NWRT Final Report

NWRT Project Number: 0000000022

Project Title: NEM Caribou Telemetry Program

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Summary:

The Northeast Mainland (NEM) barren-ground caribou populations are collectively made up of the Ahiak Herd, Wager Bay Herd, and the Lorillard Herd. Monitoring programs including reconnaissance surveys have been utilized since the 1980s to track herd trend as a collective of NEM caribou herds. Telemetry studies were incorporated more recently, beginning in the late 1990s and early 2000's. These early telemetry programs, however, were temporarily discontinued in 2006. Since this earlier program the need to develop a more quantitative database of seasonal range use began with mining interests north of Baker Lake and the general concerns raised on how theses interests could impact caribou by wildlife Biologists and Inuit Organizations a like. A more intensive monitoring program incorporating NEM caribou telemetry as its core activity began as a 15-collar deployment completed on Ahiak caribou cows in the vicinity of Baker Lake in spring 2010, and again in 2012, and a mixed deployment of 15 collars (11 Lorillard and 4 Ahiak) completed in 2014. More recent deployments were conducted in 2017 and 2018 where 35 collars were deployed on adult caribou cows north of Baker Lake, largely made up of the Lorillard herd.

Disturbance of spring and fall migrating Ahiak, Lorillard, and Wager Bay caribou along mining roads has been reported, and in the case of the Lorillard herd, documented through both scientific studies and IQ. However, automatic collar drops for the Lorillard herd in fall 2021 and remaining active collar drops scheduled for fall 2022, coupled with covid related program cancellations and postponements since spring 2020, was in danger of leaving managers and other stakeholder with no active tracking of caribou cow movements North of

Baker Lake within the NEM herds. Complicating our understanding of impacts to migrating NEM caribou was the fact that the Wager Bay subpopulation has not been collared substantively since 2006. To understand the possible effects of mining access roads on the Ahiak, Lorillard, and Wager Bay herds of caribou, all of which have interacted with the AEM Meadowbank and Whale Tail mining roads, the GN ENV successfully completed a deployment of 40 collars on adult cows in the spring of 2022, 15 on Wager Bay caribou and 25 on Lorillard and Ahiak caribou within their known spring ranges. The program is critical to the studies of seasonal range use and importance, for survey and composition work, and for assessing impacts and possible mitigation of those impacts in and around mining infrastructure and roads, and other developments on caribou range. Nunavut, at present, does not have detailed information on the movements of the Wager Bay and Ahiak Herds to better understand important seasonal range use, migratory movements and associated corridors, and to assess the magnitude of resource Development infrastructure conflicts.

This work is part of an ongoing program aimed to continue a targeted collaring program on adult Ahiak, Lorillard, and Wager Bay caribou cows in support of an expansion of our knowledge of seasonally important range and habitats of the NEM herds, including migratory corridors and timing. Satellite based GPS telemetry offers a useful tool to monitor caribou and identify potential conflicts with resource development, as well as improving our understanding of caribou range use. The telemetry program will address land use planning information needs, climate change and changes in behavior, as well as be able to locate caribou for ongoing demographic monitoring and disturbance monitoring, help to develop mitigative measures where and when possible, with an overarching aim to lessen negative impacts to caribou health and movement across their annual range.

Introduction:

Ungulate telemetry programs, as long-term herd monitoring programs, are crucial to our regulatory and Management systems including but not limited to; reconnaissance and abundance aerial survey programs, seasonal range delineation and mapping programs (largely lacking for the NEM caribou herds), the development of management plans and actions, land use planning, research into effective mitigation methods and plans, the establishment of seasonal closures, and the development of protected areas programs and strategies. As land use activities heighten to meet the needs of a rapidly growing natural resource-based economy, the maintenance of viable wildlife populations with high sustainable yields will require an escalation in our attempts to monitor caribou movements and quantify and protect seasonally important caribou habitat from being negatively impacted (Gray and Donihee, 1983; Scotter, 1980; Thompson et al, 1980). Knowing where the caribou are is the key to protecting critical habitats and avoiding conflicts between natural resource industries and caribou (Tennenhouse, 1986).

The Northeastern Mainland (NEM) caribou subpopulations, or herds, within the context of this report, include the Ahiak, Wager Bay, and Lorillard herds of tundra wintering barren-ground caribou (Nagy and Campbell, 2012). Of the communities living on, and/or harvesting from the NEM caribou herds, including Chesterfield Inlet, Rankin Inlet, Naujaat, Gjoa Haven, Taloyoak, Baker Lake, Sanirajak, Igloolik, and Kugaaruk, many have reported concerns regarding Northeastern Mainland caribou health and abundance. Of these same communities, all have communicated the need for abundance monitoring and many, the need for Telemetry research so that all co-management partners might better understand the herds needs, and therefore, manage the herds sustainably into the future. Some prominent concerns raised regarding these herds include but are not limited to; 1-impacts from industrial development, 2-the internet sale of caribou meat, 3-increased disease prevalence, and 4-predation. With limited information available on the number and size of caribou populations within the NEM region, their range requirements and seasonal range use, managers had been unable to address community concerns fully.

Surveys flown between 1976 and 1987 found three distinct herds/densities of caribou and associated calving grounds occupying the NEM in June; 1-the Melville, 2-Wager, and 3-Lorillard Herds (Calef and Helmer, 1976; Calef and Heard, 1981; Heard *et al*., 1981; Heard *et al*, 1987; Donaldson, 1981). A VHF collaring program deployed within the Wager and Lorillard ranges during the 1980’s found the presence of at least three additional aggregations of caribou displaying calving ground fidelity (Heard *et al.*, 1986). Further research to confirm these aggregations involved a series of aerial surveys, of which only one, flown in 1983, has examined the entire Northeastern Mainland Region, including the spring range of the Ahiak caribou herd, producing an estimate of 119,800 +/- 13,900 caribou (Heard *et al*., 1987). The 1983 survey also identified a fourth area with high caribou densities south of the Queen Maud Gulf. A follow up survey in this area in 1986 (Gunn and Lambert in prep.) found a discrete calving ground utilized by approximately 40,000 animals, which at the time was considered the Ahiak heard. The most recent population estimate of Northeastern mainland caribou was made in May 1995. The survey results suggested that caribou numbers had dropped significantly from 119,800 +/- 13,900 animals in 1983 to 73,994 +/- 11,670 caribou in 1995. Though survey results suggested a decline, survey effort (measured as survey area coverage) was very low and more representative of a reconnaissance level survey effort. This low survey coverage raises concerns that smaller aggregations of calving caribou, typical of this herd in certain years, could have been missed, despite apparent statistical confidence. On Melville Peninsula, caribou had all but disappeared and had significantly declined north of Wager Bay which was also indicated in March 2014, during an assessment of caribou on northern Melville Peninsula (Campbell et al., 2015). Reasons for this possible 84% decline in caribou are unknown, as are the populations or population involved. By the early 2000's communities, Wildlife Biologists, and Wildlife Managers were generally in agreement that the main herds of the NEM included the Ahiak (**Figure 1**), Wager Bay (**Figure 2**), and Lorillard herds (**Figure 3**) (Nagy and Campbell, 2012; Nagy et al., 2011). Little demographic work across the entire NEM was completed following the 1995 reconnaissance level survey effort up until June 2011, when the Ahiak abundance survey, the first of its kind, was successfully completed (Campbell et al., 2013). During this survey effort 71,340 (SE=3,882:CV=0.05) adult and yearling caribou were estimated. The most recent survey of the 3 NEM herds was successfully completed in June 2021, at which time 39,131 (95%CI=33385-45867, CV=7.8%) Ahiak caribou, 45,005 (95%CI=38735-52,293, CV=7.3%) Wager Bay caribou, and 33,454 (95%CI=22,502-49,735, CV=19.2) Lorillard caribou, for an estimated 117,590 caribou within Nunavut's Northeast Mainland (Campbell et al., 2022). Though we could not discuss trend within the Wager Bay or Lorillard herds as they were the first abundance surveys flown, a statistically significant decline ($p<0.0001$) within the Ahiak herd was detected between June 2011 and June 2021. Overall, however, NEM herd numbers were consistent with 1983 survey results suggesting that the herds within the NEM had, at some point, recovered from the lower assessment of abundance made in 1995.

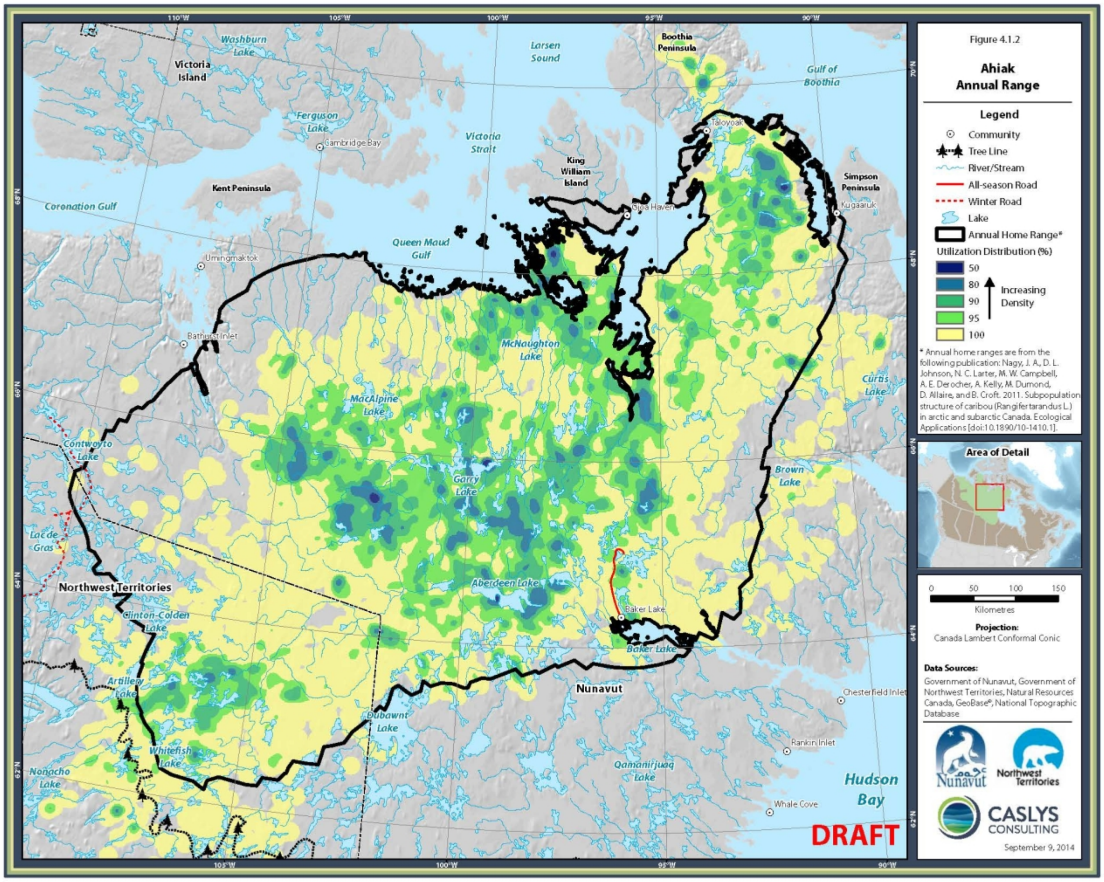


Figure 1. Ahiak herd annual range based on a kernel analysis of multi-annual telemetry locations of collared Lorillard cows.

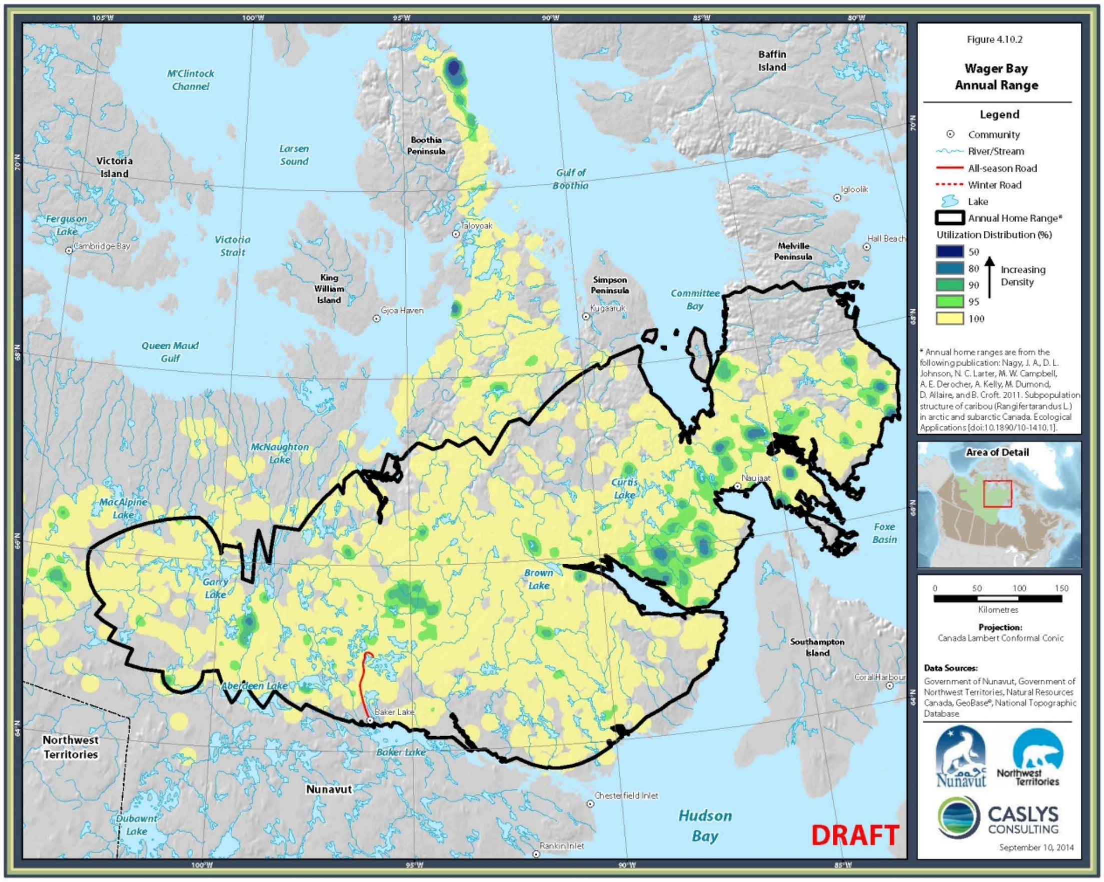


Figure 2. Wager Bay herd annual range based on a kernel analysis of multi-annual telemetry locations of collared Wager Bay cows.

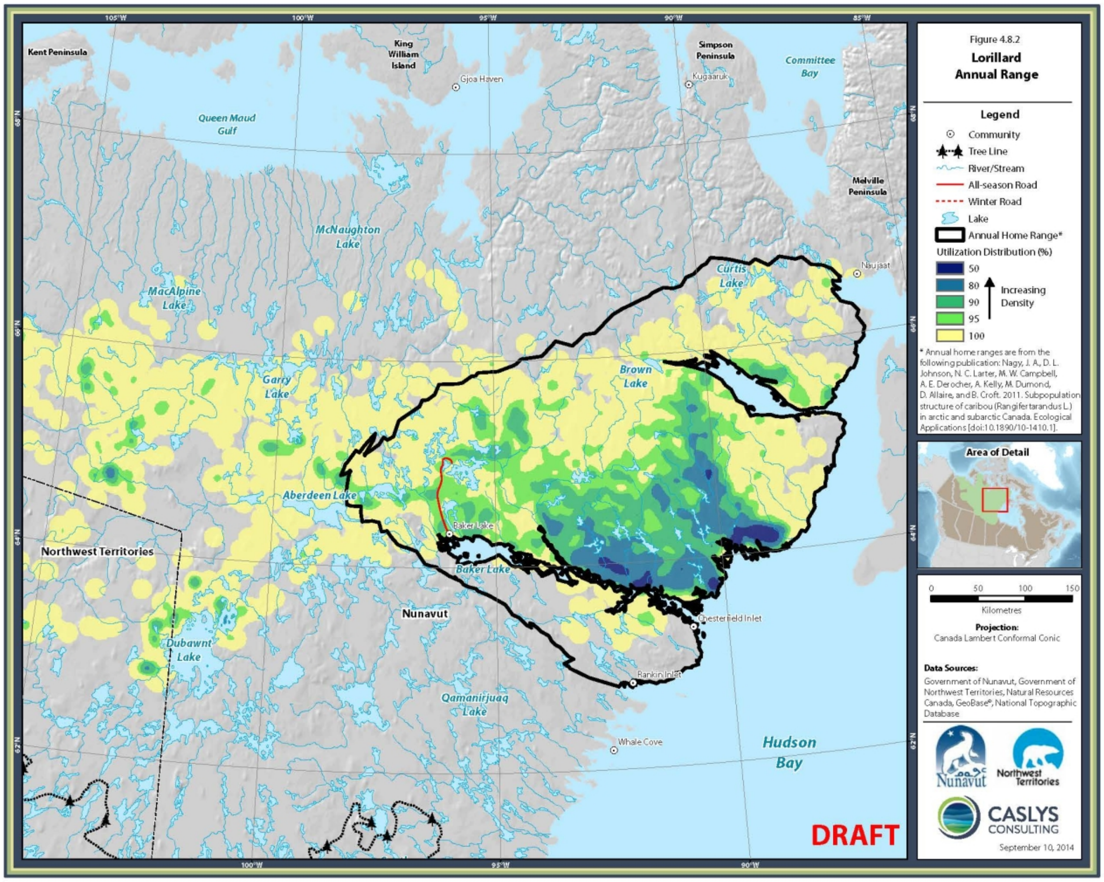


Figure 3. Lorillard herd annual range based on a kernel analysis of multi-annual telemetry locations of collared Lorillard cows.

A study of NEM Caribou through the use of satellite telemetry and periodic calving ground delineation's began April 15th, 1999 (Campbell, 2005). All collaring study areas were based on past survey observations, and local Inuit knowledge. From mid to late April 1999 and again in April 2000, ten ST-14 satellite collars were systematically placed on barren-ground caribou cows (total = 20). Collaring occurred between the north shore of Chesterfield Inlet and the south shore of Wager Bay (Lorillard Herd), and the following year between the north shore of Wager Bay and the northern tip of Repulse Bay (Wager Herd). Calving ground delineations were then flown, using satellite collar locations to guide survey effort within each of these study area extents. Reconnaissance level surveys were flown in June from 1999 through to 2004. This program aimed to delineate important seasonal range for the Lorillard and Wager Bay Herds with an emphasis on delineating core calving range extents and migratory corridors.

Following a 5-year gap, monitoring programs targeting the NEM herds were re-initiated due to concerns by communities and Biologists over industrial development in the region. A 15-collar deployment was completed on Ahiak caribou cows in the vicinity of Baker Lake in spring 2010, and again in 2012, and a mixed deployment of 15 collars, 11 on Lorillard and 4 Ahiak caribou cows, completed in 2014. Since 2014, collar deployment on Ahiak caribou cows has been problematic due to spring concentrations of Lorillard caribou having difficulty crossing the Meadowbank all weather mining road, effectively concentrating Ahiak cows along the mining road corridor up-stream of migratory directional movements. The Wager Bay subpopulation has not been extensively collared since 2006.

This ongoing collaring program has been instrumental in detecting significant migratory delays and changes in some seasonal range use along an all-weather mining road north of Baker Lake. Additionally, locations of collard NEM caribou cows have and are currently used to assess seasonally important caribou range, and to design and deploy abundance surveys to monitor herd abundance and trend. More recent studies have aimed to specifically target collaring efforts on the Wager Bay and Ahiak Herds. Following program cancellations due to the global pandemic, the Government of Nunavut (GN) research staff, in partnership with local HTOs, were able to successfully deploy 40 collars on NEM caribou cows, 15 on Lorillard, 10 on Ahiak, and 15 on Wager Bay in April 2022.

This report represents the continuation of an investigation into the seasonal distribution and herd delimitation of caribou populations occupying ranges north of Baker Lake, Chesterfield Inlet, and Wager Bay collectively referred to as the Northeast Mainland caribou subpopulations. This report is meant to provide a 2-year reporting of the current program, discuss results received to date, and discuss program deficiencies and needs moving forward. We will also assess mixing between the NEM herds as it applies to individual herd assessments, trend, and calving ground fidelity.

Project Objectives:

The objectives of this research are to initiate and maintain a 40-collar deployment of GPS/satellite collars on adult female Ahiak, Wager Bay, and Lorillard barren-ground caribou. The information collected from these collars will be used to: 1) establish an important habitats information base for the NEM herds by integrating the location and activity database, using spatial analysis software, with vegetation, hydrological, topographical, exploration, and land use databases, 2) provide resource users, regional Wildlife Organizations, Jurisdictional and inter-jurisdictional Management Boards access to an information base with which to make management decisions and steer land use activities in an informed and conservation minded direction, 3) locate caribou concentrations for annual spring classifications, future population surveys, and calving ground and other seasonal delineations, and 4) Continue analysis into the effects of Anthropogenic disturbance/infrastructures on caribou distribution, movements, and long-term viability, health, and abundance. Following is a breakdown of the main objectives:

A) **To provide a near real-time accessible information base to wildlife managers, commercial stakeholders, land use regulators, RWO's, and HTOs***:* To provide the necessary deliverables for informed land use planning, to assess and steer land use in an environmentally sustainable manner. Conflicts can and will arise when commercial development occurs on caribou seasonal range. To effectively manage barren-ground caribou within Nunavut, managers will require adequate knowledge of commercial impacts on caribou health, distribution, and ultimately, productivity, as well as long-term and/or permanent alterations of wildlife and habitat use resulting from development and other anthropogenic uses/disturbances, all at high risk of occurring (Donihee and Grey, 1982). Telemetry will be used to monitor Ahiak, Lorillard, and Wager Bay adult cow movements to ensure conflicts with natural resource users, and associated infrastructure can be avoided and/or mitigated in a timely manner and, using methods that are proven effective through peer-reviewed scientific study and collective IQ.

B) **Locate and quantify the seasonally important range for the Ahiak and Wager Bay caribou subpopulations using GPS/satellite telemetry**: Habitat quality, quantity and availability, largely define the biological limitations of wild populations (Gray and Donihee, 1983; Scotter, 1980; Thompson et al, 1980; Dasmann, 1981). An understanding of the locations and size of important habitat, and how these habitats are important to the Ahiak and Wager Bay subpopulations of barren-ground caribou will assist wildlife managers and land use planners in assessing; acceptable seasonal levels of disturbance, potential cumulative effects on herd distribution and productivity, and impacts to Inuit harvesting rights under the

Nunavut Agreement. A GPS/satellite telemetry program offers the most cost effective and logistically achievable means of identifying and monitoring caribou seasonal range use annually.

C) **To cost effectively locate Ahiak and Wager Bay caribou cows for population studies**: The most time consuming and costly component in the assessment of caribou demography is the assurance that all possible aggregations of caribou are located and assessed. Because of the sheer size of barren-ground caribou range, telemetry programs have become a critical component used to insure appropriate coverage during demographic surveys such as reconnaissance, composition, and abundance surveys. Using collar locations as the focal points for any proposed scientific study offers the advantage of saving considerable time and money relative to the cost of collar deployment and maintenance, as well as providing a reduction in wildlife disturbance.

Materials and Methods:

Forty (40) Telonics Iridium GPS-5 collars with automatic breakaway devices, were deployed on Ahiak and Lorillard cows (25), and Wager Bay cows (15) in April/early May 2022. All collars deployed on Kivalliq caribou have collar release mechanisms attached that are programmed to release the collar from the caribou's neck automatically, four years following deployment. The GPS-5 collar system is also equipped with a satellite beacon to transmit 6 GPS locations daily to DOE offices. Collars were deployed on adult female caribou using helicopter and net-gun. Chase times were restricted to 90 seconds or less. The program deployed collars on Ahiak and Lorillard caribou cows out of the community of Baker Lake, and collars on Wager Bay caribou cows out of the community of Naujaat. HTO selected handlers and field assistants from each of Baker Lake and Naujaat took part in the field work. Collar deployment was spread evenly throughout late spring seasonal range as indicated through an assessment of past telemetry data and hunter observations, and where possible, based on distributions of active collars. HTO and ENV based protocols were strictly followed, and field program reporting provided back to the HTO and the ENV program manager.

Spatial Analysis of telemetry data:

In order to relate caribou locations and movement to habitat and location, different types of spatial data will be compiled to cover the full extent of the study area following one full year of telemetry. Telemetry data, showing the caribou locations over time, will form the main dataset for analyses. Base data (at various scales) and anthropogenic information will also be compiled to facilitate the mapping and to provide a time snapshot of what the current conditions are on the landscape. Telemetry data will be partitioned into seasons and analysed according to subpopulation, as seasonal space-use patterns for subpopulations in the study area are distinct (Nagy et al. 2011). Seasonal ranges will be identified for the calving, post-calving, summer, late summer, rut/breeding and winter seasons using utilization distribution surfaces derived from a kernel density analysis on the location data (points). Movement corridors, characterized by high movement rates, will be identified for spring, fall pre-breeding, and fall post-breeding migration seasons using the movement paths represented by walk lines between locations. The resulting seasonal use and corridor surfaces will be combined to define the core seasonal ranges once sufficient data has been collected. These analyses will be developed separately for each subpopulation and the results merged together to derive a study area-wide dataset depicting regional distributions for the Lorillard, Ahiak and Wager Bay caribou herds. All derived polygons will be consulted on within each range community prior to their completion to ensure the more detailed knowledge of hunters on the range is incorporated in a meaningful way.

While there are many possible approaches to seasonal range identification, minimum convex polygon (MCP) (e.g., Dyer et al., 2001; Hins et al., 2009; Mosnier et al.,, 2003) and utilization distribution Methods (UD) (e.g., Koehler & Pierce, 2003; Rivrud et al., 2010; Skarin et al., 2008; Smulders et al., 2012) are most commonly applied (Laver and Kelly 2008; Powell 2000). The MCP approach delineates home ranges by creating a minimum bounding convex polygon that encompasses all sampled location points. Defining seasonal ranges using MCP is practical, as it is straightforward to implement and interpret, and requires no input parameter selection by the user. However, the approach’s simplicity is also limiting, as it can overestimate range size by incorporating unused areas found between outlying points and unequal use of the land base within its boundaries (Powell 2000, Börger et al. 2006, Nilsen et al. 2007, Long and Nelson 2012).

Utilization distribution (UD) approaches differ from MCP in that they delineate seasonal ranges based on probability of use contours derived from density surfaces. Kernel density estimation (KDE) is arguably the most common UD method (Börger et al. 2006, Kie et al. 2010). KDE generates a density surface from sample location points by placing a probability density function over each location point to estimate a density value for that area. A user-defined continuous grid is superimposed on the data and a density estimate is produced for each cell. For cells where the probability density functions overlap, estimates are averaged (Silverman 1986, Worton 1989, Seaman and Powell 1996). KDE requires the user to select an output grid size, kernel shape[1] and search radius size; however, of these, the search radius has been shown to have the most influence on the resulting range boundaries (Worton 1989, Seaman and Powell 1996, Hemson et al. 2005, Kie et al. 2010). Many

[1] Default kernel shape in ArcMap is a quartic kernel function

search radius selection methods have been proposed (e.g., least squares cross validation, likelihood-cross validation, reference search radius selection, plug in search radius selection), but no consensus has been reached on which is most appropriate.

KDE is an improvement over MCP as it better represents seasonal range boundaries and provides a measure of space-use that can be used to distinguish areas of intense versus occasional use within the defined range (Börger et al. 2006; Kie et al. 2010; Laver and Kelly 2008; Worton 1987). KDE was selected for this proposed analysis since it would allow for the identification of key habitats, characterized by high use, within each of the caribou subpopulations' seasonal ranges. Additionally, KDE has been widely used to identify seasonal and home ranges for wide ranging mammals living in multi-use landscapes similar to that of the barren-ground caribou subpopulations in the study area (Dalerum et al. 2007, Mitchell and Powell 2007, Berland et al. 2008, Sorensen et al. 2008, Sjoberg 2013).

The methods of this research have been peer reviewed and approved by members of the Nunavut Department of Environments Wildlife Research Group, ECCC spatial experts, Caslys consulting spatial experts, and members of the NWT's Wildlife Research Division. Methods have also been discussed with, and approved by, the Kivalliq and Kitikmeot Wildlife Boards and the HTOs of Baker Lake, Rankin Inlet, Naujaat, Kugaaruk, and Gjoa Haven.

Study Area:

The study area for the 2021 spring monitoring program encompassed the Ahiak, Lorillard, and Wager Bay herds spring range (**Figure 4, 5 & 6**). The range sits entirely within tundra habitats.

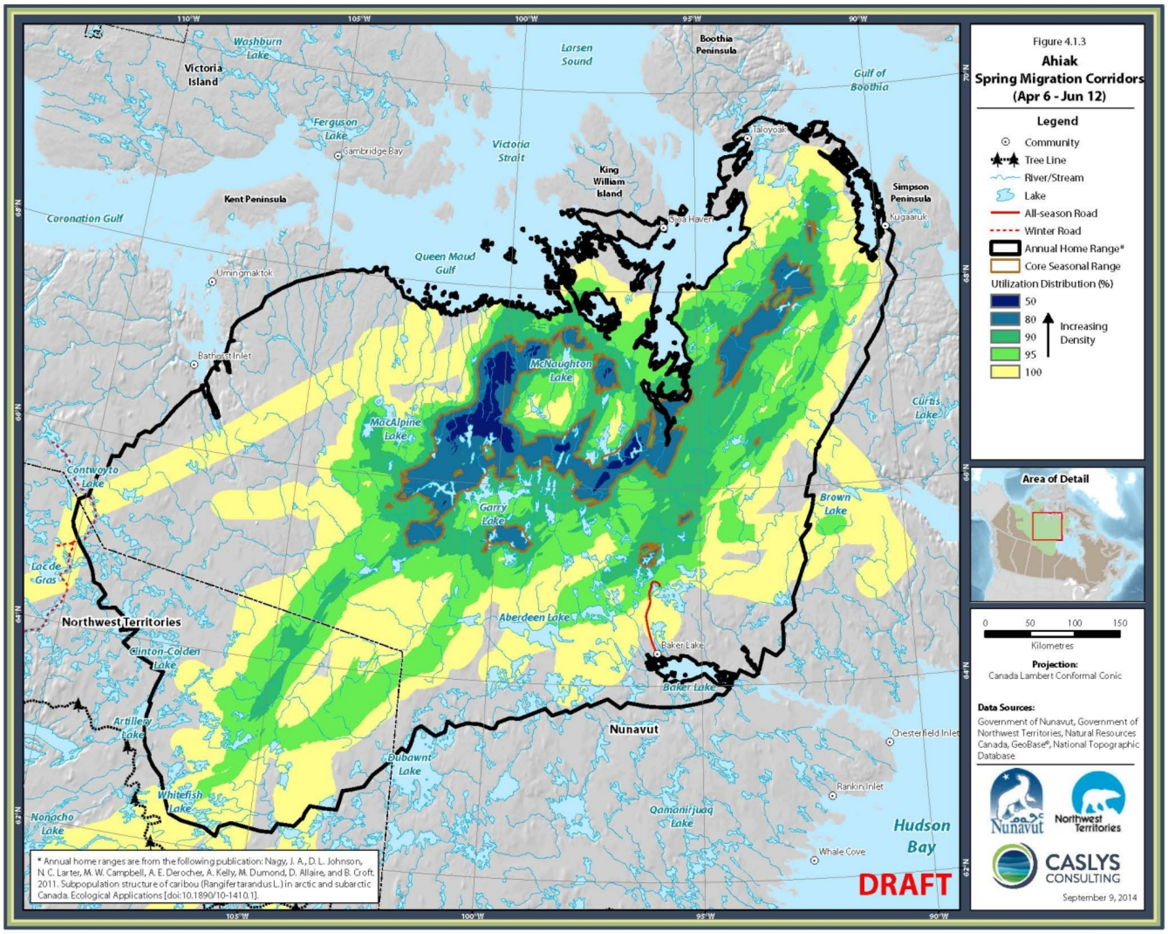


Figure 4. The Ahiak herd spring migratory range and cooridors. Darker colors indicate more heavily used spring range/migration extents. Collaring activities were focused, where possible, within dark green to dark blue polygons.

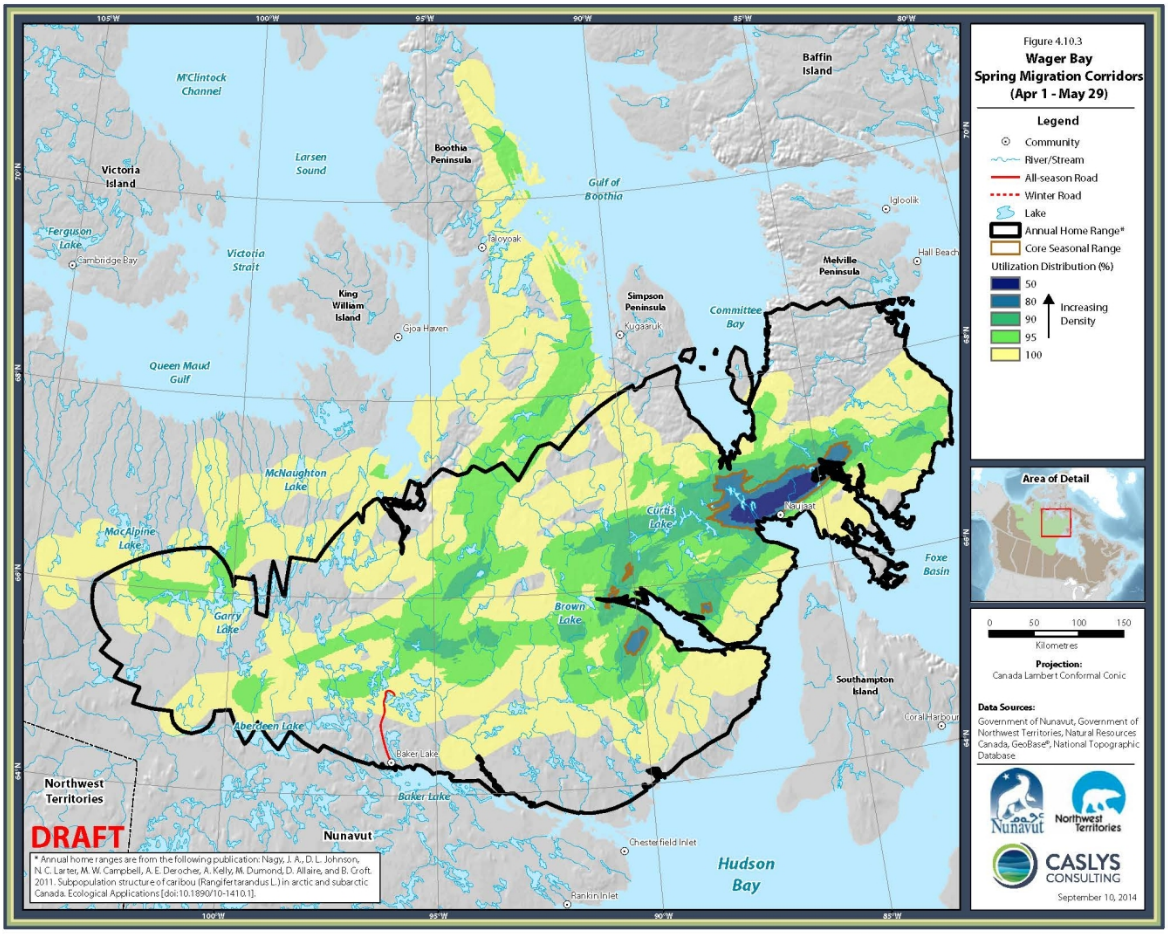


Figure 5. The Wager Bay herd spring migratory range and cooridors. Darker colors indicate more heavily used spring range/migration extents. Collaring activities were focused, where possible, within dark green to dark blue polygons.

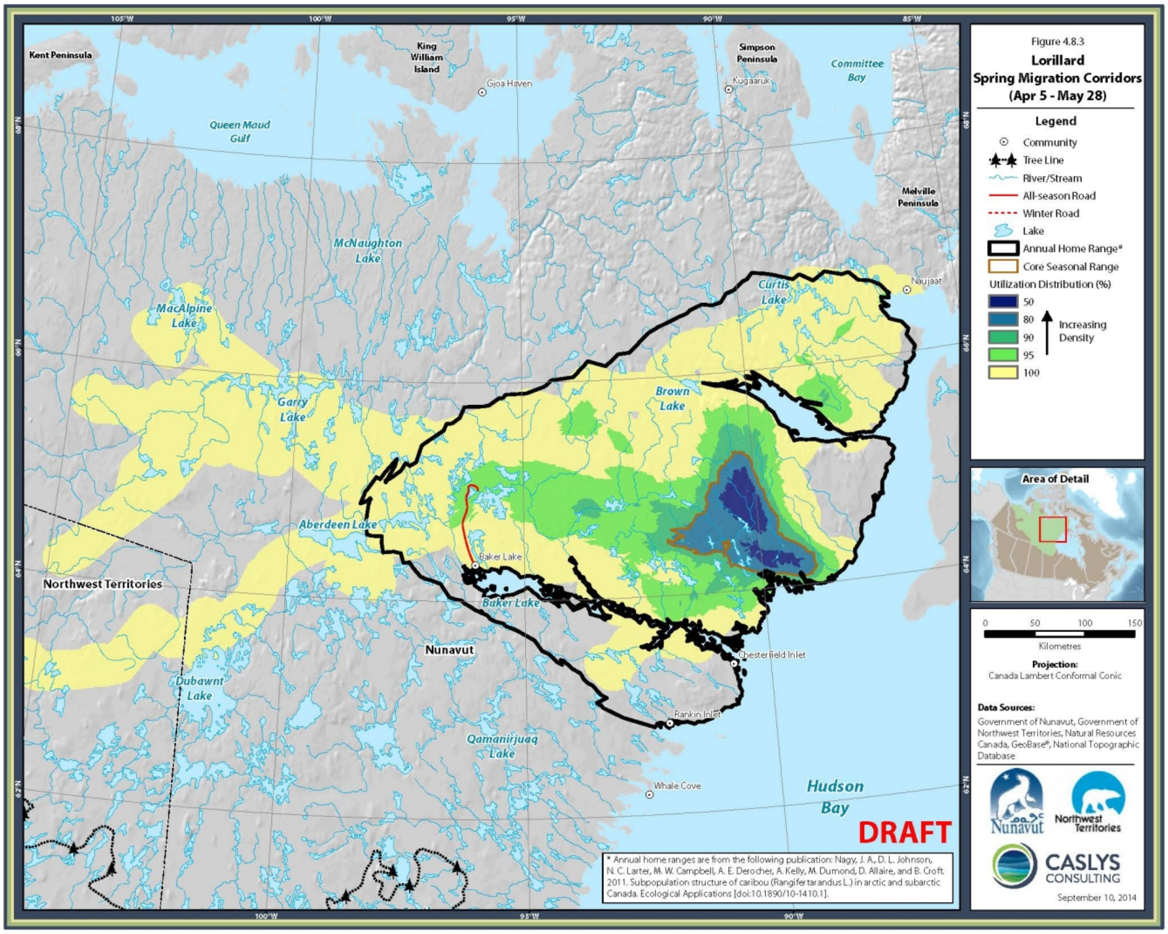


Figure 6. The Lorillard Herd spring migratory range and cooridors. Darker colors indicate more heavily used spring range/migration extents. Collaring activities were focused, where possible, within dark green to dark blue polygons.

Results/Discussion:

NEM Caribou Cow Movements 2021-2023

Forty (40) Telonics Iridium GPS-5 collars with automatic breakaway devices, were deployed on Ahiak and Lorillard cows (25), and Wager Bay cows (15) in April/early May 2022. Target capture locations, though modified to incorporate known groups of migratory caribou, were consistent with objectives (**Figure 7**). Generally, collared NEM caribou cows followed predicted tracks from deployment to present and utilized similar seasonal ranges through the 2-year program. Caribou cow movements and seasonal range use are shown (**Figures 8 through 16**). The NEM telemetry program continues into 2023 with a second 70 collar deployment in spring 2023, designed to bring collar numbers up to the target 35 collars (cows) for each of the Ahiak, Lorillard, and Wager Bay herds.

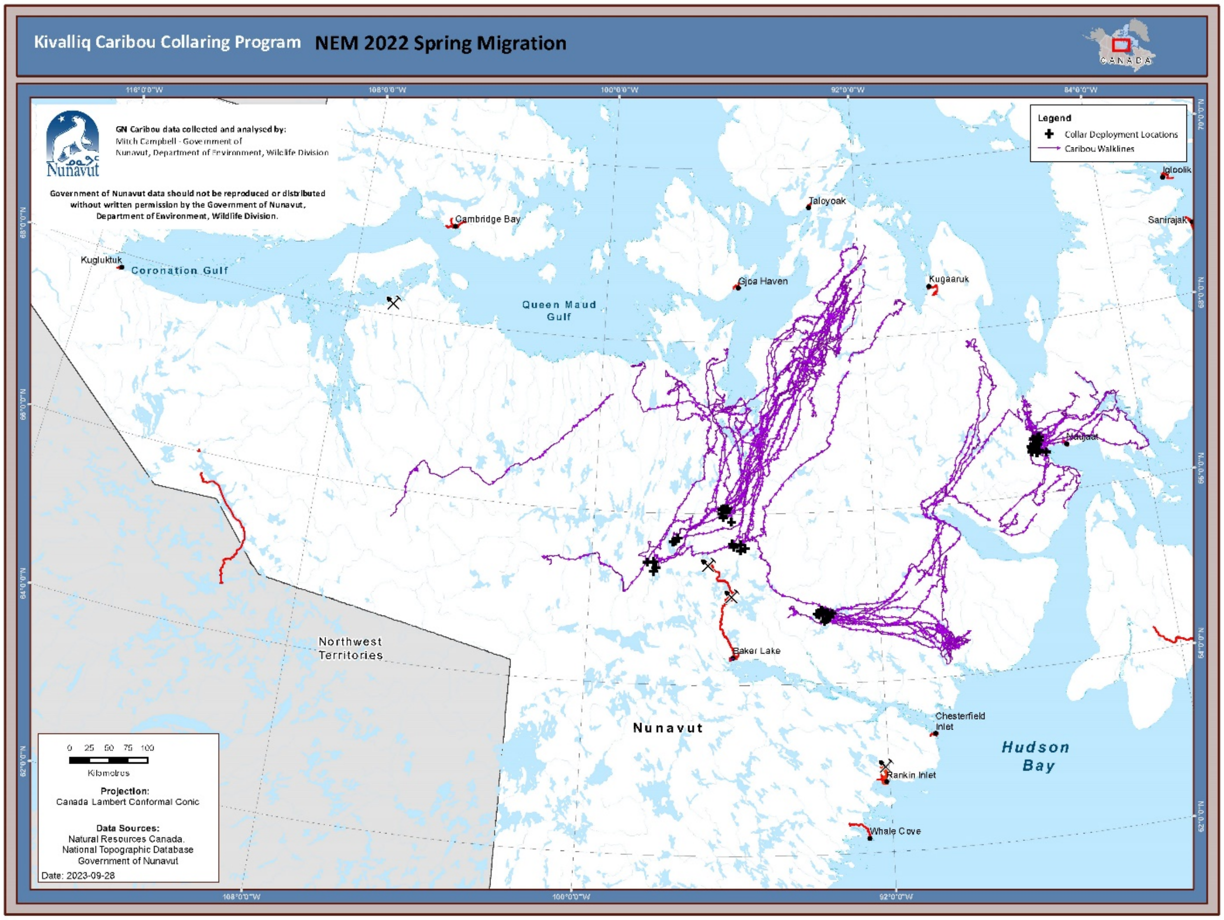
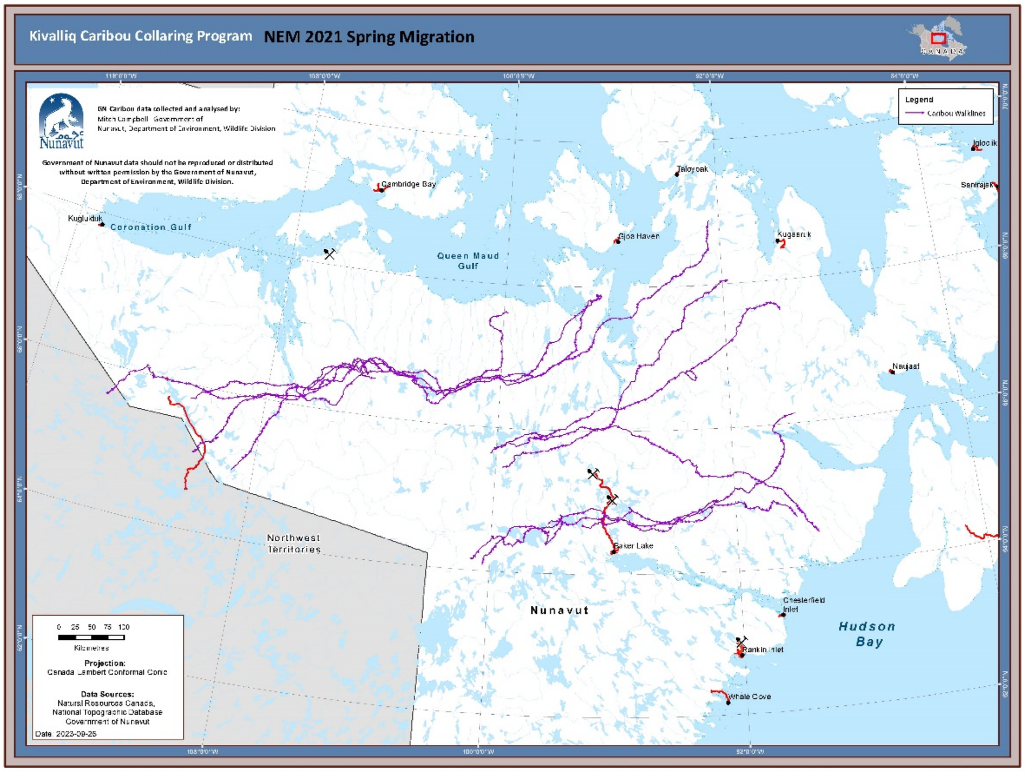


Figure 7. NEM spring collar deployment locations and initial movements. Track lines without an "+" were from existing collars.



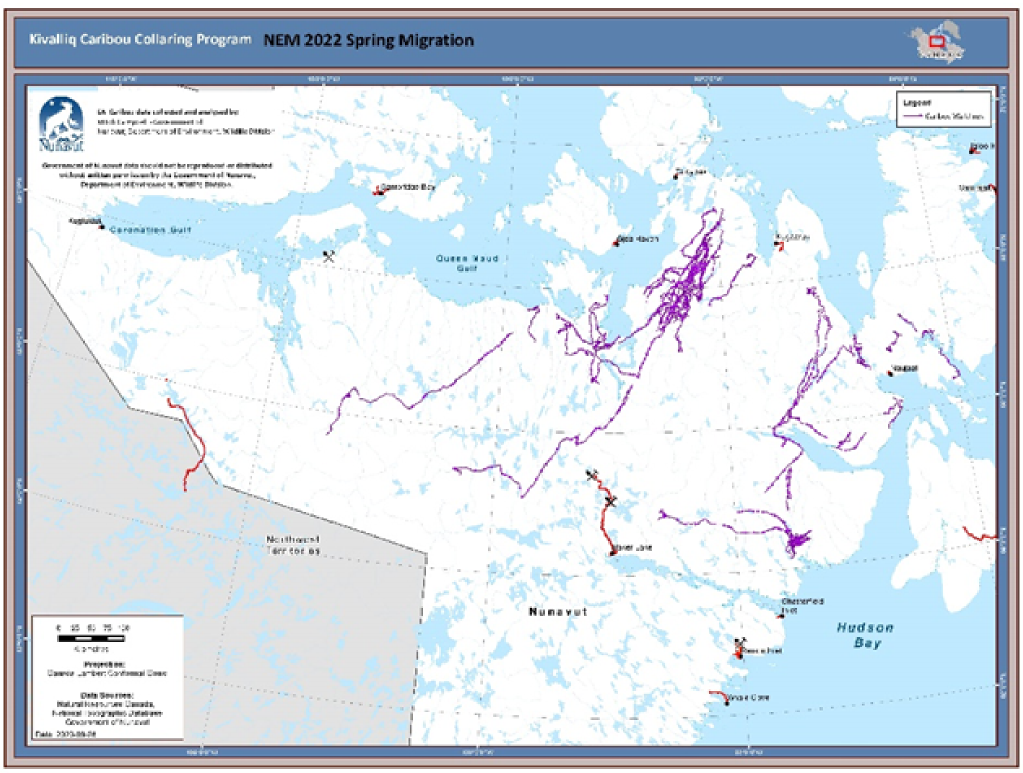
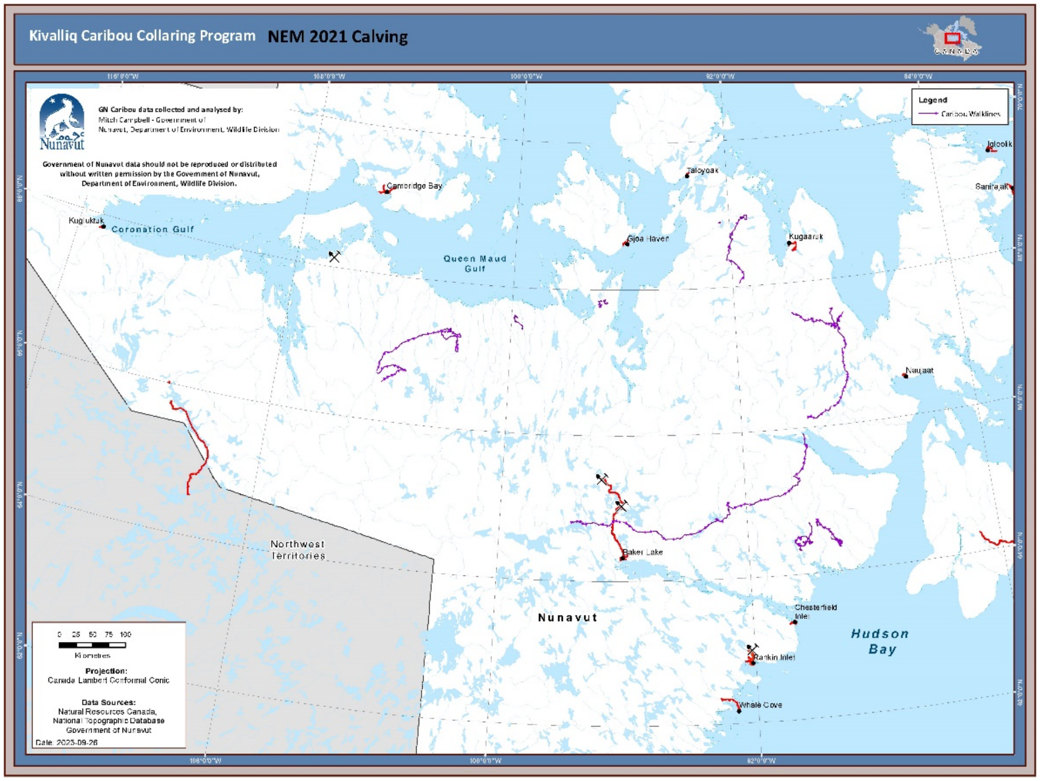


Figure 8. NEM caribou cow movements during spring 2021 (above) and spring 2022 (below). Includes all collar data from April 6th through June 12th.



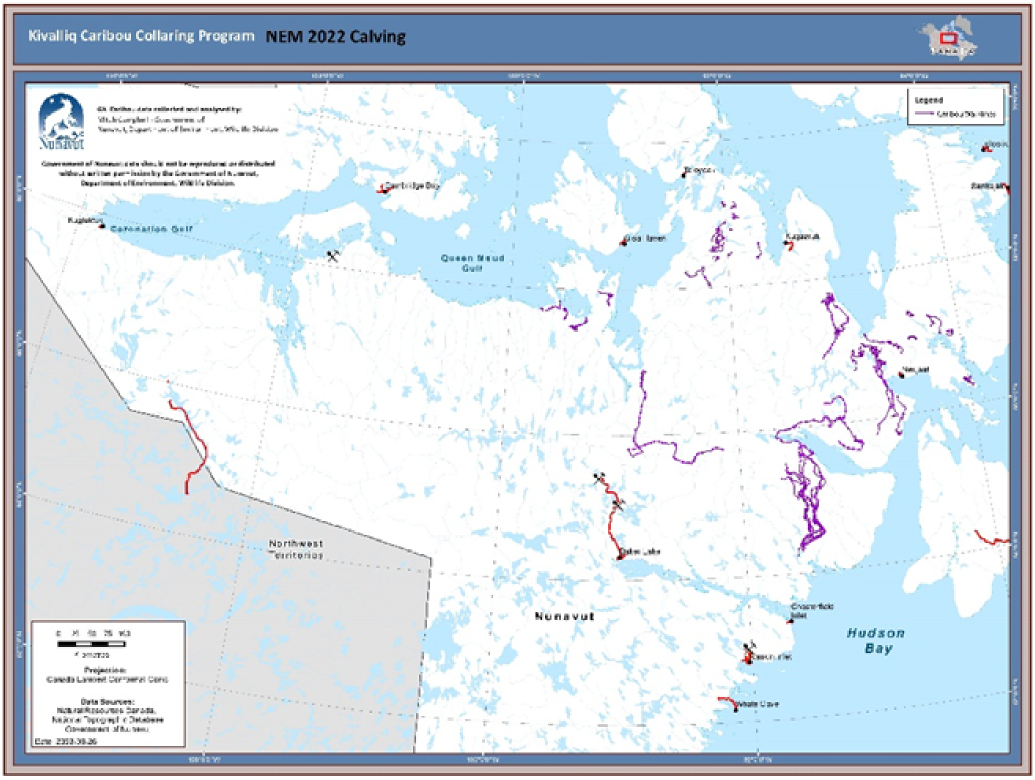
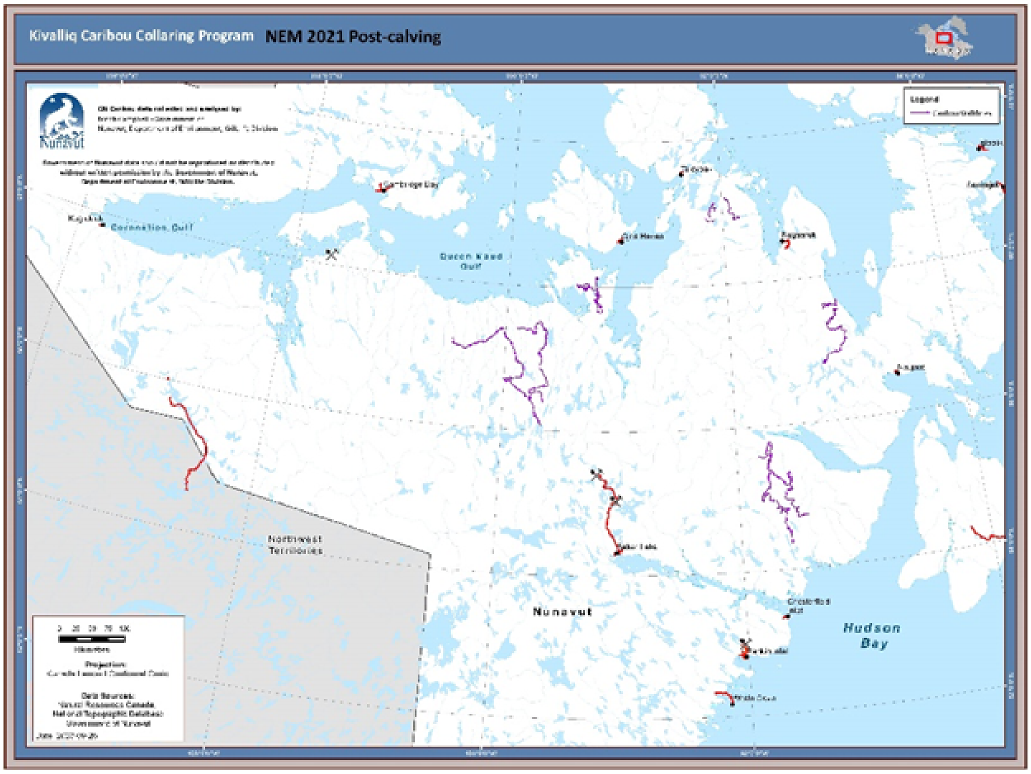


Figure 9. NEM caribou cow movements during calving 2021 (above) and calving 2022 (below). Includes all collar data from June 13th through June 25th.



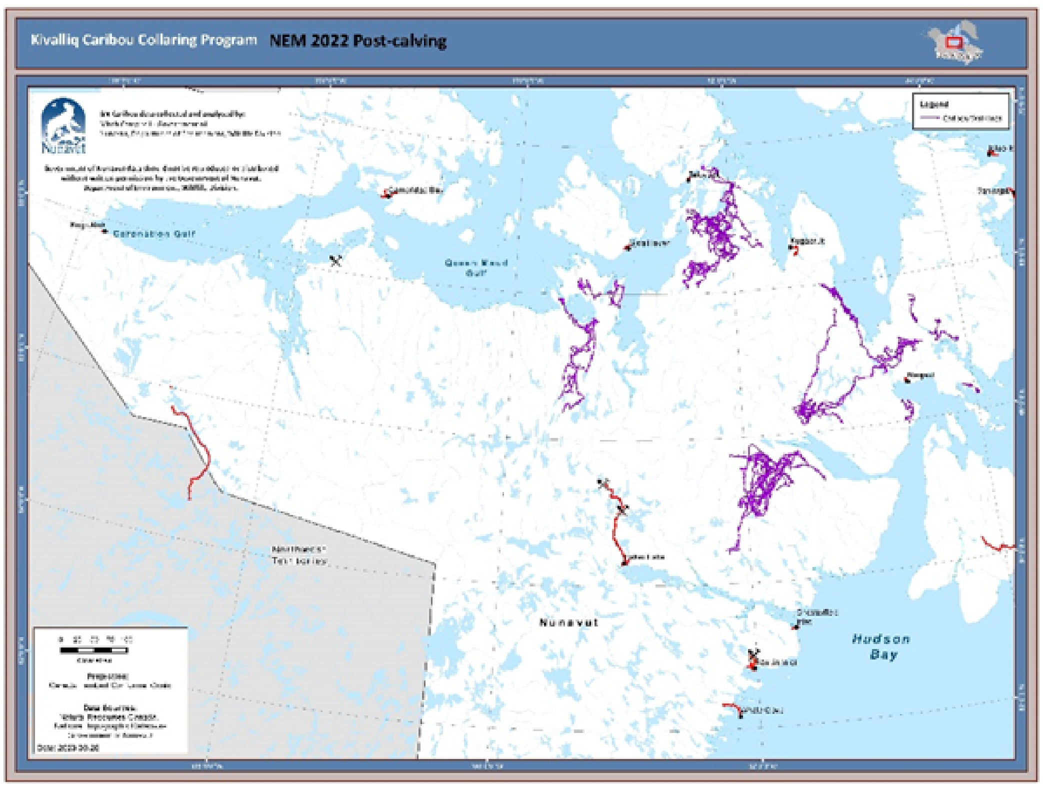
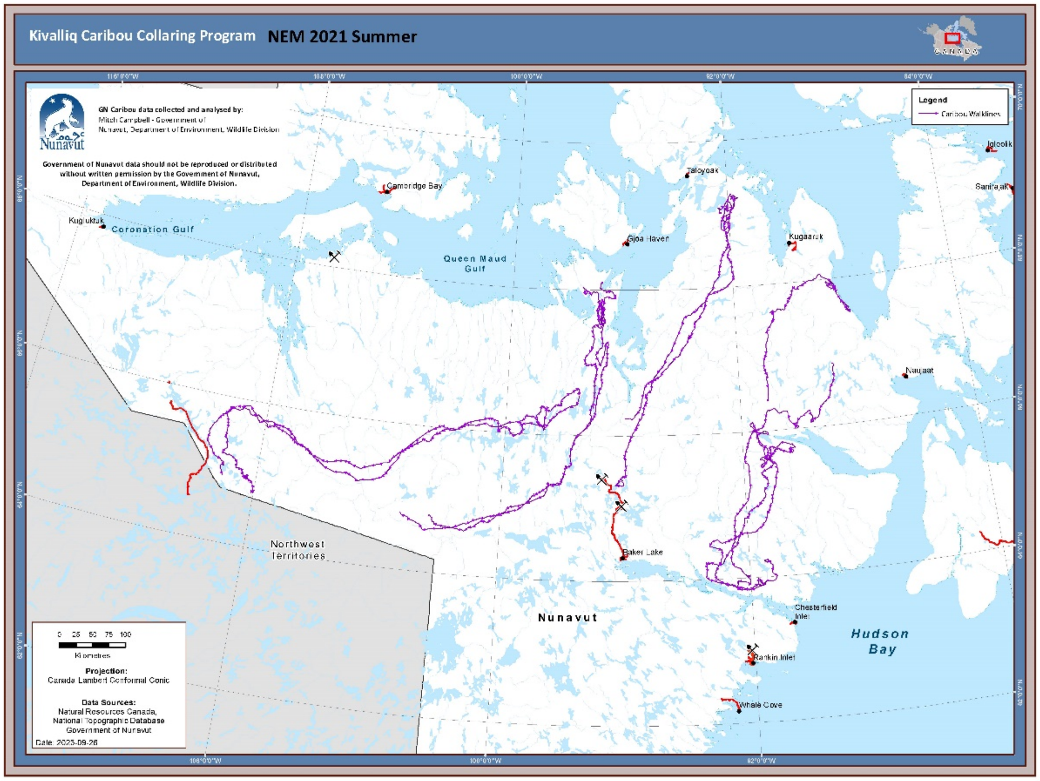


Figure 10. NEM caribou cow movements during post-calving 2021 (above) and post-calving 2022 (below). Includes all collar data from June 26th through July 12th.



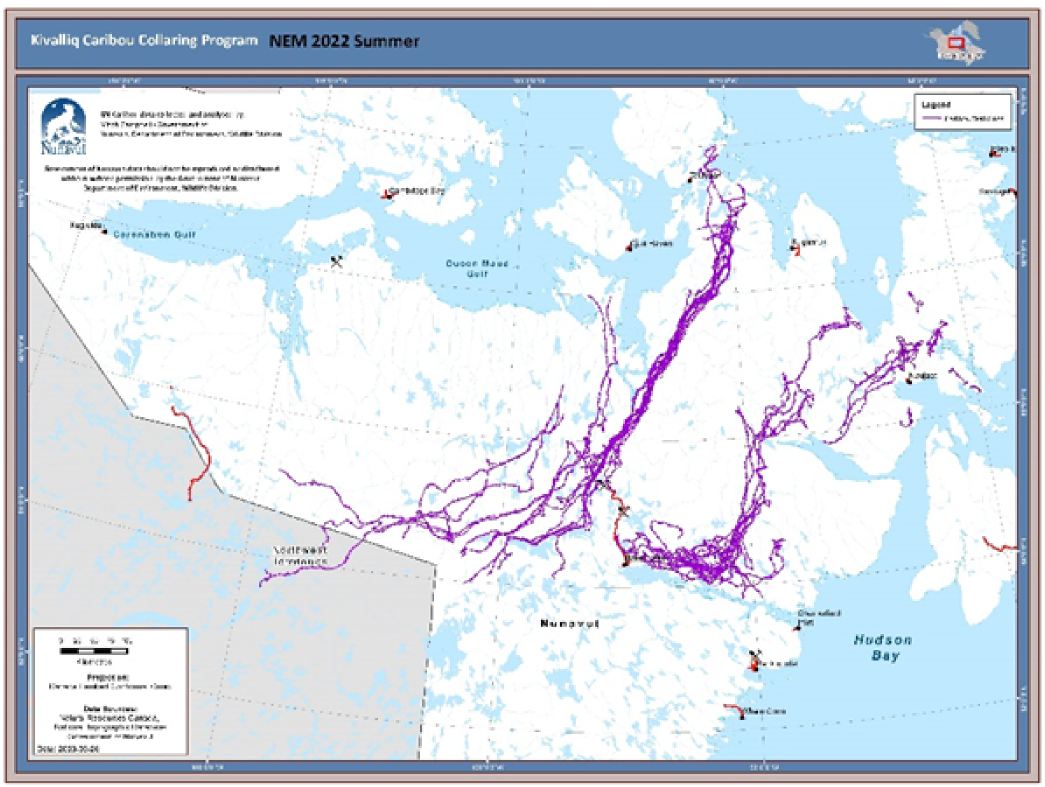
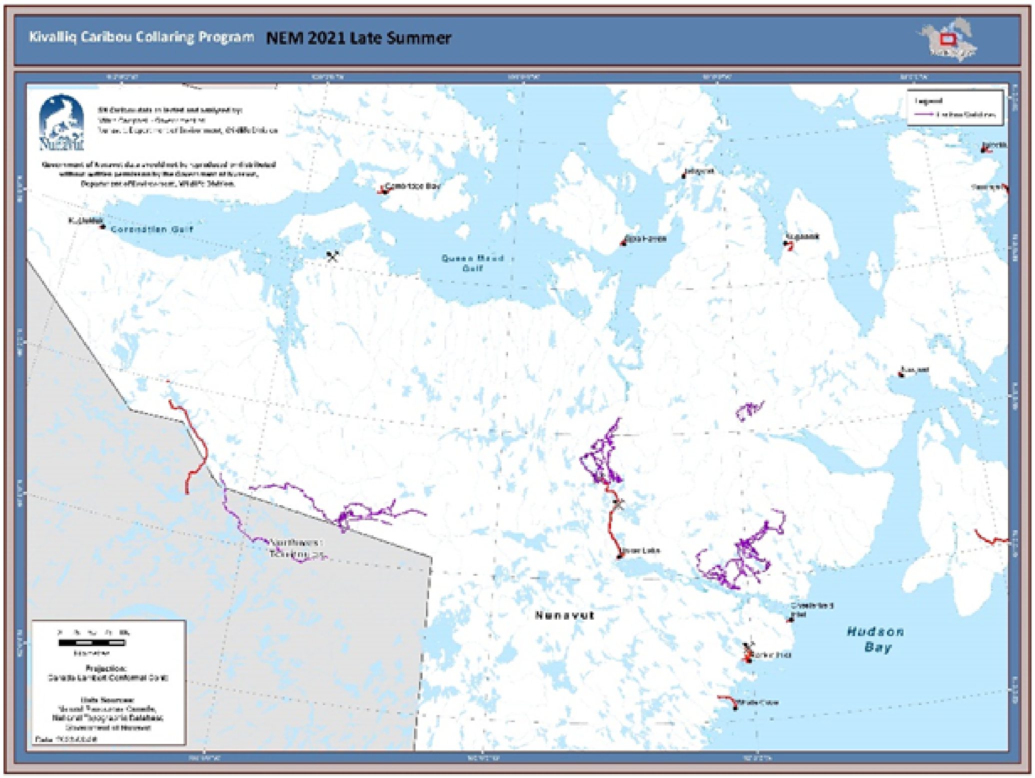


Figure 11. NEM caribou cow movements during summer 2021 (above) and summer 2022 (below). Includes all collar data from July 13th through August 12th.



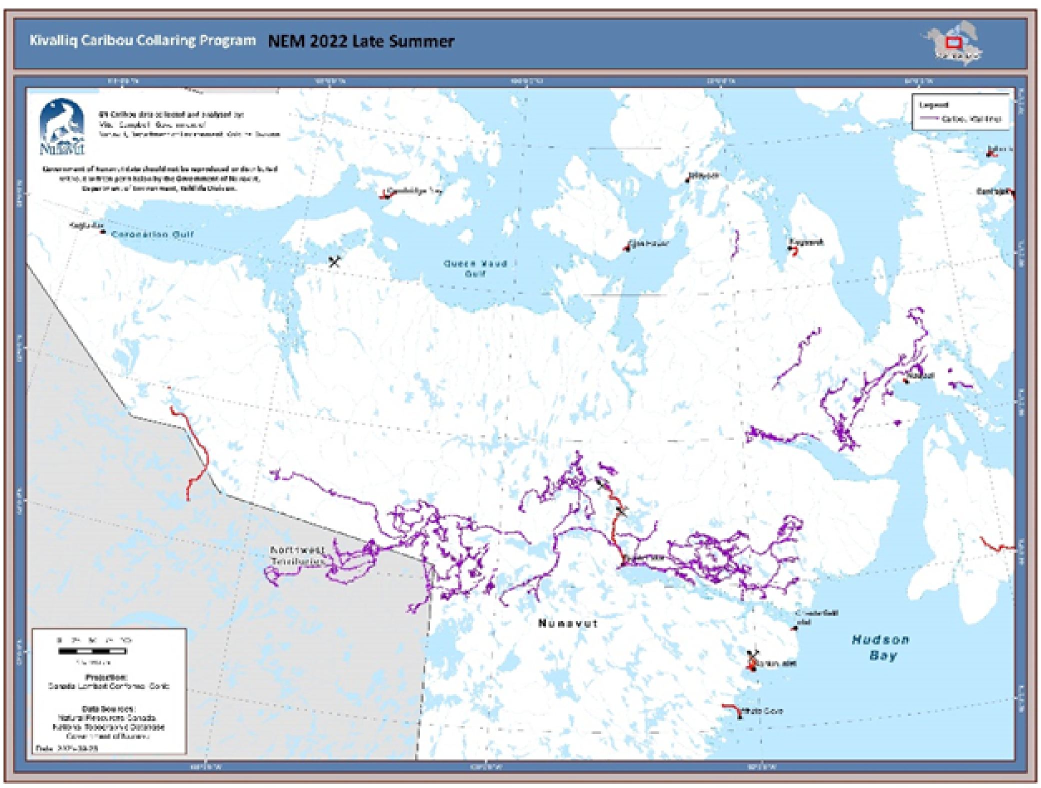
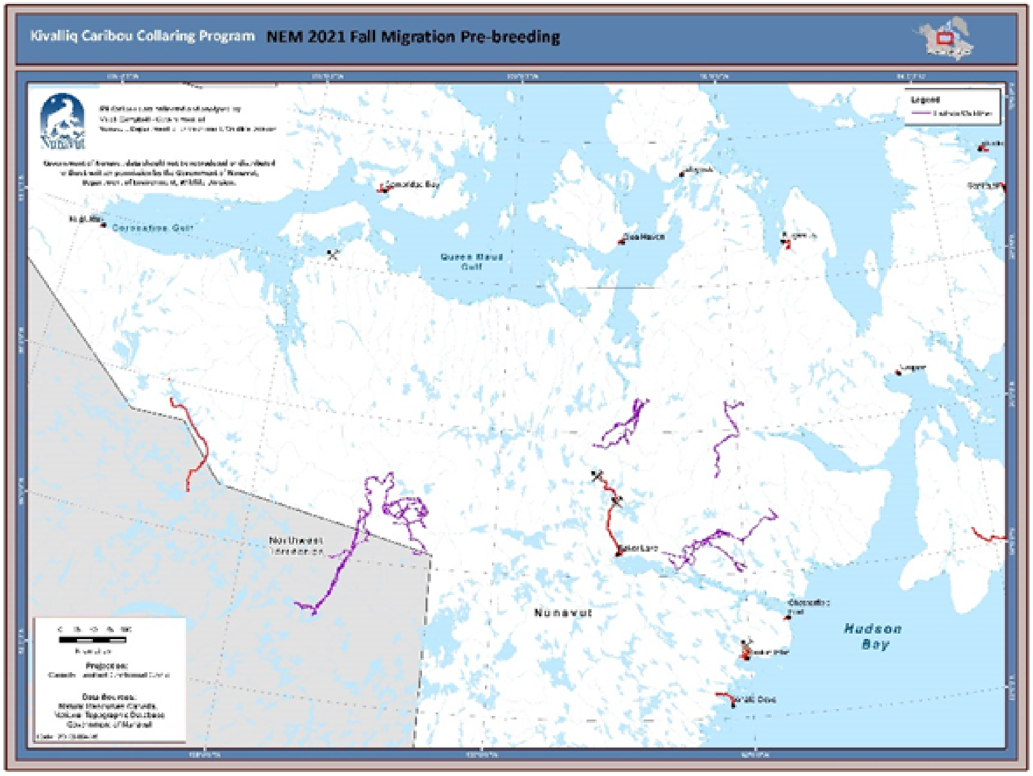


Figure 12. NEM caribou cow movements during late-summer 2021 (above) and late-summer 2022 (below). Includes all collar data from August 13th through September 21th.



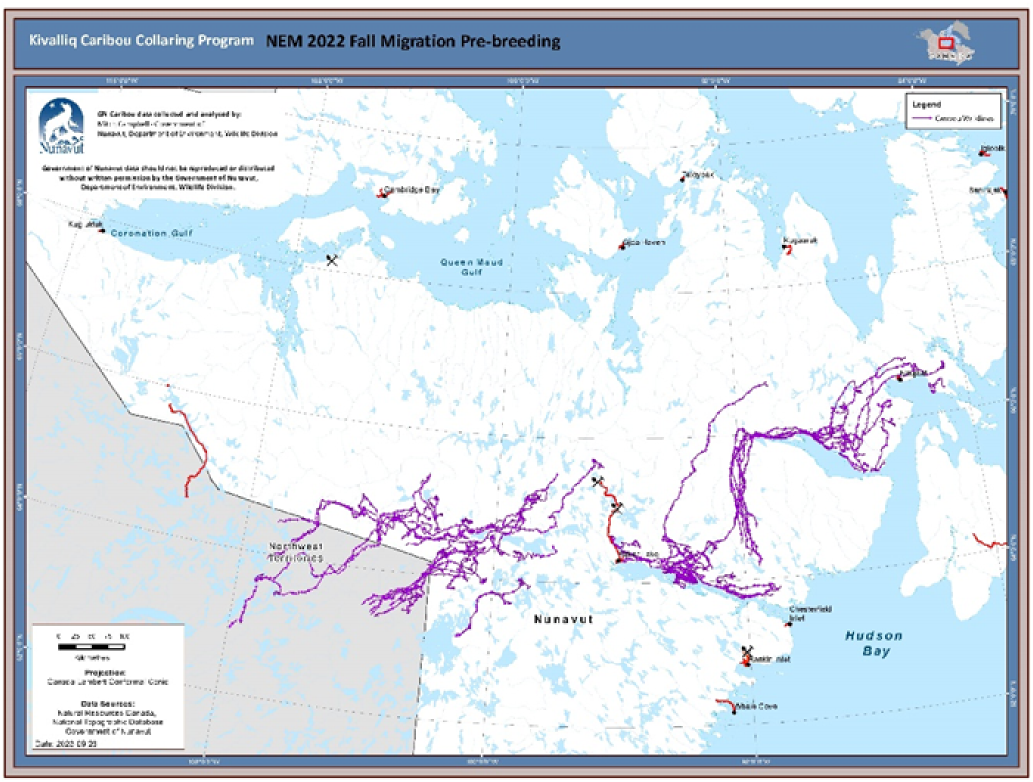
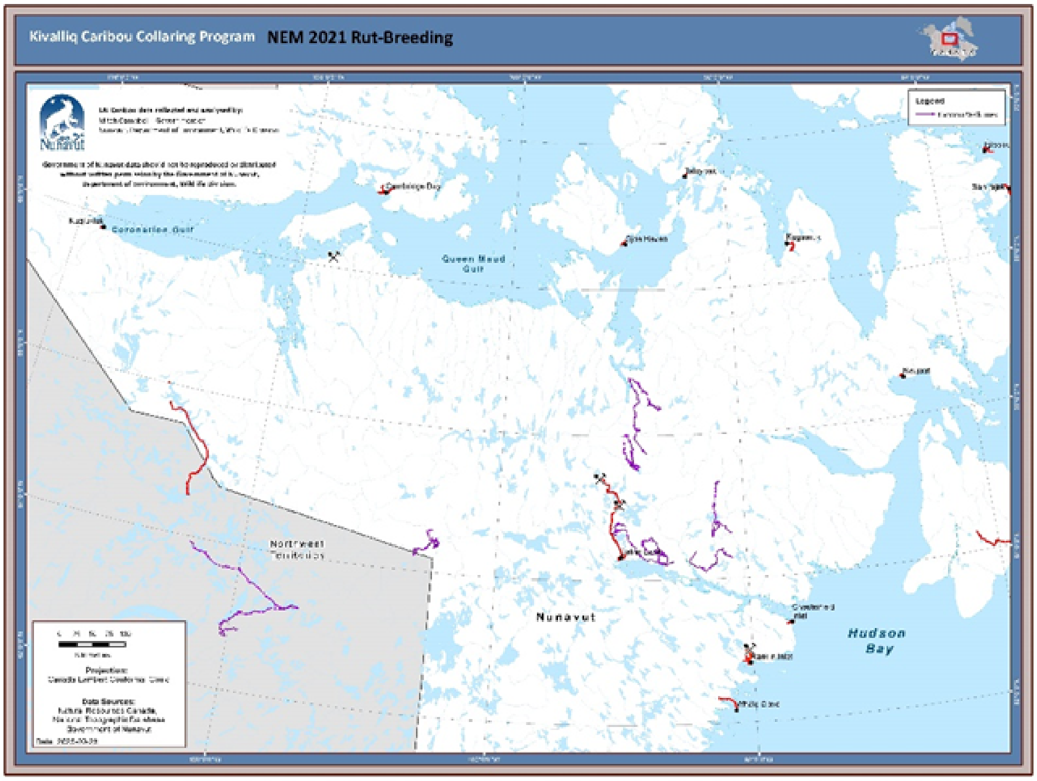


Figure 13. NEM caribou cow movements during fall migration pre-breeding 2021 (above) and fall migration pre-breeding 2022 (below). Includes all collar data from September 22nd through October 22nd.



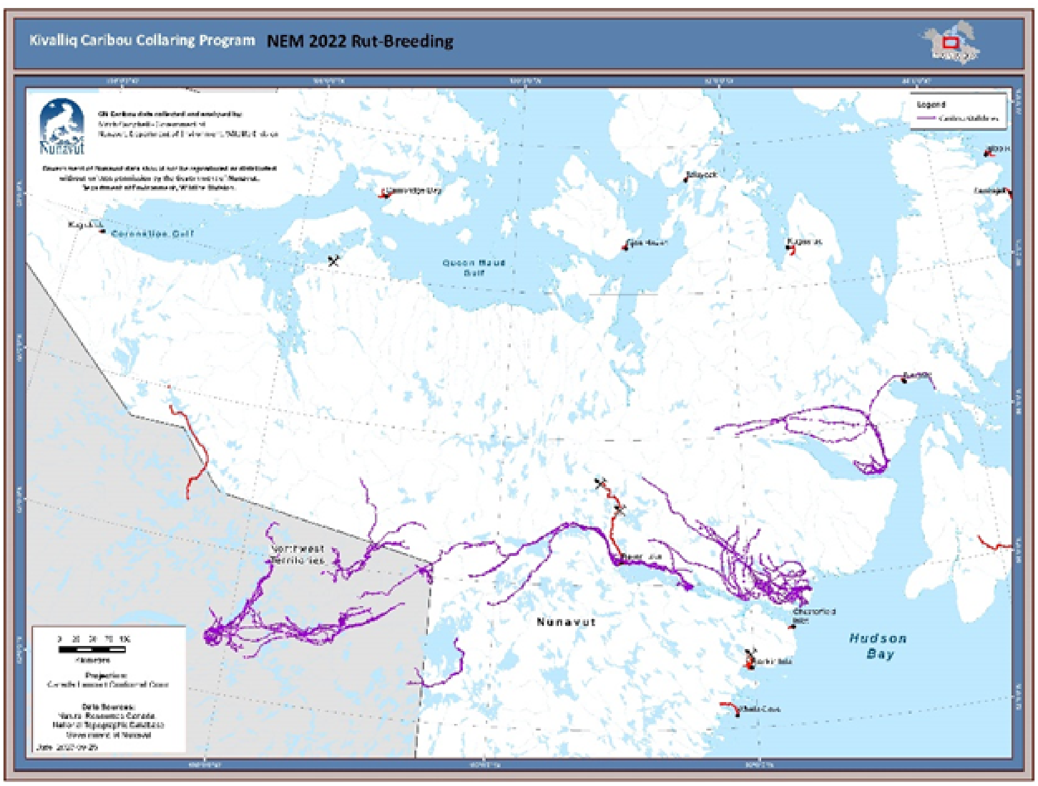
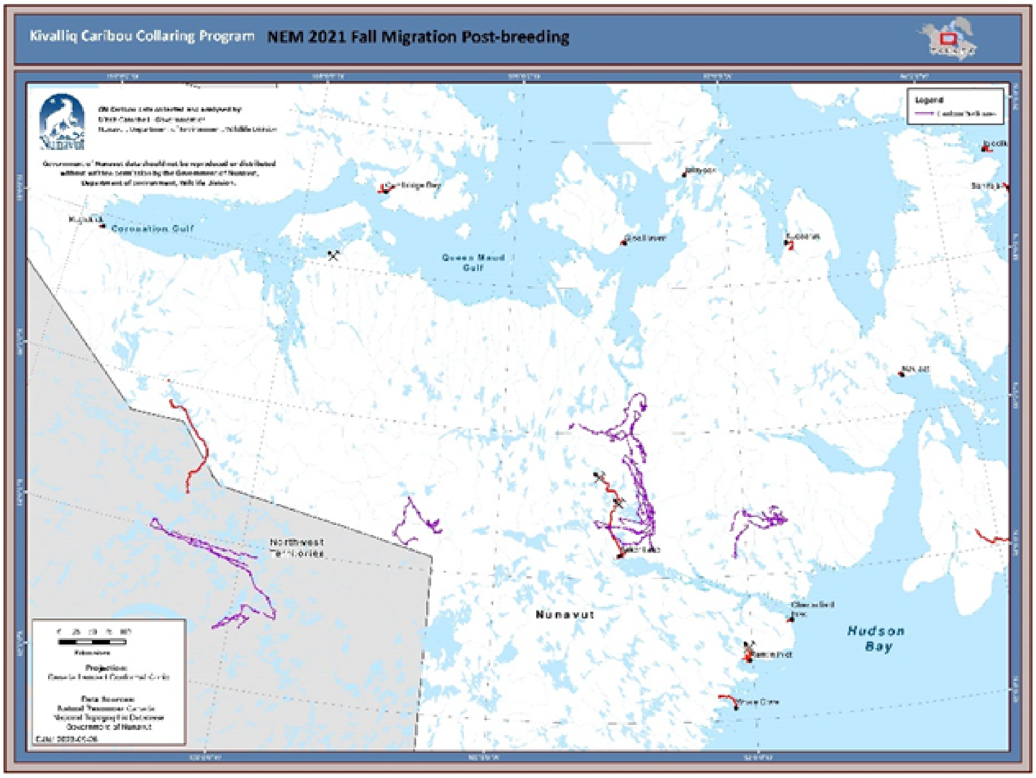


Figure 14. NEM caribou cow movements during rut/breeding 2021 (above) and rut/breeding 2022 (below). Includes all collar data from October 23rd through November 8th.



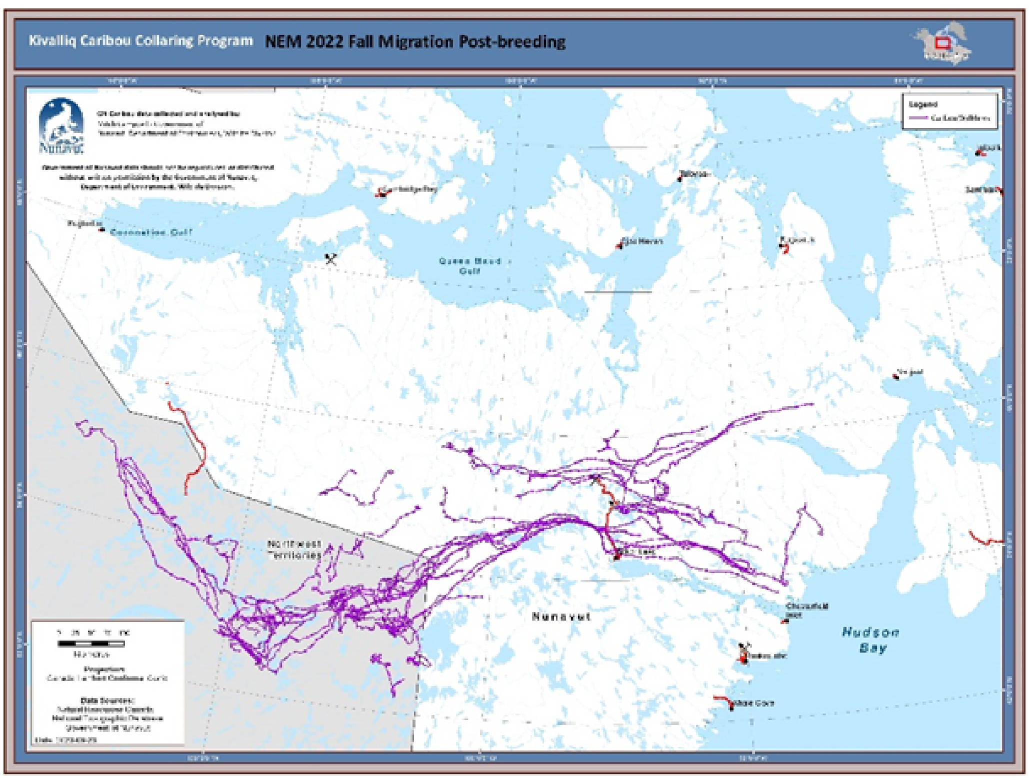
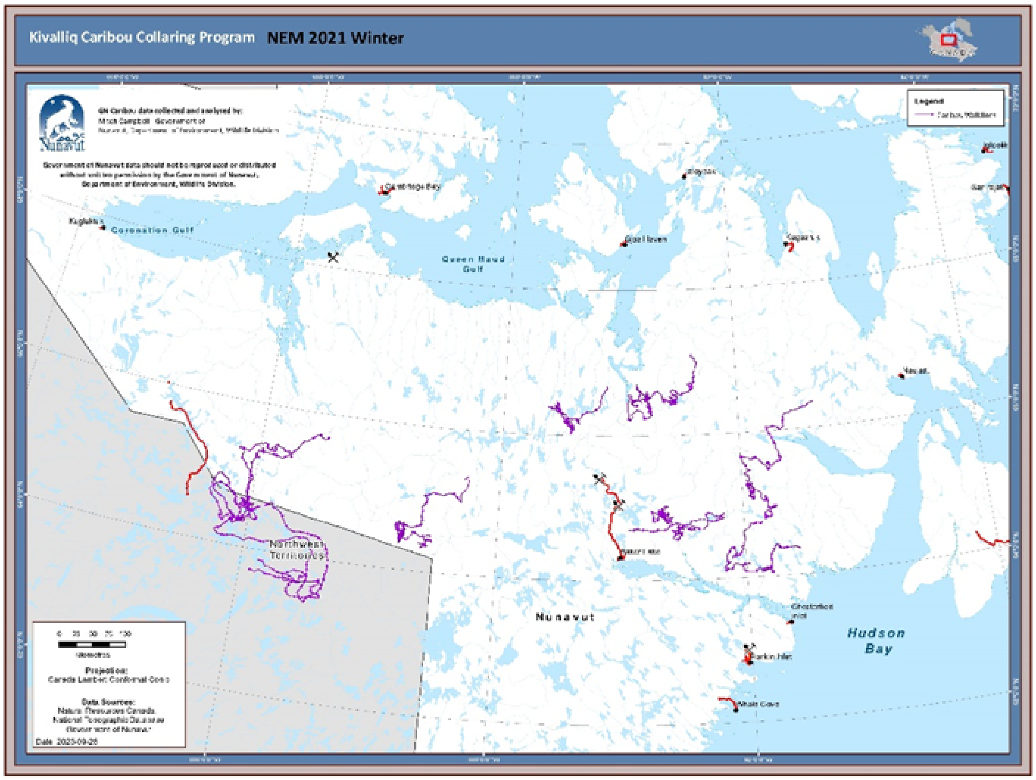


Figure 15. NEM caribou cow movements during post-breeding 2021 (above) and post-breeding 2022 (below). Includes all collar data from November 9th through December 15th.



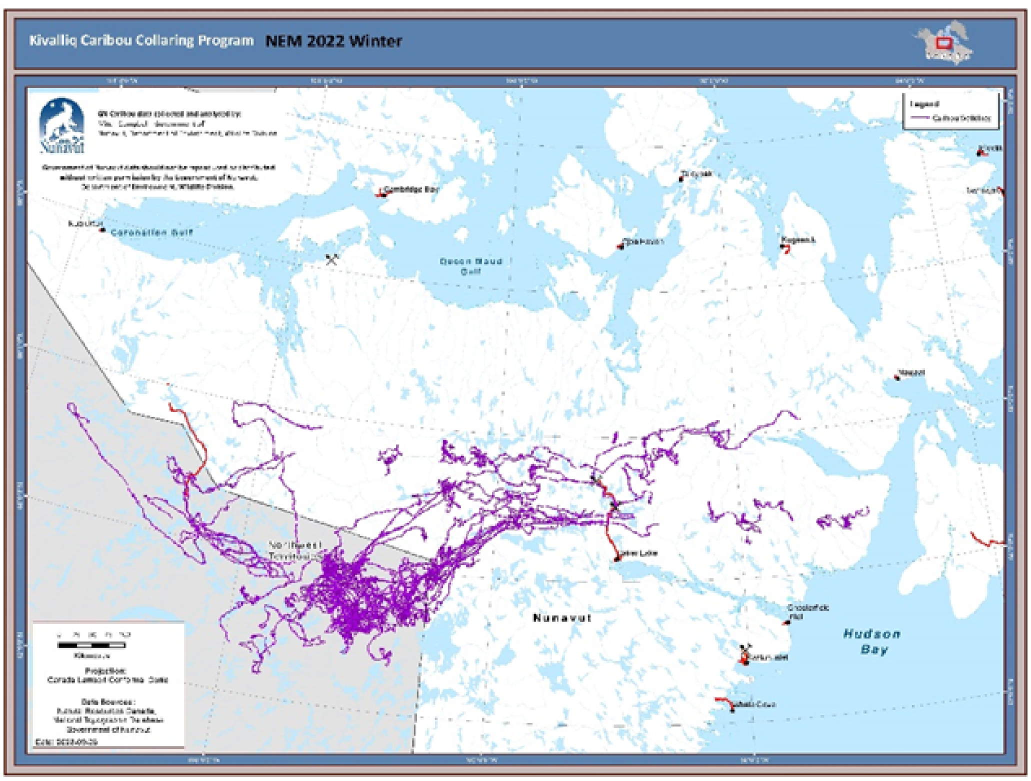


Figure 16. NEM caribou cow movements during winter 2021 (above) and Winter 2022 (below). Includes all collar data from December 16th through April 5th.

Other Telemetry Based Research Programs

An update to caribou seasonal range use for the Ahiak, Wager Bay, and Lorillard herds is ongoing with an expected completion date of winter 2024 following the addition of past years location data. Collar movements of NEM caribou cows over the past year are illustrated in **Figure 17**. Seasonal range use has been within GN mapped seasonal ranges for all NEM herds since the initiation of this telemetry program (**Figure 1, 2, & 3)**.

For interpretation of estimates of the NEM 2021 survey estimate we used telemetry data to determine the relative fidelity of caribou to calving seasonal range. As done in 2018 for the Beverly survey analysis (Campbell et al. 2019), we assigned calving grounds to caribou based on polygons shown below. These were adjusted to mirror the 2021 survey strata (**Figure 18**). We then assessed whether caribou show fidelity to their calving areas each year. Below is a plot that show migration paths and locations for collared females from 2016-2021 (**Figure 19**). Migration paths often are fairly intertwined suggesting some overlap in wintering areas. The data in **Figure 19** was further analyzed to assess fidelity (**Figure 20**). The plot below shows mean locations of calving each year for caribou monitored more than 1 year with an arrow connecting successive mean calving ground locations. The tail of the arrow is the previous year calving location, and the head of the arrow is the current year location. So, caribou that moved little are basically shown as the head of an arrow. Arrows are colored based on the previous year's calving ground. This plot illustrates movement between most areas each year with a reasonable amount of variation in the location of calving for Wager Bay.

The data set was reduced to caribou detected in at least 2 years to allow observation of fidelity of movement to other calving grounds. Yearly sample sizes of caribou in calving ground polygons were low (<10) for most calving grounds with the exception of the Beverly. A summary of movements pooled across all years suggests movement within the Beverly-Adelaide-Ahiak, and Wager Bay-Lorillard calving ground complexes with occasional movement between these two groupings/complexes. In addition, a reasonable level of fidelity was suggested for the Beverly, Wager Bay, and Lorillard calving grounds. For example, 115 caribou calved in successive years in the Beverly calving ground.

A challenge with interpreting these summaries is differing sample sizes of collared caribou on each calving ground. Multi-state models were fit to this data to estimate probabilities of movement based on the frequencies in **Table 1**. A simple model with calving ground-specific movements (termed transition probabilities) was fit with no yearly variation in movements. This estimated a mean movement across all years. Limited sample sizes precluded more elaborate model fitting (**Table 2**). Movement parameters were fixed at zero if there were zero recorded movement events in the data set. This strategy allowed model fitting to the relatively sparse data set. Markov Chain Monte Carlo methods were used to crosscheck estimates.

Table 17 lists the estimates of movement from each calving ground. If the same calving ground is listed then it is an estimate of fidelity (movement from a calving ground back to the same calving ground). These estimates suggest higher fidelity to the Beverly (0.86), Wager Bay (0.69) and Lorillard Calving grounds (0.85) (**Table 1**). In contrast, fidelity was lower for the Adelaide (0.25) and Ahiak (0.44) with relatively high movement probabilities between Adelaide to Beverly (0.61) and Ahiak to Beverly (0.29) as well as Wager Bay to Lorillard (0.29) (**Table 1**). A graphical representation of these results provides a spatial understanding of the results. **Figure 21** illustrates movement events from each calving ground with the boxed numbers giving frequencies of caribou returning to the calving ground in successive years and the arrows illustrating movements. A plot of movement probabilities shows how geographic location influences probability of movement (**Figure 22**). Namely, caribou in the Adelaide are more likely to occur in the Beverly calving ground compared to the Ahiak calving ground. Ahiak caribou often end up in any of the other calving grounds with a tendency to move towards the Adelaide or Beverly calving grounds. The Wager Bay and Lorillard have inter-calving ground movement with a suggestion of directional movement to the Lorillard.

A further challenge with interpreting probabilities of movement is that they can represent different numbers of caribou given differences in herd size based on each calving ground. To explore this further we used estimates of adult females for each of the calving ground areas (**Table 3**) and estimates of adult females for the Beverly in 2018 (62,620 excluding the Adelaide Peninsula)(Campbell et al. 2019). These were then multiplied by the movement probabilities between calving-grounds and an approximate yearly survival rate (0.8) to estimate the number of adult female caribou that might stay and move between calving-grounds in a given year. We note that this estimate is a gross simplification since it does not account for yearly variation in movements, the role of recruitment, as well as variance estimates. These conclusions therefore **<u>should be interpreted cautiously.</u>** As discussed, later a more elaborate meta-population simulation, IPM is needed to better understand the role of movements in herd dynamics.

The approximate N estimates demonstrate that while the movement probability estimates from larger herds like the Beverly are low (<0.1) they still amount to a relatively large number of caribou moving to the Adelaide and Ahiak calving grounds (relative to the number of caribou present on these calving grounds) (**Figure 23**). These results illustrate the need for a simulation or IPM approach to better understand the role of movement in the demography of these herds.

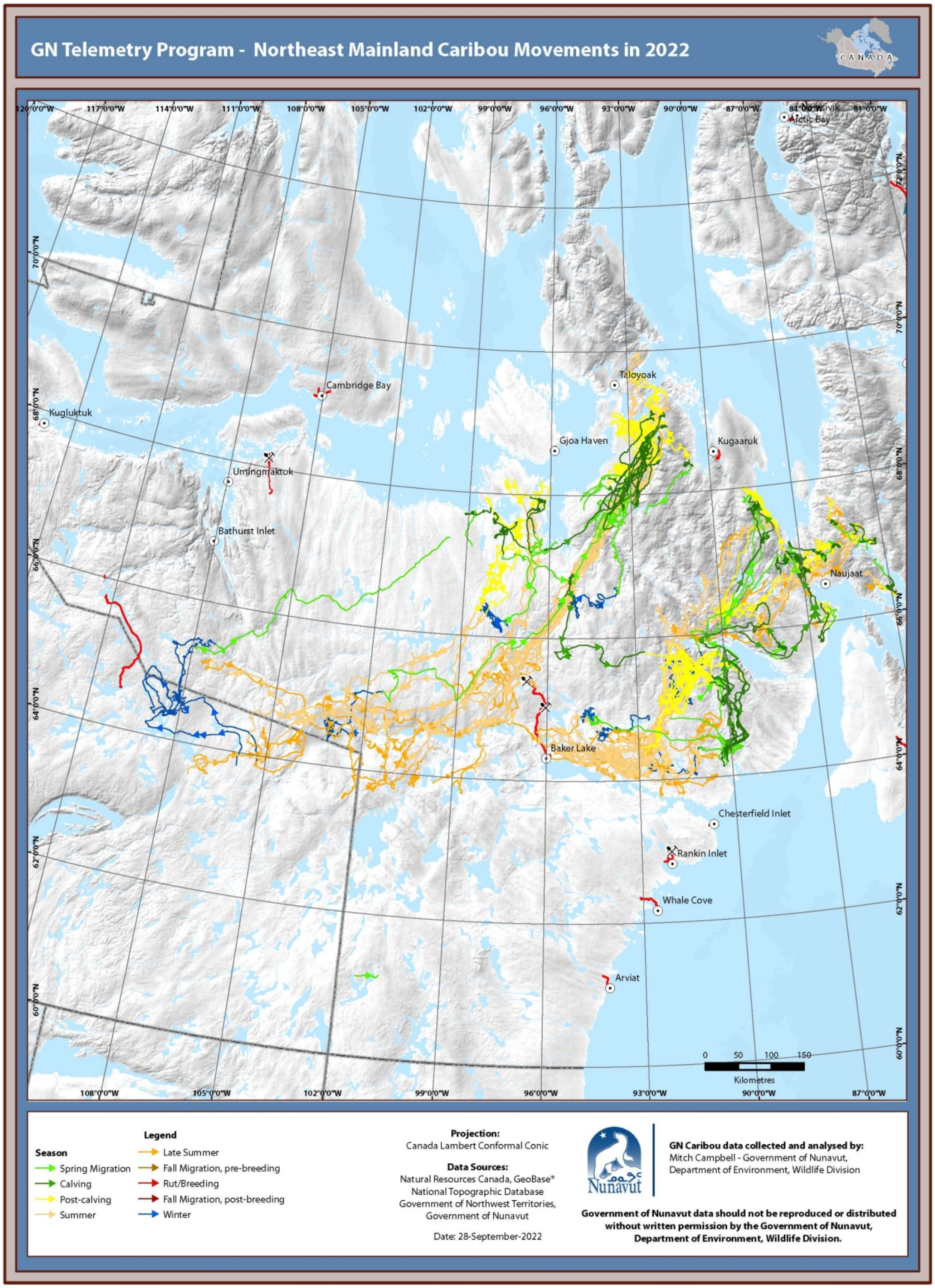


Figure 17. Movements of NEM collared caribou since deployment in late April, 2022.

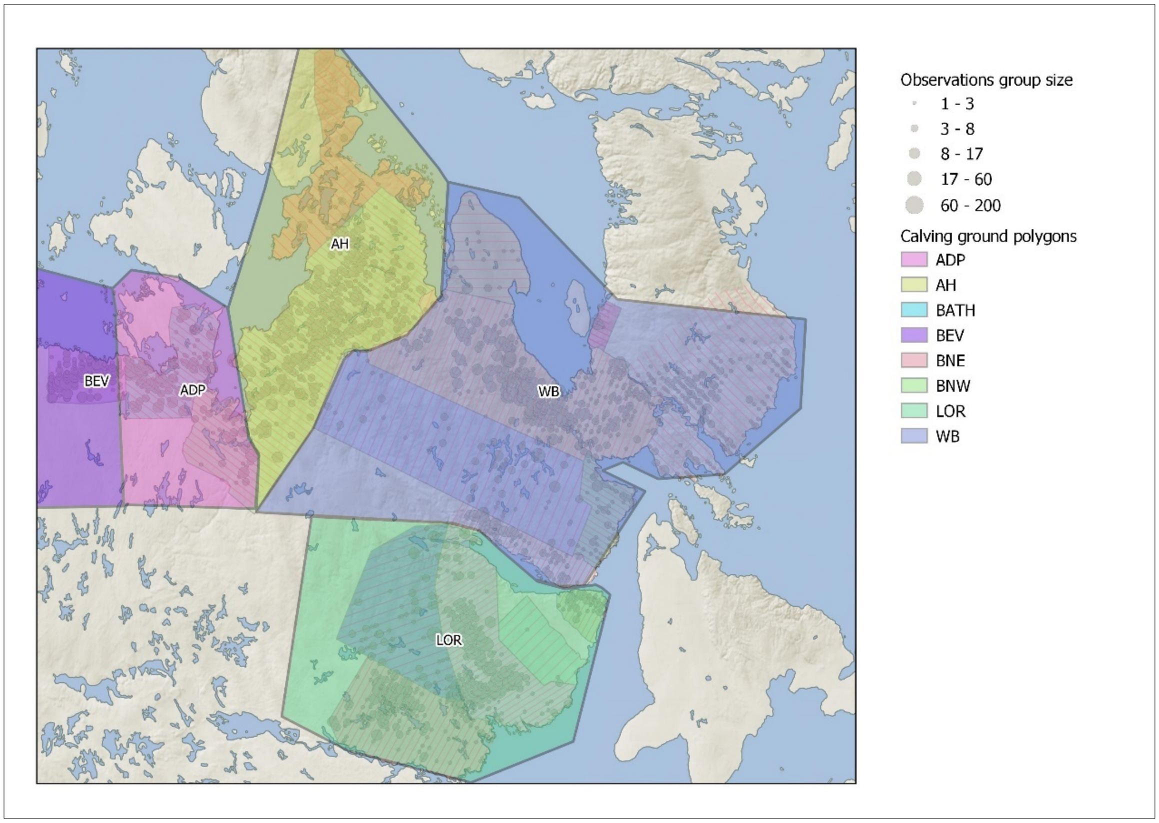


Figure 18. Polygons used to assign calving grounds to mean collar locations (on June 15 each year).

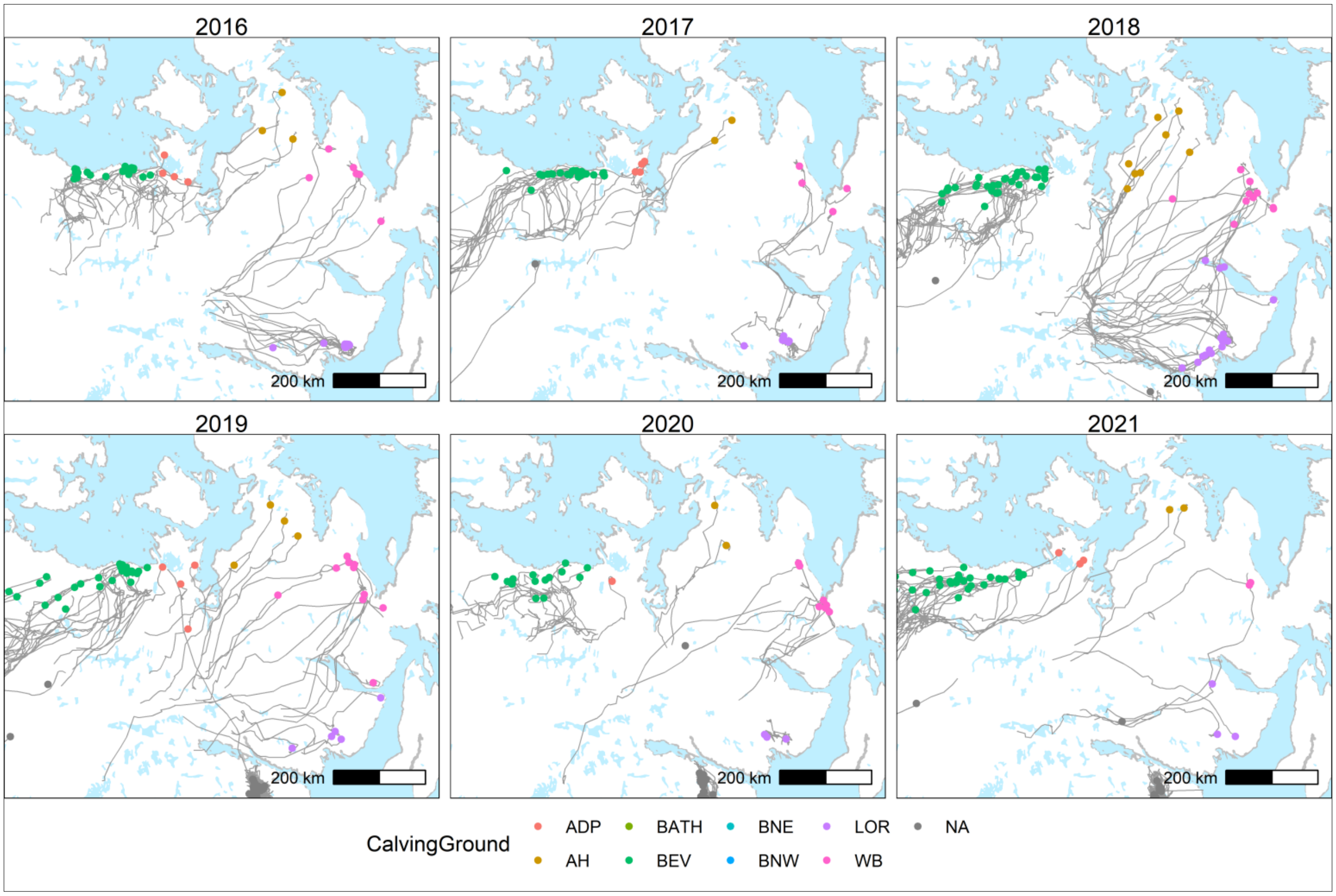


Figure 19. Migration paths and mean collar locations from 2016-2021. The locations of collars.

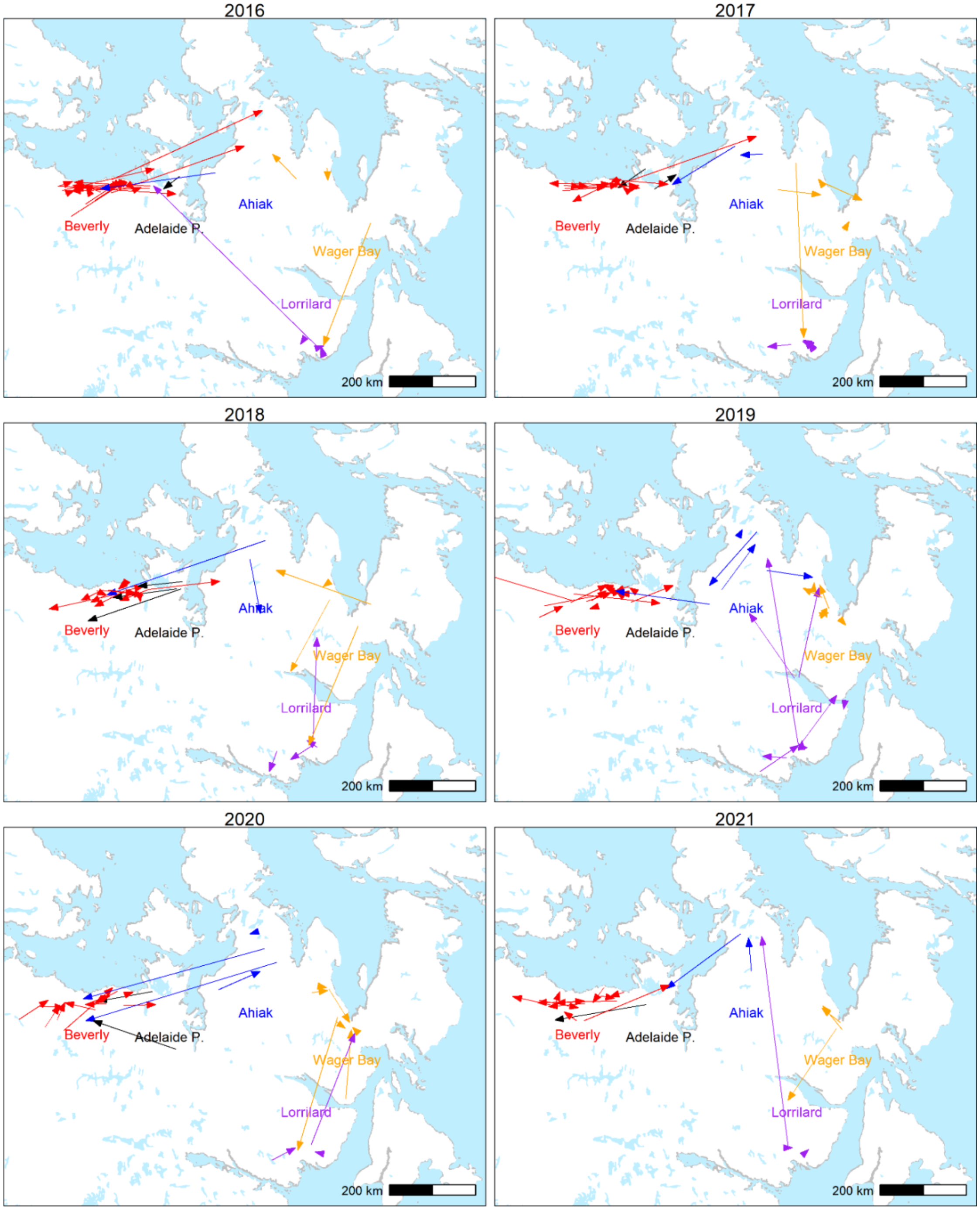


Figure 20. Mean calving ground locations for caribou in the previous year (tail of arrow) and current year (head of arrow) with the arrow colored according to the previous year calving ground.

Table 1. Multi-strata model estimates of movement probabilities between calving grounds. Estimates were not derived for movement events that had 0 frequency.

Movement	events	Movem	SE	Conf. Limit	
Beverly to:					
Beverly	115	0.86	0.03	0.80	0.91
Adelaide	11	0.07	0.02	0.03	0.11
Ahiak	8	0.05	0.02	0.02	0.09
Wager Bay	0				
Lorrilard	0				-
Adelaide to:					
Beverly	10	0.61	0.11	0.38	0.80
Adelaide	5	0.25	0.10	0.07	0.44
Ahiak	2	0.11	0.07	0.03	0.35
Wager Bay	0				
Lorrilard	1	0.03	0.01	0.00	0.10
Ahiak to					
Beverly	7	0.29	0.08	0.12	0.45
Adelaide	2	0.11	0.06	0.01	0.22
Ahiak	11	0.44	0.09	0.26	0.63
Wager Bay	3	0.11	0.06	0.02	0.22
Lorrilard	3	0.06	0.03	0.00	0.10
Wager Bay					
Beverly	0				
Adelaide	0				
Ahiak	3	0.07	0.05	0.01	0.17
Wager Bay	20	0.69	0.08	0.52	0.84
Lorrilard	5	0.22	0.07	0.08	0.37
Lorillard to					
Adelaide	0				
Ahiak	0				
Wager Bay	6	0.13	0.05	0.05	0.27
Lorillard	34	0.85	0.05	0.73	0.95
Beverly	1	0.03	0.02	0.00	0.07

Table 2. Yearly sample sizes of female collared caribou that were detected at a calving ground based on collared caribou detected in at least 2 different years.

Year	Beverly	Adelaide	Ahiak	Wager Bay	Lorillard
2011	6	1	7	0	6
2012	15	1	6	0	5
2013	6	5	4	0	4
2014	24	4	0	1	3
2015	27	2	1	3	5
2016	23	4	3	5	9
2017	22	4	2	4	8
2018	28	0	6	8	13
2019	24	4	4	10	5
2020	15	1	2	7	3
2021	13	2	2	2	3
Total	**203**	**28**	**37**	**40**	**64**

Table 3. Summary of movement events between calving grounds pooled across 2011-2021.

Current Calving ground	Previous calving ground				
	Beverly	**Adelaide**	**Ahiak**	**Wager Bay**	**Lorillard**
Beverly	115	11	8	0	0
Adelaide	10	5	2	0	1
Ahiak	7	2	11	3	3
Wager Bay	0	0	3	20	5
Lorillard	1	0	0	6	34

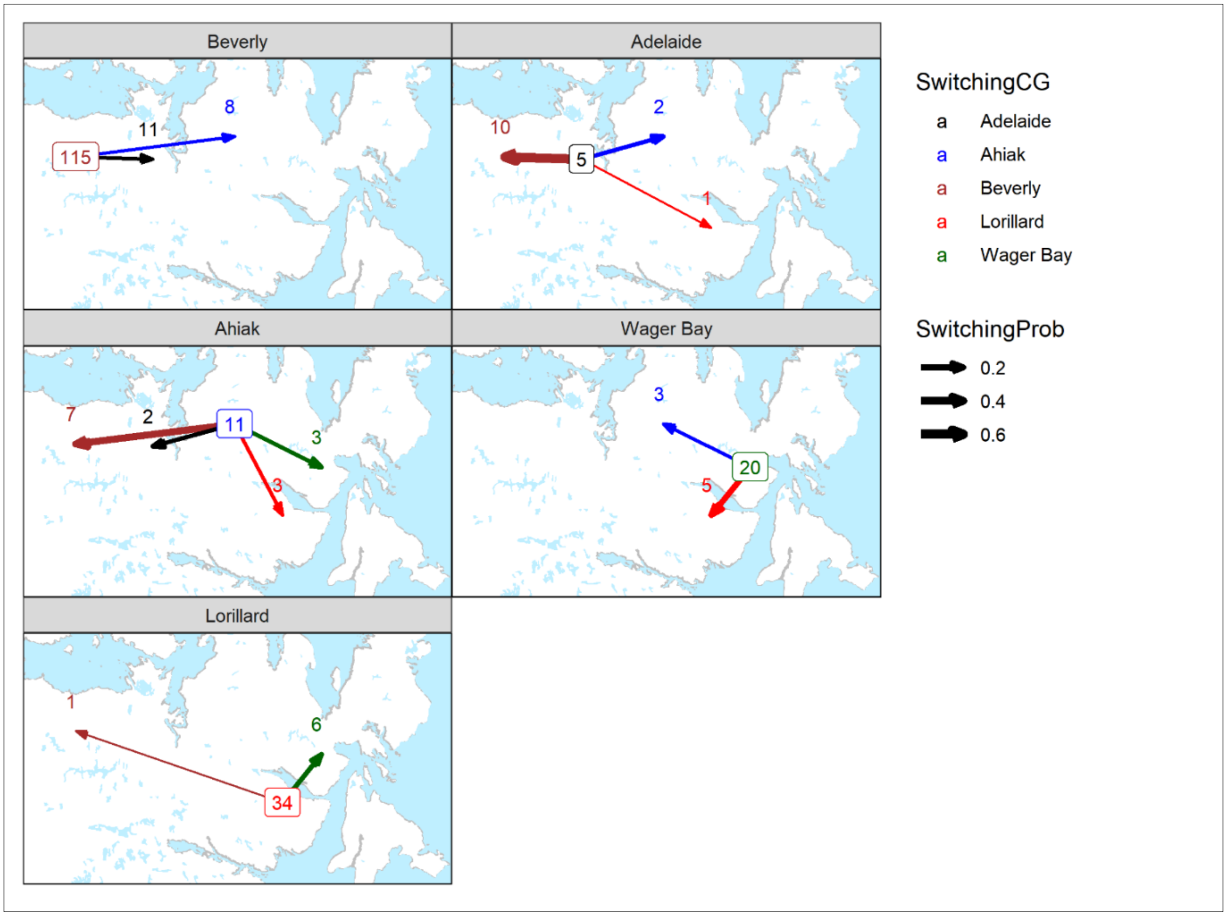


Figure 21. Frequencies of movement events between each calving ground from 2011-2021. Each plot shows movement from the given calving ground. The boxed number is the number of successive yearly movements back to the calving ground (fidelity) whereas the arrows and associated numbers are movements to other calving grounds (delineated by color and location of arrow endpoint). The width of the arrow is proportional to the movement probability (**Table 2**).

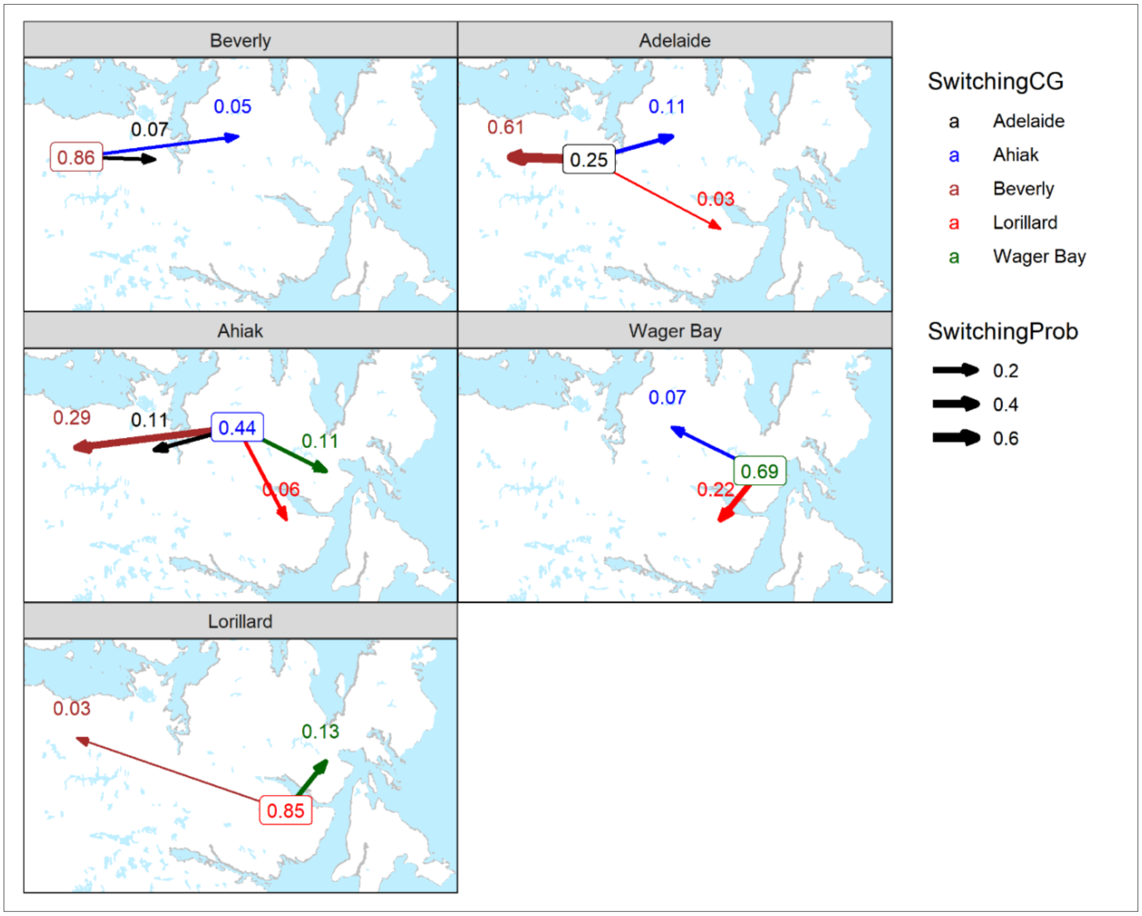


Figure 22. Movement probabilities between each calving ground from 2011-2021. Each plot shows movement from the given calving ground. The boxed probability is the probability of going back to the calving ground (fidelity) whereas the arrows and associated probabilities are movements to other calving grounds (delineated by color and location of arrow endpoint). The width of the arrow is proportional to the movement probability (**Table 2**).

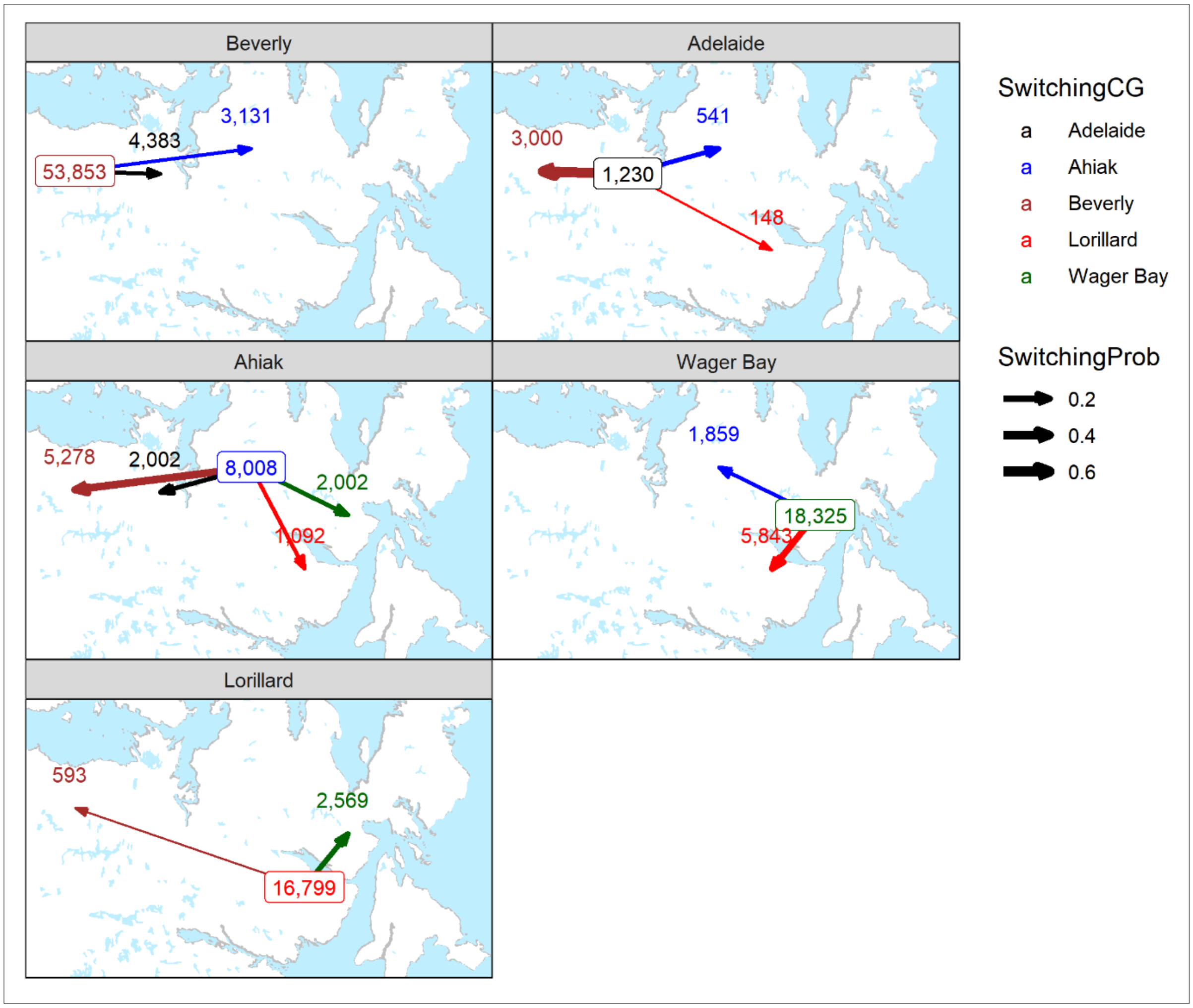


Figure 23. Approximate relative mean numbers of caribou moving between each calving ground from 2011-2021. Each plot shows an estimated number of caribou moving from the given calving ground in a year assuming initial herd sizes estimated in this survey and the 2018 Beverly. The boxed estimate is the number of caribou returning calving ground (fidelity) whereas the arrows and associated probabilities are movements to other calving grounds (delineated by color and location of arrow endpoint). The width of the arrow is proportional to the movement probability (**Table 2**). These numbers are more for illustrative purposes and <u>should be interpreted</u>

Management Implications:

At present the results of this study suggest more effort is needed to address impacts to migratory caribou from industrial linier infrastructure as current mitigation measures along this infrastructure is falling short of resolving significant impacts to caribou distribution and movements. We strongly recommend that accelerated research into the mechanisms of disturbance along roads and other linear infrastructure within caribou habitat be advanced as soon as possible. We further suggest there be more accountability of industrial developments to their impacts on northern wildlife, specifically migratory caribou in this case. Active mitigation measures have had very limited success and for the most part, proven ineffective as protection to migrating caribou. We also recommend a protected areas strategy be developed and actioned for Barren-ground caribou before critical areas such as calving grounds and key access corridors, are lost to regulatory "existing rights" developed following permissions for exploration within these critical areas for caribou. Each year more and more existing rights are being secured within caribou critical habitat. As industrial development accelerates across caribou range, we will start to see behavioural, distributional, and abundance changes within our caribou populations that if left uncorrected, will likely lead to range/herd fragmentation, lower long-term abundance, loss of local hunting areas, and loss of Inuit harvesting opportunities.

Reporting to communities/resource users:

Initial results of collard caribou movements have been presented at the KWB (Kivalliq Wildlife Board) fall annual general meeting (2020-2023) and to the Kivalliq and Kitikmeot Wildlife Boards and range HTOs in February, 2023. All programs have received unanimous support from the KWB as well as support from the Arviat, Whale Cove, Rankin Inlet, Naujaat, and Baker Lake HTOs. Information on caribou seasonal movements is provided to HTOs during consultations and on request, and when for management purposes and engagement in the land use planning process. A collaborative partnership to assess the effects of mining infrastructure on caribou movements in the vicinity of Rankin Inlet is being developed with the KWB, Rankin Inlet, and Baker Lake HTO (all other Kivalliq HTOs welcome to take part). Though planned for mid-winter 2023, staffing changes primarily within the KWB, have delayed the initiation of this program. Studies of the significant impacts of the Meadowbank mining road on the NEM herds is also ongoing and all results shared with regional HTO and RWO's during annual consultations and on request.

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References:

Banfield, A.W.F. 1954. Preliminary investigation of the barren-ground caribou: Part 1: Former and present distribution, migrations, and status. Part 11: Life history, ecology and utilization. Canadian Wildlife Service. Wildlife Management Bulletin, Series 1, No. 10 A and 10B. 79 and 112 pages.

Berland, A., T. Nelson, G. Stenhouse, K. Graham, and J. Cranston. 2008. The impact of landscape disturbance on grizzly bear habitat use in the Foothills Model Forest, Alberta, Canada. Forest Ecology and Management 256:1875–1883. <http://linkinghub.elsevier.com/retrieve/pii/S0378112708005719>. Accessed 5 Mar 2013.

Börger, L., N. Franconi, G. De Michele, A. Gantz, F. Meschi, A. Manica, S. Lovari, and T. Coulson. 2006. Effects of sampling regime on the mean and variance of home range size estimates. The Journal of animal ecology 75:1393–405. <http://www.ncbi.nlm.nih.gov/pubmed/17032372>. Accessed 27 Feb 2013.

Boulanger, J., K. G. Poole, A. Gunn, and J. Wierzchowski. 2012. Estimating the zone of influence of industrial developments on wildlife: a migratory caribou Rangifer tarandus groenlandicus and diamond mine case study. Wildlife Biology 18:164–179. <http://www.bioone.org/doi/abs/10.2981/11-045>.

Campbell, M.W., A. Kelly, B. Croft, J.G. Shaw, C.A. Blyth. 2014. Barren-ground Caribou in Nunavut and Northwest Territories – Map Atlas. Government of Nunavut, Department of Environment. Government of Northwest Territories, Department of Environment and Natural Resources. Map series.

Campbell, M.W., J. Boulanger, J. Ringrose, A.R. Charron, and C. Mutch. 2022. Abundance Estimates of the Northeast Mainland Tundra Wintering Subpopulations of Barren-ground Caribou (*Rangifer tarandus groenlandicus*) on the Nunavut Eastern Mainland – June 2021. Executive Summary Report to the Nunavut Department of Environment. Government of Nunavut. 86pp.

Campbell M.W., J. Nishi, and J. Boulanger. 2010. A Calving Ground Photo Survey of the Qamanirjuaq Migratory Barren-Ground Caribou (*Rangifer tarandus groenlandicus*) Population – June 2008. Nunavut Department of Environment. Technical Report Series. No. 1–10. 121 pp.

Caslys Consulting LTD. 2010. Analysis of Wildlife Geospatial Data in Support of the Nunavut Land Use Plan: Summary Report for the Nunavut Planning Commission.

Caslys Consulting LTD. 2012. Caribou Migration Corridor Mapping-Kivalliq Region, Nunavut. Summary Report for the Department of Environment, Government of Nunavut.

Dalerum, F., S. Boutin, and J. S. Dunford. 2007. Wildfire effects on home range size and fidelity of boreal caribou in Alberta, Canada. Canadian Journal of Zoology 85:26–32.

Donihee, J. and P.A. Gray. 1982. Critical habitat in the Northwest Territories. Can. Comm. Ecol. Land. Classif. Newsletter, No. 12:13-15.

Dyer, S. J., J. P. O’Neill, S. M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65:531–542. <http://www.jstor.org/stable/3803106\n<Go to ISI>://WOS:000169650900019>.

Gates, C.C. 1983. Composition of the Kaminuriak caribou population in the fall of 1979 and 1981. N.W.T. Wildlife Service File Report No. 00. 25pp.

Gates, C.C. 1984. The fall and rise of the Kaminuriak caribou population. Proceedings of the Second North American Caribou Workshop. McGill Subarctic Research Paper 40. 215-228.

Gates, C. 1989. IN: People and Caribou in the Northwest Territories. Ed Hall, Editor. Department of Renewable Resources Publication. 190pp.

Heard, D.C. 1981. An estimate of the size and structure of the Kaminuriak Caribou Herd in 1977. ESCOM Report No. AI-40. 40pp.

Heard, D.C. and G.W. Calef. 1986. Population dynamics of the Kaminuriak Caribou Herd, 1968-1985. Rangifer. Special Issue 1. 159-166.

Hemson, G., P. Johnson, A. South, R. Kenward, R. Ripley, and D. Mcdonald. 2005. Are kernels the mustard? Data from global positioning system (GPS) collars suggests problems for kernel home-range analyses with least-squares cross-validation. Journal of Animal Ecology 74:455–463.

Hins, C., J. P. Ouellet, C. Dussault, and M. H. St-Laurent. 2009. Habitat selection by forest-dwelling caribou in managed boreal forest of eastern Canada: Evidence of a landscape configuration effect. Forest Ecology and Management 257:636–643.

Horne, J. S., E. O. Garton, S. M. Krone, and J. S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology 88:2354–63. <http://www.ncbi.nlm.nih.gov/pubmed/17918412>.

Kie, J. G., J. Matthiopoulos, J. Fieberg, R. a Powell, F. Cagnacci, M. S. Mitchell, J.-M. Gaillard, and P. R. Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philosophical transactions of the Royal Society of London. Series B, Biological sciences 365:2221–31. <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2894967&tool=pmcentrez&rendertype=abstract>. Accessed 23 May 2013.

Koehler, G. M., and D. J. Pierce. 2003. Black bear home-range sizes in Washington: climatic, vegetative, and social influences. Journal of Mammalogy 84:81–91. <http://asmjournals.org/doi/abs/10.1644/1545-1542(2003)084%3C0081%3ABBHRSI%3E2.0.CO%3B2>. Accessed 18 Jun 2013.

Laver, P. N., and M. J. Kelly. 2008. A critical review of home range studies. Journal of Wildlife Management 72:290–298. <http://www.bioone.org/doi/abs/10.2193/2005-589>.

Long, J., and T. Nelson. 2012. Time geography and wildlife home range delineation. The Journal of Wildlife Management 76:407–413. <http://doi.wiley.com/10.1002/jwmg.259>. Accessed 2 Mar 2013.

Long, R. A., J. G. Kie, R. Terry Bowyer, and M. A. Hurley. 2009. Resource Selection and Movements by Female Mule Deer Odocoileus hemionus: Effects of Reproductive Stage. Wildlife Biology 15:288–298.

Mitchell, M. S., and R. a. Powell. 2007. Optimal use of resources structures home ranges and spatial distribution of black bears. Animal Behaviour 74:219–230. <http://linkinghub.elsevier.com/retrieve/pii/S0003347207001182>. Accessed 3 Apr 2013.

Mosnier, A., J. Ouellet, L. Sirois, and N. Fournier. 2003. Habitat selection and home-range dynamics of the Gaspé caribou: a hierarchical analysis. Canadian Journal of Zoology 81:1174–1184.

Nagy, J.A.S. 2011. Use of Space by Caribou in Northern Canada. Department of Biological Sciences. University of Alberta. Edmonton Alberta. PhD Thesis. 164 pp.

Nagy, J.A., D.L. Johnson, N.C. Larter, M.W. Campbell, A.E. Derocher, A. Kelly, M. Dumond, D. Allaire, and B. Croft. 2011. Subpopulation Structure of Caribou (*Rangifer tarandus L.*) in Arctic and Subarctic Canada. Ecological Applications. 21(6): 2334-2348.

Nilsen, E. B., S. Pedersen, and J. D. C. Linnell. 2007. Can minimum convex polygon home ranges be used to draw biologically meaningful conclusions? Ecological Research 23:635–639. <http://www.springerlink.com/index/10.1007/s11284-007-0421-9>. Accessed 8 Mar 2013.

Parker, G.R. 1972. Biology of the Kaminuriak population of barren-ground caribou. Canadian Wildlife Report Series number - 20. 95pp

Powell, R. 2000. Animal home ranges and territories and home range estimators. Pages 65 –110 in L. Boitani and T. K. Fuller, editors. Research technologies in animal ecology - controversies and consequences. Columbia University Press, New York, NY.

Rivrud, I. M., L. E. Loe, and A. Mysterud. 2010. How does local weather predict red deer home range size at different temporal scales? Journal of Animal Ecology 79:1280–1295.

Russell, H.J. 1990. A photocencus of the Kaminuriak Herd in July 1987. Dept. of Renewable Resources Government of the N.W.T. File Report No. 97. 24pp.

Scotter, G.W. 1980. Management of wild ungulate habitat in the Western United States and Canada: A Review. Journal of Range Management. 33(1):16-24.

Seaman, D. E., and R. A. Powell. 1996. An Evaluation of the Accuracy of Kernel Density Estimators for Home Range Analysis. Ecology 77:2075–2085.

Silverman, B. W. 1986. Density estimation for statistics and data analysis. CRC Press.

Sjoberg, J. 2013. Relationship between moose (Alces alces) home range size and crossing wildlife fences. Examensarbete i ämnet biologi.

Skarin, A., Ö. Danell, R. Bergström, and J. Moen. 2008. Summer habitat preferences of GPS-collared reindeer Rangifer tarandus tarandus. Wildlife Biology 14:1–15.

Smulders, M., T. a. Nelson, D. E. Jelinski, S. E. Nielsen, G. B. Stenhouse, and K. Laberee. 2012. Quantifying spatial–temporal patterns in wildlife ranges using STAMP: A grizzly bear example. Applied Geography 35:124–131. Elsevier Ltd. <http://linkinghub.elsevier.com/retrieve/pii/S0143622812000653>. Accessed 22 Mar 2013.

Sorensen, T., P. D. McLoughlin, D. Hervieux, E. Dzus, J. Nolan, B. Wynes, and S. Boutin. 2008. Determining Sustainable Levels of Cumulative Effects for Boreal Caribou. Journal of Wildlife Management 72:900–905. <http://www.bioone.org/doi/abs/10.2193/2007-079>. Accessed 17 Mar 2014.

Taillon, J., M. Festa-Bianchet, and S. D. Côté. 2012. Shifting targets in the tundra: Protection of migratory caribou calving grounds must account for spatial changes over time. Biological Conservation 147:163–173.

Tennenhouse, E. 1986. Caribou Protection Measures for the Beverly and Kaminuriak Caribou herds. Series ED: E. Hall. Publication of the N.W.T. Dept. of Renewable Resources. 17pp.

Thompson, D.C. and C.A. Fisher. 1979. Distribution and numbers of the Kaminuriak Herd in March and April, 1977. Arctic 32(3). 266-274.

Thompson, D. C. G.H. Klassen, and J. Cihlar. 1980. Caribou Habitat Mapping in the Southern District of Keewatin, N.W.T.: An application of digital Landsat data. Journal of Applied Ecology. 17:125-138.

Worton, B. 1987. A review of models of home range for animal movement. Ecological modelling 38:277–298. <http://www.sciencedirect.com/science/article/pii/0304380087901013>. Accessed 13 May 2013.

Worton, B. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168. <http://www.esajournals.org/doi/abs/10.2307/1938423>. Accessed 13 Aug 2013.