Seal River Estuary & Knife River Delta:

Report on 2013-15 Waterfowl Surveys

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Ducks Unlimited Canada
Conserving Canada's Wetlands

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Executive Summary
In 1990, the Government of Manitoba committed to conserving the suite of ecosystems and biodiversity found within the province. Since making that commitment, the areas protected within the province have increased 20-fold to 7.1 million hectares. Canada's Target 1 is a commitment to the United Nations Convention on Biodiversity to protect 17% of Canada's land and freshwater by 2020. Approximately 11% of Manitoba is currently protected.

The Government of Manitoba established the Protected Areas Initiative (PAI) to support conservation planning in the province. The PAI used an enduring features analysis to identify landscapes that represented the unique ecological characteristics of each of the province's 18 natural regions and sub-regions. Representative landscapes not adequately protected in the current network of protected areas were identified as Areas of Special Interest (ASI) for future protection.

The Seal River Estuary, which is located in the Southern Arctic Ecozone approximately 30 km northwest of Churchill, was identified as a priority Area of Special Interest for future protection. The purpose of this study was to ensure the proposed protected area boundary included the most valuable habitat for waterfowl and other water birds. During 2013 to 2015 we performed aerial breeding surveys across approximately 77,000 km^2 of boreal, tundra and coastal landscapes of northern Manitoba. We detected an estimated 22,617 breeding birds representing 24 species. The majority of birds were geese (57%) followed by diving ducks (27%) and dabbling ducks (14%). Black Scoter, a species of conservation concern, was the most abundant duck recorded during the breeding period. We also performed two rounds of coastal surveys between Churchill, MB, and the Manitoba-Nunavut border during the moult and fall migration periods. Black Scoter was the most abundant waterfowl species recorded during moult and Common Goldeneye was the most common species during migration.

In general, the abundance and diversity of waterfowl in the Seal River region was higher than that recorded in the surrounding Eastern Prairie Population Canada goose study area. This region also supported densities of waterfowl that were comparable to many regions of the continent considered important for waterfowl. As well, the high diversity of waterfowl species was comparable to the most diverse survey strata on the continent. Finally, the region supported several species outside of their predicted range and continentally significant densities of Black Scoters, a species considered near threatened by the IUCN. However, areas of highest regional importance to waterfowl were outside the currently proposed protected area boundary, located nearby in the Knife River Delta and the inland portion of the Seal River. The coastal waters that encompass the Seal, Knife and Caribou River estuaries were also identified as being relatively important for moulting and migrating waterfowl. We recommend the proposed protected area be expanded to include adjacent Knife River Delta and Seal River uplands. Expanding the proposed boundary to include these adjacent terrestrial and marine areas would greatly improve the value of the protected area for waterfowl populations. The Seal River ASI is roughly 56,000 hectares and represents an excellent opportunity for the Government of Manitoba to expand their network of protected areas.

Introduction to Manitoba's Protected Areas Initiative

In 1990, Manitoba became the first jurisdiction in Canada committed to conserving the suite of ecosystems and biodiversity found within the province (Manitoba Conservation and Water Stewardship, Protected Areas Initiative 2003). To achieve this goal the province established the Protected Areas Initiative to identify and permanently protect landscapes that represent the unique ecological characteristics of each of the province's 18 natural regions and sub-regions. Protected areas include terrestrial, freshwater, and marine sites where potentially destructive industrial development is prohibited.

Manitoba used an enduring features analysis to identify representative landscapes for protection. An enduring features analysis is a scientific process rooted in sound ecological principles of representation and integrity and is based on scientific data, and local and Indigenous traditional knowledge (Manitoba Conservation and Water Stewardship, Protected Areas Initiative 2003). Landscapes were defined based on soils and landforms. These characteristics determine, to varying extents, the biological diversity a landscape can support. Unlike biological diversity, which is difficult to quantify and subject to change over time in response to ecological process and natural and anthropogenic disturbance, soils and landforms are stable through time (i.e., enduring features) and are well suited to a protected area conservation strategy. Representative landscapes are those that have enduring features characteristic of their natural region and are considered to have ecological integrity (i.e., are self-sustaining). Representative landscapes within a natural region also represent the proportional and spatial arrangement of landscapes within that region and are spatially separate to capture the region's genetic diversity. Representative landscapes not adequately protected in the current network of protected areas where identified as Areas of Special Interest for future protection.

Since the program began, protected areas in Manitoba have increased 20-fold to 7.1 million ha or approximately 11% of the province (https://www.gov.mb.ca/sd/parks/education-and-interpretation/protected_areas/index.html). Canada's Target 1 is a commitment to the United Nations Convention on Biodiversity to protect 17% of Canada's land and freshwater by 2020 (www.cbd.int). The Seal River ASI is roughly 56,000 hectares and represents an excellent opportunity for the Government of Manitoba to expand their network of protected areas.

Seal River Estuary Area of Special Interest

The enduring features analysis identified the Seal River Estuary to be an Area of Special Interest for future protection. The estuary is located in the Southern Arctic Ecozone approximately 30 km northwest of Churchill, Manitoba (Figure 1). The Seal River is one of Canada's most pristine rivers and the largest remaining undeveloped river in Manitoba (Manitoba Conservation and Water Stewardship, Parks and Protected Spaces Branch 2014). It was designated to the Canadian Heritage River System (CHRS) in 1992 and the estuary was designated an Important Bird Area (IBA) in 1999 (Figure 1; www.ibacanada.ca). The Seal River and surrounding area are rich in biodiversity that includes polar bear, barren ground caribou, moose, seal, and large concentrations of shorebirds, waterfowl and other water birds (Manitoba Conservation and Water Stewardship, Parks and Protected Spaces Branch 2014). The Seal River Estuary is also an important calving and feeding ground for thousands of beluga whale, which are part of the largest concentration of beluga in the world (Manitoba Conservation and Water Stewardship, Parks, and Protected Species Branch 2014). In 2016, the Government of Manitoba produced a beluga habitat management plan to provide long term protection for this vital resource (Manitoba Western Hudson Bay Ad Hoc Beluga Habitat Sustainability Plan Committee 2016). Other values associated with this region include the largest drumlin field in Manitoba, 28 species of plants that are rare to Manitoba, world class recreational opportunities and ecotourism destination, and a rich Indigenous history (Manitoba Conservation and Water Stewardship, Parks and Protected Spaces Branch 2014).

Current threats to the Seal River and surrounding area are few. The region is remote and sees limited amounts of mineral exploration or tourism, neither of which are currently considered to pose a threat to the regions natural, cultural, or recreation values. However, development in the region is expected to increase, including the potential for an all-weather road that has been investigated which would open up this area to a variety of activities (Manitoba Conservation and Water Stewardship, Parks and Protected Spaces Branch 2014). Neither the CHRS nor an IBA designation provide long-term protection.

Proposed Study

In recognition of the ecological value of the Seal River Estuary and to ensure the boundaries of the proposed protected area capture the most important habitat in the region for waterfowl and water birds, Ducks Unlimited Canada and Oceans North Canada in cooperation with the Government of Manitoba conducted aerial surveys in 2013 to 2015. The survey area included the Seal River Estuary and Knife River Delta (located approximately 15 km south of the estuary), and the adjacent nearshore marine waters. The Knife River Delta was reported by biologists with the Government of Manitoba to support a large diversity and abundance of waterfowl and shorebirds, as well as other wildlife, notably as a winter range for moose. Wetland densities are also comparable to or exceed that of the Seal River. Our goals were to quantify the diversity and abundance of waterfowl in the region to support designation of the Seal River Estuary as a protected area and, if warranted, promote expansion of the boundary to include the adjacent upstream area, Knife River delta and adjoining marine waters.

Project Area

***Breeding Surveys* -** All surveys were performed in Manitoba on the inland, coastal, and nearshore marine habitats adjacent to Hudson Bay. The Eastern Prairie Population (EPP) of Canada geese have been surveyed in this region since 1972 and a detailed description of the area is provided by Malecki et al. (1981). The Seal River (SEA) project area included five survey strata that encompass the Seal River Estuary Important Bird Area, the Seal River Estuary Area of Special Interest, and the Knife River Delta (Strata 10-14, Figure 2). Our goal was to estimate intra-annual variation in abundance between locations (i.e., status) rather than inter-annual variation within a location (i.e., trend). Therefore, unique strata and transects were established during each of the three years of breeding surveys to increase spatial coverage. Strata 10-12 were established in 2013 to represent three regional differences in available habitat based on a visual assessment of satellite imagery and past experience of Government of Manitoba biologists. Stratum 10 was located within the Seal River Estuary, stratum 11 was immediately upriver and south of stratum 10, established to sample an inland region with high density of ponds, and stratum 12 was located in the Knife River Delta. Stratum 13 was established in 2014 to capture a greater spatial extent of the area and encompassed strata 10-12. Stratum 14 was established in 2015 to encompass strata 10 to 13 and include a 10 km strip of adjacent nearshore marine waters. Transects were systematically located in each SEA stratum to proportionally sample available habitats of each stratum. Strata ranged in size from 168 km^2 (stratum 11) to 4,916 km^2 (stratum 14). The length of transects ranged from six kilometers (stratum 12) to 56 kilometers (stratum 13; Figure 1). Surveys covered approximately four percent of stratum 14, seven percent of strata 12 and 13 and eight percent of strata 10 and 11 (Table 1).

Data from the SEA breeding surveys were compared to 1) regional data from the 2013 to 2015 EPP surveys, which encompassed the SEA survey areas, 2) continental data from the 2013 to 2015 Waterfowl Breeding Population and Habitat Surveys (WBPHS; commonly referred to as the BPOP or May surveys), and 3) data from the experimental High Arctic Surveys (2005 – 2011). The EPP project area consisted of six survey strata ranging from approximately 4,400 km^2 (stratum 4) to 21,000 km^2 (stratum 1; Figure 3). Transects were randomly placed in each stratum. The number and length of transects vary among strata, ranging from 3 to 8 and 23 km to 140 km, respectively (Maleki et al 1981). Approximately five percent of stratum four, two percent of stratum 5, and 1 percent of the remaining strata were surveyed annually (Table 1). The WBPHS program included 52 strata distributed across prairie, boreal and tundra habitats (United States Fish and Wildlife Service and Canadian Wildlife Service 1987, Smith 1995, Figure 3). Each stratum contained 1 to 18 transects (6.4 ± 0.4 [1 SE, Poisson distribution]) ranging in length from 13 km to 903 km. The High Arctic program included 23 strata. A longer time period was included for this program because not all strata were sampled in all years (revisit frequency ranged from 1 to 4; average = 2.5 visits/stratum).

Moult and Fall Migration Surveys - In addition to the breeding strata (above), a coastal stratum was established in 2015 to survey mid to late summer moulting and migrating waterfowl using marine habitats within 10 km of the high tide mark between Churchill and the Manitoba-Nunavut border. The area north of Churchill had not previously been surveyed for moulting or migrating waterfowl. However, scoters and Long-tailed Duck are known to migrate though this region (SDJV 2015) and large concentrations of moulting Black Scoters (*Melanitta americana*) have been recorded in nearby nearshore marine areas of Hudson Bay (Badzinski et al. 2013). A total of 52 transects and 433 km were surveyed during each round with higher densities of transects established in the estuaries of the Caribou, Seal and Knife Rivers (Figure 4).

Aerial Survey Methods

Breeding Surveys – Breeding surveys were timed to be completed near the average mid-incubation point of Canada goose nests in the northern part of the EPP range (Malecki 1971). This date varied based on spring phenology and was estimated annually using egg floatation data from a sample of nests near Churchill, MB. Spring phenology in 2013 was near average in both study areas, with mean May temperatures in Churchill almost 1 °C warmer than the 1970-2012 long term average. Median hatch date in 2013 was estimated as 19 June. EPP surveys were flown 5-8 June, 2013, and SEA surveys were flown 6 and 8 June, 2013. Despite a relatively late spring in southern MB in 2014, mean May temperatures in Churchill were above 2013 and the long term average and spring phenology was near average. Median hatch date in 2014 was estimated as 16 June. Sleet and snow interrupted survey efforts for three days. EPP surveys were flown 3-4 and 9-10 June, 2014, and SEA surveys were flown 8 and 11 June, 2014. Mean May temperature in Churchill in 2015 was similar to 2014 but nearly 2 °C above the long term average. Median hatch date was estimated as 14 June. EPP transects were flown between 31 May and 1 June and 4 to 6 June, and SEA transects were flown on 3 June. EPP transects were sampled sequentially from south to north and SEA transects were ordered based on logistical considerations. All surveys were flown during excellent conditions to maximize visibility (clear skies or intermittent scattered cloud cover).

Breeding surveys were flown with a Partenavia P68 Observer aircraft at speeds of 140-165 km/h, and at altitudes of 100-150 feet above ground level. The front left seat pilot-observer and the front right seat observer were experienced aerial waterfowl survey biologists. Observations were recorded on voice-activated recording systems equipped with automated coordinate loggers. Observations of species, numbers, and forms of aggregation (i.e., single, pair, flocked drakes, groups) were recorded up to 200 m on either side of the aircraft (total transect width = 400 m). Singles were defined as isolated drakes without a visible associated hen. A drake with a hen was defined as a pair. Flocked drakes were defined as 2-4 drakes in close association. Groups were defined as 5 or more flocked drakes or 3 or more birds in a mixed-sex grouping (of the same species) in close association that could not be separated into singles and pairs. Observers communicated regularly to avoid double counting birds that rose near or crossed the transect center line.

Moult and Migration Surveys – Survey timing was derived from the literature to coincide with peak moult and migration periods (Badzinski et al. 2013, SDJV 2015). Moult surveys were flown on 12 August 2015, and migration surveys were flown on 2 September 2015. Each survey was initiated two hours prior to high tide such that the survey midpoint roughly coincided with high tide. Both surveys were flown from north to south using a Britten-Norman Islander aircraft at speeds of 140-165 km/h, and at altitudes of 100-150 feet above ground level. A single trained observer recorded total number of ducks of each species within 200 m of the right side of the aircraft. Observations were recorded on a handheld recorder. A back seat observer, also on the right side of the aircraft, confirmed species identities, recorded birds missed by the front seat observer, and logged coordinates of each detection using a hand held GPS. Observation and positional information were later reconciled based on time stamps.

Statistical Methods:

Correcting for imperfect detection – Bird behaviour and habitat factors prevent observers from detecting all individuals that are present during a survey. Methods established by the United States Fish and Wildlife Service and Canadian Wildlife Service (1987) for breeding waterfowl surveys were used to correct for imperfect detection due to bird behavior by converting raw count data (RAW) from breeding surveys to numbers of total indicated birds (TIB) and numbers of indicated breeding pairs (IBP) using the following equations:

All species except Ring-necked Duck, scaup, Sandhill Crane, and swans:

$$TIB = (\#\ pairs \times 2) + (group\ size \times 1) + (\#\ single\ hens \times 2) + (\#\ single\ drakes \times 2) + (\#\ flocked\ drakes < 5 \times 2) + (\#\ flocked\ drakes \geq 5 \times 1)$$

IBP = (# pairs × 1) + (group size × 0) + (# single hens × 1) + (# single drakes × 1) + (# flocked drakes <5 × 1) + (# flocked drakes ≥5 × 0)

Ring-necked Duck, scaup species, Sandhill Crane, and swan species:

TIB = (# pairs × 2) + (group size × 1) + (# single hens × 1) + (# single drakes × 1) + (# flocked drakes × 1)

IBP = (# pairs × 1) + (group size × 0) + (# single hens × 0) + (# single drakes × 0) + (# flocked drakes × 0)

Visibility correction factors (VCF) are commonly applied to TIB and IBP values to account for less than perfect detection due to habitat or other regional factors. Correction factors were not estimated for this study area. Instead correction values were obtained from 2013 Waterfowl Breeding Population and Habitat Surveys in adjacent strata 24, or from 'bush units' provided by the United States Fish and Wildlife Service and Canadian Wildlife Service (1987). For species without a correction factor VCF = 1. These out-of-sample correction factors may not accurately account for imperfect detection in this study and were used to calculate VCF-corrected RAW, TIB and IBP values to enable comparisons of densities with other waterfowl surveys. For breeding birds, we refer to total indicated birds (TIB) throughout unless explicitly stated otherwise. Observations from the moult and migration surveys were not corrected. Instead, we refer to RAW values for these two periods.

Density – RAW, TIB and IBP density estimates (per km^2) were calculated at the transect level for each species, group (duck, goose, swan, loon and crane), and duck foraging guild (dabbler and diver) by dividing the number of birds in the respective category by transect area (length × width). Transect-level density estimates were used to calculate average (± 1 SD) estimates of density.

Transect-level density estimates were compared using mixed-effects maximum likelihood regression models. Comparisons were made between years, project areas, and strata (independent variables). Year was not a variable of interest but was included as a fixed effect in all models to control for inter-annual differences in abundance. Transect (strata model) or transect nested within stratum (year and project area models) were included as random effects to account for the lack of spatial and temporal independence in the data. Density estimates were transformed [ln(TIB + 1)] prior to analysis to meet the assumption of normally distributed residuals.

Diversity – Diversity was calculated as the average number of waterfowl species (ducks, geese, swans) per stratum (i.e., species diversity). We used a rarefaction process to account for unequal sampling effort among strata. This process draws 100 samples of 75 individuals randomly selected without replacement per combination of stratum and year. The number of species per sample are tallied and averaged as a measure of diversity.

Breeding Results

Sampling effort –Total area sampled in SEA survey areas increased four-fold over the course of the study as the length of transect flown increased from 111 km in 2013 to 434 km in 2014 and 480 km in 2015 (Table 1). Total area sampled in the EPP survey areas was similar across years with the exception of area sampled for geese in 2013 (Table 1). Voice-recorded observations were the methodological standard in this study. In 2013, geese on the EPP strata were voice recorded only by the pilot observer. The area sampled for geese in 2013 was, therefore, calculated based on a half-transect width (i.e., 200 m). All other observations were voice-recorded by both the pilot and front seat observers. Data were not recorded on three EPP transects in 2014 (16, 17 and 1617) because of technical problems.

Abundance – Twenty-four species were recorded during three years of breeding surveys (Table 2). Swan and goldeneye were not identified to species in the field but are assumed to include only Tundra Swan and Common Goldeneye, respectively, based on range maps. An additional four groups of species could not always be identified to species in the field and so were grouped into generic categories when uncertain (unknown scaup [UNSC], unknown scoter [USCT], unknown duck [UNDU], and unknown loon [UNLO]; Table 2). UNDU were not assigned to a foraging guild and were excluded from guild-level analyses.

More than 15,000 individuals (∑Raw), or an estimated 22,617 birds (∑TIB), were recorded during three years of breeding surveys (Table 2). Most birds were recorded as singles (Figure 5). Geese represented 57% of ∑TIB (Table 2). Canada Geese were the most abundant species and were more than twice as abundant as the next most abundant Lesser Snow Goose. Ducks represented 41% of ∑TIB. The majority of ducks were divers (66% of ∑TIB-ducks; 12 of 20 species; Table 2). Black Scoter were the most abundant duck species, comprising 23% of ∑TIB for ducks. Significant numbers of scaup and Northern Pintail were also recorded. The remaining 2% of ∑TIB were swans, loons, and cranes in decreasing order of prevalence (Table 2). Average total bird density per transect did not differ between years (df = 2, $\chi^2 = 4.13$, $P = 0.127$). However, 13 species did have statistically different TIB densities between years (Table 3).

Spatial variation – Controlling for the effects of year, average total bird density per transect did not differ between study areas (EPP: 8.4 ± 9.6; SEA: 12.0 ± 10.8; $P = 0.085$). While the majority of species (18 of 27) tended to be more abundant on the SEA study area, only 8 species had significantly different densities between areas (Figure 6; Table 4). At the guild level, the densities of both diving ducks (EPP: 1.4 ± 1.1; SEA: 4.8 ± 8.7; $P = 0.003$) and dabbling ducks (EPP: 0.9 ± 0.6; SEA: 2.7 ± 3.2; $P = 0.006$) were significantly higher in the SEA study area (Figure 6, 7; Table 5). Average density of geese, loons, swans and cranes per transect did not differ significantly between study areas (all $P > 0.23$).

The highest density of all birds combined was recorded on SEA stratum 12, the Knife River Delta (Table 6). Densities in strata 4 and 11 were not statistically different from stratum 12 (both $P > 0.30$). The high average density in stratum 4 reflected the large numbers of geese in this coastal region, principally Lesser Snow Geese. The densities of dabbling ducks and of all ducks combined was significantly higher on strata 11 and 12 ($P < 0.03$ for all other strata; Figure 8, Table 6). The highest densities of diving ducks were recorded in stratum 11, south of the Seal River Estuary (Figure 8, Table 6). All EPP strata had significantly fewer diving ducks (all $P < 0.05$) with the exception of stratum 1 (Figure 8, Table 6).

From a continental perspective, the average transect-level density of all waterfowl in the SEA study area was moderately high relative and comparable to many other regions considered important for waterfowl (Figure 9). This relative importance of the SEA region was largely explained by the density of geese (Figure 10) rather than the density of ducks (Figure 11). Note, Snow Geese were excluded from the goose density calculation because of their colonial nature.

Their inclusion would further increase the relative importance of northern strata for geese. Sea duck density in the SEA region was amongst the highest recorded in the continent (Figure 12) owing in large part to the number of Black Scoter in western Hudson Bay. The density of Northern Pintail, which was the second most abundant duck in this study, also was moderately high in the SEA region compared to other areas of the continent (Figure 13). The average number of waterfowl species recorded on SEA strata ranged between 10 and 12. Most SEA strata, particularly strata 11 and 12 (Seal River Estuary and Knife River Delta), had waterfowl diversity estimates comparable to the most diverse strata on the continent and higher than the diversity recorded on the EPP strata (Figure 14).

Moult and Migration Results

Diversity and abundance – Fewer species and fewer numbers of birds were recorded during the moult period (19 and 2,826, respectively) than during the migration period (21 and 3,340, respectively). The majority of birds in both periods were ducks (81% and 63% during moult and migration, respectively), and the majority of these were diving ducks (63% and 50% during moult and migration, respectively). A greater diversity of dabbling ducks was recorded during the moult period (5 species) than during migration (2 species), but the total number of birds from this guild was <7% of the total birds encountered during either period. Black Scoter were the most abundant species recorded during the moult survey (39% of all birds) whereas Common Goldeneye were the most abundant species recorded during migration (23%; Figure 15). Significant numbers of Canada Geese (19%) and unknown ducks (14%) also were recorded during both survey periods.

Spatial variation – Despite variation in prevalence of the constituent species between the moult and migration surveys, the spatial distribution of individuals was seemingly less variable. During moult most waterfowl were recorded in the middle portion of the survey area between the Caribou River and the north branch of the Knife River (Figure 16). Anecdotally, the majority of detections were within 1 to 2 km of the coast as opposed to being further offshore. During migration the majority of birds were further concentrated near the Seal River estuary and the estuary of the south branch of the Knife River, whereas fewer birds were recorded near the Caribou River estuary and in the waters between estuaries (Figure 16).

Discussion

The purpose of this field study was to support the Government of Manitoba’s initiative to establish a protected area in the vicinity of the Seal River Estuary by ensuring the proposed protected area boundary included the most valuable waterfowl and water bird habitat in the region. We found the Seal-Knife (SEA) study area supported a high diversity waterfowl that was comparable to the most diverse survey strata on the continent. The SEA also supported high densities of waterfowl that were comparable to many regions of the continent considered important for waterfowl. Most species occurred at higher densities on SEA strata compared to EPP strata, but the majority of differences were not statistically significant. However, at the guild level, both diving and dabbling ducks were present at significantly higher densities on SEA strata compared to EPP strata. These results are consistent the general impressions of the observer pilots that the diversity and abundance of waterfowl in the Seal-Knife region is noticeably greater than what is typically encountered on other boreal and Alaska strata (Frank Baldwin, personal communication).

Those SEA strata with the highest densities and diversity of breeding waterfowl species were outside the currently proposed protected area boundary in the Knife River Delta (stratum 12) and the inland portion of the Seal River (stratum 11). The coastal waters that encompass the Seal, Knife and Caribou River estuaries also support relatively large numbers of waterfowl during the moult and migration periods. The repeated use of the same areas during moult and migration by different species suggests the presence of one or more preferred resources (e.g., forage or safe resting habitat). Expanding the proposed boundary to include the Knife River Delta, a greater portion of the lower Seal River, and the adjacent coastal waters would greatly improve the value of the protected area for waterfowl populations.

The Seal-Knife region supports continentally significant densities of Black Scoter (BLSC), a species of conservation concern that is considered Near Threatened (IUCN 2017). Until recently, the breeding distribution of BLSC was poorly understood. Satellite telemetry studies and targeted surveys reveal breeding individuals distributed across northern Quebec, northwestern Ontario, northern Manitoba, and central Northwest Territories (Brook et al. 2012, SDJV 2015). A BLSC indicated breeding pair (IBP) density of 0.16/km^2 in northern Ontario is considered among the highest densities of breeding BLSC in North America (Brook et al. 2012). We estimated an average 0.24 IBP/km^2 on SEA strata. A direct comparison of densities is not possible because the Ontario study used helicopters rather than fixed-wing aircraft. Observers in helicopters may have a higher probability of detecting BLSC compared to observers in fixed-wing aircraft (positive helicopter bias; Cole et al 1987, Conant et al. 1991). However, BLSC may be more prone to flee from helicopters leaving fewer individuals available to be sampled (negative helicopter bias; Cole and Dickson 1986). Despite these uncertainties, BLSC densities in the SEA region appear at the very least to be comparable to other high density breeding areas.

Barker et al. (2014) used WBPHS data and a suite of biogeoclimatic variables to predict the distribution and abundance of 17 species or species groups of waterfowl across a large portion of Canada. Several species recorded in the Seal-Knife region were outside their predicted range (Barker et al. 2014) and (or) the generally accepted range (Birdlife International and NatureServe 2012): American Black Duck, Blue-winged Teal, Bufflehead, and Northern Shoveler were outside both their predicted and accepted ranges; American Widgeon was outside of its predicted range; American Green-winged Teal, Common Goldeneye, and Ring-necked Duck were outside of their accepted ranges. For those species whose predicted range included our study area, our estimated pair densities for the larger EPP area were roughly similar to those predicted by Barker et al. (2014). The predicted densities of all waterfowl combined in northern Manitoba rival those predicted for northwest Ontario, both of which exceed predicted densities for the remainder of coastal Hudson Bay, the eastern boreal, and a large portion of the western boreal (Barker et al. 2014; see also Slattery and Robin 2007). These results further support the contention that continentally significant densities of waterfowl are found in the SEA strata, hence making the value of a protected area in this region important from both a Manitoba and continental perspective. We recommend the proposed protected area be expanded to include adjacent Knife River Delta and Seal River uplands, which contained the highest densities in this region.

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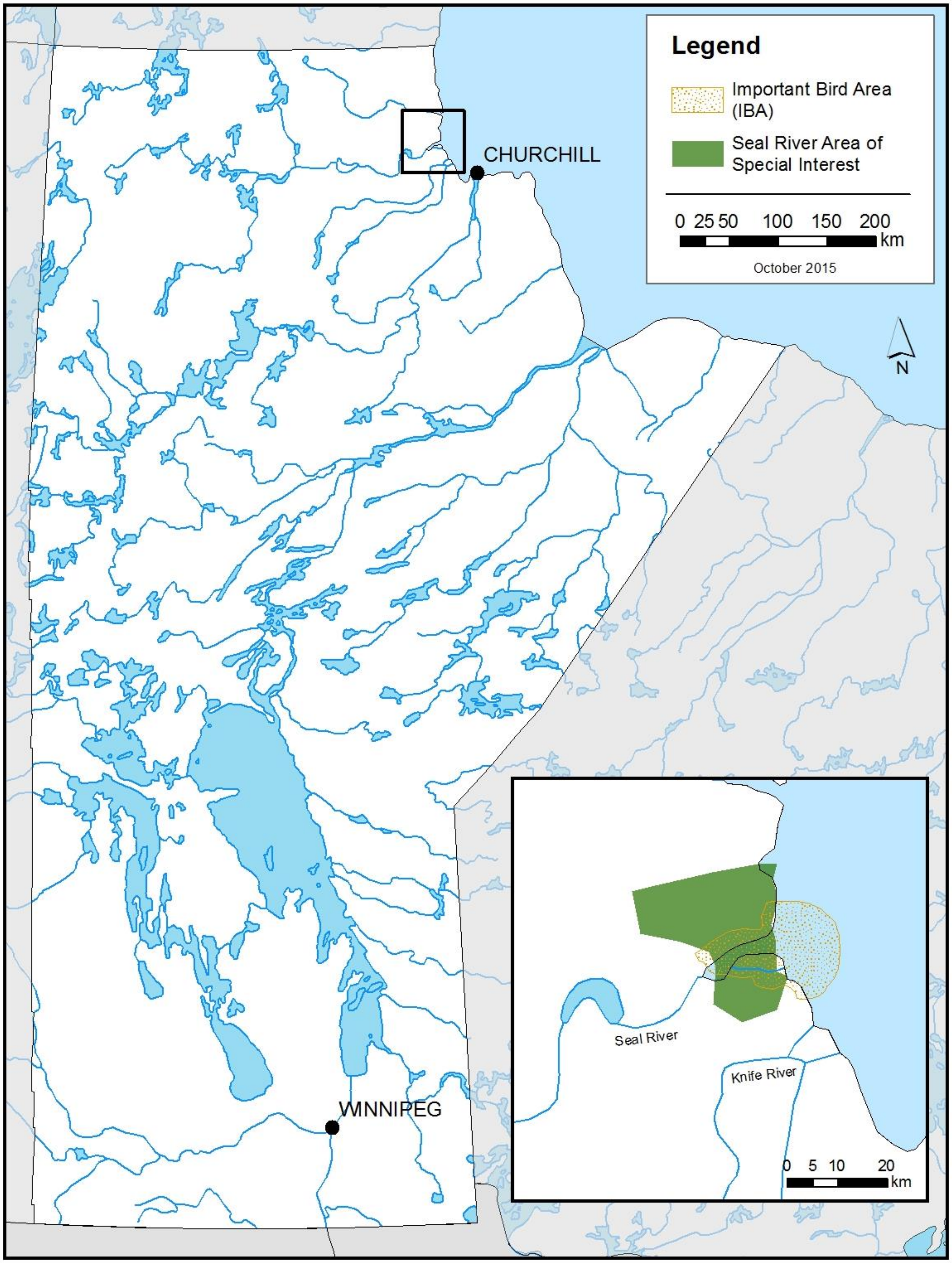

Figure 1. Location of the Seal River Estuary Area of Special Interest, the Seal River Important Bird Area, and the Knife River Delta in relation to Churchill and Winnipeg, Manitoba.

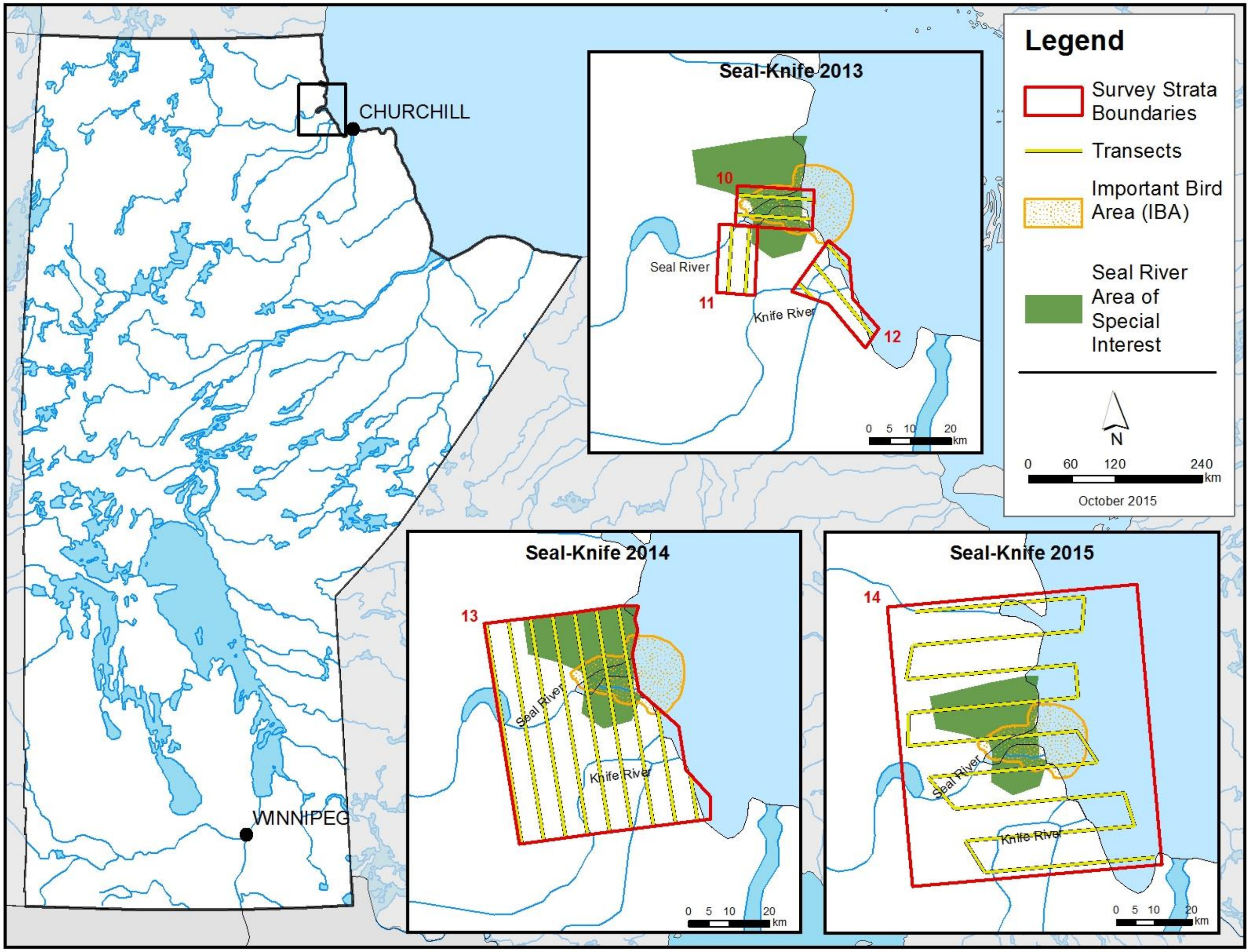

Figure 2. Location of the Seal River Estuary Important Bird Area (orange), Seal River Area of Special Interest and proposed Protected Area (green), and SEA survey strata (red boxes) and transects (yellow lines) from this study.

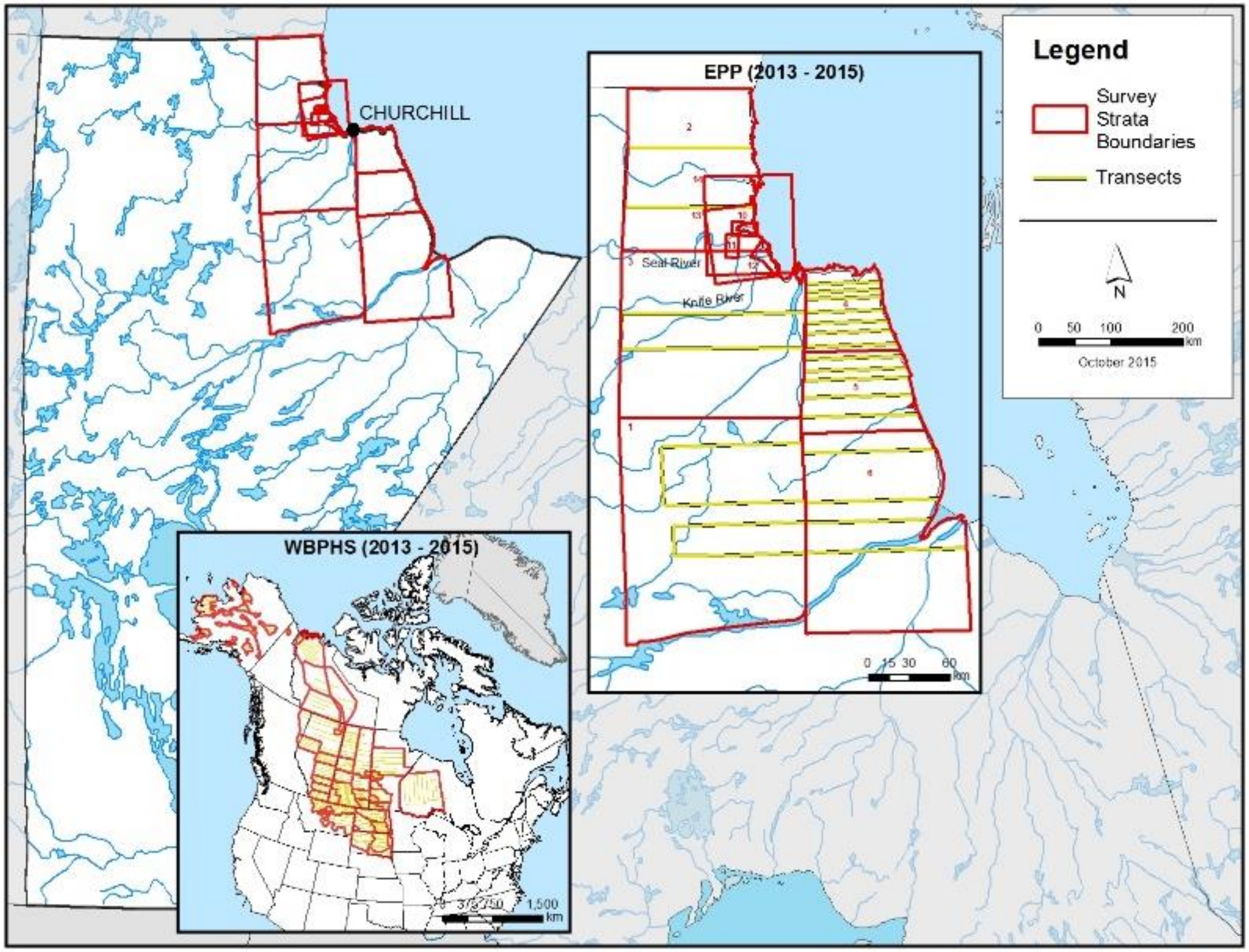

Figure 3. Strata (red boxes and numbers) and transect (yellow lines) locations in relation to Churchill, MB. Strata 10 to 12, 13 and 14 were the focus of this study and were surveyed in spring of 2013, 2014 and 2015, respectively. Comparative data were drawn from two concurrent long term waterfowl survey programs, the Eastern Prairie Population (EPP; Strata 1 to 6) program and the Waterfowl Breeding Population and Habitat Survey (WBPHS; inset) program.

Table 1. Area sampled (transect length × transect width; km^2) for breeding waterfowl in the Eastern Prairie Population (EPP) and Seal and Knife River (SEA) survey areas in 2013 to 2015. Equipment malfunctions resulted in geese being sampled from one side of the aircraft (i.e., half transect widths) on EPP transects in 2013, and data not being recorded on three EPP transects in 2014.

				Area sampled (km^2)	
Survey area	Year	Strata area (km^2)	Number Transects Sampled	Geese	Other species
EPP	2013	77,106	28	456.0	912.0
	2014	77,106	25	807.6	807.6
	2015	77,106	28	912.0	912.0
SEA	2013	584	7	44.4	44.4
	2014	2,345	9	173.6	173.6
	2015	4,916	17	192.1	192.1
Total		239,163	114	2,585.7	3,041.7

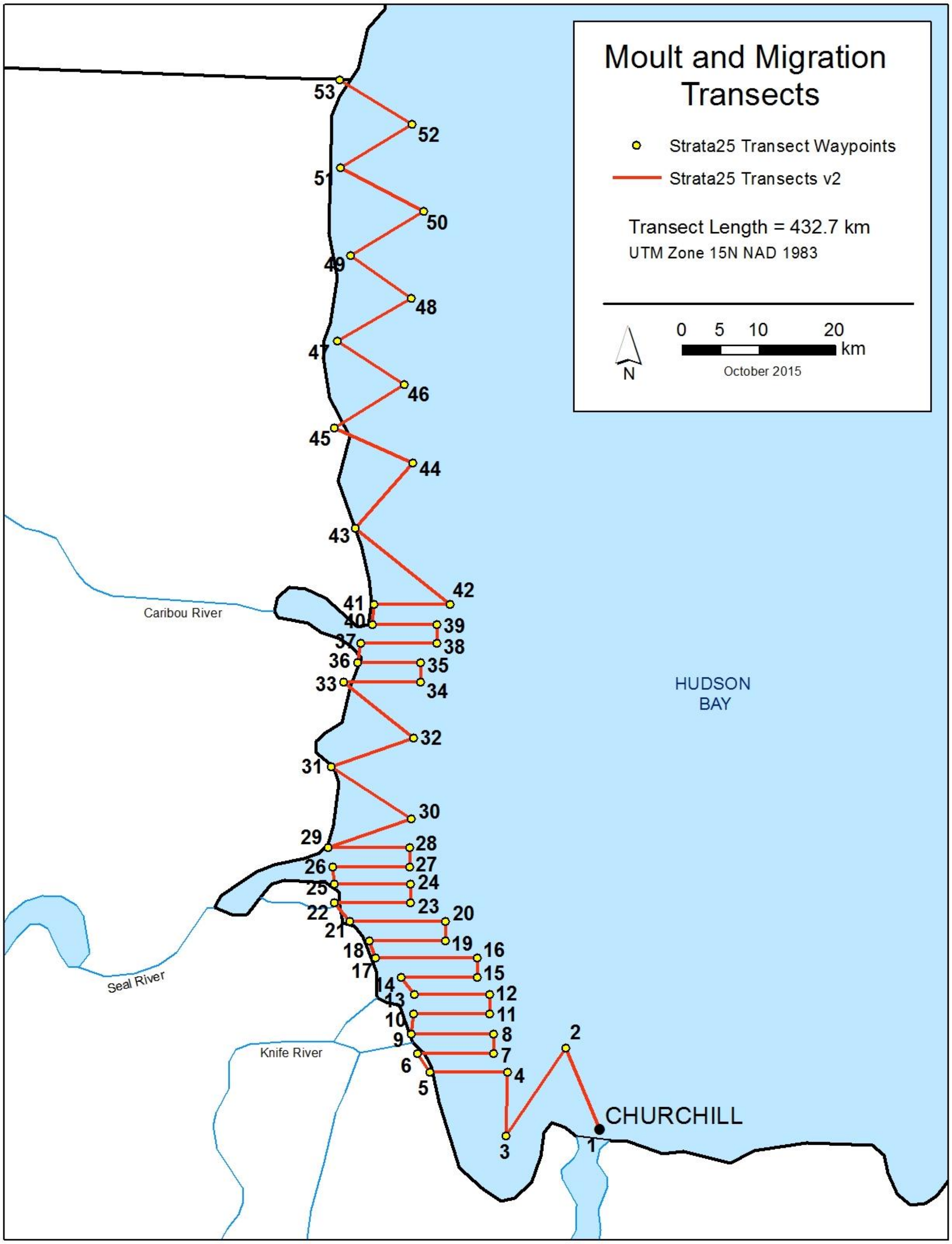

Figure 4. Transects surveyed in 2015 to assess the distribution and abundance of moulting and migrating waterfowl

Table 2. Total numbers of each species, group, and guild of birds recorded during 2013 to 2015 aerial breeding surveys of the EPP and SEA study areas. Total area surveyed was 2,586 km^2 for geese and 3,042 km^2 for other species. A correction for behavior-related phenology (Corr) was applied to the field data of counted birds (RAW) to calculate total indicated birds (TIB) and numbers of indicated breeding pairs (IBP). These values were further corrected for imperfect detectability (VCF).

Common Name	Species	Code	Group	Guild	Corr[a]	VCF[d]	∑RAW	∑TIB	∑IBP	∑VCF-RAW	∑VCF-TIB	∑VCF-IBP
American Black Duck	*Anas rubripes*	ABDU	duck	dabbler	A	4.80[c]	61	92	31	293	442	149
American Green-winged Teal	*Anas crecca*	AGWT	duck	dabbler	A	4.17[b]	337	632	295	1405	2635	1230
American Wigeon	*Anas americana*	AMWI	duck	dabbler	A	5.71[b]	123	229	106	702	1308	605
Blue-winged Teal	*Anas discors*	BWTE	duck	dabbler	A	6.66[b]	1	2	1	7	13	7
Mallard	*Anas playtrhychos*	MALL	duck	dabbler	A	2.74[b]	409	697	288	1121	1910	789
Northern Pintail	*Anas acuta*	NOPI	duck	dabbler	A	2.66[b]	720	1328	608	1915	3532	1617
Northern Shoveler	*Anas clypeata*	NOSH	duck	dabbler	A	3.49[b]	70	130	60	244	454	209
Black Scoter	*Melanitta americana*	BLSC	duck	diver	A	1.30[c]	1869	2166	297	2430	2816	386
Bufflehead	*Bucephala abeola*	BUFF	duck	diver	A	2.21[b]	38	76	38	84	168	84
Common Eider	*Somateria mollissima*	COEI	duck	diver	A	3.60[c]	41	71	30	148	256	108
Common Goldeneye	*Bucephala clangula*	COGO	duck	diver	A	2.60[b]	190	271	81	494	705	211
Common Merganser	*Mergus merganser*	COME	duck	diver	A	2.00[c]	187	254	67	374	508	134
Hooded Merganser	*Lophodytes cucullatus*	HOME	duck	diver	A	2.00[c]	40	72	32	80	144	64
Long-tailed duck	*Clangula hyemalis*	LTDU	duck	diver	A	6.50[c]	214	402	188	1391	2613	1222
Red-breasted Merganser	*Mergus serrator*	RBME	duck	diver	A	1.00	6	12	6	6	12	6
Ring-necked Duck	*Aythya collaris*	RNDU	duck	diver	B	3.16[b]	114	185	71	360	585	224
Surf Scoter	*Melanitta perspicillata*	SUSC	duck	diver	A	1.30[c]	144	238	94	187	309	122
Unknown Scaup	*Aythya marila, A. affinis*	UNSC	duck	diver	B	1.98[b]	952	1513	561	1885	2996	1111
Unknown Scoter	*Melanitta* spp.	USCT	duck	diver	A	1.30[c]	166	219	53	216	285	69
White-winged Scoter	*Melanitta fusca*	WWSC	duck	diver	A	1.30[c]	491	578	87	638	751	113
Unknown Duck	Anas spp.	UNDU	duck	unknown	A	1.00	96	132	36	96	132	36
Canada Goose	*Branta canadensis*	CAGO	goose	goose	A	1.44[b]	6030	8784	2754	8683	12,649	3966
Lesser Snow Goose	*Chen caerulescens*	LSGO	goose	goose	A	1.00	2632	4159	1527	2632	4159	1527
Tundra Swan	*Cygnus columbianus*	TUSW	swan	swan	B	1.00	130	189	59	130	189	59

Common Name	Species	Code	Group	Guild	Corr[a]	VCF[d]	∑RAW	∑TIB	∑IBP	∑VCF-RAW	∑VCF-TIB	∑VCF-IBP
Common Loon	*Gavia immer*	COLO	loon	loon	A	1.00	22	30	8	22	30	8
Pacific Loon	*Gavia pacifica*	PALO	loon	loon	A	1.00	18	31	13	18	31	13
Unknown Loon	*Gavia* spp.	UNLO	loon	loon	A	1.00	19	34	15	19	34	15
Sandhill Crane	*Grus grus*	SACR	crane	crane	B	1.00	70	91	21	70	91	21

[a] Rules to calculate TIB and IBP from USFWS-CWS (1987), Conant et al. (1991), and Brook et al. (2012), supplemented by Dzubin (1969).
TIB: A = (pairs × 2) + (singles × 2) + (flocked drakes < 5 × 2) + (flocked drakes ≥ 5 × 1) + (groups × 1)
TIB: B = (pairs × 2) + (singles × 1) + (flocked drakes × 1) + (groups × 1)
IBP: A = (pairs × 1) + (singles × 1) + (flocked drakes < 5 × 1) + (flocked drakes ≥ 5 × 0) + (groups × 0)
IBP: B = (pairs × 1) + (singles × 0) + (flocked drakes × 0) + (groups × 0)
[b] Values calculated from 2013 WBPHS survey data from Strata 24, which is adjacent to the study region.
[c] 'Bush units' from USFWS-CWS (1987).
[d] VCF = 1 for species without a correction factor.

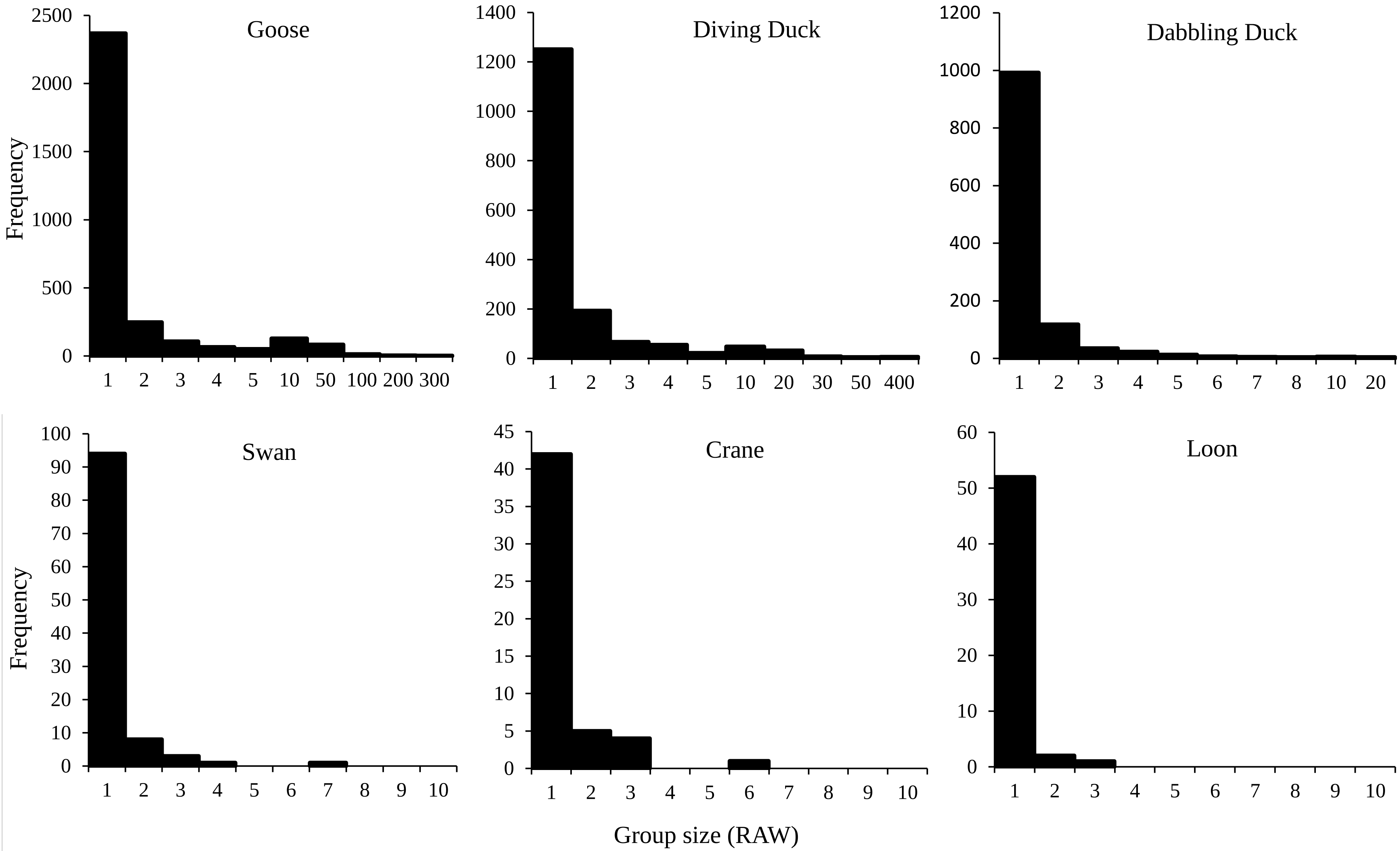

Figure 5. Numbers of each group size of birds (RAW) encountered during breeding surveys of the Eastern Prairie Population (EPP) and Seal River (SEA) study areas. Note, scale of axes differs among panels.

Table 3. Average density (km^{-2}; ± 1 SD) of each species per transect during each year of study. Raw values represent observed number of individuals whereas total indicated birds (TIB) and numbers of indicted breeding pairs (IBP) were calculated based on correction rules for phenology and behaviour (see Table 2 for species-specific corrections). Species in bold text had significantly different TIB densities between years ($\alpha = 0.05$).

	Raw						TIB						IBP						
	2013		2014		2015		2013		2014		2015		2013		2014		2015		
Code	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	*P*
ABDU	0.140	0.575	0.034	0.124	0.011	0.043	0.217	0.902	0.048	0.146	0.021	0.085	0.077	0.381	0.014	0.040	0.011	0.043	0.352
AGWT	**0.171**	**0.278**	**0.049**	**0.063**	**0.192**	**0.339**	**0.335**	**0.556**	**0.096**	**0.124**	**0.338**	**0.489**	**0.164**	**0.279**	**0.046**	**0.063**	**0.146**	**0.162**	**<0.001**
AMWI	0.096	0.189	0.074	0.121	0.012	0.031	0.192	0.379	0.125	0.171	0.024	0.062	0.096	0.189	0.051	0.070	0.012	0.031	0.068
BWTE	0.003	0.018	0.000	0.000	0.000	0.000	0.006	0.037	0.000	0.000	0.000	0.000	0.003	0.018	0.000	0.000	0.000	0.000	0.313
MALL	**0.210**	**0.369**	**0.113**	**0.229**	**0.204**	**0.336**	**0.399**	**0.722**	**0.173**	**0.276**	**0.327**	**0.481**	**0.189**	**0.359**	**0.060**	**0.071**	**0.124**	**0.164**	**0.013**
NOPI	**0.289**	**0.346**	**0.277**	**0.460**	**0.446**	**0.988**	**0.569**	**0.689**	**0.498**	**0.743**	**0.717**	**1.199**	**0.280**	**0.344**	**0.236**	**0.306**	**0.271**	**0.283**	**0.003**
NOSH	0.026	0.092	0.016	0.055	0.048	0.146	0.052	0.183	0.032	0.109	0.084	0.229	0.026	0.092	0.016	0.055	0.036	0.091	0.130
BLSC	**0.158**	**0.454**	**0.138**	**0.184**	**1.886**	**6.987**	**0.211**	**0.506**	**0.266**	**0.352**	**2.039**	**7.199**	**0.053**	**0.126**	**0.130**	**0.174**	**0.152**	**0.273**	**0.005**
BUFF	0.018	0.044	0.012	0.030	0.007	0.022	0.035	0.088	0.023	0.061	0.014	0.044	0.018	0.044	0.012	0.030	0.007	0.022	0.513
COEI	0.021	0.072	0.013	0.046	0.031	0.101	0.041	0.144	0.020	0.065	0.053	0.160	0.021	0.072	0.008	0.021	0.022	0.065	0.075
COGO	0.042	0.123	0.072	0.113	0.056	0.109	0.060	0.167	0.115	0.148	0.083	0.153	0.018	0.067	0.047	0.066	0.026	0.062	0.068
COME	**0.102**	**0.333**	**0.023**	**0.108**	**0.243**	**0.939**	**0.147**	**0.346**	**0.045**	**0.216**	**0.285**	**1.088**	**0.045**	**0.069**	**0.023**	**0.108**	**0.041**	**0.172**	**0.009**
HOME	0.023	0.055	0.005	0.029	0.008	0.021	0.042	0.107	0.010	0.058	0.015	0.036	0.020	0.054	0.005	0.029	0.007	0.017	0.116
LTDU	**0.036**	**0.054**	**0.109**	**0.125**	**0.144**	**0.499**	**0.072**	**0.108**	**0.204**	**0.230**	**0.275**	**0.993**	**0.036**	**0.054**	**0.108**	**0.127**	**0.131**	**0.496**	**0.001**
RBME	**0.000**	**0.000**	**0.000**	**0.000**	**0.005**	**0.017**	**0.000**	**0.000**	**0.000**	**0.000**	**0.010**	**0.034**	**0.000**	**0.000**	**0.000**	**0.000**	**0.005**	**0.017**	**0.037**
RNDU	0.074	0.152	0.016	0.035	0.050	0.198	0.134	0.296	0.022	0.050	0.065	0.206	0.060	0.146	0.007	0.019	0.015	0.039	0.165
SUSC	**0.070**	**0.141**	**0.018**	**0.039**	**0.058**	**0.114**	**0.113**	**0.199**	**0.036**	**0.078**	**0.089**	**0.154**	**0.043**	**0.081**	**0.018**	**0.039**	**0.031**	**0.063**	**0.019**
UNSC	**0.297**	**0.402**	**0.323**	**0.302**	**0.399**	**0.372**	**0.498**	**0.672**	**0.502**	**0.454**	**0.646**	**0.587**	**0.202**	**0.278**	**0.187**	**0.176**	**0.248**	**0.236**	**0.018**
USCT	0.088	0.259	0.043	0.074	0.014	0.065	0.109	0.282	0.073	0.131	0.019	0.082	0.021	0.048	0.030	0.062	0.004	0.017	0.073
WWSC	0.135	0.400	0.013	0.036	0.165	0.464	0.173	0.445	0.025	0.073	0.183	0.484	0.038	0.084	0.013	0.036	0.019	0.054	0.060
UNDU	**0.000**	**0.000**	**0.080**	**0.115**	**0.021**	**0.077**	**0.000**	**0.000**	**0.111**	**0.136**	**0.031**	**0.104**	**0.000**	**0.000**	**0.031**	**0.040**	**0.010**	**0.042**	**<0.001**
CAGO	2.273	2.432	2.784	2.908	2.614	3.579	3.889	4.087	3.838	3.403	3.593	4.001	2.141	2.301	1.085	0.951	0.979	1.025	0.968

	Raw						TIB						IBP						
	2013		2014		2015		2013		2014		2015		2013		2014		2015		
Code	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	*P*
LSGO	0.639	1.626	1.733	5.764	0.872	3.329	0.978	2.364	2.974	10.565	1.229	4.843	0.339	0.824	1.241	4.857	0.356	1.528	0.324
TUSW	0.044	0.083	0.041	0.056	0.045	0.064	0.063	0.113	0.058	0.075	0.068	0.106	0.019	0.039	0.017	0.029	0.023	0.045	0.546
COLO	0.007	0.020	0.003	0.011	0.007	0.023	0.011	0.038	0.003	0.011	0.009	0.030	0.004	0.018	0.000	0.000	0.002	0.010	0.384
PALO	**0.000**	**0.000**	**0.005**	**0.015**	**0.011**	**0.024**	**0.000**	**0.000**	**0.006**	**0.019**	**0.022**	**0.048**	**0.000**	**0.000**	**0.001**	**0.008**	**0.010**	**0.024**	**0.002**
UNLO	**0.019**	**0.039**	**0.003**	**0.010**	**0.003**	**0.010**	**0.033**	**0.068**	**0.003**	**0.010**	**0.005**	**0.020**	**0.014**	**0.032**	**0.000**	**0.000**	**0.003**	**0.010**	**0.012**
SACR	**0.021**	**0.034**	**0.010**	**0.022**	**0.033**	**0.081**	**0.027**	**0.044**	**0.013**	**0.029**	**0.044**	**0.110**	**0.006**	**0.018**	**0.003**	**0.010**	**0.011**	**0.033**	**0.046**

Table 4: Average densities (km^{-2}; ± 1 SD) of each species per transect in the Eastern Prairie Population (EPP) and Seal River (SEA) study areas. Raw values represent observed numbers of individuals whereas total indicated birds (TIB) and numbers of indicted breeding pairs (IBP) were calculated based on correction rules for phenology and behaviour (see Table 2 for species-specific corrections). Species in bold text had statistically different TIB densities between study areas after controlling for the effect of year on density (α = 0.05).

	Raw				TIB				IBP				
	EPP		SEA		EPP		SEA		EPP		SEA		
Code	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	*P*
ABDU	0.012	0.078	0.168	0.590	0.016	0.084	0.269	0.926	0.004	0.011	0.101	0.392	0.057
AGWT	**0.089**	**0.108**	**0.275**	**0.451**	**0.169**	**0.199**	**0.500**	**0.733**	**0.080**	**0.093**	**0.225**	**0.307**	**0.023**
AMWI	**0.031**	**0.074**	**0.117**	**0.201**	**0.056**	**0.110**	**0.228**	**0.393**	**0.025**	**0.048**	**0.110**	**0.194**	**0.011**
BWTE	0.001	0.012	0.000	0.000	0.003	0.024	0.000	0.000	0.001	0.012	0.000	0.000	0.648
MALL	**0.136**	**0.254**	**0.283**	**0.428**	**0.226**	**0.356**	**0.493**	**0.782**	**0.090**	**0.115**	**0.210**	**0.380**	**0.042**
NOPI	**0.220**	**0.192**	**0.661**	**1.214**	**0.406**	**0.329**	**1.098**	**1.568**	**0.193**	**0.164**	**0.436**	**0.472**	**0.020**
NOSH	0.014	0.040	0.076	0.188	0.027	0.079	0.136	0.312	0.014	0.040	0.060	0.135	0.073
BLSC	**0.212**	**0.420**	**2.362**	**8.132**	**0.277**	**0.464**	**2.597**	**8.362**	**0.066**	**0.104**	**0.236**	**0.329**	**0.020**
BUFF	0.013	0.034	0.009	0.030	0.026	0.067	0.017	0.060	0.013	0.034	0.009	0.030	0.765
COEI	**0.005**	**0.030**	**0.065**	**0.130**	**0.007**	**0.042**	**0.119**	**0.221**	**0.003**	**0.013**	**0.054**	**0.098**	**0.020**
COGO	0.050	0.113	0.074	0.118	0.069	0.130	0.127	0.204	0.021	0.045	0.052	0.097	0.137
COME	**0.018**	**0.038**	**0.419**	**1.119**	**0.034**	**0.068**	**0.508**	**1.289**	**0.016**	**0.031**	**0.089**	**0.227**	**0.012**
HOME	0.016	0.043	0.000	0.000	0.031	0.084	0.000	0.000	0.014	0.042	0.000	0.000	0.107
LTDU	0.061	0.099	0.197	0.575	0.115	0.181	0.379	1.147	0.060	0.096	0.182	0.574	0.095
RBME	0.002	0.010	0.003	0.013	0.003	0.019	0.007	0.027	0.002	0.010	0.003	0.013	0.640
RNDU	0.048	0.153	0.044	0.152	0.071	0.170	0.079	0.297	0.023	0.043	0.035	0.148	0.725
SUSC	0.059	0.121	0.027	0.070	0.091	0.159	0.055	0.141	0.032	0.061	0.027	0.070	0.863
UNSC	**0.274**	**0.262**	**0.518**	**0.498**	**0.444**	**0.406**	**0.836**	**0.811**	**0.174**	**0.162**	**0.318**	**0.335**	**0.029**
USCT	0.051	0.172	0.033	0.109	0.068	0.193	0.050	0.152	0.017	0.036	0.017	0.063	0.926
WWSC	0.151	0.432	0.008	0.034	0.180	0.461	0.016	0.067	0.029	0.069	0.008	0.034	0.116
UNDU	0.028	0.083	0.043	0.092	0.035	0.095	0.072	0.133	0.007	0.018	0.029	0.058	0.055
CAGO	2.229	2.248	3.374	4.378	3.530	3.420	4.315	4.698	1.541	1.750	0.941	1.015	0.350

	Raw				TIB				IBP				
	EPP		SEA		EPP		SEA		EPP		SEA		
Code	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	*P*
LSGO	1.478	4.537	0.025	0.145	2.333	7.797	0.051	0.290	0.855	3.366	0.025	0.145	0.453
TUSW	0.048	0.071	0.033	0.058	0.070	0.105	0.047	0.083	0.023	0.041	0.014	0.031	0.833
COLO	0.007	0.022	0.002	0.010	0.010	0.031	0.003	0.019	0.003	0.013	0.002	0.010	0.315
PALO	0.004	0.013	0.010	0.025	0.007	0.022	0.020	0.051	0.002	0.010	0.010	0.025	0.229
UNLO	0.007	0.018	0.009	0.036	0.013	0.034	0.013	0.057	0.006	0.017	0.004	0.026	0.456
SACR	0.029	0.064	0.007	0.018	0.038	0.087	0.008	0.025	0.009	0.027	0.002	0.010	0.222

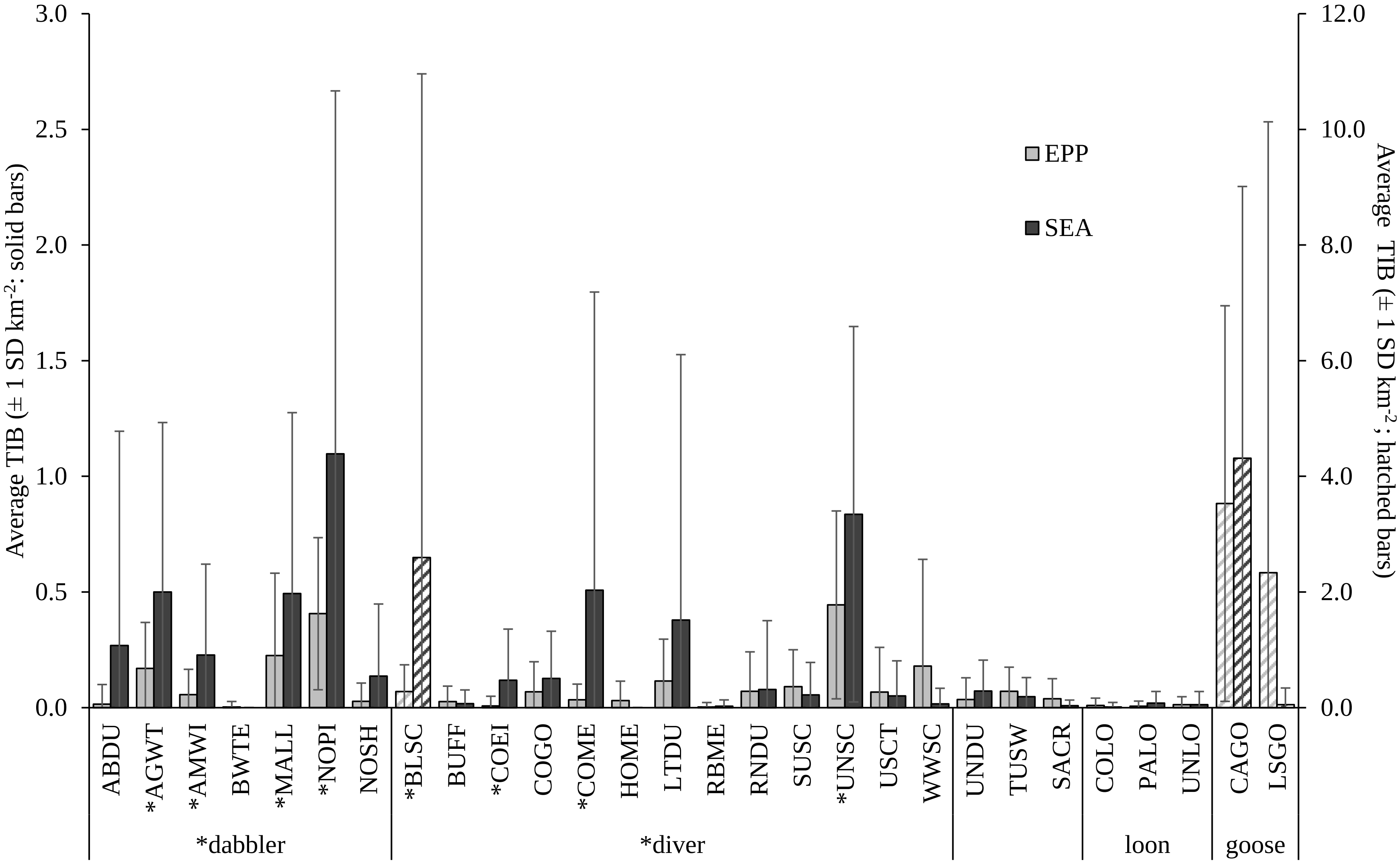

Figure 6. Average densities of total indicated birds (TIB) per transect in the Eastern Prairie Population (EPP) and Seal River (SEA) survey areas. Values of hatched bars are on the right-hand axis and grey bars and black bars represent EPP and SEA, respectively, irrespective of

whether they are solid or hatched. Species and guilds marked with an asterisk were statistically different between study areas after controlling for the effect of year on density ($\alpha = 0.05$).

Table 5. Average densities of total indicated birds (TIB $km^{-2} \pm 1$ SD) per transect of each group or guild in the Eastern Prairie Population (EPP) and Seal River (SEA) study areas. Species included in each group or guild are listed in Table 2. Groups and guilds in bold text had statistically different TIB densities between study areas after controlling for the effects of year ($\alpha = 0.05$).

	TIB ($km^{-2} \pm 1$ SD)												
	2013				2014				2015				
	EPP		SEA		EPP		SEA		EPP		SEA		
Group/Guild	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	Ave	± 1 SD	*P*
Total birds	7.015	6.078	13.981	7.169	9.788	13.808	8.027	7.222	8.418	8.041	13.373	13.208	0.085
Ducks	**2.056**	**1.279**	**8.808**	**4.115**	**1.909**	**0.718**	**3.862**	**3.103**	**3.051**	**1.294**	**9.056**	**11.740**	**<0.001**
Dabbling ducks	**0.797**	**0.414**	**5.663**	**3.835**	**0.660**	**0.418**	**1.840**	**1.975**	**1.227**	**0.757**	**1.981**	**2.787**	**0.006**
Diving ducks	**1.259**	**1.314**	**3.145**	**1.595**	**1.140**	**0.734**	**1.905**	**1.329**	**1.821**	**1.177**	**6.996**	**11.790**	**0.003**
Geese	4.817	6.349	5.068	3.908	7.788	13.575	4.100	4.259	5.190	7.936	4.216	5.409	0.532
Swans	0.069	0.114	0.042	0.111	0.060	0.071	0.055	0.089	0.081	0.121	0.046	0.071	0.833
Loons	0.039	0.065	0.063	0.116	0.013	0.020	0.010	0.030	0.034	0.060	0.039	0.078	0.663
Cranes	0.034	0.047	0.000	0.000	0.018	0.033	0.000	0.000	0.061	0.135	0.016	0.033	0.222

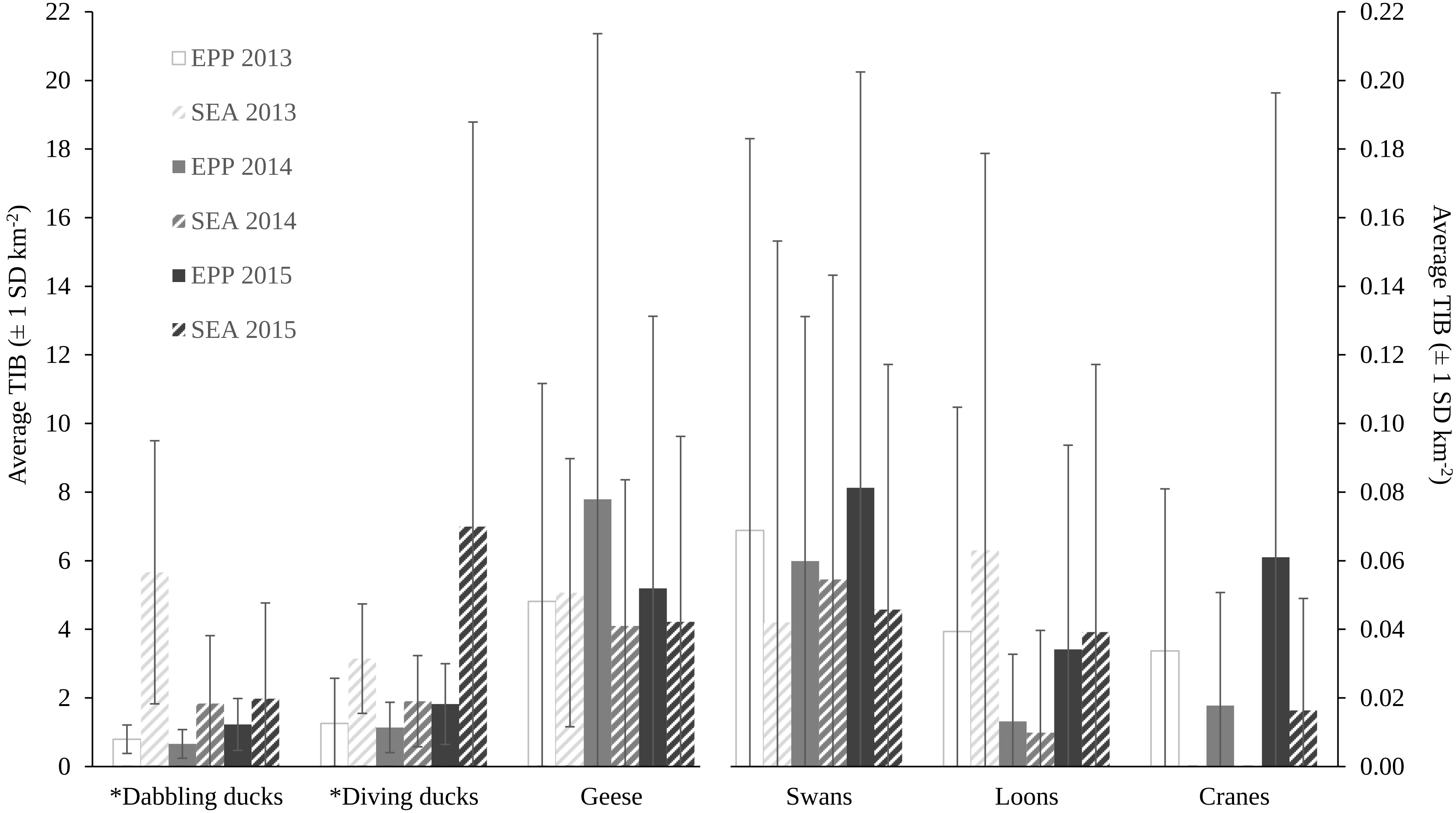

Figure 7. Average densities (km^{-2}; ± 1 SD) of total indicated birds (TIB) per transect in Eastern Prairie Population (EPP; solid bars) and Seal River (SEA; hatched bars) survey areas in each year of study. Duck and goose values are on the left-hand axis whereas swan, loon, and crane values are on the right-hand axis. Groups and guilds marked with an asterisk were statistically different between years, study areas, or year × study area (α = 0.05).

Table 6. Predicted densities of total indicated birds (TIB $km^{-2} \pm 1$ SE) per stratum in the Eastern Prairie Population (EPP) and Seal River (SEA) study areas after controlling for the effect of year. Species included in each group or guild are listed in Table 2. Groups and guilds in bold text had statistically different TIB densities between study areas after controlling for the effects of year (α = 0.05).

		Total birds		Ducks		Dabbling ducks		Diving ducks		Geese		Swans		Loons		Cranes	
Study Area	Stratum	Ave ±	1 SE	Ave ±	1 SE	Ave ±	1 SE	Ave ±	1 SE	Ave ±	1 SE	Ave ±	1 SE	Ave ±	1 SE	Ave ±	1 SE
EPP	1	4.14	1.12	3.34	0.79	0.81	0.30	2.40	0.73	0.64	0.38	0.03	0.02	0.06	0.02	0.01	0.01
EPP	2	3.38	1.32	2.15	0.79	0.73	0.40	1.40	0.71	1.21	0.71	0.00	0.03	0.03	0.02	0.02	0.02
EPP	3	4.10	1.54	2.41	0.86	1.01	0.47	1.31	0.69	1.41	0.77	0.01	0.03	0.02	0.02	0.00	0.02
EPP	4	14.82	2.93	2.08	0.48	1.08	0.30	0.87	0.34	12.00	2.55	0.16	0.02	0.01	0.01	0.09	0.01
EPP	5	6.13	1.67	1.90	0.57	0.92	0.35	0.90	0.44	4.01	1.25	0.06	0.02	0.04	0.02	0.01	0.01
EPP	6	2.38	1.02	1.74	0.69	0.45	0.34	1.20	0.65	0.58	0.51	0.02	0.03	0.01	0.02	0.03	0.02
SEA	10	6.03	2.95	4.44	1.94	2.01	0.93	1.66	1.11	1.72	1.21	0.00	0.05	-0.01	0.03	0.00	0.04
SEA	11	13.19	5.95	10.67	4.15	4.39	1.67	5.76	2.82	2.72	1.65	0.14	0.06	0.21	0.04	0.00	0.04
SEA	12	22.58	8.10	13.65	4.28	9.37	2.63	3.40	1.51	9.22	3.72	0.00	0.04	-0.01	0.03	0.00	0.03
SEA	13	6.72	1.58	3.67	0.81	1.78	0.42	1.81	0.57	2.89	0.84	0.06	0.03	0.02	0.02	0.02	0.02
SEA	14	7.82	1.31	4.71	0.72	0.96	0.21	2.87	0.57	2.24	0.51	0.03	0.02	0.03	0.01	0.00	0.02

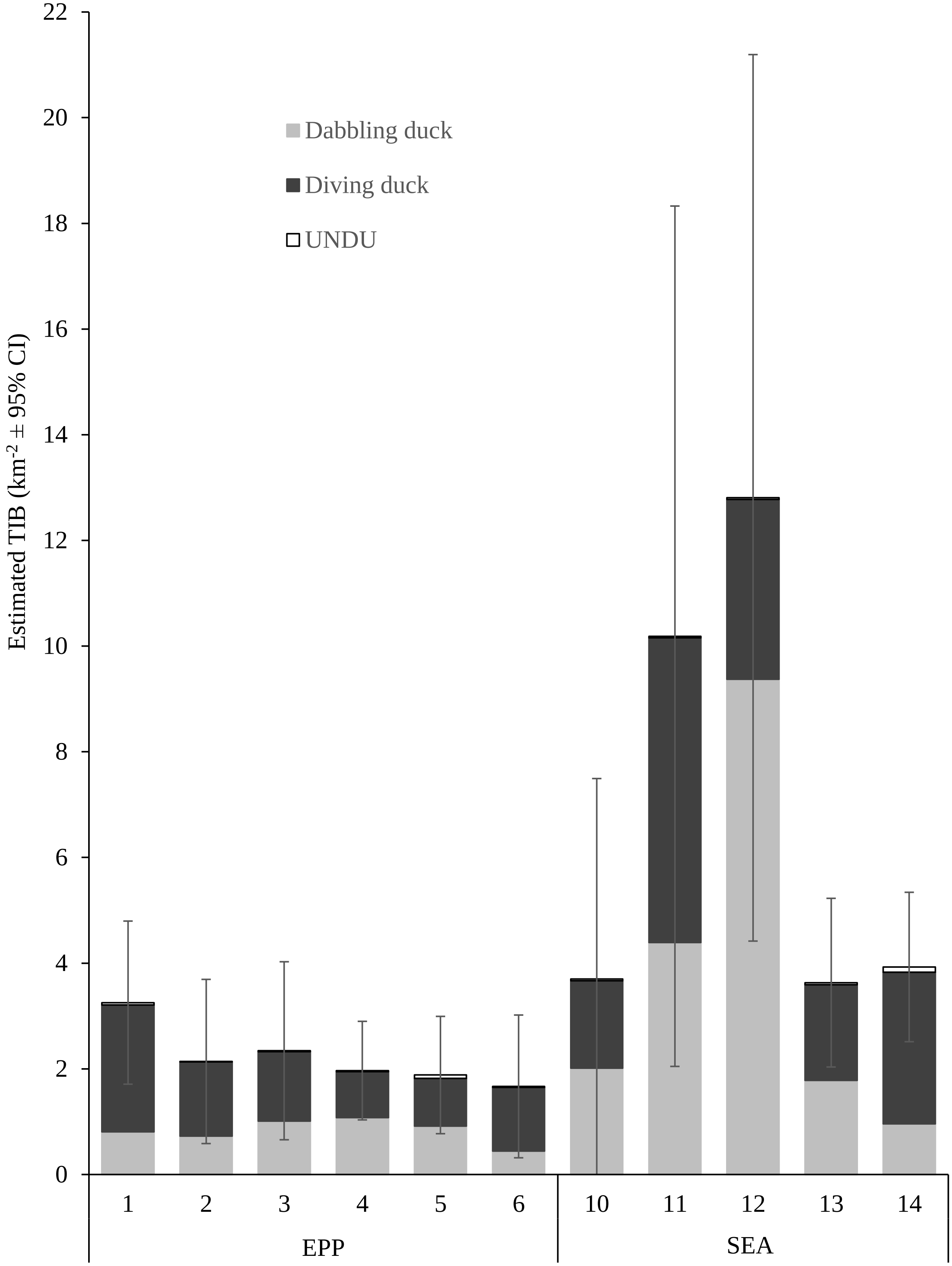

Figure 8. Predicted total indicated broods (TIB km^{-2}) per stratum in the Eastern Prairie Population (EPP) and Seal River (SEA) study areas after controlling for the effects of year on

densities of dabbling ducks (grey bar), diving ducks (black bar), and unknown ducks (UNDU; white bar). Error bars represent 95% CI of all ducks combined.

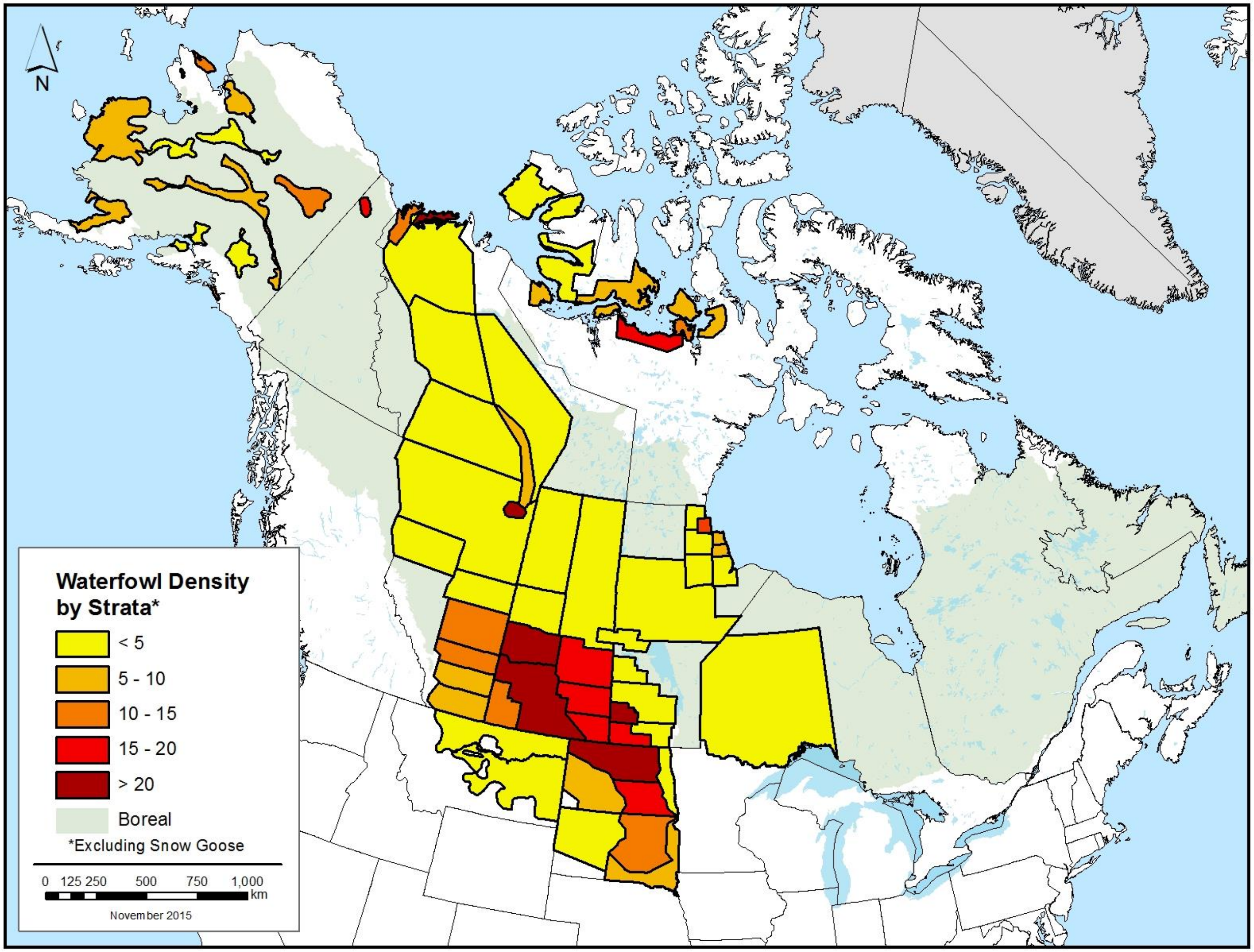

Figure 9. The average transect-level density of all breeding season waterfowl (excluding Snow Geese) in the Waterfowl Breeding Population and Habitat Survey, High Arctic, Eastern Prairie Population, and Seal River study area strata.

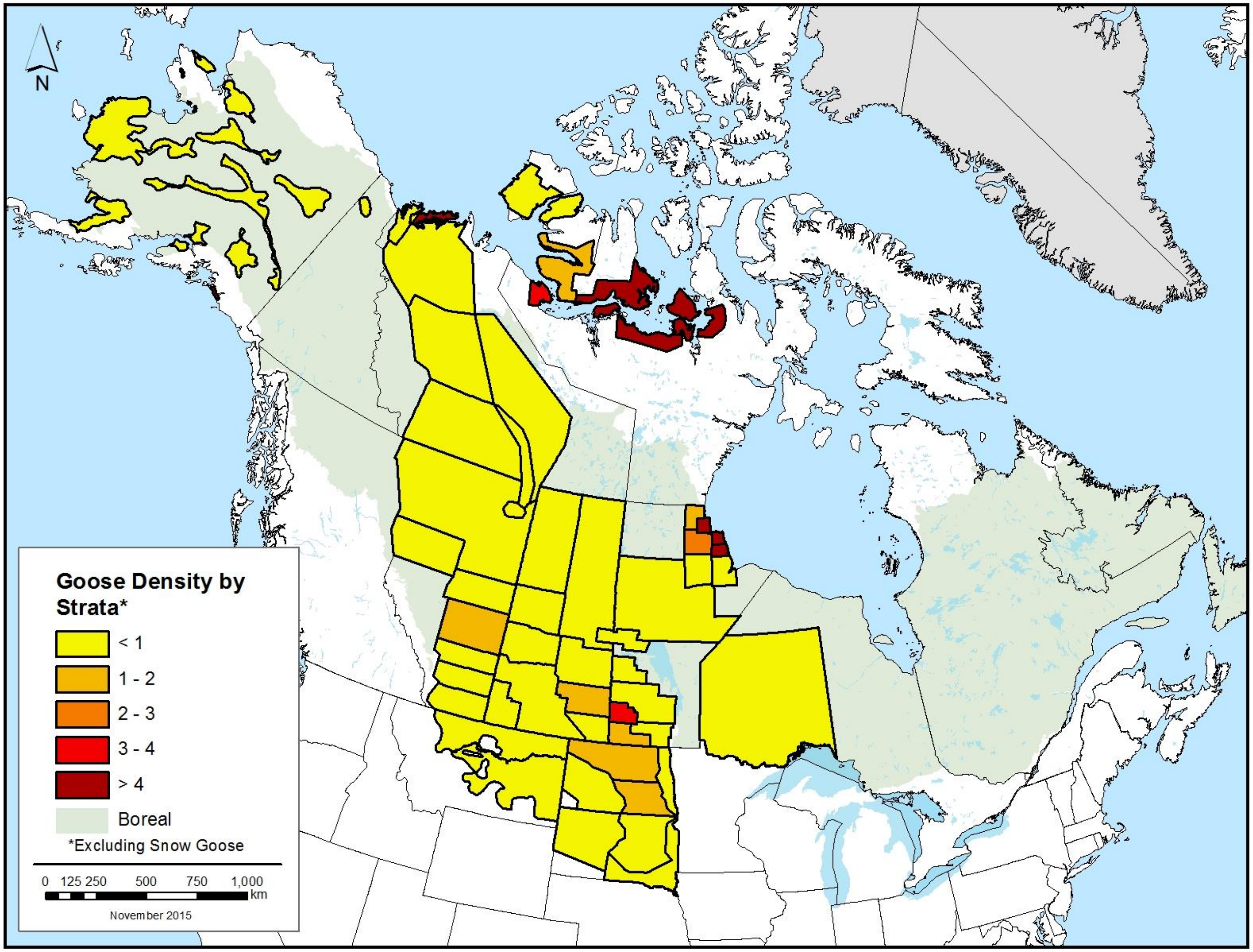

Figure 10. The average transect-level density of breeding season geese (excluding Snow Geese) in the Waterfowl Breeding Population and Habitat Survey, High Arctic, Eastern Prairie Population, and Seal River study area strata. Snow Geese were excluded because of their colonial habit. Their inclusion would further increase the relative importance of northern strata, including the Seal River strata.

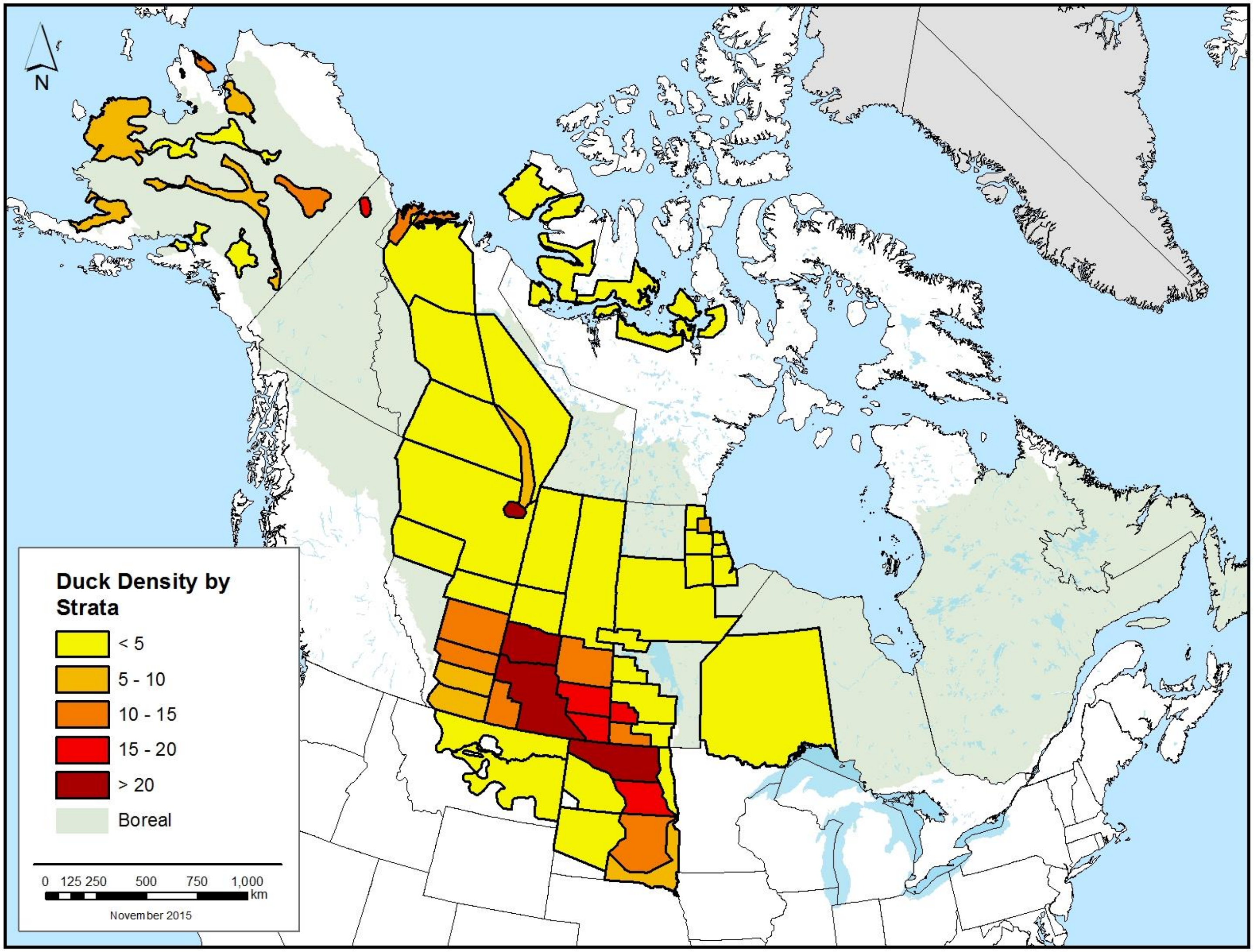

Figure 11. The average transect-level density of breeding season ducks in the Waterfowl Breeding Population and Habitat Survey, High Arctic, Eastern Prairie Population, and Seal River study area strata.

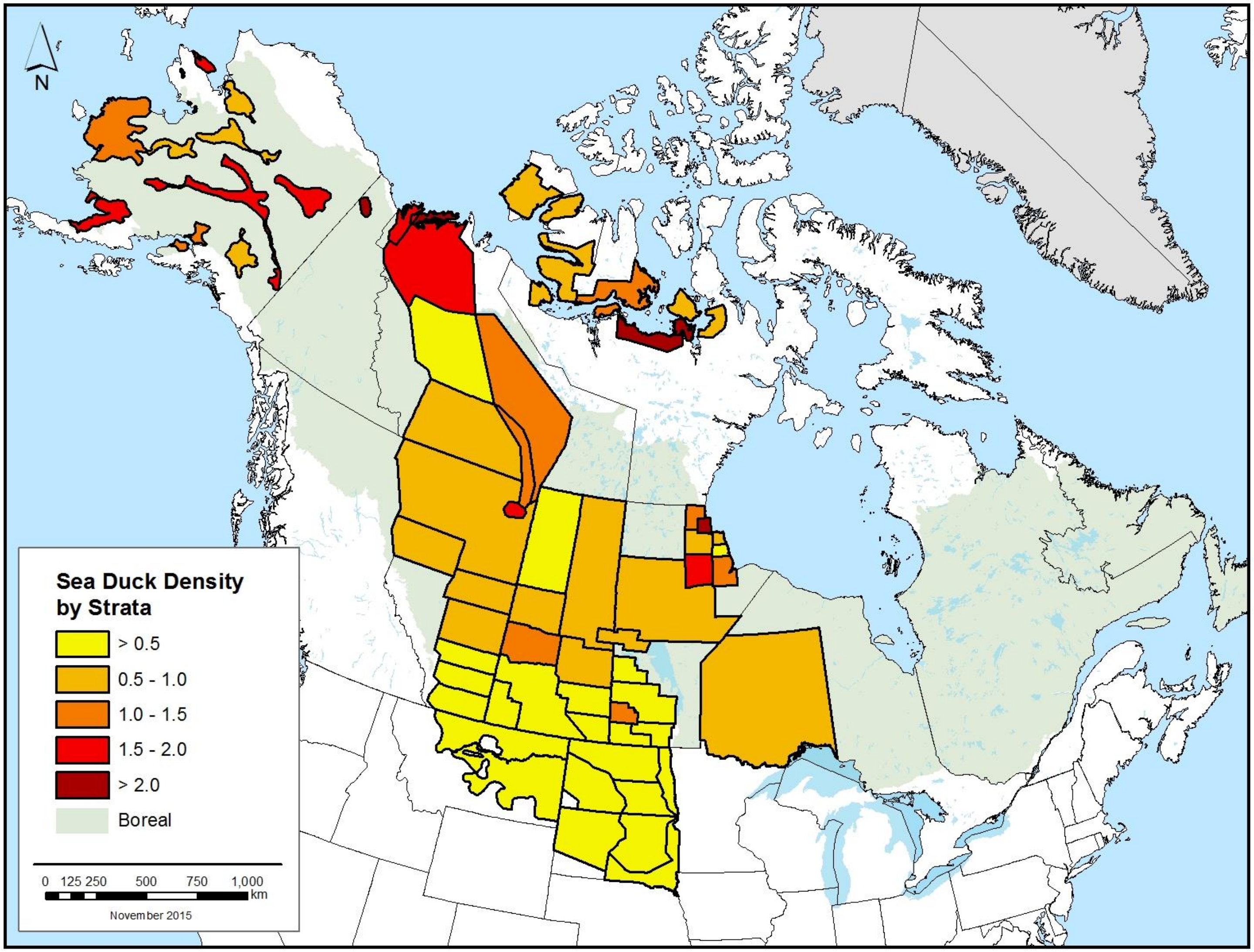

Figure 12. The average transect-level density of breeding season sea ducks in the Waterfowl Breeding Population and Habitat Survey, High Arctic, Eastern Prairie Population, and Seal River study area strata.

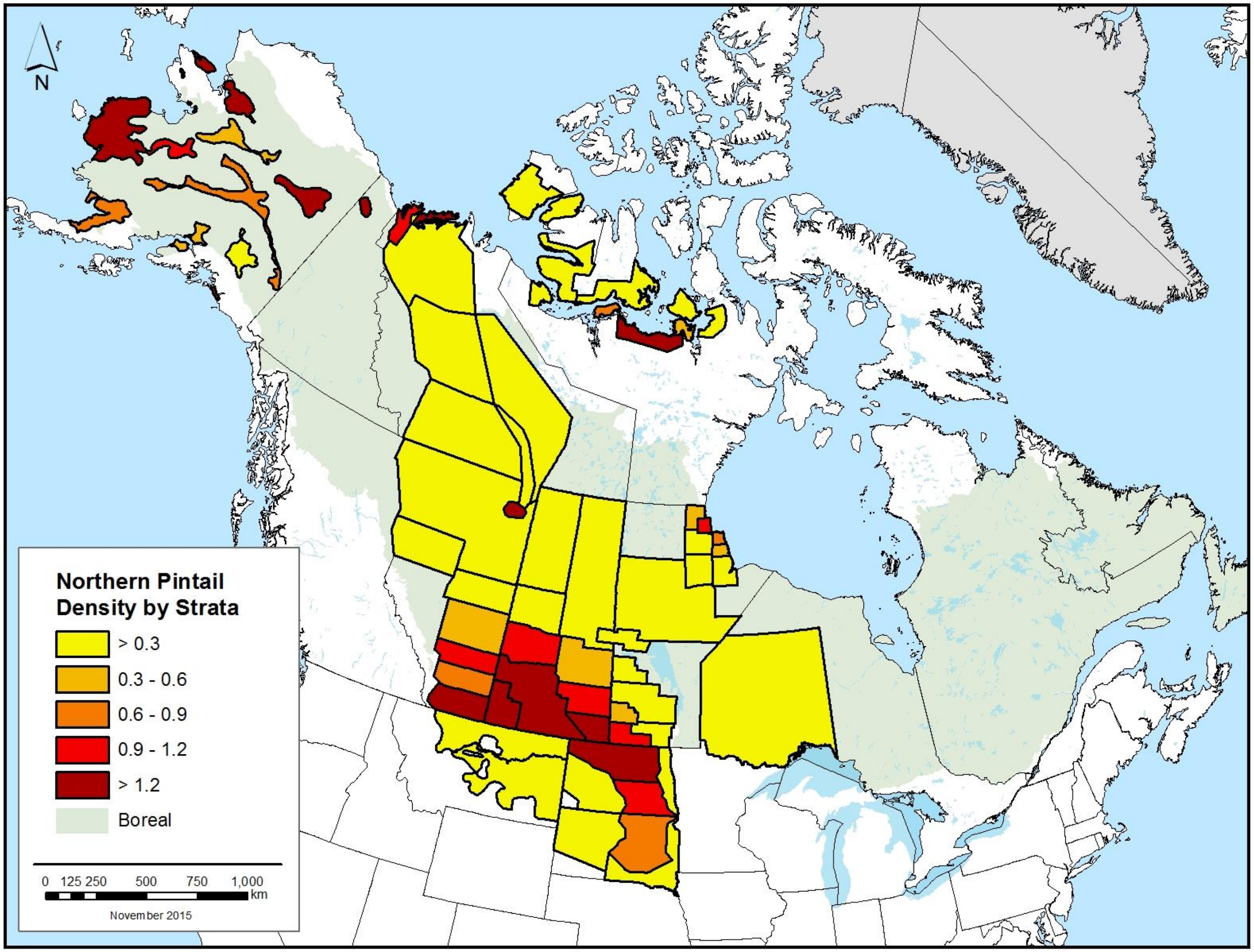

Figure 13. The average transect-level density of breeding season Northern Pintail in the Waterfowl Breeding Population and Habitat Survey, High Arctic, Eastern Prairie Population, and Seal River study area strata.

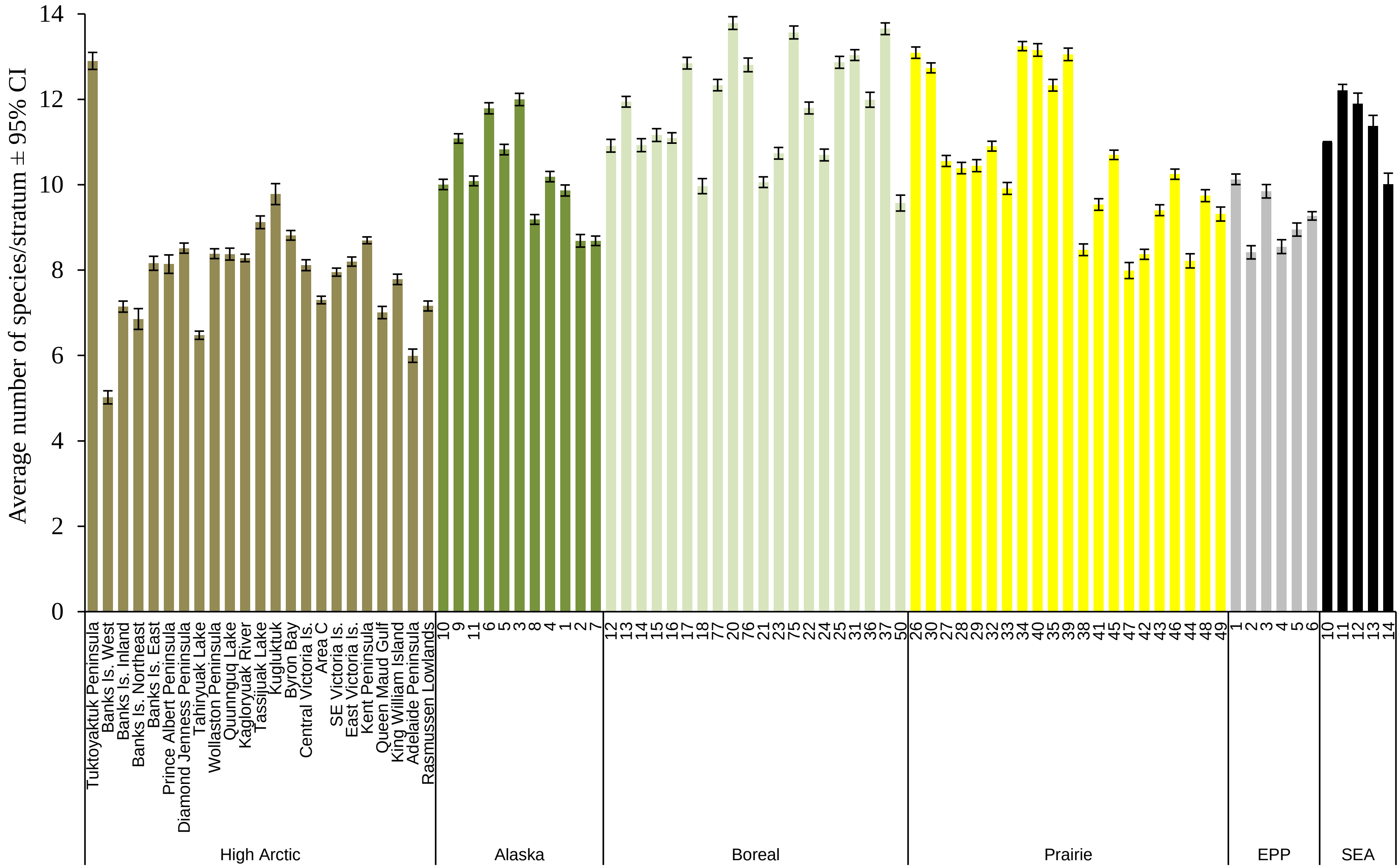

Figure 14. Average (± 95% CI) number of breeding season waterfowl species (ducks, geese, swans) per stratum as estimated from rarefaction. Strata within each regional grouping are roughly ordered NW to SE from left to right.

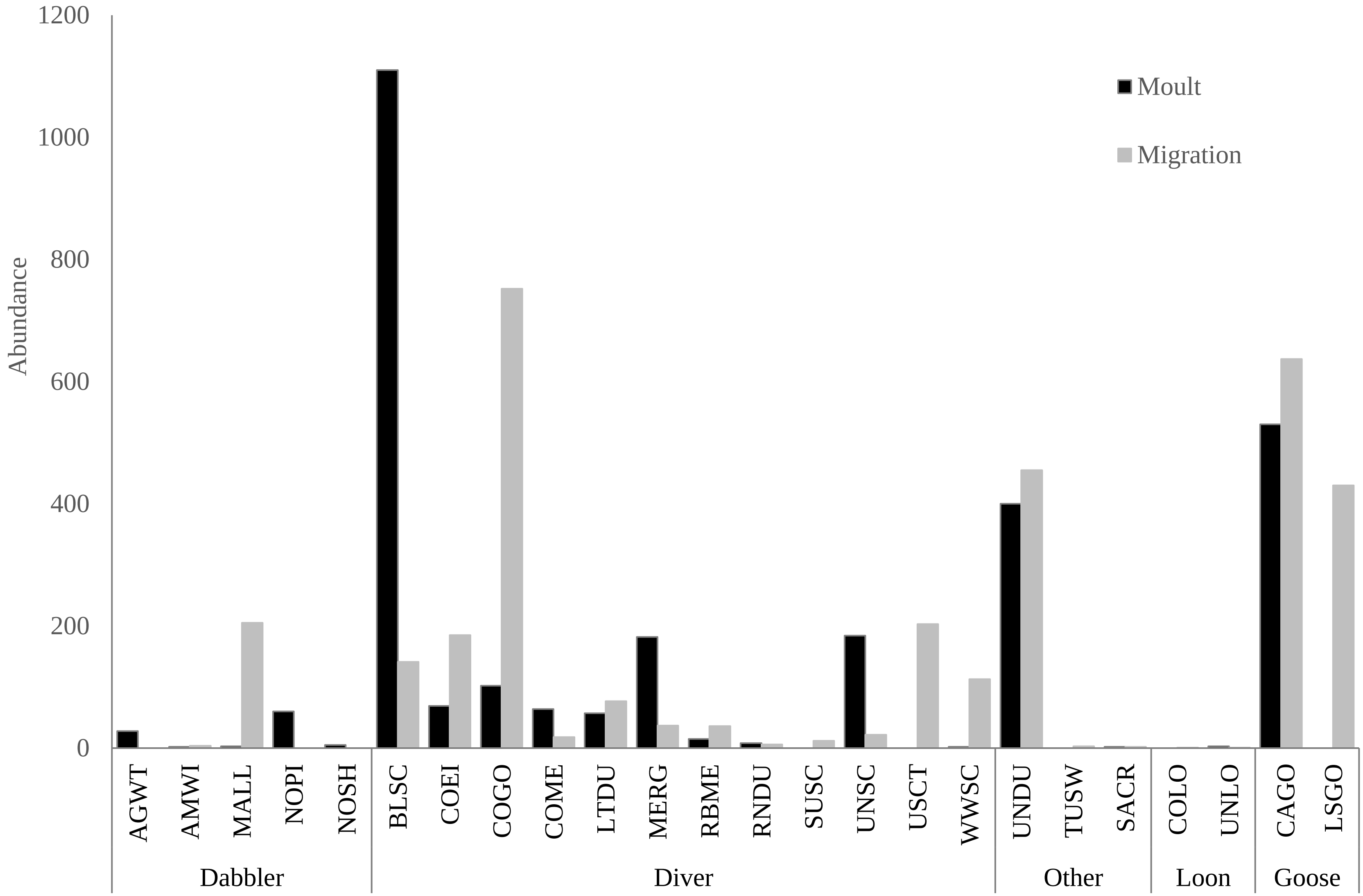

Figure 15. Total numbers of birds recorded on 433 km of transects located in nearshore waters (0 to 10 km offshore) between Churchill, MB, and the Manitoba-Nunavut border during the moult and migration periods of 2015 (Figure 4). MERG includes all merganser species (*Mergus*) that could not be further identified.

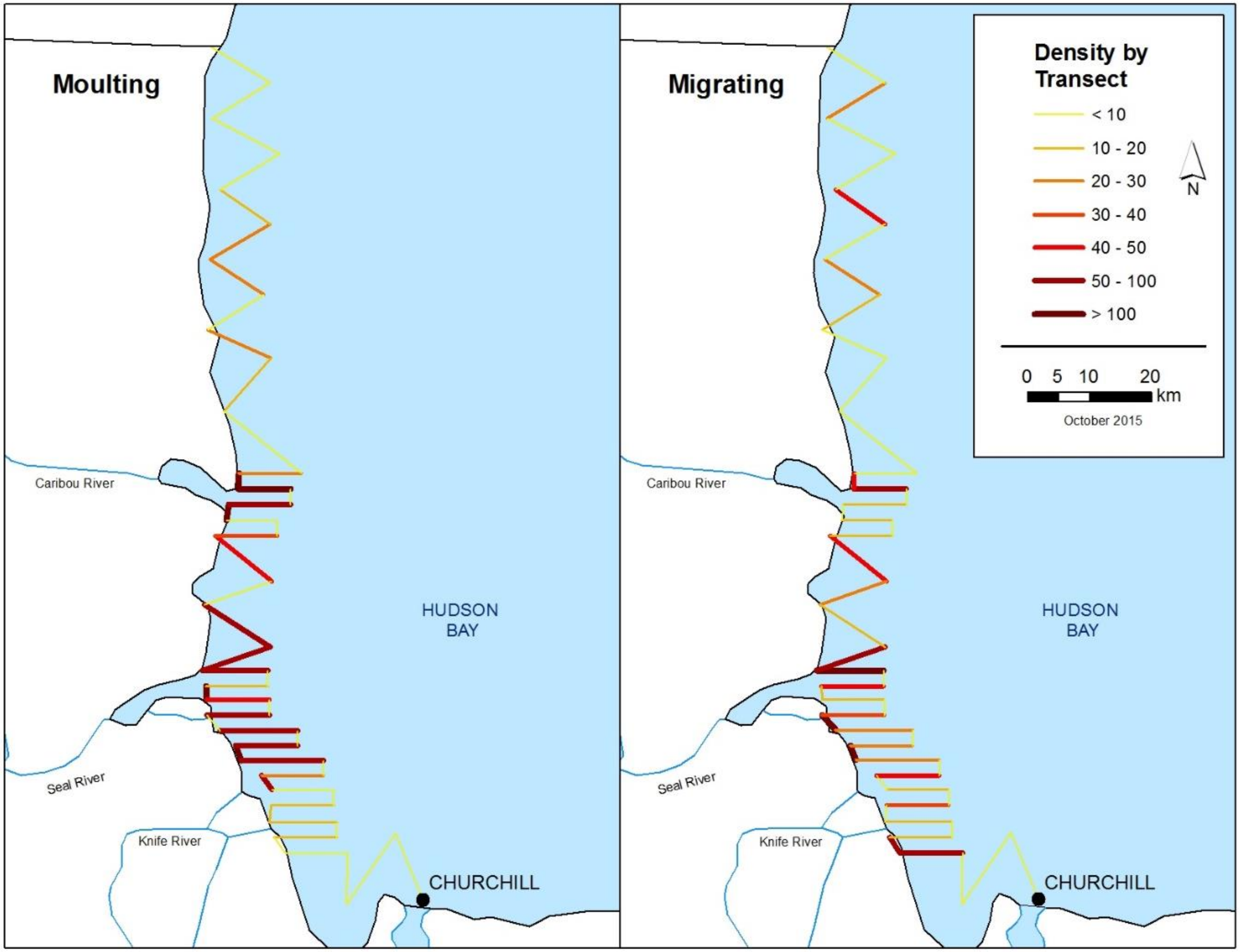

Figure 16. Density of all waterfowl (ducks, geese and swans) on each transect located in nearshore waters (0 to 10 km offshore) between Churchill, MB, and the Manitoba-Nunavut border during the moult (left pane) and migration (right pane) periods of 2015.