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Distribution and habitat use of Canada Goose (*Branta canadensis*) during spring and fall migration along the James Bay east coast

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Abstract

Canada Goose (*Branta canadensis*) is the main waterfowl harvested by Cree hunters in James Bay. Environmental changes that could affect the number, distribution, and migration patterns of geese have occurred along James Bay's east coast in the last 50 years, including isostatic rebound, climate warming, and hydroelectric development. We determined the spring and fall distribution of Canada Geese along the James Bay east coast in 2018 and identified habitats associated with the greatest goose densities. We conducted four helicopter surveys between Waskaganish and Chisasibi, two each during spring and fall. The main goose concentrations were between Eastmain and Wemindji in both seasons. In spring, goose densities increased with the percentage of salt marshes whereas in fall, the highest densities were in areas with the greatest proportion of tidal flats and turbid water. We did not find any relationships between Common Eelgrass (*Zostera marina* L.) beds and the distribution of Canada Geese although it was an important habitat for geese in the 1970s. Our observations are consistent with surveys conducted in the 1990s that found limited use of eelgrass beds by migrating geese. This suggests that geese may be using alternative habitats during migration following the decline of eelgrass beds reported by Cree land users and confirmed by ground surveys and remote sensing. Changes in distribution and habitat use of goose flocks along the James Bay east coast are probably a consequence of habitat changes, natural and human disturbances, and the increasing number of moult migrant temperate breeding Canada Goose (*Branta canadensis maxima*).

Key words: Aerial surveys; *Branta canadensis*; disturbance; Common Eelgrass; Eeyou Istchee; habitat use; James Bay; migration; Traditional Ecological Knowledge

Résumé

La Bernache du Canada (*Branta canadensis*) est la principale espèce de sauvagine récoltée par les chasseurs Cris de la Baie James. L'abondance, la distribution et les mouvements migratoires des bernaches ont certainement été affectés par les nombreux changements environnementaux qu'a connus la Baie James au cours des 50 dernières années, incluant l'ajustement isostatique, les changements climatiques et les développements hydroélectriques. Nous avons déterminé la distribution des bernaches du Canada le long de la côte est de la Baie James en 2018 et identifié les habitats associés avec les plus grandes densités de bernaches. Pour cela, nous avons mené quatre inventaires aériens entre Waskaganish et Chisasibi, deux au printemps et deux en automne. Au printemps, la densité des bernaches augmentait avec la proportion de marais salés alors qu'en automne, nous avons trouvé les plus grandes densités de bernaches dans les sections avec les plus grandes proportions de vasières et d'eaux turbides. Nous n'avons pas pu établir de relation entre les herbiers marins (*Zostera marina* L.) et la distribution des bernaches bien qu'ils aient constitué un habitat important pour les bernaches dans les années 1970. Nos observations sont cohérentes avec les inventaires menés dans les années 1990 qui ont permis de documenter une utilisation limitée des herbiers marins par les bernaches en migration. Cela suggère que les bernaches utilisent des habitats alternatifs au cours de leur migration depuis le déclin des herbiers marins rapporté par les communautés Cries et confirmé par des inventaires terrestres et la télédétection. Ces changements dans la distribution et l'utilisation des habitats par les bernaches du Canada sur la côte est de la Baie James sont probablement une conséquence de la modification des habitats, des perturbations humaines et naturelles, ainsi que du nombre croissant de bernaches résidentes (*Branta canadensis maxima*) en migration de mue.

Mots clés : Inventaires aériens; *Branta canadensis*; perturbation; Zostère; Eeyou Istchee; utilisation des habitats; Baie James; migration; Savoir traditionnel

Introduction

Canada Goose (*Branta canadensis*) is one of the main waterfowl species harvested by Cree hunters along the James Bay coasts and has been part of their subsistence hunting for centuries (Prevett *et al.* 1983; Berkes *et al.* 1994). The traditional annual spring goose break is important socially and culturally for all coastal communities in Eeyou Istchee, the Eastern James Bay Cree territory (Royer and Herrmann 2013). Canada Geese harvested along the James Bay east coast belong to two subspecies and four populations (Giroux *et al.* 2022). These include the Atlantic Population composed of *Branta canadensis interior* that breeds in northern Quebec with the largest concentrations on the Ungava Peninsula and winters along the Atlantic coast of the United States. The Southern Hudson Bay Population is also composed of *B. c. interior* that breeds in southwestern James Bay (Ontario) and southern Hudson Bay (Ontario and Manitoba) and winters in the Midwest states of the United States. The harvest includes temperate breeding geese (*Branta canadensis maxima*), including individuals from the Atlantic Flyway Resident Population and the Mississippi Flyway Giant Population. Geese from the three latter populations are harvested by Cree hunters as they undertake a moult migration to northern Quebec, most likely after nesting failure (Sorais *et al.* 2023). The *B. c. interior* and *B. c. maxima* subspecies are referred to as short-necked and long-necked geese by Cree hunters, respectively.

Cree land users have reported that fewer short-necked geese migrate along the James Bay east coast compared to the 1980s (Royer and Herrmann 2013; Idrobo *et al.* 2024). They also observed that the fall distribution of geese was less predictable now than in the 1980s when the birds were moving between the coast where they fed on Common Eelgrass *(Zostera marina* L.) and the adjacent tundra where they foraged for berries (Idrobo *et al.* 2024). The distribution of waterfowl along the east coast of James Bay was assessed in the early 1970s before hydroelectric development in Eeyou Istchee through a series of aerial surveys conducted by the Canadian Wildlife Service (Curtis and Allen 1976). In spring, sub-arctic breeding Canada Geese were found wherever there was open water with concentrations in all major bays along the entire east coast. In fall, the greatest numbers of Canada Geese were found north of Wemindji where they were reported to feed extensively on eelgrass beds (Curtis and Allen 1976). In the 1990s, Reed *et al.* (1996) conducted aerial and ground surveys along the northeast part of James Bay after completion of the first phase of the hydroelectric complex on La Grande River, which drains into James Bay. They found that sub-arctic breeding Canada Geese were feeding on different plant species including berries during their fall migration but made limited use of eelgrass beds.

Several environmental changes that occurred since the 1970s along the James Bay east coast might have affected the abundance and distribution of short-necked geese in the area. One noteworthy change observed by Cree land users (Peloquin and Berkes 2009; Dickey 2015; Idrobo *et al.* 2024) and confirmed by ground surveys (Leblanc *et al.* 2022) and remote sensing (Clyne *et al.* 2024) is the decline of eelgrass in subtidal meadows in the late 1980s and 1990s. This decline may have resulted from several environmental stressors including the development of hydroelectricity in Quebec's boreal region and ongoing climate change (Leblanc *et al.* 2022). Using satellite imagery from 1985 and 2020, Olatunji (2022) found an increase of deciduous forests, shrub fens, and shrub swamps that is likely related to the greening of sub-arctic regions of northern Canada (Davis *et al.* 2021; Leipe and Carey 2021). Also, isostatic rebound estimated at 10–12 mm/yr in James Bay (Henton *et al.* 2006) has resulted in a coastal raise of ~35–42 cm in the last 35 years. During this period, the area of tidal flats declined while those of salt marshes and freshwater wetlands increased (Olatunji 2022). In addition, it is estimated that several hundred thousand temperate breeding Canada Geese are now crossing James Bay during their moult migration (Sorais *et al.* 2023). This may also influence the distribution and habitat use of sub-arctic breeding geese during fall because their migration along the James Bay coast overlaps (Sorais *et al.* 2023) and competition between the two subspecies could occur (Ankney 1996; Abraham *et al.* 1999; Sheaffer *et al.* 2007; Luukkonen *et al.* 2008). In spring, short-necked geese (*B. c. interior*) migrate through James Bay before the long-necked geese (*B. c. maxima*; Sorais *et al.* 2023).

The objectives of our 2018 study were to use aerial surveys to update our knowledge of the distribution and habitat use of Canada Geese in Eastern James Bay during their spring and fall migration. Specifically, we assessed the density of geese along the James Bay east coast during migrations. Second, we determined how habitat composition influenced goose density on coastal habitats such as salt marshes, tidal flats, and eelgrass beds.

Methods

Study area

Our study took place in Eeyou Istchee, the territory of the Cree Nation in Quebec's boreal region. The territory covers ~400 000 km^2 and includes lands on the eastern shore of James Bay and southeastern Hudson Bay, as well as the lakes and rivers that drain into them. It is divided into formally recognized family hunting territories, referred to as traplines, the use of which is supervised by a tallyman designated by family members. Cree land user interests, including those of tallymen, are represented at the local and regional level by the Cree Trappers Association. We conducted aerial surveys along ~250 km of coast from Waskaganish to Chisasibi (Figure 1). The coast is highly sinuous with numerous bays, points, and peninsulas fringed by numerous islands, islets, and reefs (Dignard *et al.* 1991). The area is generally low, alternating between flat, gradually sloping shorelines and rockier, hilly shores. Subtidal meadows are characterized by Common Eelgrass beds that vary in density and biomass in time and space (Lalumière *et al.* 1994; Leblanc *et al.* 2022). Vast stretches of mud and sand tidal flats are found on the mainland shore with salt marshes occurring inshore. Islands and exposed points are usually covered by heath with lichens and ericaceous shrubs. White Spruce (*Picea glauca* (Moench) Voss) is the dominant species on the coastline, replaced by Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) in interior forests (Dignard *et al.* 1991).

Aerial surveys

We conducted two aerial surveys during each of the spring and fall migration of Canada Geese in 2018. We used a Eurocopter AStar 350 helicopter (Airbus Helicopter, Marignane, France) flying from south to north ~100 m above ground along the coastline. We focussed mainly on the shoreline and estimated a maximum width of our observation corridor to be ~500 m on each side of the flight path. Each survey was completed during a single day with low to moderate winds and clear conditions. The spring surveys were 3.6 hr (6 May) and 3.8 hr (13 May) in duration, and occurred between 8 am and 3 pm at an average speed of 140 km/hr. The fall surveys were 5.9 hr (16 September) and 6.2 hr (23 September), and occurred between 7 am and 7 pm at an average speed of 100 km/hr. A few traplines were not surveyed to respect the will of tallymen who were concerned that the helicopter would disturb the geese and consequently their hunting activities. Hence, the number of traplines and distance travelled by helicopter varied among surveys. The same pilot, principal observer, and navigator flew on the four surveys although there was a different second observer assistant from the Cree community for each survey. We recorded the location of the helicopter when a flock of Canada Geese was detected regardless of the distance from the flight path and recorded the number of individuals using the software Avenza Map (Avenza Systems Inc., Toronto, Ontario, Canada) on a tablet computer. The helicopter followed a straight flight path without circling above flocks to avoid disturbing hunting activities. We recorded the flight path of each survey (Figure 1) using a global positioning system (GPS) device. We calculated a goose density index as the number of geese counted in a section of coast divided by the length of the flight path in km within the section.

Habitat mapping

We produced a 15-m resolution habitat map of the east coast of James Bay by classifying a combination of optical and synthetic-aperture radar (SAR) satellite imagery. We acquired optical imagery from the US Landsat-8 Operational Land Imager satellite and SAR imagery from the European Sentinel-1B satellite in 2017, 2018, and 2020 for spring, summer, and fall to consider the phenological stages of the vegetation (Tables S1, S2). The detailed procedure for image classification can be found in Clyne *et al.* (2021) and Sorais *et al.* (2023). Briefly, we re-projected Landsat-8 and Sentinel-1 raw images to a 15-m pixel resolution using the Pansharpening module of PCI Geomatica Banff (PCI, Ontario, Canada). We used the "randomForest" package in R software (version 4.3.3; R Development Core Team 2021) for applying Random Forests to the images, a non-parametric decision tree type supervised classifier that requires delineation of training areas (Breiman 2001). A total of 555 randomly distributed training polygons of 23 classes were delineated from photointerpretation of high spatial resolution (32 to 65-cm pixel size) optical satellite images obtained from the ArcGIS archive (Figures S1–S10). The photointerpretation was also guided by pictures taken in the field by A.L. in 2019 (Figures S1–S10). We further processed the resulting classified images with ArcGIS Pro (ESRI, California, USA) to produce a map with 15 habitat types of which 10 were considered to have potential to explain the density of Canada Geese based on Cree traditional knowledge (Dickey 2015) and field observations of Dignard *et al.* (1991) and Reed *et al.* (1996; Table 1).

Modelling goose density

We wanted to determine if goose density was influenced by the habitats on the coast. Because geese can move a few km between their resting and feeding

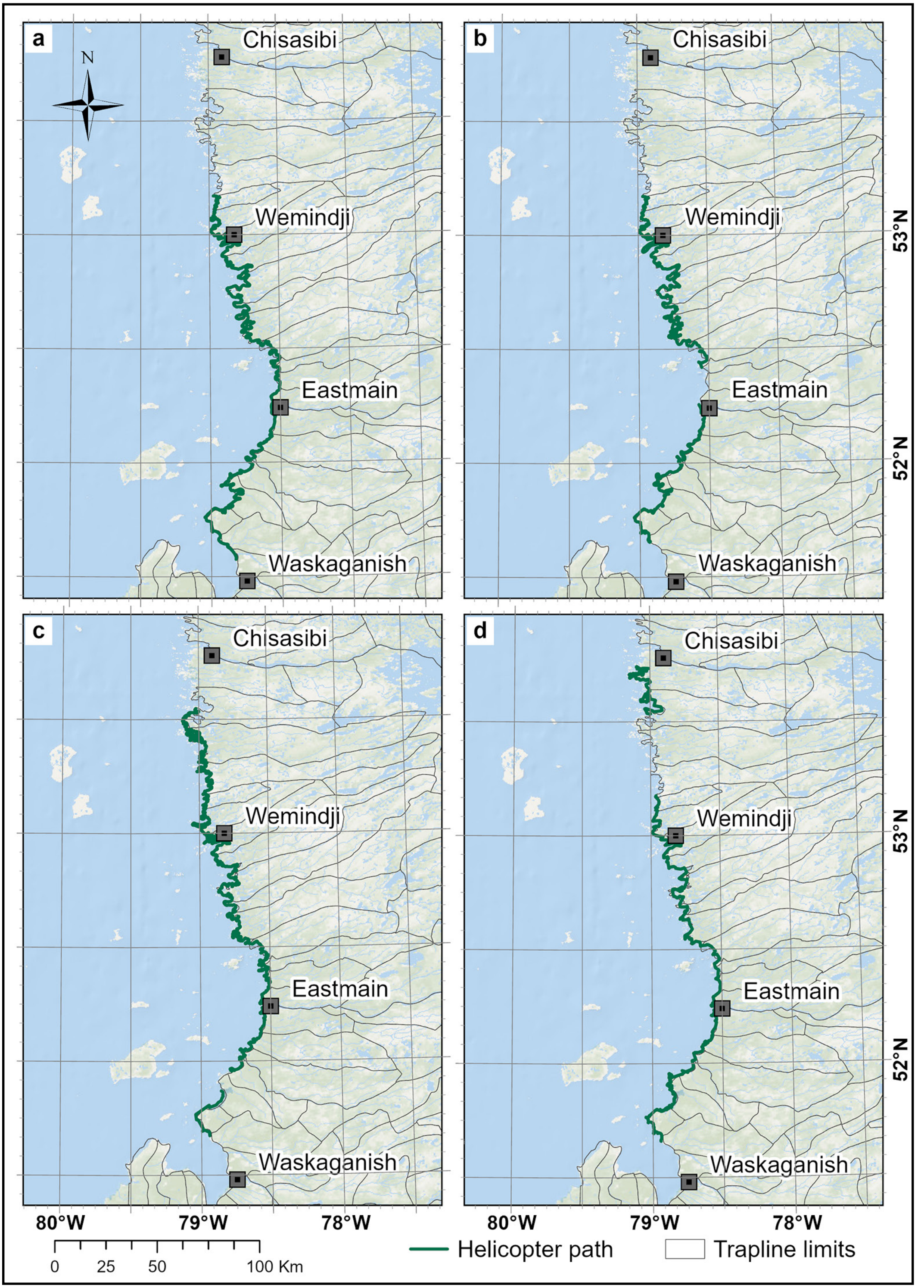

FIGURE 1. Helicopter flight paths (dark green line) during the aerial surveys along the James Bay east coast in spring (a: 6 May, b: 13 May) and fall 2018 (c: 16 September, d: 23 September). Traplines are delimited by grey lines.

TABLE 1. Characteristics of 10 habitats used to establish relationships with the density of Canada Geese (*Branta canadensis*) surveyed along the James Bay east coast. Photos and satellite images of each habitat are shown in Figures S1–S10.

Habitat	Description	References
Eelgrass bed (Figure S1)	Vegetation submerged in coastal shallow water dominated by Common Eelgrass (*Zostera marina* L.). Other plants like *Ruppia* spp. and *Potamogeton* spp. are also reported. Use by Canada Geese as a feeding habitat during fall and spring when ice-free.	Dignard *et al.* (1991); Dickey (2015)
Turbid water (Figure S2)	Turbid open water often observed in river estuaries with important amount of transported mineral and organic particles. The presence of submerged vegetation remains undetected. Potential use by Canada Geese as feeding habitat.	Clyne *et al.* (2021)
Shallow water (Figure S3)	Open water with a depth <3 m. Vegetation can be found at the surface of inland bodies of shallow water. Use by Canada Geese as a resting habitat during fall and spring when ice-free.	Dignard *et al.* (1991); Sorais *et al.* (2023)
Tidal flat (Figure S4)	Unvegetated habitat located between minimum and maximum limits of sea level consisting of mud and sand. Use by Canada Geese as a resting habitat during fall and spring when ice-free.	Dignard *et al.* (1991); Sorais *et al.* (2023)
Cobble beach (Figure S5)	Unvegetated habitat located in the upper part of the foreshore consisting mainly of coarse rocks. Use by Canada Geese as a resting habitat during fall and spring when ice-free.	Dignard *et al.* (1991); Sorais *et al.* (2023)
Salt marsh (Figure S6)	Coastal wetlands dominated by low-lying vegetation including Chaffy Sedge (*Carex paleacea* Schreber ex Wahlenberg), Four-leaved Mare's Tail (*Hippuris tetraphylla* L. f.), Needle Spikerush (*Eleocharis acicularis* (L.) Roemer & Schultes), and Marsh Arrowgrass (*Triglochin palustris* L.). This habitat is periodically flooded by saltwater. Use by Canada Geese as a feeding habitat during spring and fall.	Dignard *et al.* (1991); Reed *et al.* (1996)
Freshwater wetland (marsh, open fen, string fen; Figure S7)	Freshwater marshes dominated by low-lying vegetation such as *Carex* spp., open fen with *Carex* spp., and moss permanently saturated with stagnant freshwater, and string fen characterized by an alternance of elevated ground strings and narrow depressions. Potential use by Canada Geese as feeding habitat but data are limited.	Dignard *et al.* (1991)
Tundra (Figure S8)	Heath habitat covered by low-lying vegetation, including Black Crowberry (*Empetrum nigrum* L.) and Mountain Cranberry (*Vaccinium vitis-idaea* L.), associated with subarctic vegetation such as lichens, mosses, herbaceous plants, and shrubs. This habitat is found along the coast above the high-water limits and further inland in the northern part of the study area. Use by Canada Geese as a feeding habitat in fall and to a lesser extent in spring.	Dignard *et al.* (1991); Reed *et al.* (1996)
Deep water (Figure S9)	Open water with a depth >3 m without vegetation. Potential use by Canada Geese as resting habitat during fall and spring when ice-free.	Dignard *et al.* (1991)
Peatland (open bog, muskeg; Figure S10)	Wetland dominated by low-lying vegetation, mainly moss, growing on an organic soil. Potential use by Canada Geese.	Sorais *et al.* (2023)

areas during the day, we wanted to characterize the habitats found in the vicinity of goose observations (i.e., geese were observed at a maximum of 500 m from the helicopter). We assessed the relationship between goose density and habitat coverage using two approaches based on different types of sampling units. The first approach was based on trapline limits because this was relevant for resource management in the coastal communities. Because traplines represent inland geographic entities and we were interested in coastal habitats, we extended trapline limits into the bay following the latitude at the junction between two traplines (Figure 2a,b). For each survey, we set longitudinal limits of trapline sections at 5 km on each side of the flight path. We calculated goose density within each trapline section, as well as the proportion of the 10 potential habitats for geese such as Common Eelgrass beds, tidal flats, and salt marshes (Table 1).

The second approach was based on smaller sampling units that maximized variation in goose density and increased sample sizes (Figure 2c,d). To establish these sampling units, we first created a 1-km wide buffer on each side of the flight path. We then sectioned these buffers every 2 km along the latitudinal axis (south to north). We selected this section length because it maximized the coefficient of variation of

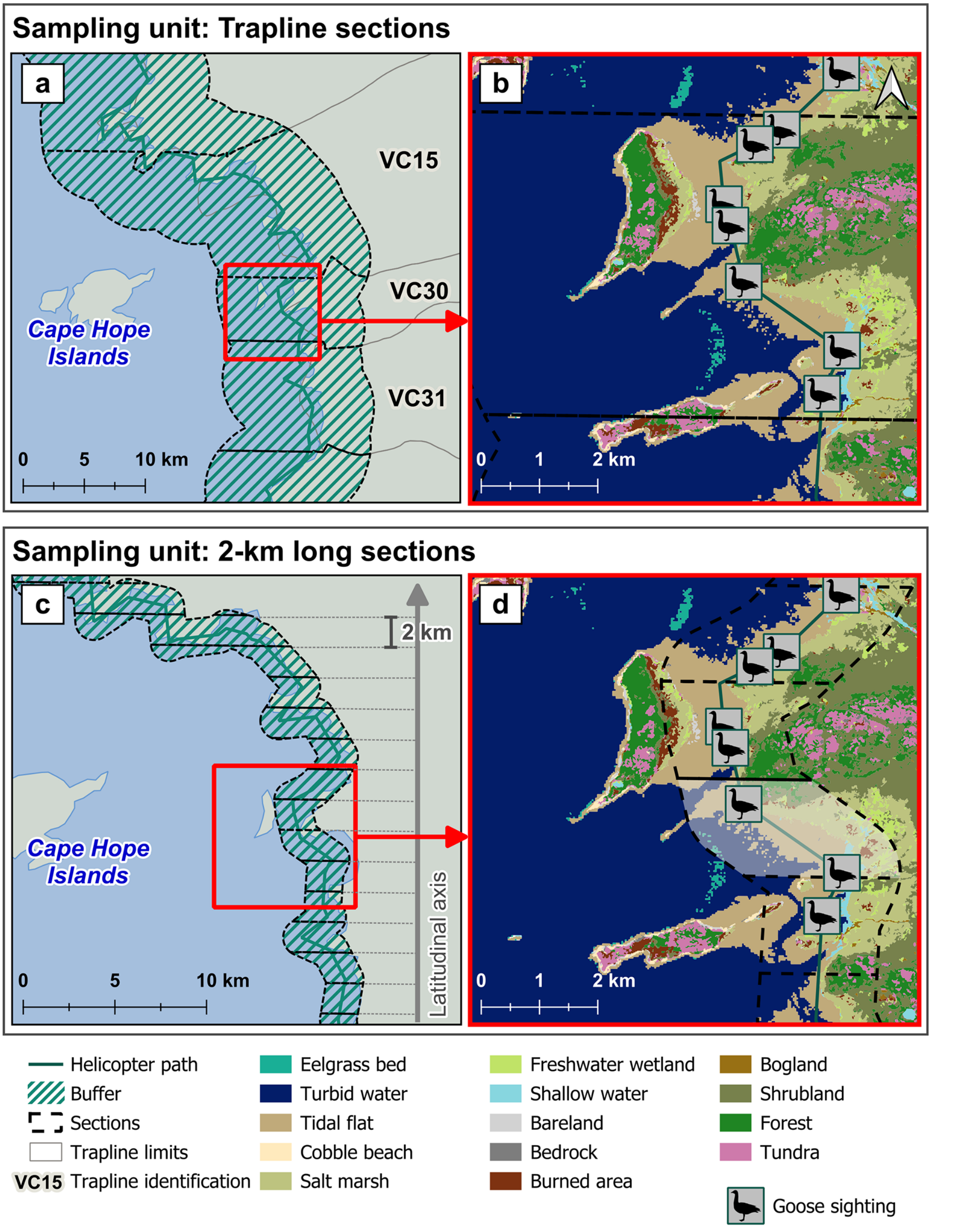

FIGURE 2. Illustration of the two types of sampling units used to study the relationship between Canada Goose (*Branta canadensis*) density and habitats: trapline sections (a, b) and 2-km long sections (c, d). a. A 5-km buffer was delimited on each side of the helicopter flight path and divided into sections following trapline limits that were extended towards the bay. b. Example with the 23 September 2018 goose survey for trapline VC30 and the eelgrass habitat: flight distance = 6941 m; *n* observed geese = 1055; goose density = 152 geese/km; percentage of the section covered by eelgrass beds = 0.2 %. c. A 1-km buffer was delimited on each side of the same helicopter flight path and divided into sections every 2 km following the latitudinal axis. d. Example for the highlighted section: flight distance = 24 501 m; *n* observed geese = 775; goose density = 300 geese/km; percentage of the section covered by eelgrass beds = 0.5 %. Note: these sampling units were used to characterize goose density and the habitats in the vicinity of goose observations. As such, the buffers were established to create trapline sections and 2–km long sections extended beyond the 500-m maximum observation corridor on either side of the helicopter.

goose density among sections when comparing section lengths ranging from 2 to 50 km (Figure S11). We therefore used these 2-km long sections to assess the association between goose density and the proportion of the habitats within each section.

Using these two different sets of sampling units allowed us to analyze goose density variation at a coarse scale (i.e., traplines sections) and finer scale (i.e., 2-km long sections). Because the helicopter followed the coastline as much as possible during each survey, we considered the longitudinal variation between the flight paths to be negligible (Figure 1). However, the length of the flight path differed between surveys based on the number of traplines that we were authorized to fly over at the time. As such, for calculating the Pearson correlation of goose density in traplines between two different surveys, we only considered traplines that we flew during both surveys.

We assessed the relationship between goose density and habitat composition for each survey at the scale of traplines and 2-km long sections. Sample sizes varied among analyses because not all traplines or 2-km long sections were covered during the four surveys. At the trapline scale, we fit multiple linear regressions models to explain the log transformed goose density, i.e., log(density + 1), as a function of the proportion of each potential habitat in the trapline. Using the 2-km long sections, we used two approaches to analyze goose density. Geese were absent in 35–80% of sections according to surveys, which skewed the goose density distribution towards maximum values similar to a Poisson distribution. However, because we wanted to be able to analyze this absence/presence phenomenon, we decided to analyze the presence/absence in sections and the density in occupied sections with geese separately. Hence, we first fit logistic regression models to explain the presence/absence of geese as a function of the proportion of the different habitats in each section. Next, we used the subset of sections where geese were present and fitted a multiple regression model to explain the log-transformed goose density as a function of the proportion of each habitat. For each modelling procedure, we determined the best model using a stepwise approach by testing model performance that maximized R^2 ensuring that predicting variables included in a model were not strongly correlated (Pearson correlation coefficient < 0.6). We verified homoscedasticity and normality of residuals by performing visual diagnosis. We performed statistical analyses using R software (version 4.3.3; R Development Core Team 2021). We used the "ggplot2" package to create graphic representations. We used ArcGIS Pro (ESRI, California, USA) and QGIS 3.34 Prizren (QGIS 2023) for mapping.

Results

Our first spring survey (6 May) occurred before the peak migration of Canada Geese in James Bay as shown by the low number of geese counted ($n = 815$) compared to the number tallied one week later ($n = 11\,332$ on 13 May). We saw no major concentration of geese during the first survey, but we recorded the greatest densities between Eastmain and Wemindji during the second (Figure 3). We found no correlation in goose density calculated within traplines between the first and second survey (Pearson $r_{15} = 0.22$; $P = 0.40$). The presence/absence of geese in 2-km long sections was not significantly influenced by the proportion of any habitat for both surveys. Moreover, we did not find any relationship between goose density estimated during the first survey and habitat composition using either traplines or 2-km long sections. For the second spring survey, however, goose density increased with the percentage of salt marshes in traplines ($F_{1,15} = 8{,}37$; $R^2 = 0.32$; $P = 0.01$) and in 2-km long sections ($F_{1,51} = 10.27$; $R^2 = 0.15$; $P < 0.01$; Figure 4).

The fall surveys were better synchronised with the Canada Goose migration with 8458 and 11 057 birds counted on 16 and 23 September, respectively (Figure 5). We saw the greatest densities in traplines just north of Eastmain. There was a weak correlation in the density of geese between the two fall surveys (Pearson $r_{17} = 0.42$; $P = 0.07$) indicating that some traplines may have been more attractive for geese than others, at least during the period when the two surveys were conducted. However, neither the first fall survey (Pearson $r_{15} = -0.25$; $P = 0.33$) nor the second (Pearson $r_{15} = -0.02$; $P = 0.93$) correlated with the second spring survey, in terms of density in traplines. The presence/absence of geese in 2-km long sections was not significantly influenced by the proportion of any habitats during the two fall surveys. Goose density in traplines increased significantly with the proportion of turbid water ($F_{1,19} = 16.79$; $R^2 = 0.44$; $P < 0.01$) during the first survey and with the proportion of tidal flats ($F_{1,18} = 8.86$; $R^2 = 0.29$; $P = 0.01$) during the second survey (Figure 4). In 2-km long sections, goose density increased with the proportion of tidal flats and turbid water during the first survey ($F_{2,78} = 15.59$; $R^2 = 0.27$; $P < 0.01$). During the second survey, it also increased with tidal flats but slightly decreased with the proportion of freshwater wetlands ($F_{2,73} = 13.68$; $R^2 = 0.25$; $P < 0.01$; Figure 4).

Discussion

These surveys determined how Canada Geese were distributed along the eastern coast of James Bay in spring and fall 2018. Although we could not distinguish between subspecies, most geese counted

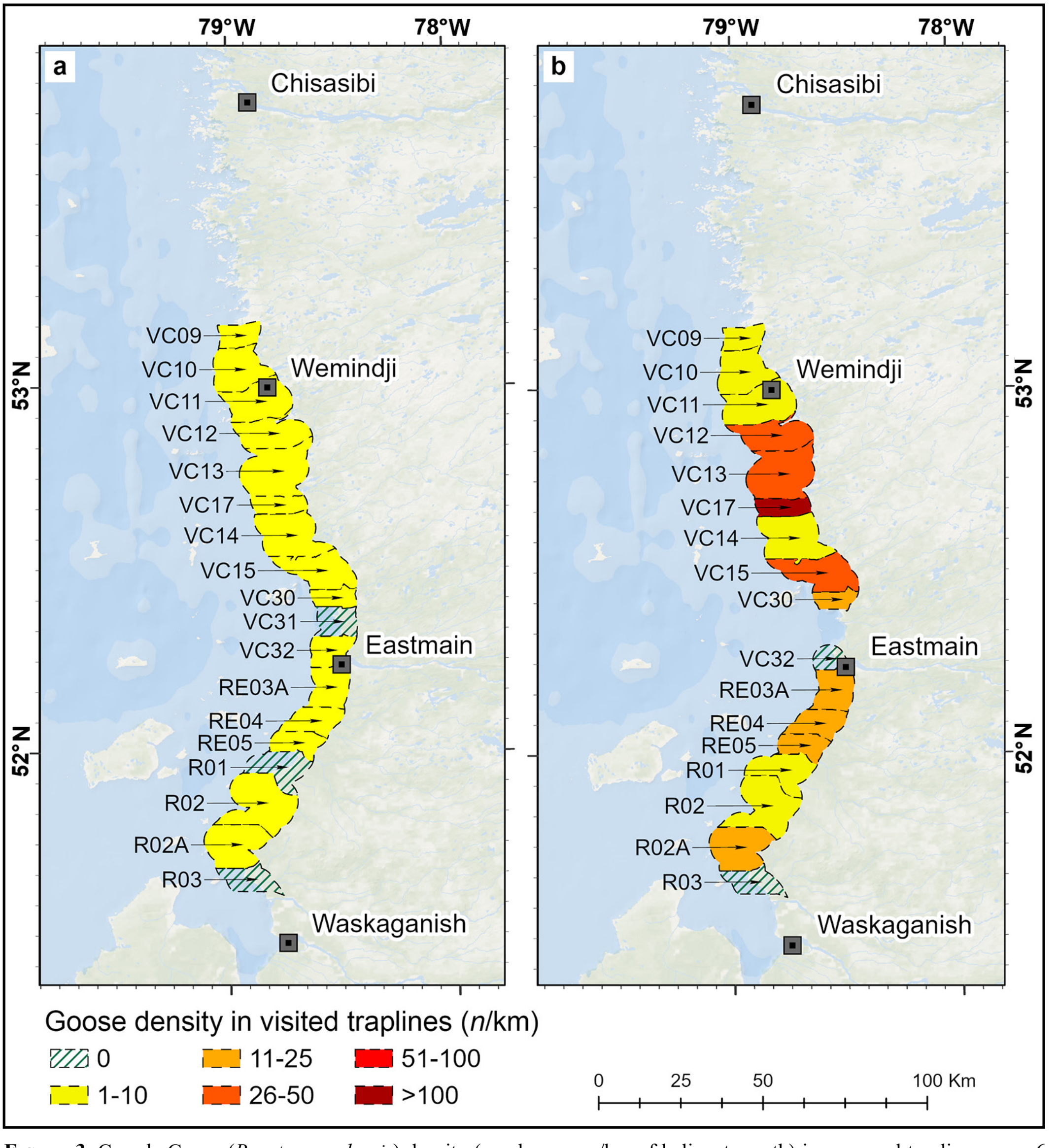

FIGURE 3. Canada Goose (*Branta canadensis*) density (number geese/km of helicopter path) in surveyed traplines on a. 6 and b. 13 May 2018 along the James Bay east coast. Traplines surveyed are identified by their Cree Trappers' Association numbers.

during the spring surveys in May were likely sub-arctic breeding geese because temperate breeding geese that migrate north to moult arrive in James Bay in early June after our surveys (Sorais *et al.* 2023). In fall, however, both subspecies migrate through the area in September and can sometimes be found on the same staging sites as shown by the simultaneous capture of the two subspecies in Boatswain Bay near Waskaganish (Sorais *et al.* 2023). Hence, geese counted in fall were most probably a mixture of the two subspecies. However, several aspects of our study prevented us from drawing general habitat use patterns during goose migration. The spring of 2018 was late and characterized by extensive snow cover persisting throughout northern Quebec, and in particular across the main breeding grounds of the Atlantic Population of Canada Geese (Harvey *et al.* 2018). Consequently, the annual production of juveniles was nearly absent and the worst since 1997 (Lefebvre and Orichefsky 2020). Our results therefore reflect

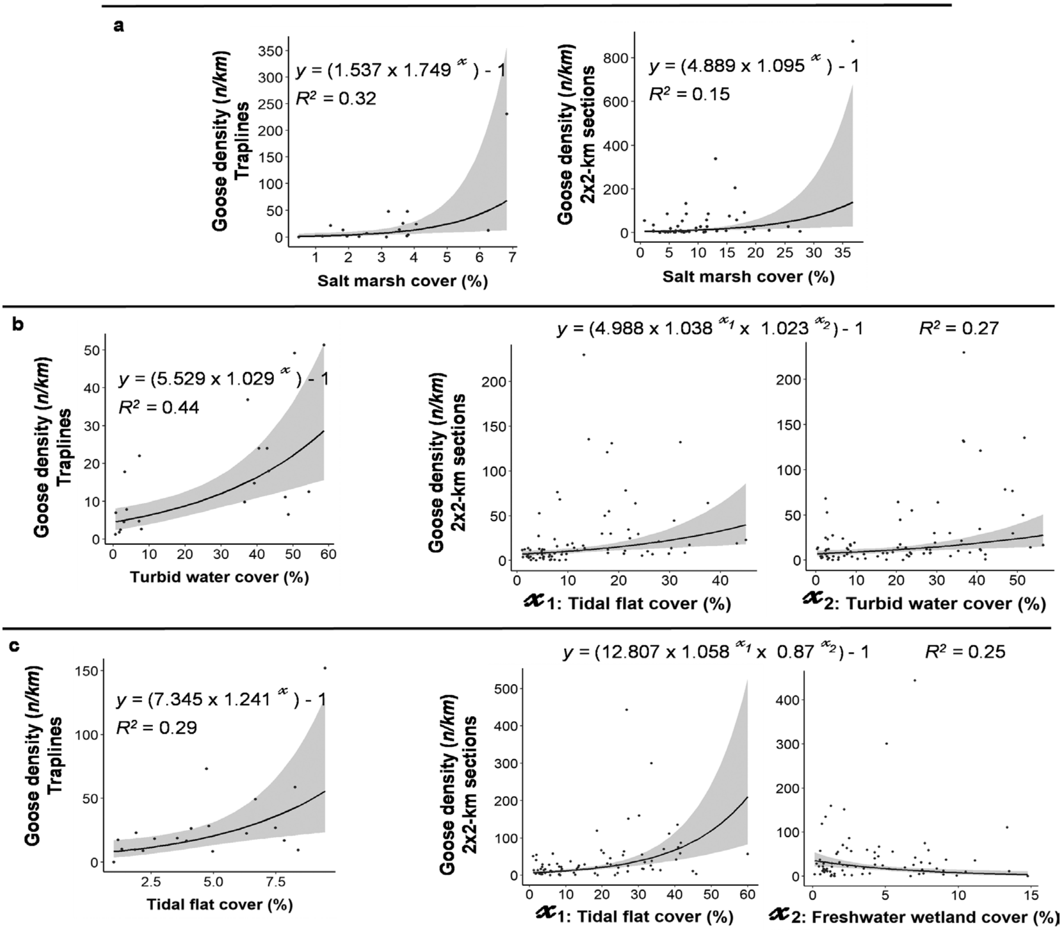

FIGURE 4. Relationships between habitat composition and the density of Canada Geese (*Branta canadensis*) in traplines and 2-km long sections surveyed on a. 13 May, b. 16 September, and c. 23 September 2018.

conditions prevailing during a late spring and in presence of very few juveniles during the fall migration. During both seasons, we saw the greatest concentrations of geese between Eastmain and Wemindji. Unfortunately, our coverage of the coast was incomplete, especially in traplines north of Chisasibi. Nevertheless, our surveys enabled us to highlight some associations between goose density and different coastal habitats.

In spring, the proportion of salt marshes in traplines and in 2-km long sections was the only significant predictor of Canada Goose density. While it explained little variation in goose density ($R^2 = 0.15$), this result is consistent with the observations of Curtis and Allen (1976) along the entire east coast and Reed *et al.* (1996) in the northeastern portion of the bay. The GPS tracking of temperate breeding geese has also shown that moult migrants used salt marshes when staging along the James Bay east coast in spring (Sorais *et al.* 2023). Reed *et al.* (1996) reported that Canada Geese consumed a wide variety of plants during their spring migration including Chaffy Sedge (*Carex paleacea* Schreber ex Wahlenberg), Needle Spikerush (*Eleocharis acicularis* (L.) Roemer & Schultes), Four-leaved Mare's Tail (*Hippuris tetraphylla* L. f.), and Marsh Arrowgrass (*Triglochin palustris* L.) found in salt marshes that are among the first habitats to become available after ice melt in May.

In fall, the greatest goose densities occurred in traplines and 2-km long sections that had a greater proportion of tidal flats and turbid water. The use by Canada Geese of tidal flats where vegetation wrack accumulates was also reported by Curtis and Allen (1976) and Reed *et al.* (1996). The latter suggested

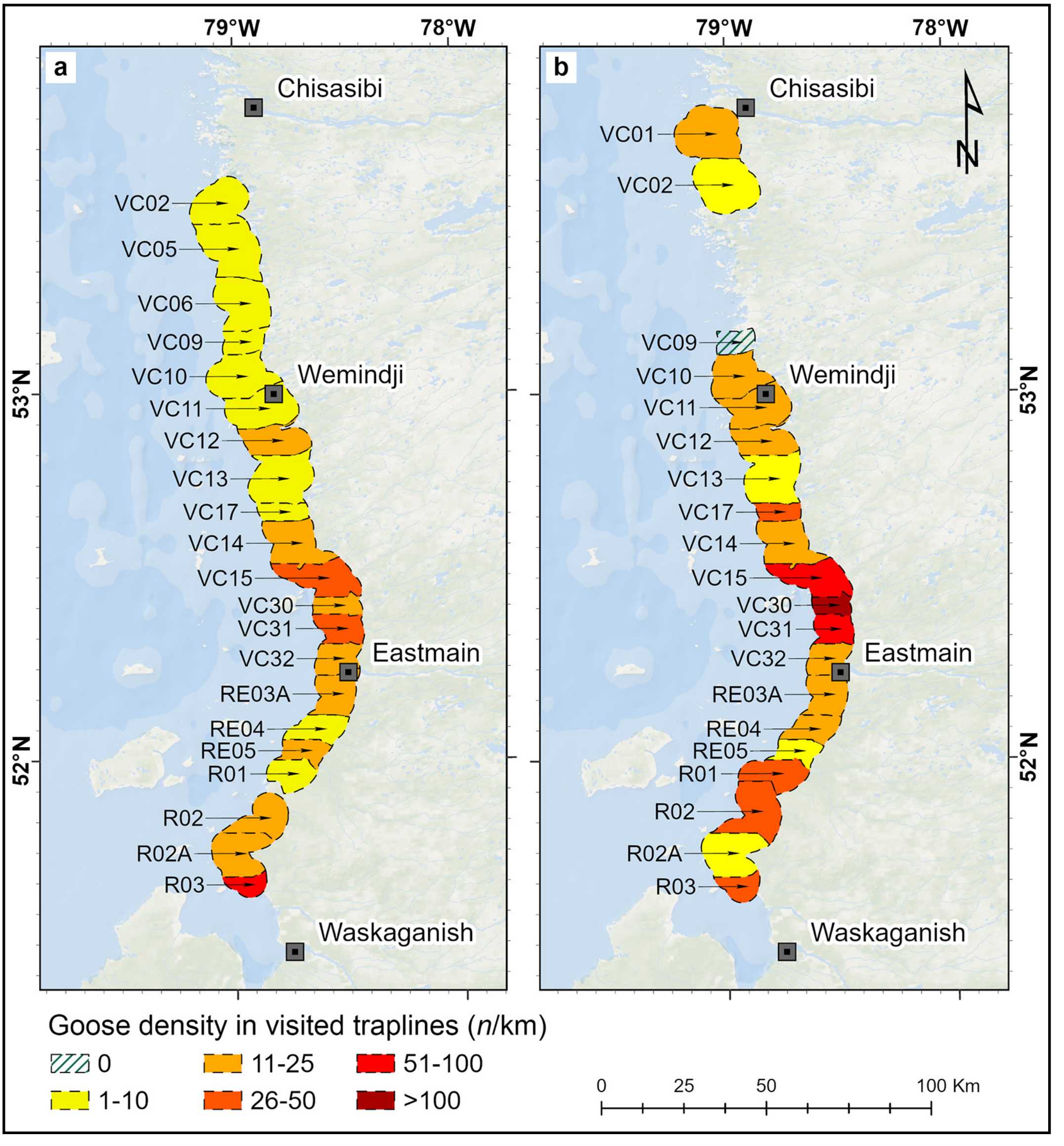

FIGURE 5. Canada Goose (*Branta canadensis*) density (number of geese/km of helicopter path) in surveyed traplines on a. 16 and b. 23 September 2018 along the James Bay east coast. Traplines surveyed are identified by their Cree Trappers' Association number.

that the presence of geese in tidal flats was likely due to their proximity to salt marshes where geese were feeding. The lower portions of salt marshes are dominated by Creeping Alkaligrass (*Puccinellia phryganodes* (Trinius) Scribner & Merrill; Dignard *et al.* 1991), a food item found in the stomach contents of geese examined by Reed *et al.* (1996). However, unlike in spring, we failed to find a relationship between goose density and the proportion of salt marshes in traplines or in 2-km long sections. This could suggest that tidal flats are currently used for resting more than for feeding during fall, thus reducing the importance of salt marshes.

The relationship between goose density in fall and turbid water is not obvious. While this habitat could be used by geese for resting, it may also support submerged vegetation that could not be detected by remote sensing due to murky water. Indeed, eelgrass has been observed by scuba divers at control points in the turbid water habitat (Clyne *et al.* 2024). However, we found no relationship between goose density and the proportion of traplines or 2-km long sections covered by clearly identified eelgrass beds. This contrasts with the observations of Curtis and Allen (1976) who reported extensive use of eelgrass by Canada Geese in fall in the early 1970s, which has been widely corroborated by Cree hunters (Ettinger *et al.* 1995; Peloquin and Berkes 2009; Dickey 2015; Idrobo *et al.* 2024). However, our results are consistent with those of Reed *et al.* (1996) who reported no eelgrass in stomach contents of Canada Geese sampled in the 1990s in northeastern James Bay.

We did not find any association between goose density and the tundra habitat that was previously reported to provide food resource, such as berries of blueberry (*Vaccinium* spp.) and Black Crowberry (*Empetrum nigrum* L.; Reed *et al.* 1996). Cree land users have reported a general decline of berry production in Eeyou Istchee in recent years (Idrobo *et al.* 2024). Moreover, 2018 may have been a year of particularly poor production due to the very late spring. Also, subarctic greening induced by climate warming has reduced the area covered by the tundra habitat (Olatunji 2022).

Finally, we were not expecting a negative relationship between goose density and the proportion of freshwater wetlands in 2-km long sections during the second fall survey because Sorais *et al.* (2023) found that moult migrants were commuting between inland freshwater wetlands and coastal habitats. However, it is possible that freshwater wetlands along the coastline, within 1 km on each side of the helicopter flight path, were more exposed and less suitable for resting and feeding than those further inland.

Conclusion

This study is a description of the distribution of Canada Geese during their spring and fall 2018 migration in Eastern James Bay. It is a reference point in the long-term monitoring of this waterfowl species in a region where and on which local communities strongly rely. Cree hunters of the coastal communities partially attribute their reduced Canada Goose harvest compared to the 1980s to the fact that short-necked geese modified their habitat use strategy (Idrobo *et al.* 2024). We wanted to better understand the relationship between goose distribution and the different habitats available along Eastern James Bay during spring and fall migration. However, we found that habitat composition only partly explains the density of Canada Geese along James Bay east coast. Moreover, because we could not explain the presence/absence of geese in traplines nor in 2-km long sections suggests that their distribution is driven by factors other than those we considered. Several land users suggested that the increasing presence of Bald Eagle (*Haliaeetus leucocephalus*) and increasing use of helicopters for travelling to hunting camps are disturbances that contribute to modifying the distribution of geese along James Bay east coast (Idrobo *et al.* 2024). Also, we did not consider how the distance from human settlements or hunting pressure could factor into explaining the presence/absence of geese along the coast. Finally, the increasing number of moult-migrant long-necked Canada Geese in this area since the 1980s (Giroux *et al.* 2022) could affect habitat use by short-necked geese. It is possible that when using habitats with a diversity of food resources during the fall migration, moult migrant temperate geese act as decoys and attract subarctic breeding geese to these habitats (Sorais *et al.* 2023). Tracking of individual subarctic breeding geese, as has occurred with temperate breeding geese (Sorais *et al.* 2023), would help to better understand the distribution and habitat use by Canada Geese along the James Bay east coast.

Author Contributions

Writing – Original Draft: M.S. and J.-F.G.; Writing – Review & Editing: M.P.-M., B.L., and A.L.; Conceptualization: J.-F.G. and M.P.-M.; Investigation: M.S., M.P.-M., B.L., and A.L.; Formal Analysis: M.S., A.L., and B.L.; Funding Acquisition: J.-F.G.

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Literature Cited

Abraham, K.F., J.O. Leafloor, and D.H. Rusch. 1999. Molt migrant Canada Geese in northern Ontario and western James Bay. Journal of Wildlife Management 63: 649–655. https://doi.org/10.2307/3802654

Ankney, C.D. 1996. An embarrassment of riches: too many geese. Journal of Wildlife Management 60: 217–223. https://doi.org/10.2307/3802219

Berkes, F., P.J. George, R.J. Preston, A. Hughes, J. Turner, and B.D. Cummins. 1994. Wildlife harvesting and sustainable regional native economy in the Hudson and James Bay Lowland, Ontario. Arctic 47: 350–360.

Breiman, L. 2001. Random Forests. Machine Learning 45: 5–32. https://doi.org/10.1023/a:1010933404324

Clyne, K., A. LaRocque, B. Leblon, and M. Costa. 2024. Use of landsat imagery time-series and random forests classifier to reconstruct eelgrass bed distribution maps in Eeyou Istchee. Remote Sensing 16: 2717. https://doi.org/10.3390/rs16152717

Clyne, K., B. Leblon, A. LaRocque, M. Costa, M.L. Leblanc, E. Rabbitskin, and M. Dunn. 2021. Use of Landsat-8 OLI imagery and local indigenous knowledge for eelgrass mapping in Eeyou Istchee. ISPRS Annals Photogrammetry Remote Sensing Spatial Information Sciences V-3-2021: 15–22. https://doi.org/10.5194/isprs-annals-V-3-2021-15-2021

Curtis, S.G., and L. Allen. 1976. The waterfowl ecology of the Quebec coast of James Bay. Unpublished report. Canadian Wildlife Service, Ottawa, Ontario, Canada.

Davis, E., A. Trant, L. Hermanutz, R.G. Way, A.G. Lewkowicz, L. Siegwart Collier, A. Cuerrier, and D. Whitaker. 2021. Plant–environment interactions in the low arctic Torngat mountains of Labrador. Ecosystems 24: 1038–1058. https://doi.org/10.1007/s10021-020-00577-6

Dickey, M.-H. 2015. Status of eelgrass beds on the east coast of James Bay. Wildlife and Landscape Science Directorate. Environment Canada, Québec, Quebec, Canada. Accessed 30 August 2024. Accessed 11 March 2025. https://publications.gc.ca/collections/collection_2021/eccc/En84-231-2015-eng.pdf.

Dignard, N., R. Lalumière, A. Reed, and M. Julien. 1991. Habitats of the northeast coast of James Bay. Canadian Wildlife Service Occasional Paper 70: 1–27. Accessed 11 March 2025. https://publications.gc.ca/site/archivee-archived.html?url=https://publications.gc.ca/collections/collection_2018/eccc/CW69-1-70-eng.pdf.

Ettinger, K., G. Lajoie, and R. Beaulieu. 1995. Wemindji Cree knowledge of eelgrass distribution and ecology. Unpublished report submitted to the Cree Regional Authority. Canada Department of Fisheries and Oceans, Québec, Quebec, Canada.

Giroux, J.-F., J. Rodrigue, R.W. Brook, and M. Patenaude-Monette. 2022. Canada Goose populations harvested in Eastern James Bay by Eeyou Istchee Cree hunters. Avian Conservation and Ecology 17: 5. https://doi.org/10.5751/ace-02059-170105

Harvey, W.F., J. Rodrigue, and R. Spangler. 2018. A breeding pair survey of Canada Geese in northern Québec – 2018. Unpublished report, Maryland Department of Natural Resources and Canadian Wildlife Service, Quebec Region, Québec, Quebec, Canada.

Henton, J.A., M.R. Craymer, H. Dragert, S. Mazzotti, R. Ferland, H. Dragert, S. Mazzotti, and D.L. Forbes. 2006. Crustal motion and deformation monitoring of the Canadian landmass. Geomatica 60:173–191. Accessed 11 March 2025. https://cdnsciencepub.com/doi/abs/10.5623/geomat-2006-0021.

Idrobo, C.J., M.-L. Leblanc, and M.I. O'Connor. 2024. The "turning point" for the fall goose hunt in Eeyou Istchee: a social-ecological regime shift from an Indigenous knowledge perspective. Human Ecology 52: 617–636. https://doi.org/10.1007/s10745-024-00499-0

Lalumière, R., D. Messier, J.-J. Fournier, and C.P. McRoy. 1994. Eelgrass meadows in a low arctic environment, the northeast coast of James Bay, Québec. Aquatic Botany 47: 303–315. https://doi.org/10.1016/0304-3770(94)90060-4

Leblanc, M.-L., M.I. O'Connor, Z.Z.A. Kuzyk, F. Noisette, K.E. Davis, E. Rabbitskin, L.-L. Sam, U. Neumeier, R. Costanzo, J.K. Ehn, D. Babb, C.J. Idrobo, J.-P. Gilbert, B. Leblon, and M.M. Humphries. 2022. Limited recovery following a massive seagrass decline in subarctic eastern Canada. Global Change Biology 29: 423–450. https://doi.org/10.1111/gcb.16499

Lefebvre, J., and S. Orichefski. 2020. Breeding ground banding of Atlantic Population Canada Geese – 2019. A progress report prepared for the Atlantic Flyway Council. Accessed 11 March 2025. https://dnr.maryland.gov/wildlife/Documents/2019_AP-CanadaGeese_Breeding-ground-banding.pdf.

Leipe, S.C., and S.K. Carey. 2021 Rapid shrub expansion in a subarctic mountain basin revealed by repeat airborne LiDAR. Environmental Research Communications 3: 71001. https://doi.org/10.1088/2515-7620/ac0e0c

Luukkonen, D.R., H.H. Prince, and R.C. Mykut. 2008. Movements and survival of molt migrant Canada Geese from southern Michigan. Journal of Wildlife Management 72: 449–462. https://doi.org/10.2193/2007-029

Olatunji, A. 2022. Use of satellite imagery for monitoring Canada and Brant Geese habitat changes in Eeyou Itschee (James Bay, Québec). M.Sc. thesis, University of New Brunswick, Fredericton, New Brunswick, Canada.

Peloquin, C., and F. Berkes. 2009. Local knowledge, subsistence harvests, and social-ecological complexity in James Bay. Human Ecology 37: 533–545. https://doi.org/10.1007/s10745-009-9255-0

Prevett, J., H.G. Lumsden, and F.C. Johnson. 1983. Waterfowl kill by Cree hunters of the Hudson Bay Lowland, Ontario. Arctic 36: 185–192.

QGIS Development Team. 2023. QGIS Geographic Information System. Open Source Geospatial Foundation Project. Accessed 10 March 2025. http://qgis.osgeo.org.

R Development Core Team. 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

Reed, A., R. Benoit, R. Lalumière, and M. Julien. 1996. Goose use of the coastal habitats of northeastern James Bay. Canadian Wildlife Service Occasional Paper 92: 1–35. Accessed 11 March 2025. https://publications.gc.ca/collections/collection_2018/eccc/CW69-1-92-eng.pdf.

Royer, M.-J.S., and T.M. Herrmann. 2013. Cree hunters' observations on resources in the landscape in the context of socio-environmental change in the eastern James Bay. Landscape Research 38: 443–460. https://doi.org/10.1080/01426397.2012.722612

Sheaffer, S.E., R.A. Malecki, B.L. Swift, J. Dunn, and

K. Scribner. 2007. Management implications of molt migration by the Atlantic Flyway resident population of Canada Geese, *Branta canadensis*. Canadian Field-Naturalist 121: 313–320. https://doi.org/10.22621/cfn.v121i3.481

Sorais, M., M. Patenaude-Monette, C.M. Sharp, R. Askren, A. Larocque, B. Leblon, and J.-F. Giroux. 2023. Migration patterns and habitat use by molt migrant Canada Geese in James Bay, Canada. Wildlife Biology 2023: e01062. https://doi.org/10.1002/wlb3.01062

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SUPPLEMENTARY MATERIALS:

TABLE S1. List of Landsat-8 OLI optical images used as a function of the season to characterize habitat composition on the east coast of James Bay, Canada.

TABLE S2. List of the Sentinel-1 C-band imagery used as a function of the season, orbit, and polarization to characterize habitat composition on the east coast of James Bay, Canada.

FIGURE S1. Photo and satellite image of Common Eelgrass (*Zostera marina* L.).

FIGURE S2. Photo and satellite image of turbid water.

FIGURE S3. Photo and satellite image of shallow water.

FIGURE S4. Photo and satellite image of tidal flat.

FIGURE S5. Photo and satellite image of cobble beach.

FIGURE S6. Photo and satellite image of salt marsh.

FIGURE S7. Photo and satellite image of freshwater wetlands.

FIGURE S8. Photo and satellite image of tundra.

FIGURE S9. Photo and satellite image of deep water.

FIGURE S10. Photo and satellite image of peatland.

FIGURE S11. Coefficient of variation of Canada Goose (*Branta canadensis*) density (number of geese/km of helicopter path) calculated for increasing section length for each survey conducted in 2018 along the James Bay east coast.