Government of Northwest Territories Gouvernement des Territoires du Nord-Ouest

DRAFT TECHNICAL REPORT

WOLF (DÌGA) MANAGEMENT PROGRAM

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Executive Summary

Tłı̨chǫ Government and the Government of the Northwest Territories (GNWT) are working together to implement management actions to reduce wolf (dìga) predation on the Bathurst (Kǫ̀k'èetı) and Bluenose-East (Sahtì) migratory barren-ground caribou (ekwǫ̀) herds because of ongoing conservation concerns related to significant population declines over the past 10-15 years. The five-year program includes support for wolf harvesters and the traditional economy to increase annual ground-based harvest of wolves in winter, combined with a research, monitoring and assessment program.

The GNWT and Tłı̨chǫ Government provided measurable wolf-centered objectives to the Wek'èezhìi Renewable Resources Board (WRRB) in response to the WRRB's recommendation (#1-2020). Appendix L of the Wolf Feasibility Assessment (WFATWG 2017) provides guidance on monitoring for evaluating numerical targets for wolf removal. However, establishing measurable wolf-centered objectives is confounded by the complexity in the seasonal and annual affiliation of tundra wolves to caribou herds, in particular their lack of territoriality on the winter range, and the influence of immigration of wolves from adjacent caribou herds in times of range overlap. Therefore, ongoing research and monitoring is required to inform the adaptive management of wolves. The aims of the research and monitoring program as well as a summary of the progress for each wolf-centered objective is provided below.

1) **Research and Monitoring.** Understanding wolf population abundance, movement and interaction with caribou on the winter range of the Bathurst and Bluenose-East herds is required to inform our management actions. Collaring wolves was initially done to track seasonal and annual movements as well as assess affiliation with caribou movements and specific herds. In the last year, the use of collar data has expanded to inform predation rates on caribou and detection rate surveys.

Wolf collaring. Seven GPS collars were placed on wolves captured on the range of the Bluenose-East and Bathurst barren-ground caribou herds during March 2022. Wolves encountered were in six packs (27 wolves total), with pack size ranging from 2-8 wolves. Collars were deployed on 3 adult females, 1 juvenile female, and 3 adult males. All animals were in good body condition with body condition scores ranging from 2.5-5 (avg = 3.6). Four wolves were observed to be aggressive, with a high struggle index (score of 8-10), while two wolves were given a struggle index of 4-5 (no struggle index was recorded for the seventh wolf). Average handling time was 27±6 mins. Of the seven deployments, two wolves were subsequently harvested, one wolf was found dead from a natural mortality event (the collar was since retrieved), and one collar remains active (transmitting data). The remaining three collars have become stationary and will be investigated opportunistically throughout the program. To increase the number of collars deployed on wolves, collaring at different times of the year and near den sites will be considered for next year.

Movement. The GPS collars provide a means to monitor wolf movements and predation rates in relation to caribou. Analyses of wolf collar location data shows the degree of spatial fidelity of the collared wolves over the three-year period is variable. However, there was a high degree of consistency in annual movement patterns within individuals. When visualized seasonally, wolves displayed clustered movements and space-use for both the spring and calving time periods. Identifying these strategies is a first-step exploratory tool that can be used to understand the spatial distribution of potential wolf-caribou interactions and inform further analyses. Fifty-six location cluster site investigations were completed in March and April 2022 to estimate the kill rate of wolves on large prey, which will be used to estimate wolf predation rate on caribou. Photos of each kill site were collected, and the number of animals present at the site or nearby was recorded. Preliminary data show there were signs of caribou, moose, and muskox predation. Analyses are in progress.

Caribou winter distribution. Based on winter 2021/2022 caribou satellite collar data, the Bathurst monthly range extents (as defined by the 95% utilization distributions) were almost completely overlapped (96-100%) by Beverly caribou from January to March, 2022. Together, the Beverly and Bluenose-East overlapped the Bathurst winter range minimally in October (1.5%) with increasing coverage through January (30.3%) and then decreasing through to May (10.6%). The Bluenose-East monthly winter range extents in 2021/2022 were overlapped minimally in October (2.9%) by Bathurst and Beverly herds and the proportion of overlap ranged from 14.8% to 59.1% from November through to May. High winter overlap among adjacent caribou herds makes implementation of the wolf management program challenging with respect to targeting wolves associated with particular caribou herds, given the potentially reduced territoriality of wolves in the winter.

Herd association. The location data provided by GPS collars also allows for testing of any affiliation of wolves to any one caribou herd. The strongest associations were recorded with Bathurst and Bluenose-East with five wolves showing interaction percentages greater than 60%, while three other wolves did not have any herd associations greater than 40%. In the last three years, many wolves collared on the winter ranges of specific caribou herds occupied a much larger area during the rest of the year. Assigning wolves to an initial caribou herd affiliation at winter capture likely does not inform caribou herd affiliation which may rather be related to den site location.

Detection rate survey. In March 2021, a geospatial aerial survey estimated 89 wolves (95% Cl: 31 – 147) on the Bathurst caribou winter range (Clark et al., 2021). The estimate had low precision (CV=33.4), which limits the ability of this survey design to detect changes in wolf densities over time. To increase the accuracy of future surveys, a wolf detection survey was flown in March 2022. Wolf detection rates were estimated and the potential factors influencing wolf detection were recorded to correct density estimates based on these covariates. Of the 21 plots surveyed for collared wolves, there were 12 wolf detections and 9 misses for an overall detection rate of 57%. Visual obstruction in treed habitats, distance, wolf movement, and number of caribou within 1km and 2.5km from wolves influenced detection rates. Incorporating the collection of additional detection rate samples into a full aerial survey will be considered in Year 5 of the program (winter 2024).

2) **Wolf Removal. The number of wolves removed annually through the five-year program was identified as a measurable wolf-centered objective.** The GNWT and Tłįchǫ Government continued to provide enhanced support for wolf harvesters and the traditional economy and closely monitored the ground-based harvest.

From February to April 2022, 69 wolves were harvested within the North Slave Enhanced Wolf Harvest Incentive Area on the winter ranges of the Bathurst and Bluenose-East caribou herds. During this time, 97-98.1% of the Bathurst caribou range was overlapped by the Bluenose-East and Beverly caribou herds, making it difficult to target wolves found on a specific caribou herd range. Hunting occurred primarily along the winter-road (17 wolves removed), around hunting camps set up by Tłı̨chǫ Government near Roundrock Lake (9 wolves), and by Inuit harvesters near Contwoyto and Yamba lakes (24 wolves). An additional 19 wolves were removed by guided non-resident hunters. The 9 wolves removed by the Tłı̨chǫ Government's Community-based Dìga Harvest Program was a 3.5-fold decrease in number of wolves harvested compared to 2021. Similarly, Inuit hunters harvested fewer wolves in 2022 compared to 87 wolves in 2021. Poor snow conditions and bad weather were reported to have influenced the success of both harvesting groups. Additionally, inexperience of some harvesters and a shortened season due to COVID-19 also influenced the Tłı̨chǫ Government's Community-based Dìga Harvest Program. At this point in the program, the number of wolves removed in the incentive area is variable across years: 85 removed in 2019-2020, 135 removed in 2020-2021, and 69 removed in 2021-2022.

3) **Measures of Effort. Catch-per-unit-effort (CPUE) metrics for wolf removals were identified as a measurable wolf-centered objective**. Detecting whether greater hunter-effort was needed to find wolves would suggest that wolf numbers are decreasing. Consequently, CPUE was calculated by measuring the effort of ground-based hunters (hunting days and distance) per wolf removed and the hours flown per wolf sighted by aerial survey crews.

Harvester Questionnaires. Harvesters returned 25 completed questionnaires, dated between January 25 and April 08, 2022, reflecting 22 hunting trips and 52 wolves killed in the North Slave Enhanced Wolf Harvest Incentive Area (out of a total harvest of 69 wolves). Of the 52 wolves reported killed in the questionnaires, 19 did not have corresponding effort data due to recording errors. There were some confounding factors related to the wolf harvest questionnaire design and how harvesters reported information that led to uncertainties in calculating CPUE. This may have been because the new questionnaires were not filled out daily, but rather per hunting trip and therefore daily hours spent hunting and kilometers travelled were not recorded. The original questionnaire with improvements will be used moving forward to reduce variability in how effort is reported by harvesters and ultimately calculated and compared.

Effort by ground-based hunters. The Tłıçhǫ Government's dìga harvest camp reported a CPUE-day of 0.43 wolves/hunting day in 2022, which was less than CPUE-day from 2021 (0.65 wolf/hunting day), but greater than CPUE-day from 2020 (0.08 wolf/hunting day). The effort data reported by both Kugluktuk and winter road harvesters showed an increase in CPUE-day from 2020-2022, which is similar to the pattern shown when CPUE-day was averaged across all groups. The Tłıçhǫ Government's dìga harvest camp reported a CPUE-km of 2.3 wolves/1,000 km in 2022, which is less than CPUE-km from 2021 (8.3 wolves/1,000km). Similarly, winter road harvesters reported a lower CPUE-km in 2022 of 0.7 wolves/1,000 km compared to 0.9 wolves/1,000 km in 2021. Kugluktuk harvesters reported a CPUE-km of 7.2 wolves/1,000 km in 2022, which was greater than last year (4.4 wolves/1,000 km). On average, CPUE-km decreased from 2021-2022.

Hours flown per wolf sighted. During the helicopter flights for collar deployment, 27 wolves were observed in 4 separate encounters during 31.2 hours of helicopter survey time. Pack sizes ranged from one to eight. Crews sighted 0.86 wolves per hour, which is less than in 2021 (1.82 wolves per hour).

4) **Demographics and Health: Age structure of harvested wolves was identified as a measurable wolf-centered objective.** The GNWT has committed to monitor the health, condition and demographics of wolves harvested through the 5-year wolf management program. A sample of wolves removed from the program undergoes a full necropsy. To determine if the age composition of harvested wolves has shifted from an age structure of mostly adults to mostly young wolves (which may indicate a decrease in the wolf population), the age class of harvested wolves has been estimated and more accurate ages will be determined through cementum annuli analysis.

Demographics. Forty-six (22 males and 24 females) wolves of 69 harvested in the incentive area in winter 2022 were necropsied for demographics and health analyses. We identified a declining trend in the proportion of mature/breeding age harvested animals from 2021 to 2022 ($p=0.07$). Skewing of age structure towards younger, immature animals is expected in a harvested population. The number of pups being produced by females, as indicated by either number of placental scars, implantations, or fetuses *in utero*, ranged from 2 to 11, with a mean litter size of 6.3 pups in 2021 ($n=18$), and ranged 5 to 9 with a mean litter size of 6 pups in 2022 ($n=9$) – there was no statistically significant difference in litter sizes between years. Reproductive status of the female wolves assessed did not significantly correlate with year of harvest, even when considering the time of year (month) the animal was killed ($p=0.13$).

Health. We observed a significant declining trend in body condition as indicated by body condition score and xyphoid fat weight, even when taking age structure changes into account ($p<0.001$). This trend may be an indicator of declining health and/or condition in the wolf population. The proportion of stomachs that contained barren-ground caribou tissue declined from 66.7% in 2021 to 50.0% in 2022. The proportion of empty stomachs was relatively consistent: 30.3% and 26.1% of stomachs analyzed in each year. Additional health analyses for existing archived samples and for those collected in coming years to assess diet and predator-prey dynamics using alternative techniques will be considered.

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1 Introduction

The Bathurst (Kǫ̀k'èetı) and Bluenose-East (Sahtì) migratory barren-ground caribou (ekwǫ̀) herds have rapidly declined over the past 10-15 years, resulting in serious and continued conservation concerns shared among co-management partners across the respective annual herd ranges in the Northwest Territories (NWT) and Nunavut. In the NWT, several management actions for these two caribou herds have been implemented within and outside of the Wek'èezhìı management area[1], established under the Tłıchǫ Agreement.

The traditional territory of the Tłı̨chǫ is vast, and the network of hunting trails extends far into every corner of their lands. The four Tłı̨chǫ communities of Behchokǫ̀, Whatì, Gametì and Wekweètì are located in the boreal forest, and the territory stretches far north of the tree line into the tundra, where many Ekwǫ̀ hunting grounds are located. The traditional land use areas of the Tłı̨chǫ lie within the boundary known as "*Mǫwhì Gogha Dè Nı̨ı̨tłèè,*" which was outlined by Chief Mǫwhì during the negotiations of Treaty 11 in 1921 (Helm, 1994). The traditional land consists of the area between Great Slave Lake and Great Bear Lake, from the Horn Plateau in the southwest, and as far north as the Coppermine River and Contwoyto Lake (Kokètì) (Tlicho Government., 2019). The modern treaty area of *Mǫwhì Gogha Dè Nı̨ı̨tłèè* is described in an illustrative map to the Tłı̨chǫ Agreement[2], which was ratified in 2005 by the Tłı̨chǫ Nation with the Government of Canada; the Tłı̨chǫ Agreement is the first combined comprehensive land claim and self-government agreement in the Northwest Territories.

From time immemorial, the barrenland was populated with Inuit and Dene families. Several Inuit families lived and hunted along Kokètì as well as the large lakes further south to the treeline. From the treeline and north, Dene families lived and hunted as far north as Kokètì, and some harvested further north towards the Arctic coast. On numerous occasions, Inuit and Dene families met on the barrenlands. Since the mid-1800s, and the influence of market trade in wildlife, which included the European fur trade and commodification of ekwǫ̀ (Zoe 2012), Tłı̨chǫ families travelled by canoe and canvas boat to the barrenlands in the fall to hunt Ekwǫ̀. While the women and children remained in camp, the trappers ran their dog teams along the shoreline of the large lakes further north towards Kokètì. These harvesters hunted caribou and trapped wolves, white fox and wolverine throughout the winter months. When spring arrived with warmer temperatures and sunlight, the Tłı̨chǫ trappers and their families returned south while the ice was still strong enough to hold the dog teams (Tlicho Government, 2019).

Times have changed from when Tłı̨chǫ families used to travel on the barrenlands to hunt Ekwǫ̀. With communities becoming more permanent in the 1970s, peoples' time available to travel on-the-land changed and hunters began using aircraft to fly to the barrens and bring back ekwǫ̀ meat (Zoe 2012). Sahti Ekwǫ̀ (Bluenose-East) and Koketi Ekwǫ̀ (Bathurst) herds have been the main source of the Tłı̨chǫ diet and have been key species that connects them to their culture, language, and way of life (Tlicho Government, 2019).

[1] Although this report is focussed in Wek'èezhìı, we also recognize the importance of co-management strategies and actions for Bathurst and Bluenose-East caribou that are also being implemented by other organizations across the herds' ranges including the Advisory Committee for Cooperation on Wildlife Management (2014, 2019), Délı̨nę ekwę́ Working Group (2016), Kugluktuk Angoniatit Association (2019), Łútsël K'é Dene First Nation (2020), Nunavut Wildlife Management Board (2020a, 2020b) and Sahtú Renewable Resources Board (2016).

[2] Tłı̨chǫ Agreement – Part 3 to Chapter 1 - Illustrative Maps - p.17

Over the past decade, the two herds have declined rapidly necessitating significant harvest management actions. Sahti Ekwǫ̀ population decline was determined after the 2013 survey which estimated 68,000 caribou following a herd estimate of 121,000 in 2010. The most recent survey was done in 2021 and the estimate was 23,200 (Boulanger et al., 2022). A photographic calving ground survey in June 2009 documented a rapid decline from more than 100,000 caribou in the Koketi Ekwǫ̀ herd in 2006 to 31,980 ± 10,853 adults in 2009 (Adamczewski et al., 2020). This was very concerning because in the 1980's this herd was estimated at approximately 470,000. The most recent population survey in 2021 resulted in an estimate of 6,240 (Adamczewski et al., 2022)

Since its inception in 2005, the Tłı̨chǫ Government has been playing a direct role in wildlife co-management and has been working with the Government of the Northwest Territories (GNWT) Department of Environment and Natural Resources (ENR) and the Wek'èezhìi Renewable Resources Board (WRRB) to implement actions that will help Ekwǫ̀ recover. Tłı̨chǫ leadership has been instrumental in developing and supporting difficult but necessary actions to support Ekwǫ̀ recovery, especially with regard to harvest management. In 2010, WRRB held a public hearing on management of Koketi Ekwǫ̀ and recommended that resident and commercial (outfitter) hunting be closed, and that all subsistence harvest by Indigenous peoples - including Tłı̨chǫ - be managed through implementation of a harvest target of 300 caribou and a recommended 85:15 bull to cow ratio (WRRB 2010). Harvest management recommendations have been updated, and since 2016 a Total Allowable Harvest (TAH) of zero has been in place for Koketi Ekwǫ̀. For Sahti Ekwǫ̀, the WRRB has determined TAHs of 750 (bull only) in 2016, and 193 (bull only) in 2019. In addition to harvest management actions, Tłı̨chǫ Government has been strongly supportive of increased harvesting of wolves on ekwǫ̀ winter ranges to help the caribou herds recover.

Because of the ongoing conservation concern for these two caribou herds, the scope of management has extended beyond actions that initially emphasized implementing caribou harvest targets or total allowable harvests (TAH), along with other strategies focused on range disturbance and management of important habitat features (e.g. Bathurst Caribou Range Plan; see summaries in WRRB 2010, 2016a, 2016b, 2016c, 2016d, 2019a, 2019b). Management actions have been expanded to include reducing wolves (dìga) on the winter range of these two herds. Wolves are the primary predator of caribou; wolf predation can influence the abundance of large migratory populations of caribou especially during the decline phase of cyclic populations (Couturier et al., 1990; Messier et al., 1988) and when caribou are at low numbers (Bergerud, 1996; Messier et al., 1988).

In January 2020, following the WRRB's (2016a, 2016b) recommendations on wolf management and completion of a wolf management feasibility assessment (WFATWG 2017), the Tłı̨chǫ Government and the GNWT submitted a Joint Proposal to the WRRB entitled "*Joint Proposal on Management Actions for Wolves (dìga) on the Bathurst and Bluenose-East Barren- ground Caribou (ekwǫ̀) Herd Winter Ranges: 2021 – 2025*". Based on their review, the WRRB decided to treat the 2020 Joint Proposal as a pilot project and requested that Tłı̨chǫ Government and GNWT resubmit a proposal based on experience gained and lessons learned from the pilot project.

Subsequently in August 2020, GNWT and Tłı̨chǫ Government submitted a revised joint management proposal, entitled "Revised Joint Proposal on Management Actions for Wolves (dìga) on the Bathurst and

Bluenose-East Barren-ground Caribou (ɂekwǫ̀) Herd Winter Ranges: 2021 – 2024", and a technical report that summarized activities and lessons learned from initial implementation of the pilot project (Nishi et al., 2020). The WRRB conducted a Level 2 review of the Revised Joint Management Proposal and other evidence submitted to the public record. The WRRB (2021) concluded that wolf management is needed to support caribou recovery: "in addition to harvest limitations and reducing disturbance to the ekwǫ̀ herds and their habitat, additional management and monitoring actions that focus on reducing predation, specifically dìga, are required to support the recovery of the Kǫ̀k'èetì and Sahtì ekwǫ̀ herds". The Board also made 20 recommendations that were accepted or varied by GNWT and Tłįchǫ Government (Appendix A).[3]

The goal of the five-year wolf (dìga) management program is to sufficiently reduce wolf (dìga) predation on the Bathurst and Bluenose-East herds to allow for an increase in calf and adult caribou (ekwǫ̀) survival rates to contribute to the stabilization and recovery of both herds. This report summarizes wolf management and monitoring activities undertaken by GNWT and Tłįchǫ Government during winter 2022. It provides an update to the previous reports on wolf management activities in Wek'èezhìı during winter 2020 (Nishi et al., 2020) and winter 2021 (Clark et al., 2021) and is intended to fulfill the WRRB's recommendation (#20-2020) that an *"annual report be prepared by GNWT and TG and presented to the Board at a scheduled board meeting to allow for the discussion of adjustments in methodology based on the evidence, beginning fall 2021"*.

2 Research and Monitoring

2.1 Wolf Collaring

Understanding wolf population abundance, movement, and interaction with caribou on the winter range of the Bathurst and Bluenose-East herds is required to inform our management actions. The wolf collaring program is intended to improve our understanding of wolf movements within and between caribou herds on the central barrens. Specifically, collaring wolves allows for analysis of wolf movement, which can be used to determine if wolves display caribou herd association; collared wolves also facilitate estimation of kill rates and detection rate surveys. Wolves show fidelity to den sites with summer movements centered around those dens, whereas wolf movements in fall and throughout winter are dictated largely by caribou distribution (Walton et al., 2001). While previous studies in the central mainland NWT have studied wolf movements in relation to Bathurst caribou movements (Hansen et al., 2013) and seasonal range use (Klaczek et al., 2015, 2016), analyses specifically looking at coincident movements of wolves with several caribou herds is unique. The main objectives were to:

- Determine how wolves travel among caribou on their winter ranges;
- Determine broader wolf movement patterns on an annual and multi-year basis;
- Determine fidelity of wolves to den sites and caribou herd ranges; and,
- Assist in the evaluation of wolf management actions in the NWT.

The collaring program fulfills the WRRB's recommendation (#11-2020) to: *continue the dìga collaring program, beginning in 2021, using a statistically rigorous design to measure dìga movements relative to the dìga-ekwǫ̀ spatial distribution, including reducing the uncertainties involved with assigning dìga to ekwǫ̀ herds*.

[3] WRRB Reasons for Decision Final Report - 2020 Diga Management Proceeding.pdf

2.1.1 Methods

In the winter of 2022, caribou from the Bluenose-East and Beverly caribou herds overlapped with the Bathurst herd, which influenced the relative distribution and abundance of caribou and wolves within the North Slave region. To efficiently locate and collar wolves across the winter range, this search effort was done collaboratively with the collaring of Bluenose-East, Bathurst and Beverly caribou. The community of Wekweètì was the primary base of operations.

An experienced pilot and net-gunner, together with ENR handlers, carried out the capture and collar deployments. Wolves were captured using net-gun methods following GNWT's Standard Operating Procedures[4], with chase times ranging from 6 to 153 seconds; chemical immobilization was not used (Figure 1). Depending on the size of wolf, one of two Telonics collar models were deployed: TGW 4477-4 (750 grams; 7.06 x 4.57 x 3.6 cm) and 4577-4 (890 grams; 6.85 x 5.1 x 3.6 cm). Based on the primary program schedule, the 4477-4 collars are estimated to transmit for at least 28 months, while the larger 4577-4 collars should transmit for 52 months. While the capture and handling time was extended from 15 minutes in 2021 to 25 minutes in 2022 (with approval from the Wildlife Care Committee), the average handling time was 27±6 minutes. This was not sufficient time to collect complete sets of biological samples (e.g., hair, blood, morphological measurements). However, photos of 6 individuals were taken, and hair and blood samples were collected from 4 and 1 individual, respectively. These samples are used for population structure assessment and health screening[5]. The capture and collaring of wolves adheres to GNWT Standard Operating Procedures for the handling of wolves to minimize trauma and stress to the animal and was conducted under Wildlife Research Permit #WL500830 with review and recommendations by the NWT Wildlife Care Committee[6].

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[4] https://www.enr.gov.nt.ca/sites/enr/files/resources/wolf_handling_sop.pdf

[5] Photos are used to determine age and sex structure, while hair and blood are analyzed for genetics, reproductive status, and disease dynamics.

[6] https://www.enr.gov.nt.ca/en/services/apply-research-observe-and-handle-wildlife-nwt/wildlife-care-committee

Figure 1. Wolves were captured using standard net-gun methods and fitted with a Telonics collar (model TGW 4477-4 or 4577-4) in March 2022.

2.1.2 Results

Between March 10th and March 16th 2022, seven GPS collars were deployed on wolves on the Bluenose-East, Bathurst and Beverly winter ranges. Figure 2 shows the deployment locations and flight lines during this effort (31.2 hours on survey). Of the seven deployments, two wolves were subsequently harvested by ground-based hunters, one wolf was found dead from an assumed natural mortality event (the collar was since retrieved), and three collars were active (transmitting data) through the winter. Two collars have become stationary as of April 14th and July 31, 2022, respectively, which will be investigated further to confirm wolf death or collar drop. As of October 2022, only one collared wolf of the seven deployed in winter was actively transmitting (Tables 1 and 2).

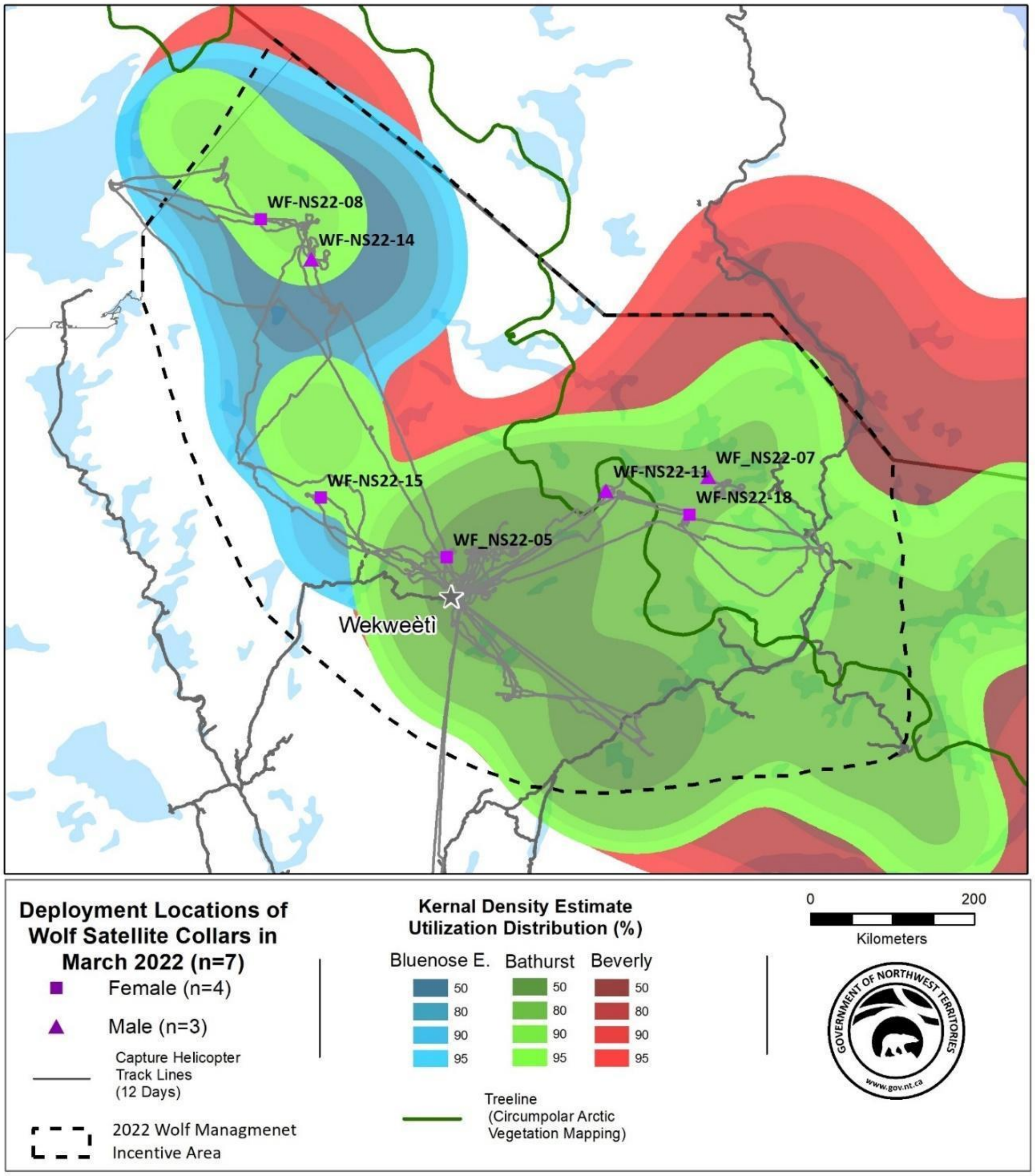

Figure 2. Deployment locations and flight lines of wolf collaring effort in 2022.

Table 1 shows the collaring details of the seven wolves collared in winter 2022. Of the 27 wolves encountered during the March caribou collaring efforts, one was located and captured as a solitary animal. The remaining six collared wolves encountered were in separate packs, with pack size ranging from 2-8 wolves (average pack size was 4.3 wolves, SD = 2.1 wolves). The composition of the collared individuals was 4 females and 3 males. The four females were one yearling (22 months) and three adult females (3-5 years). One captured male was estimated to be 3-5 years old. Based on heavier patterns of observed tooth wear and breakage, the remaining two males were estimated to be 6+ years old. All animals were in good body condition, with scores ranging from 2.5-5 (average body condition was 3.6). No wolves were observed to be skinny (score of 1) and two were observed to be fat (score of 5). Four wolves were observed to be aggressive, with a high struggle index (score of 8-10), while two wolves were given a medium struggle index of 4-5 (the struggle index for the seventh wolf was not recorded). Each collared wolf was ear tagged, providing further means of identifying these individuals after collars are released.

Table 1. Wolf collar deployments in March 2022.

Date	ID	Sex	Age Class	Fate (November 2022)
3/10/2022	WF_NS22-05	Female	Yearling (22 months)	Harvested
3/16/2022	WF_NS22-07	Male	Adult (3-5 yrs)	Stationary
3/14/2022	WF-NS22-08	Female	Adult (3-5 yrs)	Active
3/16/2022	WF-NS22-11	Male	Adult (6 yrs +)	Harvested
3/14/2022	WF-NS22-14	Male	Adult (6 yrs +)	Stationary
3/10/2022	WF-NS22-15	Female	Adult (3-5 yrs)	Retrieved (mortality)
3/12/2022	WF-NS22-18	Female	Adult (3-5 yrs)	Stationary

2.1.3 Discussion

All seven wolves were captured and collared on the range of the Bluenose-East and Bathurst barren-ground caribou herds in March 2022. The GPS collars monitor wolf movements in relation to caribou and we evaluate the nature of affiliation, if any, of wolves to any one caribou herd. So far (2020-2022), 39 collars have been deployed on wolves, 29 collars have been completed (i.e., mortality or released) and 10 collars are currently transmitting data (Table 2). Prior to the start of collaring in March 2022, there were still two active wolf collars that had been deployed in 2020 and seven active collars that had been deployed in 2021. Four collars dropped off as programmed on 15 May 2022 and therefore are no longer on those wolves. Stationary and released collars will be retrieved opportunistically throughout the program. Consequently, ENR plans to capture and collar 20 wolves during winter 2023 to maintain 30 collared wolves in the region.

Table 2. Collar deployments and Status from 2020-2022.

Deployed		Capture/Handling Mortalities	Post-Capture Mortalities	Stationary	Total Active Collars
2020	13	3	6	2	2
2021	19	0	4	8	7
2022	7	0	3	3	1
Total	39	3	12	14	10

2.2 Wolf Movement patterns

GNWT contracted Caslys Consulting Ltd. in June 2022 to conduct an analysis of wolf movements from wolf collar location data acquired starting in March 2020. Wolf telemetry datasets from March 2020 to June 2022 and collar data for the three barren-ground caribou herds (i.e., Bluenose-East, Bathurst, and Beverly) whose ranges overlap the wolf distributions were used to explore wolf movement patterns relative to barren-ground caribou movements. Sections of the report are provided below, and the full report is available upon request. The goal of this project was to complete a multi-year exploratory analysis of the wolf telemetry data, with the following objectives identified:

- Develop annual movement profiles for barren-ground caribou and wolves to determine if there are any commonalities and to explore seasonal patterns of wolf movement behaviours;
- Generate occupancy models from wolf telemetry data to explore annual and seasonal space-use patterns; and,
- Perform a spatial analysis to summarize wolf and caribou interactions, with the goal of determining whether collared wolves show consistent association with specific barren-ground caribou herds.

2.2.1 Data Compilation

Collars were deployed on both male and female wolves and collected locations at varying fix rates depending on the time of year. To account for differences in the collection frequencies, two datasets were generated: a daily dataset where all data were resampled to 24-hour intervals, and a sub-daily dataset where locations were standardized to six, eight or 12-hour frequencies depending on an individual collar's collection schedule.

As collars were deployed in three batches, a mixture of collar life spans was available for analysis. Of the 55 wolf collars available: 18 were excluded due to insufficient data, 14 had three to four months of data, four had approximately six months of data, 13 had a year of data, and six had multiple years of data. As each of the analyses has different data requirements, different combinations of wolf collars were used at each step.

Telemetry data for the three barren-ground caribou herds (i.e., Bluenose-East, Bathurst, and Beverly) whose ranges overlap the wolf distributions were obtained, as the objective of these analyses was to explore wolf movement patterns relative to barren-ground caribou. To provide additional context, telemetry data for the Qamanirjuaq, Ahiak, Wager Bay, and Lorillard herds were obtained from the Government of Nunavut (GN).
To account for differences in collection frequencies between collars, all data were resampled to daily locations. Collars that had no herd designation were excluded from certain analyses. Data were further restricted to include only collars that had at least ten locations per month. These restrictions ensured that only collars with a representative sample of locations for a given month were used to characterize range use and movement patterns.

2.2.2 Methods: Seasonal patterns

To explore wolf movement patterns relative to barren-ground caribou, variation in seasonal movement for each species was characterized using daily movement rate. Daily movement rate represents the total straight-line distance moved over a 24-hour period. For both species, the daily movement rate was calculated using the daily datasets rather than the sub daily data, so the straight-line distance represents the displacement between two successive locations and not the cumulative distances between all locations collected within the same 24-hour period. To remove any biases due to missing fixes, only displacements for 23 to 25 hours were included in the analysis. For the caribou, daily movement rate was calculated at the individual level and then averaged across individuals belonging to the same herd to provide a herd level estimate of seasonal movement patterns. For the wolves, we assumed that all the collared animals were moving as separate individuals, so the daily displacement values were calculated only at the individual level.

To further characterize seasonal patterns of wolf movement, the net-squared displacement (NSD) for each individual was also calculated. The NSD is calculated as the squared displacement between a location in a trajectory and the first location in that trajectory. As the displacements are measured relative to the origin of the trajectory, it is a useful metric for distinguishing periods of spatially restricted movement from periods of dispersal or migration. Since NSD is a relative metric, it was not appropriate for use in characterizing the herd level seasonal movement patterns for the caribou.

2.2.3 Methods: Brownian bridge occupancy models

To explore seasonal space-use patterns by wolves relative to barren-ground caribou, two approaches were used: Brownian Bridge occupancy models (BBOM) and grid cell counts. These approaches were selected as they characterize space-use at different spatio-temporal scales and could be used to inform different aspects of caribou-wolf interactions. The Brownian bridge approach provides a fine-scale description of space-use appropriate to exploring individual wolf-caribou interactions; while the grid cell count approach provides a regional scale description more appropriate to herd level wolf-caribou interactions (see Section 2.5.1). To provide additional context for individual wolf-caribou interactions, a tabular summary analysis was performed to provide a per wolf collar break down of all caribou herd associations.

Brownian bridge movement models (BBMM) are a continuous time approach to modelling wildlife movement and space-use where the probability of an animal using a particular area are determined according to the start and end location of each movement, the time between those two locations, and the speed of that movement (Horne et al., 2007). While BBMM produces a utilization distribution (UD), similar to a kernel density approach, the UD differs from that of a kernel density in that the sequence of the telemetry points was taken into account when the probabilities were calculated. The resulting surface represents the relative UD for an individual that highlights areas of high use representing spatially restricted movements and areas of low use that could indicate movement corridors or areas of dispersal. For this project, we are interested in wolf space-use in relation to caribou from an occupancy perspective. As such, we used the term occupancy model (BBOM) rather than movement model (BBMM).

Since BBOM is conditioned on the time elapsed between locations, it is a method that benefits from using subdaily telemetry data. As such, the sub-daily telemetry dataset was used for this analysis and only collars that had more than six months of data were included. Two parameters are required to calculate a BBOM: the Brownian motion variance parameter and the standard deviation of location error for the trajectory. The motion variance parameter was calculated for each individual using the maximum-likelihood approach proposed by Horne et al. 2007 and the location error was set to 5 metres based on error estimates calculated from mortality location clusters obtained from the barren-ground caribou telemetry dataset.

BBOM UDs were calculated for two different scales: the whole trajectory and multiple shorter time periods representing seasons. The three seasonal periods were defined as: December 1st to March 31st - Winter, April 1 to May 30th, 2021 - Spring, and June 1st to June 31st, 2021 - Calving. These time periods roughly match the seasonality of barren-ground caribou movement and range use patterns to examine the potential for seasonally important interactions between the two species.

2.2.4 Results: Seasonal patterns

Characterizing movement patterns for barren-ground caribou using daily movement rate captured the expected changes in seasonal movement behaviours associated with annual caribou life cycles. Increases in movement rates were present in May and September/October indicating the beginning of the spring and fall migrations, respectively. Beverly caribou did not show strong changes in movement rate associated with the start and end of spring migration. Another increase in movement rate was present in July possibly corresponding to higher movements associated with insect avoidance. Lower movement rates were present from November to April characteristic of winter range use. A complete set of barren-ground caribou movement profiles are available upon request. During the first phase of the analysis, daily movement rates were calculated for the wolf collars; however, we found that daily movement rate was an uninformative metric for wolf behaviour as there was no discernible seasonal variation in movement pattern.

As an alternative movement metric to daily movement rate, NSD graphs were produced for all collared wolves for the full time period (March 2020 – June 2022). Almost every collared wolf showed periods of area restricted movement (i.e., plateaus) and periods of high movement (i.e., sharp increases or decreases and high variability). While no consistent patterns were evident between collars, NSD plateaus in April through June could be linked to denning and shorter plateaus in July through November could indicate caribou kills or hunting.

Examining the NSD profiles for each collar in combination with the collar movement maps allowed for the identification of three general movement groups: north-south movers, east-west movers, and stationary wolves (Table 3). The north-south movers were generally characterized by north-south movements timed to match caribou migrations, interactions with only one barren-ground caribou herd, and periods of area restricted movement. East-west movers displayed periods of clustered movements connected by east-west dispersals. Unlike the north- south group, these east-west dispersals had the potential for interactions with multiple caribou herds. Nine wolves (6 females and 3 males) showed no seasonal movement during at least one year of monitoring, remained in the same area year-round, and therefore classified as stationary for that year.

Table 3. General movement groupings for 34 collared wolves from 2020 to 2022.

Collar	Sex	Year	Movement Group: North-South	East-West	Stationary
WF-NS20-01	Male	2020	✓		
		2021	✓		
		2022	✓		
WF-NS20-02	Female	2020			✓
		2021		✓	
		2022			✓
WF-NS20-12	Male	2020		✓	
WF-NS20-18	Male	2020	✓		
WF-NS20-21	Female	2020	✓		
		2021	✓		
		2022			✓
WF-NS20-22	Female	2020	✓		
WF-NS20-23	Female	2020			✓
		2021			✓
		2022			✓
WF-NS20-26	Male	2020	✓		
WF-NS20-27	Male	2020		✓	
		2021		✓	
		2022	✓		
WF-NS20-29	Female	2020			✓
		2021			✓
		2022			✓
WF-NS20-30	Male	2020		✓	
		2021			✓
WF-NS21-03	Male	2021	✓		
WF-NS21-04	Male	2021	✓		
		2022	✓		
WF-NS21-06	Female	2021		✓	
WF-NS21-07	Male	2021		✓	
WF-NS21-08	Female	2021		✓	

		2022		✓	
WF-NS21-10	Male	2021		✓	
		2022	✓		
WF-NS21-11	Male	2021		✓	
WF-NS21-14	Female	2021			✓
		2022			✓
WF-NS21-15	Female	2021		✓	
		2022		✓	
WF-NS21-16	Male	2021	✓		
		2022	✓		
WF-NS21-17	Male	2021		✓	
WF-NS21-20	Male	2020			✓
WF-NS21-24	Female	2021	✓		
		2022	✓		
WF-NS21-25	Female	2021	✓		
		2022	✓		
WF-NS21-28	Male	2021		✓	
		2022		✓	
WF-NS21-32	Female	2021	✓		
		2022	✓		
WF-NS21-33	Female	2021		✓	
		2022			✓
WF-NS21-34	Male	2021		✓	
		2022		✓	
WF-NS22-05	Female	2022		✓	
WF-NS22-07	Male	2022		✓	
WF-NS22-08	Female	2022		✓	
WF-NS22-14	Male	2022			✓
WF-NS22-18	Female	2022		✓	

* groupings for the 2022 deployed collars are preliminary due to limited time collecting locations

For collars that had multiple years of data, there appears to be a high degree of consistency in annual movement patterns. For example, WF-NS20-01 consistently displays north-south movement patterns across all three years; while WF-NS20-03 is consistently stationary. WF-NS21-28 appears to be an east-west mover in 2021 and 2022, as does, WF-NS21-34. There are some exceptions, WF-NS20-02 switches back and forth between stationary and east-west over the 3-year period and WF-NS21-10 switches between east-west and north-south. There appears to be no strong relationship between movement group and sex. The stationary group had more females than males; however, both sexes demonstrated periods of area restricted movement.

The degree of spatial fidelity demonstrated by the wolves over the 3-year period is variable. Some collars show a high degree of fidelity consistently using the same areas through time; while others, remain within the same region of the study area through time but do not reuse the same areas. WF-NS20-01 is an excellent example of a wolf who demonstrated a high degree of both spatial and movement pattern fidelity (Figure 3). In contrast, WF-NS20-27 switched between movement groups, and while he remained in the same general region, did not appear to have a high degree of spatial fidelity (Figure 3).

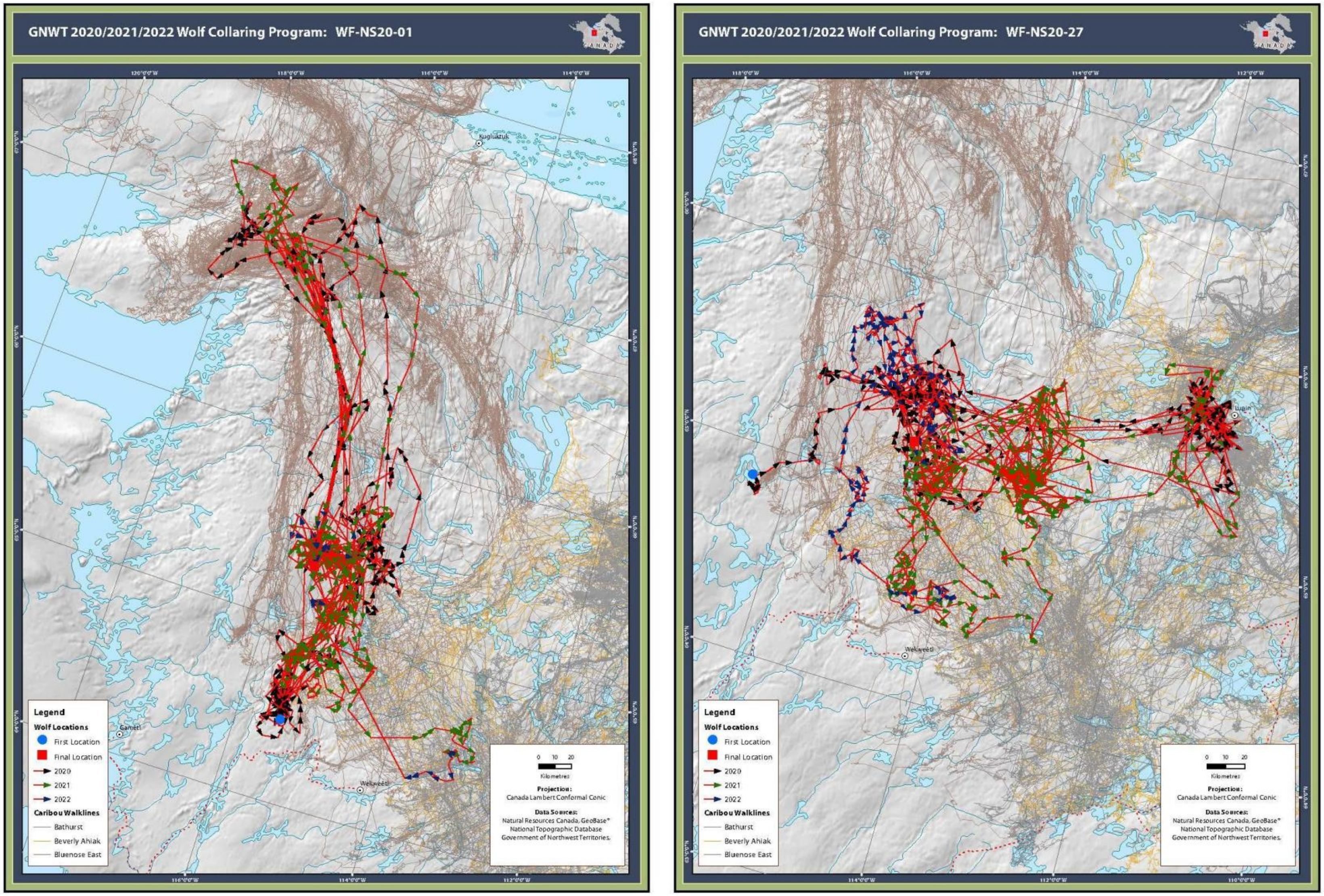

Figure 3. Collar map for WF-NS20-01 on left. Over the three year study period the collared male wolf appears to show a high degree of both north-south movement pattern and spatial fidelity. Map for collared male wolf WF-NS20-27 is on the right. This collar shows consistent east-west movement patterns across the three year period; however, appears to show a weak degree of spatial fidelity.

2.2.5 Results: Brownian bridge occupancy models

The Brownian bridge occupancy models successfully distinguished areas of high, medium, and low use from the wolf telemetry data. Visualizing the BBOM UD for the whole trajectory provided a broad scale characterization of space use for each of the wolves; while the seasonal BBOMs provided a much finer characterization of both space use and movement patterns. At the trajectory level, the BBOM UDs are another tool for comparing the general movement groups identified using the NSD profiles and movement maps. Figure 4(A) shows the BBOM UD for north-south mover WS-N20-01 with pockets of high use spread across two different areas in a north-south direction. Figure 4(B) shows the BBOM UD for east-west mover WS-N20-27 with two major areas of high use connected by east-west movements; and Figure 4(C) shows the BBOM UD for stationary wolf WS-N20-02 with only one major area of high use with many low use pockets corresponding to a high movement period. Visualizing the occupancy models at such a high level allows for the differentiation of annual space-use strategies adopted by wolves within barren-ground caribou ranges. Identifying these strategies is a first-step exploratory tool that can be used to understand the spatial distribution of potential wolf-caribou interactions and prioritize and inform further analyses.

At the seasonal level, the BBOMs again highlight areas of high, medium, and low use but at a much finer temporal and spatial scale. Since these models were calculated from a subset of the wolf telemetry data, they enable a more direct comparison of seasonal wolf and caribou distributions. To explore seasonal patterns, BBOMs were produced using the locations of three wolf collars (WF-NS20-01, WF-NS20-02, WF-NS20-27) for the spring (2020, 2021, 2022), calving (2020, 2021), and winter (2020/2021, 2021/2022) seasons.

When visualized seasonally, wolves from all three movement groups displayed clustered movements and space-use for both the spring and calving subsets. There appears to be the potential for caribou interaction, specifically with individuals from Bluenose-East, for wolves WF-NS20-01 and WF-NS20-27 in the spring. However, the potential for interaction decreases during the calving period as the caribou move further away from the location of the clustered wolf distributions. Wolf movement also appears to be restricted, possibly as a result of denning behaviour.

During the winter period the potential for wolf-caribou interaction seems to be high for WF-NS20-01 and WF-NS20-27. Both of these wolves have occupied an area further south which allows for more overlap with the locations of several caribou herds in their wintering ranges. WF-NS20-02 appears to have more restricted movement, occupying the northern region of its total area.

Wolf space use patterns in the spring appear to be more restricted for WF-NS20-01 and WF-NS20-27, while WF-NS20-02 appears to be less restricted. In this time period the caribou have started the migration to the calving grounds, and it appears that both WF-NS20-01 and WF-NS20-27 have situated themselves in positions whereby the caribou must travel through the area occupied by the wolf. For WF-NS20-01 this coincides with the Bluenose-East movements, and for WF-NS20-27 it appears to coincide with the Bathurst, Beverly and Bluenose-East movements. The stationary wolf (WF-NS20-02) appears to travel more during this period.

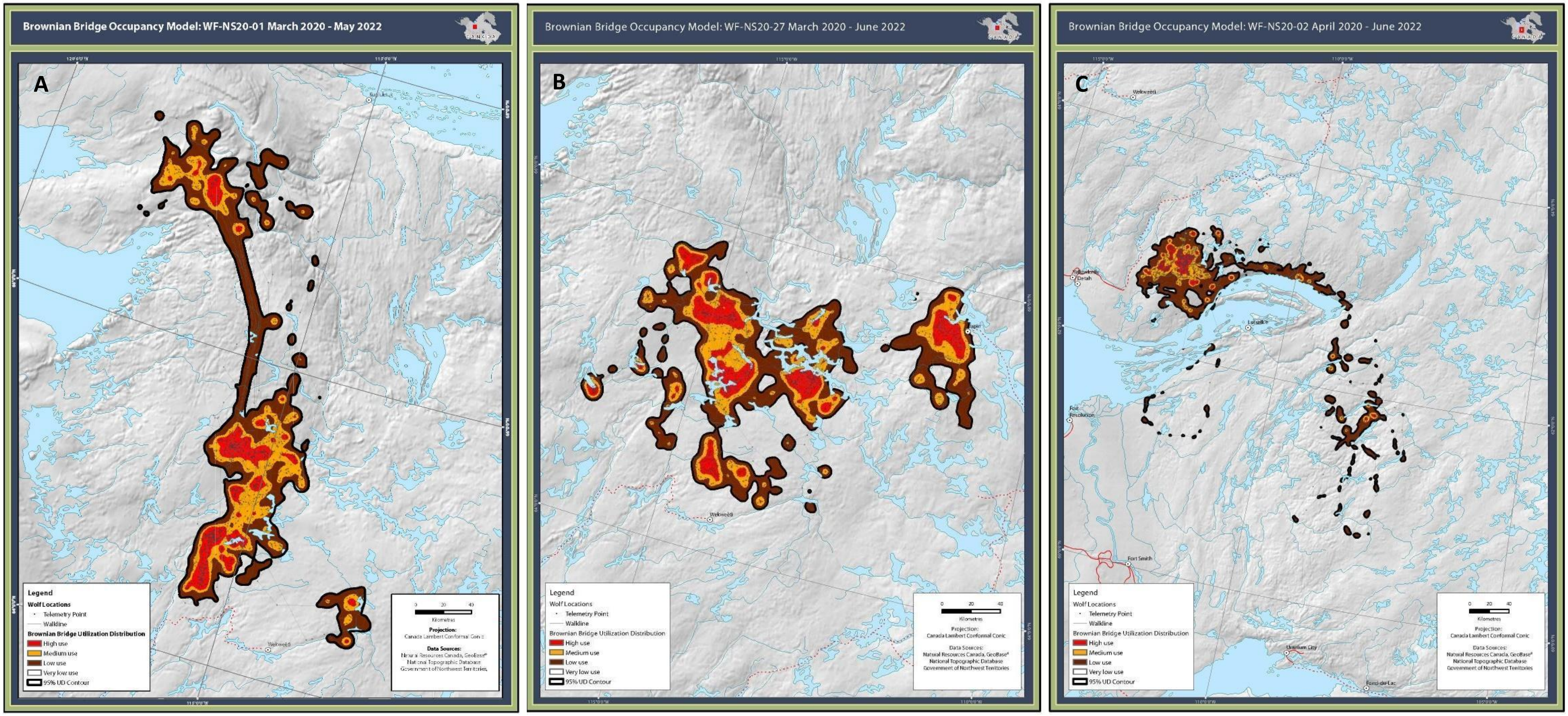

Figure 4. Brownian bridge utilization distribution for (A) WF-NS20-01, (B) WF-NS20-27, and (C) WF-NS-20-02.

Developing occupancy models at the seasonal level represents a spatially explicit method for quantifying wolf occupancy that is easily compared to caribou movement patterns and distributions. If the wolf data subsets were informed using wolf movement NSD profiles, this method could be used to identify high and low use areas associated with denning or hunting. However, this approach is limited by the quality of data collected by each collar and the size of the data subsets used. Data subsets must be large enough to be biologically relevant and the quality of data (i.e., presence of missing fixes) must be sufficiently high to ensure that the motion variance parameter estimated from the data is representative of actual movement patterns.

2.2.6 Discussion

Examining inter-annual variation in wolf movement patterns will provide information on the degree of fidelity these wolves display in their space-use patterns and caribou herds. Inter-annual (2020, 2021,2022) data now exists for 4 months (March, April, May, June), and has permitted the comparison of wolf and caribou behaviour over three years. Two topics that would benefit from further examination are an in-depth fidelity analysis based on the multi-year wolf collars and a deeper analysis of the relationship between animal sex and individual movement patterns. Both analyses are important next steps towards a better understanding of wolf movement patterns and space-use.

The BBOM is a data intensive method that requires sub-daily telemetry data with very few missing locations. If the goal of future analyses is to look at finer-scale movement patterns by wolves, then collecting data at sub-daily frequencies is required. In the BBOM analysis, there was not much difference in the models generated from the eight and twelve-hour datasets. However, as the time between locations increases so does the uncertainty built into the BBOM UDs. As a result, the UD surfaces are more generalized leading to a probability of use surface that may not be appropriate to inform management decisions at finer spatial scales. For example, identifying how wolf movement may vary relative to human related disturbance, identifying den sites, or delineation of travel corridors. However, collecting data at high frequencies will reduce collar life and impact the feasibility of quantifying variation in wolf movement patterns through time. These spatial-temporal analyses would inform long term dynamics between wolf and caribou and would be a valuable tool for developing population management strategies. If a fine scale examination of wolf space-use and movement patterns is required by the project, then collecting data at the eight-hour fix rate would be ideal. Collecting data at a 12-hour fix rate would represent an increase in uncertainty in fine scale patterns; however, may present a balance between increased data collection and collar life span.

2.3 Kill-site Investigation

Fifty-six location cluster site investigations were completed in March and April 2022 to estimate the kill rate of wolves on large prey, which will be used to estimate wolf predation rate on caribou. Photos of each kill site were collected, and the number of animals present at the site or nearby was recorded. Preliminary data show there were signs of caribou, moose, and muskox predation. Analyses are in progress.

2.4 Winter Distribution Patterns of Caribou in the North Slave Region

Grey wolves are a primary predator of barren-ground caribou and display strong spatial association with caribou (Musiani et al., 2007; Walton et al., 2001) especially during the winter (Hansen et al., 2013). Barren-ground caribou have exhibited a greater amount of annual spatial overlap, especially during winter months (February-April) with adjacent herds on winter ranges in 2021 and 2022 (Nishi et al., 2020; Prichard et al., 2020; Clark et al., 2021; Adamczewski et al., 2022) compared to 2020. This may complicate application of winter removal of wolves as a management action to help recovery of a specific caribou herd. Thus, understanding dynamics of winter range use of caribou herds is integral to implementing and evaluating wolf management actions.

An initial analysis of the spatial-temporal patterns of winter range use by Bluenose-East, Bathurst, and Beverly caribou herds based on satellite collar location data from 2015 – 2020, specifically looking at overlapping winter range use of the three herds, was provided in the 2020 Wolf (Dìga) Management Pilot Program Technical Report (Nishi et al., 2020). That analysis demonstrated that monthly utilization distributions for barren-ground caribou derived from kernel density estimation (KDE) provide a repeatable method for utilizing empirical data and displaying complex and scale-dependent temporal- spatial dynamics to support management decisions.

2.4.1 Methods

Telemetry data collected by the GNWT between October 2021 and May 2022 were accessed for three herds: Bathurst, Bluenose-East and Beverly. To account for differences in collection frequencies and collar performance, data were resampled to daily locations and restricted to include only collars that had at least ten daily locations per month. These restrictions ensured that only collars that had a representative sample of locations for a given month were used to characterize winter range use patterns.

Winter ranges were delineated using a KDE approach on a monthly time scale. Telemetry locations were pooled by month and then winter range use boundaries generated for each herd. The KDE range boundaries were defined using the 95% utilization boundary generated using the reference (href; smoothing parameter) bandwidth estimator. Individual href values were calculated for each group to ensure that the winter range use boundaries were representative of the spatial use patterns for the given monthly time period. While the href bandwidth selector has been reported to overestimate the true bandwidth size, a large bandwidth provides a more generalized estimate of winter range use appropriate to gregarious ungulates like barren-ground caribou (Kie et al., 2010; Boulanger et al., 2021; Nagy et al., 2011). All KDE polygons were generated using the adehabitatHR (Calenge, 2006) package within R (R Core Team, 2022).

The overlap of 2021-2022 monthly winter range boundaries between the three herds was quantified by an overlay analysis which calculated the percent of Bathurst and Bluenose-East herd ranges overlapped by either the Bluenose-East or Beverly ranges and the percent of that was part of all three herd ranges. Also calculated was the percent of each Bathurst and Bluenose-East monthly range not shared with the other two herds. Overlay analysis was conducted within the R environment (R Core Team, 2022).

2.4.2 Results

Sample sizes of daily collar locations by month and herd are shown in Table 4. The Beverly herd had the lowest number of collars in March 2022 (n=52) compared to the Bathurst (n=60) or Bluenose-East (n=75) caribou herds as well as a much lower proportion of collared animals relative to herd size than the Bathurst or Bluenose-East caribou herds.

Table 4. Sample Sizes of Collared Caribou by Herd in 2022

	Bathurst		Bluenose East		Beverly	
	est. herd size 6,243 (2021)		est. herd size 23,202 (2021)		est. herd size 103,400 (2018)	
Month	# Collared Caribou	# Locations	# Collared Caribou	# Locations	# Collared Caribou	# Locations
October	45	1395	67	2038	44	1363
November	45	1347	66	1955	44	1313
December	45	1378	66	2008	44	1360
January	43	1331	65	1990	44	1357
February	43	1188	64	1732	44	1217
March	60	1613	75	2118	52	1463
April	54	1606	68	1980	40	1178
May	52	1591	67	2049	37	1126

Figure 5 shows monthly KDE utilization distributions for Bluenose-East, Beverly and Bathurst caribou herds from October to December 2022 showing the movement into and during rut in October, post-rut movements in November and subsequent movement onto winter ranges through December. Figure 6 shows monthly KDE utilization distributions for Bluenose-East, Beverly and Bathurst caribou herds from January to April 2022 showing the high amount of spatial overlap of the three herds during that time period.

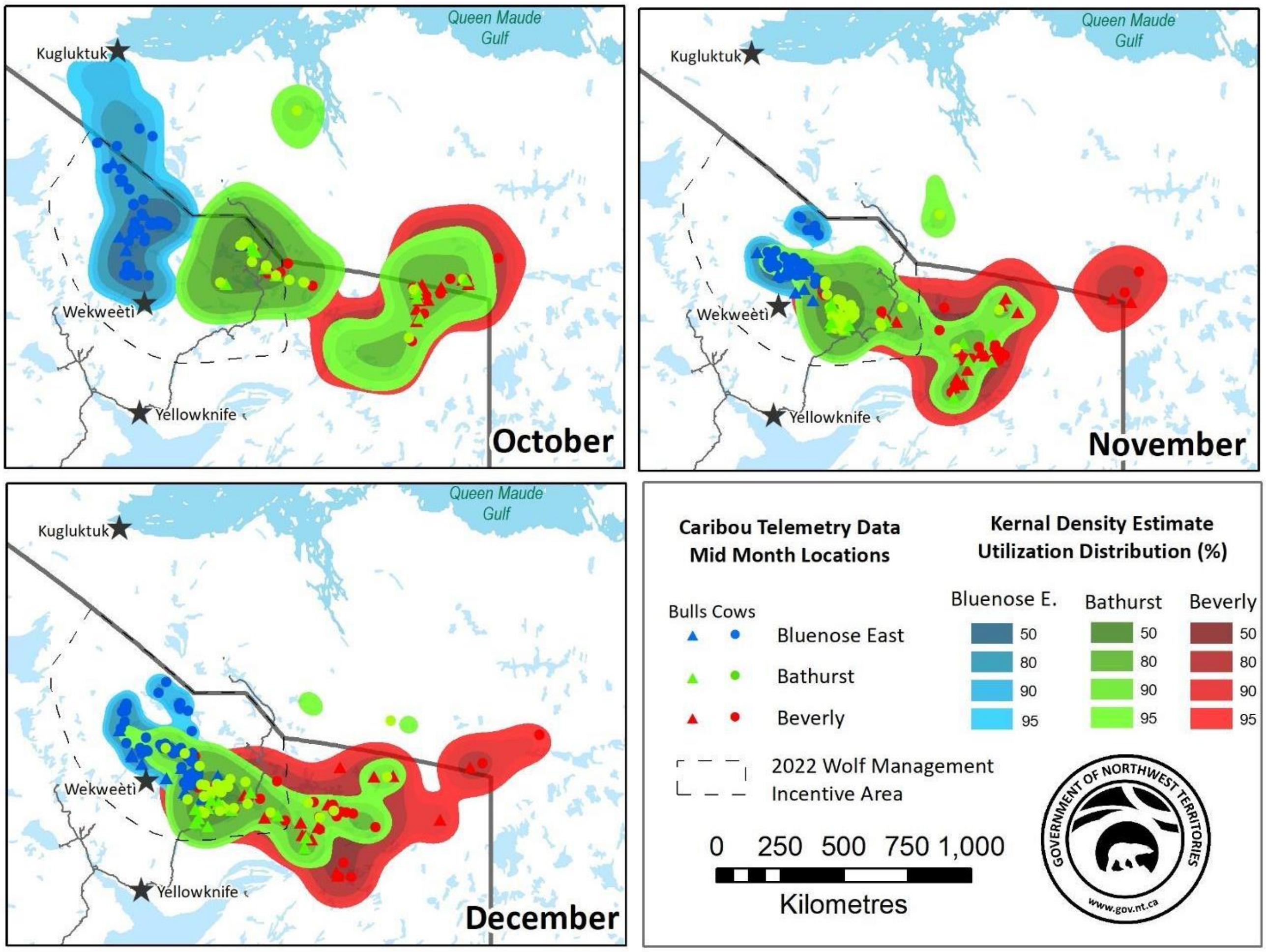

Figure 5. Monthly utilization distributions from October to December 2022 for Bathurst, Bluenose-East and Beverly caribou herds based on kernel density estimates.

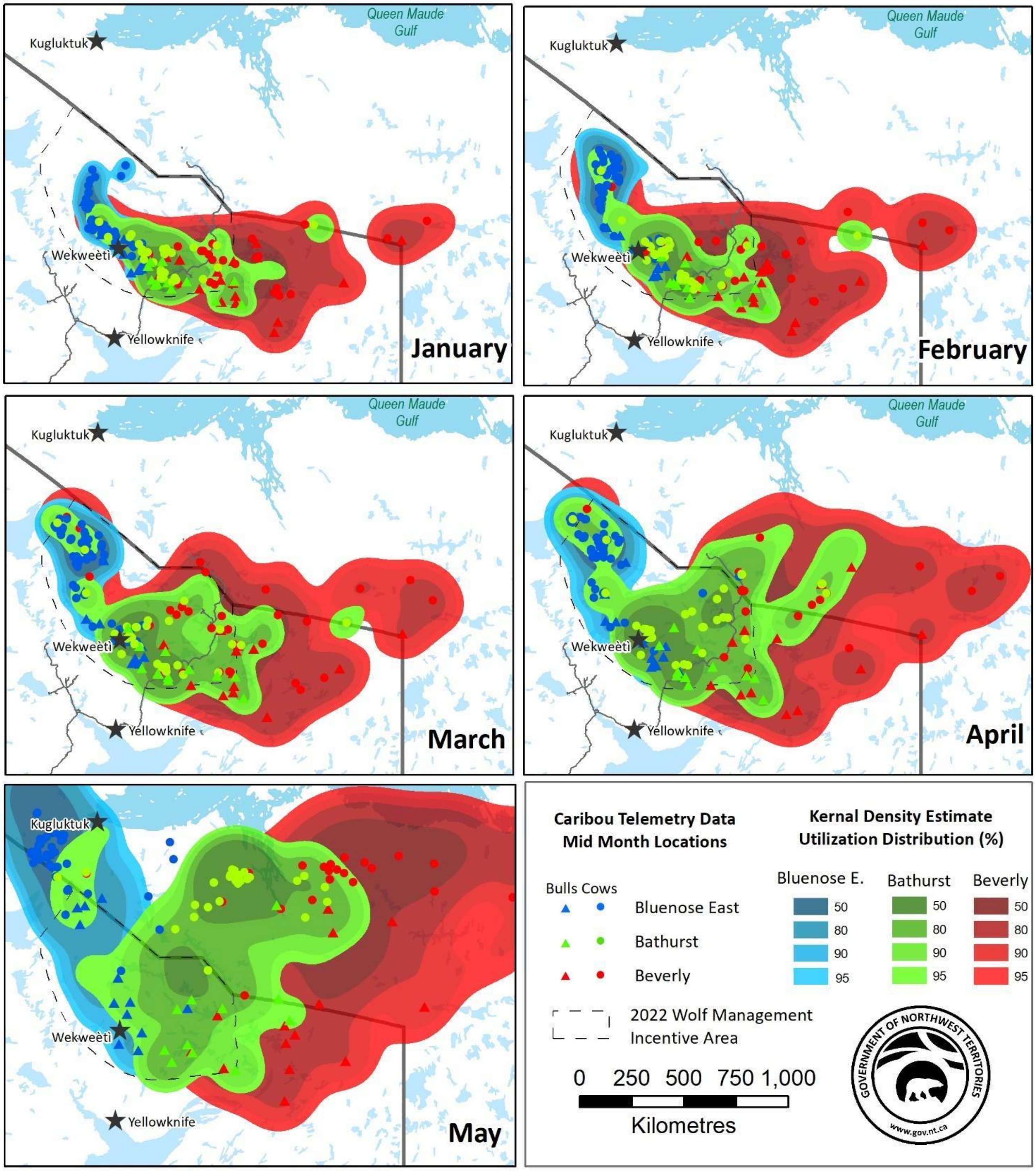

Figure 6. Monthly utilization distributions from January to May, 2022 for Bathurst, Bluenose-East and Beverly caribou herds based on kernel density estimates.

Table 5 provides a summary of the spatial overlap of the Bathurst herd 95% home range contours overlapped by Bluenose-East and Beverly herds individually and combined from October 2021 through May 2022. In late fall and winter of 2021/2022, the Beverly herd overlapped the Bathurst monthly winter ranges 70.9 – 100% excluding May (start of spring migration) when the Beverly herd overlap was 66.1%. Complete overlap of the monthly ranges of Bathurst by the Beverly was observed in January. The Bathurst was overlapped by the Bluenose-East only 1.8% in October but then increasing from 11.8% in November through to 30.3% in January. From February through to May Bluenose-East overlap of Bathurst winter ranges decreased to 30%. Both the Beverly and Bluenose-East herds overlapped the Bathurst winter range minimally in October (1.5%) and then followed the same pattern of increasing to a maximum overlap of 32.6% in February and then decreasing through to May (10.6% overlap) (Table 5).

Table 5. Spatial overlap of collared Bathurst caribou monthly ranges (based on 95% kernel utilization distribution isopleths) with collared Bluenose-East and Beverly caribou during the 2021/2022 harvest season. No overlap represents the amount of territory where solely Bathurst caribou reside. Both herds overlap represents the amount of territory shared among all three herds.

	Bathurst			Bluenose East		Beverly		Both Herds Overlap	
Month	Total Area (km2)	No Overlap (km2)	No Overlap (%)	Overlap (km2)	Overlap (%)	Overlap (km2)	Overlap (%)	Overlap (km2)	Overlap (%)
October	103,485.3	29,858.2	28.9	1,859.4	1.8	73,359.9	70.9	1,592.2	1.5
November	66,171.2	9,029.4	13.6	7,784.3	11.8	54,110.1	81.8	4,752.6	7.2
December	60,394.5	3,134.7	5.2	13,680.7	22.7	53,121.4	88.0	9,542.3	15.8
January	51,108.4	NA	NA	15,493.6	30.3	51,108.4	100.0	15,493.6	30.3
February	60,926.4	1,811.9	3.0	19,888.1	32.6	59,114.5	97.0	19,888.1	32.6
March	91,731.3	1,750.6	1.9	27,797.9	30.3	88,603.8	96.6	26,420.9	28.8
April	137,028.1	4,057.1	3.0	42,478.2	31.0	118,598.0	86.6	28,105.3	20.5
May	195,631.3	28,301.3	14.5	58,607.5	30.0	129,376.1	66.1	20,653.6	10.6

Table 6 provides a summary of the spatial overlap of the Bluenose-East herd 95% home range contours overlapped by Bathurst and Beverly herds individually and combined from October 2021 through May 2022. In late fall and winter of 2021 / 2022, the Bathurst monthly winter ranges overlapped the Bluenose-East minimally in October (3.4%) and by variable amounts ranging from 42.0 – 67.4% November through May. The Beverly herd monthly winter ranges overlapped those of the Bluenose-East with a similar pattern, minimal in October (2.9%) and variable amounts November through May (20.7 – 89.9%). Both Bathurst and Beverly overlapped Bluenose-East monthly winter ranges the least in October (2.9%) before and during the rut, and then spatial overlap varied from 14.8 – 59.1% from November through May (Table 6).

Table 6. Spatial overlap of collared Bluenose-East caribou monthly ranges (based on 95% kernel utilization distribution isopleths) with collared Bathurst and Beverly caribou during the 2021/2022 harvest season. No overlap represents the amount of territory where solely Bluenose-East caribou reside. Both herds overlap represents the amount of territory shared among all three herds.

	Bluenose East			Bathurst		Beverly		Both Herds Overlap	
Month	Total Area (km2)	No Overlap (km2)	No Overlap (%)	Overlap (km2)	Overlap (%)	Overlap (km2)	Overlap (%)	Overlap (km2)	Overlap (%)
October	54,419.3	5,255,989.3	9,658.3	1,859.4	3.4	1,592.2	2.9	1,592.2	2.9
November	15,416.7	743,581.8	4,823.2	7,784.3	50.5	4,949.2	32.1	4,752.6	30.8
December	25,584.4	1,162,664.7	4,544.4	13,680.7	53.5	9,819.3	38.4	9,542.3	37.3
January	26,203.4	644,293.7	2,458.8	15,493.6	59.1	19,760.5	75.4	15,493.6	59.1
February	35,838.9	362,152.9	1,010.5	19,888.1	55.5	32,217.4	89.9	19,888.1	55.5
March	45,122.4	500,988.5	1,110.3	27,797.9	61.6	38,735.6	85.8	26,420.9	58.6
April	63,025.3	1,761,760.8	2,795.3	42,478.2	67.4	31,034.8	49.2	28,105.3	44.6
May	139,398.2	7,255,821.8	5,205.1	58,607.5	42.0	28,886.1	20.7	20,653.6	14.8

2.4.3 Discussion

The high amount of spatial overlap by all three herds in winter 2022, but especially the Beverly herd, resulted in increased caribou density on the winter range. The Beverly caribou herd is approximately 12.5 times the size of the Bathurst herd (based on 2018 estimates for both herds) but with half as many collared caribou. There was a relatively higher level of uncertainty, therefore, in Beverly monthly range extents due to lower numbers of collars. The high amount of spatial overlap likely had a strong influence on distribution and relative abundance of wolves on the winter range of the Bathurst and Bluenose-East herds and our ability to target wolves of any particular herd.

2.5 Wolf affiliation to caribou herd

While Walton et al. (2001) suggested that wolves residing alongside migratory caribou reduce their territorial behavior during the winter by moving with the caribou to their breeding grounds, empirical evidence for the correlation between wolf and caribou movements was not shown until 2007 by Musiani et al. (2007). This study established wolves as migratory and showed a pattern of migration for both caribou and wolves. However, there is still a need for further research to assess whether the association is in relation to a specific herd (see section 5.2 in Nishi et al., 2020). Further, while seasonal and directional movements of wolves were compared to Bathurst caribou in particular it is unknown as to how they might also relate to adjacent herds (Hansen et al. 2013).

2.5.1 Caribou herd affiliation from grid cell count

Further analysis of wolf and caribou movements conducted by Caslys Consulting Ltd. used a grid cell count approach to generate a cumulative surface representing relative monthly space use by caribou and wolves as well as any areas of concurrent use by the two species.

2.5.1.1 Methods

For the grid cell count approach, binary range use rasters were generated for individual animals of both species. Telemetry data were subdivided into months resulting in a binary use raster for each month for each animal. A one-kilometer fishnet raster was created for the study area to act as a baseline surface. The one-kilometer resolution was too fine to be a useful analysis unit; however, it provided an appropriate base resolution that could be aggregated across a variety of spatial scales. The baseline fishnet was iteratively intersected with each of the individual collar datasets. If a cell intersected with a telemetry location it was assigned a value of one, cells that did not intersect with any locations were assigned a value of zero. If multiple locations fell within the same cell, the cell was still assigned a value of one; intensity of use within each cell was not considered.

The initial one-kilometer binary use rasters were aggregated to a 10-kilometer grid to match with a previous seasonal range use analysis performed for the Bathurst, Bluenose-East, and Beverly herds (Nishi et al., 2020). A 10-kilometer cell size was selected for that analysis based on a sensitivity analysis that compared grid cell count results for caribou across a range of resolutions: 5 kilometers, 10 kilometers, 15 kilometers and 20 kilometers. Once aggregated, 10-kilometer raster cells with a value greater than zero were reclassified to a value of one to convert them back into binary surfaces. Cells with a value equal to zero remained unchanged. To distinguish range use between caribou and wolves, binary rasters were according to species and herd designation (if caribou). Finally, the binary rasters were combined to generate a cumulative surface representing relative monthly space use by caribou and wolves and any areas of concurrent use by the two species.

The results of the grid cell count were converted to a tabular summary to quantify the number of intersections each wolf collar had with each herd. Intersections were summarized as cumulative value over the lifetime of each wolf collar and on a monthly basis. The intersections were further summarized as a percentage of possible intersections for each wolf collar to inform possible herd affiliations.

2.5.1.2 Results

The grid cell approach provided a regional scale characterization highlighting wolf-caribou interactions at the herd level rather than at the individual level. Areas of concurrent use by wolf and caribou were present in each month of the analysis. For the winter months (Dec 1st to Mar 31st), areas of potential wolf-caribou interactions were primarily located in areas of overlap between caribou herds. For example, in December, wolf-caribou shared use areas were concentrated in the region north-east of Wekweètì where the three barren-ground caribou herds were mixing on winter ranges (Figure 7). In contrast, during the spring and summer months, potential wolf-caribou interactions appeared to be tied to individual herd distributions rather than areas of herd overlap. For example, in May 2021, one set of wolf-caribou shared use areas were located within the Bluenose-East summer distribution and another within the Bathurst summer distribution (Figure 8). A complete set of grid cell count maps are available upon request.

The regional grid cell count approach is a useful analytical tool as its data requirements are far more flexible than those of the BBOM. The grid cell counts can be used to quickly identify data gaps, visualize changes in distribution through time, and summarize large amounts of data efficiently. Additionally, the wolf-caribou association analysis is built upon the same datasets and can easily be produced alongside this approach to provide further information on individual herd associations.

As the grid cell count analysis uses a consistent grid, relative distributions can be easily developed for any new data collected and integrated into the existing analysis. Since the analysis results are easily updatable, this approach lends itself to modelling potential wolf-caribou interactions over a longer period. Exploring space-time variation in these interactions could be used to support management planning, determine the effectiveness of any management actions, and characterize any long-term trends for the population dynamics between the species.

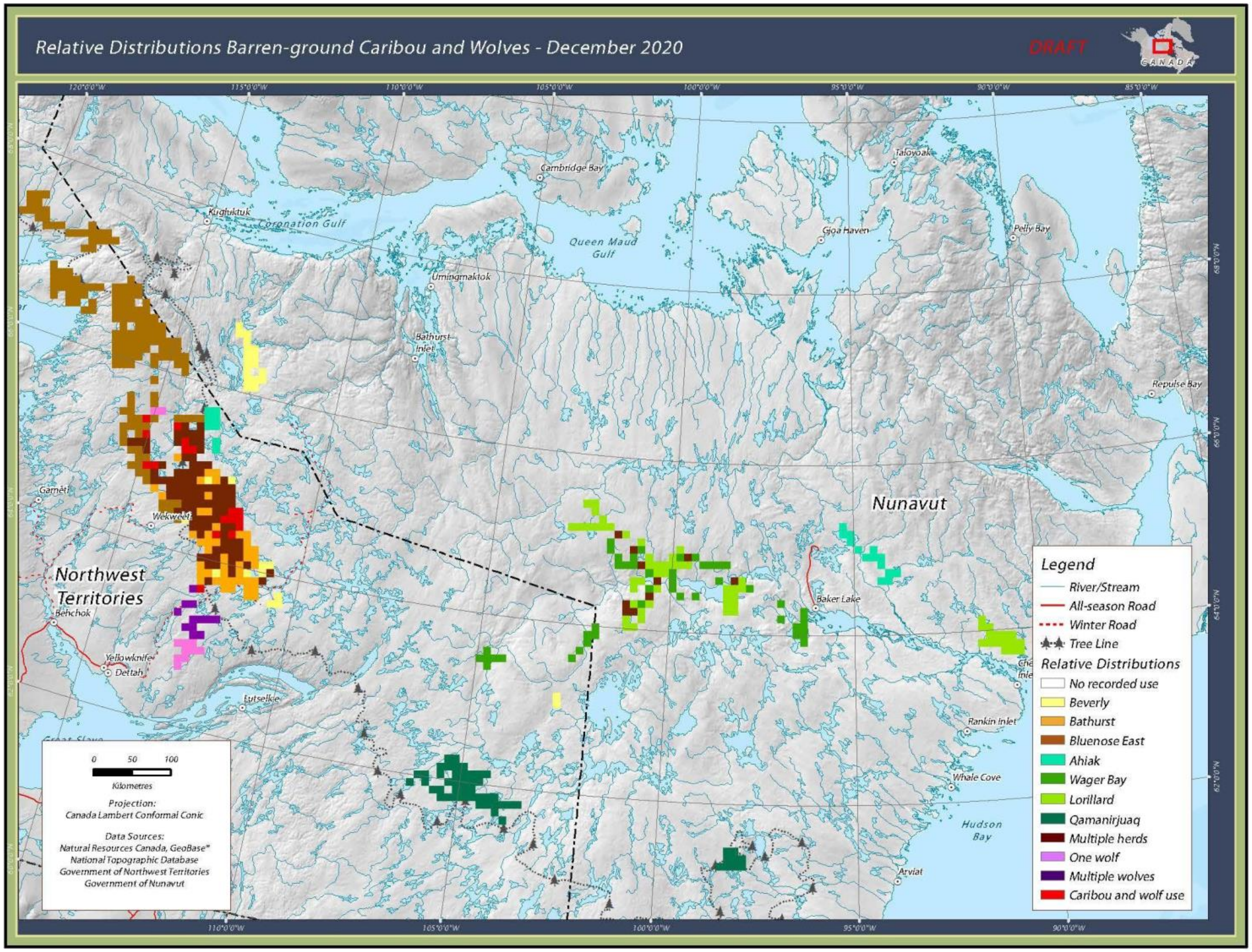

Figure 7. Grid cell count results showing wolf-caribou shared use areas were concentrated in the region north-east of Wekweètì where the three barren-ground caribou herds were mixing on winter ranges in December 2020.

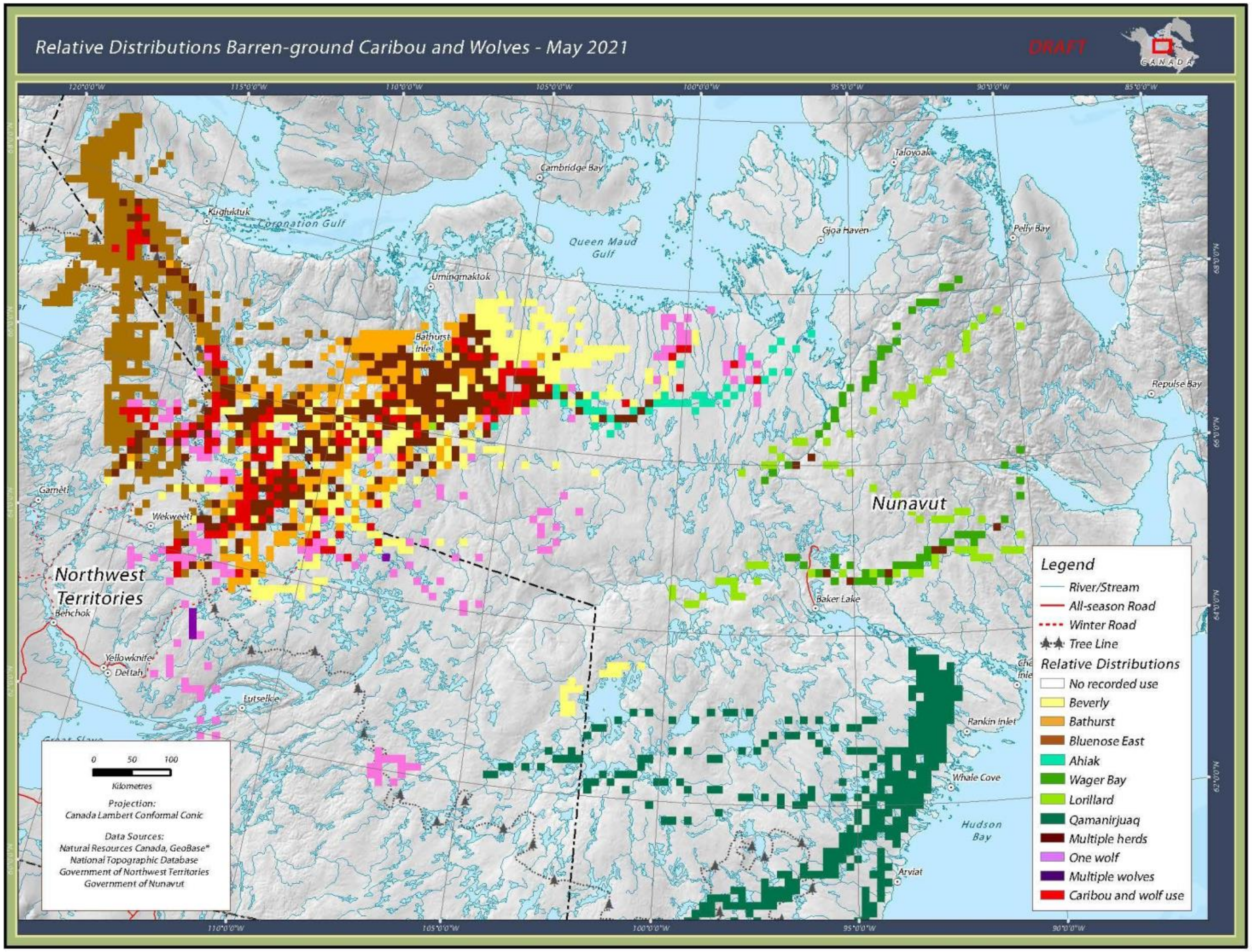

Figure 8. Grid cell count results for May 2021 highlighting wolf-caribou interactions with all three GNWT barren-ground herds.

The wolf-caribou association analysis was successfully able to summarize the degree of association between individual wolves and barren-ground caribou herds. In Table 7, the total number of wolf-caribou interactions for an individual collar were calculated and used to generate the percent interaction by herd. By comparing the percentage interaction we can begin to quantify the associations between wolves and caribou herds. The results show that some wolves are mainly associated with a single herd, while others are evenly split between multiple herds.

Bathurst had the greatest incidence of caribou-wolf interactions both in terms of the number of grid cells (513 cells), and in the number of wolves involved (i.e., 29 of the 34 collars examined interacted with Bathurst at some point). Beverly was the second highest with 410 grid cells showing co-occurrence with 24 of the 34 wolves. Qamanirjuaq was the lowest with only 9 cells indicating interaction with a single wolf. This is consistent with the collar deployment locations, as the Qamanirjuaq seasonal ranges are the furthest removed from the deployment sites.

The strongest associations were recorded with Bathurst and Bluenose east with WF-NS20-01, WF-NS20-12, WF-NS20-23, WF-NS20-29, and WF-NS21-07 showing interaction percentages in excess of 60%. Other wolves such as: WF-NS20-21, WF-NS20-27, and WF-NS21-03 did not have any herd associations greater than 40% thus interacting more evenly across all barren-ground caribou herds.

The wolf-caribou herd associations were broken down further by displaying the interactions per month. This allows for a better understanding of the timing of wolf-caribou interactions. For wolves who interact with several herds it may be beneficial to know whether those multi-herd interactions are occurring at the same time or if they are temporally exclusive. The results of this vary from one wolf to another. There is a trend of wolf-caribou interactions occurring during the spring and winter months. This corresponds well with what was seen in the BBOMs where the collars were near several caribou herds during these seasons. Wolves such as: WF-NS20-01, WF-NS20-30 appear to interact with one herd consistently throughout the year, but in the winter months interactions occur with all herds. In contrast, WF-NS21-04 has a wide range of interactions with multiple herds throughout all seasons.

The wolf-caribou association tables quantify the spatial patterns that were visible in both the BBOMs and the grid cell maps. The summaries provide insight into the strength, timing and prevalence of wolf-caribou interactions. These details can be used to build a better understanding of the strength of each wolf's affiliation with a particular barren-ground caribou herd.

Table 7. Wolf/Caribou association summary for the life of each collar. The total number of wolf-caribou interactions for an individual collar were calculated (cell count) and used to generate the percent interaction by herd (percent of total). Darker green color indicates higher percent interaction with a specific herd.

	Cell Count									Percent of Total							
Collar	**AH**	**BA**	**BV**	**BNE**	**LR**	**QM**	**WB**	**2+***	**Total**	**AH**	**BA**	**BV**	**BNE**	**LR**	**QM**	**WB**	**2+**
WF-NS20-01	15	15	3	82	3	0	1	6	125	12	12	2.4	66	2	0	0.8	5
WF-NS20-02	0	0	0	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
WF-NS20-12	0	11	0	3	0	0	0	0	14	0	79	0	21	0	0	0	0
WF-NS20-21	3	16	7	4	8	9	1	18	66	4.5	24	11	6.1	12	14	1.5	27
WF-NS20-23	0	22	0	0	0	0	0	0	22	0	100	0	0	0	0	0	0
WF-NS20-27	22	71	10	89	10	0	1	25	228	9.6	31	4.4	39	4	0	0.4	11
WF-NS20-29	0	21	0	0	0	0	0	0	21	0	100	0	0	0	0	0	0
WF-NS20-30	4	60	15	3	7	0	0	10	99	4	61	15	3	7	0	0	10
WF-NS21-03	7	3	3	12	3	0	2	0	30	23	10	10	40	10	0	6.7	0
WF-NS21-04	9	21	43	0	17	0	0	19	109	8.3	19	39	0	16	0	0	17
WF-NS21-06	1	3	6	1	2	0	0	7	20	5	15	30	5	10	0	0	35
WF-NS21-07	0	3	1	21	0	0	1	0	26	0	12	3.8	81	0	0	3.8	0
WF-NS21-08	4	6	15	0	3	0	1	3	32	13	19	47	0	9	0	3.1	9
WF-NS21-10	2	29	58	1	33	0	0	24	147	1.4	20	40	0.7	22	0	0	16
WF-NS21-11	1	11	4	1	7	0	1	9	34	2.9	32	12	2.9	21	0	2.9	27
WF-NS21-14	4	9	0	14	0	0	0	2	29	14	31	0	48	0	0	0	7
WF-NS21-15	5	4	45	0	22	0	0	21	97	5.2	4.1	46	0	23	0	0	22
WF-NS21-16	16	10	54	0	20	0	0	41	141	11	7.1	38	0	14	0	0	29
WF-NS21-17	2	5	8	0	2	0	0	16	33	6.1	15	24	0	6	0	0	49
WF-NS21-20	1	8	1	0	2	0	0	2	14	7.1	57	7.1	0	14	0	0	14
WF-NS21-24	14	68	8	6	35	0	0	16	147	9.5	46	5.4	4.1	24	0	0	11
WF-NS21-25	9	15	48	1	19	0	1	27	120	7.5	13	40	0.8	16	0	0.8	23
WF-NS21-28	3	7	4	0	20	0	5	1	40	7.5	18	10	0	50	0	13	3
WF-NS21-32	14	27	2	57	4	0	0	3	107	13	25	1.9	53	4	0	0	3
WF-NS21-33	1	20	7	0	21	0	0	13	62	1.6	32	11	0	34	0	0	21
WF-NS21-34	3	5	39	0	19	0	0	35	101	3	5	39	0	19	0	0	35
WF-NS22-05	6	5	0	7	0	0	0	0	18	33	28	0	39	0	0	0	0
WF-NS22-07	2	9	14	0	6	0	0	4	35	5.7	26	40	0	17	0	0	11
WF-NS22-08	0	20	10	3	4	0	0	5	42	0	48	24	7.1	10	0	0	12
WF-NS22-14	0	0	0	6	0	0	0	4	10	0	0	0	60	0	0	0	40
WF-NS22-18	1	9	5	0	6	0	0	2	23	4.3	39	22	0	26	0	0	9
Total number of interactions for each herd:	149	513	410	311	273	9	14	313									
	Number of individual collars interacting with a herd:									**24**	**29**	**24**	**17**	**23**	**1**	**9**	**24**

*2+ indicates grid cells with locations for two or more caribou herds. WF-NS20-18, WF-NS20-22, WF-NS20-26 did not have sufficient data.

2.5.1.3 Discussion

The grid cell count approach has more flexible data requirements but can only be used to examine wolf-caribou space-use patterns at a regional scale. Collecting coarser data (i.e., daily data) likely make for a dataset that spanned multiple years and would be suited to quantifying fidelity in both annual seasonal wolf movement patterns. If the goal of the analyses is to help plan long term regional based management strategies, then collecting daily data may be sufficient for the task.

From a spatial data analysis perspective, ideal sample sizes are difficult to determine. To generate a balanced spatial characterization of wolf movement relative to the barren-ground caribou herds, wolf collars would have to be spread equally across the herds considered in the analysis. Currently, there exists a data gap for wolves active in the overlap areas between the Bathurst and Beverly herds. Addressing this gap would provide more information about wolf movement patterns in these areas and whether wolf movement and space-use strategies differ between caribou herds. For modelling caribou ranges, we use a five-collar threshold for determining if a range is representative of caribou space-use (Gunn et al., 2011); however, we could not find a similar precedent for barren-ground wolves. A brief literature review revealed that sample sizes from between 4-30 collars have been used to ask questions pertaining to wolf caribou dynamics in the past (Courbin et al., 2009; David et al., 2011; Hansen et al., 2013; Hayes and Russel 1998; James, 1999; Walton et al., 2001). If the goal of the project is to quantify wolf movement patterns relative to specific herds, then a minimum number of collars (e.g., five) associated with each herd could be used to ensure that a balanced picture of wolf-caribou dynamics is being captured. From a spatial perspective, a balanced spatial distribution of 5-7 wolf collars per herd may be more important to the analysis than a large number of collars deployed for just one herd.

2.5.2 Caribou herd affiliation from den sites

One of the premises of wolf removal in the NWT wolf management program is to target a specific caribou herd and help that caribou herd recover from decline. The Bathurst and Bluenose East caribou herds have experienced significant declines in the last decade and are subject to management action to increase their numbers. The Beverly caribou herd occupies the tundra area east of the Bathurst caribou range but is significantly more numerous than either the Bathurst or Bluenose East caribou herds. While barren-ground caribou are migratory, i.e., showing annual movements between calving grounds on the tundra and boreal forest/taiga habitat in winter, these herds can also overlap during winter. Extent of range overlap can vary significantly among years from none at all to approaching 100%, based on collared caribou. This behavior confounds the evaluation of wolf management action as the program seeks to reduce wolf predation associated with a specific caribou herd, such as for Bathurst caribou.

Because barren-ground caribou are migratory and the main prey of wolves, those wolves that follow caribou can also be considered migratory. It seems reasonable that wolves following caribou from a specific herd in a given season could continue to do so year after year. However, such a long-term pattern has not been shown and may not hold. Alternatively, wolves may distribute themselves as more of a panmictic population. Wolves that den on the tundra would likely be associated with the caribou herd linked to that summer range and then likely migrate with that herd in fall and winter. However, if wolf den site fidelity is weak and adjacent barren-ground herds overlap significantly during winter, then wolves may follow caribou from another herd and consequently not show strong association with only one caribou herd over the long term. This would certainly be expected of many young, dispersing wolves. Nevertheless, exploring for potential caribou herd association is best done by collaring wolves during the wolf denning season where breeding adults can be easily assigned an affiliation to a caribou herd associated with the summer range where the wolf den is located. The movements of those wolves are then subsequently tracked and association(s) with caribou herds monitored.

Current wolf removal efforts seek to target wolves associated with the Bathurst and Bluenose East caribou herds, but not for the Beverly herd. The Beverly caribou herd is significantly more numerous (ca. 103,000 caribou in 2018) than either the Bathurst herd (ca. 6,200 caribou in 2021) or the Bluenose East herd (ca. 23,000 caribou in 2021 (Adamczewski et al., 2022; Boulanger et al., 2022; Campbell et al., 2019). The wolf program has sought to associate wolves collared in March/April to specific caribou herds. An alternative is that the tundra wolf population exists as a single panmictic population. If wolves do generally associate with a specific caribou herd, then that could help in assessing the effectiveness of wolf removal effort targeting that area. While this association might seem reasonable when caribou herds show minimal overlap, doing so when caribou herds overlap significantly in winter is more problematic. The accumulation of GPS collared wolves in 2020, 2021, and 2022 is providing a growing location dataset where we can examine wolf movements between caribou herds and degree of fidelity. We can also evaluate whether an initial caribou herd assignment of wolves captured in winter, especially during times of herd overlap, is reasonable.

2.5.2.1 Methods

Wolves were collared in the North Slave Region of the NWT in March/April 2020 (n=13), March 2021 (n=19), and March 2022 (n=7) on barren-ground caribou range. Given that several GPS locations are obtained per wolf per day, we applied sequential clustering analysis of the data to identify potential den sites. Locations were limited from 01 May to 15 June for each year for this analysis, which should be sufficient to identify potential den site locations for tundra-denning wolves.

The parameters we used to identify clusters were search radius, number of “window” days, and the minimum number of locations. For identifying potential den sites among clusters, we chose an initial search radius (SR) of 200 m, 5 window-days (W-D), and a minimum number of 10 locations for a cluster (CML). If no clusters were identified with these parameters, we reran the algorithm with 4 W-D and 8 CML, but kept the same 200 m SR. If clusters were still not identified, we reran the algorithm one final time with 3 W-D and 6 CML while keeping the SR constant at 200 m. If clusters were not identified in these three rounds, then we assumed that the wolf was not a breeding wolf. Wolves that showed a location cluster were still evaluated with their movements if they were likely frequenting a den by examining the time spent at the cluster and repeated movements back and forth to the cluster.

There were 11 wolves in the initial March/April 2020 collar deployment (6 males, 5 females) available for den clustering analysis for May/June 2020. However, only 8 wolves showed putative den site clusters.
Although 19 additional wolves were collared in March 2021, only 15 had locations during the May-June 2021 period. Of those, 14 showed potential den site clusters. One wolf (NS21-06f) did not show back and forth movements to a specific site, and the location cluster was likely a mortality site or a collar malfunction, and therefore was removed from further analysis.

There were only seven additional wolves collared in March 2022, of which two were subsequently harvested by ground-based hunters. One wolf was found dead from an assumed natural mortality event; the collar was retrieved but several weeks had passed and no carcass remains were evident. One collar remains stationary as of mid-April and has yet to be investigated. Therefore, only three collared wolves had locations into the May-June 2022 period. Only one of these (NS22-18f) showed den movement behavior.

For wolves collared in 2020, 2021, and 2022 that showed denning movement behavior, we plotted the capture location and their putative den site that year. Based on their denning location we assigned a caribou herd association based on the general location of each caribou herd's summer range. We also compared that affiliation with the initial caribou herd association given at capture (Nishi et al., 2020). Finally, for 11 wolves that were monitored for more than one denning period, we plotted their subsequent putative den locations in the following years as a way to explore den site fidelity, specifically to caribou herd summer range.

2.5.2.2 Results and discussion

There were eight wolves (4 males: 4 females) collared in March and April 2020 that showed denning movement behavior in June (Figure 9). Distances from the capture site to where they denned were moderate (median=66.5 km, mean=91.4 km) but were influenced by wolf NS20-21f who traveled 310 km from her capture site southwest of Mackay Lake to her denning area southeast of Lutsel K'e between Penylan and Stephenson lakes. The four wolves that were given an initial caribou herd association of "Bathurst" at capture did not den on the Bathurst summer range. Rather, three were boreal wolves (non-migratory wolves that inhabit the boreal forest, not the tundra) denning east of Gordon Lake, and the fourth wolf (NS-21f) may have been a disperser, as she travelled to the winter range area of the Qamanirjuaq caribou herd. The other four wolves were assigned as "Bluenose East" wolves. However, two of them denned in the boreal forest and one on the Bathurst caribou summer range. Only one of these wolves (NS20-18m) traveled northward towards where Bluenose-East caribou herd migrate in spring/summer (Figure 9). In winter 2020 (see Figure 29 in Nishi et al., 2020), 36.5-56.4% of the Bathurst monthly winter ranges were overlapped by the Beverly herd and 36.9-44.7% by the Bluenose-East herd, which likely influenced how captured wolves were assigned to a caribou herd.

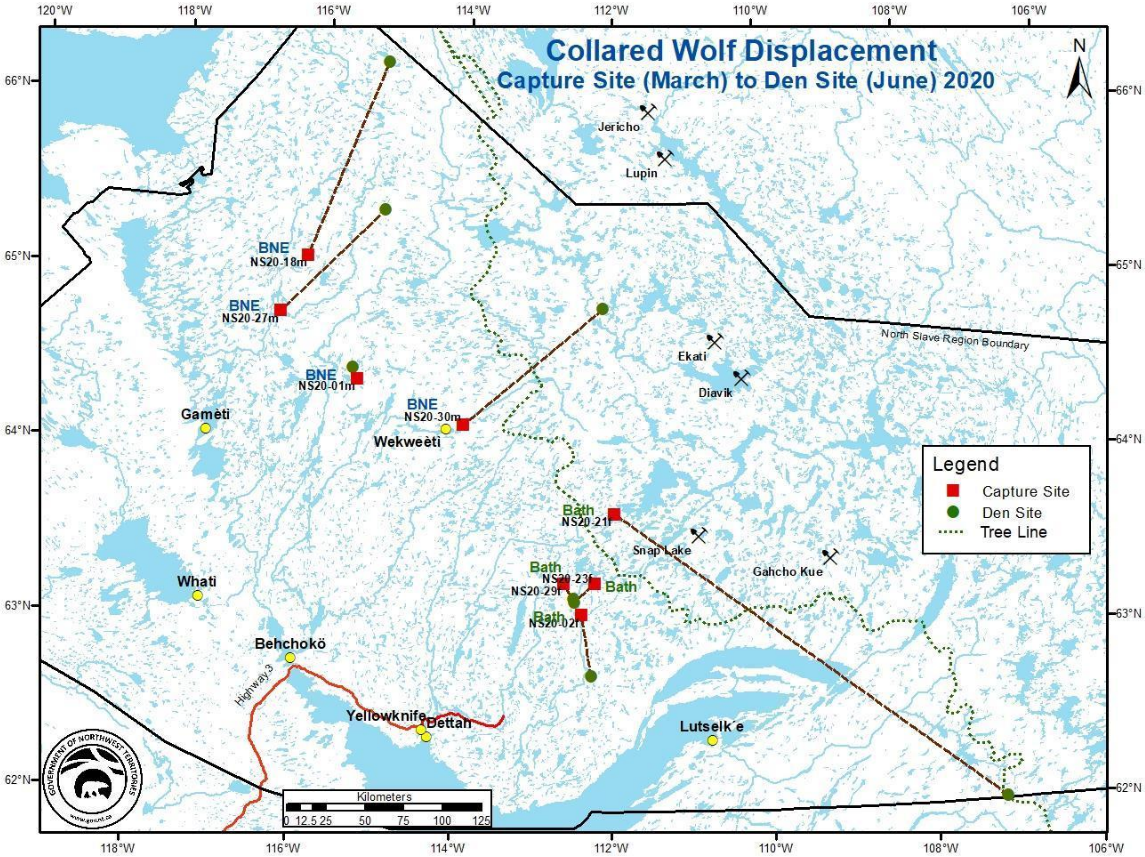

Figure 9. Straight-line displacement of 8 wolves (4 males: 4 females) collared in March/April 2020 from their capture site (red squares) to their putative den site in June 2020 (green circles).

There were 14 wolves (8 males: 6 females) collared in March 2021 that showed denning movement behavior in June (Figure 10). Distances from the capture site to where these wolves denned were variable (median=194.5 km, mean=265.2 km) ranging from 36 km to 734 km. Two collared wolves were initially assigned as “Bluenose-East” wolves when captured, of which one denned on the Bluenose-East summer range. The other “Bluenose-East” wolf traveled 734 km to its den site on the Beverly caribou calving grounds (Figure 14). Six collared wolves were initially assigned as “Beverly” wolves, three of which denned in the Beverly caribou summer range area, while the other three did not. Five wolves were initially assigned as “Bathurst” wolves and one denned on the Bathurst caribou summer range (NS21-33f). Most notably were wolf NS21-08f assigned as a “Bluenose-East” wolf and NS21-03m assigned as a “Beverly” wolf. Although these two wolves were collared in the same location, NS21-08f denned in Beverly range and NS2103m denned in Bluenose-East range (Figure 10). In winter 2021 (see Figure 3 in Clark et al., 2021), the Beverly herd overlapped the Bathurst monthly winter ranges 97.2-100% excluding May, which likely influenced how captured wolves were assigned to a caribou herd.

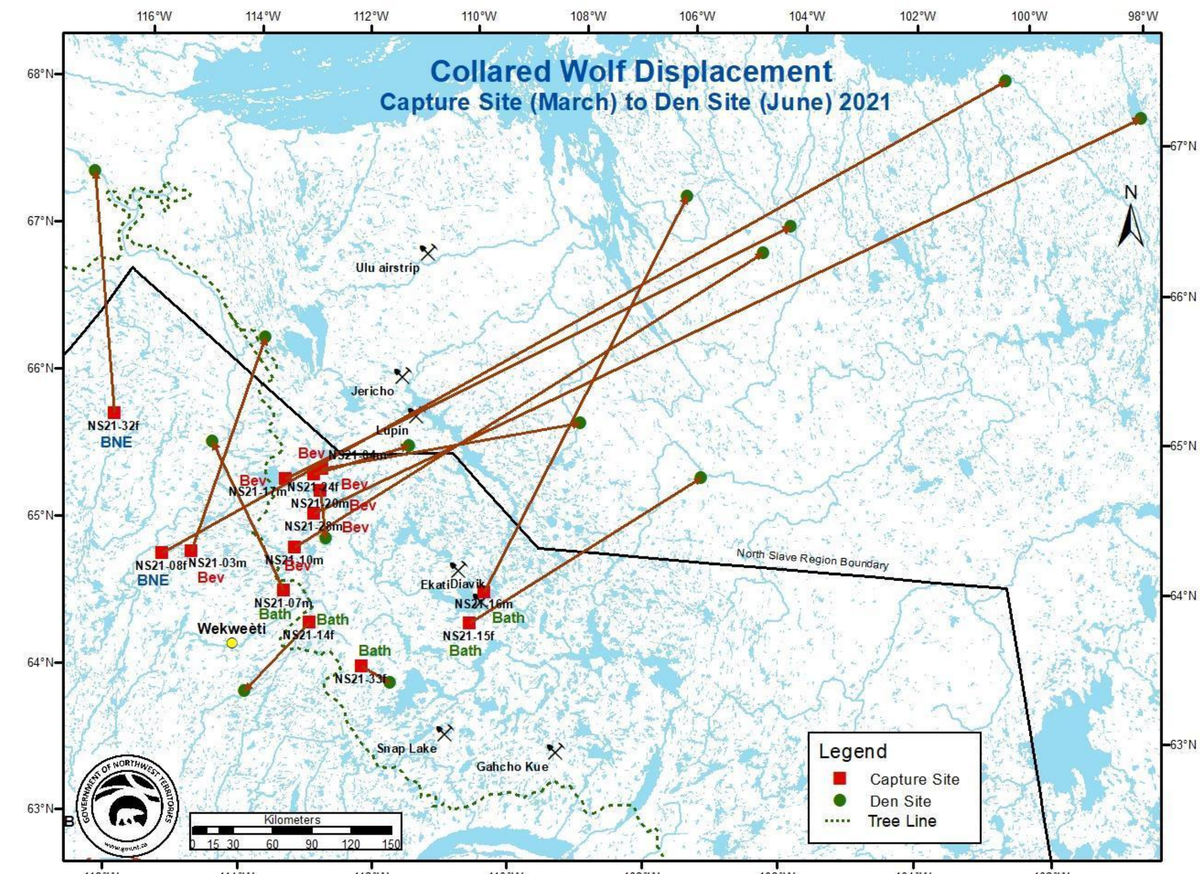

Figure 10. Straight-line displacement of 14 wolves (8 males: 6 females) collared in March 2021 from their capture site (red squares) to their putative den site in June 2021 (green circles).

Only 1 of 7 wolves collared in March 2022 showed denning behavior in June 2022. This wolf was captured closest to Beverly winter range and traveled over 298 km to her putative den site in June on the Beverly caribou range (Figure 11). The other six wolves either died (n=3) or did not show denning movement behavior (n=3). Although only one wolf could be monitored this way, it does show that the adjacent Beverly caribou herd still influences wolf movement in the Bathurst caribou winter range.

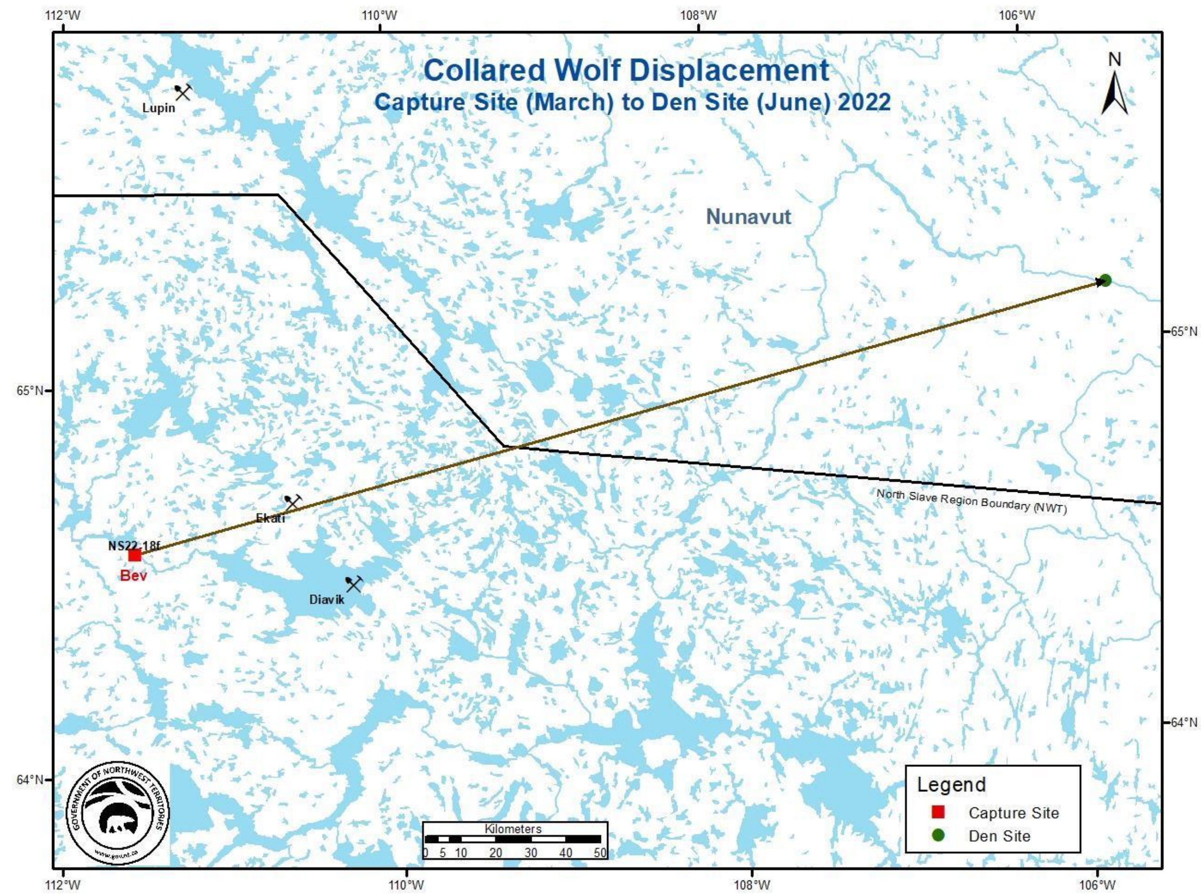

Figure 11. Straight-line displacement (298 km) of one wolf (female) collared in March 2022 from her capture site (red square) to her putative den site in June 2022 (green circle).

2.5.2.3 Multiyear comparison of denning wolves

There were 11 collared wolves (4 males:7 females) that were monitored for more than one year that also included the denning period. We explored the locations of these putative den sites to see if den site fidelity occurred within the same caribou herd range. We did not plot the extensive movements that would have occurred over the year from one den site to another. Rather, we were interested to see if a wolf that denned in a given caribou summer range in one year continued to do so the following year, regardless of its movements following caribou over the fall and winter.

Only one wolf of the 11 was a “Bluenose-East” wolf (denned near Bluenose-East calving and post calving range) over its two years of monitoring. Two wolves (21-24f, 20-30m) were considered “Bathurst” wolves, while one wolf was considered a “Boreal/Bathurst wolf (20-27m), and another a “Bathurst/Beverly” wolf (21-10m), as the association changed from year 1 to year 2 (i.e., wolf was more of a boreal wolf the first year and was then more associated with the Bathurst caribou herd the second year). Five wolves continued to den south of the tree-line and are best considered “Boreal” wolves (Figure 12). One wolf denned far to the southeast into where the Qamanirjuaq caribou wintered. We suspect that this wolf, collared by the south end of Mackay Lake, was a dispersing wolf and established herself near the tree-line southeast of Lutsel K’e (Figure 12).

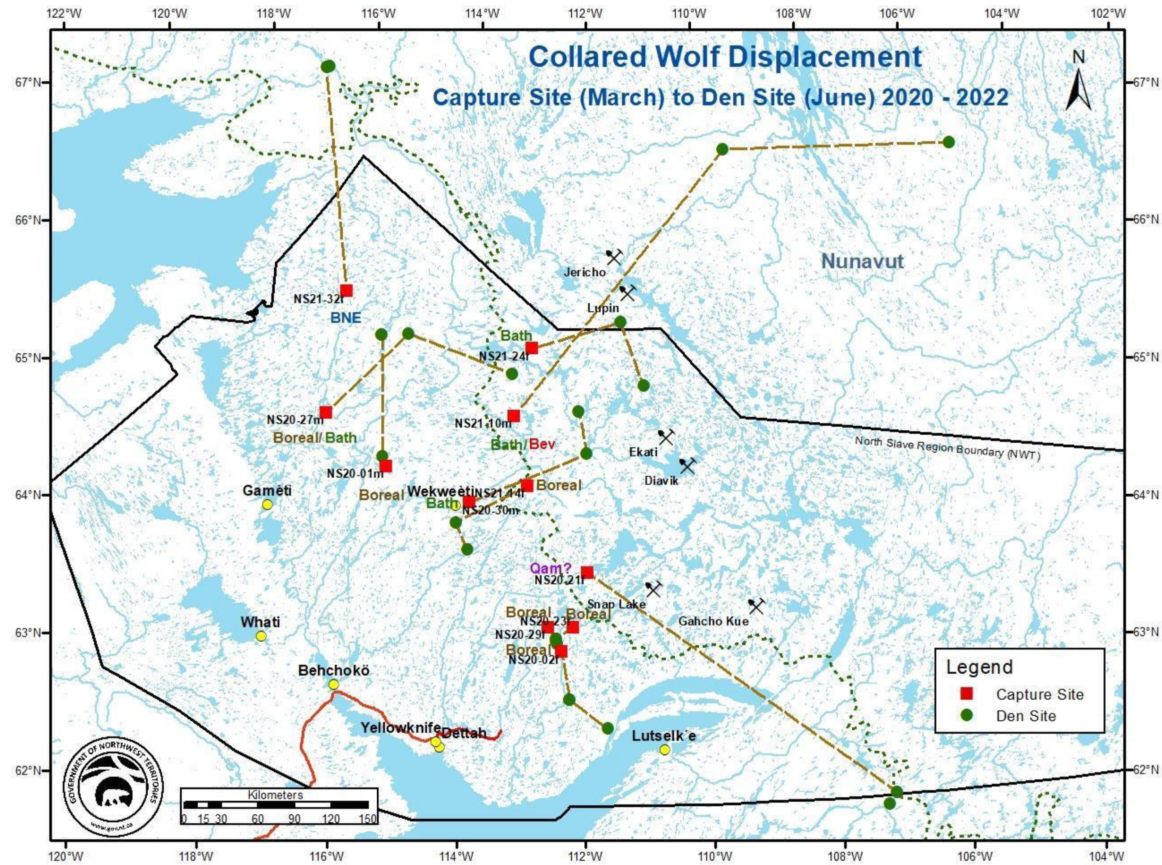

Figure 12. Collared wolves monitored for 2 or 3 sequential denning periods (May-June) and showing den movement behavior in GPS location clustering of their movements. Caribou herd assignment for each collared wolf at their capture location (red squares) assigned based on where they denned (green circles). BNE = Bluenose-East, Bath = Bathurst, Bev = Beverly, and Qam = Qamanirjuaq barren-ground caribou herds. Boreal = wolves remaining in the forested area during denning. Lines connect successive den locations only and do not show the extensive movement paths between subsequent years.

Wolves have great dispersal capability and if wolves disperse these great distances to the east, it is not unreasonable to assume that wolves to the east can similarly disperse great distances to the west. Further monitoring wolves over successive years will elucidate wolf den fidelity, especially during different degrees of winter range overlap by caribou. However, it appears that in the last three years many wolves collared on the Bathurst caribou winter range in March can range throughout a much larger area the rest of the year. Using den site location may be a better indicator of caribou herd affiliation rather than winter capture, especially when winter overlap among adjacent caribou herds occurs.

2.6 Wolf Detection Rate Survey

A geospatial aerial survey for wolves was conducted in 2021 on the Bathurst winter range in the North Slave Region. The survey data resulted in an estimate of 89 wolves (SE=29.7) with a 95% confidence limit of 31-147 wolves (Clark et al., 2021). The low precision limited the ability of this survey design to detect changes in wolf densities over time. Several factors may have contributed to low precision. First, wolves inherently have a clumped distribution and likely occur at low density on this landscape making survey design challenging over vast landscapes; the clumped distribution and low density contribute to high variability in an estimate. Using standard techniques, a very high survey intensity would be required to increase precision to useful levels. Further, the indirect estimate of caribou densities based on isopleths of caribou collar locations as a proxy for wolf densities may not be an accurate representation of the true wolf densities (See Mattson et al., 2009); wolf movements during time lags between caribou collar density estimates and wolf survey timing may also further confound the stratification design. While the geospatial survey design is generally robust, the assumption for a closed population (no movement in/out of the survey area) may be violated given the high mobility of wolves, especially when some show movement patterns associated with migratory caribou. Finally, detection rates of wolves on this landscape are likely low, especially within treed habitat types and when wolves are stationary or bedded. Indeed, the detection rate of wolves during the 2021 survey was 0.38 wolves per hour flying. Without additional data on sightability bias of detection rates, the survey intensity required to obtain precise density estimates may be logistically and economically unfeasible.

Estimating wolf detection rates would increase accuracy and precision of wolf surveys. Radio-collared wolves provide an opportunity to estimate detection rates by flying surveys around locations of known wolves and recording whether the wolf was seen by the observers. Advances in GPS and satellite communication on collars along with traditional VHF radio telemetry allow near real-time knowledge of wolf locations. This provides an opportunity for survey plots to be selected prior to arrival without observer knowledge. The ratio of seen vs missed wolves can then be used to correct population estimates for improved survey accuracy.

Recording the potential factors influencing wolf detection can further increase the accuracy of future survey data by correcting density estimates based on these covariates. Covariates hypothesized to influence wolf detection rates include distance of wolf from observer, habitat type and landscape features, other wildlife present, weather conditions, and behavior of the wolves. Distance from observer is a commonly used covariate in wildlife surveys and is the basis for distance-based sampling techniques. The general principle is that detection rates drop in a predictable fashion as distance from the observer increases. Habitat and landscape features influence detection rates as the animal is either obscured (e.g., forest canopy cover) or blend in with the surroundings (e.g., among similar size and coloured rocks). Similarly, large groups of wildlife present, such as caribou on the survey plot, can obscure and/or fatigue the observer when searching for wolves. The presence of many tracks from these animals can have a similar effect and influence detection rates. Finally, weather conditions may also factor into detection rates of wolves. Conditions such as snow or rain can obscure the animal from the observer while other conditions (e.g., rough air) may fatigue the observer. These conditions may also influence the behavior of the wolves (e.g., increasing movement rates) which in turn also influences detection rates. Measuring the influence of behavior on detection rates directly is difficult as confirming the behavior of an undetected wolf is unlikely.

2.6.1 Methods

The ideal scenario for detection rate surveys is to have near real-time GPS locations and have a non-observer select plots (to avoid bias) just prior to survey. While the GPS collar technology may allow this, the GPS acquisition and upload rates required uses excessive battery power limiting longevity of the collar. Therefore, a GPS acquisition and satellite uplink schedule was chosen to provide recent GPS locations as close to survey time as possible without significantly reducing battery longevity. Likewise, VHF programming is best when transmitters turn on during hours when surveys are likely to occur and turn off at other times to save battery life. Therefore, a new set of GPS collars to be deployed in mid-March 2022 prior to survey, were programmed to take GPS locations every 3 hours and upload data at 0900 and 1300 hours. This allowed the locations to be downloaded and survey plots to be selected just prior to departure each day and updated mid-day during refueling if needed. Further, the VHF schedule was set to be on for 8 hours each day beginning at 1100. Collars deployed prior to the 2022 deployments were programmed to take GPS locations every 6 hours, upload every 2 days, and have a VHF schedule of 4 hours each day starting at 1200 hours local time. With considerations to transit time and fuel reserves, seven new collar deployments were within range of Wekweètì, which served as the base for the survey. Additional collars deployed prior to 2022 were also within range of Wekweètì giving options for wolves to survey. To avoid bias, wolves were not repeatedly surveyed unless they had made significant movements to new areas (usually ≥ 1 day).

Due to the high mobility of wolves, especially on the tundra, it was necessary to confirm that a collared wolf was within a survey plot prior to the survey. Therefore, VHF telemetry was used to determine the general location of the wolf and confirm it was within a plot. To avoid bias, observers did not know where the wolf was within a plot prior to survey. A four-seat aircraft was used to maintain two independent observers, one on each side, plus a pilot and a designated navigator/telemetry operator/data recorder. The navigator recorded observations and covariate data and continually monitored the VHF telemetry equipment to confirm the wolf was present in the plot. This setup required the telemetry equipment to only be audible to the navigator. Further, having audio intercom equipment in the aircraft allowing isolation of the pilot and navigator communications was ideal, especially during the pre-survey telemetry.

The navigator downloaded wolf GPS locations each morning and planned a daily route that considered transit times, the last time each wolf was surveyed, and weather. An effort was made to rotate which wolves were surveyed to collect data on a wide range of habitat types and give adequate times to let the wolves move around. For example, some wolves spent multiple days on a kill site. These wolves were not surveyed again until they had left the kill site and moved to another area to avoid the observers recognizing the location and knowing there was likely a wolf nearby. The aircraft was flown to the last GPS location of the first wolf for the day. Prior to reaching the wolf, the rear observers were instructed to not look outside. The audio intercom in the airplane was then set to only allow communications between the pilot and navigator. Only the navigator was able to hear the telemetry equipment. The aircraft was flown at a far enough distance and altitude from the wolf’s last GPS location to confirm the wolf's general location without causing the wolf to run from the aircraft. To avoid the issue with a wolf near the border of a preset plot, a new survey plot was created by the navigator immediately following confirmation of the wolf's location. This was done on a tablet with GPS track logging and moving map. The aircraft would then reposition to begin flying the systematic aerial search of the plot, audio intercom was set to full communication with observers, and the observers were allowed to look outside once the plot begins.

Survey plots were flown in a similar fashion to the 2021 geospatial survey. Plots were set to be 10x10km with 10 survey lines spaced at 1km. This gave each observer an approximately 500-meter survey band to scan while flying. The plots were flown at 150-200m above ground level depending on terrain and at approximately 140 km/hr. All animals sighted during the survey were marked via GPS and counted (or estimated in the case of large caribou herds). If a wolf was observed, the aircraft would circle back to get an accurate count and determine if any collars were present. If a collar was present, the navigator would confirm the identity of the collared wolf with the radio telemetry equipment. The radio telemetry equipment remained on at low volumes during the entirety of the plot so the navigator could monitor the location of the radio marked wolf without the observers knowing. This was done to confirm the wolf was surveyed regardless of if it was seen by the observers. If a wolf was observed, the navigator would estimate the visual obstruction (VO) which is basically the percent (range 0-100 in 5% increments) of vegetation, rocks, or any other VO within approximately 10m (~5 wolf lengths) around the wolf. Photos were taken of wolves when possible. Additional data recorded for all animals was the side of the aircraft it was viewed on (left or right), the activity of the animal (e.g., standing, bedded, running, etc.), and any pertinent notes. If the collared wolf was missed during the survey, the aircraft would return to the location of the wolf after the plot was finished. Once relocated using VHF radio telemetry, the same data was collected along with additional notes taken as to why it may have been missed. Once the plot was completed, the aircraft would move on to the next wolf or return for fuel if needed. By this time of day, the second collar satellite upload had likely occurred and could update the latest wolf locations.

2.6.2 Results

A Found Bush Hawk was used to complete detection rate surveys between March 20-30, 2022. The survey crew consisted of a pilot, navigator/data recorder/telemetry operator, and two rear seat observers, one on each side. We flew 19.8 hours on 21 survey plots (Figure 13). Survey time averaged 56 minutes per plot (range 53-61) excluding pre-survey wolf locating and follow-up searches. We searched 21 plots using 9 collared wolves. For the 8 collared wolves seen, pack size averaged 3.4 (range 1-6). In addition, we saw 4,573 caribou, 4 moose, 2 fox, and 1 wolverine on survey plots.

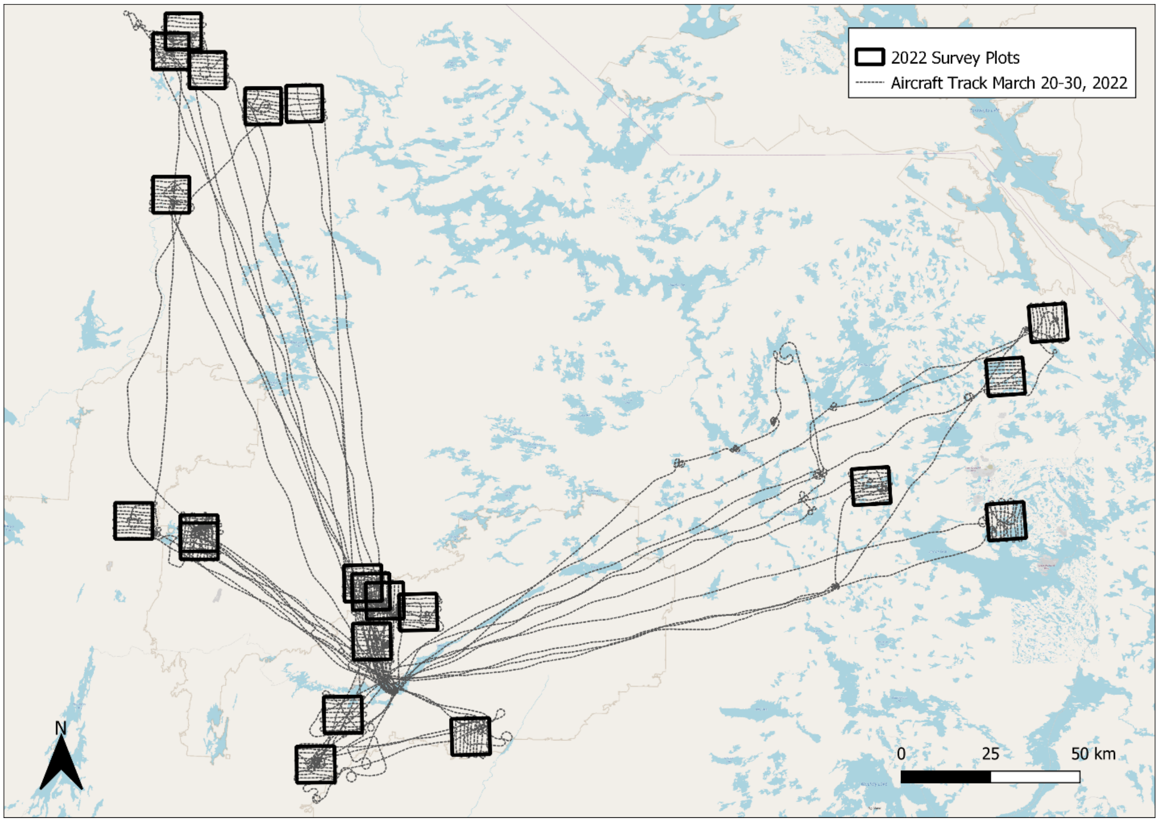

Figure 13. Flight paths for wolf detection rate surveys on 21 plots from March 20-30, 2022 in the North Slave Region of the Northwest Territories.

Of the 21 plots surveyed for collared wolves, there were 12 wolf detections and 9 misses for an overall detection rate of 57%. Low sample size (n=21) requires caution when interpreting relationships using this preliminary dataset. Additional data will be collected in the future to allow a full analysis and application of these data to correct future surveys for detectability of wolves. However, some relationships seem apparent.

There was a negative relationship between VO and detectability with higher percentage of visual obstructing cover reducing detection rates of wolves (Table 8, Figure 14). For two samples where the VO was unable to be collected, a mean VO in a similar habitat was used as an estimate. This allowed the inclusion of those samples while minimizing bias. A similar negative relationship was seen for distance from the aircraft with greater distances reducing detection rates of wolves (Table 8, Figure 15). A pack of wolves was detected running on an open lake far outside of the 500-meter search zone (1760m). This observation was considered an outlier and removed. However, this detection suggests an interesting possibility where VO and distance likely have an interacting relationship. It is possible detection rates can be higher at greater distances if the VO is low. However, preliminary models investigating this relationship were not significant likely due to low sample size.

Table 8. Logistical regression models for detection of wolves by observers March 20-30, 2022 in the North Slave Region of the Northwest Territories. Predictive variables include percent visual obstruction, distance of wolf from observer, and number of caribou within 1km radius of wolf. Number of caribou within 2.5km radius of wolf and total caribou on the plot are shown for comparative means. Models were ranked using Akaike's information criterion (AIC).

Model	Predictive variables	Estimate	Std. Error	T	P[1]	AIC	ΔAIC[2]
1	~Visibility Obstruction (%)	-0.021	0.006	-3.388	0.0029 **	28.785	0.000
	+Distance from Observer	-0.001	0.001	-2.178	0.0415 *		
	+Caribou (1km radius)	-0.003	0.001	-2.497	0.0214 *		
2	~Visibility Obstruction (%)	-0.017	0.006	-2.856	0.0092 **	31.887	3.102
	+Caribou (1km radius)	-0.003	0.001	-2.317	0.0302 *		
3	~Visibility Obstruction (%)	-0.017	0.007	-2.599	0.0167 *	33.298	4.513
	+Distance from Observer	-0.001	0.001	-1.878	0.0743 .		
4	~Visibility Obstruction (%)	-0.014	0.006	-2.232	0.0356 *	35.346	6.561
5	~Distance from Observer	-0.001	0.001	-1.092	0.2872	37.670	8.885
	+Caribou (1km radius)	-0.002	0.001	-1.461	0.1589		
6	~Caribou (1km radius)	-0.002	0.001	-1.547	0.1350	37.773	8.988
7	~Distance from Observer	-0.001	0.001	-1.105	0.2810	37.992	9.207
8	~Caribou (2.5km radius)	-0.001	0.001	-1.009	0.3240	39.166	10.381
9	~Caribou (Entire plot)	0.001	0.001	0.118	0.9070	40.233	11.448

[1]Coefficient significance indicated at P<0.1 (.), P<0.05 (*), P<0.01 (**) and P<0.001 (***)

[2]Difference from selected model with lowest AIC

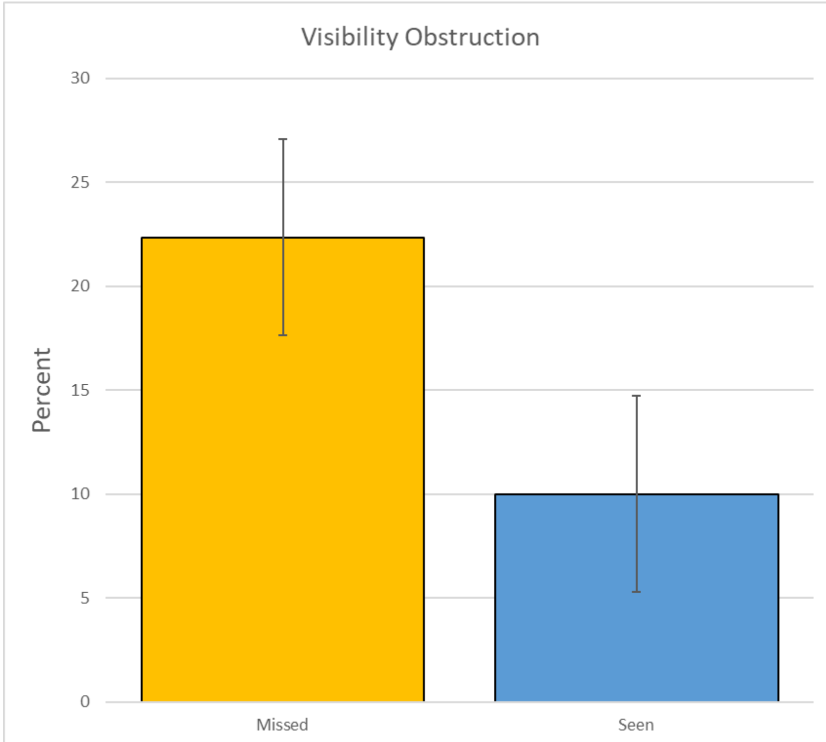

Figure 14. Mean percent visual obstruction for missed (n=9) and seen (n=12) wolf observations Mar 20-30, 2022 in the North Slave Region of the Northwest Territories. Error bars indicate standard error.

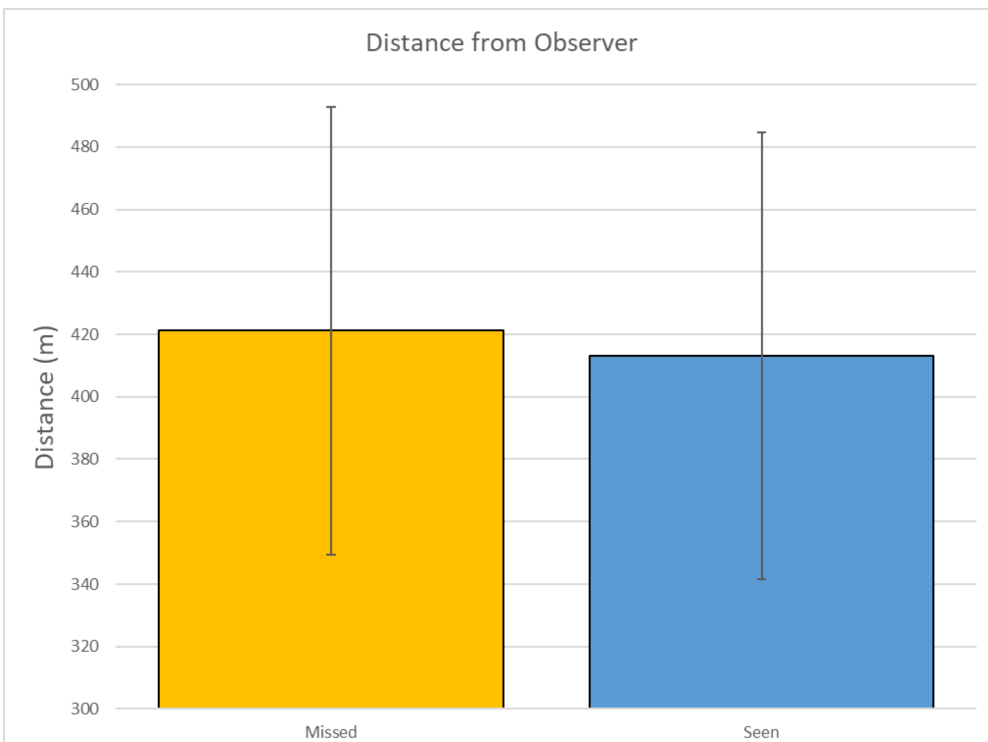

Figure 15. Mean distance between observer and wolf for missed (n=9) and seen (n=12) wolf observations Mar 20-30, 2022 in the North Slave Region of the Northwest Territories. Error bars indicate standard error.

We hypothesized the number of caribou as well as caribou tracks present near the wolves will impact detection rates. Classifying the number of tracks on the landscape is difficult and subjective. Therefore, only the number of caribou near the collared wolves was used but the relationships could also be the result of tracks. Since a 10 km x 10 km plot is a large area, the caribou on one end of a plot may not impact wolf detection on the other end. Therefore, the number of caribou within three distances from the wolf was extracted (1 km, 2.5 km, and the total number of caribou on the entire plot). There appears to be negative relationships between caribou within 1 km and 2.5 km from wolves and detection rates but not for the total number of caribou on the entire plot (Table 3, Figure 16). This may be suggestive of observer fatigue scanning through large number of caribou and/or caribou tracks and warrants further investigation when additional samples are collected.

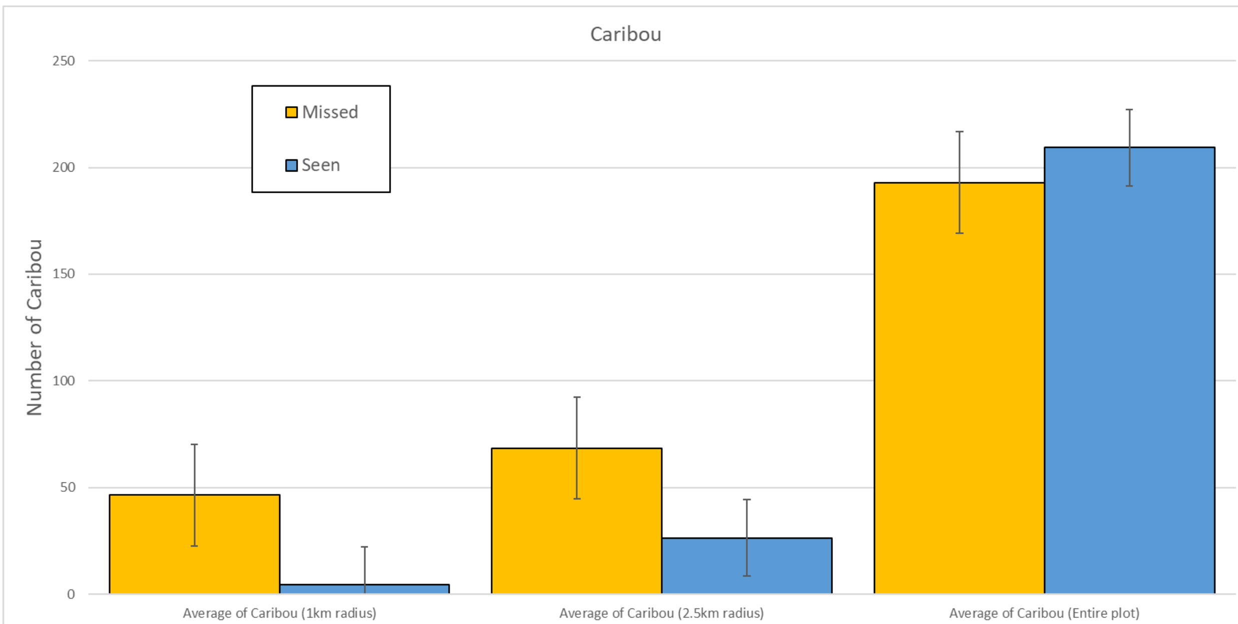

Figure 16. Mean number of caribou within 1km radius of wolf, 2.5km radius of wolf, and entire survey plot for missed (n=9) and seen wolf observations (n=12) Mar 20-30, 2022 in the North Slave Region of the Northwest Territories. Error bars indicate standard error.

We also hypothesized the activity of the wolves (e.g., running, bedded) would impact the detection rates. As previously noted, this is difficult to assess as confirming an undetected wolf's activity is extremely difficult. Returning to a missed wolf's location at the end of the plot and recording the activity at that time is assuming it hasn't changed since it was missed during the survey. If this assumption is acceptable, preliminary data suggests activity of wolves does impact detection rates. When the activities are classified into two categories, moving or stationary, a trend is present in this data. More wolves are detected when the wolves are moving than when stationary. This would be expected as wolves are relatively small animals which blend in with their surroundings and a moving animal is easier for an observer to see. However, it is based on the assumption that behavior of undetected wolves did not change, and caution should be used interpreting these results.

Other predictive variables were of interest but do not appear to influence wolf detection rates based on this preliminary dataset. Weather conditions were relatively consistent throughout the survey days. Notes were taken for weather conditions thought to potentially influence detection rates. Most notably are sunny days creating shadows and poor visibility on a couple plots. However, these do not appear to impact detection rates based on these data. Observer experience was another variable thought to potentially influence detection rates. However, this is not apparent in this data set. Like wolf activity discussed above, assumptions are made when a wolf is missed. When a missed wolf is revisited at the end of the survey, it would have to be assumed it was in that location when missed. The only way to confirm this would be for the navigator, using the telemetry equipment, to detect the wolf during the survey. This was attempted but the navigator was unable to accomplish this for every missed wolf.

2.6.3 Discussion

The data collected in March 2022 on wolf detection rates is a good start towards a comprehensive data set which may be used to correct future wolf survey data for detectability. In turn, this will increase the accuracy of wolf surveys, allowing year to year comparisons of wolf survey data. This is critical to assessing efficacy of various management actions. Additional data should be collected to fully implement this process and the collection of this preliminary data has given us some insight in how to improve future data collection. Two approaches would be another dedicated detection rate survey and incorporating sample collection into a full aerial survey.

If another dedicated detection rate survey is to be conducted, we suggest increasing efficiency of data collection by a) adopting strategic fuel placement; b) reducing size of survey plots; and c) incorporating detection rate methods into a larger scale wolf survey design.

- Fuel placement: Due to the collared wolves being spread out across a vast landscape, a significant amount of time was spent traveling to and from survey plots. Staging fuel in strategic locations is the best way to increase efficiency of another dedicated detection rate survey.
- Smaller plot size: Because the total number of caribou on a plot did not appear to influence detection rate of wolves, it is possible to survey smaller plots. This would decrease the time per plot and allow more plots to be flown increasing sample sizes. Based on the preliminary data, the number of caribou within 1km and 2.5km of the wolf's location was related to the detection rate of wolves. While the number of caribou within 1km and 2.5km are likely correlated, the decrease in the strength of this relationship suggests the plots could be reduced in size (likely by 50%) to increase survey efficiency.
- Include detection rate methods in wolf survey: Incorporating the collection of additional detection rate samples into a full aerial survey is likely the most effective solution moving forward. Since the 2022 detection rate survey was approaching the sample size needed to develop a full detection rate correction model, additional samples could be collected during a full aerial survey.

While incorporating detection rate data into a geospatial survey design to increase precision and narrow confidence limits is the approach being taken in the North Slave Region, other survey techniques are possible. A tracking type survey is an option and is commonly used in other regions (Gardner et al., 2014; Patterson et al., 2004). The detection rate survey in 2022 presented more than one opportunity to attempt this technique without significant impact to the survey. Wolves missed during the detection rate survey are returned to, usually with the aid of telemetry, to collect data on why it was missed. This presented the opportunity to follow tracks, instead of telemetry, to accomplish this goal while simultaneously testing the ability to track on this landscape. These opportunities suggested that the viability of tracking on this landscape is challenging and highly contingent on conditions. Below the tree line, following wolf tracks is possible when there is fresh snow. Areas with high densities of caribou, even with fresh snow, present significant challenges in identifying and following tracks efficiently. On the barrens, tracking is incredibly difficult due to the hard pack nature of the snow. Because of the unpredictability of these conditions and the associated economical and logistical challenges, a tracking type survey may not be the most appropriate wolf survey in the North Slave Region. Continued review and evaluation of survey design options and alternatives for stratification to reduce variation in wolf abundance estimates on the winter range of the Bathurst and Bluenose-East caribou herds will occur through program implementation in 2023.

3 Wolf Removal

3.1 GNWT's North Slave Wolf Harvest Incentive Program

3.1.1 Methods

Wolves are harvested as a furbearer and as big game in the NWT. Since 2010, the North Slave Region has administered a region-wide incentive program to encourage more wolves to be harvested to facilitate recovery of caribou (Cluff 2019). The incentive began as $100/carcass (skinned) for any wolf harvested within the region, dropped to $50/wolf skull for the 2013-14 and 2014-15 harvest years but then increased to $200/carcass (skinned or unskinned) in the 2015-16 harvest season. The increase was in response to new barren-ground caribou survey results at the time and subsequent herd recovery efforts. Beginning with the 2018-19 harvest year, a harvest incentive area for wolves was established, where an enhanced incentive amount would be provided to harvesters, based on mid-January locations of female and male caribou from both the Bathurst and Bluenose-East herds. The enhanced wolf harvested incentive area was introduced to help the Bluenose-East and Bathurst caribou herds recover from low numbers by encouraging the public to harvest more wolves on the barren-ground caribou winter range. The objective was to create a zone that wouldn't have to be changed throughout the winter. The zone was created around mid-January, as by that time the caribou usually have settled where they will winter for the remainder of the season, so significant changes would not be needed. Additionally, the Tibbitt to Contwoyto winter road typically opens at the end of January. A buffer (~60 km) was added so that the area could remain robust to localized movements over the winter. This year, three options were created with input from officers, biologists, and co-management boards and one was chosen based on size, distribution (included the entirety of the winter road), and ease of administration (included patrol stations). The 2022 harvest incentive area is shown in Figure 17, it is roughly 97,463 km^2, which is the largest incentive area to date compared to 63,041 km^2 in 2021 and 72,129 km^2 in 2020.

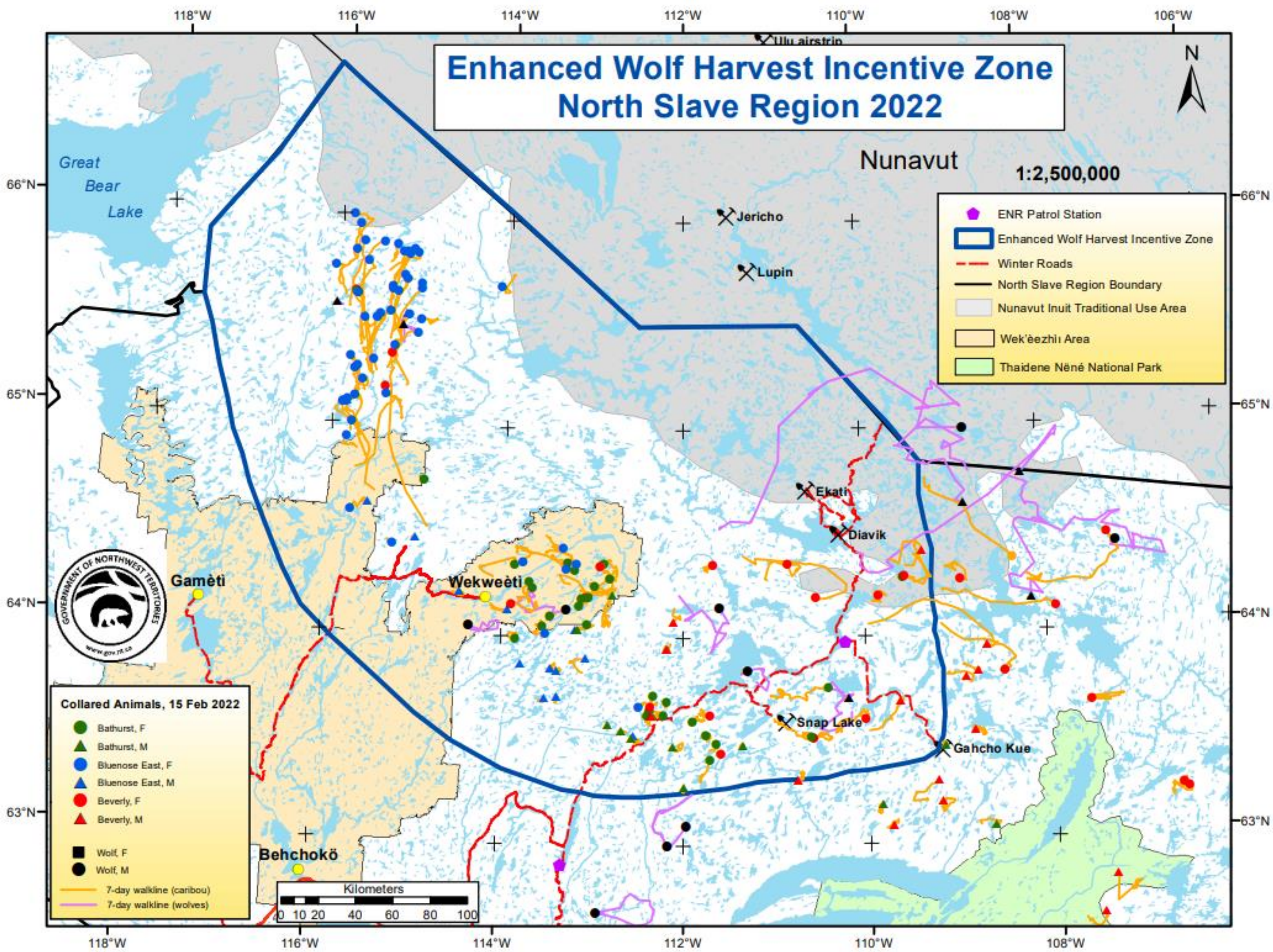

Figure 17. The 2022 North Slave Wolf Harvest Incentive Area in the Northwest Territories. The area is based on the locations of collared caribou for the Bathurst and Bluenose-East herds. There was extensive overlap on the winter range this year with the Beverly caribou herd.

The incentive for harvesting a wolf (skinned or unskinned) in this new area came into effect in January 2019, that year the incentive was $900/wolf for both Indigenous and resident hunters. The incentive amount for the North Slave Wolf Harvest Incentive Area was increased in 2019-20 to $1200/wolf and the cost of the tag was dropped throughout the NWT (Indigenous harvesters and General Hunting License holders don't require a tag). When a skinned or unskinned wolf carcass was brought to the North Slave ENR office, the harvester would receive, either $200 or $1200 for it, the latter amount if the wolf was harvested within the North Slave Wolf Harvest Incentive Area. An incentive of $900 was provided by the North Slave ENR office to hunters from Kugluktuk, with an additional $300 provided by GN. For an unskinned carcass, ENR would then arrange for an experienced skinner to remove and prepare the pelt. If a harvester shot and skinned the wolf from the incentive area and prepared the pelt for auction, they could receive $1950 per wolf ($1200 for the carcass, $400 for the pelt, and $350 prime fur bonus). If the pelt sold for more than $400, then the skinner would receive the difference between that price and the $400 advance payment.

Like last year, two hunting camps specifically for harvesting wolves were set up. One camp was set up by the Tłı̨chǫ Government with Tłı̨chǫ hunters at Roundrock Lake (see section 3.2) and another was set up and used by Inuit hunters from Kugluktuk based at Itchen Lake, Nunavut. Although the Inuit may harvest wildlife from their traditional use area that overlaps into the NWT, permission was also requested and received from the Wek'èezhìi Renewable Resources Board (WRRB) for a Special Harvester Licence (SHL) for Inuit hunters to hunt wolves in Wek'èezhìi. The WRRB supported the request on the basis it would promote recovery of the Bluenose-East and Bathurst caribou herds. More detailed information on the Tłı̨chǫ Government's 2022 Community-based Dìga Harvesting Program is provided in the following section.

3.1.2 Results

Total annual wolf harvest records in the North Slave Region based on carcass/skull collections are shown in Table 9. The harvest season spans 01 January to 30 June annually. Since 2010, regular incentive payments have varied from \$100/wolf carcass (or \$50/skull) to \$200/wolf carcass with enhanced payments starting in 2018/19.

Table 9. Total annual wolf harvest records in the North Slave Region based on carcass/skull collections (both in and outside the enhanced area).

Harvest Year	Regular	Enhanced	Other	Total Harvested
2010-11	41	n/a		41
2011-12	80	n/a		80
2012-13	56	n/a		56
2013-14	24	n/a		24
2014-15	35	n/a		35
2015-16	48	n/a		48
2016-17	73	n/a		73
2017-18	40	n/a		40
2018-19	7 (\$200/wolf)	59 (\$900/wolf)	1 (euthanized by ENR)	67
2019-20	50 (\$200/wolf)	18 (\$1200/wolf)	1 (euthanized by ENR)	69
2020-21	25 (\$200/wolf)	135 (\$1200/wolf)		160
2021-22	22 (\$200/wolf)	50 (\$1200/wolf)	19 (outfitters; no incentive paid)	91

The Tłı̨chǫ wolf hunting camp involved 12 hunters from February 26 to March 24 2022 who harvested nine wolves. The Inuit camp involved seven hunters from 18 March to 8 April 2022 and harvested 25 wolves. All wolves harvested by the Tłı̨chǫ and Inuit wolf camps were taken in the North Slave Wolf Harvest Incentive Area. Another 19 wolves were taken in the North Slave Wolf Harvest Incentive Area from 10 hunters using the Tibbitt to Contwoyto winter road. In addition, there were 19 wolves harvested by non-resident hunters as outfitters for a total wolf harvest of 69. Twenty-two wolves were harvested outside of the North Slave

Wolf Harvest Incentive area. Figure 18 shows the location of 64 wolves harvested in the North Slave region, 46 of which were within the North Slave Wolf Harvest Enhanced Incentive Area. While 69 wolves were submitted for necropsy, 50 carcasses were classified as within the enhanced incentive area and location data was not provided for four wolves.

The harvest of 69 wolves in 2022 is much less when compared to 135 wolves in 2021 and 84 wolves taken through both ground-based hunting and aerial shooting in 2020. Most wolf hunting in 2022 occurred around the hunting camps set up by the Inuit harvesters as well as along the winter road. The Tłı̨chǫ Government's Dìga Harvesting Program was less successful this year resulting in a 3.5-fold decrease in the number of wolves harvested (i.e., 9 in winter 2022 versus 32 in winter 2021 and 3 in winter 2020). Inuit hunters also had a reduced harvest compared to last year (87 wolves in 2021).

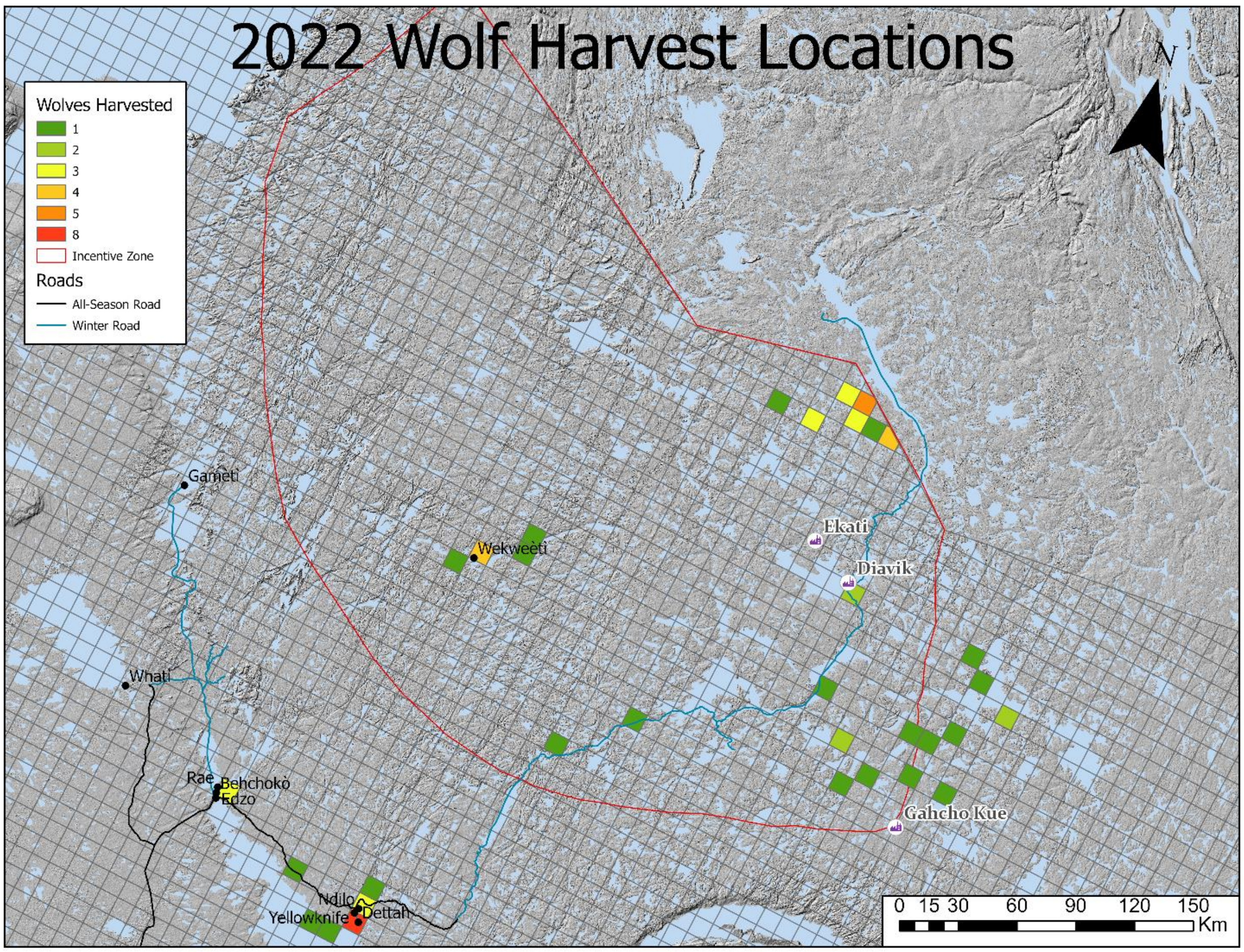

Figure 18. Location of 64 wolves harvested in the North Slave region, 46 of which were within the 2022 North Slave Wolf Harvest Enhanced Incentive Area.

3.2 Tłı̨chǫ Government's 2022 Community-based Dìga Harvesting Program

Through implementation of the Tłı̨chǫ Agreement, the Tłı̨chǫ Government and citizens have been undertaking programs that emphasize their role as stewards within their traditional territory. With an emphasis on direct on-the-land activities by staff and citizens, Tłı̨chǫ Government has implemented two innovative programs in Ekwǫ̀ monitoring and Dìga management respectively. The Ekwǫ̀ Nàxoède K'è (Boots on the Ground) program was initiated in 2016 with the objectives to examine the conditions of individual hozìı ekwò (barren-ground caribou) as well as the health of the herd in general, on its summer range, focusing on four key indicators: (1) habitat; (2) ekwǫ̀ condition; (3) predators, and (4) industrial development. The program is led by Tłı̨chǫ Government, with collaborative support from GNWT-ENR, WRRB and Dominion Diamond Mines ULC (DD) (Tłı̨chǫ Government, 2021).

In 2019, Tłı̨chǫ Government and GNWT-ENR submitted a Joint Management Proposal for Wolves (Dìga) on the Bathurst and Bluenose-East Caribou Winter Ranges to the WRRB; at request of the WRRB the proposal was revised. The main goal of the 2020 Revised Joint Management Proposal for Wolves (Dìga) was to sufficiently reduce dìga predation on the Bathurst and Bluenose-East herds to allow for an increase in calf and adult ekwǫ̀ survival rates that would contribute to the stabilization and recovery of both herds. Based on the WRRB's review and recommendation *(#4-2020 Predator[7])* to continue Tłı̨chǫ Government's community-based Dìga harvesting program and the GNWT-ENR's enhanced North Slave Wolf Harvest Incentive Program, Tłı̨chǫ Government initiated a community-based Dìga harvesting program in the winter 2019/2020. The community-based Dìga harvesting program reflects Tłı̨chǫ Government's multi-year commitment to provide training and support for Tłı̨chǫ harvesters to participate in wolf management and increase their knowledge and skills for ground-based harvest of Dìga. Sections of the final report are provided below, and the full report is available upon request.

3.2.1 Methods

Each year just before the program starts, after a camp location is determined at the elders/harvesters meeting, a request has been typically made to ENR to do a reconnaissance survey to confirm if that location is adequate and if there are any sightings of dìga or ekwǫ̀. For the first two years, ENR has done these surveys but due to the difficulty that the COVID-19 pandemic brought logistically, it was not feasible to be done for Year 3, the 2021/22 season. Rather than a reconnaissance survey done by aircraft, local harvesters were hired to scout the area to determine if there was any dìga activity.

Once the camp location was determined, several casual staff were hired from Wekweètì to set-up camp. Having the camp set-up before the harvesters arrive allows for more time to strategize and prepare for the harvesting of dìga. While the team is hired to set-up camp, having them travelling to camp from Wekweètì also allows for them to break trail for the oncoming harvesters, making it easier for the harvesters to travel to camp from Wekweètì.

[7] Wek'èezhìı Renewable Resources Board (WRRB). 2019. Reasons for Decisions Related to a Joint Proposal for the Management of the Kǫk'èetì Ekwǫ̀ (Bathurst ekwǫ̀) Herd. Wek'èezhìı Renewable Resources Board, Yellowknife, NT. 53 pp. + 8 Appendices

For the team to be most effective, a cook and camp helper are hired for the camp. Their roles are to make sure the hunters are fed before going out harvesting and to have the camp ready when hunters return. The camp helper gets firewood, maintains a tidy camp and helps the cook prepare meals. Among the harvesters there are designated roles such as a k'àowo (foreman), a safety person and a scout. The k'àowo makes decisions including travel routes for the day, the daily plans and would usually lead the prayers each day. The safety person is usually the designated first aid person who leads safety meetings, maintains electronic equipment (satellite phone, inReach, and GPS); they are also responsible for proper identification and tagging of harvested dìga and complete the harvest questionnaires provided by ENR. After each dìga was harvested, the ENR questionnaires were done to the best of the harvester's ability and were submitted to the program lead at the end of their rotation which were then sent to ENR. The scout is typically a participant from Wekweètì who knows the area well and would have a say in what areas are safe to travel or where the teams should travel for the day.

Each day consists of a safety meeting in the morning to plan for the day and determine hunters' travelling routes. On some days all harvesters would travel together and scout for dìga and on other days they would break up into 2 groups. Most of the time they were in two groups. One Garmin inReach was given to the harvesters to keep track of distance travelled and to use for communication; an inReach as well as a satellite phone was kept at camp.

To follow Tłı̨chǫ Elders' recommended protocols, harvested dìga were immediately placed into a thick plastic bag so that the wolf's blood would not spill onto the snow machines or the sleds. Before putting the carcass into the bag, the hunter would insert the muzzle of their gun into the dìga's mouth and thank it for its life, paying their respect to the animal. The dìga carcass was tagged with the date and location of the kill; it was then bagged and stored under a tarp on the lake shore near a temporary airstrip. The harvesters did not want to skin the dìga at camp and so the carcasses were picked up by air charters provided by ENR and were transported to ENR's North Slave Regional Office for subsequent necropsy. Following Tłı̨chǫ protocols, the carcasses were sent straight to Yellowknife so that there would not be any risk of the blood of dìga being dropped into any of the Tłı̨chǫ communities as requested at the Elders meeting; a lesson learned from the first year of the program.

ENR regularly provided caribou collar location and kernel density maps (daily during the work week) that showed the distribution of collared Ekwǫ̀ to help inform hunters on where to find dìga. This had been done in the first two years of the program but in the 3rd year, it wasn't as regular but considering that the hunters saw caribou almost daily, it wasn't an issue.

Due to a local resurgence of COVID-19 infections in Tłı̨chǫ communities prior to the start of the program in the third year, precautions had to be made so that risk of exposure to the hunters and to the people of Wekweètì were eliminated. One of the advising Elders suggested that we just cancel the program because of the outbreak; but following our last weekly meeting in February, he changed his mind and was supportive for the program to go ahead. The program has been run based on input and approval of Tłı̨chǫ Elders and harvesters. We had their approval to proceed under the following conditions: a) hunters would not go into the community of Wekweètì and if they had to, there would be no visiting allowed; b) all hunters had to have a negative COVID-19 test before leaving to camp; and c) the number of participants in camp would be reduced to four and tent capacity would be limited to two people.

In the first two years of the program, drums of gas were purchased from a supplier in Yellowknife. But with the 4-stroke snow machines we found that the gas from the drums were causing engine problems, most notably difficulty starting. Drums may have been contaminated with water when we purchased them or got contaminated while transferring the gas from the drum to a jerry can; either way the contaminated fuel was causing problems with snowmobile engines. We decided that we would no longer purchase the drums and would travel to Wekweètì every 3-4 days to get gas. With the conditions we had due to the COVID-19 pandemic, we had to hire a local person to purchase the gas in a contactless manner. The hunters would take all the empty jerry cans to Wekweètì and drop them off at the airport where the hired person would pick them up, fill them up and drop off at the airport while the harvesters waited. Another reason hunters had to wait at the airport was that they were following another Tłįchǫ protocol, whereby snowmobiles that are used for hunting dìga should not go into town. By having the hunters stay at the airport, it eliminated the possibility for dìga blood being inadvertently brought into town.

3.2.2 Results

We held a planning meeting with elders and hunters in Yellowknife on December 10-11, 2021 to discuss results from the previous year, and options for improving the program and logistic details for the upcoming season. Dr. N. Jutha (Wildlife Veterinarian, GNWT-ENR) presented a summary of wolf necropsies and a humaneness assessment of dìga harvested in previous years. Based on subsequent discussion, we determined that hunters should continue using rifle calibers such as the .243, .222, .223, and .22-250 to shoot wolves. We also decided that we would use the school camp at Roundrock Lake but in scouting trips made by wolf hunters, they deemed that it was too far from recent dìga activity. Hunters reported seeing a lot of tracks around the area where we had our camp last year, so we decided to use the same location (Figure 19).

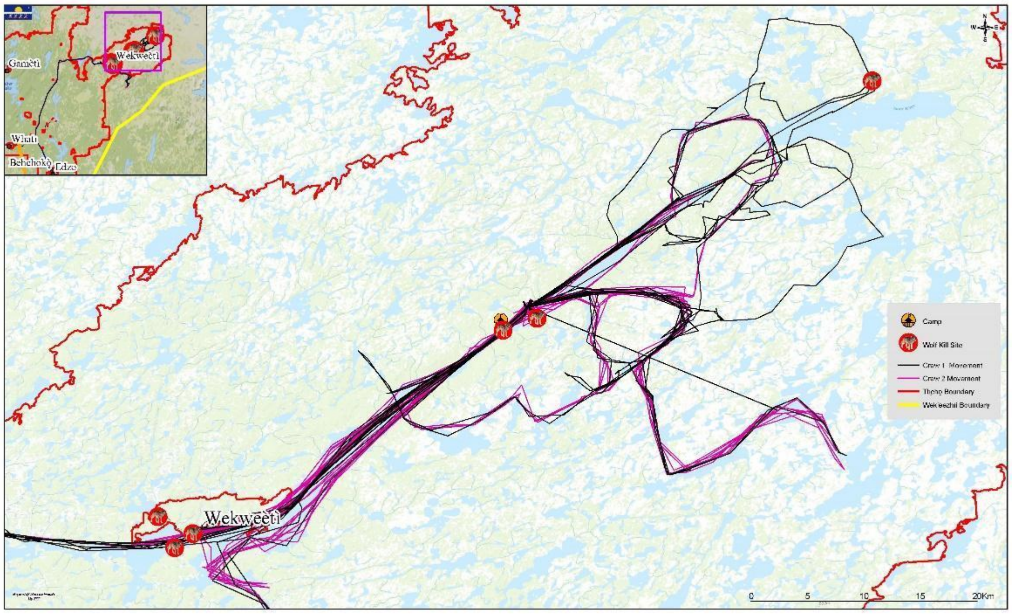

Figure 19. Location of base camp and travel routes for the Dìga Harvesting Program from February 26 to March 24, 2022.

At the planning meeting we decided that the start date would be January 13, 2022 but due to the ongoing COVID-19 pandemic and an outbreak occurring immediately after the holidays, the start date was postponed. Despite delays arising from COVID-19 Public Health Orders on gathering and travel restrictions, momentum of the program was not lost. Tłı̨chǫ Government encouraged hunters to go out on their own and provided an additional incentive of $500 for each dìga harvested. The Tłı̨chǫ Government incentive started as soon as the North Slave Incentive Area opened up on January 31, 2022 until Tłı̨chǫ Government was able to open up the harvesting camp; six dìga were harvested during this time. Each week from January 13 to February 21, 2022, Tłı̨chǫ Government staff met with elders and harvesters via conference call to determine if the program should go ahead and when would be the cut off point to when it would be too late to run the program. It was decided at the February 21, 2022 meeting that the Dìga Harvesting Program could go ahead with a start date of February 26, and an end date of March 24, starting with a meeting on February 23rd. There were two crews at 14-day rotations and with a smaller group size than in previous years to eliminate the risk of COVID-19 exposure, there were 4 hunters and 2 cooks. The first crew snowmobiled from Behchoko to camp on February 26 and stayed until March 10 when the second crew flew from Yellowknife directly to camp with a charter until they snowmobiled to Behchoko on March 24.

The Tłı̨chǫ harvesters typically would go out, look for dìga and once they see them they would hunt them. It seemed in the 2nd year (2020/21), it was easier to harvest them, hunters didn't have to travel as far to see them, most of the dìga activity and harvesting was just north of the camp site along the lake. After the first day in the 2nd year of the program, they were seeing dìga right away but in the latter part of the 2021/22 season, it seemed the dìga realized they were being hunted and began to stay away from our camp. The hunters had to start strategizing on how to hunt the dìga, focusing on using caribou kill sites and waiting for the dìga to feed which would slow them down making it easier to chase them. One harvester would also go to the top of a hill, watch the dìga until they got onto the lakes and would go after them. Different techniques were used in harvesting dìga, Tłı̨chǫ beliefs are that dìga are very smart animals and so our harvesters in turn had to learn how to effectively outsmart them.

From the time camp opened up until it closed, three dìga were harvested, two with the first crew and one with the second crew. As shown in Figure 20, many more ekwǫ̀ were seen by the first crew compared to the second crew. The hunters did not feel comfortable using traps and snares because of the high occurrence of ekwǫ̀ and the risk of them getting caught in the devices, so they only used firearms. The total number of dìga harvested through the Tłı̨chǫ Government program in 2022 was nine – this includes the ones harvested with the Tłı̨chǫ Government incentive.

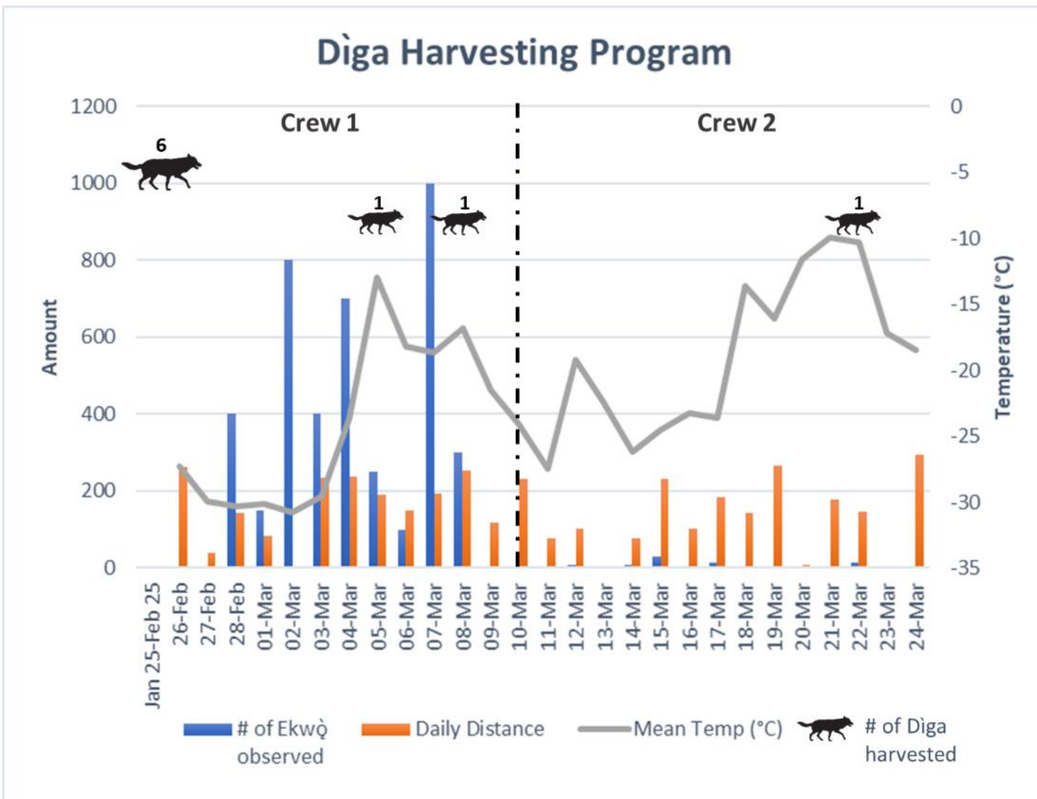

Figure 20. Data collected during the Dìga Harvesting program in 2022 (Year 3); this includes the number of dìga harvested, number of ekwǫ̀ seen, daily distance (km) travelled by hunters and daily temperature.

3.2.3 Discussion

Following advice from elders at the December 2021 meeting and through weekly phone calls through January, we had gained consensus to go ahead with the program starting in late February. Starting so late in the season, meant for a shorter season, we only had enough time to have two, two-week rotations before getting into spring temperatures and the caribou starting to move north in which the dìga would follow suit. Because the program could not be run for the whole season (Jan-March) due to the COVID-19 outbreak, an incentive was added to the program to promote and encourage hunters to go out on their own. Different options were proposed for the program including:

- lending out Tłı̨chǫ Government snowmobiles for hunters;
- Tłı̨chǫ Government would provide all equipment and supplies needed to go out;
- Tłı̨chǫ Government would send out multiple teams of two with everything supplied to them;
- Tłı̨chǫ Government would provide the extra financial incentive once a dìga was harvested; and
- cancel the program for Year 3.

The decision was that Tłı̨chǫ Government would provide an additional $500 incentive for those hunters that went out on their own. This incentive was provided to all Tłı̨chǫ communities but it was too difficult for anyone outside of Wekweètì to go harvesting for dìga within the incentive area. It was too far to travel from any of the other communities and people were not familiar with the ice conditions and did not know the best routes. The program manager reached out to people in Wekweètì to gauge interest but not many harvesters were keen except for 2 people. Through this incentive, six dìga were harvested; 5 from one individual and 1 from another. Other than the 2 harvesters, there were not any other known harvesters in the area.

With a high risk of COVID-19 exposure, we made precautions to ensure health and safety of all participants and the residents of Wekweètì because it is the closest community to our camp. We decreased the number of participants and ensured that they were fully vaccinated for COVID-19 which made things rather difficult to run the program; key harvesters that have been a part of the program in previous years were not vaccinated and were not allowed to participate. Not having those key experienced harvesters a part of the program reduced the success of the program. Unfortunately, training was not provided to the extent it had been in previous years and a lesson learned is that this training is pivotal and should be done at the start of each program year.

Table 10 shows a much higher harvester rate in the 2nd year compared to any other year with a lower number of harvesters and distance travelled but a higher number of hunting days. There were 5 two-week rotations in Year 2 which explains the higher number of hunting days, but most of that hunting took place in the first 2 weeks of the program. The harvesters that were out on that rotation were much more experienced than in any other rotation or any other year of the program. Keeping these experienced harvesters involved is essential to hunting success but people also have other priorities such as caribou hunting which usually coincides with timing of the dìga program. Running the dìga program during the winter season also means that the winter road is open which also causes issues with having participants involved in the program; hunters from the isolated communities may not be available because they prefer to travel south and stock up with groceries.

Table 10. Summarized data for the Dìga Harvesting Program in all years that the program was implemented.

	# of Field Days	# of Hunters	Days Spent Hunting	Harvested Dìga	Distance Travelled
Year 1 - 2020	49	19	37	3	4484
Year 2 - 2021	66	15	49	32	3839
Year 3 - 2022	31	12	21	9	3951

Prior to the start of the 2021 program, we contacted an experienced Nunavut wolf harvester (J. Koadluk) to request that he share his experience and knowledge on dìga harvesting strategies and techniques. Koadluk was elated that we had reached out to him and was willing to collaborate but due to COVID-19 restrictions this was not feasible. However, he did share some valuable knowledge and gave suggestions on how the program should be run and how the hunters should focus hunting for dìga on the lakes. The program manager has been networking with harvesters in Nunavut and is working on building a working relationship and would like to invite experienced hunters from Nunavut to participate and share their knowledge at future camps. Having the most knowledgeable and experienced people involved is essential to overall program success. There is still a lot of training that needs to be done for certain harvesters and bringing in harvesters from another region, gaining a new perspective will be helpful to the program.

4 Measures of Effort

4.1 Wolf Harvester Questionnaire

In winter 2022, ENR used a wolf harvester questionnaire to collect information on harvesting effort. The questionnaire asked hunters about harvest location and number of wolves taken, wolf and caribou sightings, hunter effort (i.e., hunting days and kilometers travelled), weather conditions, and other relevant factors and observations (Appendix B and C). Winter road harvesters were provided $50 gas cards for the submission of completed questionnaires. ENR officers handed out the questionnaires to the hunters travelling on Tibbitt-Contwoyto Winter Road, where they were encouraged to stop at the ENR check stations. The same questionnaires were also given to the Tłıchǫ and Kugluktuk harvesters at their respective camps. Revisions to the questionnaires were completed in 2021 to include daily data; however, these changes were not well received and as a result, previous versions of the questionnaires were used by Inuit and Tłıchǫ hunters. Winter road hunters used the revised questionnaire. The original questionnaire with slight updates from harvesters to address the original problems will be used moving forward (see section 4.2.3 and Appendix C).

4.1.1 Data compilation

Harvesters returned 25 completed questionnaires, dated between January 25 and April 08, 2022, to the ENR office, reflecting 22 hunting trips and 52 wolf harvests in the North Slave Wolf Harvest Incentive Area. There are more questionnaires than trips because some groups submitted more than one questionnaire for the same trip. Of the 52 harvests reported in the questionnaires, 19 did not have corresponding effort data due to recording errors. This was because the new questionnaires were not filled out daily, but rather per hunting trip; therefore, daily hours spent hunting and kilometers travelled was not recorded for some harvesters. Tłıchǫ harvesters only filled out questionnaires on days that wolves were harvested. Based on the questionnaires, between February 04 and April 08, 2022, there were 84 days when there were active hunting groups in the North Slave Wolf Harvest Incentive Area. During this period, an average of 17 hunters/day were actively hunting for wolves in the North Slave Wolf Harvest Incentive Area. Kugluktuk harvesters were active from March 18 to April 08; winter road harvesters were active between February 04 and March 28, and Tłıchǫ harvesters were active from January 26 to March 24 (Figure 21). Questionnaires used by Tłıchǫ and Kugluktuk harvesters did not have specific questions on hunting experience or hunting compared to the previous year; therefore, these results are only shown for 12 questionnaires submitted by winter road harvesters (see next section).

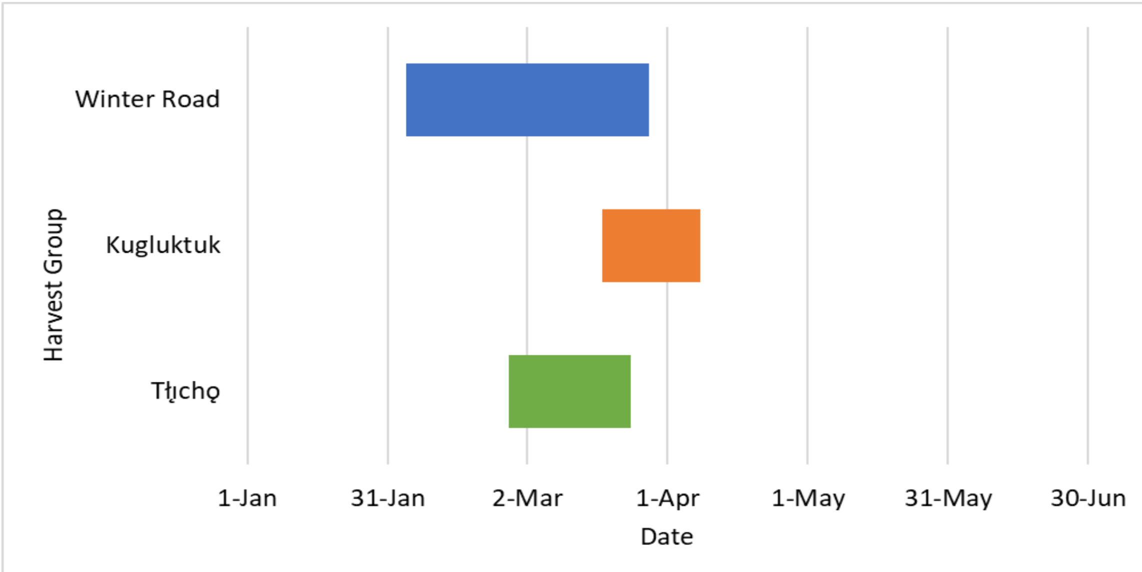

Figure 21. Comparison of winter road, Kugluktuk, and Tłı̨chǫ harvest dates.

4.1.2 Hunting experience

Hunting experience likely influences a hunter's ability to harvest wolves and should be accounted for when assessing harvest data. Therefore, three questions were asked on the questionnaire related to hunter experience. The first question was "About how many wolves have you harvested in your lifetime?" followed by "About how many years have you been hunting wolves?" and finally "When was the last year you hunted wolves?". For the first question, responses were categorized into three groups: less than 5 wolves, 5-10 wolves, and greater than 10 wolves. Half (50%) of the questionnaires reported greater than 10 wolves have been harvested in their lifetime. Similarly, the number of years harvesters have been hunting wolves was categorized into three groups: less than 5 years, 5-10 years, and greater than 10 years. Half (50%) of questionnaires reported the hunting of wolves has occurred for greater than 10 years.

4.1.3 Hunting compared to previous year

To better understand how the number of wolves is changing on the landscape, the questionnaire asked three questions compared to the last hunting season. The first question was "How hard was it to find wolves?". The second question was "How far did you have to travel?". The third question was "How big were the packs?". These answers can provide a qualitative indication of annual changes in the wolf population. If finding wolves was harder, the distance to travel was further, and the packs were smaller, it may suggest that the wolf population numbers are lower than the previous hunting season. Most questionnaires (92%) reported that it was the same difficulty to find wolves and the same distance was required to travel to find wolves compared to last year (Figure 22A-B). Similarly, 58% of questionnaires reported pack size was the same compared to last hunting season (Figure 22C).

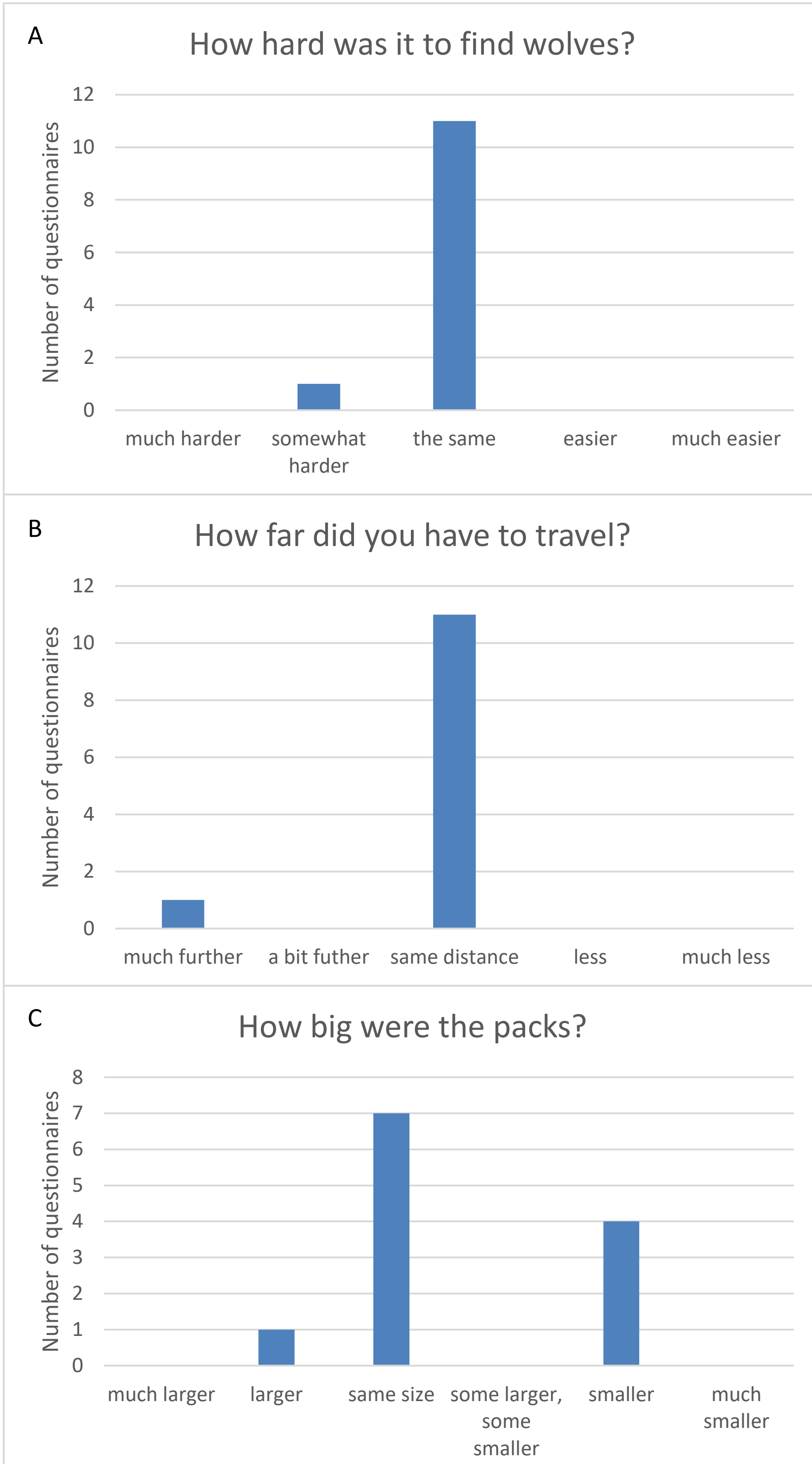

Figure 22. Qualitative summary of finding wolves, travel distance, and pack size reported in winter road harvester questionnaires compared to the previous hunting season.

4.1.4 Number of Caribou observed

Respondents were asked to record whether they saw caribou while they were looking for wolves and, if they did, how large the groups were. Winter road hunters reported seeing groups of between 40-2000 caribou, while Tłı̨chǫ hunters reported groups of 0-20 to over 500 caribou, which contrasted with Kugluktuk hunters who reported seeing predominantly larger caribou groups that were 500 or greater than 500 individuals. In addition, hunters were asked to record whether they saw caribou carcass remains that they thought were a result of wolf kills. All Kugluktuk hunters recorded seeing caribou carcass remains, while 25% (3/12) of winter road harvesters recorded seeing caribou carcass remains. Due to the questionnaire format, the respondents only provided one instance of observation for the duration of the trip. In other words, a group would record seeing 21-100 caribou during their trip whether they saw the same or different herd once or multiple times or if they also encountered other herds of smaller sizes. Therefore, the response summary to these questions should be interpreted with caution as they likely underestimate hunters' sightings of caribou groups and carcass remains. Kugluktuk harvesters also reported harvesting two wolverines, two foxes, and two caribou while hunting for wolves.

4.1.5 Weather Conditions

In the wolf harvester questionnaires, hunters were provided with space to comment on the weather conditions during their trip. The questionnaire responses reflect the harvester's observation of the overall trip without attributing to specific dates or harvests. Out of 25 questionnaires submitted, 19 of those reported comments about the weather. Harvesters' weather observations were categorized into three classes: poor, moderate, and good. Approximately half (47%) of questionnaires reported poor weather conditions that only contained adverse weather, such as "cold", "windy days", "white-out", "blowing snow", or "soft snow conditions". Similarly, 47% of questionnaires reported responses that only contained fair weather conditions, such as "warm," "clear," or "good" and were categorized as good. Those responses that contained one or more of both were categorized as moderate (11%). All Kugluktuk harvesters reported that weather conditions adversely affected their hunt with windy days that caused blowing snow, white out conditions, and soft snow. Conversely, winter road harvesters reported both good and bad weather. Tłıchǫ hunters reported cold and white out conditions as well as clear skies and warm weather. Due to the questionnaire design, the respondents only provided one observation for the trip duration. Therefore, the responses could not be used to directly test how weather influenced daily hunting effort.

4.2 Catch Per Unit Effort

Catch per unit effort (CPUE) is used to model the relationship between the probabilities of harvest and hunting effort to elicit information about the harvested population's abundance (Allen et al., 2020; Mitchell et al., 2022). CPUE is derived by dividing the total catch (i.e., harvest) by a unit of effort over a specified period of time (i.e., daily, weekly, or monthly). This report used two units of hunter effort, days spent hunting and kilometers travelled daily, for harvesting a wolf.

The questionnaire asked hunters to record "estimated number of hours spent hunting each day", which was used to estimate the number of days spent hunting (i.e., >0 hours was classified as a hunting day) and "estimated number of kilometers travelled each day." The intent of these questions was to collect the time spent and distance travelled on the hunting grounds, searching for wolves; and the time and distance travelled once wolves are seen, such as stalking, active pursuit and shooting.

4.2.1 Methods

The analysis for the 2022 CPUE is based on the submitted 25 (22 hunting trips) questionnaires completed by harvesters from Kugluktuk, Tłı̨chǫ Government's dìga harvest camp and hunters accessing the Tibbit-Contowyto Winter Road. The questionnaires reported 52 wolf harvests, accounting for 75% of the carcasses submitted to ENR. There were two additional wolves harvested along the winter road, one additional wolf harvested by Kugluktuk harvesters that were reported in the questionnaires but whose carcasses were not recorded on ENR's necropsy list. In total, CPUE analysis is based on 22 harvesting trips (considering multiple response submissions by a single harvesting party) and 52 harvests within the North Slave Wolf Harvest Enhanced Incentive Area.

To compare CPUE-day and km across multiple years, a series of steps were taken to standardize the harvest and effort data reported by Kugluktuk and winter road harvesters. Kugluktuk harvesters typically hunt in groups and often report the same hunting trip on multiple forms. Thus, field days, hunting days, and kilometers travelled were removed for hunters reporting within the same party. These duplicates were defined as reporting the same hunting dates and number of hunting days (calculated from hours reported). Given that winter road harvesters typically travel alone, and inconsistent information was reported, it was assumed there were no duplicates for winter road harvesters.

Due to the structure of the form in 2020, effort data for only the first 7 days of a hunting trip could be recorded, even if the harvesters hunted for longer than 7 days. Therefore, it was assumed that any effort data reported for ≤7 days was accurate. Days spent hunting was calculated by counting the number of days hunters reported hours hunting (>0 hours). If a zero or no hours were reported, it was considered to not be a hunting day. For hunting trips that exceeded 7 field days, the average number of days spent hunting within 7 days was calculated, multiplied by the number of days with missing information, and added to the total days spent hunting. In this way, the days with missing effort data were replaced with the average reported for the first 7 days of the trip. If only one hunting day was reported, it was assumed that every day in the field was spent hunting. Similar to the hunting days, if no kilometers were reported, the average kilometers travelled was calculated, multiplied by the number of missing days, and added to the total kilometers travelled for each hunting trip. When no distance data was reported during a hunting trip, missing values were replaced with the average kilometers reported on day one for all hunters. The same procedure was followed when analyzing the data collected in 2021 and 2022; however, the form allowed for 14 days of effort data to be recorded. Thus, any effort data reported for ≤14 days was considered to be accurate. Harvest and effort data for the Tłı̨chǫ Government's dìga harvest camp was provided separately from the harvester questionnaires. Given the absence of daily data for most harvesters, effort was not calculated within the season or by month. The data used to calculate the catch per unit effort metrics is shown in Table 11.

Table 11. Number of field days, hunters, harvested wolves, days spent hunting and distance travelled calculated from harvester questionnaires from 2020-2022.

	No. of Field Days	No. of Hunters	No. of Harvested wolves	No. of Days Spent Hunting	Distance Travelled (km)
Tłı̨chǫ					
Year 1 - 2020	49	19	3	37	4484
Year 2 - 2021	66	15	32	49	3839
Year 3 - 2022	31	12	9	21	3951
Kugluktuk					
Year 1 - 2020	134	9	36	118	19869
Year 2 - 2021	189	15	86	142	19505
Year 3 - 2022	30	7	25	18	3484
Winter Road					
Year 1 - 2020	51	10	1	47	11170
Year 2 - 2021	82	20	14	60	15734
Year 3 - 2022	46	10	19	46	27001

4.2.2 Results

To compare across multiple years, CPUE was calculated for each group and year (Figure 23A-B). The Tłı̨chǫ Government's dìga harvest camp reported a CPUE-day of 0.43 wolves/hunting day in 2022, which was less than CPUE-day from 2021 (0.65 wolf/hunting day), but greater than CPUE-day from 2020 (0.08 wolf/hunting day). The effort data reported by both Kugluktuk and winter road harvesters showed an increase in CPUE-day from 2020-2022, which is similar to the pattern shown when CPUE-day was averaged across all groups (Figure 23A). The Tłı̨chǫ Government's dìga harvest camp reported a CPUE-km of 2.3 wolves/1,000 km in 2022, which is less than CPUE-km from 2021 (8.3 wolves/1,000km). Similarly, winter road harvesters reported a lower CPUE-km in 2022 compared to 2021, 0.7 wolves/1,000 km and 0.9, respectively. Kugluktuk harvesters reported a CPUE-km of 7.2 wolves/1,000 km, which was greater than last year (4.4 wolves/1,000 km). On average, CPUE-km decreased from 2021-2022 (Figure 23B).

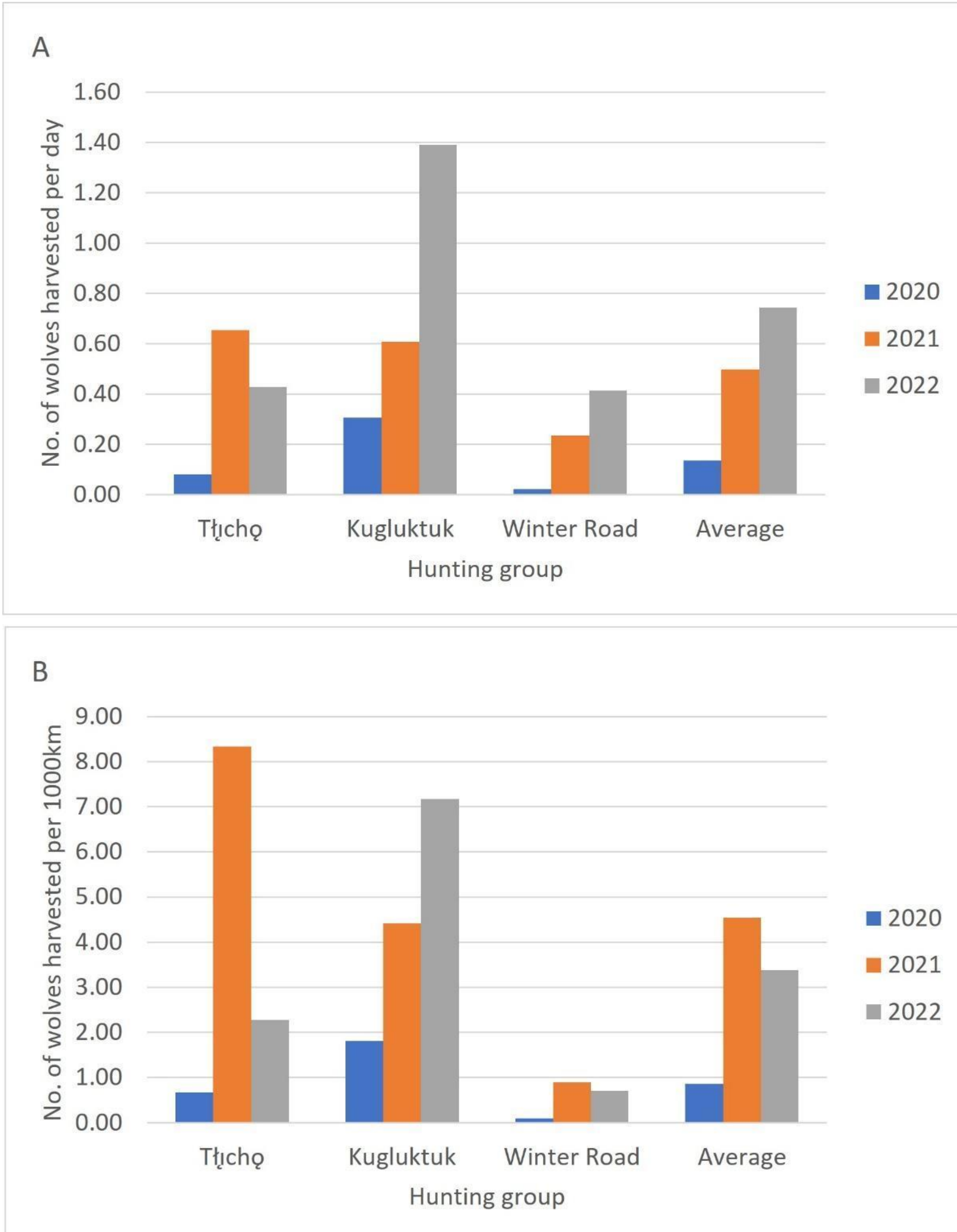

Figure 23. Catch per unit effort (CPUE) relative to hunting days (A) and distance travelled (B) for the Tłı̨chǫ Government's dìga harvest camp, Kugluktuk harvesters, and winter road harvesters in 2020, 2021, 2022 as well as the average CPUE across all groups within each year.

4.2.3 Discussion

On average, the number of wolves harvested per hunting day increased from 2020 to 2022, suggesting that the effort (relative to days spent hunting) it takes to harvest wolves decreased over time. Conversely, the average number of wolves harvested per 1,000km decreased from 2021 to 2022, which may indicate that the effort (relative to distance travelled) it takes to harvest wolves increased since last year. Poor snow conditions reported by all harvesters may have influenced the number of wolves harvested this year.

While CPUE may be a useful indicator of relative wolf abundance, improvements are needed to reduce uncertainty in how it is reported by harvesters. There were also some confounding factors related to the survey design and how harvesters reported information that led to some uncertainties in calculating CPUE. For example, the questionnaire only allowed space for effort data for either 7 days (2020) or 14 days (2021 and 2022). We attempted to correct this by using a daily logbook, but previous questionnaires were used by some hunters. Additionally, the hunting log provided to winter road harvesters in 2022 was meant to be filled out daily for the duration of the hunting trip but was only filled out once for the entirety of the trip. Future questionnaires should include ample space for harvesters to record information for every day of their trip. Other factors that may affect harvesting powers, such as the experience of the harvesters, type of transportations and weapons, or method of harvesting, can be considered for future inclusion in the questionnaire.

We have attempted revisions to address the potential sources of uncertainty to improve our interpretation of harvester responses. However, this seemed to be too complicated and resulted in the use of previous questionnaires. We recognize that these questions need to be considered from the harvester's perspective and not be difficult or burdensome to record information but will still provide the needed information. To aid NWT harvesters and ensure that the questionnaires are not too burdensome, GNWT will host a wolf harvester workshop in December 2022 at the ENR North Slave Regional office. Winter road, Tłı̨chǫ, and Kugluktuk harvesters will have the opportunity to share knowledge on hunting strategies, wolf behavior and health, and format of the questionnaires. In collaboration with harvesters, we will revise the questionnaire to create a useable format that provides the needed information.

In CPUE analyses, a general assumption is that the harvested population is closed, meaning that there is not a significant movement of individuals in or out of the population within the given period (reviewed by Hubert & Fabrizio, 2007). Thus, in a closed population and with other covariates held constant, CPUE should decrease as abundance and density of animals are reduced by the cumulative harvest. An equivalent version to the assumption for population closure, is that the population is relatively constant with respect to its exposure to harvesting effort. In this context, non-migratory wildlife are more likely than migratory wildlife to meet this assumption of constant exposure to harvest. For example, it would be difficult to attribute changes in CPUE solely to a reduction in density due to cumulative harvest for a given area, when the overall density changes are also strongly influenced by the transient and dynamic occurrence of migratory wildlife in the area. In addition, the response of CPUE to declining population abundance may be scale dependent, which means that a detectable reduction in CPUE may occur within a small, localized area, but that same trend may not be detectable within a larger area.

4.3 Sighting rates

Helicopter flights for wolf collar deployment were conducted in conjunction with caribou collaring efforts. During this time, 27 wolves were observed in 4 separate encounters during 31.2 hours of helicopter survey time (Table 12). Pack sizes ranged from one to eight compared to one to five in 2021 and one to seven in 2020. Crews sighted 0.86 wolves per hour, which is less than in 2021 (1.82 wolves per hour). The track logs of wolf collar deployment flights and observed wolf pack size from March 2022 are shown in Figure 24.

Table 12. Wolf sightings from helicopter surveys (search effort) during caribou and wolf collaring flights, March 2022.

Date	Ferry (h)	On Ground (h)	On Survey (h)	Daily Total (h)	Aircraft Time (h)	Wolves Seen (h)	Sighting Rate (wolf/h)	Comments
5-Mar	1.0	0.0	0.0	1.0	1.0	0	-	ferry: YZF to Wekweeti
6-Mar	0.0	1.5	1.3	2.8	1.3	0	0.00	survey
7-Mar	0.0	0.0	0.0	0.0	0.0	-	-	weather day
8-Mar	0.0	0.3	2.1	2.4	2.1	0	0.00	survey
9-Mar	0.0	0.0	0.0	0.0	0.0	-	-	weather day
10-Mar	0.0	2.4	2.1	4.4	2.1	14	6.72	survey; 2 wolves collared
11-Mar	0.0	1.7	2.5	4.3	2.5	0	0.00	survey
12-Mar	0.0	3.6	4.2	7.8	4.2	3	0.71	survey; 1 wolf collared
13-Mar	2.1	0.0	0.0	2.1	2.1	0	-	ferry: Wekweeti - YZF
14-Mar	0.0	3.4	5.4	8.9	5.4	6	1.11	survey; 2 wolves collared
15-Mar	0.0	2.6	5.6	8.2	5.6	0	0.00	survey
16-Mar	0.0	4.3	3.5	7.8	3.5	4	1.14	survey; 2 wolves collared
17-Mar	0.0	3.6	1.2	4.8	1.2	0	0.00	survey
18-Mar	0.0	4.4	2.6	6.9	2.6	0	0.00	survey
19-Mar	0.0	2.3	0.7	3.0	0.7	0	0.00	survey
Sum	3.1	29.9	**31.2**	64.3	34.3	**27**	**0.87**	

Wolf sighting rates during annual late winter caribou composition surveys on the Bathurst and Bluenose-East winter ranges show high variability. Sighting rates have ranged from 2.59 wolves/hr observed in 2010 to 0.45 wolves/hr in 2014 on the Bathurst range. On the winter range of the Bluenose-East herd wolf sighting rates have similarly ranged from 2.67 wolves/hr in 2013 to 0.08 wolves/hr in 2018 (GNWT, unpublished data). In 2021, the sighting rates of 1.82 wolves/hr of flying for the collaring crew was more than four times that of the two helicopters involved in the abundance survey (0.37 wolves/hr). A likely and important source of variability in comparing wolf sighting rates from composition surveys is the denominator value for hours searched or flown. In Table 12 (and the 2021 sighting rate), the 2022 sighting rate estimate is based on survey time from track logs. While it may not be appropriate to compare sighting rates among different types of surveys, there is some rationale for comparing among similar survey designs (i.e., collaring sighting rates across years). A reduction in sighting rates reported here is consistent with the decrease in overall average CPUE-km across all harvesters from 2021 to 2022 (see previous section).

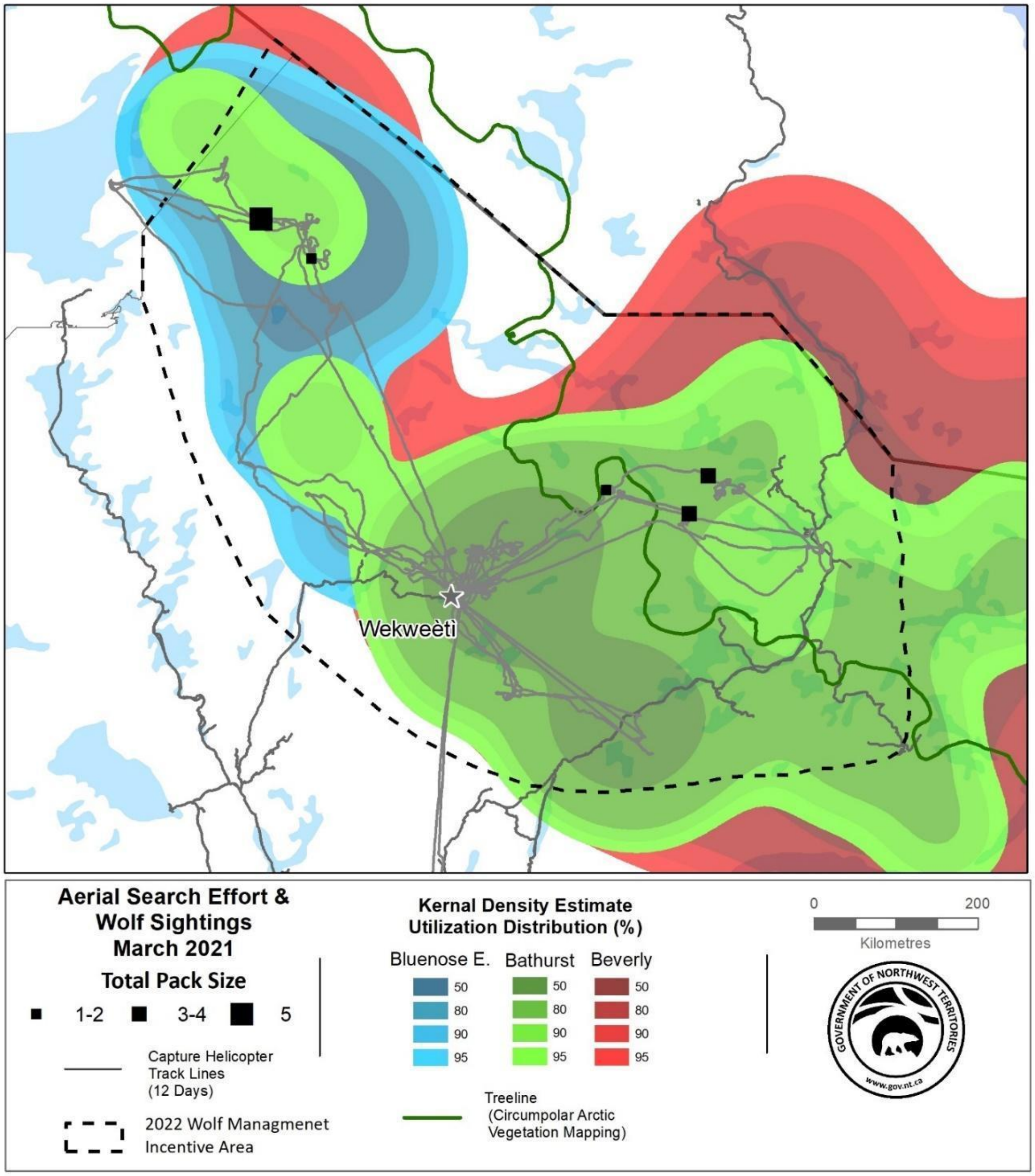

Figure 24. Track logs of wolf collar deployment flights and observed wolf pack size, March 2022

5 Demographics and health of harvested wolves

A Wolf Technical Feasibility Assessment (WFATWG 2017) identified the importance of monitoring wolf removal activities to gather information on the harvested wolves, and evaluate their impacts on humaneness and welfare outcomes of wolf harvest. In order to do this, it is important to collect detailed information including data on pack size, chase time, firearm and bullet types, number of shots and placement, time to death, wounding rate, and number of wolves harvested (Appendix K of Feasibility Assessment and Recommendation #19-2020 (Dìga) of WRRB Reasons for Decisions Related to a Joint Proposal for Dìga (Wolf) Management in Wek'èezhìi). In response to the WRRB Reasons for Decisions, the GNWT and Tłı̨chǫ Government agreed to necropsy a sample of wolves removed as part of this program to assess health and condition of harvested wolves. For ground-based harvesting, the GNWT and Tłı̨chǫ Government also committed to conduct a veterinary assessment evaluating condition, health status, injuries and humaneness of death in harvested wolves. The demographic and health of harvested wolves is presented below.

5.1 Methods

From January 26th to April 19th, 2021, and February 2nd to April 8th, 2022, 145 carcasses of grey wolves submitted by 32 different harvesters underwent necropsies led by the ENR Wildlife Veterinarian. Details regarding necropsies completed in 2020 can be found in Nishi et al., (2020). Wolves were harvested by either ground-based shooting or trapping methods. Full necropsy examinations included an assessment of health and injuries/humaneness of death, in addition to standard biological monitoring. Wolves were accompanied by a tag which had spaces for harvesters to indicate location of harvest, date, method of kill, submitter name, and animal sex. Carcasses submitted to ENR were stored frozen at -20 degrees Celsius until examination. Storage conditions between harvest in the field and submission of carcasses are unknown.

In lieu of available ante-mortem data regarding harvest details and to gain additional professional perspectives on necropsy findings, the author consulted with wildlife health professionals, wildlife biologists with backgrounds in carnivore biology and ecology, and experienced Indigenous Knowledge holders and wolf harvesters with expertise in local wolf harvesting practices.

All necropsies followed standard protocols recognized for wild and domestic canids and were conducted by or under the direct supervision of a licensed wildlife veterinarian. All individuals involved in necropsy procedures had up-to-date rabies pre-exposure prophylaxis vaccination and used appropriate personal protective equipment.

Individually assigned identification numbers, date of necropsy, and any information included on the tag associated with each wolf carcass were recorded. Skinned weight of carcasses was obtained using a laboratory-grade floor scale and recorded to the nearest hundredth of a kilogram, and any missing body parts for each individual carcass were documented. High resolution full body photographs of wolves laying in lateral recumbency, both left and right, were taken using a digital single-lens reflex camera. Morphometric measurements recorded in centimeters included full contour length (tip of nose to base of tail), tail length (when possible), neck girth, chest girth (at axillae; using measuring tape), and rump fat depth (millimeters;

using laboratory grade electronic calipers, CirumArctic Rangifer Monitoring and Assessment (CARMA) Network, 2008; see Figure 25). Skull measurements were taken using calipers, including zygomatic width, condylobasal length, and total skull length. High resolution photos of skulls were also taken, including dorso-ventral, rostro-caudal (with focus on incisor dentition), and right and left lateral views. Age class was approximated visually according to (Gipson et al., 2000), sorted into puppy, juvenile (1-2 years), adult, and geriatric (est. 8+ years). A premolar tooth will be submitted to an external reference laboratory (Matson's Laboratory, Manhattan, Montana) for aging by cementum annuli analysis (Ballard et al., 1995). An external body condition score was assigned on a semiquantitative scale of 0-4 (with 0 being poorest and 4 being best condition) based upon coverage and thickness of subcutaneous fat stores. Similarly, an internal nutritional condition score was assigned based on abdominal visceral fat deposits. An average of external and internal scores provided an overall coarse subjective nutritional condition indicator for the purposes of this report. Hair samples were plucked and placed in paper envelopes and stored at room temperature for future analysis (i.e., genetics, stable isotopes) – samples were taken from wherever available on the already-skinned body, typically the perianal region or tail.

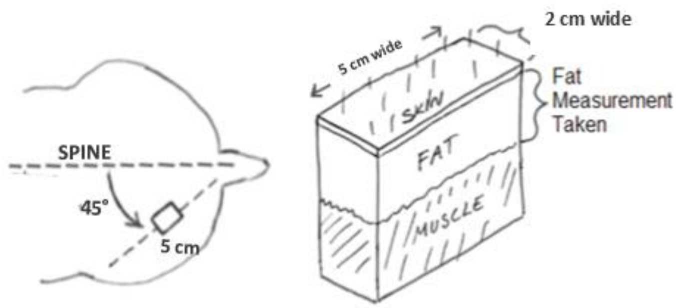

Figure 25. Location used to measure rump fat depth as an indicator of wolf body condition status.

Necropsies were performed in left lateral recumbency. All 4 limbs were reflected initially to examine associated skeletal and soft tissue structures/spaces. Blood was collected on Nobuto filter paper strips from the femoral artery. When this was not possible, jugular venous or arterial blood, blood from the thoracic cavity (when not contaminated by ingesta), or blood directly from cardiac structures (thoracic aorta, inferior vena cava, or heart) was used. Eight to 10 strips were collected for each animal where possible, and air dried for 24 hours before being stored in envelopes at room temperature. Filter paper eluate will be submitted to reference laboratories for analysis of exposure to various canine pathogens related to individual and population health. The right femur was collected, cleaned, measured for circumference, diameter, and length using caliper, and marrow was extracted from the diaphysis and air dried to determine percent femoral marrow fat as an indicator of nutritional condition (adapted from (CirumArctic Rangifer Monitoring and Assessment (CARMA) Network, 2008; Lajeunesse & Peterson, 1993; Lefebvre et al., 1999). Where the right femur was damaged or unavailable, the left femur was collected in its place. The abdominal cavity was opened and the integrity (presence of negative pressure) of the thoracic cavity was assessed using a small incision to the abdominal surface of the diaphragm. The right rib cage was removed with large shears at the level of the vertebral column and costochondral junctions. Photographs were taken of the neck and internal thoracic and abdominal cavities, in addition to full body internal photos. The 'pluck' (tongue, esophagus, trachea, thymus, heart, and lungs) was removed by disarticulating the hyoid bone and releasing the tongue from skeletal muscle attachments through the ventral jaw, and extending the incision along the neck, to the thoracic inlet, and into the thoracic cavity while applying ventral tension to the tongue along the length of the thoracic tissues being removed. The pluck was photographed ex-situ and examined in detail for any trauma or pathology – this included incising esophagus and trachea, lung tissue, and gross examination of the heart (unless incision was indicated). Subjective/relative prominence of the thymus was recorded as a contributing indicator of age class estimate. Abdominal organs including the liver, spleen, stomach, intestines, kidneys, adrenals, gonads (when applicable), and lymph nodes were examined externally and incised when indicated by evidence of trauma or pathology.

Samples were collected in WhirlPak™ bags, individually labelled to correspond with the identification number assigned to each carcass and stored at -20°C. A subsample of lung tissue (non-specific lobe/location), the heart (2021 only), and tongue were collected from the pluck. Kidneys were removed with peri-renal fat per previously described methods (Riney, 1955) and weighed. They were subsequently weighed with peri-renal fat removed to facilitate calculation of renal fat index (Riney, 1955). The entire xyphoid/falciform fat pad was excised, weighed, and subsampled. Kidneys (2021 only), liver sample, and spleen were collected. The full stomach was removed at the esophageal cardia and the gastroduodenal junction and weighed with contents. Stomach contents were removed from the organ, photographed, and subsampled. The empty stomach was then weighed. Photos of stomach contents and/or subsamples were sent to an experienced contractor for analysis and identification. The small and large intestines were tied off at the proximal duodenum and distal colon/rectum and stored frozen for future analysis. The uterus was removed (when applicable) and assessed for the presence of fetuses or evidence of implantation sites (i.e. placental scars or lochia).

R 3.6.0 statistical software was used to perform any descriptive or regression statistical analyses. The Shapiro-Wilk test and visualization of q-q plots were used to confirm normality assumptions of data. Parametric statistical tests (t-tests, linear models, ANOVA, and Tukey post-hoc tests) were used for analyses of data assessing temporal trends and interrelationships among metrics of health.

5.2 Results

Ninety-nine wolves from the 2021 North Slave Wolf Harvest Incentive Area and 45 wolves from the 2022 North Slave Wolf Harvest Incentive Area were necropsied (see Section 3.1.2). In addition, in 2021, one carcass submitted was indicated as 'found dead' and had no evidence of having been shot or trapped, and therefore was not included in the humaneness assessment. On necropsy, this animal was severely emaciated and of geriatric age class – starvation was likely a contributing factor to the animal's death, but possibility of underlying disease could not be ruled out on gross examination. Samples from this animal have been submitted to the Canadian Wildlife Health Cooperative (Saskatoon, Canada) for additional testing. Based on observations made on necropsy and consideration of tag information, we confirmed that at least two of the wolves were trapped using snares (2021). Specific snare or trap types used were not reported. Aside from date and method of kill, harvester name, location, and an indication of observed animal sex, no antemortem data (Appendix K of Feasibility Assessment; Hampton et al., 2015) was documented. Majority of tags did not have complete data recorded.

Decomposition or tissue damage suspected to be from freeze-thaw cycles and post-mortem scavenging was present to some degree on 100% of carcasses examined, and hindered complete examinations; many animals were missing the limbs, head, and/or other appendages to varying degrees (Table 13); and the majority of carcasses (136/145) were already skinned at time of presentation and presented with varying degrees of skinning artifact, which also impacted interpretation of injuries at necropsy.

Table 13. Documentation of body parts removed prior to submission of carcasses for examination.

Missing Body Part	# Carcasses (2021)	# Carcasses (2022)	2021 + 2022
Head	6	0	6
Distal Forelimbs + paws	27	15	42
Proximal + Distal Forelimbs + paws	2	0	2
Distal Hindlimbs + paws	18	0	18
Hind Paws	79	39	118
Fore paws	65	24	89
Tail	61	23	80

The wolves examined were widely distributed across sex and subjective age classes (Table 14). Results are pending for aging by cementum annuli analysis. Age structure, when considered across the four classes listed in Table 14, changed significantly from 2021 to 2022 (p=0.05). The ratio of young (juvenile and young of the year) to mature breeding age adults (adult and geriatric) declined but did not significantly change over time (p=0.07).

Table 14. Summary of wolf demographic data, including sex (determined on necropsy examination) and age class (juvenile = 1-2 years old, adult = 3-7 years old, geriatric = 8 years or older).

Sex	2021 (Freq)	2022 (Freq)
Male	53 (53.5%)	22 (47.8%)
Female	46 (46.5%)	24 (52.2%)
Total Wolves	99	46
Age Class	**2021 (Freq)**	**2022 (Freq)**
Young of the year	0 (0%)	1 (2.2%)
Juvenile	31 (31.3%)	20 (43.5%)
Adult	50 (50.5%)	20 (43.5%)
Geriatric	16 (16.2%)	5 (10.9%)
Unknown	2 (2.0%)	0 (0%)

Internal and external nutritional condition scores assigned ranged from 0.0 to 4.0 in 2021 and 2022. The average coarse (internal and external combined) nutritional condition score significantly decreased from 2.6 (0.0-4.0) in 2021 to 1.5 (range: 0.0-3.5) in 2022, even when taking age class into account (p<0.001). Average nutritional condition score across all 145 examined wolves was 2.25, considered fair nutritional condition. Weight of the internal xyphoid fat deposit, a quantitative indicator of body condition which has been shown to be a promising indicator or predictor of animal condition (Robitaille et al., 2012; Kelley et al. (unpublished data)), decreased significantly from 138.55 g (2021; range = 18.2-320.7 g, n=95) to 98.64 g (2022; range = 0 – 273.8 g, n=36), even when taking age class into account (p=0.004). Rump fat depth was on average 7.18 mm (range: 0 mm – 20.75 mm) and, in 2022, 6.68 mm (range: 0 mm – 20.12 mm) and did not vary significantly with age class or year of collection.

Findings on reproductive status of females examined are summarized in Table 15, below. Immature or unbred females were identified based on small size of the uterine body and ovaries and the absence of lochia scarring (scarring from placental attachment sites, which are indicators of the number of pups produced by a female during recent pregnancy) in the lumen of the uterus. Recent pregnancy was identified based on the presence of uterine scarring caused by lochia remaining from placental attachments of a pregnancy from the previous breeding season. Pregnant females were identified when fetuses or fetal implantations were identified in the lumen of the uterus. Reproductive senescence was diagnosed when an animal of advanced age had an atrophic uterine body without evidence of recent or current pregnancy. Some animals could not be examined for uterine characteristics due to autolysis, scavenging, or tissue destruction due to location of permanent wound tracts. Fetuses were developed enough to document crown-rump lengths and fetal weights in 2 cases. The number of pups being produced by females, as indicated by either number of scars, implantations, or fetuses in utero, ranged from 2 to 11, with a mean litter size of 6.3 pups in 2021, and ranged 5 to 9 with a mean litter size of 6.0 pups in 2022 – there was no statistically significant difference in litter sizes between years. Reproductive status of the female wolves assessed did not significantly correlate with year of harvest, even when considering the time of year (month) the animal was killed (p=0.13).

Table 15. Summary of female wolf reproductive data. Characteristics defining reproductive categories are described above.

	2021	**2022**	**TOTAL**
Immature or Unbred	22 (47.8%)	12 (50.0%)	34 (48.6%)
Recent pregnancy/ uterine scars	13 (28.3%)	6 (25.0%)	19 (27.1%)
Pregnant	5 (10.9%)	3 (12.5%)	8 (11.4%)
Reproductive senescence	1 (2.2%)	1 (4.2%)	2 (2.9%)
Unknown	5 (10.9%)	2 (8.3%)	7 (10.0%)
TOTAL FEMALES	46	24	70

Most stomachs sampled for ingested contents at necropsy contained barren-ground caribou tissues – findings are described further in Table 16. Of the stomachs that had sufficient contents to support identification and/or sampling of contents, 95.6% and 67.6% contained caribou in 2021 and 2022, respectively.

Table 16. Results of gross analysis of stomach contents. Contents were described based on direct observation during necropsy, and their identity then confirmed by high resolution photograph and/or physical analysis of stomach content subsample by a contracted expert. Results were summarized to reflect likely identity of species or material in the sampled ingesta.

Stomach Contents	2021 # wolves (%)	2022 # wolves (%)
Barren-ground caribou	66 (66.7%)	23 (50.0%)
Empty/fluid	30 (30.3%)	12 (26.1%)
Other*	2 (2.0%)	9 (19.6%)
Human food material/garbage	1 (1.0%)	2 (4.4%)

*Other includes vegetation, ptarmigan, grouse, rodent, unidentified ungulate, carnivore, etc.

Ten (6.9%) cases with incidental pathological findings unrelated to cause of death (i.e., tumours, congenital anomaly, signs of chronic inflammation or past infection, etc.) were sampled more extensively compared to the standardized approach. Fixed and frozen tissues sampled from cases requiring additional diagnostics by histopathology were submitted to be analyzed by the Western/Northern Node of the Canadian Wildlife Health Cooperative at the Western College of Veterinary Medicine, University of Saskatchewan. These cases appeared to have relevance on an individual animal health level, but not necessarily a population level – case details will be reported when further results are available.

5.3 Discussion

Monitoring the status and trends of wolf health is a critical component of the Wolf Management Program. In this context, monitoring wolf health, condition and demographics can serve as a measure to monitor the impact of management action on grey wolves at the individual and population levels. The program can also provide a better understanding of the various determinants of wolf health and resilience, how they are changing, and their cumulative impacts – these include but are not limited to diet/nutrition, demographics, morphology, behaviour, stress, reproduction, survival, and infection or exposure to different pathogens and parasites. In this section, information specific to demography, nutritional condition, diet, and reproduction in harvested grey wolves which were located within the North Slave Wolf Management Area was summarized. A more comprehensive health report on harvested wolves will be completed after all outstanding lab results are received.

Investigating the age structure of submitted wolves from the 2021 and 2022 Wolf Management Areas based on age class identified at necropsy resulted in a declining trend in the proportion of mature/breeding age harvested animals from 2021 to 2022 (p=0.07). In interpreting these outcomes, we can consider them from two key perspectives – first, as being indicative of the demography of animals that were removed from the population by the wolf management program; and second, as potentially representative of population level changes in age structure. Depletion of younger individuals may reduce the availability of local young maturing wolves to contribute to reproduction in the population, and perhaps dispersal of young animals between packs (Adams et al., 2008). If we consider our findings as an indicator of population level changes in composition, skewing of age structure towards younger, immature wolves is expected in an exploited population (Fuller and Novakowski, 1955; Fuller et al., 2003). A decreasing age structure has implications on reproductive capacity, individual survival, animal hunting success, dispersal rates and movements, territory, and pack social behaviours (Fuller et al., 2003).

Nutritional body condition is an important indicator of animal health which reflects the available energy reserves to that individual, which are critical for survival particularly in overwintering animals. An animal with greater available energy reserves would reasonably have greater overall fitness, reproductive success, and resilience to stressors such as disease, competition, and environmental change (Sacks et al., 2005; Schulte-Hostedde et al., 2005). Xyphoid fat deposit mass is an indicator of wolf nutritional condition (Robitaille et al., 2012; Kelley et al., unpublished data) and varied significantly with subjective body condition score, as did rump fat depth. On gross necropsy, rump fat depth was subjectively variable, depending on where an incision was made over the rump muscle and where a measurement was taken, despite attempting to standardize the approach. We did observe a significant declining trend in body condition as indicated by body condition score and xyphoid fat weight, even when taking age structure changes into account ($p<0.001$), and a non-statistically significant decline in rump fat depth from the first to second year of study. Continued monitoring of this metric is recommended, and investigation into whether it may be an indicator of an exploited population and could serve as a potential benchmark for control activities.

Diet analysis thus far has consisted of assessing stomach contents as indicators of prey/diet composition for individual animals. A large proportion of stomachs assessed in harvested wolves are empty – this may be an indication of a wolf that has not ingested a recent meal, but also could reflect behavioural explanations, such as the wolf vomiting or voiding its gastrointestinal tract due to recent stress. Contents of full stomachs must be interpreted with caution, as these only reflect the most recent meal by that animal. The proportion of stomachs that contained barren-ground caribou tissue declined from 60.6% in 2021 to 50.0% in 2022. The proportion of empty stomachs was relatively consistent: 30.3% and 26.1% of stomachs analyzed in respective years.

Additional health analyses are recommended for existing archived samples and for those collected in coming years to assess diet and predator-prey dynamics using alternative techniques. These may include evaluating stable isotope profiles of wolves and prey species, assessing parasite diversity trends and dynamics, and surveying pathogens that are shared between wolves and ungulates or other prey. Additional metrics of health such as stress and reproductive steroid hormone profiles; pathogens and parasites that may impact reproductive success, survival, or be indicators of proximity to domestic animals and humans; contaminants and heavy metal profiles; and changes in demography and behaviour are also of interest.

6 Discussion and Lessons Learned

The goal of the wolf management program is to sufficiently reduce wolf predation on the Bathurst and Bluenose-East caribou herds to allow for an increase in calf and adult caribou survival rates to contribute to the stabilization and recovery of both herds. To evaluate the success of the management actions, three wolf centered metrics are used: number of wolves harvested, CPUE, and age structure of harvested wolves. At this point in the program, the number of wolves removed in the incentive area is variable across years: 85 removed in 2019-2020, 135 removed in 2020-2021, and 69 removed in 2021-2022. On average, CPUE-km calculations as well as aerial sighting rates decreased this year compared to 2021, suggesting there may be less wolves on the landscape. However, these results are confounded by the CPUE-day calculations which have increased from 2020 to 2022. The age structure of harvested wolves appears to be changing, as the harvested population was made up of 42.5% juveniles and 45% adults this year compared to 31% juveniles and 51% adults in 2021.

Based on the 2021 estimates of breeding females and adult herd size and analyses of demographics for the Bathurst and Bluenose-East herds of barren-ground caribou reported in the 2021 calving ground photographic survey reports (Adamczewski et al., 2022; Boulanger et al., 2022), the demographic indicators for a stabilizing population have improved for the two herds since 2018, most notably in the Bluenose-east herd. The estimates for the Bluenose-East herd for 2021 suggest stabilization from 2018, based on estimated numbers of females, and possibly the beginnings of recovery based on the herd estimate that includes the males. This was a major improvement from the trend in 2018 for that herd, which was rapid decline. The estimate for the Bathurst herd suggests a slower rate of decline and an improvement in demographic indicators from 2018, and it appears that emigration estimated from collared cows that switched from Bathurst to Beverly may have been more of a driver in recent decline than numeric decline. While population estimates and demographic indicators of a stable population have improved, it is difficult to know whether and to what extent it may reflect wolf removals or any other specific management action currently being undertaken.

Overall, the 2022 wolf management program provided valuable information and areas of key learnings that provide opportunity for program improvement and adaptation. These are summarized below.

- The collaring program will continue in winter 2023 to achieve and maintain 30 collared wolves in the region with which to examine wolf movements, predation rates, and improve detection rates in surveys. Seven wolves were captured and collared in winter 2022 bringing sample size to 29 collared wolves, with 10 collars currently transmitting data.

- Aerial survey design options for obtaining more reliable estimates of wolf abundance on the winter range of Bathurst and Bluenose-East caribou will continue to be assessed for application in 2023. Detection surveys have contributed to initial characterization of detectability of wolves during aerial surveys.

- Spatial overlap of the Bathurst, Bluenose-East and Beverly caribou herds on the winter range was less in 2022 compared to 2021, but likely influences the local abundance and seasonal movements of wolves.

- Wolf movements and capture site locations show low fidelity to a single caribou herd, and den site location may be more indicative of affiliation to any one herd.

- Ground-based harvest of wolves in 2022 on the combined winter range of the Bathurst and Bluenose- East caribou herds was less than that of 2021, primarily due to low snow depth and difficult travel conditions.

- Twenty-eight hunters participated in the program and received incentive payments for 50 wolves harvested in the North Slave Enhanced Wolf Harvest Incentive Area. The remaining 19 wolves were harvested by guided non-resident hunters.

- In collaboration with hunters and trappers, revisions to the wolf harvester questionnaire design and delivery are recommended to improve survey completion, calculation of CPUE and response rates, while not over-burdening the respondent.

- Results of detailed post-mortem examinations of carcasses suggest that the percent of stomachs that contained caribou has decreased compared to last year and wolves are in poor body condition. Age structure was made up of 43.5% juveniles and 43.5% adults.

7 Acknowledgements

We thank the NWT, Tłı̨chǫ and Nunavut harvesters and skinners for their significant effort and contribution towards the program in 2022. We also thank Great Slave Helicopters, Acasta Helicopters, and Hoarfrost River Huskies for support conducting the surveys and collaring programs. We thank Robert Mulders for his work in establishing the wolf collaring and monitoring program. The contributions of Caslys Consulting Ltd. and Bryce Olson have directed us towards a greater understanding of our data and areas for improvement. The assistance and dedication of our 2022 summer wildlife health technicians/students and summer veterinary student was invaluable. And lastly, we acknowledge and thank members and staff of the Wek'èezhìı Renewable Resources Board for their ongoing support and collaboration.

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9 Appendix A – WRRB Recommendations

Reference	Response	Final Recommendation
#1-2020	VARY	GNWT and TG update the objectives of the dìga management program to be measurable for effects on ekwǫ̀ and dìga in order to be able to assess the impacts of the program and provide these objectives to the WRRB by ~~May 1,2021~~ July 31, 2021. Updated objectives should consider that the Kǫ̀k'èetì and Sahtì ekwǫ̀ herds have different vulnerabilities and vital rates and, thus, success may be measured differently.
#2-2020	VARY	GNWT and TG identify ~~and implement~~ alternative methods to measure and index dìga abundance and calibrate these with the Ungulate Biomass Index to ensure the most accurate and precise population estimates are used for dìga management by ~~May 31~~ March 31, 2021.
#3-2020	ACCEPT	Dìga sighting rates, during ɂekwǫ̀ sex and age composition surveys, be assessed by GNWT to determine if and how it contributes to understanding seasonal trends in dìga abundance on the Kǫ̀k'èetì and Sahtì ekwǫ̀ ranges by May 1, 2021.
#4-2020	VARY	The ground-based harvest proceed as proposed with the addition of harvester supports provided by TG and GNWT. This should include ɂekwò̜ and dìga distribution information, gas caching, and could include ~~/or~~ bait stations, starting in the 2020/2021 harvest season. These supports are necessary for ground-based harvest removals as per the Wolf Technical Feasibility Assessment: Options for Managing Dìga on the Range of the Bathurst Barren-ground Caribou Herd (2017).
#5-2020	ACCEPT	GNWT and TG improve the harvest reporting program to ensure that appropriate information is being collected through questionnaires, starting 2020/2021 harvest season. This could be accomplished by using a contractor with expertise in this area.
#6-2020	VARY	GNWT and TG incorporate lessons learned from Nunavut's high success rate with their harvester's questionnaire responses and ~~ensure~~ invite Nunavut harvesters to attend Harvester Training Workshops, starting 2020/2021 harvest season.
#7-2020	VARY	GNWT and TG should not continue aerial removals of dìga on Kò̜k'èetì and Sahtì ekwǫ̀ ranges in winter 2020-2021. Instead, more resources should be put towards ground-based harvest. Subject to review based on an annual assessment of evidence during the annual review of the program, the WRRB would consider a proposal of other methods of dìga removal
#8-2020	VARY	TG and GNWT explore alternative methods of assigning harvested dìga to an ɂekwǫ̀ herd ~~and to statistically determine confidence in the allocation~~. GNWT and TG should provide enough information to determine how the uncertainty affects the success of the program and submit results to the WRRB by September 30, 2021.
#9-2020	VARY	GNWT and TG will review the feasibility of monitoring dìga den occupancy to measure pup production, recruitment, and diet ~~and disease incidence~~ to describe the extent of compensatory breeding and to better understand the minimum number of dìga on the Kò̜k'èetì and Sahtì ekwǫ̀ summer ranges, starting in the 2020/2021 harvest season.
#10-2020	VARY	GNWT and TG ensure ~~all~~ a sufficiently representative sample of dìga removed as part of this program from 2021-2024 undergo a full necropsy to determine injuries, physical condition, reproductive status, and diet, to fully understand health of the dìga on the ranges of the Kò̜ k'èetì and Sahtì ekwǫ̀ herds.
#11-2020	ACCEPT	GNWT continue the dìga collaring program, beginning in 2021, using a statistically rigorous design to measure dìga movements relative to the dìga-ɂekwǫ̀ spatial distribution, including reducing the uncertainties involved with assigning dìga to ɂekwǫ̀ herds.
#12-2020	VARY	GNWT and TG develop an approach to assessing ~~complete a~~ caribou (ekwǫ̀) calf mortality ~~study in conjunction with 2021 calving~~

		~~ground surveys~~ to determine the effect of dìga and other predators on calf survival beginning on the ~~both~~ Kǫ̀ k'èetı̀ ekwǫ̀ calving ground, and potentially expanding to the Sahtì ekwǫ̀ calving grounds, if feasible. This calf mortality study should, if possible, be done in cooperation with Government of Nunavut and with the assistance of experienced Dene and Inuit elders as field observers.
#13-2020	ACCEPT	TG collect and document stories about the changes that Tłıchǫ elders and their families have observed to the dìga and ɔekwǫ̀ relationship through time, and in the present considering other animal behaviour, climate change, loss of habitat, and population declines.
#14-2020	ACCEPT	TG collect Tłıç hǫ stories about dìga and ɔekwǫ̀, while on the land, from elders participating in the Ekwǫ̀ Nàxoède K'è program to increase the understanding of the current relationship between dìga and ɔekwǫ̀ and how it has changed through time.
#15-2020	VARY	GNWT and TG explore possibilities and develop an approach ~~undertake field studies and modelling~~ to determine causes of death of collared ɔekwǫ̀ ~~so that the assumption that 60% of mortality is caused by dìga predation can be tested~~, and to estimate the influence of other factors in mortality of caribou (ekwǫ̀), by Sept. 30, 2021 ~~in the 2020/2021 harvest season~~.
#16-2020	VARY	GNWT and TG, in collaboration with the WRRB through the Barrenground Caribou Technical Working Group, establish benchmarks for key caribou (ekwǫ̀) vital rates and integrate them into the Adaptive Co-Management Framework to identify at which point dìga removals would stop in time for the annual fall meeting ~~by March 31, 2020~~.
#17-2020	VARY	Any key vital rates of dìga and Kǫ̀ k'èetı̀ and Sahtì ekwǫ̀ collected by GNWT and TG be reported to the Barren-ground Caribou Technical Working Group throughout the year~~, in alignment with the Adaptive Co-Management Framework, to contribute to the implementation of the adaptive management framework~~.
#18-2020	ACCEPT	The annual review of the dìga management program be collaborative with TG, GNWT, and the WRRB and coincide with the November Barren-ground Caribou Technical Working Group Meeting, beginning in 2021.
#19-2020	ACCEPT	In time for the 2021 annual review, GNWT and TG implement the recommendations in the Wolf Technical Feasibility Assessment: Options for Managing Dìga on the Range of the Bathurst Barren-ground Caribou Herd (2017) to develop the annual monitoring protocols for efficiency, effectiveness, and humaneness.
#20-2020	VARY	An annual report on the wolf (dìga) management program be prepared by GNWT and TG and presented to the Board at a scheduled board meeting to allow for the discussion of adjustments in methodology based on the evidence, beginning fall 2021.

10 Appendix B – NWT Harvester Questionnaire

HUNTING LOG

Thank you for providing your professional input on wolf harvesting in the NWT and sharing information about your hunts.

Survey data will help to document wolf hunting efforts and support caribou recovery. Any information you provide will remain confidential and will only be used to determine average hunting efforts.

Information provided will have no effect on your hunt compensation.

This logbook was designed to take less than a minute of your time to fill at the end of your hunting effort for the day.

ONCE YOUR HUNTING TRIP IS OVER, PLEASE RETURN THIS LOGBOOK TO:

REGIONAL BIOLOGIST

Environment and Natural Resources – North Slave Region

Government of the Northwest Territories

PO Box 2668, 3803 Bretzlaff Drive

Yellowknife, NT X1A 2P9
867-767-9238 ext 53254

Questions? Contact: ENR North Slave Regional Office
ENR_NorthSlave@gov.nt.ca
867-767-9238

Hunter's community ....

Bullet caliber: .... **Carried firearms:** ....

Dates of hunt: (m/d) .... /.................... **to:** (m/d) .... /....................

Booklet ID: ....

Government of Northwest Territories
Tłı̨chǫ Ndek'àowo
Tłı̨chǫ Government

FILL OUT AT END

Thank you for telling us about your hunting experiences.
This information will help us prepare for future hunting projects.

ANY INFORMATION YOU PROVIDE WILL REMAIN CONFIDENTIAL.

About how many wolves have you harvested in your lifetime? ....

About how many years have you been hunting wolves? ....

When was the last year you hunted wolves? ....

COMPARED TO THIS LAST HUNTING SEASON...

1. How hard was it to find wolves?

Much harder | Somewhat harder | The same | Easier | Much easier

2. How far did you have to travel?

Much further | A bit farther | Same distance | Less | Much less

3. How big were the packs?

Much larger | Larger | Same size | Some larger, some smaller | Smaller | Much smaller

FILL OUT DAILY

Date: ....../.......   **Number of hunters in the group** ....

Started hunting at: ....../.......(am/pm) **Finished hunting at:** ....../.......(am/pm)

How many breaks did you take today? ....

How long were your breaks on average? .... hr .... mn

Number of wolves:

Seen

☐
On the map, please mark with **O** the location and number of wolves seen.

Shot at

☐
On the map, please mark with **S** the location and number of wolves wounded.

Harvested

☐
On the map, please mark with **X** the location and number of wolves harvested.

Number of caribou:

Alive

☐

Dead

☐

How was the weather?

Perfect

Good

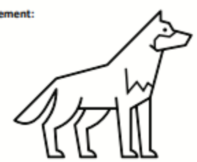
Bad

Very bad

If you shot at wolves today please fill this section:

☐ Shot at ☐ Harvested

Placement:



Mark with X placements of bullets hit

Number of shots fired..............................

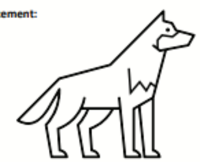
Time from first shot to death: .... min

Chase time: .... min **Pack size:** ....

Bullet caliber(s): ....

☐ Shot at ☐ Harvested

Placement:



Mark with X placements of bullets hit

Number of shots fired..............................

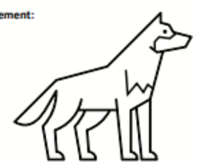
Time from first shot to death: .... min

Chase time: .... min **Pack size:** ....

Bullet caliber(s): ....

☐ Shot at ☐ Harvested

Placement:



Mark with X placements of bullets hit

Number of shots fired..............................

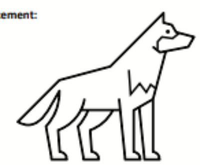
Time from first shot to death: .... min

Chase time: .... min **Pack size:** ....

Bullet caliber(s): ....

☐ Shot at ☐ Harvested

Placement:



Mark with X placements of bullets hit

Number of shots fired..............................

Time from first shot to death: .... min

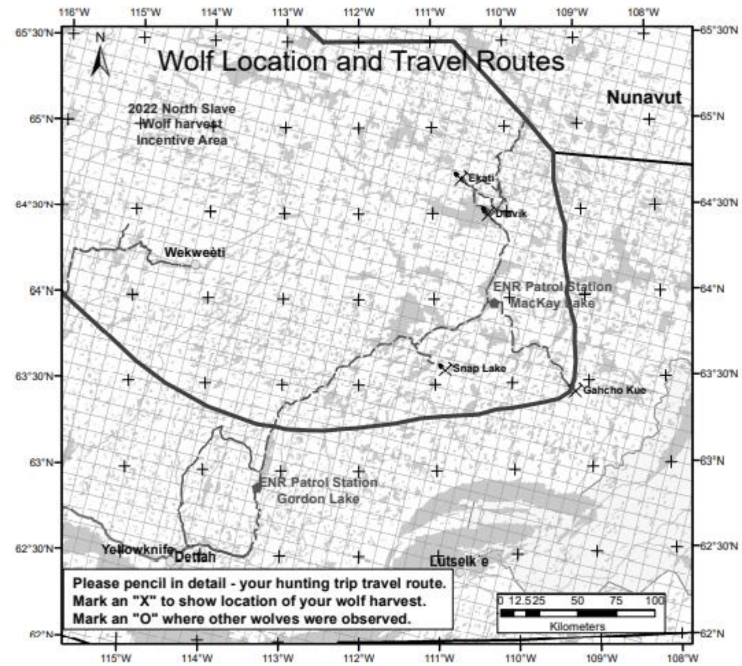
Chase time: .... min **Pack size:** ....

Bullet caliber(s): ....

FILL OUT DAILY

Approximate distance travelled ....km (sketch the route on the map)

Note: squares on the map are 10km x 10km in size



Did you see anything else that you think is important today?

11 Appendix C – Nunavut Harvester Questionnaire

Wolf Survey for Nunavut wolf harvesters in the North Slave Region

Name of hunter: ____________________

E-mail: ____________________ Phone: ____________________

Type of Licence/Hunter Residency: ____________________

1. Hunting trip **started** on Month: ______ Day: ______ approx. time: ______

   ended on Month: ______ Day: ______ approx. time: ______

2. In **total**, how many wolves did you **see** on your trip? ☐

3. Number of wolves seen in each wolf pack? ____________________

4. In **total**, how many wolves did you **harvest** on your trip? ☐

5. If available, please include GPS location of your wolf harvests:

   Lat: ______ Long: ______ General area: ______

   Lat: ______ Long: ______ General area: ______

6. Number of other wolf **hunters** travelling with you: ☐

7. Estimated number of **hours spent hunting each day**:

Day 1	2	3	4	5	6	7

8. Estimated number of **kilometres travelled each day**:

Day 1	2	3	4	5	6	7

9. Other species (number) harvested during your trip?

   Muskox ☐ Wolverine ☐

   Other species: ____________________

10. Estimated **number of caribou seen** while hunting wolves.

    Check one: None ☐ 1-20 ☐ 21-100 ☐ 101-500 ☐ Over 500 ☐

11. Did you see any sign of **caribou remains**; likely killed by wolves?

    Yes ☐ **No** ☐

12. What was the weather like during your hunt? Did it make hunting harder? ____________________

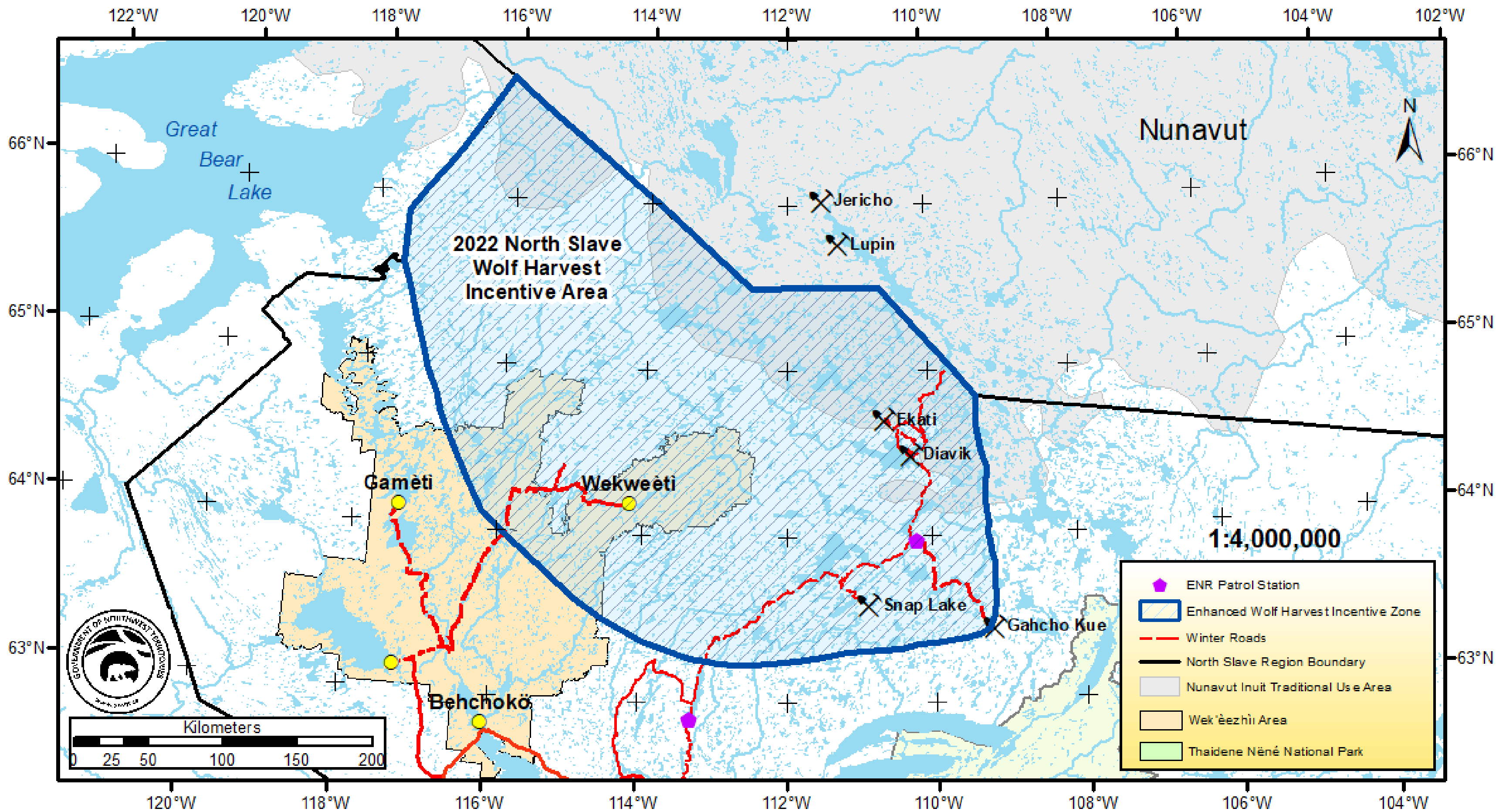
13. Do you have any other comments or wildlife observations about your trip? ____________________

14. On the back of this sheet is a **MAP** of the winter roads in the North Slave Region. Please mark down your **travel route**, **wolf harvest** & **wolf observation locations**. ____________________

Thank you for participating! *Survey data will help ENR document wolf hunting efforts and support caribou recovery. Any information you provide will remain confidential.*

Questions? *Contact: Allen Niptanatiak, Conservation Officer III, Kugluktuk Office at 1-867-982-7451.*

Government of Northwest Territories Gouvernement des Territoires du Nord-Ouest



2022 North Slave Wolf Harvest Incentive Area
Great Bear Lake
Nunavut
Jericho
Lupin
Ekati
Diavik
Snap Lake
Gahcho Kue
Gamètì
Wekweètì
Behchokǫ̀
1:4,000,000
Kilometers
0 25 50 100 150 200
ENR Patrol Station
Enhanced Wolf Harvest Incentive Zone
Winter Roads
North Slave Region Boundary
Nunavut Inuit Traditional Use Area
Wek'èezhìı Area
Thaidene Nëné National Park