portion of the Great Lakes (Morris *et al.* 2012) and the mid-Atlantic coast (Brinker *et al.* 2007). Herring Gulls and Common Terns are also common breeders across the boreal forest where survey coverage is limiting (Stelfox and Brewster 1979; Pierotti and Good 1994; Nisbet 2002; Wilson 2013), and it is not clear how their abundance or distribution has changed across this portion of their range.

A second pattern of abundance that needs further study is an apparent decline for Caspian Terns, Common Terns and Double-crested Cormorants in southern Manitoba since the 1990s. While Caspian Terns have generally increased since about 1970, colony summaries from the early 1990s estimated 8,780-9,980 pairs breeding in southern Manitoba (Wires and Cuthbert 2000), whereas our total estimate was only 3,207 pairs. Common Tern numbers also appear to have peaked in the early 1990s at between 15,140 and 19,997 pairs not including Lake Winnipegosis (Manitoba Conservation, unpubl. data), although higher numbers have been reported (Morris *et al.* 2012). Common Tern abundance then decreased to the nearly 6,568 pairs estimated in 2012 in the same region, a 57-67% decline in 20 years. This trend is considerably more rapid than that observed for Common Terns in the Canadian Great Lakes (-41%, 1976-2009) where declines are of conservation concern (Morris *et al.* 2010, 2012) and suggest a need to revise the conclusions in Morris *et al.* (2012) regarding listing of this species only in Ontario.

Apparent declines for Caspian Terns, Common Terns and Double-crested Cormorants may be influenced by a shift in distribution, and different survey methodologies add to uncertainty in the extent of population change over time. However, for all three species, a drop in abundance of this magnitude over a large spatial scale since the 1990s is concerning and needs further consideration and study. Potential threats to colonial waterbirds exist on Lakes Winnipeg, Winnipegosis and Manitoba. The perception that waterbirds adversely affect fish populations can result in persecution from local fisherman. This is a well-known issue affecting populations of Double-crested Cormorants throughout North America (Weseloh *et al.* 1995; Wires and Cuthbert 2006; Doucette *et al.* 2011), and the persecution of Double-crested Cormorants and Caspian Terns has been observed previously on Lake Winnipegosis (Koonz 1982; Hobson *et al.* 1989). Persecution of Double-crested Cormorants at breeding colonies may also adversely affect other colonial waterbird species breeding at those sites. Flooding of breeding colonies during years of high water may have caused recent population declines. The floods of 2011 were the most serious in recent years, but high water years also occurred in 1997 and 2006. The extent to which flooding results in demographic declines vs. temporary movement to non-flooded areas is unknown and may depend on the frequency of flood events and the availability of alternate sites. A third potential impact on colonial waterbirds is eutrophication, which has been particularly severe on Lake Winnipeg since the mid-1990s (Schindler *et al.* 2012). An increase in livestock waste and synthetic fertilizer application have contributed to a substantially higher nutrient input

into the lake, leading to regular blooms of Cyanobacteria (Schindler *et al.* 2012; Yates *et al.* 2012). Alterations in aquatic community structure often result from eutrophication and can lead to further changes to the ecosystem (Schindler 2006), but the effects of eutrophication on the productivity of colonial waterbirds on Lake Winnipeg has yet to be studied. It is also possible that declines may be related to threats to colonial waterbirds outside of the breeding season (Wetlands International 2010).

Southern Manitoba is a critical breeding area for colonial waterbirds. The intermittent survey coverage of this region since the 1970s has hindered our knowledge of continental trends in abundance and distribution, as noted in several previous assessments (King and Anderson 2005; Wires and Cuthbert 2006; Morris *et al.* 2012). This survey provides a new baseline for abundance and distribution in southern Manitoba, but regular surveys using consistent methodologies need to be maintained in the future. We recommend the continuation of surveys at 10-year intervals as done by Environment Canada and the U.S. Fish and Wildlife Service to monitor colonial -waterbird abundance on the Great Lakes of central Canada and the United States (Weseloh *et al.* 2002; Morris *et al.* 2011).

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