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RESEARCH ARTICLE

Bridging Cree knowledge and Western science to understand the decline in hunting success of migratory Canada geese

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Abstract

Canada goose (*Branta canadensis*) is one of the main waterfowl species harvested by Cree hunters in James Bay, Canada. Land users who hunt geese along coastal Eeyou Istchee (Eastern James Bay, Quebec) report that they are now much less successful in harvesting sub-arctic breeding geese (*B. c. interior*) than in the 1980s, especially during the fall hunting season. We followed a mixed-methods triangulation design in which we simultaneously gathered Indigenous and scientific knowledge. For the Indigenous knowledge, we conducted semi-structured interviews with Cree land users who shared their knowledge about how the goose populations that stage in Eeyou Istchee have changed within living memory. They attributed their reduced hunting success to fewer migrating geese and modification of their behavior. They also identified many environmental changes, especially the decline of eelgrass (*Zostera marina*), that may have affected the number, distribution, and migration patterns of Canada geese along the coastal Eeyou Istchee in the past 50 years. We complemented this information using waterfowl study techniques including aerial surveys, band recovery analyses, and GPS tracking of individually marked geese. Habitat changes both at the local scale in Eeyou Istchee and in other parts of the staging and wintering ranges of Canada geese, natural and human disturbances along the coast, and a gradual increase in molt migrant temperate breeding Canada geese (*B. c. maxima*) likely resulted in changes in habitat use and migration patterns of sub-arctic breeding Canada geese along the James Bay east coast. By bridging Cree knowledge and Western science, we identified the various factors that affect the harvest success of Eeyou Istchee goose hunters. Such an approach should be encouraged when Indigenous peoples rely upon migratory bird or mammal species that spend only a portion of their annual cycle within the hunting territories of land users.

Keywords *Branta canadensis* · Eelgrass · Eeyou Istchee · James Bay · Subsistence hunting · Indigenous knowledge

1 The importance of Canada geese for Cree land users

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 (Berkes et al. 1994, p. 353; Prevett et al. 1983, p. 188; Fig. 1A and B). While the traditional annual spring goose break remains important socially and culturally for all coastal communities in Eeyou Istchee, the Eastern James Bay Cree territory (Fig. 2), the fall hunt has lost relevance during the past 30 years (Idrobo et al. 2024; Peloquin and Berkes 2009, p. 540; Royer and Herrmann 2013, p. 447). Canada geese harvested along the Eeyou Istchee coast belong to two subspecies associated with four populations (Giroux et al. 2022, p. 3 of 8) (Fig. 3). These include the Atlantic Population composed of *B. c. interior* that breed in northern Quebec with the largest concentrations on the Ungava Peninsula and winter along the Atlantic coast of the US. There is the Southern Hudson Bay Population which is also composed of *B. c. interior* that breed in southwestern James Bay (Ontario) and Southern Hudson Bay (Ontario and Manitoba) and winter in the Midwest states of the US. The Cree harvest also includes temperate breeding geese

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Fig. 1 Photographs illustrating the Eeyou way of life along the eastern coast of James Bay and the activities conducted as part of the Niskamoon Coastal Habitat Comprehensive Research Project. **a** Darson Sam accompanied by his grandfather Jeffrey Sam with his first ever harvested Canada goose which is a very special and proud moment in a young hunter life; **b** roasted geese hang over an open fire in a traditional Cree hunting camp along the James Bay east coast; **c** Ernie Rabbitskin, manager of special projects for the Niskamoon Corporation, during the helicopter goose survey along the James Bay east coast in May 2018; **d** Harold Whiskeychan, tallyman of trapline R02, near a pen holding Canada geese before their release during a banding operation in Boatswain Bay in September 2018. Photo credits: Reggie Scipio (**a**), Réal Courcelles (**b**), and Martin Patenaude-Monette (**c**, **d**). Photos used with permission

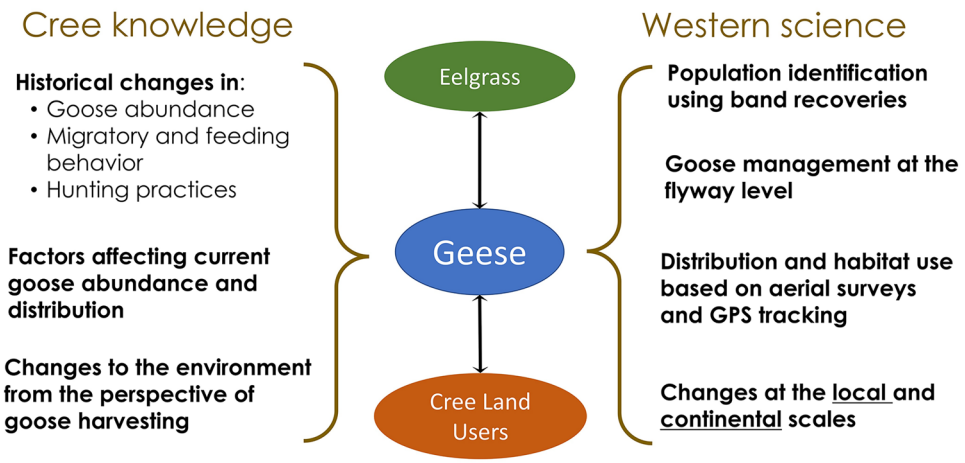

Fig. 2 A description of the integration process of Cree knowledge and Western science to study links between Canada geese and eelgrass and between land users and Canada geese

(*B. c. maxima*) that are associated with the Atlantic Flyway Resident Population and the Mississippi Flyway Giant Population. For the last three populations, Cree hunters of Eeyou Istchee harvest subadults and failed-breeder adults that undertake a molt migration to northern Quebec (Giroux et al. 2022, p. 2 of 8; Sorais et al. 2023, p. 2 of 12). The *B. c. interior* and *B. c. maxima* subspecies are, respectively, referred to as short-necked and long-necked geese by Cree hunters. In Cree, Canada geese are called *nisk* independently of the subspecies. *B. c. maxima* are noticeably larger than *B. c. interior* (Moser and Roley 1990, p. 383; Merendino et al. 1994, p. 16). However, small individuals of *B. c. maxima* can

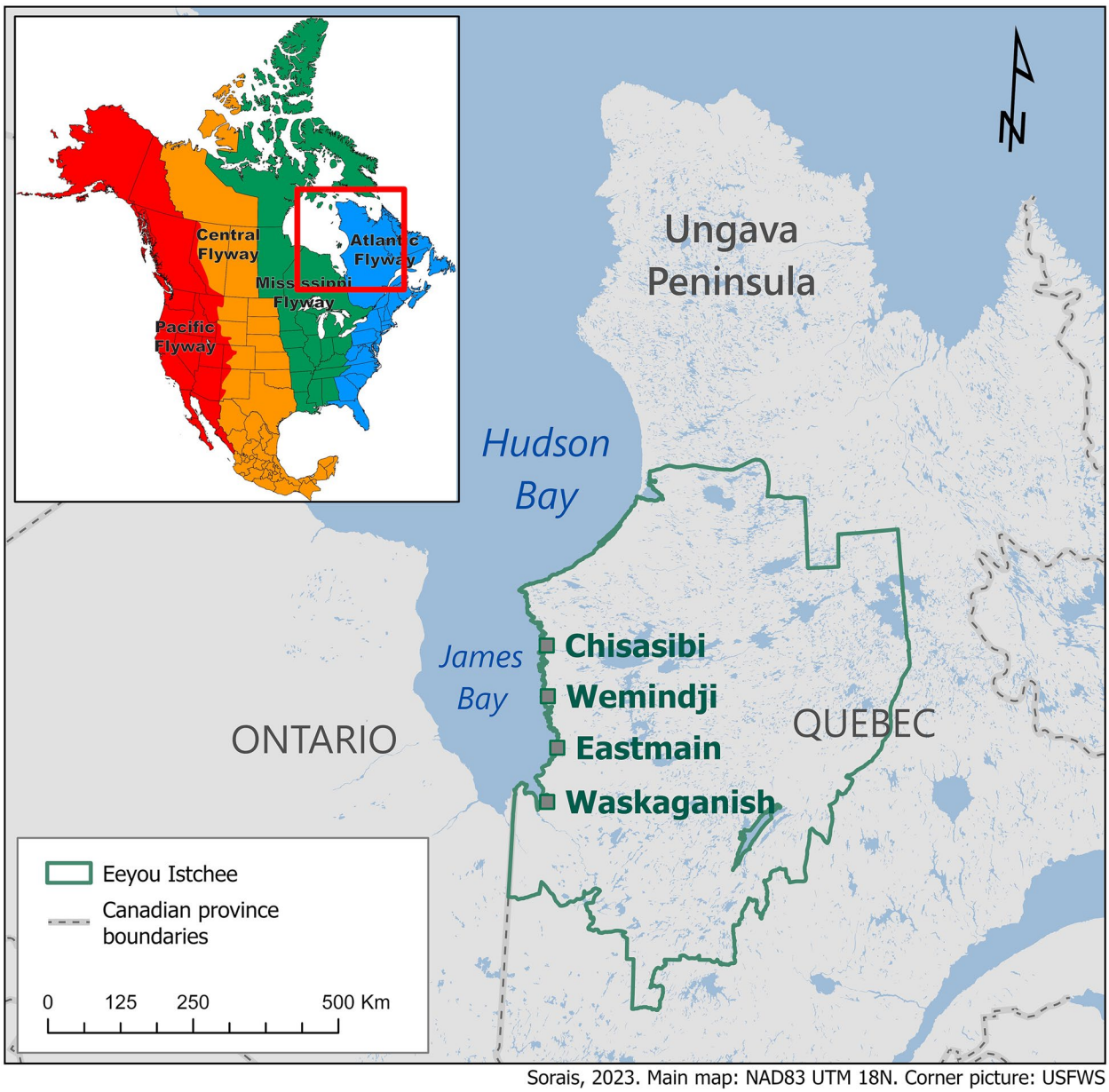

Fig. 3 Migratory bird program administrative flyways (https://www.fws.gov/partner/migratory-bird-program-administrative-flyways) and location of the four coastal Eastern James Bay Cree communities that participated in the study in Eeyou Istchee

be confused with large individuals of *B. c. interior*, whereas male *B. c. interior* are almost the same size as female *B. c. maxima*. Misidentifications of the two subspecies are thus possible by both Cree hunters and Western scientists.

Cree hunters of the coastal communities consider that their goose harvest is now much less successful than in the 1980s and attribute this to the lower number of short-necked geese that migrate along James Bay, especially during the fall hunting season (Idrobo et al. 2024; Peloquin and Berkes 2009, p. 538; Royer and Herrmann 2013, p. 453). They observed that the fall distribution of geese is now less predictable than in the 1980s when the birds were moving between the coast where they fed on eelgrass *(Zostera marina)* and the adjacent tundra where they foraged for berries (Idrobo et al. 2024). Cree land users also suspect that geese have changed their behavior by migrating further inland away from the coast (Idrobo et al. 2024; Peloquin and Berkes 2009, p. 538). Information about population sizes and migration routes of Canada geese prior to 1990 is limited, which makes difficult to determine the exact causes of the reported decline. Nevertheless, several factors including changes in the goose populations that migrate through

James Bay, habitat modifications, and different types of disturbances along the coast may have affected the number of geese and hunting success.

In this paper, we combined information provided by Cree land users and data obtained using conventional waterfowl study techniques to explain the reduced harvest of short-necked Canada geese as reported by Eeyou Istchee Cree hunters (Fig. 2). Indigenous peoples have a thorough knowledge about the wildlife species that complete their entire annual cycle within their hunting or trapping territory. Land users are thus quite aware how local changes can affect these resident species. In contrast, migratory bird and mammal species spend only a portion of their annual cycle in Indigenous peoples' territories. Land users are thus less informed about the factors that may influence the numbers and behavior of these migratory species when they are away from their lands. We used different sources of evidence to understand a complex phenomenon with real implications for the Cree and their way of life. The results of this study would have been impossible to achieve through the sole lens of a single discipline or knowledge perspective. In that way, our research aligns with the multiple evidence-based approach (Tengö et al. 2014) and other knowledge co-production processes in which mutual learning reveals a more complex picture (Idrobo and Berkes 2012; Chapman and Schott 2020). Our study was part of a larger investigation referred to as the Eeyou Coastal Habitat Comprehensive Research Project supported by the Niskamoon Corporation. The objective of the project was to understand the causes of eelgrass decline and its impact on Canada geese and the Cree hunting success (Fink-Mercier et al. 2024).

2 Bridging multiple sources of evidence: Indigenous knowledge and conventional goose studies

We followed a mixed-methods triangulation design in which we simultaneously gathered Indigenous and scientific knowledge (Idrobo et al. 2016, p. 40). We assigned equal importance to both data types as we integrated them during the analysis phase. Cree knowledge tells how the goose populations that stage in Eeyou Istchee have changed within living memory. It is based on the everyday experience of Cree land users in the bay. Cree knowledge provides precise insights about goose feeding behavior, migration patterns, and abundance at the local scale (Fig. 2). Cree knowledge also contributes to understanding how their hunting practices, livelihoods, and way of life are intertwined with the dynamics of the different goose populations. For the Indigenous knowledge component, we followed a community-based case study approach in which we conducted semi-structured interviews of Cree land users associated with 14 coastal traplines in Chisasibi and Wemindji between August and September 2019 (Idrobo et al. 2024). A trapline is the fundamental unit of governance where traditional harvesting activities are conducted. In each trapline, the harvest is overseen and stewarded by a tallyman, a knowledgeable hunter designated by his family according to traditional Eeyou law and customs. We interviewed the tallyman of each trapline and selected male and female Eeyou elders and active hunters. These interviews focused on Cree perspectives and experience of waterfowl and the associated hunting practices in the context of environmental changes within living memory (Idrobo et al. 2024).

In North America, waterfowl species are managed by federal (Canadian and American), provincial, and state wildlife agencies that coordinate their management measures and population assessment through four administrative flyways (Fig. 3). Each species is managed by populations that have their distinct breeding, wintering, and migration routes (Fig. 4). Each population has its own dynamic determined by specific fecundity and mortality rates, which require different management measures to insure their conservation. It was, therefore, essential to first identify the different populations of Canada geese harvested in Eeyou Istchee. This was achieved by using recoveries of geese banded by wildlife agencies across the Atlantic and Mississippi Flyways and reported by Cree hunters to the Bird Banding Laboratory (https://www.usgs.gov/labs/bird-banding-laboratory) between 2000 and 2020. Geese were associated to a subspecies and population during the banding operations and their relative contribution to the Cree harvest was assessed using the band recoveries (Giroux et al. 2022, p. 3 of 8). We relied upon the annual surveys conducted by wildlife agencies to examine trends in the size of the different goose populations (U.S. Fish and Wildlife Service 2023). The current distribution of Canada geese along the east coast of James Bay during their spring and fall migrations was determined in 2018 using aerial surveys, which is a well-established technique (Sorais et al. 2024). One member of the Eeyou Istchee community participated in each survey (Fig. 1C). Finally, the detailed migration route and timing as well as habitat use along the coast by molt migrant geese was determined using GPS tracking of tagged birds (Sorais et al. 2023). The geese were captured and marked along James Bay in September 2018 with the help of a tallyman and his family (Fig. 1D).

3 Hunting success and population trends of Canada geese

The decline in goose harvest along the James Bay east coast has been clearly documented during the interviews of land users (Idrobo et al. 2024). The turning point between fruitful to unsuccessful hunts occurred in the 1990s and early

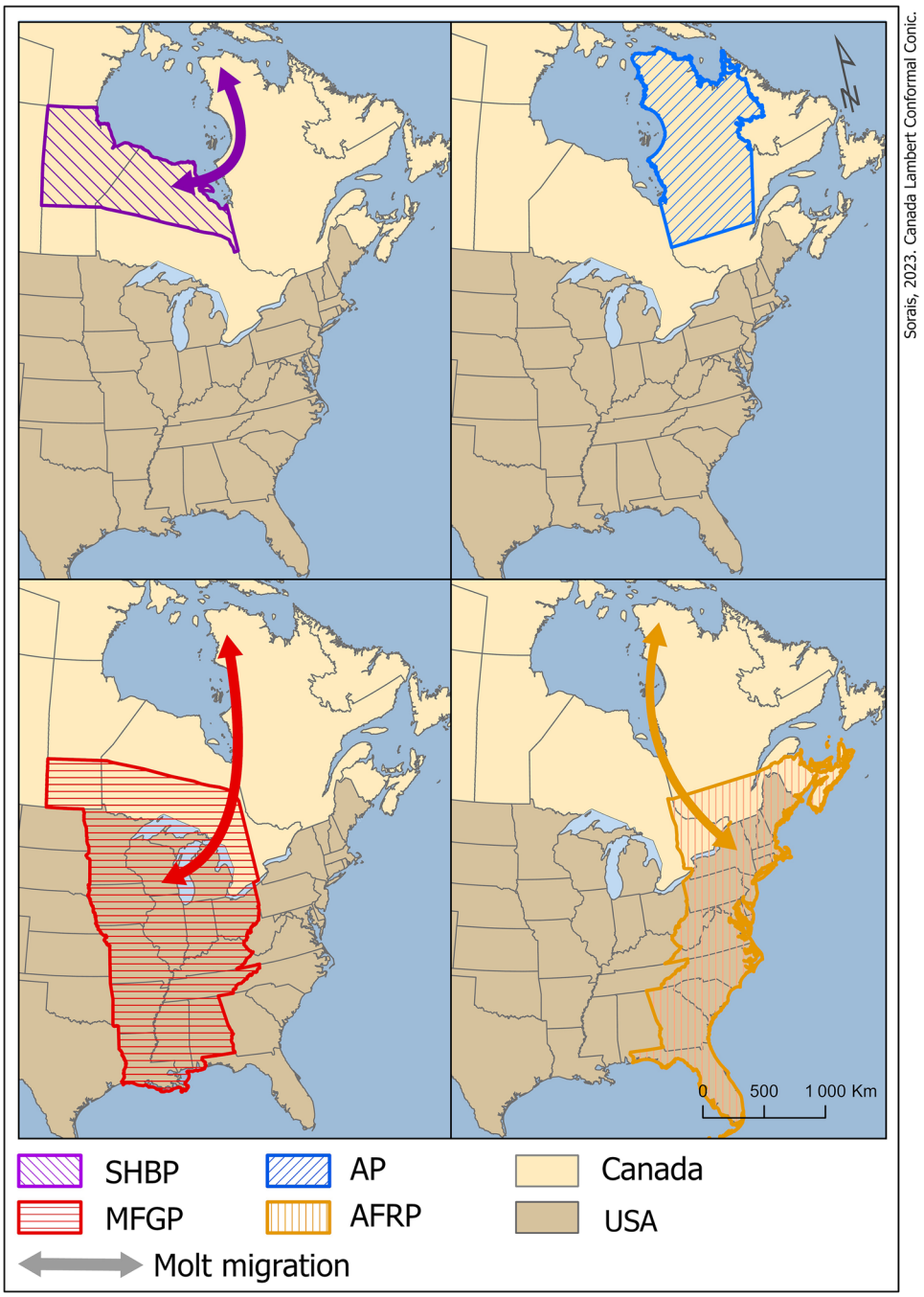

Fig. 4 Breeding range of the four populations of Canada geese harvested in Eastern James Bay. Arrows represent molt migration movements between the breeding grounds and the molting area in northern Quebec. SHBP: Southern Hudson Bay Population; MFGP: Mississippi Flyway Giant Population; AP: Atlantic Population; and AFRP: Atlantic Flyway Resident Population. Nomenclature follows U.S. Fish and Wildlife Service (2023)

2000s, and the decline has been ongoing since. Conversely, quantitative assessments of the harvest are limited. A first survey referred to as the Native Harvesting Research Study was conducted between 1972 and 1979 in the four Eeyou Istchee coastal communities whereas a second survey was conducted in 2005–2006 in two of these communities (Wemindji and Waskaganish). Comparisons must be made with caution but declines of 28 and 60% were, respectively, recorded in the number of Canada geese harvested (spring and fall) in these two communities between the two periods (Cree Regional Authority 2008, p. 22). In absolute numbers, this represents a reduction of about 7500 harvested geese.

In the 1970s, coastal Cree hunters harvested short-necked geese associated with the Atlantic and Southern Hudson Bay Populations. This was confirmed by recoveries of Canada geese banded as adults in the mid-1960s along the west coast of the Ungava Peninsula. Recoveries were distributed nearly evenly between the Atlantic and Mississippi Flyways (Heyland and Garrard 1974, p. 67). Although some restoration programs of temperate breeding geese had begun, they did

not really take hold until the 1970s and the numbers of geese of the Atlantic Flyway Resident Population and the Mississippi Flyway Giant Population were limited then. Therefore, we can conclude that Heyland and Garrard (1974) captured and banded breeding geese associated with the Atlantic Population and molt migrant geese of the Southern Hudson Bay Population, some of them being subsequently harvested by Cree hunters (Giroux, J.-F. unpublished data).

Spring aerial surveys conducted in the core breeding area of the Atlantic Population began in 1993. Number of breeding pairs increased between 1995 and 2002 and remained relatively stable until 2018 when numbers started to decline (U.S. Fish and Wildlife Service 2023, p. 56–57). Outside the core breeding area, population trend is unknown, but we can assume that it has been similar throughout the range. The decline of short-necked geese reported by Cree hunters along the James Bay east coast is, therefore, unlikely related to a change in size of the Atlantic Population, at least not during the past 25–30 years. Land users report that geese are now migrating further inland whereas they were flying along the coast in the past (Idrobo et al. 2024). The inland route of Canada geese breeding on the Ungava Peninsula has been documented in the mid-1990s by Malecki et al. (2001, p. 244) using the first generation of satellite transmitters. We recently found that all geese tagged with GPS devices on the Ungava Peninsula also followed this inland route during their fall migration, passing on average 260 km away from James Bay (Sorais et al. unpublished data). This is the shortest and most direct trajectory between the breeding grounds on the Ungava Peninsula, and the attractive southern staging areas characterized by agricultural lands. Likely, this route was already the main trajectory used by geese of the Atlantic Population breeding on the Ungava Peninsula in the 1980s. We cannot discard the possibility that a greater proportion of geese from the Atlantic Population are now using the inland route, but we have no tracking data to support this. Because the numbers of geese tracked during the telemetric studies were limited, it is possible that some geese from the Atlantic Population are still migrating along the James Bay east coast. However, Cree hunters reported that geese are now flying at a much higher altitude than in the past, which further reduces their chance to harvest these birds (Idrobo et al. 2024). The higher altitude may be related to longer flight distances between stopovers resulting in a lower number of stopovers and allowing the geese to reach the southern agricultural lands faster.

Geese of the Southern Hudson Bay Population that are returning from their molting sites in northern Quebec are most likely following the Hudson Bay east coast up to the northeastern tip of James Bay before heading southwest across the bay. During the fall hunting season, Cree hunters in northeast James Bay can thus harvest these returning molt migrants. The number of breeding pairs of the Southern Hudson Bay Population has declined since the 1980s, possibly because of habitat degradation due to the large number of staging and breeding lesser snow geese (*Chen caerulescens caerulescens*) (Brook et al. 2015, p.8 of 15; Jefferies et al. 2006, p. 238; Leafloor et al. 1996, p.106). We submit the hypothesis that the lower number of short-necked geese observed by Cree hunters in fall along the northeast coast of James Bay is partly explained by a lower number of molt migrants of the Southern Hudson Bay Population rather than by a change in population size of the Atlantic Population. However, migration patterns and abundance of Canada geese of the Atlantic Population that breed on the coastal islands of James Bay and Hudson Bay as well as on the mainland south of the core breeding area on the Ungava Peninsula still remain to be determined.

Molt migrant temperate breeding Canada geese became more abundant in James Bay in the 1980s as their populations grew in the Atlantic and Mississippi Flyways following their reintroduction in the 1960s (Davies and Hindman 2008, p. 7; Luukkonen and Leafloor 2017, p.8). It is estimated that several hundred thousand temperate breeding Canada geese are now crossing James Bay during their molt migration (Sorais et al. 2023, p. 10 of 12). Most geese harvested during the traditional spring goose break in May are subarctic breeding geese because temperate breeding geese that migrate north to molt do not arrive in James Bay until early June (Sorais et al. 2023, p. 5 of 12). 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, p. 8 of 12). Hence, geese harvested in fall are a mixture of the two subspecies. It is possible that when using habitats with a diversity of food resources, molt migrant temperate geese act as decoys and attract sub-arctic breeding geese to these habitats. Competition for food between the two subspecies is suspected but has not been demonstrated nor its potential impact (Abraham et al. 1999, p. 653; Ankney 1996, p. 218; Luukkonen et al. 2008, p. 461; Sheaffer et al. 2007, p. 314).

4 The impact of habitat changes on geese

Habitat changes impacting Canada goose distribution along the James Bay east coast have occurred in the past 50 years. One noteworthy change observed by Cree land users (Dickey 2015, p.43; Idrobo et al. 2024; Peloquin and Berkes 2009, p. 541) and confirmed by ground surveys (Leblanc et al. 2022, p. 439) and remote sensing (Clyne 2022, p. 68) is the decline of eelgrass in subtidal meadows that started in the late 1980s in the northeast portion of the bay followed by a general steep decline all along the coast in the late 1990s. In most of the bay, eelgrass has failed to recover

in the present day. In the 1970s, Curtis and Allen (1976, p. 7) observed that Canada geese were feeding extensively on eelgrass beds in fall in Eastern James Bay. Interviewed land users reported that geese were also feeding in spring on eelgrass that had been produced during the previous year and accumulated in wrack along the shore. It is suspected that the eelgrass decline resulted from several environmental stressors including the development of hydroelectricity in Quebec boreal region and the ongoing climate change. The construction of dams and river diversion altered the hydrology and water physical chemistry in some sections of the James Bay east coast (Leblanc et al. 2022, p.441; Prinsenberg 1984, p. 194). The intense goose grazing that likely occurred in the 1970s cannot be discarded to explain eelgrass decline and the subsequent reduced use by Canada geese. Based on a meta-analysis, Kollars et al. (2017, p. 6 of 14) concluded that overgrazing by waterfowl may result in long-term reduction of eelgrass biomass and coverage. Along the Atlantic coast, Rivers and Short (2007, p. 274) documented the decline and slow recovery of an eelgrass bed following its use by a wintering flock of Canada geese. Furthermore, Seymour et al. (2002, p. 200) observed a lower number of fall migrant Canada geese in Antigonish Harbour, NS, following a decline of eelgrass attributed to the invasion of the European green crab (*Carcinus maenas*) (Garbary et al. 2014, p. 8). On the other hand, Cree land users consider that moderate grazing of eelgrass by Canada geese can promote its growth. Nevertheless, eelgrass beds along the east coast of James Bay may have become less profitable for Canada geese that can use a wide variety of alternative food plants such as scaly sedge (*Carex paleacea*), needle spikerush (*Eleocharis acicularis*), mare's-tail (*Hippuris tetraphylla*), and marsh arrowgrass (*Triglochin palustris*) (Reed et al. 1996, p. 17).

Other environmental changes may have affected habitats available for waterfowl along the James Bay east coast and may have modified the migration and staging patterns of geese. Using satellite imagery taken in 1985 and 2020, Olatunji (2022, p. 53) found an increase in 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). Cree land users consider that these changes have reduced the abundance of berries (*Empetrum nigrum* and *Vaccinium vitis-idaea*) consumed by Canada geese (Idrobo et al. 2024; Reed et al. 1996, p. 17). Also, isostatic rebound estimated at 10–12 mm/year in James Bay (Henton et al. 2006, p. 179) has resulted in a coastal raise of about 35–42 cm in the past 35 years. During this period, the area of tidal flats declined while those of salt marshes and freshwater wetlands increased (Olatunji 2022, p. 53). The eelgrass decline and the transformation of coastal terrestrial habitat, among other social and economic drivers, have resulted in less predictable hunting success. Not only the abundance of geese declined, but also the fewer geese that still migrate through the Eastern James Bay Coast became less predictable. Geese are not moving between eelgrass beds and the adjacent tundra in relation to tide as they used to do in the past (Idrobo et al. 2024).

5 The effects of disturbances on geese and hunting success

Natural and human disturbances may also explain the lower number of short-necked geese reported by Cree hunters along the Eastern James Bay coast. Several land users consider that the increasing presence of bald eagles (*Haliaeetus leucocephalus*) along the coast is disturbing the geese (Idrobo et al. 20,234. Likewise, they also suggest that the use of helicopter by some land users to reach their hunting camps may affect the presence of geese (Idrobo et al. 2024). The effect of hunting activities on the distribution of Canada geese was not assessed during our study but hunting has been shown to influence local and regional movements of several goose species in North America and Europe (Béchet et al. 2003, p. 559; Leblanc et al. 2023, p. 12 of 16; Madsen and Fox 1995). Disturbances can increase energy demands of geese and reduce their time available for feeding as shown by Stillman et al. (2021, p. 20 of 28) for black brant (*Branta bernicla nigricans*) feeding on eelgrass in Alaska. This can reduce net energy gain to a level at which geese may move away from the coast. Tracking individual sub-arctic breeding Canada geese along the James Bay east coast as done for temperate breeding geese by Sorais et al. (2023) would help to better understand the distribution and habitat use of geese along the James Bay east coast.

6 Bridging Cree knowledge and Western science

A dialog between Cree knowledge and Western science about the goose populations that migrate through coastal Eeyou Istchee provided complementary information to understand how the harvest of short-necked geese has changed since the 1980s and to identify factors driving that change. Fifty years ago, short-necked geese were feeding in fall on eelgrass at low tide and flying inland to feed on berries at high tide. The hunt was predictable and successful. Geese were also abundant in spring. Cree land users already identified many factors that can affect the number and distribution of Canada geese including the relative abundance of different goose populations that migrate through Eastern

James Bay, habitat modifications including the decline of eelgrass and the natural and human disturbances along the coast.

Although Cree land users have thorough knowledge about their hunting territories and the behavior of geese migrating through their area, Canada geese spend only a portion of their annual cycle along the James Bay east coast. Factors that may occur away from the bay throughout the range of each goose population can also influence the number of geese and their migration patterns. For instance, the increasing use of agricultural lands by Canada geese staging in southern Quebec (Giroux and Bergeron 1996, p. 950) may delay their spring migration to the north. It could also reduce the need for geese to stop along the bay as they may be already in good condition to complete their migration further north and initiate breeding. Similarly, geese may be more inclined to fly at high altitude to move south quickly in the fall to reach the agricultural lands where spilled grains are an important food resource. This information based on Western science was complementary to Cree knowledge and contributed to determining the various factors that affect their hunting success. The dialog was enhanced through a series of meetings with land users and formal symposia held in the communities and that were broadcast on the local radio. We also arranged for a representative of the Cree Trappers Association to attend a meeting of the Atlantic Flyway. This allows flyway biologists to understand better the situation in James Bay and the Cree representatives to learn about the status of the waterfowl populations and the management measures taken in other parts of the flyway. Such participation should be encouraged in the future. Our study shows that bridging Indigenous knowledge and Western science is useful and essential to understand changes in numbers and behavior of migratory wildlife species.

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Author contributions JFG conceived and supervised the goose study and wrote the first draft of the manuscript. CJI conceived and conducted the land use study involving Indigenous peoples and edited the manuscript. MS collected and analyzed the goose data, prepared the figures, and reviewed the manuscript. All authors approved the final manuscript.

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Declarations

Conflict of interest The author declares that they have no conflict of interest.

Ethical approval The Behavioral Research Ethics Board of the University of British Columbia approved the land use study conducted by CJI (H20-02942) and fully complies with the current version of the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2 (2018)). The ethical obligations surrounding informed consent in research involving Indigenous peoples align with Article 9.1 of the TCPS. The capture and marking of Canada geese in the Boatswain Bay Migratory Bird Sanctuary were conducted under Canadian Wildlife Service banding permits 10410 and 10546, and scientific permit RE-78. Capture and marking methods were approved by the Institutional Animal Protection Committee of the Université du Québec à Montréal (Protocol 952 of JFG).

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