




Divergent migration strategies within a population of Snow Buntings

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Abstract

Arctic songbirds such as Snow Buntings (*Plectrophenax nivalis*) have a broad distribution across the Arctic in summer, and travel to temperate areas during winter. Previous work suggested a pattern of strong, parallel connectivity between North American breeding and wintering sites (i.e., longitudes positively correlated). In this study, we used multiple lines of evidence to determine migratory connectivity of eastern populations of Snow Buntings, both from a breeding site in the eastern Canadian Arctic and a wintering site in southern Ontario, Canada. Using light-level geolocators, Motus radio-telemetry, and band-recaptures, we found evidence that birds breeding in Iqaluit, Nunavut winter in at least two distinct regions separated by > 1,600 km, primarily longitudinally. This suggests Iqaluit may be at the centre of the previously inferred migratory divide, with locally breeding birds exhibiting diverse migration phenotypes. We found that birds wintering in southern Ontario, Canada, used at least two distinctive spring migration pathways: either directly north or eastwards, suggesting multiple breeding origins for this wintering population. Overall, this suggests that the Iqaluit population contains individuals with diverse migration patterns and overwintering sites, which could have important consequences for subsequent life history events such as the timing of breeding arrival, mate choice, and reproductive success. Importantly, this diversity of migratory connections could result in differential contributions from migration- and wintering-specific pressures on survival for individuals within the same breeding population, highlighting the importance of confirming connectivity between breeding and wintering sites in this species.

Keywords Citizen science · Migratory connectivity · Migration route · Songbird · Motus Wildlife Tracking System · Geolocators · *Plectrophenax nivalis*

Zusammenfassung

Unterschiedliche Zugstrategien innerhalb einer Population von Schneeammern.

Arktische Singvögel wie die Schneeammer (*Plectrophenax nivalis*) sind im Sommer in der gesamten Arktis verbreitet und ziehen im Winter in gemäßigte Breiten. Frühere Studien deuteten auf eine starke, parallele Zugkonnektivität zwischen nordamerikanischen Brut- und Überwinterungsgebieten hin (z. B. positiv korrelierte Längengrade). In dieser Studie nutzten wir mehrere unabhängige Datengrundlagen, um die Zugkonnektivität östlicher Populationen der Schneeammer zu

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untersuchen, sowohl von einem Brutgebiet in der östlichen kanadischen Arktis als auch von einem Überwinterungsgebiet im südlichen Ontario. Mithilfe von Geolokatoren, Motus-Funktelemetrie und Wiederfinden beringter Vögel fanden wir Hinweise darauf, dass in Iqaluit (Nunavut) brütende Individuen in mindestens zwei deutlich getrennten Regionen überwintern, die hauptsächlich in Längsrichtung mehr als 1600 km voneinander entfernt liegen. Dies deutet darauf hin, dass Iqaluit im Zentrum einer zuvor vermuteten Zugtrennlinie liegt, wobei lokal brütende Vögel unterschiedliche Migrationsphänotypen aufweisen. Zudem zeigten Vögel, die im südlichen Ontario überwintern, mindestens zwei unterschiedliche Routen während der Frühjahrmigration: entweder direkt nach Norden oder ostwärts, was auf mehrere Brutursprünge dieser Überwinterungspopulation hindeutet. Insgesamt weist dies darauf hin, dass die Population in Iqaluit Individuen mit vielfältigen Zugmustern und Überwinterungsgebieten umfasst, was wichtige Konsequenzen für nachfolgende Lebensgeschichteereignisse wie den Zeitpunkt der Ankunft im Brutgebiet, die Partnerwahl und den Fortpflanzungserfolg haben könnte. Diese Vielfalt der Zugvernetzung könnte zudem zu unterschiedlichen, zug- und überwinterungsspezifischen Selektionsdrücken auf das Überleben von Individuen innerhalb derselben Brutpopulation führen und verdeutlicht, wie wichtig es ist, die Zugkonnektivität zwischen Brut- und Überwinterungsgebieten bei dieser Art zu kennen.

Introduction

Connecting breeding and wintering populations for migratory birds is important for understanding population dynamics (Hallworth et al. 2021), locating critical stopover sites (Faaborg et al. 2010), and assessing carry-over effects (Harrison et al. 2011). Identifying connected populations can allow researchers to estimate mortality during different phases of the annual cycle (Sillett and Holmes 2002), and thus pinpoint where in time and space conservation actions could be most beneficial. Despite advances in tracking technology (McKinnon and Love 2018), we still know very little about migratory ecology or connectivity for tundra-breeding songbirds. Recent analyses have confirmed this group is declining overall, but no clear causes of declines have been identified (Johnston et al. 2025).

Snow Buntings (*Plectrophenax nivalis*) are a cold-adapted Arctic-breeding songbird (Le Pogam et al. 2020). Previous migratory connectivity work on buntings using stable isotope analysis, geolocator tracking, and band recoveries, suggested a pattern of east–west parallel connectivity in the North American population, with a migratory divide at Hudson Bay (Macdonald et al. 2012). Our objective was to determine migratory connectivity for a breeding population of buntings at a new study site in the eastern Canadian Arctic in Iqaluit, Nunavut, and confirm connections between this region and our long-term winter study site in southern Ontario, which is also in the east of the North American winter range (Macdonald et al. 2012).

To analyze migratory connections, we deployed light-level geolocators on breeding buntings in Iqaluit and radio-tags on wintering buntings in southern Ontario. Radio-tags were detected by Motus Wildlife Tracking System receivers throughout southern Canada and northern USA. Working with the NunatuKavut Community Council (NCC) and a community group, the Canadian Snow Bunting Network (CSBN), we initiated banding and resighting nodes along the eastern coast of Labrador, Canada, which would be along

an eastern migratory route between our winter study site and Iqaluit. Documenting migratory connectivity and routes is of critical importance to begin quantifying how potential differential impacts of breeding-, migration- and wintering-specific pressures may be contributing to the reported rapid declines in this species.

Methods

Field methods

Bird capture and banding

Snow Buntings were captured in baited walk-in traps (winter, migration) or at natural and anthropogenic nest cavities (breeding). Birds were processed by NCC/CSBN banders following standard protocols (Love et al. 2012). In addition to a metal band, buntings banded in Labrador were assigned a colour band. Community members were encouraged to report sightings of banded buntings on social media.

Tag deployments

Geolocators ($n = 21$, Lotek model ML67A0, 0.75 g) were deployed on breeding adult buntings captured in Iqaluit (63.74°N , -68.52°W) in 2023, and one bird returning with a tag was re-trapped in 2024. Recapture rates at this study site are low (15% of banded adults; unpubl. data). We also report here the analysis of a geolocator recovered from a Snow Bunting at this study site in 2014 (Migrate Technology Integeo-P65C2J, 0.75 g).

We deployed 118 radio-telemetry tags (0.8 g Lotek Nano-tags, model NTQB2-3-2) on wintering buntings in 2023 ($n = 71$; Fergus, Ontario, further details in Simard-Provençal 2024) and 2024 ($n = 47$) (42.04°N , -82.74°W , near Windsor, Ontario). Radio-signals from these units were monitored by > 150 active Motus receivers.

Data collection and preparation

Motus data preparation

We downloaded radio-tracking data from the Motus Wildlife Tracking System via R version 4.3.2 (R Core Team 2025) packages “motus” and “motusData”, and filtered following the Motus R Book protocols (Birds Canada 2025). To examine spring migration routes, we retained detections in March or later and located outside of the medium-density contour of all winter locations (416 winter detections of 55 tagged birds). We further categorized the spring detections into three categories: east of the wintering site ($> -79.0^\circ\text{W}$), north only ($> 44.5^\circ\text{N}$), or ambiguous (south of 44.5°N but not east of -79.0°W).

Geolocator analysis

We processed raw light data using “FLightR” (Rakhimberdiev et al. 2017), with a light threshold of 1.5 to define twilights, and stationary locations post-deployment for calibration (see supplemental information). We ran a particle filter with 1 million particles ($sd = 25$ km), constraining stationary locations to within 50 km of land to account for typical geolocation error. Final locations were further filtered, retaining only daily locations < 500 km apart, based on estimates of travel speed from previous studies (Macdonald et al. 2012; McKinnon et al. 2019), and averaging latitudes and longitudes for consecutive days < 50 km apart. Stationary events during migration of > 5 days were considered significant stopovers.

Results

Both geolocator-tracked buntings (2013–2014 and 2023–2024) wintered in the Northern Great Plains region, with mean locations of 50.43°N , -104.36°W (2013–2014, near Regina, Saskatchewan, Canada) and 46.8°N , -101°W (2023–2024, near Bismark, North Dakota, USA) (Fig. 1). Spring migration routes passed through the Nunavik region of Quebec, Canada, on the eastern side of Hudson Bay. Both birds took notable 21- and 19-day spring stopovers at the southern coast of Hudson Bay (54.0°N , -83.50°W , 12 May–1 Jun; 55.54°N , -87.17°W , 11–19 May). Of the 19 Motus-tagged individuals for which we detected spring migration, 12 individuals were categorized as travelling eastward and 7 northwards (Fig. 2).

In July 2024, a Snow Bunting originally banded in January 2024 in southern Ontario was recaptured in Iqaluit, NU, during the breeding season (Fig. 1). Two additional Snow Buntings banded during spring migration in Labrador were resighted in Iqaluit during the known breeding season, and

reported on CSBN social media on 21 July 2023 and 24 June 2025 (Fig. 1).

Discussion

Contrary to our expectations, we found that birds breeding in an eastern Canadian Arctic site in Iqaluit showed connections both to wintering sites in the eastern part of the nonbreeding range (band recapture from southern Ontario) and $\sim 1,600$ km further west (data from geolocators). The western wintering sites were in the same region as wintering sites for buntings tracked by Macdonald et al. (2012) from a more western breeding population at Qaqsauqtuq (formerly East Bay) Migratory Bird Sanctuary. The climate at the two wintering sites identified for Iqaluit breeding birds is very different, as temperatures are moderated in southern Ontario by the Great Lakes, compared to the dry and cold continental influence in the Northern Great Plains. Macdonald et al. (2012) also reported band recaptures connecting southern Ontario wintering sites with breeding sites in Greenland. Overall, this suggests that if there is a migratory divide, Iqaluit and southern Ontario are sites where both ‘western’ and ‘eastern’ birds mix. Birds wintering in southern Ontario could breed in either the eastern Canadian Arctic or in Greenland (~ 800 km further eastwards), and birds breeding in Iqaluit (e.g., southern Baffin Island, Nunavut) may overwinter in Ontario or much further west ($\sim 1,600$ km westwards).

While Motus-tracked birds confirmed a previously identified northeastern spring route, we were surprised to find a small but significant number of birds travelling northwards, including a notable detection in southern James Bay (Fig. 2). We suggest that some proportion of buntings from this wintering population are following the coast of Hudson Bay northwards, a route similar to that used by geolocator-tracked birds. There are currently no community banders in this area, nor are there many Motus receiving towers. This illustrates that multiple techniques are often needed to determine migratory routes and connectivity, as each technique has limitations that may result in incomplete information.

Our results suggest that Iqaluit-breeding birds wintered in significantly different places, with correspondingly large differences in spring migration distance. The shortest potential spring migration pathway, measuring due north from southern Ontario up the eastern coast of Hudson Bay to Iqaluit, is $\sim 2,400$ km, while the longest (following our Motus and banding records, eastwards up the St. Lawrence River and around Labrador) is $> 1,000$ km farther ($\sim 3,700$ km). Western routes from the Northern Great Plains to Iqaluit would be intermediate in length, depending on routes around or across Hudson Bay (geolocator-tracked birds appeared to fly over at least part of the bay, see Supplemental Information).

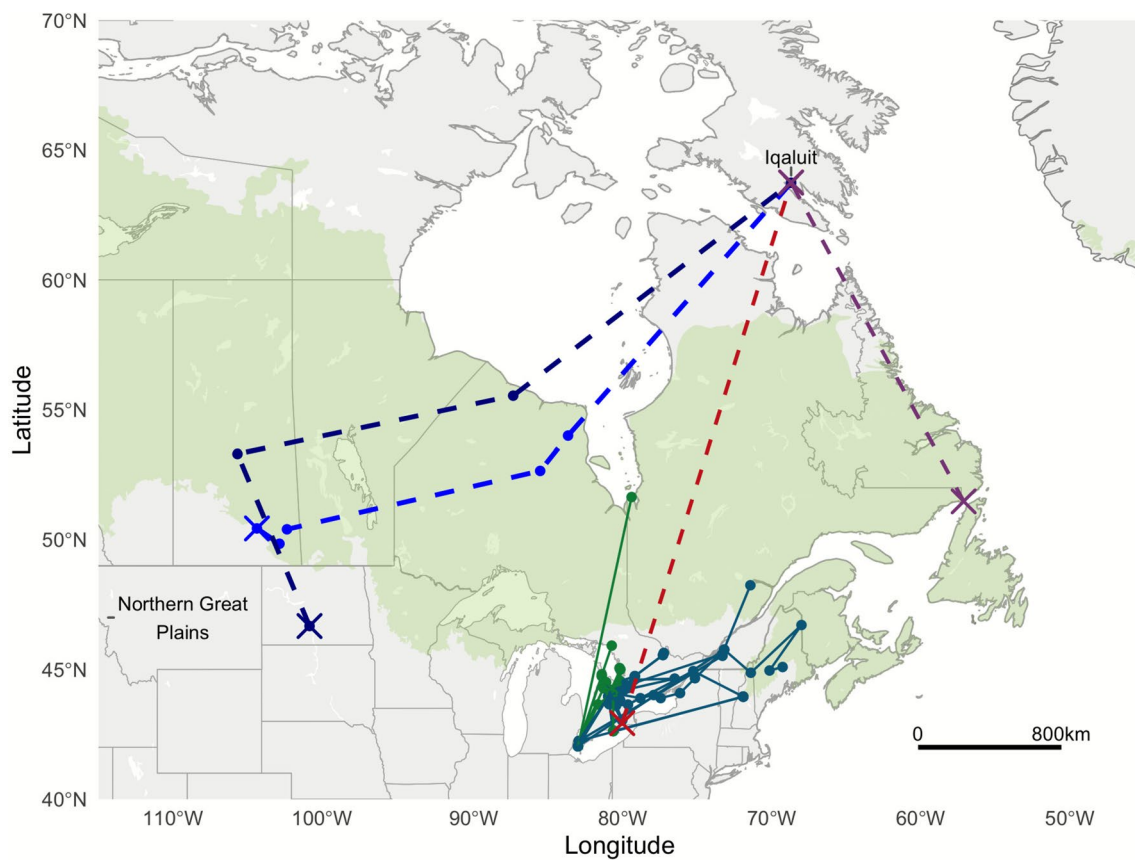


Fig. 1 Three methods showing connections between a Snow Bunting breeding population in Iqaluit, NU and wintering sites. Blue dashed lines (dark blue: 2014 bird, lighter blue: 2024 bird) connect winter centroids to spring migration stopover points (>5 days) for two birds tracked with geolocators. Green (northward) and teal (eastward) lines show consecutive detections of Snow Buntings at Motus receivers in spring. Red dashed line shows a band recapture between a wintering

site in Cayuga, Ontario, and the purple dashed line connects a spring migration banding site in Labrador with confirmed re-sighting of two individual Snow Buntings. Forest extent is shown by green shading; forest is an unsuitable stopover habitat for Snow Buntings and is considered a migration barrier. Forest data (which includes boreal and hemi-boreal forest; per Brandt (2009)

The consequences of such differences in migration routes for Snow Buntings breeding in the same place are unknown. In Swainson's Thrushes (*Catharus ustulatus*), hybrids of birds with eastern and western migration phenotypes took a sub-optimal intermediate migration route, providing selective pressure against hybridization (Delmore et al. 2012).

Tracking and banding data showed that most Snow Buntings from our long-term study area in southern Ontario migrated eastwards. However, there is bias in the location of the Motus receivers as well as CSBN sites, which are

primarily located in areas with high human population density. Only 19 of the 55 birds we detected during the winter were detected in March or later; more towers along the coast of Hudson Bay could provide further insights into the importance of this area for migration. Banding Snow Buntings is an engaging tool for community research and conservation, and also generates important spatial distribution data. Social media can facilitate sharing information on banded birds quickly and make immediate migratory connections, as shown in this study. Expanding the CSBN to communities

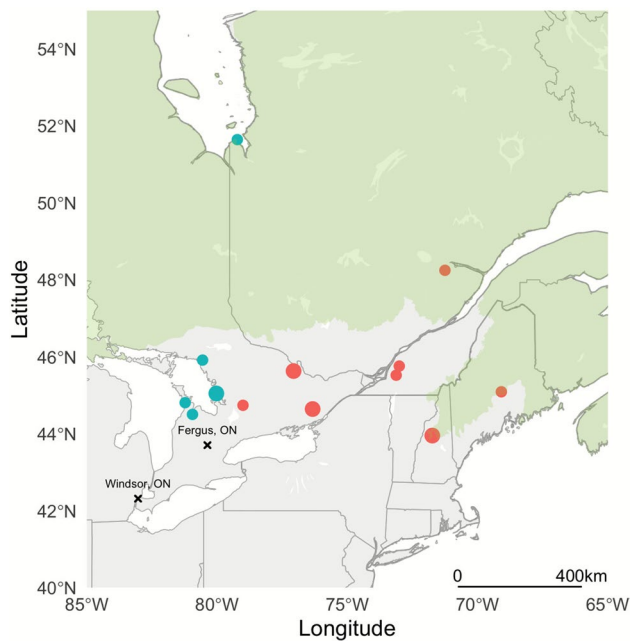


Fig. 2 Final spring Motus receiver detections of Snow Buntings tagged in winter (tagging locations indicated by crosses and labeled). We considered detections in pink to be eastwards movements and detections in teal were considered northwards; larger dots are towers that detected two birds. Green shading shows the extent of boreal and hemi-boreal forest (Brandt 2009), which is unsuitable habitat for Snow Buntings

along the James Bay and Hudson Bay coast would help to further identify spring migration routes, while providing engaging science outreach and building capacity for community-based monitoring.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10336-026-02366-9>.

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Data availability All Motus and geolocator tracking data are archived on Movebank.org under the projects “Snow Bunting Migration Phenology” (Movebank ID 959128259) and “Wintering Snow Buntings in southern Ontario” (Movebank ID 3168300958). Band-recapture data can be accessed by requesting records from the Bird Banding Office, Canadian Wildlife Service, and resights reported by community members can be found on the Facebook page of the Canadian Snow Bunting Network <https://www.facebook.com/SNBUnetwork>.

Declarations

Conflict of interest The authors declare they have no competing interests.

Ethical approval All protocols for this project were reviewed and approved by the University of Windsor Animal Care Committee (AUPP-22-04), Canadian Federal Bird Banding Office (Canadian Wildlife Service permits 10885B, 10808 and the Government of Nunavut (2023-048).

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