TECHNICAL REPORT WOLF (DÌGA) MANAGEMENT PROGRAM JANUARY – MAY 2021

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EXECUTIVE SUMMARY

Tłı̨chǫ Government and the Government of the Northwest Territories are working together to implement management actions to reduce wolves (dìga) on the winter ranges of the Bathurst (Kǫ̀k'èetı) and Bluenose-East (Sahtì) migratory barren-ground caribou (ekwǫ̀) herds because of the ongoing conservation concern related to severe population declines over the past 10-15 years. The five-year program includes support for wolf harvesters and the traditional economy, the use of aerial removals to reach wolf harvest targets combined with an extensive research and monitoring program; aerial removals were not recommended by the Wek'èezhìı Renewable Resources Board in their Reasons for Decision Report[1] and were not undertaken in 2021.

Wolf abundance in winter 2021 appeared to be strongly influenced by increased caribou density resulting from the high amount of spatial overlap of Bathurst, Bluenose-East and Beverly caribou herd monthly range extents. Based on winter 2020/2021 caribou satellite collar data, the Bathurst monthly range extents were almost completely overlapped (99-100%) by Beverly caribou from October to April. Together, the Beverly and Bluenose-East overlapped the Bathurst winter range minimally in October (1.9%) with increasing coverage through January (59.1%) and then decreasing through to May (27.9%). The Beverly caribou herd is approximately 12.5 times the size of the Bathurst herd (based on June 2018 survey estimates) 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 Bluenose-East monthly winter range extents in 2020/2021 were overlapped minimally in October (4%) by Bathurst and Beverly herds and the proportion of overlap ranged from 16.8-45.8% from November through to May, with no directional trend. The extensive overlap of caribou herds, compounded with the uncertainty of Beverly caribou distribution due to low collar numbers, affected several program components.

A geospatial aerial survey estimated 89 wolves (95% Cl: 31-147) on the Bathurst caribou winter range in March 2021. The estimate had low precision (CV=33.4) and therefore has a limited ability to detect numerical change. Reduced sightability of wolves on the winter range especially when stationary, bedded or within treed habitat, and their inherent low densities and clumped distribution are key challenges to designing surveys to detect and accurately estimate wolf abundance. The low sighting rate of the survey crew (0.37 wolves/hour of flying) is perhaps indicative of these challenges. While the geospatial survey design has benefits related to accommodating spatial auto- and cross-correlation of observations it is challenging for surveying wolves on the barrens. Wolves are mobile animals. Survey timing is critical and should coincide with reduced wolf movement rates, likely when caribou

[1] Wek'èezhìı Renewable Resources Board. 2021. Reasons for Decisions Related to a Joint Proposal for Dìga (Wolf) Management in Wek'èezhìı. Submitted to Tłı̨chǫ Government and Department of Environment and Natural Resources, Government of the Northwest Territories, January 8, 2021, Wek'èezhìı Renewable Resources Board, Yellowknife, NT. 74pp. + Appendices

reduce their daily movements during mid-winter (December through February). Collared wolf movements during the survey timeframe showed a fair amount of movement into and out of the survey area and likely among grid cells; a small proportion of wolves (17%) showed directional movement seemingly associated with caribou movements. These movements could have contributed to the high variance around the estimate. In addition, using caribou abundance to infer wolf abundance for survey stratification was complicated by the low number of collars on Beverly caribou combined with high abundance of Beverly caribou in the survey area. Continued evaluation of options for improving survey design for wolves and alternative approaches to stratification is recommended for 2022.

A total of 35 GPS collars were placed on wolves captured on the range of the Bluenose-East and Bathurst barren-ground caribou herds during the months of March and April in 2020 and 2021. The collars provided a means to monitor wolf movements in relation to caribou and evaluate the possible nature of affiliation of wolves, if any, to a particular caribou herd. Preliminary analyses of wolf collar location data showed three general movement patterns among wolves collared in the North Slave Region of the Northwest Territories: North-South (23%), East-West (50%) and Stationary (27%). Wolves exhibiting North-South movements tend to be associated with a single caribou herd; wolves with East-West movements (the majority of those collared) tend to be associated with two or three caribou herds and the stationary wolves mainly associate with caribou of one or more herds on the winter range.

Seasonal movements of non-stationary wolves show times of low overlap with caribou in June, when caribou are calving and wolves are constrained by denning and pupping. Collared wolves had higher overlap with collared caribou in summer and winter. Given that wolves appear to display fidelity to den site locations and movement analyses show some indication for seasonal affiliation to a single caribou herd during summer months, we suggest this may provide the basis for an alternate approach to defining wolf affiliation to caribou herd. Additional analyses of the wolf collars deployed in 2021 and those planned for deployment in 2022 will aid us in further understanding seasonal affiliation and its potential application for allocating wolf harvest. Assigning herd affiliation to a harvested wolf in years with overlap or close proximity of caribou herds continues to be assessed.

Based on experience in other jurisdictions, 60-80% of wolves need to be removed in the first year of a management program followed by sustained removal levels for at least four years to maintain low wolf density and promote ungulate population growth. The approach taken to derive wolf removal targets in 2021 was adapted from that taken in 2020 to accommodate the high degree of overlap in Bathurst, Bluenose-East and Beverly herds and the anticipated associated wolves. We took an alternative approach, to start conservatively, given the uncertainty in wolf abundance estimates, and adapt as needed. An interim number of wolves was set as a trigger for review, which would be revisited as harvest levels approached this number and revised based on observations from harvesters, survey and collar crews and if available, within season catch per unit effort (CPUE). This approach allowed for adaptive management with possible adjustments based on information coming in over the harvest season.

An ungulate biomass index and extrapolated caribou herd size was used to estimate wolf abundance for establishing a removal target. This approach was needed as we did not have an empirically based estimate of wolf abundance at the start of the 2021 winter harvest season. The interim trigger level was set at 80% of the estimated wolves associated with the Bathurst and Bluenose-East herds, 114 wolves (80% of 142). The application of this process provided flexibility in a situation of high overlap of caribou herds and high uncertainty in actual wolf abundance. As the reported harvest approached the interim trigger level of 114 in late March, the Government of the Northwest Territories decided to continue supporting the wolf harvest as, other than the Tłı̨chǫ Dìga harvester camp, there were no reports that harvest rates or sighting rates of wolves were declining.

From January to April 2021, a total of 135 wolves were harvested within the North Slave Wolf Harvest Incentive Area on the winter ranges of the Bathurst and Bluenose-East caribou herds (Figure 1). Most wolf hunting occurred around the hunting camps set up by Tłı̨chǫ Government near Roundrock Lake, and Inuit harvesters near Itchen and Point lakes. The Tłı̨chǫ Government's Community-based Dìga Harvest Program resulted in the removal of 32 wolves, which was a ten-fold increase in number of wolves harvested compared to 2020. Similarly, Inuit hunters almost tripled their harvest compared to last year. The increased success of both harvesting groups was likely due to their camp location providing access to areas of increased wolf abundance related to the overlapping distribution of all three caribou herds.

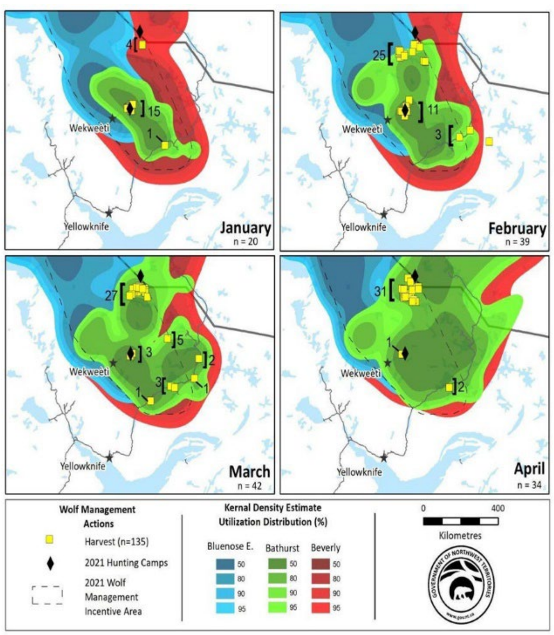

Figure 1. Location of 2021 wolf harvest in relation to monthly caribou utilization distributions for Bathurst, Bluenose-East and Beverly barren-ground caribou herds.

Assessment of hunter effort within the 2021 harvest season indicated that CPUE across all harvesters gradually increased through the season to mid-March and then declined to moderate levels. At a more localized scale, that of the harvesting camps, the CPUE of Inuit and Tłı̨chǫ harvesters showed a downward trend as their harvesting progressed while the CPUE of the winter road harvesters did not. We suggest that caribou gut piles may have been an attractant to wolves drawing them into the region of the winter road making them relatively more available even as the season progressed.

Peak CPUE varied considerably among harvester group: Tłı̨chǫ hunters' peak CPUE of 0.5 wolf/km was an order of magnitude higher than the peak CPUE of Kugluktuk hunters (~0.042 wolf/km) and Tibitt-Contwoyto winter road hunters (0.08 wolf/km). Such differences were likely related to differences in caribou density and in turn wolf abundance at the local scale; harvester experience and harvesting method may have also influenced rates of CPUE. Also, there were some confounding factors related to the wolf harvest survey design and how harvesters reported information that led to some uncertainties in calculating CPUE. Improvements are needed to reduce variability in how it is reported by harvesters.

Harvested wolves were widely distributed across sex and age classes with the majority (~70%) being adults. Based on coverage and thickness of subcutaneous fat stores, the average body condition score across all necropsied wolves was 2.6; this average score indicated that harvested wolves were in good body condition based on a rank scale of 0-4 (0 being poorest and 4 being best condition). Of the wolves examined with contents in their stomachs (83/111; 74.5%), caribou comprised 86.8% of gross stomach contents.

Overall, the 2021 wolf management program had a number of successes and areas of key learnings that provided opportunity for program improvement and adaptation. These are summarized below.

- Ground harvest of wolves in 2021 on the combined winter range of the Bathurst and Bluenose-East caribou herds exceeded that of 2020 with both the Tłı̨chǫ and Inuit camps substantially increasing wolf harvest.
- Fifty-six hunters participated in the program and received incentive payments for a total of 135 wolves harvested in the North Slave Enhanced Wolf Harvest Incentive Area.
- Harvest continued to be supported as numbers approached the interim trigger level since harvest rates and sighting rates were not declining over the season suggesting wolves across the winter range were not being significantly reduced.
- Extensive spatial overlap of the Bathurst, Bluenose-East and Beverly caribou herds on the winter range most likely resulted in higher local abundance of wolves, contributing to higher CPUE and higher overall harvest levels in winter 2020/2021 than 2019/2020.
- Results of detailed post-mortem examinations of 111 carcasses showed that wolves were primarily eating caribou, were in good condition and age structure was made up of predominantly adults.
- The collaring program will continue in winter 2022 to achieve and maintain a total of 30 collared wolves in the region with which to examine wolf movements and seasonal/annual association

with caribou herds. Nineteen wolves were captured and collared in winter 2021 bringing sample size to 22 collared wolves.

- Analyses of the wolf collar location data provided key insights for refining the program with respect to wolf affiliation to caribou herds and clarifying the methods for setting wolf removal targets.
- Revisions to the harvester questionnaire design and delivery are recommended to improve survey completion, calculation of CPUE and response rates, while not overburdening the respondent.
- 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 2022.

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INTRODUCTION

The Bathurst (Kǫ̀k'èetı̀) and Bluenose-East (Sahtì) migratory barren-ground caribou (ekwǫ̀) herds have rapidly declined over the past ten to 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 (NU). In the NWT, a number of management actions for these two caribou herds have been implemented within the Wek'èezhìı management area[2], which was established under the Tłıchǫ Agreement. Any Party[3] to the Tłı̨chǫ Agreement, proposing a wildlife management action within Wek'èezhìı must submit a management proposal to the Wek'èezhìı Renewable Resources Board (WRRB) - an institution of public government that acts as a co-management tribunal to exercise advisory and decision-making responsibilities related to wildlife, forest, plant and protected areas management.

Because of the ongoing conservation concern for these two caribou herds, the scope of management in Wek'èezhìı 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 (Messier et al. 1988, Couturier et al. 1990) and when caribou are at low numbers (Messier et al. 1988, Bergerud 1996).

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 (TG) and the Government of the Northwest Territories (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 (ʔekwǫ̀) 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 TG and GNWT resubmit a proposal based on experience gained and lessons learned from the pilot project.

Subsequently in August 2020, GNWT and TG 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 (ʔekwǫ̀) 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.

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[2] Although this report is focused 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 Renewable Resources Council (2016), Kugluktuk Angoniatit Association (2019), Łutsel K'é Dene First Nation (2020), Nunavut Wildlife Management Board (2020a, 2020b) and Sahtú Renewable Resources Board (2016).

[3] Includes the TG, the GNWT and the Government of Canada.

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 ɂekwǫ̀ 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 subsequently accepted or varied by GNWT and TG (Appendix A).[4]

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 TG through winter 2021. It provides an update to the previous report on wolf management activities in Wek’èezhìı during winter 2020 (Nishi et al. 2020) 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”*.

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[4] https://wrrb.ca/sites/default/files/WRRB%20Reasons%20for%20Decision%20Final%20Report%20-%202020%20Diga%20Management%20Proceeding.pdf

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 (Walton et al. 2001, Musiani et al. 2007) especially during the winter (Hansen et al. 2013).

Further, barren-ground caribou can have a high amount of overlap with adjacent herds on their winter seasonal ranges (Prichard et al. 2020) which can confound the application of management actions aimed at predators that might be associated with a single herd. Thus, understanding winter range use of caribou is integral to implementing and evaluating wolf management actions.

An 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 (UD) 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.

Monthly KDEs for Each Bathurst, Bluenose-East and Beverly Herds

Telemetry data collected by the GNWT between October 2020 and April 2021 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) 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 wide-ranging gregarious ungulates like barren-ground caribou. All KDE polygons were generated using the adehabitatHR (Calenge 2006) package within R.

The overlap of 2020 and 2021 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 ESRI ArcDesktop using the union geoprocessing tool.

Results of KDE Analysis

Sample sizes of daily collar locations by month and herd are shown in Table 1. The Beverly herd had the lowest number of collars in winter 2021 and a much lower proportion of collared animals relative to herd size than the Bathurst or Bluenose-East caribou herds.

Table 1. Sample sizes of collared caribou by herd in 2021.

Herd	Est. herd size (2018)	Month	# Locations	# Collared Caribou
BAT	8,200	October	1,328	43
		November	1,251	42
		December	1,230	41
		January	1,395	45
		February	1,251	45
		March	1,472	51
		April	1,620	54
		May	1,578	53
BEV	103,400	October	775	25
		November	748	25
		December	728	25
		January	619	20
		February	553	20
		March	795	31
		April	1,004	34
		May	960	32
BNE	19,300	October	1,586	53
		November	1,453	50
		December	1,408	49
		January	1,429	47
		February	1,262	46
		March	1,,527	59
		April	2187	74
		May	2,183	73

Figure 2 shows monthly KDE UDs for Bluenose-East, Beverly and Bathurst caribou herds from October to December 2020 showing the movement into and during rut in October, post-rut movements in November and subsequent movement onto winter ranges through December.

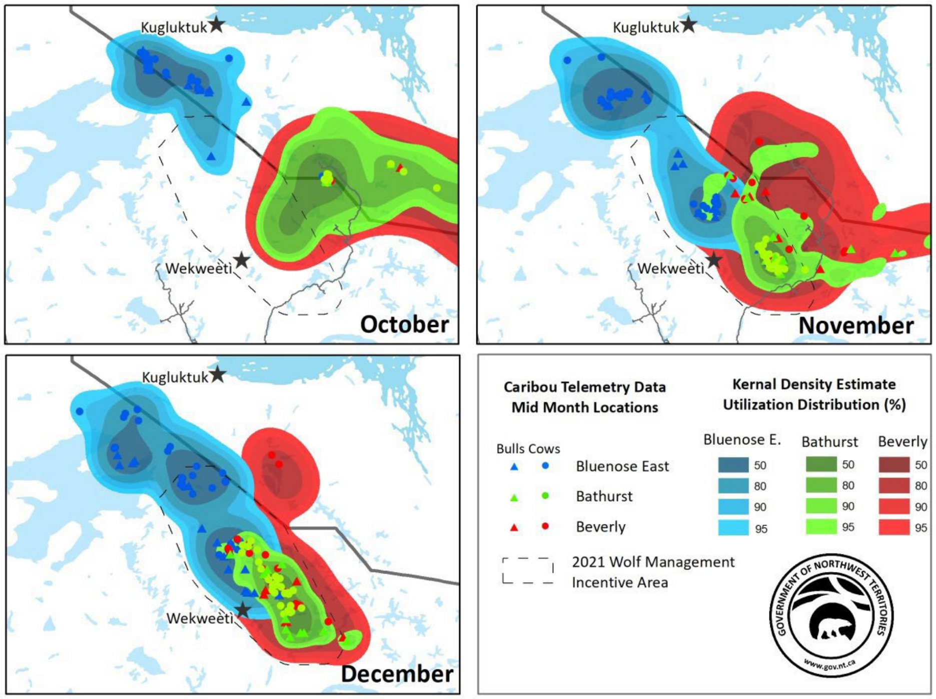


Figure 2. Monthly UDs from October to December 2020 for Bathurst, Bluenose-East and Beverly caribou herds based on KDE.

Figure 3 shows monthly KDE UDs for Bluenose-East, Beverly and Bathurst caribou herds from January - April 2021 showing the high amount of overlap of the three herds during that time period. In comparison, Figure 4 shows the monthly KDE UD for the same three herds in 2020.

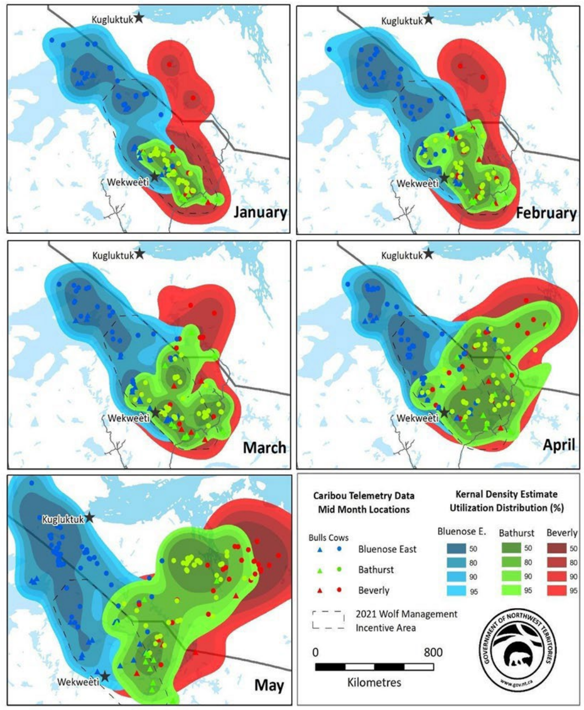


Figure 3. Monthly UDs from January to May, 2021 for Bathurst, Bluenose-East and Beverly caribou herds based on KDE.

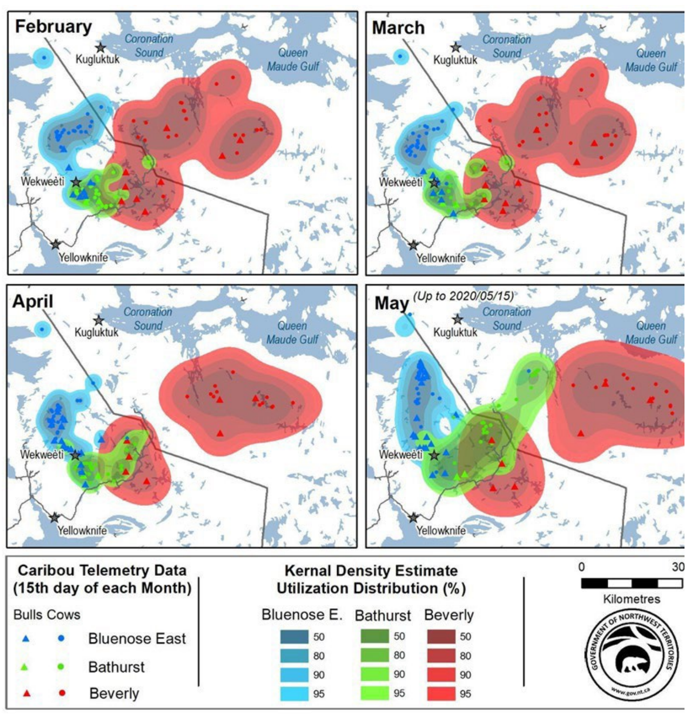


Figure 4. Monthly UDs from 2020 for Bathurst, Bluenose-East and Beverly caribou herds based on KDE. Adapted from Nishi et al. 2020.

Table 2 through Table 4 provide a summary of the percent of the Bathurst and Bluenose-East herd 95% home range contours overlapped by Bluenose-East and Beverly herds individually and combined from January to May in 2020 and October 2020 through May 2021. In 2020, during the winter months (February - April), 36.5-56.4% of the Bathurst monthly winter ranges were overlapped by the Beverly, 36.9-44.7% by the Bluenose-East and only 0-3.7% overlap by both the Bluenose-East and Beverly ranges (Table 2). The Bluenose-East monthly winter ranges were overlapped by the Bathurst, 16.9-29.5%, 0-4.9 % by the Beverly and only 0-2% by both the Bathurst and Beverly herds (Table 3).

Table 2. Summary of % overlap of Bathurst (BAT), Bluenose-East (BNE) and Beverly (BEV) caribou herd monthly ranges in 2019/2020 harvest season based on 95% kernel UD isopleths.

Month	BAT (km²)	BNE overlap (km²)	BNE overlap (%)	BEV overlap (km²)	BEV overlap (%)	BAT (km²) No Overlap	BAT (%) No Overlap	BAT (km²) BNE&BEV Overlap	BAT (%) BNE&BEV Overlap
Jan	-	-	-	-	-	-	-	-	-
Feb	19,538.0	8,735.9	44.7	9,791.1	50.1	1,729.6	8.9	718.6	3.7
Mar	24,753.5	10,979.1	44.4	9,026.6	36.5	4,747.8	19.2	0.0	0.0
Apr	26,589.9	9,799.7	36.9	14,991.3	56.4	2,568.6	9.7	769.7	2.9
May	87,366.6	15,406.5	17.6	33,743.2	38.6	38,217.6	43.7	0.0	0.0

Table 3. Summary of % overlap of Bluenose-East (BNE), Bathurst (BAT) and Beverly (BEV) caribou herd monthly ranges in 2019/2020 harvest season based on 95% kernel UD isopleths.

Month	BNE (km²)	BAT overlap (km²)	BAT overlap (%)	BEV overlap (km²)	BEV overlap (%)	BNE (km²) No Overlap	BNE (%) No Overlap	BNE (km²) BAT&BEV Overlap	BNE (%) BAT&BEV Overlap
Jan	-	-	-	-	-	-	-	-	-
Feb	47,184.0	8,735.9	18.5	718.6	1.5	38,448.1	81.5	718.6	1.5
Mar	37,244.4	10,979.1	29.5	0.	0	26,265.4	70.5	0	0
Apr	39,028.8	9,799.7	25.1	1931.5	4.9	28,067.3	71.9	769.7	2.0
May	91,421.2	15,406.4	16.9	0	0	76,014.8	83.1	0	0

In late fall and winter of 2020/2021, the Beverly herd overlapped the Bathurst monthly winter ranges 97.2-100% excluding May (start of spring migration) when the Beverly herd overlap was 88%. Complete overlap of the monthly ranges of Bathurst by the Beverly was observed December through March. Bathurst was overlapped by the Bluenose-East only 1.9% in October but then increasing from 31.1% in November through to 59.1% in January. From February through to May Bluenose-East overlap of Bathurst winter ranges decreased to 30.5%. Both herds overlapped the Bathurst winter range minimally in October (1.9%) and then followed the same pattern of increasing to a maximum overlap of 59.1% in January and then decreasing through to May (27.9% overlap) (Table 4). In late fall and winter of 2020/2021, the Bathurst monthly winter ranges overlapped the Bluenose-East minimally in October (4%) and by variable amounts ranging from 15.8-45.8% November through May. The Beverly herd monthly winter ranges overlapped those of the Bluenose-East with a similar pattern, minimal in October (4%) and variable amounts November through May (26.3-56.8%). Both Bathurst and Beverly overlapped Bluenose-East monthly winter ranges from 16.8-45.8% from November through May and again 4% in October before and during the rut (Table 5).

Table 4. Summary of % overlap of Bathurst (BAT), Bluenose-East (BNE) and Beverly (BEV) caribou herd monthly ranges in 2020/2021 harvest season based on 95% kernel UD isopleths.

Month	BAT (km²)	BNE overlap (km²)	BNE overlap (%)	BEV overlap (km²)	BEV overlap (%)	BAT (km²) No Overlap	BAT (%) No Overlap	BAT (km²) BNE&BEV Overlap	BAT (%) BNE&BEV Overlap
Oct	70,378.3	1,322.2	1.9	69,834.6	99.2	543.7	0.8	1,322.2	1.9
Nov	33,613.0	10,443.0	31.1	32,664.5	97.2	948.5	2.8	10,443.0	31.1
Dec	23,354.6	13,006.8	55.7	23,354.6	100	0	0	13,006.8	55.7
Jan	22,538.8	13,313.5	59.1	22,538.8	100.0	0.0	0.0	13,313.5	59.1
Feb	40,995.9	23,275.9	56.8	40,995.9	100.0	0.0	0.0	23,275.9	56.8
Mar	59,698.7	33,120.3	55.5	59,698.7	100.0	0.0	0.0	33,120.3	55.5
Apr	98,048.7	46,618.9	47.5	97,161.6	99.1	887.1	0.9	46,618.9	47.5
May	116,025.6	35,375.3	30.5	102,092.1	88.0	10,877.5	9.4	32,319.4	27.9

Table 5. Summary of % overlap of Bluenose-East (BNE), Bathurst (BAT) and Beverly (BEV) caribou herd monthly ranges in 2020/2021 harvest season based on 95% kernel UD isopleths.

Month	BNE (km²)	BAT overlap (km²)	BAT overlap (%)	BEV overlap (km²)	BEV overlap (%)	BNE (km²) No Overlap	BNE (%) No Overlap	BNE (km²) BAT&BEV Overlap	BNE (%) BAT&BEV Overlap
Oct	32,994.6	1,322.2	4.0	1,322.2	4.0	31,672.5	96.0	1,322.2	4.0
Nov	62,035.1	10,443.0	16.8	22,992.8	37.1	39,042.3	62.9	10,443.0	16.8
Dec	75,601.1	13,006.8	17.2	27,920.4	36.9	47,680.7	63.1	13,006.8	17.2
Jan	84,084.6	13,313.5	15.8	28,465.0	33.9	55,619.6	66.1	13,313.5	15.8
Feb	94,148.3	23,275.9	24.7	41,956.0	44.6	52,192.3	55.4	41,956.0	44.6
Mar	99,650.2	33,120.3	33.2	51,362.5	51.5	48,287.6	48.5	33,120.3	33.2
Apr	101,735.5	46,618.9	45.8	57,760.3	56.8	43,975.2	43.2	46,618.9	45.8
May	139,422.0	35,375.3	25.4	36,625.7	26.3	99,740.3	71.5	32,319.4	23.2

Summary of Winter Distribution Analysis

Based on winter 2020/2021 collar data, the Bathurst monthly range extents were almost completely overlapped (99-100%) by the Beverly caribou from October to April. At the start of spring migration in May, that overlapped decreased to 88%. Both Beverly and Bluenose-East overlapped the Bathurst winter range minimally in October (1.9%) with increasing coverage from November (31.1%) through January (59.1%) and then decreasing February (56.8%) through May (27.9%). In comparison, in winter 2019/2020 the monthly overlap of the Bathurst by the Beverly herd (February through May) was quite a bit less and varied between 36-56% with no directional trend. There was negligible overlap (i.e., 0-4%) of the monthly ranges of all three herds in winter 2019/2020.

The Bluenose-East monthly winter range extents in 2020/2021 were overlapped minimally in October (4%) by Bathurst and Beverly herds and then variable amounts ranging from 16.8-45.8% from November through to May, with no directional trend. Because of the almost complete overlap of Bathurst monthly ranges by the Beverly herd, the amount of overlap of the Bluenose-East herd ranges by those two caribou herds is almost identical. In contrast, the 2019/2020 winter season showed 16.9-29.5%, of the Bluenose-East monthly winter ranges were overlapped by the Bathurst, and very little overlap by Beverly (i.e., 0-5%), or Beverly combined with Bathurst (i.e., 0-2%).

The high amount of spatial overlap by all three herds in winter 2021, 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 herd estimates) 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.

AERIAL SURVEY OF WOLVES

From March 22-31, 2021, the Department of Environment and Natural Resources (ENR[5]) conducted an aerial survey of the Bathurst winter range within the North Slave Region to estimate wolf abundance and test a geospatial survey methodology on wolves. Because the monthly winter range distribution of Bathurst caribou (as defined by the 95% KDE isopleth of collared caribou) had been completely spatially overlapped by the Beverly herd with about 55% mean monthly overlap with the Bluenose-East herd (Table 2, Figure 1), we expected a higher density of wolves within the survey area than if there was no spatial overlap with the two adjacent caribou herds.

The survey objectives were to estimate wolves within the winter range of the Bathurst herd, assess survey methodology and precision, and determine whether the resulting wolf survey estimate was consistent with extrapolated wolf densities based on an ungulate (i.e., caribou) biomass index (UBI) and the spatial overlap with adjacent caribou herds. The survey fulfilled the WRRB's recommendation (#2- 2020) to: *identify alternative methods to measure and index dìga abundance and calibrate these with the UBI to ensure the most accurate and precise population estimates are used for dìga management by May 31, 2021*. Due to logistical challenges and the large geographic area involved, the survey was focused on the Bathurst winter range due to the large number of Bluenose-East caribou overwintering within the Sahtú region (north of Great Bear Lake) and Beverly caribou in the Kitikmeot region.

Initially it was ENR's intent to conduct a wolf abundance survey on the winter range to test wolf track survey methods (e.g. Stephenson 1978, Becker et al. 1998, Patterson et al. 2004, Gardner and Pamperin 2014) using small fixed wing aircrafts with pilots and observers experienced in spotting and following wolf tracks. Although aerial survey methods for estimating wolf abundance in Alaska and elsewhere are based on a combination of tracking and observing wolves, aerial wolf tracking has not yet been attempted on a broad geographic scale such as on the winter range of large migratory caribou herds, which may include hard packed snow conditions.

GNWT issued a Request for Tenders in late February 2021 but received no bids. Therefore, ENR was unable to conduct the initially intended design for a wolf track survey on the central barrens. Plans were changed to conduct a geospatial survey by helicopter. The time required to design a new survey and procure suitable aircraft resulted in the survey being delayed into late March. Geospatial survey designs are used to survey wildlife populations that are spatially correlated in their distribution. They have advantages over other survey designs primarily because of their flexibility in sample design (i.e., nonrandom), reduced vulnerability to weather interruptions and increased precision of the estimate (Kellie and Delong 2006). Given the challenge of reliably detecting wolf tracks on densely packed snow,

[5] The GNWT re-named ENR to Environment and Climate Change (ECC) in 2023 but the earlier departmental name has been retained where needed in this report.

or difficulty of tracking wolves that followed caribou trails, the primary means of detecting wolves was by direct observation of wolves within the designated survey blocks.

Survey Methods

Because of the changes in caribou distribution through the winter, we delineated an initial wolf survey area based on the 95% kernel density UD of known collared Bathurst caribou for a two-week period, 6-20 March 2021 (Figure 5). We used this criterion to initially select a survey area that would be representative of the March distribution of Bathurst caribou and provide a basis for estimating late winter wolf abundance. A grid was overlaid with a cell size of 8x8 km (or 64 km^2). That process resulted in identifying 940 contiguous grid cells which was expected to be too many to survey in a timely or cost-effective manner. Permits for this year's survey did not include work in NU, so we selectively removed 18 grid cells that overlapped with the NU boundary. We also removed three other cells we could not likely survey completely (e.g. mine footprint sites). Finally, we removed another 292 grid cells along the perimeter, most of which were along the southeastern and southwestern sides and far removed from current collared caribou locations and therefore likely devoid of caribou, and by association, wolves. We did not remove any grid cells that were on large lakes because frozen lakes are commonly used by caribou and wolves. Consequently, the final survey area covered 40,128 km^2, or 627 grid cells.

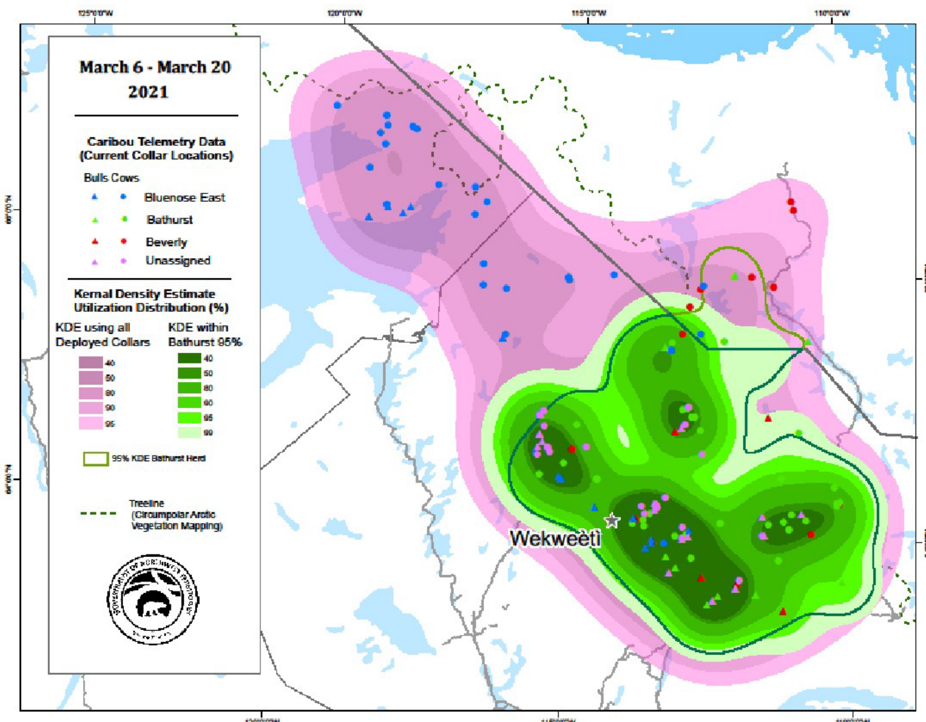


Figure 5. Caribou collar locations and UD contours for all three herds combined (pink) and those contours within Bathurst 95% KDE isopleth (green), March 6-20, 2021.

We stratified the survey area on the premise that wolf abundance, i.e., high or low probability of wolf presence, would primarily be associated with caribou density. Therefore, we identified areas with higher concentrations of caribou distribution as a proxy for wolf occurrence using a KDE that encompassed all collared caribou within the survey area including caribou that had been recently collared (Figure 6). We chose the 80% KDE polygons representing caribou density to identify which grid cells comprised the high probability stratum for seeing wolves (n=444) while the remainder were deemed low probability cells (n=183). In Figure 6, the pink shaded cells depict high probability cells for observing wolves (based on expected caribou density), and the green cells show locations of the low probability cells for wolves.

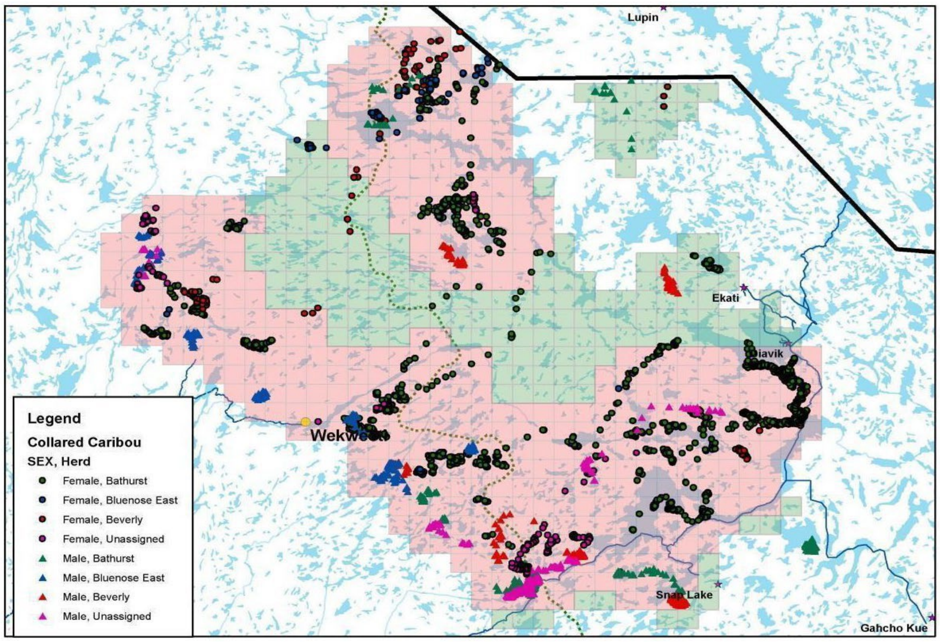


Figure 6. Stratification of survey area based on caribou density inferred from 95% KDE isopleths for Bathurst, Bluenose-East and Beverly caribou herds, March 6-20, 2021. The pink areas represent high density stratum and green the low-density stratum.

With consideration given to available hours of helicopter flight time as well as positioning times and available fuel, a sample of 160 blocks was selected to be surveyed (25.5%). About 85% of sampling effort was allocated to the high-density stratum in which 135 of 444 cells were selected (30% coverage); the remaining sampling effort was allocated to survey 25 of 183 cells in the lower density stratum (14% coverage) (Figure 7). Selection of grid cells within each of the strata was done at random for 80% of them. The remaining 20% of cells were selected subjectively by filling in any larger areas not sampled in the random selection process. The geospatial method is robust to this procedure and it is recommended to do so (Kellie and DeLong 2006).

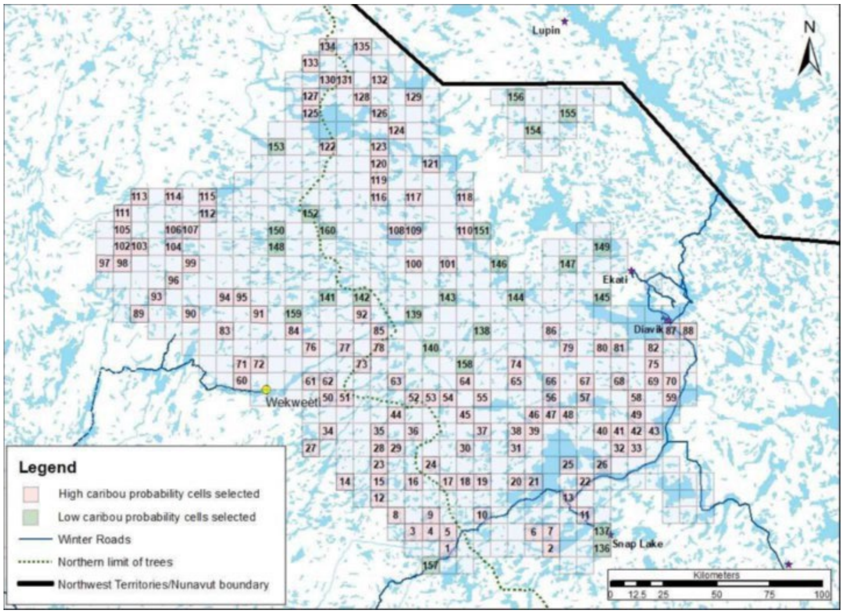


Figure 7. Distribution of 8x8 km survey blocks in areas of higher caribou abundance (135 pink cells) and lower caribou abundance (25 green cells).

Survey Results

Two Bell 206L helicopters were used to survey the 160 blocks based out of the community of Wekweètì. Survey crews comprised a pilot, front seat navigator/observer/data recorder, and a rear seat observer. Although the crews' focus was on wolves, other wildlife observations (i.e., caribou, moose, muskox and wolverine) within survey blocks were also recorded. The survey took place from March 22-31. A total of 74.8 survey hours were flown across the 160 survey blocks by the two helicopters (Figure 8).

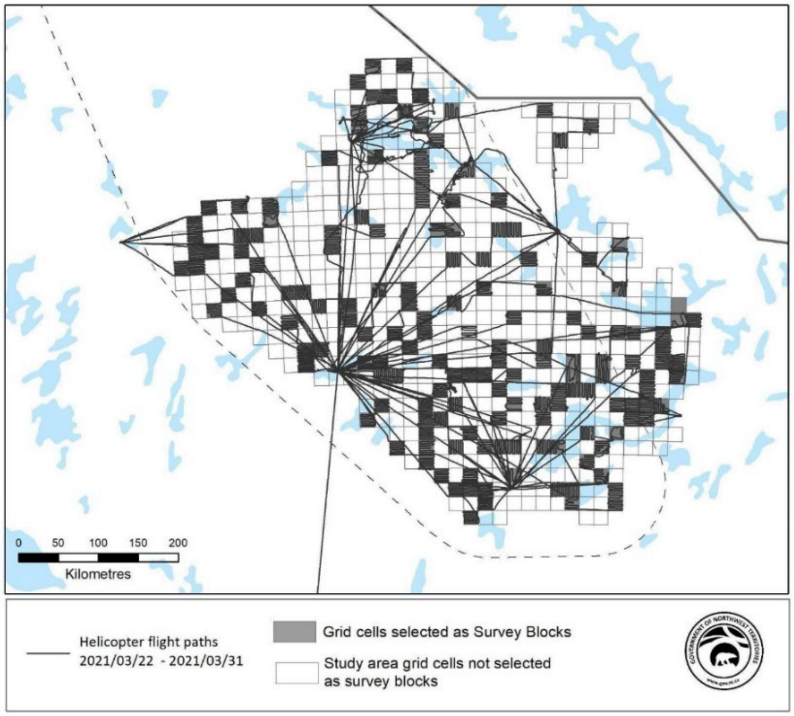


Figure 8. Flight paths of the two-survey aircraft across the 160 blocks.

We saw a total of 26 wolves in nine grid cells and approximately 26,464 caribou in 156 grid cells (Figures 9, 10). In seven of the nine grid cells with wolf observations, caribou were also observed. In addition, 133 muskoxen were observed along with 24 moose and four wolverine. While the survey was flown in late March, ground harvest was ongoing predominantly in the Point Lake and Itchen Lake area removing a total of 42 wolves in March with 21 during the survey time period (Figure 10).

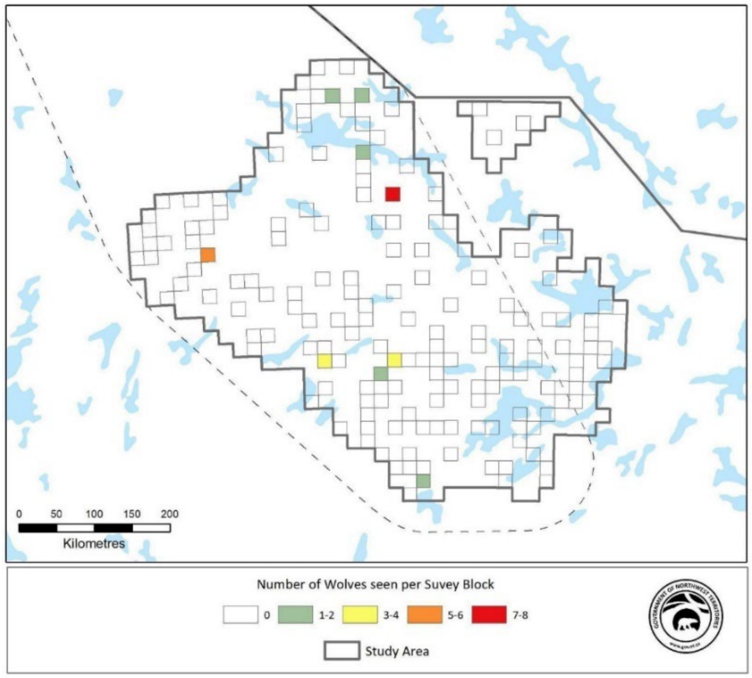


Figure 9. Wolves sighted per survey block. Dotted line represents the North Slave Wolf Harvest Incentive Area (see GNWT's North Slave Wolf Harvest Incentive Program below).

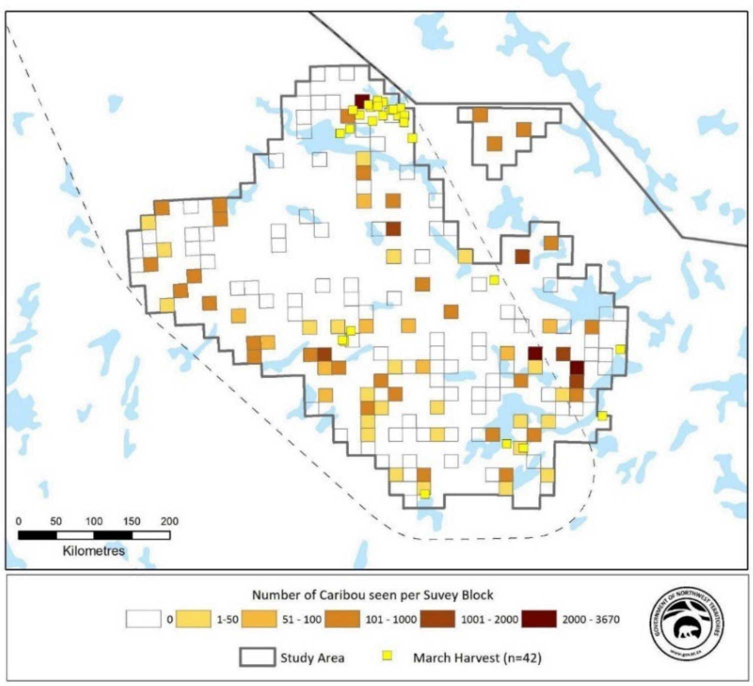


Figure 10. Caribou sighted per survey block. Dotted line represents the North Slave Wolf Harvest Incentive Area (see GNWT's North Slave Wolf Harvest Incentive Program below).

Using WinfoNet Geospatial Population Estimator Software, hosted by the Alaska Department of Fish and Game (https://winfonet.alaska.gov), abundance estimates were derived for wolves and caribou (Table 6). We derived an overall estimate of 89 wolves in the survey area with a standard error of 29.7 and a 95% confidence limit from 31 to 147 wolves in the study area. An estimate of 101,921 caribou was derived with a standard error of 21,150 and 95% confidence limits of 70,845 to 132,996 caribou.

Table 6. Abundance of wolves and caribou derived from a geospatial population estimator wolf survey in the North Slave Region, 22-31 March 2021.

	Low Density Stratum (km^2)	**High Density Stratum (km^2)**	**Total Survey Area (km^2)**
	11,712	28,416	40,128
Wolves			
Population Estimate	0	89	89
Standard Error (SE)	2.2	29.7	29.7
Coefficient of Variation (CV)	n/a	33.3%	33.4%
95% Lower Limit	-4	31	31
95% Upper Limit	4	147	147
Density (animal/km^2)	0	0.003	0.002
Caribou			
Population Estimate	25,219	76,701	101,921
Standard Error (SE)	7,343	14,052	15,855
Coefficient of Variation (CV)	29.1%	18.3%	15.6%
95% Lower Limit	10,828	49,159	70,845
95% Upper Limit	39,611	104,243	132,996
Density (animal/km^2)	2.153	2.699	2.540
95% Lower Limit	0.925	1.730	1.765
95% Upper Limit	3.382	3.668	3.314

Based on the proportion of caribou collars in the survey area in March 2021 and an extrapolated herd size (Nishi et al. 2020) we estimated the number of caribou we might expect to be in the survey area for each herd along with the corresponding number of wolves based on an ungulate biomass index (Table 7).

Table 7. Estimated number of caribou and wolves within the 95% KDE contour of Bathurst herd, as of March 20, 2021 using known collars deployed prior to February 2021, extrapolated herd sizes and UBI.

	Est. # Caribou in 2020*	Est. # Wolves (UBI)	Caribou Collar # in BATH 95% KDE (NSR)	Proportion Collars	Est. # of Caribou Based on This Proportion	Est. # Wolves Based on This Proportion
BNE	12,154	138	15/42	0.35714	4,341	49
Bathurst	4,567	55	44/47	0.93617	4,275	51
Beverly	95,458	1,029	10/19	0.55556	53,033	572
Total	**112,179**	**1,222**			**61,649**	**672**

*see Nishi et al. 2020 s. 5 for methods for estimating 2020 herd sizes and applying UBI.

We examined movements of collared wolves in the survey area to test the assumption of a closed population during the timing of the survey. Figure 11 shows collared wolf movements relative to the study area and stratification boundaries. With the exception of one or two animals there did not appear to be large-scale directional movements or movements out of the stratification boundaries. However there does appear to be movement out of grid cell boundaries which may have affected results. Table 8 shows that for 12 collared wolves in the survey area from March 22-31, 2021, seven (58%) were within the boundaries the entire time, three (25%) of the collars left the survey area and two individuals (17%) started within the boundaries, moved out and returned. Three of the twelve wolves moved between high and low density strata.

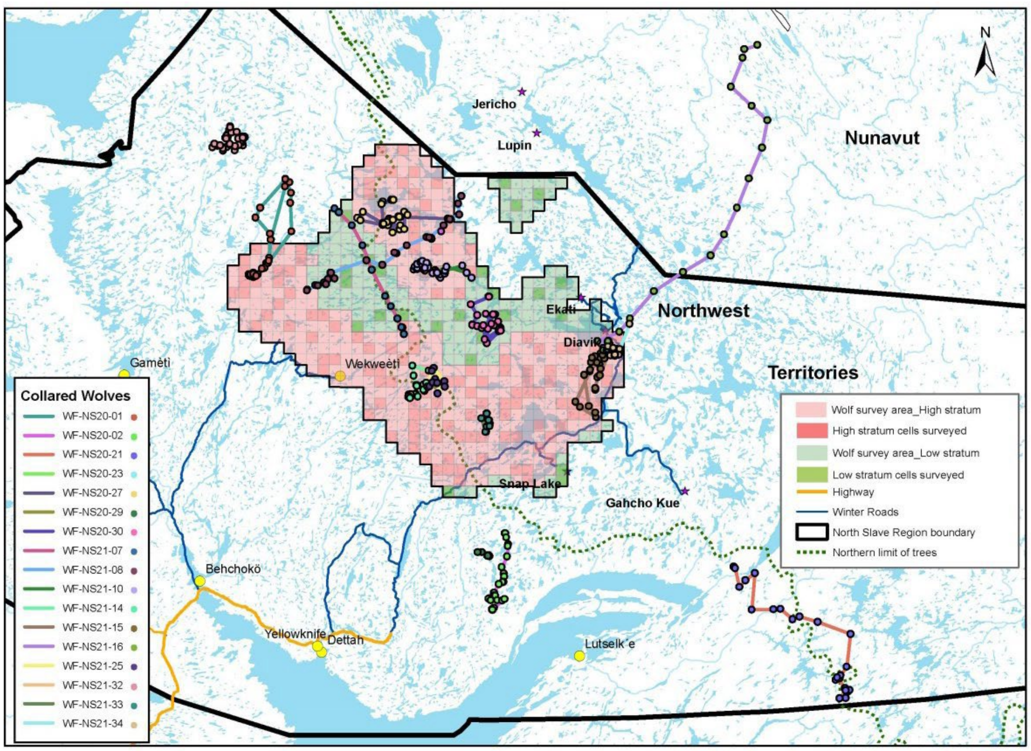


Figure 11. Collared wolf movements in the survey area March 22-31, 2021.

Table 8. Collared wolf locations by grid cell stratum during the aerial abundance survey, 22-31 March 2021.

Wolf Id	Grid Cells Traversed in Survey Area: High Stratum	Low Stratum	Total	Days in Survey Area: Total Days	Date Range
Wolves inside survey area and remained inside during survey					
20-27	15		15	10	22-31 Mar.
20-30		13	13	10	22-31 Mar.
21-10	10	1*	11	10	22-31 Mar.
21-14	7		7	10	22-31 Mar.
21-15	17		17	8	24-31 Mar.
21-25	5		5	4	28-31 Mar.
21-33	5		5	4	28-31 Mar.
Wolves inside survey area, moved outside area, but came back inside before survey ended					
20-01	8		8	3+6	22-24 Mar.; 26-31 Mar.
21-07	2	14	16	4	27-30 Mar.
Wolves inside survey area but then left area during survey and did not re-enter					
21-08	11	9	20	7	24-30 Mar.
21-16	5		5	4	25-28 Mar.
21-34	5		5	5	27-31 Mar.

* Virtually all time in the high stratum as only one location in a low stratum grid cell.

Sighting Rates

During the wolf abundance survey conducted in March 2021 the two helicopters flew a total of 69.3 hours and observed 26 wolves in nine separate encounters for an overall sighting rate of 0.37 wolves/hour and 0.13 encounters/hour (Table 9).

Table 9. Search effort and sighting rates of wolf survey crew, March 2021.

Date	Hours on Survey	# Caribou Obs	# Wolf Obs	# Wolf Encounters	Pack Size	Wolves/Hr	Encounters/Hr
22-Mar	3.8	631	0	0	0	0.00	0
23-Mar	9.0	4,088	6	1	6	0.67	0.074
24-Mar	10.1	1,551	2	2	1,1	0.20	0.020
25-Mar	8.5	5,223	7	4	3,1,2,1	0.82	0.097
26-Mar	4.8	131	0	0	0	0.00	0
27-Mar	7.9	4,406	0	0	0	0.00	0
28-Mar	7.3	1,732	3	1	3	0.41	0.056
29-Mar	7.9	4,108	8	1	8	1.01	0.128
30-Mar	8.3	4,517	0	0	0	0.00	0
31-Mar	1.8	77	0	0	0	0.00	0
Sum	**69.3**	**26,464**	**26**	**9**		**0.37**	**0.130**

Aerial Survey Summary

The estimate of 89 wolves (31-147, 95% confidence limits) on the Bathurst winter range in March 2021 had low precision (CV=33.4) and therefore there is a limited ability to detect numerical change. Reduced sightability of wolves on the winter range especially when stationary, bedded or within treed habitat and their inherent low densities and clumped distribution provide key challenges to designing surveys to accurately estimate wolf abundance. The low sighting rate (0.37 wolves/hour of flying) is perhaps indicative of these challenges.

One factor that could have influenced the precision of the estimate is if the stratification was not reflective of actual wolf density. In absence of information on relative abundance of wolves in the survey area, the 95% KDE contours for the March 6-20 Bathurst range were used to stratify the survey. While a reasonable assumption, difficulty in characterizing caribou abundance meant wolf abundance was likely not adequately represented. Due to the low numbers of collars on the Beverly herd and that the Beverly herd is approximately 12.5 times the size of the Bathurst herd (based on 2018 herd estimates), the KDE contours likely did not adequately represent actual density of Beverly caribou, confounding the stratification. The caribou densities estimated for the low and high survey strata and associated confidence limits show caribou densities were not significantly different between the two strata. Further, only 6% of the survey blocks contained wolf observations while 98% of the survey blocks contained caribou observations. Mattson et al. (2009) estimated 211±66 wolves and 41,004±8,431 caribou on the Bathurst winter range in 2006; an area encompassing 494,000 km^2 and when the Bathurst herd was estimated at 128,000. Their work showed a weak relationship between wolf and caribou abundance suggesting that stratification based on caribou density alone did not appear to adequately represent wolf abundance and distribution.

While the geospatial survey design has benefits related to accommodating spatial auto- and cross-correlation of observations (Kellie and DeLong 2006) it is challenging for surveying wolves on the barrens. Wolves are mobile animals and grid cell size needs to be large enough to accommodate movement during the survey. Survey timing is also critical and should be conducted when wolves tend to move less, likely when caribou tend to slow down their daily movements during mid-winter (December through February). Based on the movements of collared wolves during the survey period it is possible the sampling design and timing was not optimal. The detectability of wolves is also a key factor, and that wolves tend to be clumped in distribution and at relatively low densities further affect survey results.

The wolf abundance survey was conducted March 22 to March 31 and the geospatial survey design, assume a closed population during the time period of the survey. This assumption could have been violated in two ways. Collared wolf movements show a fair amount of movement into and out of the survey area and likely among grid cells, a small proportion (17%) of which show directional movement likely associated with caribou movements. Towards the end of March, caribou were observed to be beginning their movements north-eastward towards their calving grounds. The March KDE for caribou winter distribution (Figure 1) shows the beginning of that range extension into NU in the northeast portion of the range. While wolf movements in spring often precede those of caribou (Hansen et al. 2013), this early spring directional movement was unexpected. Secondly, we have records of 107 wolves harvested from January through to the end of March and of those, 21 were taken within the survey area while the survey was taking place. Survey timing was largely influenced by the logistical challenges of procuring survey crew and aircraft in winter 2021 resulting in the survey being conducted later than desired and corresponding with unexpected, early spring movements of caribou and wolves.

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 2022.

WOLF COLLARING

The wolf collaring program is intended to enhance monitoring efforts and improve our understanding of wolf movements within and between caribou herds on the central barrens. Wolves show fidelity to den sites with summer movements centred around those dens, whereas wolf movements later in the fall and throughout the winter are dictated largely by caribou distribution (Walton et al. 2001). While previous studies in the central mainland NWT have looked at wolf movements in relation to Bathurst caribou movements (Hansen et al. 2013) and seasonal range use (Klazcek et al. 2015), analyses specifically looking at coincident movements of wolves with several caribou herds is unique.

The main objectives for the wolf collaring program are to:

- Determine how wolves travel among caribou on their winter ranges;
- Determine broader wolf movement patterns across caribou ranges 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-ʔekwǫ̀ spatial distribution, including reducing the uncertainties involved with assigning dìga to ʔekwǫ̀ herds*.

Wolf Capture and Collaring Methods

In the winters of 2020 and 2021, 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, net gunner, together with ENR handlers, carried out the capture efforts using an A-Star helicopter. One wolf was to be collared per pack. Wolves were searched for and positioned appropriately for the net-gunner. Once a wolf was netted and the helicopter landed, it was physically restrained with leg hobbles and blindfolds were placed over the eyes to help calm the animals; no drugs were used to immobilize captured wolves. For each wolf handled, data were collected on pack size, general condition, sex and age (estimated from tooth wear). The capture and collaring of wolves adheres to NWT Standard Operating Procedures for the handling of wolves to minimize trauma and stress to the animal and is conducted under a Wildlife Research Permit (www.gov.nt.ca/ecc/en/services/apply-research-observe-and-hangle-wildlife-nwt) with review and recommendations by the NWT Wildlife Care Committee (www.gov.nt.ca/ecc/en/services/apply-research-observe-and-handle-wildlife-nwt/wildlife-care-committee).

Wolf Collar Deployment in 2020

In winter 2020, a total of 16 wolves were captured between March 13 and April 29, with 13 collars deployed on the Bathurst and Bluenose-East caribou winter ranges, (Table 10, Figures 12 and 13). Initial herd assignments were derived based on methods described in Nishi et al. (2020) and were reassessed in Caribou Herd Affiliation of Wolf Mortalities below.

Table 10. Wolf collar deployments and herd assignments in 2020.

Date	Initial Herd Assignment	Collar ID	Sex
13-Mar	BATH	NS20-29	F
16-Mar	BNE	NS20-27	M
17-Mar	BNE	NS20-30	M
17-Mar	BNE	NS20-13	F
18-Mar	BNE	NS20-12	M
19-Mar	BNE	NS20-18	M
19-Mar	BNE	NS20-19	M
19-Mar	BNE	NS20-26	M
1-Apr	BNE	NS20-21	F
25-Apr	BNE	NS20-01	M
26-Apr	BNE	NS20-22	F
27-Apr	BATH	NS20-02	F
29-Apr	BATH	NS20-23	F

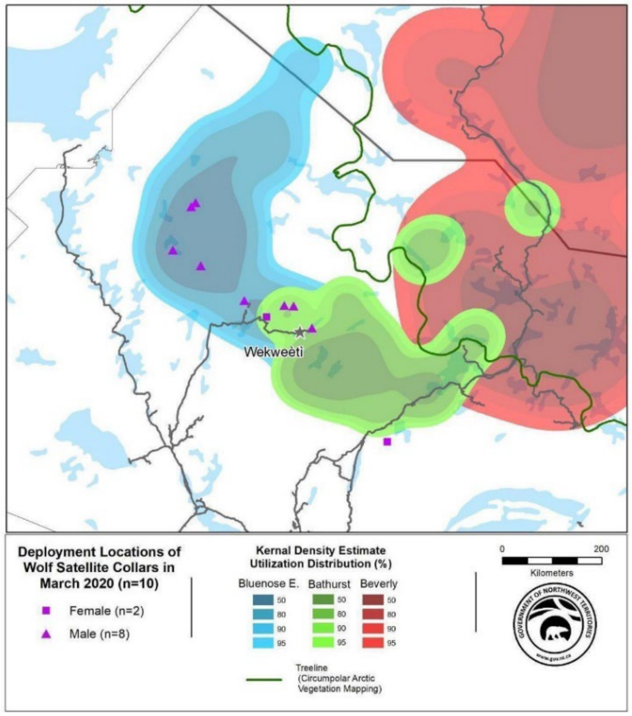


Figure 12. Wolf captures in March 2020 in relation to UD of Bathurst, Bluenose-East and Beverly caribou herds

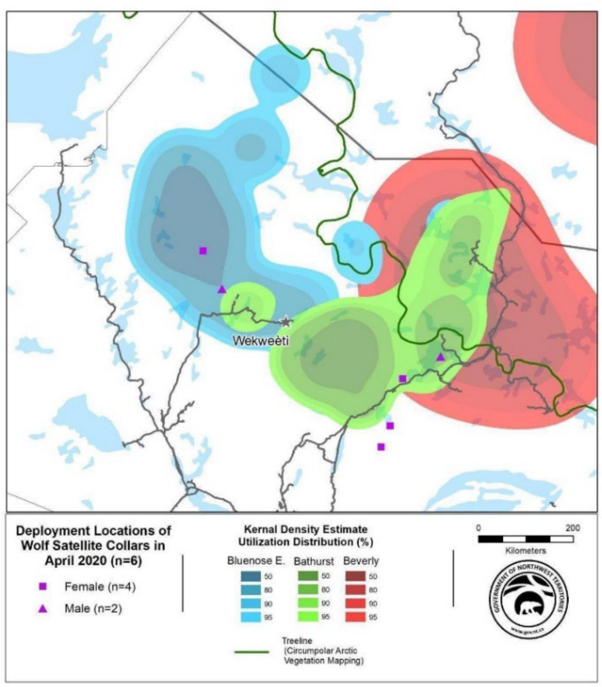


Figure 13. Wolf captures in April 2020 in relation to UD of Bathurst, Bluenose-East and Beverly caribou herds.

During the collaring, two male wolves died during the capture and handling process due to choking and suffocation on March 16 and March 31 respectively. Necropsies confirmed these causes of death. A male wolf captured on April 1 had skin lesions of unknown cause and was assessed by the capture crew as unhealthy. The crew then sought and received permission to euthanize this animal. A subsequent necropsy, diagnosed hemorrhage, bruising and puncture wounds in this wolf consistent with attempted predation or aggression, likely by another wolf or wolves.

Post-capture Mortalities and Follow-up on Wolves Collared in 2020

Of the 13 wolves captured and collared in March and April 2020, six wolves died and one wolf has a malfunctioning GPS transmitter on its collar.

- One female wolf traveled at least 124 km before dying nine days post capture. When the crew visited the mortality site, they found the wolf carcass had been slightly scavenged, caribou were in the area and wolves were heard howling nearby. The crew speculated as to whether this wolf might have been kicked while chasing caribou.
- A male wolf died 28 days post capture, after having made a significant northern excursion towards Kugluktuk and back, conservatively traveling 879 km in four weeks. A subsequent necropsy found it to be in poor health and nutrition.
- One female wolf died in late summer in an emaciated state. The carcass appeared to be in extremely poor nutritional condition with the cause of death being most likely starvation and dehydration.
- A male wolf died northwest of Kugluktuk. Local Inuit who investigated the site suspect that this wolf had been killed by an adjacent wolf pack since the wolf had been heavily scavenged.
- Two additional collared male wolves died, one in late summer, the other in the fall. The first was in a remote area to the northeast of Contwoyto Lake; several bones subsequently retrieved several months later provided few clues as to cause of death. The second apparent mortality was unable to be investigated.
- One collar has been malfunctioning since June 2021. It is not sending a GPS location but is still transmitting satellite locations.

Wolves Captured and Collared in 2021

Prior to initiation of collaring in 2021, there were seven wolves with functional collars from 2020. Between March 11 and 31, 2021 an additional 19 GPS collars were deployed on wolves on the Bluenose-East, Bathurst and Beverly winter ranges (Figure 14).

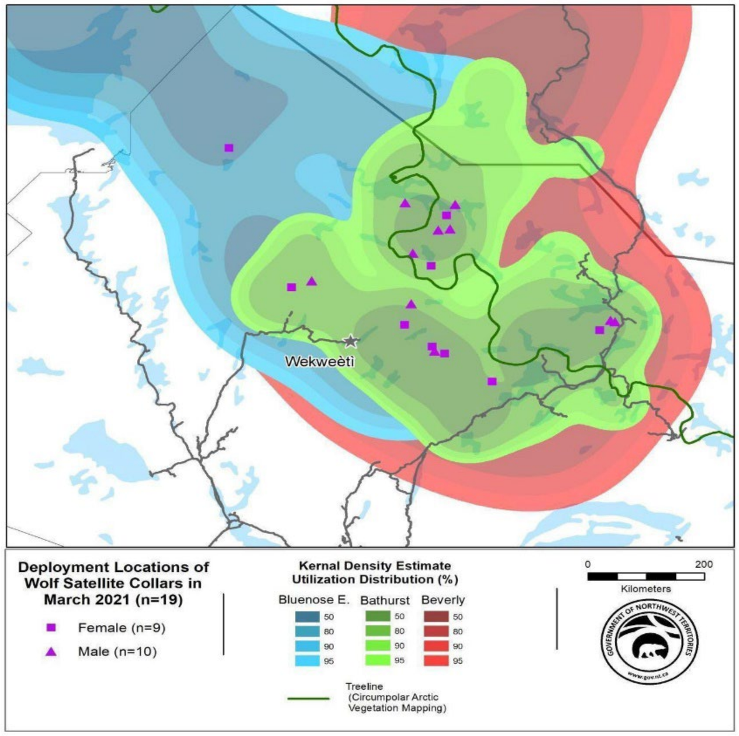


Figure 14. Wolf collar deployments in March 2021 in relation to UD of Bathurst, Bluenose-East and Beverly caribou herds.

ENR contracted a small fixed-wing airplane (Aviat Husky) to assist with spotting wolves for collaring. The first flight occurred on March 18, 2021 in the Grizzle Bear Lake area between Lockhart Lake and Wekweètì, then back to the Hoarfrost River base (6.1 hours total trip time). Numerous caribou were observed during the flight, plus two muskoxen and one wolverine, but only two lone wolves were seen (southeast of Grizzle Bear Lake) about 7 km apart. These two wolf sightings were reported to the capture crew and both wolves were subsequently collared. The pilot also noted that no kill sites or ravens were observed during the flight.

A second flight occurred on March 24, 2021 between Mackay Lake and Lac de Gras. Total flight time was 6.6 hours and many thousands of caribou were observed. Only two wolves were observed near the end of the day and as a result of being directed to search that area by the capture crew. During that time, the capture crew found another wolf elsewhere and proceeded to capture and collar it. Meanwhile, the pilot of the Husky airplane found two wolves in the area he was directed to search and circled high overhead to keep the wolves in sight until the capture crew could arrive. Given the behaviour of the wolves and distance between them, the wolves were assumed to be from different packs and captured and collared. Subsequent movements of these two collared wolves showed they were not traveling together and therefore not likely to be associated with the same pack. No kill sites or ravens were observed during this second Husky flight.

Table 11 shows the date, ID and sex of the 19 wolves collared in winter 2021. Of the 54 wolves encountered during the March caribou and wolf collaring efforts, five were captured as solitary animals. Of the remaining 14 wolves collared, pack sizes ranged from two to five wolves (average pack size was 3.6).

Table 11. Wolf collar deployments in 2021.

Date	Collar Id	Sex
03-11-2021	WF-NS21-05	Female
03-15-2021	WF-NS21-08	Female
03-16-2021	WF-NS21-10	Male
03-16-2021	WF-NS21-06	Female
03-18-2021	WF-NS21-14	Female
03-18-2021	WF-NS21-11	Male
03-22-2021	WF-NS21-32	Female
03-23-2021	WF-NS21-03	Male
03-24-2021	WF-NS21-15	Female
03-24-2021	WF-NS21-16	Male
03-27-2021	WF-NS21-07	Male
03-27-2021	WF-NS21-34	Male
03-28-2021	WF-NS21-25	Female
03-28-2021	WF-NS21-33	Female
03-29-2021	WF-NS21-20	Male
03-31-2021	WF-NS21-04	Male
03-31-2021	WF-NS21-28	Male
03-31-2021	WF-NS21-24	Female
03-31-2021	WF-NS21-17	Male

Collar deployment locations of all collared wolves are shown in Figure 15. The composition of the collared individuals was ten males and nine females. Based on tooth wear, sixteen of these adults were estimated between two and five years of age. Heavier patterns of tooth wear and breakage suggested three wolves were six years of age or more. Each collared wolf received a single ear tag, providing an additional means of identifying individuals, which allows identification of wolves once the break-away device releases the collar. The observed health and body condition of captured wolves ranged from average to slightly above average. None of the 19 captured wolves were assessed as being either abnormally under or overweight.

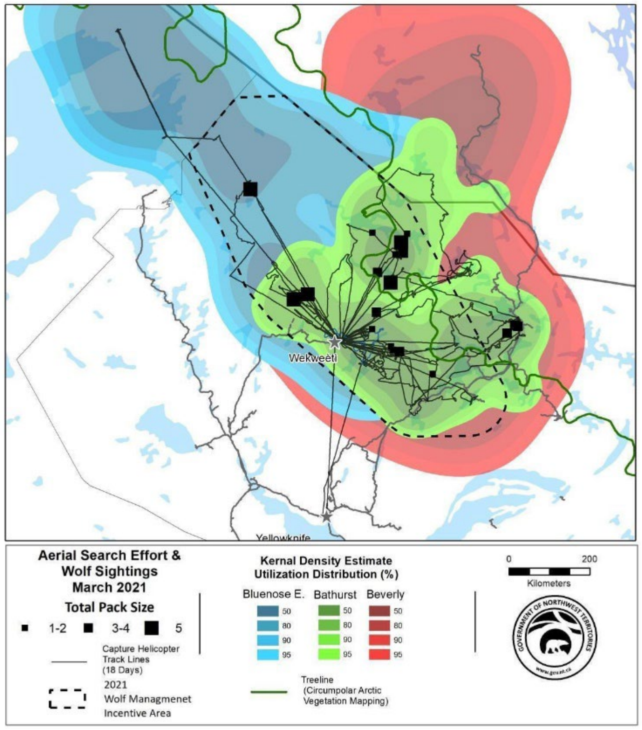


Figure 15. Track logs of wolf collar deployment flights and observed wolf pack size, March 2021.

Using methods described in Caribou Herd Affiliation of Wolf Mortalities below, herd affiliation was derived for the collared wolves (Table 12). Because of the extent of overlap of the Bathurst, Bluenose-East and Beverly caribou herd KDE UDs, in only 37% of the cases could a single herd be assigned to a given wolf capture location.

Table 12. Spatial overlap of wolf capture locations in March 2021 with distributions of collared caribou from Bluenose-East, Bathurst and Beverly herds.

	1 Herd*			2 Herds			3 Herds	Count
Winter 2021	**BNE**	**BAT**	**BEV**	**BNE-BAT**	**BNE-BEV**	**BAT-BEV**	**BNE-BAT- BEV**	
March	3	1	3	0	0	7	5	19
Sum	7			7			5	19
%	37%			37%			26%	100%

Post Capture Follow-up 2021

Unfortunately, the first wolf collared on March 11 was subsequently harvested by ground-based hunters the next day. Between June 4 and 6 three collared wolves became stationary indicating that they likely died, but the collars have not yet been retrieved or investigated.

Sighting Rates

During the helicopter flights for collar deployment, 54 wolves were observed in 19 separate encounters during 36.7 hours of flying (Table 13). Pack sizes ranged from one to five. Crews had on average 0.64 encounters per hour of flying and sighted 1.82 wolves per hour. In 2020, the aerial removal crew observed 1.05 and 0.7 wolves per hour of flying (see Table 18, Nishi et al. 2020)

Table 13. Search effort, sighting and encounter rates of wolf collar deployment crew, March 2021.

Date	Ferry (hr)	Ground (hr)	Survey (hr)	Total (hr)	# Wolves	# Encounters	Pack size	Wolf/hr	Encounters/hr
11-Mar	0.2	1.6	0.9	2.7	1	1	1	1.1	1.1
12-Mar	0.2	4.8	1.9	6.8	0	0	0	0.0	0
13-Mar	0.7	3.4	1.2	5.3	0	0	0	0.0	0
15-Mar	0.4	0.4	0.4	0.4	5	1	5	12.5	2.5
16-Mar	0.5	3.7	2.5	6.7	8	2	3,5	3.2	0.8
17-Mar	0.5	5.6	1.1	7.2	0	0	0	0.0	0
18-Mar	0.1	3.3	2.5	5.9	2	2	1,1	0.8	0.8
19-Mar	0.5	2.3	0.9	3.8	0	0	0	0.0	0
22-Mar	0.1	3.8	2.7	6.6	5	1	5	1.9	0.4
23-Mar	0.8	6.0	2.2	9.1	5	1	5	2.3	0.5
24-Mar	0.3	4.0	2.5	6.7	6	2	3,3	2.4	0.8
25-Mar	0.4	3.0	1.6	5.0	0	0	0	0.0	0
26-Mar	0.2	0.2	0.2	0.2	0	0	0	0.0	0
27-Mar	0.3	1.8	2.0	4.0	6	2	3,3	3.0	1.0
28-Mar	0.9	2.9	1.8	5.5	4	2	3,1	2.2	1.1
29-Mar	0.5	1.1	1.0	2.5	3	1	3	3.0	1.0
30-Mar	0.6	0.2	1.5	2.3	0	0	0	0.0	0
31-Mar	0.0	3.6	2.8	6.3	9	4	2,2,4,1	3.2	1.4
Sum	**7.1**	**51.4**	**29.6**	**86.8**	**54**	**19**		**1.82**	**0.64**
	19%	**81%**	**100%**						

Summary of Wolf Collaring in the North Slave Region

A total of 35 wolves were captured and collared on the range of the Bluenose-East and Bathurst barren-ground caribou herds during the months of March and April in 2020 and 2021 (Table 14). The GPS collars provide a way to monitor wolf movements in relation to caribou and evaluate the nature of affiliation, if any, of wolves to any one caribou herd. While Walton et al. (2001) demonstrate wolf association with caribou they acknowledged the need for further research to assess whether the association is in relation to a specific herd. And 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).

Table 14. Collar deployments and status from 2020 and 2021.

	Deployed	Capture/Handling Mortalities	Post-Capture Mortalities	Total
2020	16	3	6	7
2021	19	0	4	15
	35	3	11	22

At the time of writing this report (fall 2021) there were 22 active collars on wolves in the North Slave Region of the NWT (Table 14). In May 2022, eight collars are programmed to drop off. Consequently, ENR plans to capture and collar 16 wolves during winter 2022 to maintain a total of 30 collared wolves in the region.

Sighting rates of 1.82 wolves per hour 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). Both activities utilized rotary wing aircraft with experienced crews and therefore could not account for the discrepancy. The collaring crew had the benefit of receiving information on wolf sightings from spotter aircraft on two occasions (Hoarfrost River Huskies on March 18 and 24) and from the aerial survey crews from March 22-31, therefore the sighting rate for wolves by the collaring crew is likely inflated. Further, their positioning would primarily be focused in areas of high caribou abundance, and they would be following tracks as they were encountered to search out wolves. In contrast, the abundance survey aircraft flew low density areas as well as high density areas and were obligated to fly transect survey lines as opposed to following any encountered tracks. 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).

Comparisons of wolf sighting rates from different surveys (i.e., caribou composition surveys, caribou/wolf capture flights, and dedicated wolf surveys) should be based on a standardized approach for establishing the denominator value of hours flown on survey, which would provide a consistent way to disaggregate total survey time into ferrying or positioning time, and actual search time. In addition, criteria and guidance should be developed to improve methodological consistency for conducting surveys that report wolf sighting rates. For example, aircraft type, ground speed, altitude, number and alertness/training of observers, weather conditions, snow cover and snow conditions should be considered in designing and/or reporting wolf sighting rates from surveys. This may be difficult for retrospective assessments but should be established for future monitoring. Importantly, consistent methods for conducting surveys and reporting wolf sighting rates should reduce sightability bias and improve our ability to detect actual variation in wolf abundance and distribution patterns.

WOLF MOVEMENT PATTERNS

GNWT contracted Caslys Consulting Ltd. in June 2021 to conduct an analysis of wolf movements from wolf collar location data acquired starting in March 2020. The goal of the analysis was to build upon a previously completed exploratory analysis of the wolf telemetry data (December 2020), with the following objectives identified:

1. Generate occupancy models from wolf telemetry data to explore annual and seasonal space-use patterns; and,
2. Perform a spatial analysis to summarize wolf and caribou interactions and determine whether collared wolves associate with one or more caribou herds.

Wolf telemetry datasets from March 2020 to June 2021 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; the full report is included in Appendix D.

Methods

Collars were deployed on both male and female wolves and collected locations across a range of sampling intervals. To account for differences in the collection frequencies between collars, two datasets were generated: a daily dataset where all data was resampled to 24-hour intervals, and a 12-hour dataset.

To account for differences in collection frequencies in barren-ground caribou herds (i.e., Bluenose-East, Bathurst and Beverly) all data were resampled to daily locations. Collared caribou that had no herd designation were excluded from certain analyses. Data were further restricted to include only collared caribou that had at least ten locations per month. These restrictions ensure that only collared caribou that had a representative sample of locations for a given month were being used to characterize range use and movement patterns.

Seasonal Patterns in Wolf Movements

To characterize seasonal patterns of wolf movement, the net-squared displacement (NSD) for each individual was calculated. 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.

Occupancy Models

To explore seasonal space-use patterns by wolves relative to barren-ground caribou, two approaches were used. Brownian bridge occupancy models (BBOM) were generated for three wolf collars. In addition to this, grid cell counts are generated, and summarized to better understand the relationship between wolves and barren-ground caribou. 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; the grid cell count approach provides a regional scale description more appropriate to herd level wolf-caribou interactions.

Brownian Bridge

Brownian bridge movement models are a continuous time approach to modeling 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 BBOM produces a 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. BBOM UDs were calculated for two different scales: the whole trajectory covered from March 2020 to June 2021, and three shorter periods: (December 1 to March 31, 2021 winter), (April 1 to May 30, 2021 spring), and (June 1 to June 31, 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. BBOM were only generated for the wolf data and the results compared to the location of the caribou as defined by the telemetry data.

Grid Cell Approach

Intersections were computed between a 10 km grid and both the caribou and wolf telemetry datasets. From these intersections the data are sorted by grid cell, and month. These results were summarized and linked back to the grid cell polygons to visualize the spatial distribution of wolf and caribou interactions. Grid cells are attributed with values corresponding to the presence of single or multiple wolves and caribou, as well as the presence of both a wolf and a caribou. These maps were produced for each month to be aligned with the temporal resolution of the wolf/caribou association analysis (Appendix D).

Wolf Affiliation with Caribou Herd

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. Building upon this with the goal of gaining a better understanding of which caribou herds a wolf was associated with throughout the year, 10 km grid cell intersections were computed between the grid and both the caribou and wolf telemetry datasets. From these intersections the data were sorted by grid cell and month.

From there the intersections were examined, and if the presence of a wolf was found alongside a caribou, the information was recorded. This resulted in a table of wolf and caribou herd interactions which contained information pertaining to the location (grid) and time (month) of the activity. This table was then further summarized for each wolf collar to describe in detail which caribou herd(s) it was affiliated with. By comparing the number of intersections that a collared wolf shared with a given herd to the total number of its caribou interactions a percentage was produced for each herd. Another table was also created which broke this down further for each month, and thus showed how herd affiliations may change month by month, and season by season.

Results

Figure 16 shows wolf movement paths for each collared wolf. The number of wolf locations collected by each collar by month is provided in Table 15 and number of caribou collar locations by herd by month in Tables 16 and 17. This formed the base dataset used in the analysis.

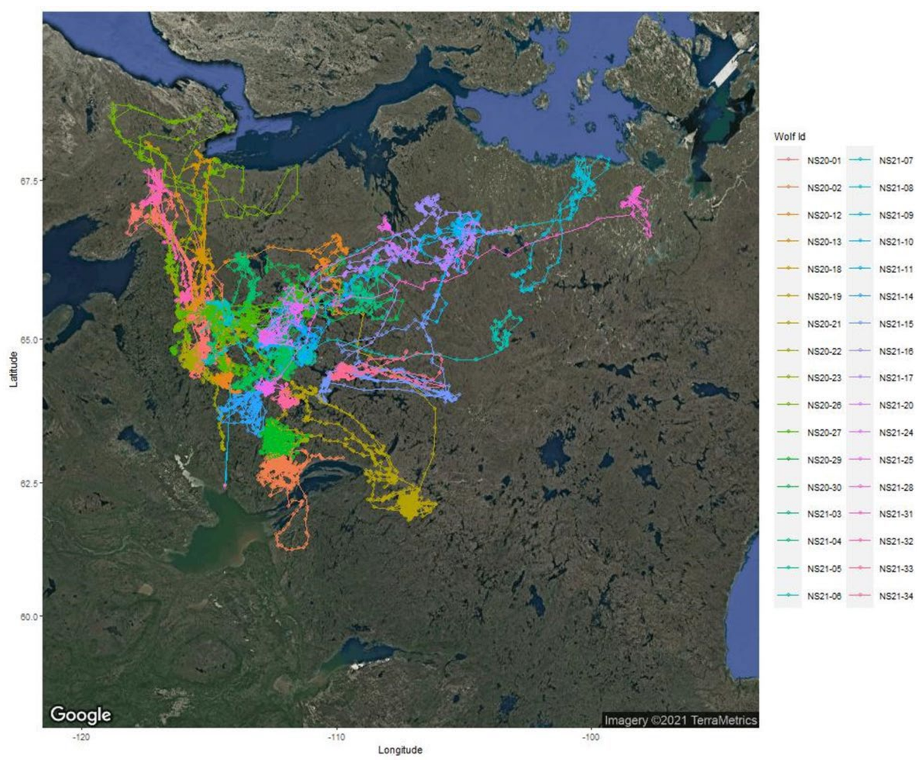


Figure 16. Wolf GPS locations 13 March 2020 to 26 June 2021.

Table 15. Wolf collar telemetry data summary (March 2020 - June 2021). The values presented in the table represent the number of locations collected for each month for each of 32 collared wolves.

Collar ID	Sex	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
WF-NS20-01	M		21	157	87	87	89	90	93	90	94	124	111	123	119	93	78
WF-NS20-02	F		15	100	71	89	93	90	93	90	94	123	110	123	120	93	84
WF-NS20-12	M	55	121	171	90	77											
WF-NS20-13	F	44															
WF-NS20-18	M	50	121	168	90	88	8										
WF-NS20-19	M	50	71														
WF-NS20-21	F		90	164	60	55	60	60	62	60	62	93	84	93	90	62	57
WF-NS20-22	F		14	155	57	41	56	50									
WF-NS20-23	F		5	42	59	60	61	59	62	59	61	92	84	93	90	55	51
WF-NS20-26	M	38	91	164	60	53	61	26									
WF-NS20-27	M	47	91	165	60	59	60	60	62	60	62	93	84	93	90	62	56
WF-NS20-29	F	56	90	113	59	58	61	60	62	60	62	93	84	93	90	38	57
WF-NS20-30*	M	44	91	164	59	59	61	60	62	60	62	93	84	93	89	47	
WF-NS21-03	M													34	119	93	15
WF-NS21-04	M													1	120	93	77
WF-NS21-05	F													2			
WF-NS21-06	F													62	120	91	13
WF-NS21-07	M													18	118	93	77
WF-NS21-08	F													65	120	80	66
WF-NS21-10	M													62	120	93	86
WF-NS21-11	M													53	120	93	9
WF-NS21-14	F													54	120	93	85
WF-NS21-15	F													30	120	93	85

Collar ID	Sex	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
WF-NS21-16	M													29	120	93	86
WF-NS21-17	M													1	120	93	77
WF-NS21-20	M													10	120	93	77
WF-NS21-24	F													1	90	62	48
WF-NS21-25	F													11	90	62	57
WF-NS21-28	M													2	90	62	51
WF-NS21-32	F													38	119	63	66
WF-NS21-33	F													14	120	92	74
WF-NS21-34	M													18	120	93	77

*GPS transmitter failed in June 2021, satellite still transmitting

Table 16. Barren-ground caribou collar summary. The values presented in the table represent the number of collars used in the analyses by month for the year 2020.

Herd	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bathurst	45	59	59	56	56	54	52	50	49	48
Beverly	30	22	22	22	22	22	19	19	19	19
Bluenose-East	66	58	56	55	54	54	52	50	48	47

Table 17. Barren-ground caribou collar summary. The values presented in the table represent the number of collars used in the analyses by month for the year 2021.

Herd	Jan	Feb	Mar	Apr	May	Jun
Bathurst	48	50	59	59	58	57
Beverly	18	20	55	55	53	53
Bluenose-East	46	46	77	76	76	76

Seasonal Patterns in Wolf Movements

Examining the NSD profiles for each collared wolf 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 18). The north-south movers were generally characterized by north-south movement occurring in July and August, interactions with only one barren-ground caribou herd, area restricted movement March to June, and a return south in September/October matching the return of the caribou to their winter ranges. 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. The stationary wolves displayed no seasonal movement and remained in the same area March through to November. These collars generally were located south of the Bathurst range.

Table 18. General wolf movement groupings. Collar numbers with asterisk from 2020 have at least 12 months of location data. Groupings for the 2021 deployed collars were preliminary due to limited time collecting locations (four months of location data).

North–South	East-West	Stationary
2020 Deployed Collars (n=12)		
WF-NS20-01*	WF-NS20-12	WF-NS20-02*
WF-NS20-18	WF-NS20-21*	WF-NS20-23*
WF-NS20-19	WF-NS20-27*	WF-NS20-29*
WF-NS20-22	WF-NS20-30*	
WF-NS20-26		
2021 Deployed Collars (n=18) (preliminary)		
WF-NS21-03	WF-NS21-04	WF-NS21-07
WF-NS21-32	WF-NS21-06	WF-NS21-14
	WF-NS21-08	WF-NS21-20
	WF-NS21-10	WF-NS21-24
	WF-NS21-11	WF-NS21-33
	WF-NS21-15	
	WF-NS21-16	
	WF-NS21-17	
	WF-NS21-25	
	WF-NS21-28	
	WF-NS21-34	

Occupancy Models

Brownian Bridge

The BBOM 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 17 shows the BBOM UD for north-south mover WS-N20-01 with pockets of high use spread across three different areas in a north-south direction; the BBOM UD for east-west mover WS-N20-27 with two major areas of high use connected by east-west movements; and the BBOM UD for stationary wolf WS-N20-02 with only one major area of high use. 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.

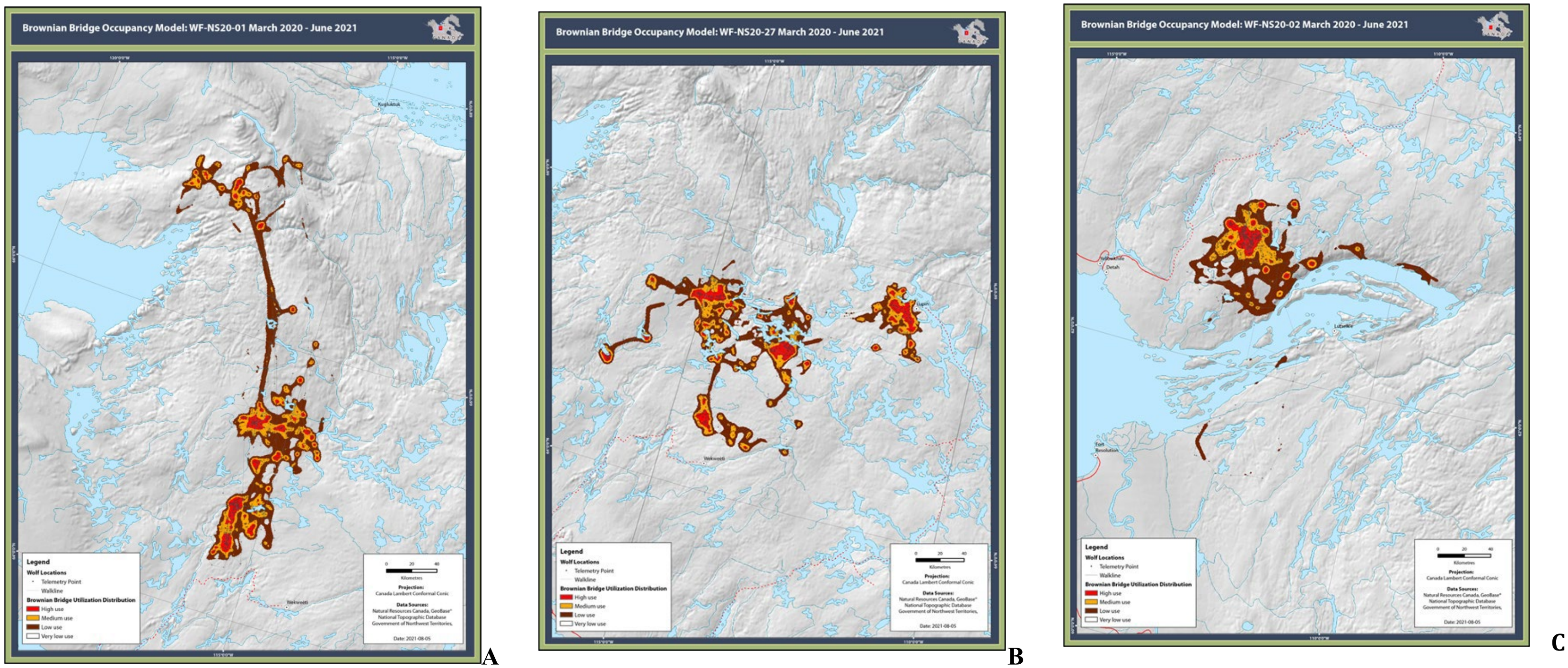


Figure 17. Brownian Bridge UD for three wolves showing the three general patterns observed in 2020 and 2021 collared wolves: a) North-South movements, b) East-West movements and c) Stationary.

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. BBOMs were produced using the locations of three wolf collars (WF-NS20-01, WF-NS20-02, WF-NS20-27) for the winter, spring, calving, summer, and fall seasons of 2020/2021.

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 (Appendix D).

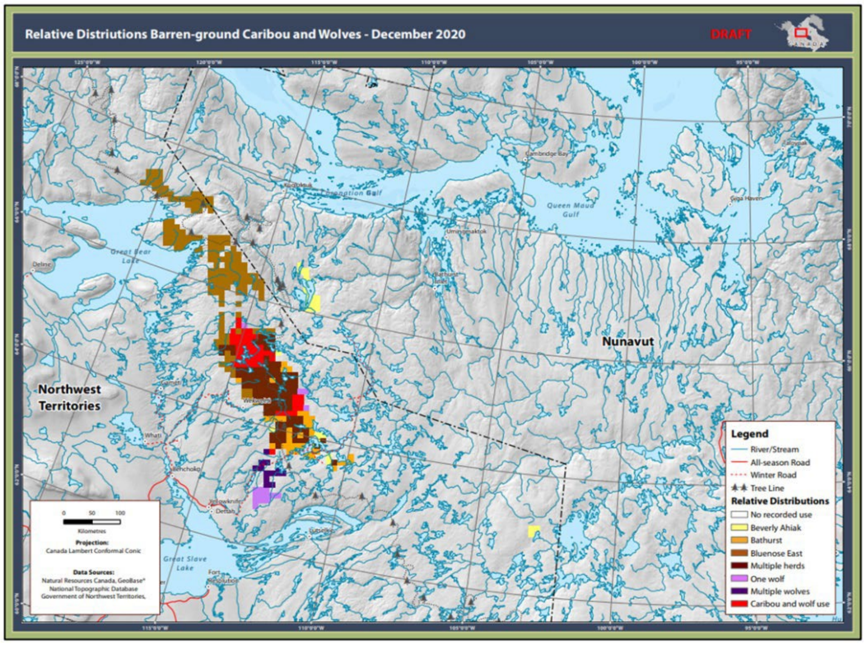
During the summer period, there was a dramatic shift in space-use and movement patterns by the non-stationary wolves away from spatially restricted movements to long dispersal movements followed by areas of high intensity use that overlapped with summer caribou distributions. Wolf space-use patterns for the fall continued to be more variable than those observed during the spring and calving periods.

Again, the non-stationary wolves followed a pattern of traveling between high use areas which overlapped with collared caribou distributions. During the winter period the potential for wolf and 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. 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 travel through the area occupied by the wolf.

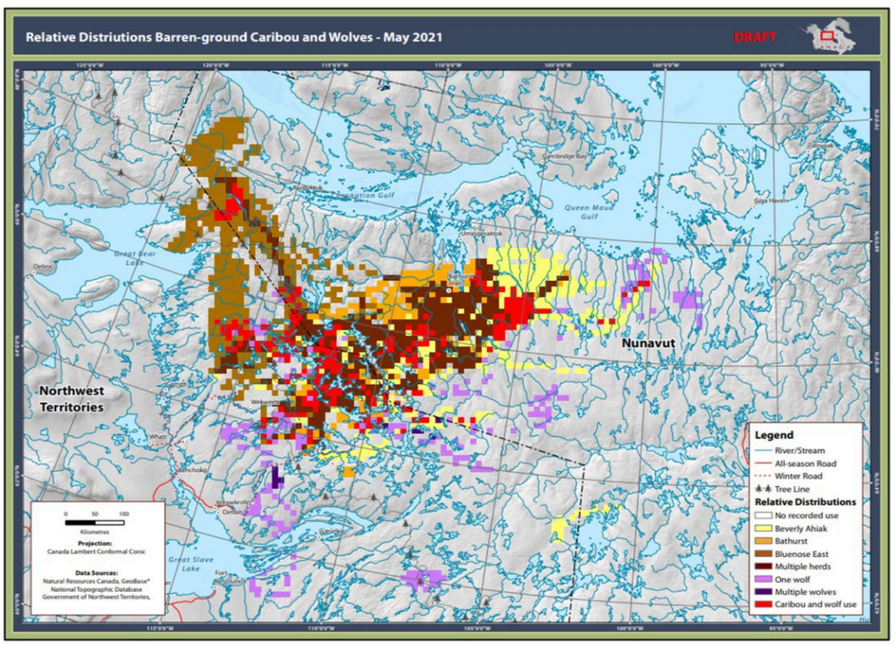
During the month of June 2021, the potential for wolf-caribou spatial interaction goes down as the caribou move further away from the area occupied by the wolves. Wolf movement also appears to be restricted, as a result of denning behaviour and due to the BBOM spanning only one month.

Grid Cell Approach

The 10 km grid cell approach provided a regional scale characterization highlighting wolf-caribou interactions at the caribou herd level rather than at the individual animal level. Areas of concurrent use by wolf and caribou were present in each month of the analysis. For the winter months (December 1 to March 31), areas of potential wolf-caribou interactions were primarily located in areas of overlap between caribou herds. For example, in December 2021, 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 18a). 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 18b). A complete set of grid cell count maps are available in Appendix D.



a)



b)

Figure 18. Grid cell (10 km) count results for December 2020(a) and May 2021(b) showing concurrent wolf-caribou use based on locations of collared wolves (n=7 collars December 2020; n=25 collars May 2021) and caribou (n=114 collars December 2020; n=187 collars May 2021).

Wolf Affiliation to Caribou Herd

The wolf and caribou association analysis were able to summarize in detail the level to which each wolf is associated with a barren-ground caribou herd. In Table 19 the total number of interactions between a collared wolf and caribou collar locations are recorded, alongside the totals for each herd. By comparing the total for a given herd to the total across all caribou herds, we get a sense of the strength of association between each collared wolf and collared caribou from each herd. The results show that some wolves are mainly associated with a single herd, while others are evenly split between multiple herds.

Table 19. Associations of collared wolves and caribou based on a 10 km grid-cell approach. The green shading provides an indication of the relative proportion that a wolf is associated with a caribou herd. Darker green reflects a higher proportion.

Wolf Collar	Wolf Movement grouping	Caribou Herd Cell Count					Percent of Total				Time span			
											Start		End	
		BAH	BEV	BNE	Unk	Total	BAH	BEV	BNE	Unk	Year	Mth	Year	Mth
WF-NS20-01	N-S	29	31	161	2	223	13.0	13.9	72.2	0.9	2020	4	2021	6
WF-NS20-02	Stationary	0	0	0	0	0	0.0	0.0	0.0	0.0	2020	4	2021	6
WF-NS20-12	E-W	32	0	23	0	55	58.2	0.0	41.8	0.0	2020	3	2020	7
WF-NS20-13		3	0	4	0	7	42.9	0.0	57.1	0.0	2020	3	2020	3
WF-NS20-18	N-S	0	0	40	0	40	0.0	0.0	100.0	0.0	2020	3	2020	7
WF-NS20-19	N-S	0	0	10	0	10	0.0	0.0	100.0	0.0	2020	3	2020	3
WF-NS20-21	E-W	57	58	37	0	152	37.5	38.2	24.3	0.0	2020	4	2021	2
WF-NS20-22	N-S	1	0	14	0	15	6.7	0.0	93.3	0.0	2020	5	2020	5
WF-NS20-23	Stationary	5	0	0	0	5	100.0	0.0	0.0	0.0	2020	5	2021	1
WF-NS20-26	N-S	0	0	90	0	90	0.0	0.0	100.0	0.0	2020	3	2020	8
WF-NS20-27	E-W	115	74	109	5	303	38.0	24.4	36.0	1.7	2020	3	2021	5
WF-NS20-29	Stationary	3	0	0	0	3	100.0	0.0	0.0	0.0	2020	5	2021	1
WF-NS20-30	E-W	144	53	29	2	228	63.2	23.3	12.7	0.9	2020	3	2021	5
WF-NS21-03	N-S	35	27	49	13	124	28.3	21.8	39.5	10.5	2021	3	2021	6

Wolf Collar	Wolf Movement grouping	Caribou Herd Cell Count					Percent of Total				Time span			
											Start		End	
		BAH	BEV	BNE	Unk	Total	BAH	BEV	BNE	Unk	Year	Mth	Year	Mth
WF-NS21-04	E-W	46	41	1	8	96	48.0	42.7	1.0	8.3	2021	3	2021	6
WF-NS21-05		1	1	0	1	3	33.3	33.3	0.0	33.3	2021	3	2021	3
WF-NS21-06	E-W	35	30	6	3	74	47.3	40.5	8.1	4.1	2021	3	2021	5
WF-NS21-07	Stationary	6	7	20	3	36	16.7	19.4	55.6	8.3	2021	3	2021	6
WF-NS21-08	E-W	24	33	16	1	74	32.4	44.6	21.6	1.4	2021	3	2021	6
WF-NS21-10	E-W	38	52	6	0	96	39.6	54.2	6.3	0.0	2021	3	2021	6
WF-NS21-11	E-W	49	40	17	9	115	42.6	34.8	14.8	7.8	2021	3	2021	5
WF-NS21-14	Stationary	13	11	17	0	41	31.7	26.8	41.5	0.0	2021	3	2021	5
WF-NS21-15	E-W	16	30	0	1	47	34.0	63.8	0.0	2.1	2021	3	2021	6
WF-NS21-16	E-W	49	54	3	0	106	46.2	50.9	2.8	0.0	2021	3	2021	6
WF-NS21-17	E-W	46	49	7	5	107	43.0	45.8	6.5	4.7	2021	3	2021	6
WF-NS21-20	Stationary	32	18	14	4	68	47.1	26.5	20.6	5.9	2021	3	2021	6
WF-NS21-24	Stationary	39	24	16	13	92	42.4	26.1	17.4	14.1	2021	3	2021	6
WF-NS21-25	E-W	32	29	15	3	79	40.51	36.7	19.0	3.8	2021	3	2021	6
WF-NS21-28	E-W	16	8	1	2	27	59.3	29.6	3.7	7.4	2021	3	2021	6
WF-NS21-32	N-S	4	0	30	0	34	11.8	0.0	88.2	0.0	2021	3	2021	6
WF-NS21-33	Stationary	14	3	0	3	20	70.0	15.0	0.0	15.0	2021	3	2021	5
WF-NS21-34	E-W	14	22	0	2	38	36.8	57.9	0.0	5.3	2021	3	2021	6

For example, WF-NS20-01, WF-NS21-32, WF-NS20-26 all have herd associations greater than 70% with the Bluenose-East caribou. This evidence corroborates previous findings as all three of these wolves have been identified with North-South movement behaviour. As described earlier this North-South movement behaviour of collared wolves is often associated with a single caribou herd.

Other wolves such as: WF-NS20-21, WF-NS20-27, and WF-NS21-03 did not have any herd associations greater than 40%, and thus were evenly split across all three barren-ground caribou herd ranges. These wolves were all identified as having an East-West movement behaviour.

Table 20 summarizes the number and proportion of collared wolves in the three movement groups and shows that in 2020 more of the collared wolves exhibited the North-South movement pattern followed by East-West. Whereas in 2021, the highest proportion of collared wolves exhibited East-West movement followed by stationary.

Table 20. Movement group assignment for all wolves collared in the North Slave Region, NWT in 2020 and 2021. Note: The 2021 wolf collar movement groups should be considered preliminary as they were based on only 4 months of data at time of writing (fall 2021).

	# collars	North-South		Stationary		East-West	
year	assigned	#	%	#	%	#	%
2020	12	5	42	3	25	4	33
2021	18	2	11	5	28	11	61
	30	7	23	8	27	15	50

The wolf and caribou herd associations were broken down further by displaying the interactions per month (Table 7, Appendix D). This allowed for a better understanding of the seasonal timing of wolf/caribou interactions. For wolves that interacted 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 winter months. This corresponds well with what was seen in the BBOMs where the collars were in close proximity to several caribou herds over the winter season. Wolves such as: WF-NS20-01, WF-NS20-30 appeared to interact with one herd consistently throughout the year, but in the winter months interactions occur with all herds.

This analysis helped quantify the patterns that were spatially visible in both the BBOMs and the grid cell maps. It also provided a detailed breakdown of wolf/herd interaction and may be used to better understand the strength of each wolf's affiliation with a barren-ground caribou herd.

Wolf Movement Analysis Summary

The NSD and BBOM analyses showed three general movement patterns among 30 wolves collared in the North Slave Region of the NWT: North-South (23%), East-West (50%) and stationary (27%). Wolves (n=7) exhibiting North-South movements tended to be associated with a single caribou herd; wolves (n=15) with East-West movements (the majority of collared wolves) tended to be associated with two or three caribou herds and the stationary wolves (n=8) mainly associated with caribou of one or more herds on the winter range.

Seasonal movements of non-stationary wolves show times of low overlap with caribou as in June when caribou are calving and wolves are constrained by denning and pupping, and times of high overlap such as summer and winter. Similarly, Walton et al. (2001) in their examination of wolf movements in the same study area found wolves exhibited restricted movements around a den site on the tundra from late April through October after which they followed caribou to their wintering grounds. Previous analyses looking at the relation between caribou and wolf movement showed that during winter, caribou and wolves displayed similar directional movements east and westward while during spring migration their movements were more asynchronous (Hansen et al. 2013). Stationary wolves, in the present analysis, showed seasonal overlap primarily in winter.

Given that wolves appear to display fidelity to den site (Walton et al. 2001), and movement analyses show some indication for affiliation to a single caribou herd during summer months, this may provide a basis for an alternate approach to defining wolf affiliation to caribou herd. The short record of data from collared wolves thus far shows fidelity of at least one wolf to caribou herd in spring and summer (e.g. NS20-01). Additional analyses of the wolf collars deployed in 2021 and those planned for deployment in 2022 will aid us in further understanding seasonal affiliation and its potential application for allocating wolf harvest.

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 potentially 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.

The regional grid cell count approach is a useful analysis 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. In addition to this the wolf/caribou association analysis is built upon the same datasets and can easily be produced alongside this approach.

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 grid cell results are easy to update, this approach lends itself to modeling potential wolf-caribou interactions over a longer period.

WOLF REMOVAL TARGETS

The "*Joint Proposal on Management Actions for Wolves (dìga) on the Bathurst and Bluenose-East Barren-ground Caribou (ʔekwǫ̀) Herd Winter Ranges: 2021-2025*" submitted to WRRB in August of 2020 provides a rationale for establishing wolf removal targets consistent with the Wolf Technical Feasibility Assessment (WFATWG 2017). The primary assumption was that wolves in the tundra/taiga of the NWT are migratory and predominantly associated with migratory barren-ground caribou (Walton et al. 2001, Musiani et al. 2007, Klazcek et al. 2015).

In 2020 (year one of the program) targets were established using wolf abundance estimates based on caribou density, extrapolated herd size and UBI, in absence of reliable wolf abundance estimates for populations associated with barren-ground caribou. Using this approach, wolf abundance associated with the Bathurst caribou herd on its winter range was estimated at 49 wolves and 121 wolves on the Bluenose-east herd's winter range (Nishi et al. 2020). The removal targets for each herd were set as a range representing 60-80% of the estimate (29-39 on the Bathurst and 73-97 for Bluenose-East range) in keeping with a review of wolf management programs from other jurisdictions where improvement in caribou survival rates was associated with wolf removal efforts of approximately 60-80% initially followed by sustained removals (McLaren 2016).

The Joint Proposal suggests that removal targets will be assessed on an annual basis and adjusted as necessary but that they should remain high, as wolf populations are able to sustain removal levels up to 30%, and in-migration of wolves is expected to be high with overlapping winter ranges of adjacent caribou herds.

Methods

The approach taken by GNWT to derive harvest targets in 2021 was adapted from that taken in 2020 to accommodate the high degree of overlap in Bathurst, Bluenose-East and Beverly herds (see Winter Distribution Patterns of Caribou in the North Slave Region) and the anticipated associated wolves. We took an alternative approach, to start conservatively, given the uncertainty in wolf abundance estimates and adapt as needed. An interim number of wolves was set as a trigger for review, which would be revisited as harvest levels approached this number and revised based on observations of harvesters, aerial survey and collaring crews, and if available, within season CPUE. This approach allowed for adaptive management with possible adjustments based on information coming in over the harvest season.

In absence of an empirically based estimate of wolf abundance at the start of the 2021 winter harvest season we used an UBI and extrapolated herd size to estimate wolf abundance; acknowledging that the UBI assumes an unharvested wolf population. Table 21 shows the extrapolated herd size for 2020, estimated wolf numbers using UBI and the proportion of wolves on the winter range based on collar numbers for each herd overlapping the North Slave Wolf Harvest Incentive Area in mid-January 2021.

Using this method, the number of wolves associated with the Bathurst and Bluenose-East herds within the North Slave Wolf Harvest Incentive Area was estimated to be 142 and those associated with the much larger Beverly herd, 858 wolves. Due to the low number of collars on the Beverly herd in January 2021, there was a greater amount of uncertainty in the estimate of associated wolves. As a result, the interim trigger was set at 80% of the estimated wolves associated with the Bathurst and Bluenose-East herds, which was 114 wolves (80% of 142). As harvest occurred through the season, if the interim trigger was reached it would be revisited and harvest continued if information gained from hunters and aerial survey crews showed there were still high numbers of wolves. Conversely, if wolves were not being encountered, suggesting a depleted population, harvest may be halted.

Table 21. Estimated number of wolves expected in the North Slave Wolf Harvest Incentive Area based on proportion of caribou collars and UBI estimates.

	Extrapolated Caribou Numbers*	Estimate of Wolves based on Caribou Biomass (a)	Caribou Collars in North Slave Wolf Harvest Incentive Area	Percent (%) of Collared Caribou in North Slave Wolf Harvest Incentive Area (b)	Estimated Wolves in North Slave Wolf Harvest Incentive Area (a X b)
Bluenose-East	12,154	138	29/46	63%	87
Bathurst	4,567	55	48/48	100%	55
TOTAL					142
Beverly	95,468	1029	15/18	83.3%	858

*see Nishi et al. 2020, Section 5, for methods of extrapolating herd sizes and applying UBI.

Summary

The wolf technical feasibility assessment (WFATWG 2017) proposed that sustained removal pressure means removing 60-80% of wolves in year one followed by removal at levels needed to prevent wolves from recovering to pre-removal density. An interim trigger level for 2020/2021 was set at 80% (114 wolves) of the estimated wolves associated with the Bathurst and Bluenose-East herds (142) to guide wolf harvest levels over the season and to allow for adjustments if observations from harvesters and aerial survey crew members suggested there were high numbers of wolves (Table 21). This approach provided flexibility in a situation of high overlap with the Beverly caribou herd and high uncertainty in actual wolf abundance. As the reported harvest approached the interim trigger level of 114 in late March, a decision was made by the GNWT to continue supporting the wolf harvest as, other than the Tłįchǫ dìga harvester camp, there were no reports that harvest rates of wolves were declining.

It is acknowledged, in a recent review of wolf management programs in other jurisdictions (McLaren 2016), that there are no direct comparisons for managing tundra wolves on migratory barren-ground caribou ranges. Because of the spatial-temporal dynamics of herd overlap on winter ranges there is uncertainty in prescribing herd-specific removal targets for tundra wolves on caribou winter ranges and corresponding uncertainty in assessing the effectiveness of winter wolf removals on caribou herds (in combination with other factors affecting herd dynamics).

We applied a regression based on analyses of North American field studies with data on ungulate biomass and wolf densities (Keith 1983, Fuller 1989, Fuller et al. 2003, Kuzyk and Hatter 2014), and derived estimates of tundra wolves (circa 2020 and prior to wolf management actions) associated with Bluenose East, Bathurst and Beverly caribou herds (see Nishi et al. 2020, and Commitment #9 to WRRB[6]). We recognize that ungulate biomass is a relatively imprecise estimator of wolf density (Kuzyk and Hatter 2014); and as highlighted by Fuller et al. (2003), 'for a given prey biomass, wolf numbers may vary as much as fourfold (Fuller 1989). However, in the absence of direct empirical field estimates of wolves, a derived estimate based on caribou abundance provided a transparent approach.

Four key assumptions underpin our application of the UBI approach and the derived tundra wolf estimates prior to wolf management actions that were initiated in winter 2019/2020:

1. Barren-ground caribou are the primary prey of tundra wolves and occurrence of other ungulate species (i.e., moose and muskoxen) do not meaningfully contribute to tundra wolf density;
2. Caribou population estimates (and projections) were relatively accurate and representative;
3. Previous harvest of tundra wolves - prior to winter 2019/2020 - did not exceed sustainable thresholds and wolf numbers are adjusted to caribou biomass (i.e., abundance); and,
4. There is strong association in population structure of tundra wolves and barren-ground caribou at the scale of the migratory herds' annual range.

Contravening these assumptions adds uncertainty to the task of determining wolf removal targets; and not meeting the fourth assumption contributes to uncertainty in assessing effectiveness of wolf removals in combination with other factors affecting caribou population dynamics.

With respect to the first assumption, barren-ground caribou are considered the primary prey for tundra wolves, which is supported by analyses of stomach contents of harvested wolves in winters of 2019/2020 and 2020/2021 respectively (Nishi et al. 2020 and this report). However, there are stable and/or increasing trends in muskox density across the caribou ranges (Cuyler et al. 2019). Moose are also present on the winter ranges of the Bluenose-East and Bathurst herds (Nishi et al. 2020) and occur on caribou summer range areas (TRTI 2020). Thus, the extent to which muskoxen and/or moose serve as alternate prey to tundra wolves and whether prey switching from caribou occurs seasonally is unknown, although it is likely that wolves opportunistically kill muskox and moose. If muskox and moose are important for supporting tundra wolf survival rates - especially during the spring-summer denning and pup rearing periods - then omitting those species as contributors to ungulate prey biomass would likely underestimate wolf density.

The second assumption is that caribou population estimates (and projections) are accurate. Our initial approach was to use the ungulate biomass regression model to estimate expected numbers of wolves in the Bluenose-East and Bathurst winter range areas from surveys in March 2020, and to also develop

[6] www.wrrb.ca/sites/default/files/GNWT%20to%20WRRB%20let%20Tech%20Commitments%20Oct%202020%20FINAL.pdf

plausible wolf population estimates based on projected (2020) estimates for the Bluenose-East, Bathurst and Beverly herds respectively (Nishi et al. 2020). Our projected population sizes were calculated by applying the observed population rates of change derived from the two most recent calving ground surveys, and applying those trends to population estimates from 2018; estimated rates of change (r) were -0.231, -0.293 and -0.040 for the Bluenose-East, Bathurst and Beverly herds respectively. In comparison, initial results from calving ground photographic surveys in June 2021 (GNWT unpublished data) indicate that the population trend of the Bluenose-East herd is likely stable, and the declining trend of the Bathurst herd has slowed. Thus, our projected population (2020) estimates (at time of writing – fall 2021) for the Bluenose-East and Bathurst herds were likely lower than the true caribou population sizes, and consequently the UBI wolf population estimates could have underestimated the true density and abundance of wolves.

The third assumption is that wolf densities have adjusted to prey biomass and wolves have not been reduced as a result of human exploitation rates. If human-caused mortality of wolves exceeds sustainable limits, then a UBI derivation based on prey biomass would overestimate wolf density. In this case, it is unlikely that reported wolf harvests in the North Slave Region for the Bluenose East, Bathurst and Beverly ranges prior to winter 2019/2020 (Cluff 2019, Cluff 2020, Nishi et al 2020), would have exceeded a maximum sustainable exploitation of up to 30% of the wolf population (see Keith 1983, Fuller 1989, Adams et al. 2008).

The fourth assumption is that wolf density is largely food-limited and closely related to per-capita prey abundance. To fulfill this assumption, the estimate of tundra wolves derived from the biomass (i.e., abundance) of a barren-ground caribou herd should reflect a population of wolves that is associated with the migratory herd's annual range, to the extent that there is coupling in numerical abundance between predator and its primary prey. Thus, a lag in a wolf population's numerical response to a rapidly declining caribou herd may result in an underestimate of wolf density based on caribou biomass alone. Correspondingly, this assumption reflects a strong association of predator and prey populations and a feedback pathway between a reduction in wolf abundance and a direct, proportionally positive numerical response in the caribou herd. If wolf population structure is strongly associated with a migratory caribou herd, then we would expect a relatively transparent interpretation of the effect of wolf management removals. In contrast, if there is a weaker or more variable association between a wolf population and a caribou herd, then we would expect a higher level of variability in response indicators and uncertainty in interpreting effects of management actions on wolves.

We reiterate that ungulate biomass is a relatively imprecise estimator of wolf abundance, however, in the absence of direct empirical field estimates of wolves, it provides a transparent approach. Modeling of potential impacts of wolf removal on Bathurst and Bluenose-East caribou herds was updated in October 2020 in support of the public review by the WRRB. The analysis considered uncertainty in predation rates and wolf removal levels partially exploring some of the potential variation in outcomes related to key uncertainties.[7] Issues of herd overlap, the difficulty in estimating wolf abundance combined with new information on wolf movement patterns impact our approach to setting wolf harvest targets and will need further consideration.

[7] https://wrrb.ca/sites/default/files/GNWT%20to%20WRRB%20let%20Tech%20Commitments%20Oct%202020%20FINAL.pdf

GNWT'S NORTH SLAVE WOLF HARVEST INCENTIVE PROGRAM

Wolves are harvested as furbearers 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 2013-2014 and 2014-2015 harvest years but then increased to $200/carcass (skinned or unskinned) in the 2015-2016 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 2018-2019 harvest year, an additional harvest incentive area for wolves was introduced as a result of discussions at a gathering of ENR staff and Indigenous leaders/representatives at François Lake in August 2018. The North Slave Wolf Harvest Incentive Area was established based on collar locations of Bathurst and Bluenose-East caribou that December corresponding with the area the Bathurst and Bluenose-East caribou herds were expected to winter in 2018-2019. 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. Since 2018-2019, the North Slave Wolf Harvest incentive Area has been established based on mid-January locations of female and male caribou from both the Bathurst and Bluenose-East herds. The incentive amount for the North Slave Wolf Harvest Incentive Area was increased in 2019-2020 to $1,200/wolf and the cost of the tag was dropped throughout the NWT (Indigenous harvesters and General Hunting Licence holders don't require a tag). The area encompassed by the North Slave Wolf Harvest Incentive Area in 2021 is shown in Figure 19. It is roughly 63,041 km^2 and somewhat smaller than the 72,129 km^2 area in 2020. In 2021, the adjacent Beverly caribou herd significantly overlapped with the Bathurst and much of the Bluenose-East herd.

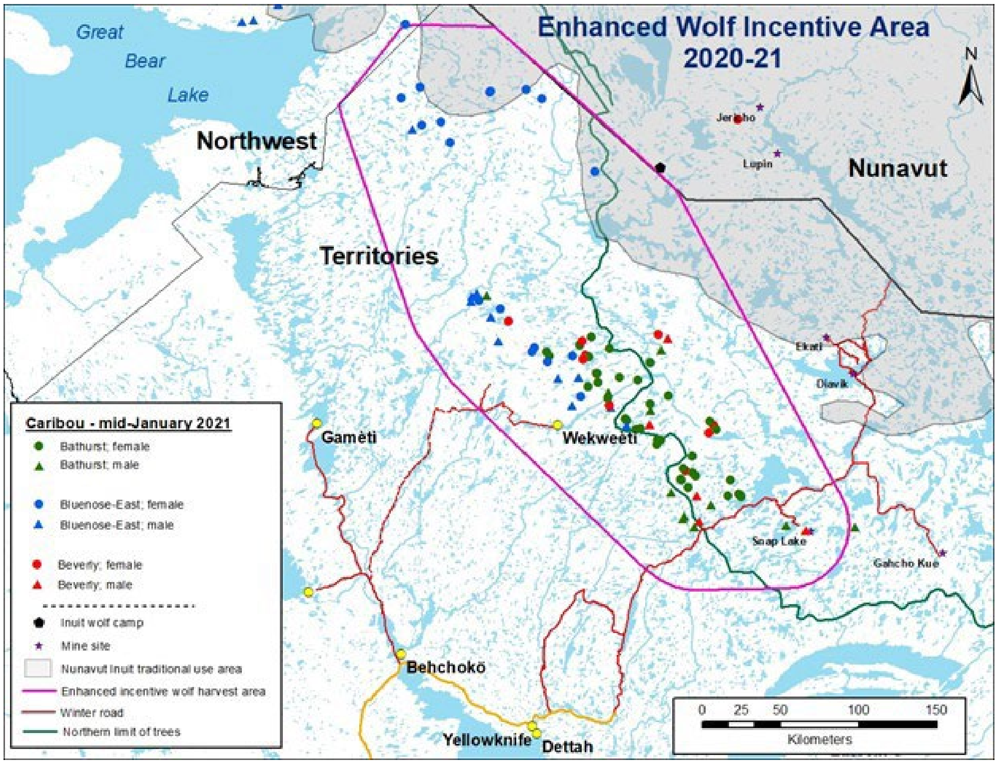


Figure 19. The 2021 North Slave Wolf Harvest Incentive Area in the NWT. The area is based on the locations of collared caribou for the Bathurst and Bluenose-East herds. There was extensive overlap on the winter range this year with the Beverly caribou herd.

When a skinned or unskinned wolf carcass was brought to the North Slave ENR office, the harvester would receive either $200 or $1,200 for it, the latter amount if the wolf was harvested within the North Slave Wolf Harvest Incentive Area. For an unskinned carcass, ENR would then arrange for an experienced skinner to remove and prepare the pelt. Skinners would get possession of the pelt afterward. If a harvester shot and also skinned the wolf from the North Slave Wolf Harvest Incentive Area and prepared the pelt for auction, they could receive $1,950 per wolf ($1,200 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.

Skinning a wolf pelt to taxidermy standards is not mandatory for the prime fur bonus. Skinning a wolf to taxidermy standards takes more time as the ears, lips, and toes need to be turned and dried. Many skinners have said there is little financial incentive to undertake this extra effort.

Harvester Training in the North Slave Region

Trapper training workshops were held in Łutsel K'e on 1 December 2020 and in both Yellowknife and Behchokǫ, 3-4 December 2020. There were 12 participants in the Yellowknife workshop, and two participants in Łutsel K'e. Participants learned about humane trapping for fur, effective pelt preparation, making trap boxes and snares, and general information about fur prices and sales.

Although there were some wolves at the workshops that were skinned and stretched, there were no wolf-specific training workshops in 2021. The Tłı̨chǫ wolf program manager had arranged for an experienced NU wolf hunter to conduct a wolf hunting training camp for Tłıchǫ harvesters but COVID-19 restrictions prevented that from happening. Trappers did express an interest in conducting more extensive wolf workshops in the future.

Harvest Summary in the North Slave Region

The winter of 2021 had two hunting camps specifically for harvesting wolves set up; one with Tłı̨chǫ hunters at Roundrock Lake (see Summary of Harvest in the North Slave Wolf Harvest Incentive Area) and another with Inuit hunters from Kugluktuk based at Itchen Lake, NU. Although the Inuit may harvest wildlife from their traditional use area that overlaps into the NWT, permission was also requested and received from the WRRB for a Special Harvester Licence for Inuit hunters to hunt wolves in Wek'èezhìı. The WRRB supported the request on the basis it would promote recovery of the Bluenose-East and Bathurst caribou herds.

The Tłı̨chǫ wolf hunting camp involved 16 hunters from 22 January to 29 March 2021 and harvested 32 wolves (13 females, 19 males). The Inuit camp involved 15 hunters from 31 January to 29 April 2021 and harvested 87 wolves (37 females, 50 males). All wolves harvested by the Tłı̨chǫ and Inuit wolf camps were taken in the North Slave Wolf Harvest Incentive Area. Another 16 wolves were taken in the North Slave Wolf Harvest Incentive Area from seven hunters using the Tibbitt to Contwoyto winter road Figures 1 and 20) for a total wolf harvest of 135. There were no wolves harvested by non-resident hunters as outfitters were limited by NWT COVID-19 public health orders and the Canadian border was closed to Americans for "non-essential" travel.

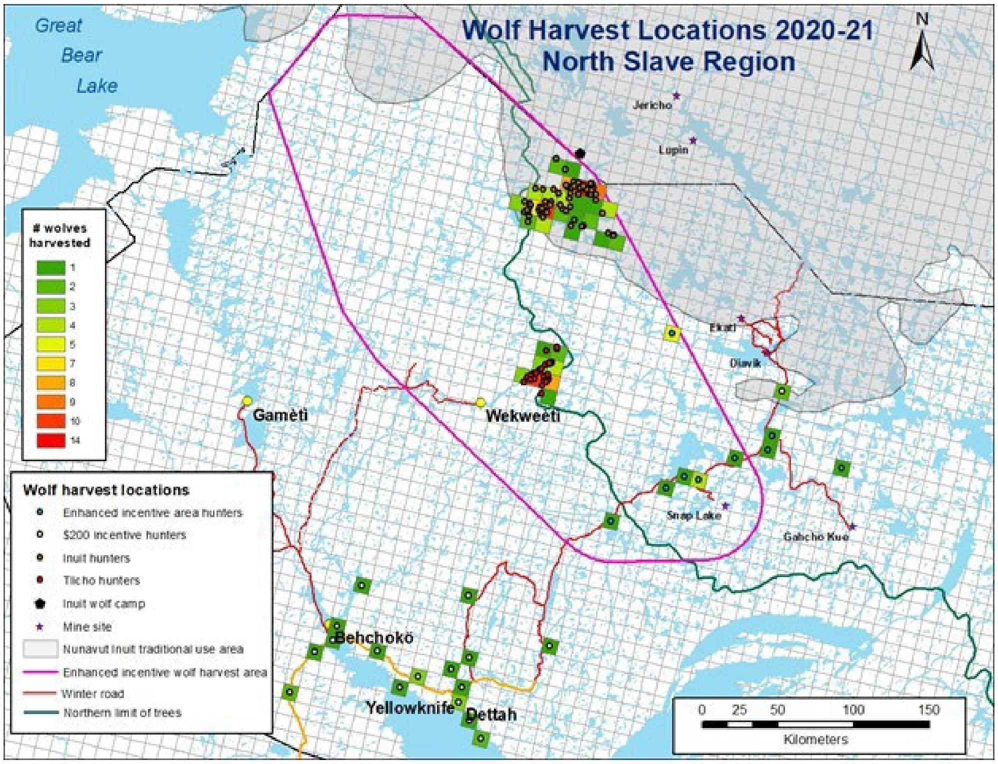


Figure 20. Location of wolves harvested in the North Slave Wolf Harvest Incentive Area and broader North Slave Region, 2020-2021 (n=160).

Of the 160 wolves harvested in the North Slave Region as a whole, in 2020-2021, 72 were female and 88 were male. Age class determination based on visual assessment of tooth wear and body size shows adults comprised the predominant proportion of the harvested wolves (Figure 21). Annual wolf harvest records for the region are provided in Table 22 and shows the 2020-2021 harvest season is the highest recorded since 2010-2011.

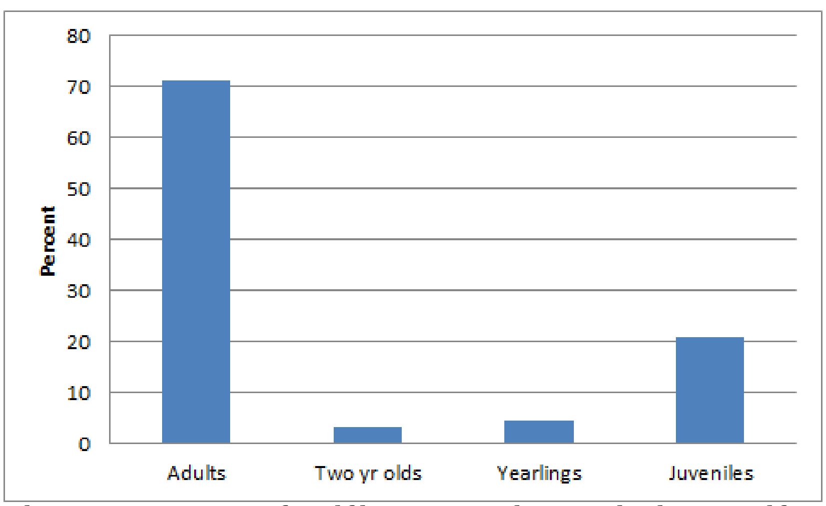


Figure 21. Age class composition of wolf harvest in the North Slave Wolf Harvest Incentive Area in the North Slave Region of the NWT, January - April 2021.

Table 22. Annual wolf harvest records in the North Slave Region based on carcass/skull collections. The harvest season spans 01 July to 30 June annually. Since 2010, regular incentive payments have varied from $100/wolf carcass (or $50/skull) to $200/wolf carcass.

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[a]	59[b]	1[c]	67
2019-20	50[a]	18[d]	1[c]	69
2020-21	25[a]	135[d]		160

[a] $200 incentive/wolf carcass (skinned or unskinned).
[b] $900 incentive/wolf carcass (skinned or unskinned).
[c] Gahcho Kue mine wolf euthanized by ENR.
[d] $1200 incentive/wolf carcass (skinned or unskinned);
[e] road-killed wolf at Ekati mine.

Most (91.9%) of the wolf carcasses submitted to ENR were provided by Indigenous hunters, the remaining hunters were resident licence holders (8.1%). There were 353 hunting licences purchased with a total of 677 wolf tags issued. The number of wolf tags issued at the time of licence purchase averaged two per hunter but ranged from one to 12. There were 73 tag receipts issued after a hunting licence purchase. This amounted to an additional 182 wolf tags also averaging two tags and ranging from one to 11 per hunter.

Tłįchǫ Government's Community-based Dìga Harvest Program

Background

The traditional territory of the Tłıchǫ is vast, and the network of hunting trails extends far into every corner of their lands. The four Tłıchǫ communities of Behchokǫ̀, Whatì, Gamètì and Wekweètì are located in the boreal forest, and the land stretches far north of the treeline into the tundra, where many Ekwǫ̀ hunting grounds are located. The traditional land use areas of the Tłıchǫ lie within the boundary known as "Mǫwhì Gogha Dè Nıı̨ ţ łèè," 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) (TG 2019). The modern treaty area of Mǫwhì Gogha Dè Nıı̨ ţ łèè is described in an illustrative map to the Tłı̨chǫ Agreement[8], which was ratified in 2005 by the Tłıchǫ Nation with the Government of Canada; the Tłıchǫ Agreement is the first combined comprehensive land claim and self-government agreement in the NWT.

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), Tłıchǫ families traveled 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 Tłıchǫ trappers and their families returned south while the ice was still strong enough to hold the dog teams (TG 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 ekwǫ̀ meat back to their home communities (Zoe 2012). Sahti Ekwǫ̀ (Bluenose-East) and Koketi Ekwǫ̀ (Bathurst) herds have been the main source to the Tłıchǫ diet and have been key species that connects them to their culture, language, and way of life (TG 2019). Over the past decade, the two herds have been declining rapidly. Sahti Ekwǫ̀ population decline was determined after the 2013 survey which resulted in an estimate of 68,000 and it was estimated at 121,000 in 2010. The most recent survey was done in 2018 and the estimate was at 19,300 (Boulanger et al. 2019). 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 1980s this herd was nearly half a million animals. The most recent population survey in 2018 resulted in an estimate of 8,200 (Adamczewski et al. 2019).

Since its inception in 2005, the TG has been playing a direct role in wildlife co-management and has been working with ENR and the 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, the WRRB held a public hearing on the 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

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

bull to cow ratio. Harvest management recommendations have been updated, and since 2016 a TAH of zero (0) 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. TG has also been strongly supportive of increased harvesting of wolves on caribou winter ranges.

Through implementation of the Tłı̨chǫ Agreement, the TG and citizens have been undertaking programs that emphasize their role as land stewards within their traditional territory. With an emphasis on direct on-the-land activities by staff and citizens, TG 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) ekwò̜ condition; (3) predators and (4) industrial development. The program is a collaboration between the TG, ENR, WRRB and Dominion Diamond Mines ULC (TG 2021).

The TG's community-based Dìga harvesting program was initiated in the winter 2019/2020 and reflects a key recommendation by the WRRB Recommendation #4-2020 (Predator[9]) to continue TG's community-based dìga harvesting program and the ENR's enhanced North Slave Wolf Harvest Incentive Program. The community-based dìga harvesting program reflects TG'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. This summary focuses on implementation of the community-based dìga harvesting program in winter 2020/2021.

The Dìga Harvest Program

Year 1 (2019/2020)

The TG initiated its community-based dıg̀a harvesting program for the 2019/2020 harvest season in three phases.

1) Community consultation was undertaken by TG staff with Tłı̨chǫ harvesters and elders to ensure the program followed and respected Tłı̨chǫ protocols of harvesting dıg̀a and determined specific logistics for the camps.
2) TG staff hired provided training specific to dìga harvesting for local Tłı̨chǫ hunters. TG worked with the Alberta Trappers' Association, and held a four-day wolf trapper workshop in Wekweètì for 18 Tłı̨chǫ hunters
3) TG staff and Tłı̨chǫ hunters established dìga harvester camps to further support training and develop on-the-land skills to effectively hunt dıg̀a.

[9] Wek'èezhìı Renewable Resources Board. 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. 53pp. + 8 Appendices

In the first year of the program, the harvesting camps ran from January 31, 2020 to March 20, 2020. There were four crew rotations of about ten to 14 days for each crew. The participants established a base camp and traveled up to 80 km a day searching for dìga, depending on snow and weather conditions. Traps and snares were used with bait stations (fresh whitefish and rotten lake trout collected from Whatì were used). Although traps and snares were used, the dıg̀a harvested during the program were all shot. In total there were three dìga hunted during the program and one harvested during the workshop (this one was snared). The snared dìga was caught at the dump in Wekweètì.

Year 2 (2020/2021)

The second year of the program started with a meeting in December 2020 with 19 participants from the previous year as well as advising elders. The main focus of the meeting was to discuss the previous years successes and challenges and identify ways to improve the program. During the meeting, elders provided advice on camp location. Learning from the previous year, the need to have the camp in an area where the harvesters are able to easily traverse the area was a necessity. The location used in 2019/2020 was within the treeline in an area where there was not much Dìga activity although there were plenty of ekwǫ̀; ekwǫ̀ were seen almost on a daily basis when the camp was located at Reindeer Lake (K’aıtı). The snow was softer and deeper, making it difficult for the harvesters to travel around. Criteria for a camp location in winter 2021 included having hard packed snow and in areas where participants from the closest community, Wekweètì, were familiar with. It was decided that the camp would be located at Roundrock Lake, about 40 km northeast of the community (“basecamp” in Figure 22). This area was above the treeline and made travel conditions much easier with the hard-packed snow.

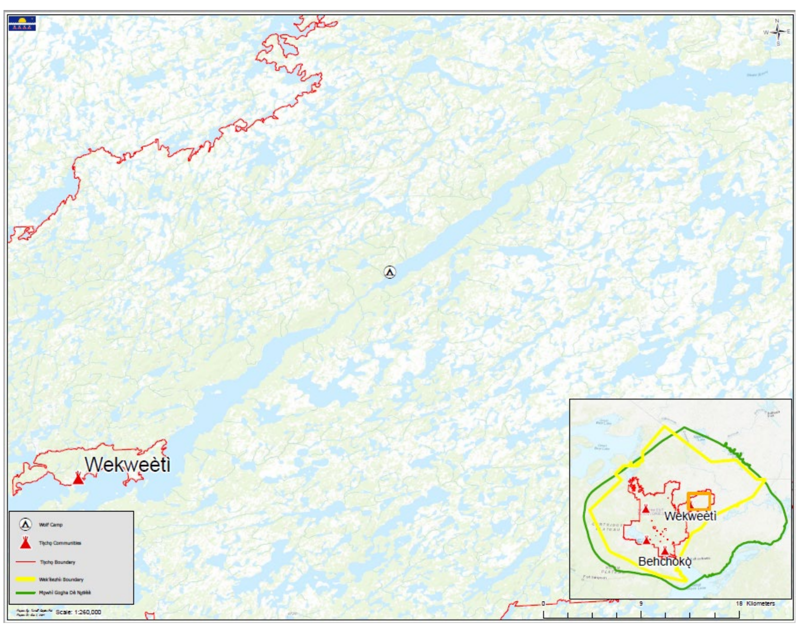


Figure 22. TG’s dìga harvester camp location (Roundrock Lake), 2021.

Once the location was finalized, TG requested ENR to conduct an aerial reconnaissance survey prior to the program starting. ENR flew the survey on January 21 with two observers that would be participating in the dìga harvesting program. Observations from the aerial survey included no sightings of dìga and approximately 5,800 ekwǫ̀ (Figure 23). On January 22, 2021, eight hunters traveled by snowmachine from Behchokǫ̀ to Wekweètì and stayed there until January 24, which was the day they left for camp. A few days before the harvesters arrived in Wekweètì, local residents were hired to break trail to Roundrock Lake and set up camp; this made things easier for the harvesters once they arrived at camp.

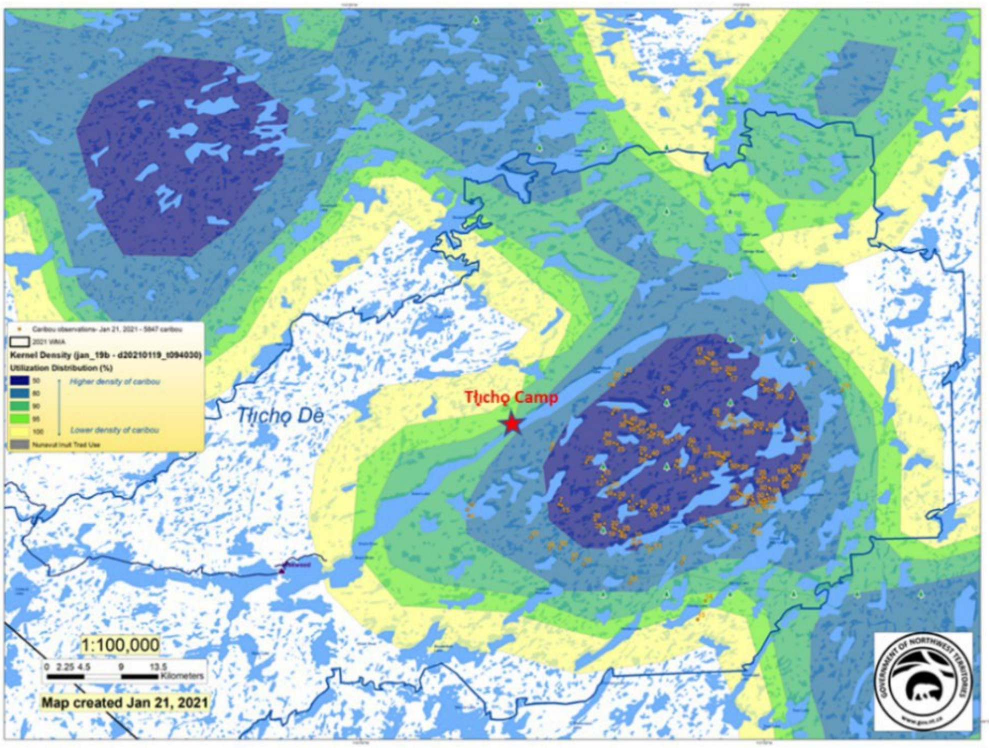


Figure 23. Reconnaissance survey completed by ENR on January 21, 2021 (map provided by GNWT/ENR).

The first crew established base camp at Roundrock Lake on January 24, 2021. The first crew started off very strong amongst the challenges of the bitter cold facing them. After being at camp for two days, dìga were being harvested (Figure 24). All of the dìga harvested in the Tłı̨chǫ program were shot. There were attempts to use snares and traps, but because of the high occurrence of ekwǫ̀ surrounding the area, there was reluctance for the fear of capturing ekwǫ̀ in the traps or snares. Each crew consisted of six hunters and two cooks, who were on a two-week rotation until March 29 which ended in a total of five rotations.

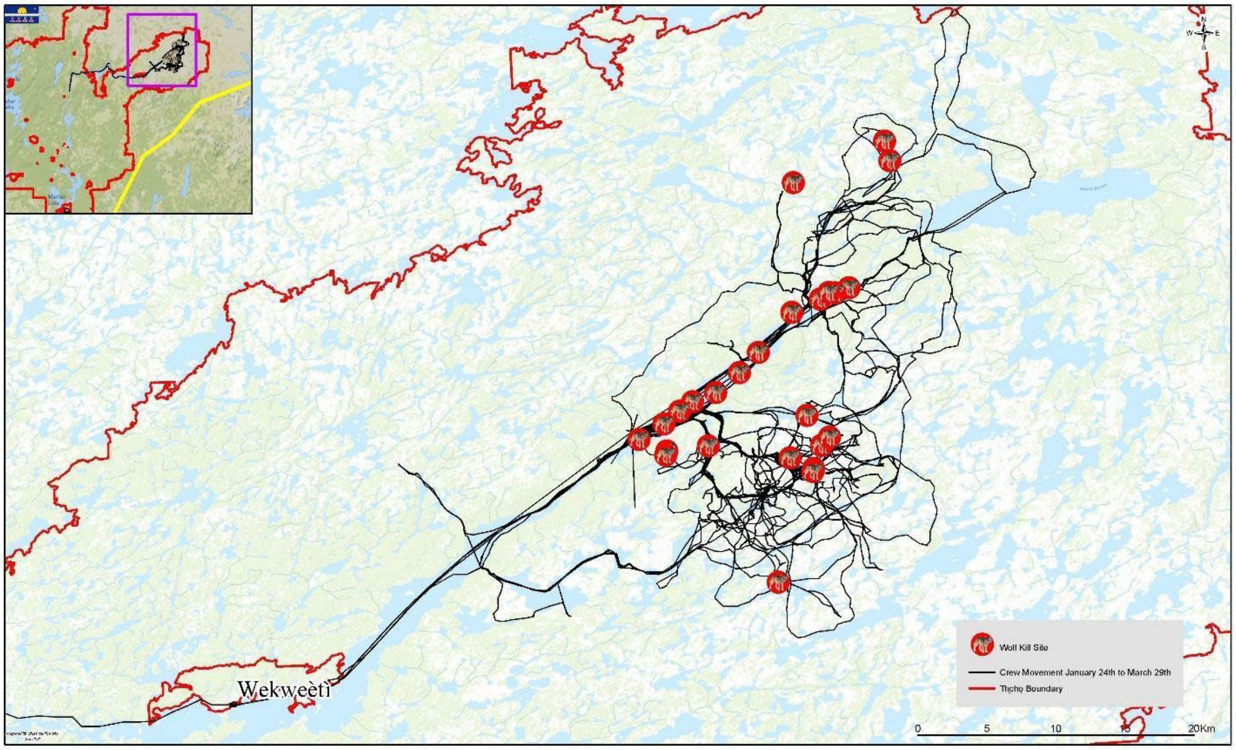


Figure 24. Trails used by dìgà harvesters and locations of where dìga was harvested between January 24, 2021 to March 29, 2021. At times there was more than one dìga harvested at the same location.

Dìga Harvesting Methods

On the first day being at camp, the first crew noticed a large pack of an estimated 40 dìga not too far from camp while out snowmobiling on the northern part of the lake. They decided that they would target them the next day. The first crew didn't have to make too much effort when harvesting dìga at the beginning of their rotation. They would see them on the lakes and chase after them and would shoot them. This went on for the first week of their rotation. After the first week, harvesting began to slow down. It seemed as though the dìga caught on that they were being hunted and were staying away from the area surrounding the camp, making it difficult for the harvesters to go after them. The Tłı̨chǫ harvesters began to strategize in how to hunt the dìga, focusing on using kill sites and waiting for the dìga to feed which would slow down 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 hunt them.

Once a dìga was harvested, the carcass was immediately put into a thick plastic bag so that the blood of the animal would not go onto the snowmobiles or the sleds as per following Tłı̨chǫ protocols. Before putting the carcass into the bag, the hunter would insert the muzzle of their gun into the mouth of the animal and thank it for its life, paying their respect to the animal. A tag would be put on the animal with the harvest date and location, then it would be stored on the shore of the lake near the airstrip that was made for the plane. The harvesters did not want to skin the dìga at camp and so the wolf carcasses were picked up by air charters provided by ENR and were transported to ENR's North Slave Regional Office to confirm incentive payments and for subsequent necropsy.

One of the harvesters in camp was designated as the "safety person" who took care of the satellite phone, inReach, GPS, tagging of the dìga as well as completing the 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. 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. Each day consisted of a safety meeting in the morning to plan for the day and determine their traveling routes. On some days all harvesters would travel together and scout for dìga and on other days they would break up into two groups. The majority of the time they were in two groups. One Garmin inReach was given to the harvesters to keep track of distance traveled and to use as a communication device; one was kept at the camp with the cooks as well as the satellite phone.

Dìga Harvest Results

In the first rotation, there were 19 dìga harvested and the crew traveled a total of 524.3 km around the camp with snowmachines (Figure 25). In the second rotation, the crew traveled 1,016.3 km with not as great luck as in the first crew but were able to harvest four dìga. The first crew went back to the camp for the third rotation and traveled 636.6 km and harvested seven dìga. At this point, harvesting was lower with the second crew going back to camp in the fourth rotation and only two dìga harvested with high effort of traveling 959.6 km. The first crew went back to camp for the final rotation and didn't have any luck in harvesting dìga and little traveling around with a mere 108.6 km.

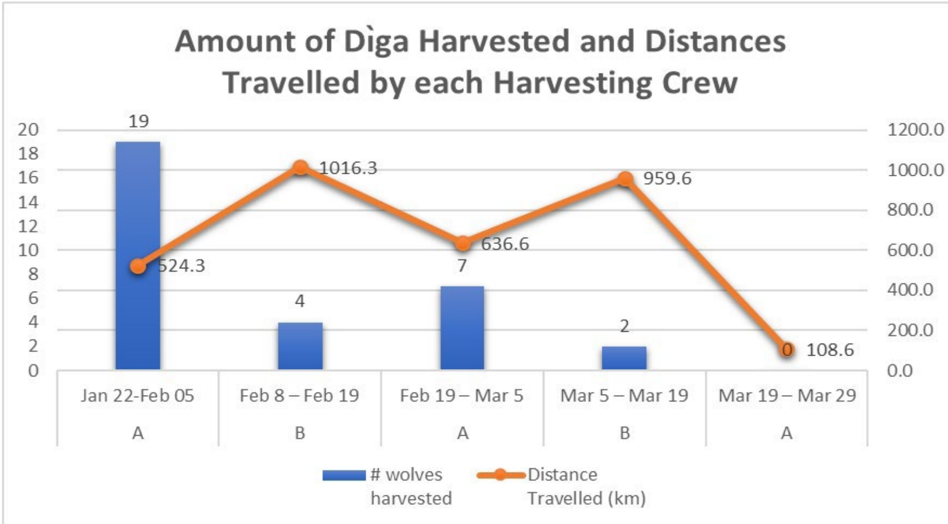


Figure 25. Amount of dìga harvested by each crew along with the distances traveled by snowmachine.

Based on the harvest data, the pattern in dìga kill rate among the different crew rotations showed a relatively high kill rate (3.6 wolves/100 km) by the first crew followed by a rapid decline to 0.4 wolves/100 km for the second crew (Figure 26). The dìga kill rate for the third crew slightly improved to 1.1 wolves/100 km, but then steadily declined for the fourth and fifth crews, with no wolves harvested by the fifth and final hunting crew (Figure 26).

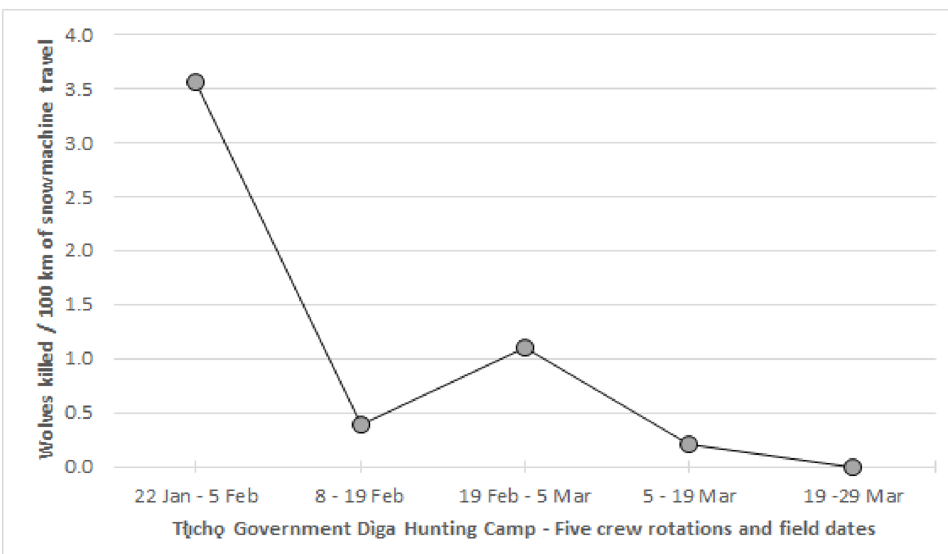


Figure 26. Wolf harvest rate of Tłı̨chǫ dìga hunting crews in winter 2021.

Discussion and Lessons Learned

Prior to the start of the 2021 program, TG staff contacted an experienced NU 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. Also, after the meeting with the elders, safety training was provided to the participants who didn't have their possession and acquisition licence (PAL)[10] and wilderness first aid. ENR had provided trapper training specifically for dìga harvesting but due to conflicting timing with the safety training and the very short notice, the participants were unable to attend the trapper training.

One of the harvesters started the process of rotting fish to use as bait and brought it out to camp. The bait was not used once it was realized that the dìga were using kill sites and the decision not to use traps or snares was made; so, bait was not necessarily needed. The first crew that was out had set traps with snares and captured a caribou calf in the trap, fortunately the calf was found shortly after it was caught and was released. After this incident, the participants of the program had a meeting with the program manager, and it was decided that traps and snares shouldn't be used.

The first crew encountered very cold temperatures during the last week of their hunt rotation, when average daily temperature declined from -30˚C to -43˚C (Figure 27). Although it was cold, traveling conditions were optimal simply because it did not snow much while they were there and the snowmobiles didn't have any issues with the drummed gas. As time progressed, water began to accumulate in the gas tanks and caused a lot of grief for the hunters with having to constantly try and get rid of the ice with antifreeze or clean out the tanks. The gas issues began during the last week of the first crew and continued on with the second crew, we decided then that we would no longer use the drummed gas and get gas from the community of Wekweètì. While retrieving gas in the community, the harvesters were told that they were to wait by the airport and were not allowed to go into the community with the snowmobiles because they were used for hunting dìga; someone would meet them at the airport to collect the jerry cans and would fill them up and return them to the hunters. By having the hunters stay at the airport, it eliminated the risk of dìga blood coming in town. The traveling to Wekweètì would give reason for the increase in mileage, each week a trip was made and the camp was approximately 30 km one way. Extreme cold temperatures also limited our hunters from traveling around, we had no hunters in camp for the first weekend of February (February 5-8) due to extreme cold temperatures (i.e., on 7 February the average daily temperature was -47˚C, with daily minimum and maximum temperatures of -52˚C and -41˚C, respectively) (Figure 27). These days coincided with the switching of crews, so the outgoing crew was delayed by a couple of days; when they returned to camp they had to unfreeze the generators and snowmobiles. Just prior to the last rotation, the hunters got hit with a heavy snowfall. There was so much snow that the hunters couldn't travel anywhere. Due to the difficult travel conditions from deep snow and no signs of dìga, we closed camp and we ended the program on the March 29, 2021.

[10] www.rcmp-grc.gc.ca/en/firearms/licensing

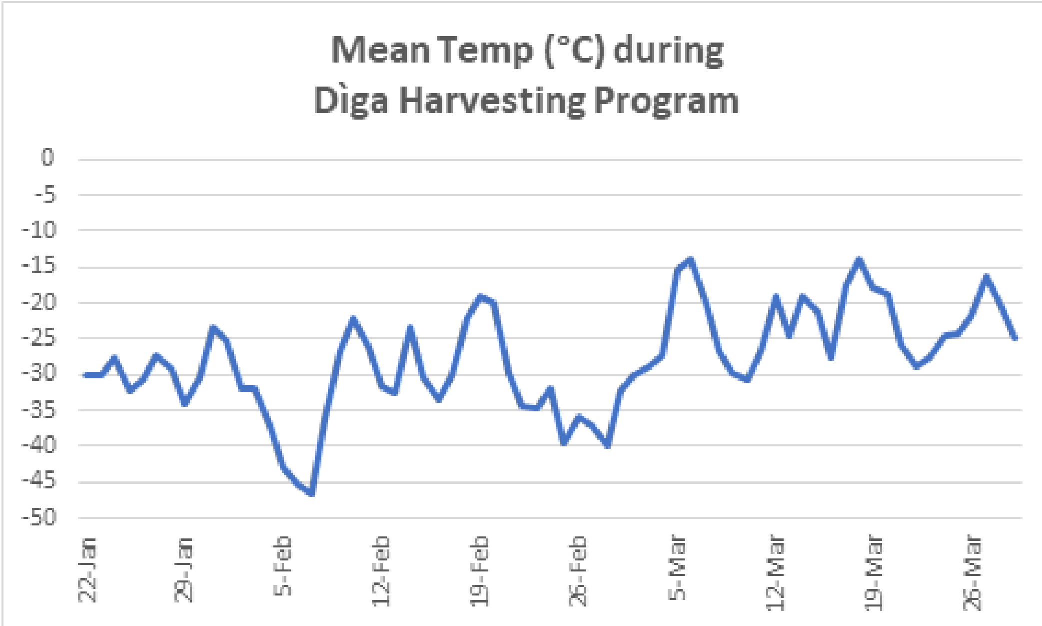


Figure 27. Average daily ambient temperature during the program for Wekweètì starting January 22 to March 29, 2021 (Historical Climate Data 2021).

ENR regularly provided maps (daily during the work week) that showed the distribution of collared ekwǫ̀ to help inform hunters on where to find dìga. The hunters were seeing anywhere from 1-100 ekwǫ̀ on a daily basis; there were ekwǫ̀ all over the place. Based on the hunter's knowledge and observations, they concluded that the ekwǫ̀ they were seeing were koketi ekwǫ̀; the hunters are able to tell the difference by the size of the ekwǫ̀ and their general appearance. Based on the location of the dìga harvester camp and the historical movement of Sahtì ekwǫ̀, we thought that the dìga harvested would be associated with the Sahtì ekwǫ̀. But because of the high mixing of herds in the winter ranges it was difficult to determine which herds the dìga were associated with. Based on the collar locations, there was a high concentration of koketi ekwǫ̀ in the area where our camp was located. Even with seeing all the ekwǫ̀ in the area, after the third rotation, there was very little dìga being harvested. It was at this point that we should have taken an adaptive approach and moved camp to target another pack of dìga, not much sign of dìga was seen and there was no point being there as it seemed as if the pack in that area may have been hunted out or moved elsewhere. As a future strategy to improve program effectiveness, we will develop an adaptive approach whereby once harvest (i.e., dìga kill rates) and sightings of dìga start to decrease then we will consider moving camp to another area.

Photo credit 1: Tłı̨chǫ Government - Roundrock Lake camp

Photo credit 2: Tłı̨chǫ Government – Left: Harvester Frederick Simpson taking a break. Right: Harvesters, Eric Laboline and Johnny Boline taking a break.

Summary of Harvest in the North Slave Wolf Harvest Incentive Area

A total of 135 wolves were harvested within the North Slave Wolf Harvest Incentive Area in 2021 on the winter ranges of the Bathurst and Bluenose-East caribou herds. Aerial removals were not undertaken. An interim harvest trigger was set at 80% of the wolves estimated to be associated with the Bathurst and Bluenose-East caribou herds which guided harvest efforts and allowed for adjustments if high numbers of wolves continued to be encountered.

As the reported harvest approached the interim trigger levels in late March, a decision was made to continue supporting the wolf harvest as, other than the Tłı̨chǫ dìga harvester camp, there were no reports that hunting rates of wolves were declining. The harvest of 135 wolves in 2021 is compared to 84 wolves taken through both ground-based hunting and aerial shooting in 2020 (Table 23). Most wolf hunting in 2021 occurred around the hunting camps set up by Tłı̨chǫ and Inuit harvesters. The TG's Dìga Harvesting Program was more successful this year resulting in a ten-fold increase in number of wolves harvested (i.e., 32 in winter 2021 versus three in winter 2020). Inuit hunters almost tripled their harvest from last years' likely as a result of the distribution of all three caribou herds overlapping their camp location.

Table 23. Monthly summaries of wolf removals in 2020 and 2021.

	2020		2021	
	Ground-Based Hunting	**Aerial Shooting**	**Ground-Based Hunting**	**Aerial Shooting**
Jan	0	0	20	0
Feb	18	0	39	0
Mar	27	0	42	0
Apr	9	30	34	0
Subtotal	54	30	135	0
Total	84		135	

In winter 2021, the trend in monthly wolf harvest in the North Slave Wolf Harvest Incentive Area for each of the three hunter groups showed three distinct patterns (Figure 28). Firstly, Kugluktuk hunters had their lowest harvest at the start of the winter in January (i.e., four wolves), and then maintained comparatively consistent and high monthly removals ranging from 25-31 through the rest of the winter to April. The Kugluktuk harvester group took a total of 87 wolves, which was the largest cumulative wolf harvest of the three hunter groups. Secondly, the monthly wolf harvest by winter road hunters ranged from one to three wolves, with the exception of March when 12 wolves were taken. The winter road hunters took 16 wolves, which was the lowest cumulative wolf harvest of the hunter groups. Thirdly, Tłı̨chǫ harvesters had their highest monthly wolf harvest of 15 animals in January. In February they maintained a similar harvest of 11 wolves, but then monthly harvest dropped to three and one wolf for March and April respectively. Tłıchǫ harvesters took 32 wolves in total.

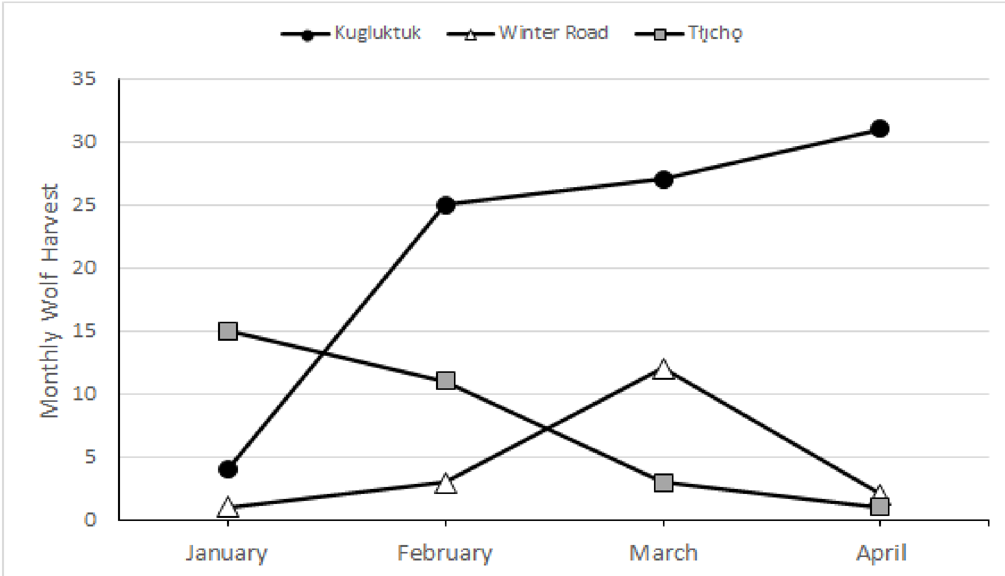


Figure 28. Trend in monthly wolf harvest in the North Slave Wolf Harvest Incentive Area by three harvester groups, winter 2021.

Wolf Harvester Questionnaire

In winter 2021, ENR used a Wolf Harvester Survey to collect information on harvesting effort. The survey posed questions about harvest location and number of wolves taken, wolf and caribou sightings, hunter effort (i.e., hours spent and kilometers traveled), weather conditions, and other relevant factors and observations (Appendix B). Winter road harvesters were provided $50 gas cards for the submission of completed surveys. ENR officers handed out the surveys to the hunters traveling on Tibbitt-Contwoyto winter road, where they were encouraged to stop at the ENR check stations. The same surveys were also given to the Tłıchǫ and Kugluktuk harvesters at their respective camps at the Roundrock and Itchen Lake locations.

Questionnaire Summary

Harvesters returned 117 completed surveys, dated between January 23 and April 25, 2021, to the ENR office, reflecting 79 hunting trips and 123 wolf harvests in the North Slave Wolf Harvest Incentive Area. There are more surveys than trips because some groups submitted more than one survey form for the same trip. Of the 123 harvests reported in the surveys, 21 did not have corresponding effort data due to recording errors. Collectively, the reported total kilometers traveled by the hunting parties, was 66,839 km, and the total reported hours spent hunting was 1,905 hours (Figure 29 and Table 24).

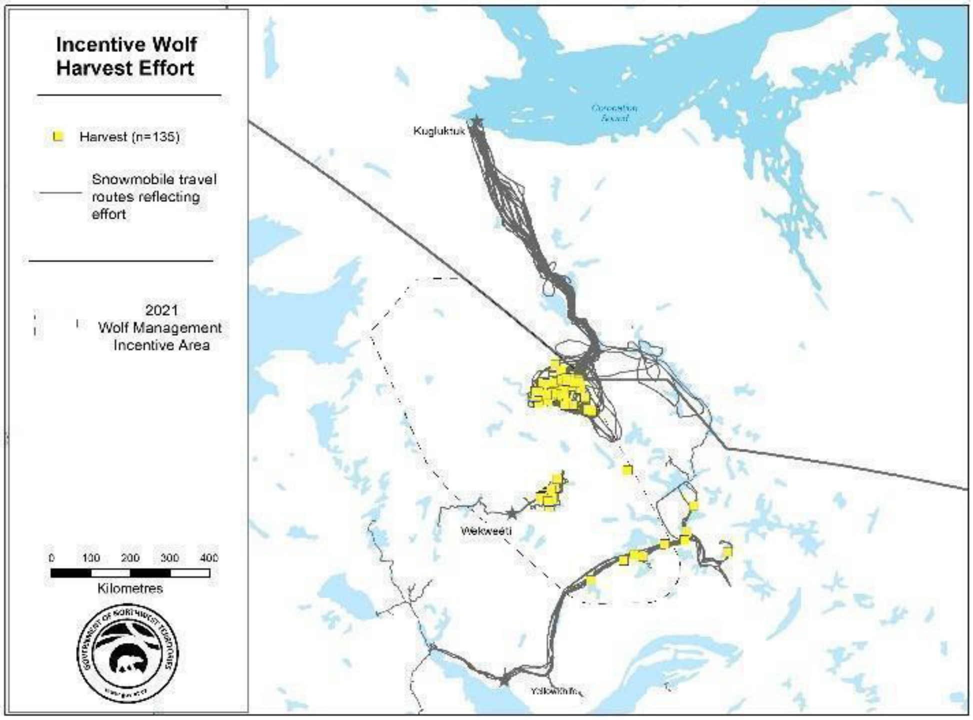


Figure 29. Wolf hunter tracks from hand-held GPS units during the 2021-2021 hunting season in the North Slave Wolf Harvest Incentive Area

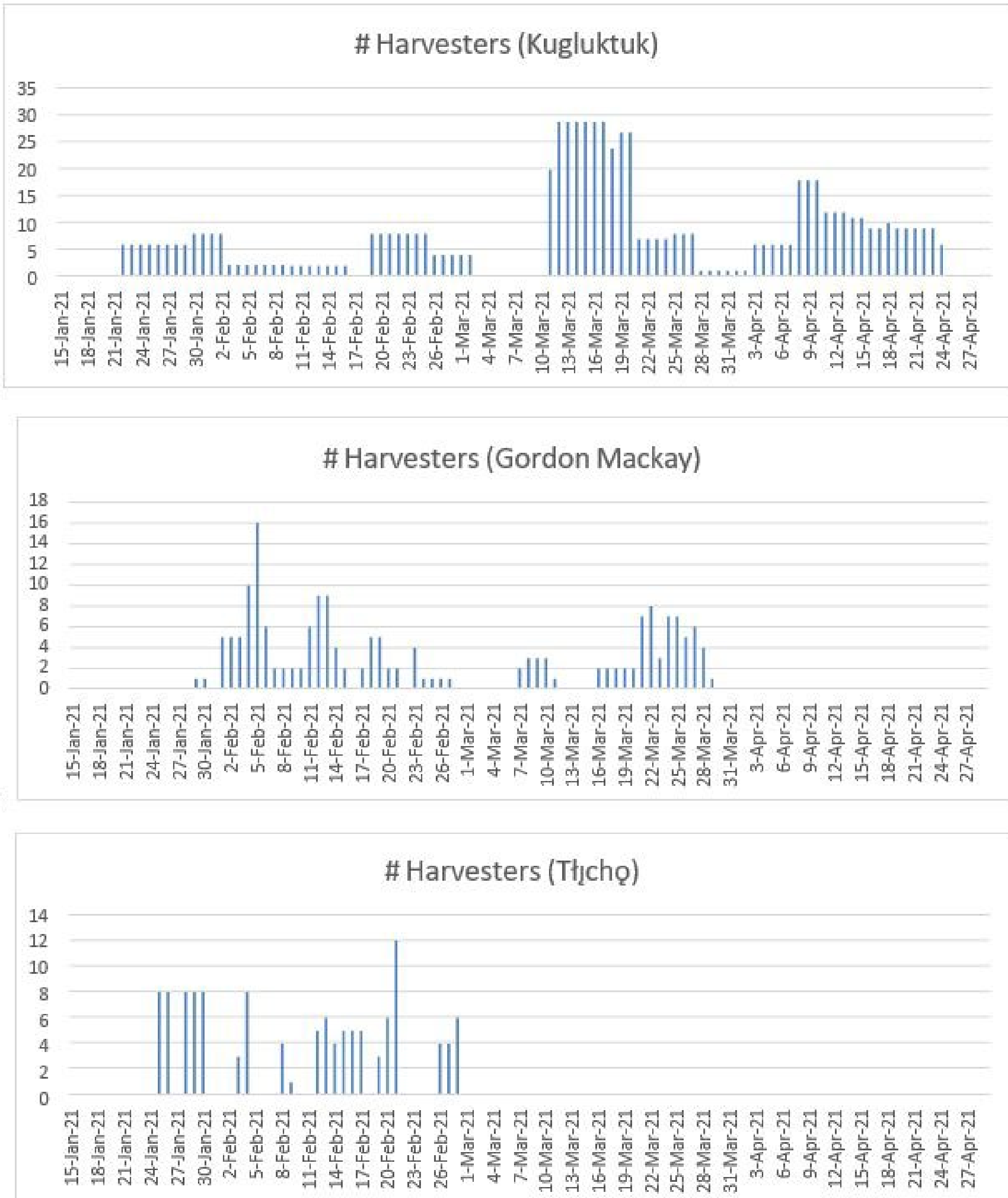
In comparison, in the 2019-2020 hunting season, 67 surveys were returned to ENR from the harvesters from Kitikmeot and the North Slave regions, reflecting 39 harvesting trips and 39 wolf harvests.

Table 24. Summary of 2019-2020 and 2020-2021 wolf harvester surveys.

	Completed Surveys	# Wolf Hunting Trips	# Wolves Killed by Hunters	Hours Spent	Km Traveled
2019 - 2020	69	39	39	1,736	25,565
2020 - 2021	117	79	123	1,905	66,839

Combined, the total kilometers traveled by the harvesting parties in the 2019-2020 season was 25,565 km, and the total hours spent were 1,736 hours (Table 24).

Based on the surveys, between January 23 and April 25, 2021, there were 89 days when there were active hunting groups in the North Slave Wolf Harvest Incentive Area. During this period, an average of 3.5 groups/day was actively hunting for wolves in the North Slave Wolf Harvest Incentive Area. During this period, the average group size was 3.5 harvesters/group, resulting in a total of 1,196 person-days. Kugluktuk harvesters were active from January 23 to April 25; Winter road harvesters were active between January 30 and March 30, and Tłı̨chǫ harvesters were active from January 26 to March 01 (Figure 30).



a) b) c)

Figure 30. Number active harvesters in the North Slave Wolf Harvest Incentive Area over the 2020-2021 harvest season a) Kugluktuk b) Winter Road c) Tłįcho.

Respondents were asked to record whether they saw caribou while they were looking for wolves and, if they did, how large the groups were. Results showed that relative frequencies of groups sizes reported by hunters on the winter roads and Tłıchǫ hunters were similar, which was in contrast to Kugluktuk hunters who reported seeing predominantly larger caribou groups (Figure 31). In addition, hunters were asked to record whether they saw caribou carcass remains that they thought were a result of wolf kills.

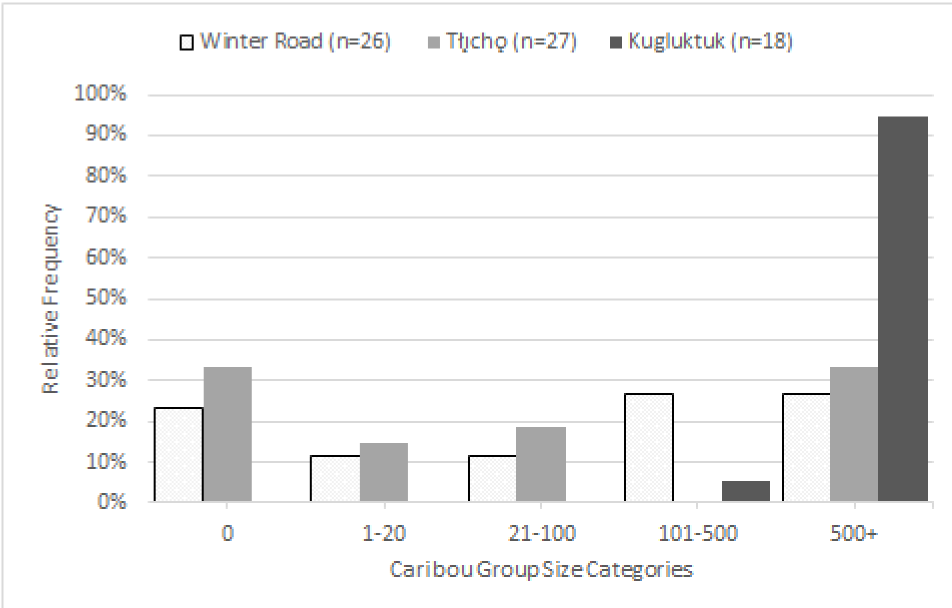


Figure 31. Relative frequency of caribou groups sizes in the North Slave Wolf Harvest Incentive Area as reported by wolf hunter groups in harvest questionnaires for winter 2021.

Due to the survey 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. This was less of an issue with Tłıchǫ harvesters at the Roundrock Lake camp who filled out their survey daily. Therefore, the response summary to these questions should be interpreted with caution.

Collectively the responses likely underestimate hunters' sightings of caribou groups and carcass remains. Respondents also reported harvesting two muskox, 16 wolverines, and 11 foxes while hunting for wolves.

Twenty-eight harvesters reported that weather conditions adversely affected their hunt, while 13 reported no adverse effects and 76 did not respond. Harvesters were asked to describe the weather conditions they encountered. Due to the survey design, the respondents only provided one observation for the trip duration. Those who traveled for more than two days could not attribute their weather observation to a specific day and effort. Therefore, the responses could not be used to directly test how weather influenced daily hunting effort.

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. 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, kilometers and hours traveled on a daily basis, for locating and harvesting a wolf.

The questionnaire asked hunters to record "estimated number of hours spent hunting each day" and "estimated number of kilometers traveled each day." The intent of these questions was to include two key parameters including:

a) time spent and distance traveled on the hunting grounds, searching for wolves; and
b) time and distance traveled once wolves are seen, such as stalking, active pursuit and shooting.

Through compilation and analyses of information from questionnaires, it became apparent that survey response information on hunter effort may be confounded by one or more of the following occurrences that should not be included in the tally of hours/kilometers traveled during harvesting:

a) Time lost through bad weather.
b) Time/distance traveling to and from the hunting area.
c) The time during which the hunters are preparing for hunting but are not actually hunting (mobilizing, getting vehicles/snowmobiles ready etc.).
d) Time spent handling the wolf after it was harvested.

Thus, for future questionnaires, the questions and design should explicitly consider these potential sources of uncertainty to improve our interpretation of harvester responses. For example, time spent handling and processing a wolf carcass should not be included in hunter effort. Similarly, the question on distance traveled should clarify that the kilometres traveled should only have the distance covered for hunting (i.e., searching for and harvesting wolves). These questions in turn need to be considered from the harvester's perspective and not be difficult or burdensome to record information.

The harvesting power, or the "kill rate" of a particular party, i.e., the harvest it takes from a given density of wolves per unit harvesting time/distance, can be thought of in two parts:

a) The extent (area) over which the party's influence extends and within which wolves are potentially available to be caught.
b) The proportion of the wolves within this area that are harvested.

The survey question includes the number of harvesters in each group to assess whether it impacts the proportion of the wolves within the area that are liable to be (and are, in fact) harvested. 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.

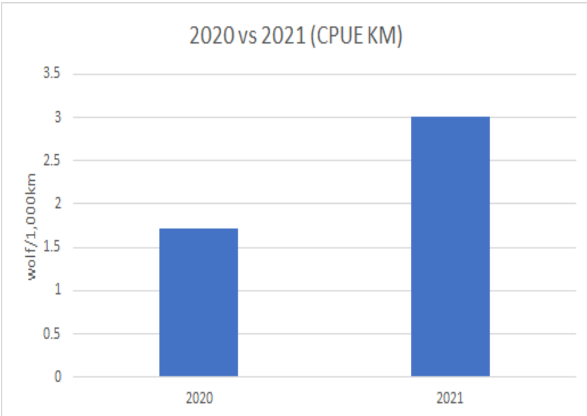
The survey includes questions that elicit external factors that may also affect the chance of success, such as weather and caribou presence. Behavioural responses (including learning) of wolves to avoid detection by hunters, is another important external factor.

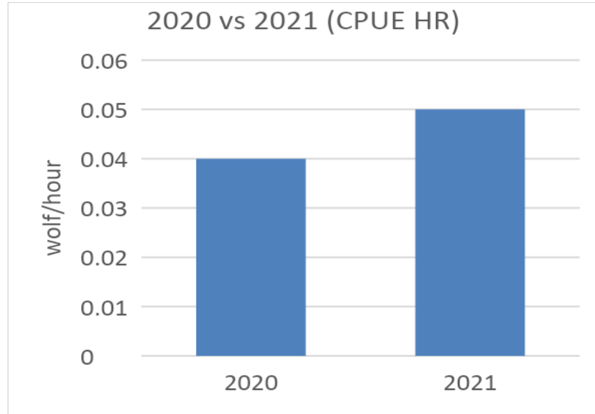
The analysis for CPUE is based on the submitted 117 surveys completed by harvesters from Kugluktuk, TG's dìga harvest camp and hunters accessing the Tibbit-Contowyto winter road (Table 25). The surveys reported one hundred thirty wolf harvests, accounting for 128 of the 160 carcasses submitted to ENR. There were two additional wolves that were reported in the surveys but whose carcasses were not recorded on the necropsy list of ENR. Of 130 harvests, only 101 had attributable effort data (including the two without the carcasses). In total, CPUE analysis is based on 79 harvesting trips (considering multiple response submissions by a single harvesting party) and 101 harvests within the North Slave Wolf Harvest Incentive Area.

Table 25. Questionnaire harvest summary.

	Overall	**Kugluktuk**	**Winter Road**	**Tłı̨chǫ**
# Returned Surveys	117	54	29	34
# Trips	73	20	26	27
# Survey reported harvests	130	86	15	29
# Harvests with effort data	101	57	15	29
# Wolves not included in the carcass analysis	2	0	2	0

In total, harvesters that submitted questionnaires for wolves harvested in the North Slave Wolf Harvest Incentive Area, had a CPUE (km) of 333 km per wolf, or 3 wolves/1,000 km. Due to the survey design, the wolf encounter rate cannot be calculated because wolf observations were not recorded consistently by many respondents. For CPUE (hr), harvesters report spending an average of 18.9 hours to harvest one wolf, or 0.05 wolf/ hour over the season. In comparison, in the 2019-2020 harvest season, the average (combining harvesters from Kugluktuk and North Slave) CPUE (km) was 585 km per wolf or 1.7 wolves/1,000 km, and CPUE (hr) was 0.04 wolf/hour (25 hours/wolf) (Figure 32).





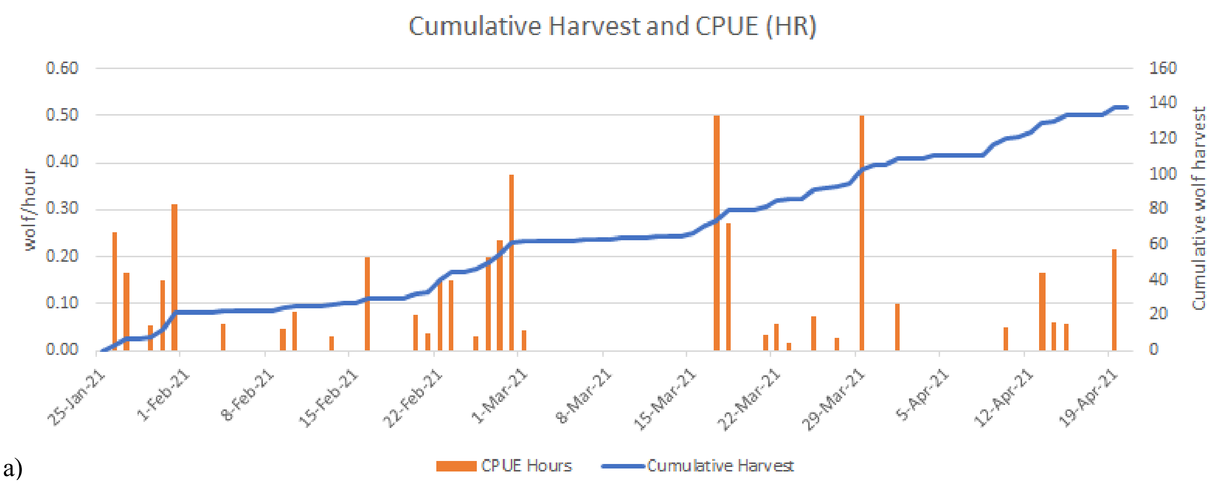
A **B**

Figure 32. Comparisons of 2019-2020 and 2020-2021 a) CPUE (km) and b) CPUE (hr)

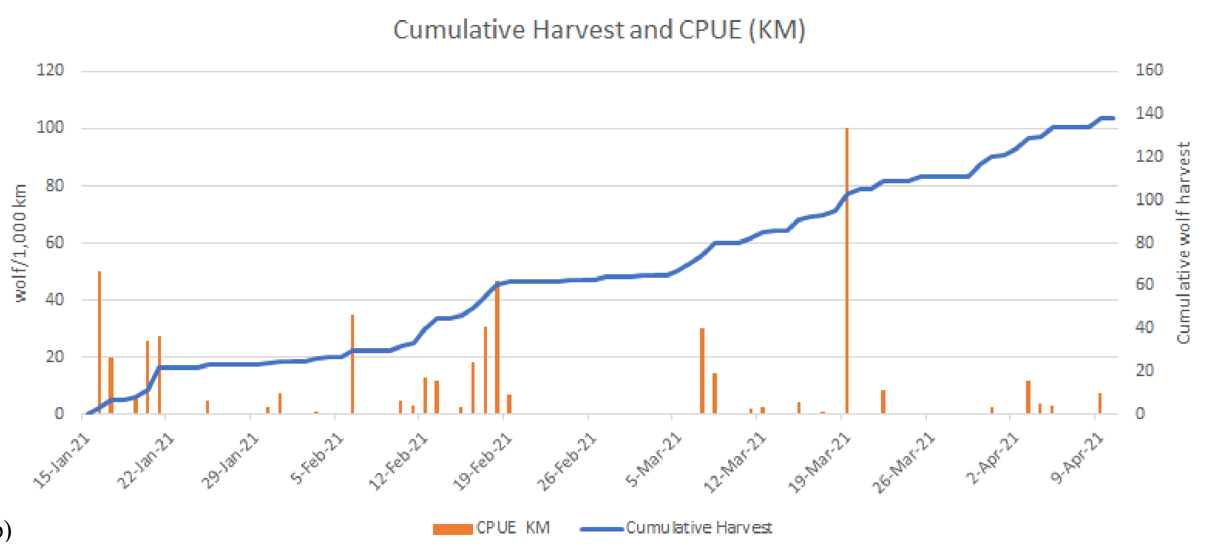
In CPUE analyses, a general assumption is that the harvested population is closed, meaning that there is not a significant movement of individuals in or out of the population within the given period. Thus, in a closed population and with other covariates held constant, CPUE should decrease as abundance 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 is 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.

For this report, all wolf harvests within the North Slave Wolf Harvest Incentive Area that had a reported kill date (n=139), regardless of whether they have associated effort data or precise GPS coordinates, were included in the cumulative wolf harvest count. However, the CPUE calculation was still based on the subset of wolf harvests that also reported effort data (n=101) in the questionnaires. Seven harvests (two on March 15 by Kugluktuk harvesters, three on March 16 by Kugluktuk harvesters and two on March 30 by winter road harvesters) recorded the effort data as zero (0 km traveled and 0 hours spent); those harvests were included in the total CPUE for the season but were not included in the within-season CPUE charts because denominators cannot be zero.

At the scale of the North Slave Wolf Harvest Incentive Area over the winter 2020/2021 hunting season, which included wolves harvested and associated effort reported by all three hunting groups (i.e., Kugluktuk, winter road, and Tłı̨chǫ), CPUE did not show a declining trend over the season (Figure 33). A declining trend in CPUE across the North Slave Wolf Harvest Incentive Area would have provided indirect evidence for a relative reduction in wolf density. Instead, the overall pattern showed that CPUE increased over the hunting season. To better understand this overall pattern, we explored trends in CPUE for each of the Kugluktuk, winter road, and Tłįchǫ harvest groups, using their respective cumulative harvest data.



a)

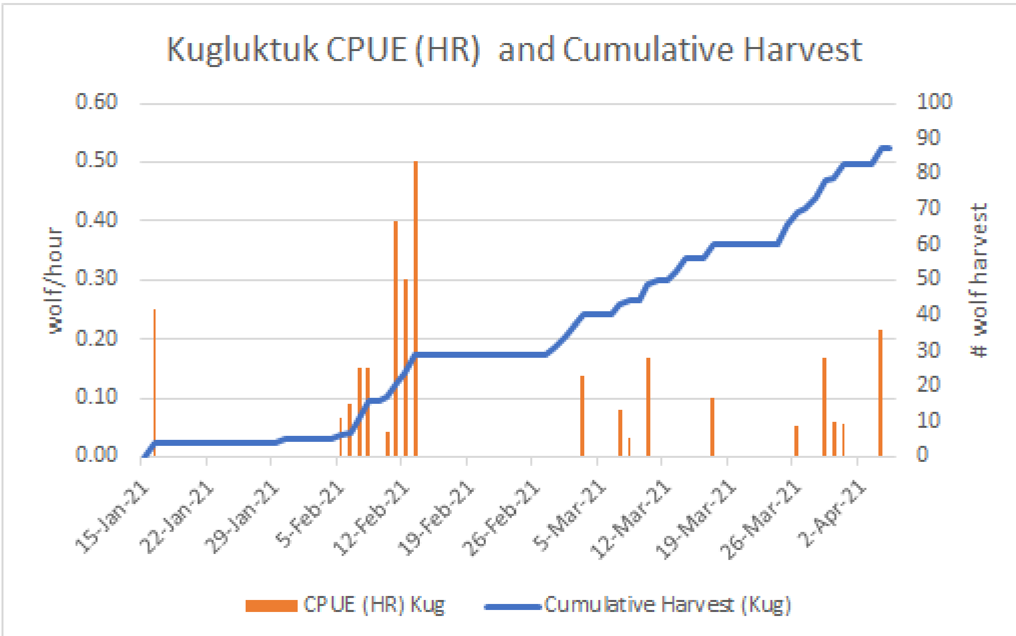


b)

Figure 33. Comparison of total cumulative wolf harvest for all hunter groups in the enhanced North Slave Wolf Harvest Incentive Area during winter 2021 and CPUE expressed as a wolf kill rate relative to a) time (hours) and b) distance traveled (km).

For NU hunters traveling from Kugluktuk to hunt in the North Slave Wolf Harvest Incentive Area, CPUE (per hr and km) appeared to be highest in early March which corresponded with the second hunting party that were out in the first half of their hunting period (Figure 30a and Figure 34). The CPUE was approximately double the rate that occurred at the beginning of the season, and more than double the rate in the last half of the hunt period (Figure 34). Despite the comparatively lower CPUE rate, Kugluktuk hunters killed most of their wolves in the last half of the hunting season, which was when the greatest number of hunters were active (Figure 30a). Kugluktuk hunters consistently observed the largest groups of caribou (Figure 31) and correspondingly harvested the most wolves in the North Slave Wolf Harvest Incentive Area.

a)



b)

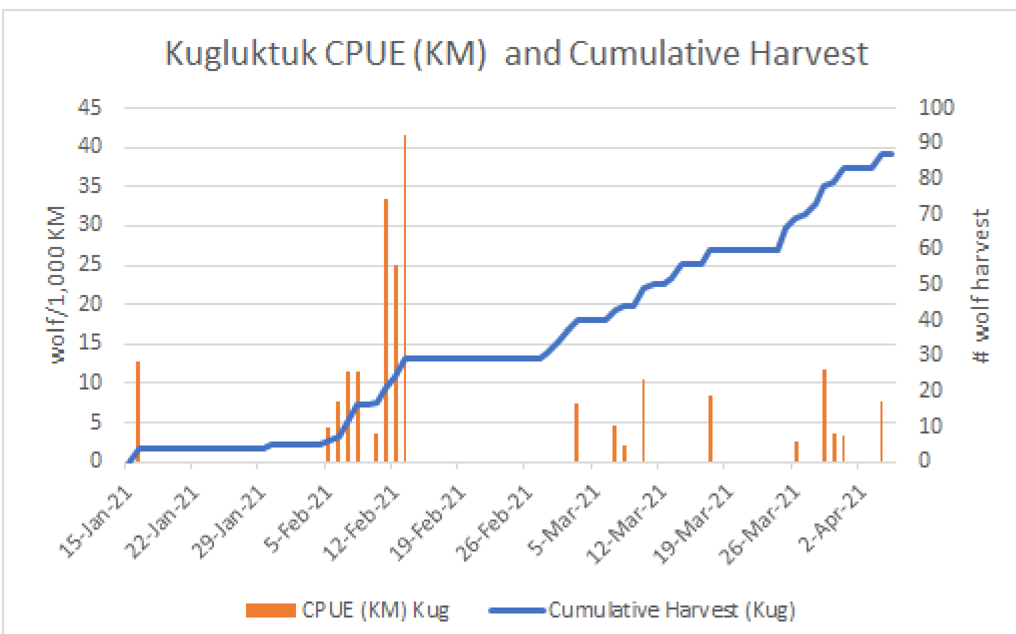
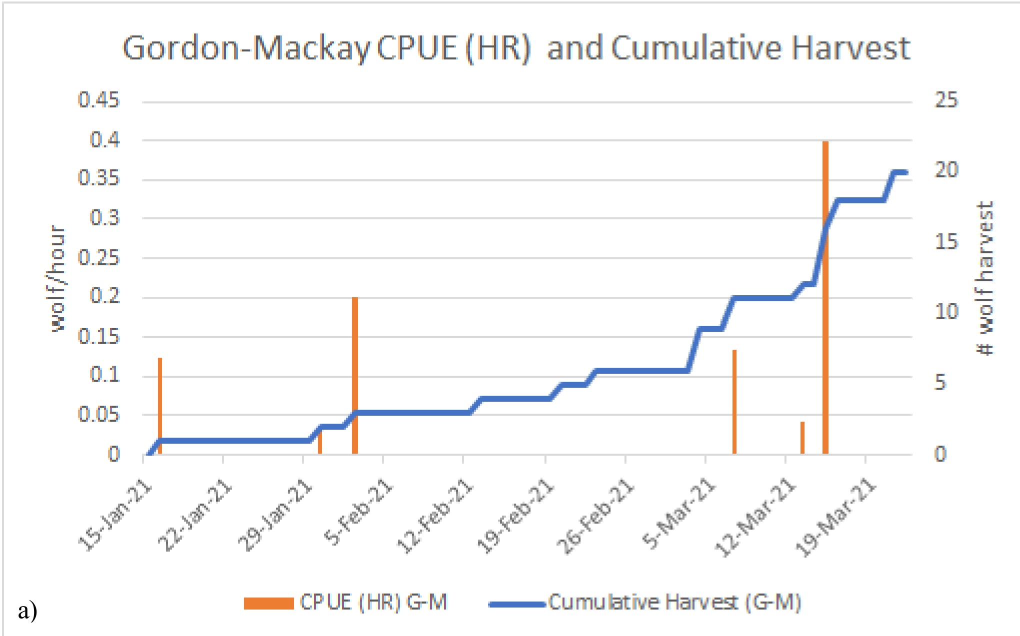


Figure 34. Comparison of total cumulative wolf harvest for Kugluktuk hunters in the enhanced North Slave Wolf Harvest Incentive Area during winter 2021 and CPUE expressed as a wolf kill rate relative to a) time (hours) and b) distance traveled (km).

Winter road wolf hunters that accessed the North Slave Wolf Harvest Incentive Area through the Tibbet to Contwoyto winter road corridor and hunted mostly in the Gordon and Mackay Lake area, experienced a low CPUE at the start of the season (February - mid March) with rates progressively increasing with the highest CPUE rates occurring in late March (Figure 35). Gut piles from harvested caribou are thought to be a likely contributing factor to increased CPUE rates for winter road wolf hunters in March. In comparison to Kugluktuk hunters who had a peak hourly CPUE rate of 0.5 wolf/hr, winter road harvesters had a peak rate of 0.4 wolf/hr. This meant that winter road harvesters had to spend more time to kill a wolf. However, when CPUE was expressed as a function of distance traveled, peak CPUE rate for winter road harvesters (0.08 wolf/km) (Figure 35) was higher than the rate experienced by Kugluktuk hunters(~0.042 wolf/km) (Figure 34b), which suggested that on average, Kugluktuk hunters had to travel more than twice the distance than winter road hunters to harvest a wolf.



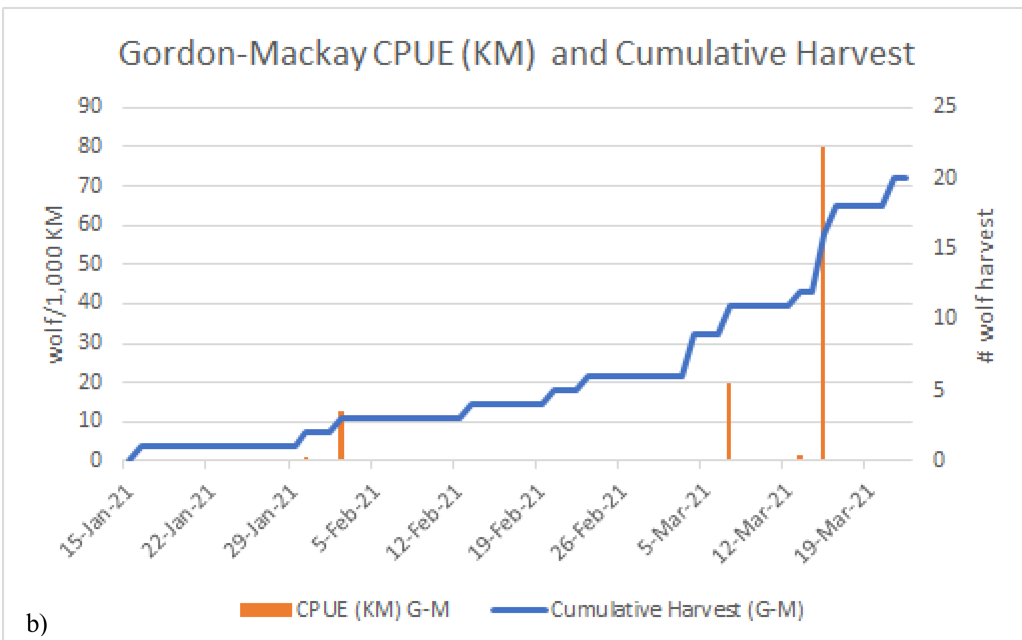
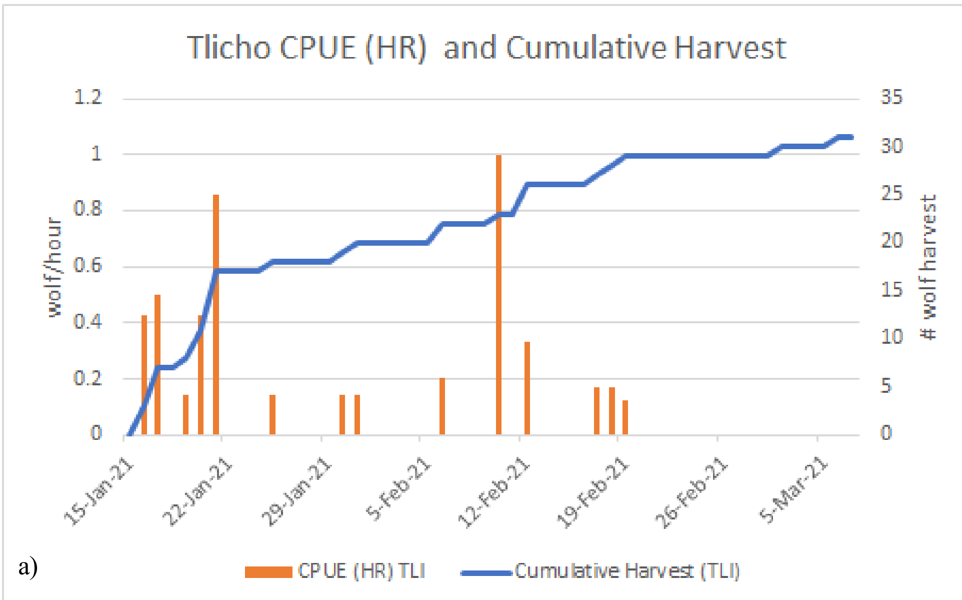


Figure 35. Comparison of total cumulative wolf harvest for hunters accessing the Tibbit to Contwoyto winter road (generally between Gordon and Mackay Lakes) within the enhanced North Slave Wolf Harvest Incentive Area during winter 2021; CPUE expressed as a wolf kill rate relative to a) time (hours) and distance traveled (km).

In comparison with the Kugluktuk and winter road hunters, Tłı̨chǫ hunters had the highest hourly CPUE rates of 1 wolf/hr (Figure 36). Tłı̨chǫ hunters' peak travel-based CPUE rate (0.5 wolf/km) was an order of magnitude higher than the peak CPUE rates experience by Kugluktuk and winter road harvesters. This pattern is well explained and corroborated by the crew-based results of the TG's Community-based Dìga Harvest Program (see TG's Community-based Dìga Harvest Program), in which the first hunting crew had the highest wolf kill rate, followed by a rapid decline to low rates for subsequent crews, with now wolves killed by the fifth and final crew (Figure 36). That declining pattern of wolf kill rates provides indirect evidence that most wolves were harvested within the local search area, although movement of wolves out of the area cannot be ruled out as a contributing factor.



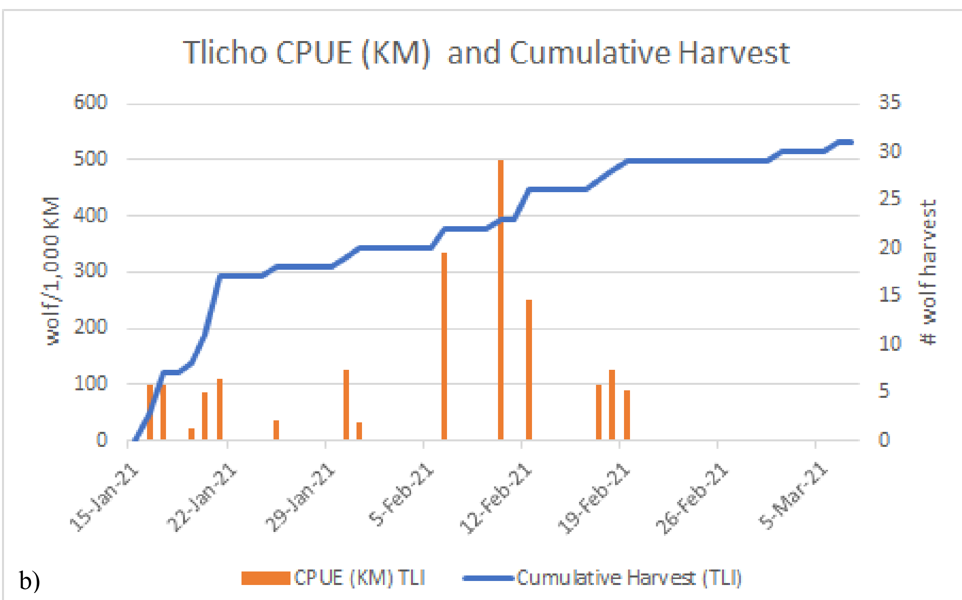


Figure 36. Comparison of total cumulative wolf harvest for Tłı̨chǫ hunters in the enhanced North Slave Wolf Harvest Incentive Area during winter 2021 and CPUE expressed as a wolf kill rate relative to a) time (hours) and b) distance traveled (km).

In the wolf harvester questionnaires, hunters were provided with space to comment on their weather observations and asked to check "yes" or "no" to the question: "Was hunting harder because of weather?" Except for the Tłıchǫ respondents who filled out the survey daily, the survey responses reflect the harvester's observation of the overall trip without attributing to specific dates or harvests of the 39 who answered "yes" or "no," 28 responded "yes" (the weather did make hunting difficult) and 11 responded "no" (the weather did not affect their hunting). The respondents who answered "yes" harvested 96 wolves, and those who answered "no" harvested five wolves (Table 26). Of the Tłıchǫ respondents, 11 answered "yes" and harvested 16 wolves, while 16 did not answer and harvested 13 wolves.

Table 26. Summary of responses to weather effect.

	Was hunting harder because of the weather?		# Harvest	
	Total	**Tłıchǫ**	**Total**	**Tłıchǫ**
Yes	28	11	96	16
No	13	0	5	-
NA	25	16	30	13

Harvesters' weather observations were categorized into three classes: poor, moderate, and good (Table 27). Those responses that only contained adverse weather conditions, such as "blizzard," "very cold," "white-out," or "blowing snow," were categorized as poor. Those responses that only contained fair weather conditions, such as "sunny," "clear," or "good" were categorized as good. Those responses that contained one or more of both were categorized as moderate.

Table 27. Summary of weather descriptions.

	# Days	# Wolf Harvest
Poor	29	62
Moderate	15	54
Good	11	9
NA	4	4

CPUE Summary

The overall CPUE of wolf harvesters in the North Slave Wolf Harvest Incentive Area in 2021 was higher than in 2020, perhaps reflective of the high amount of herd overlap and associated wolves on the winter range in 2021. Harvesters that submitted questionnaires in 2021 traveled on average 333 km to harvest one wolf in the North Slave Wolf Harvest Incentive Area, resulting in the CPUE (km) 3 wolves/1,000 km.

Due to the survey design, the wolf encounter rate cannot be calculated because wolf observations were not recorded accurately by a sizable number of respondents. Harvesters report spending an average of 18.9 hours to harvest one wolf (0.05 wolf/ hour) over the season. In comparison, in the 2019-2020 harvest season, the average CPUE (km) was 1.71 wolves/1,000 km (584.8 km/wolf), and CPUE (hour) was 25 hours to harvest one wolf (0.04 wolf/hour) (Figure 32).

Within the 2021 harvest season, the CPUE across all harvesters showed a gradual increase through the season to mid-March and then a drop-off to moderate values. When assessed on a daily basis and by harvester group, Inuit and Tłıchǫ harvesters showed a downward trend as their harvesting progressed while the CPUE of the winter road harvesters did not. We suggest that caribou gut piles may have been an attractant to wolves drawing them into the region of the winter road making them relatively more available even as the season progressed.

Peak CPUE varied considerably among harvester group: Tłıchǫ hunters' peak travel-based CPUE of 0.5 wolf/km was an order of magnitude higher than the peak CPUE of Kugluktuk (~0.042 wolf/km) and the winter road harvesters (0.08 wolf/km). Such differences are likely related to differences in caribou and in turn wolf abundance at the local scale. The activity of Tłı̨chǫ hunters was fairly localized and likely resulted in depletion of wolves surrounding the camp. Conversely, Kugluktuk hunting activity was more spread out and potentially in an area with higher caribou density and therefore wolf density (Figure 1). As a result, localized extirpation was not experienced at the Itchen/Point Lake camp. The winter road-based harvest was largely opportunistic and likely did not have a major impact on wolf abundance in that area.

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 one observation of weather for the trip duration and therefore responses could not be used to directly test how weather influenced daily hunting effort. Further, response information on hunter effort may be confounded by one or more of the following occurrences that was not to be included in the tally of hours/kilometres traveled during harvesting (but was not stated explicitly on the questionnaire):

a) Time lost through bad weather.
b) Time/distance traveling to and from the hunting area.
c) The time during which the hunters are preparing for hunting but are not actually hunting (mobilizing, getting vehicles/snowmobiles ready etc.).
d) Time spent handling the wolf after it was harvested.

While CPUE is a key indicator and useful metric of wolf abundance, improvements are needed to reduce uncertainty in how it is reported by harvesters. Such improvements in harvester data collection will be addressed to the extent possible through recommended revisions to design of the harvester questionnaire outlined in the following section.

Review of Harvest Questionnaire

GNWT contracted Data Sciences Inc. to review the wolf harvester questionnaire and provide recommendations on the format, types of questions and delivery. Contents of the report from Data Sciences, Inc. are highlighted in the sections below. This work helps to fulfill the WRRB's recommendation (#5-2020) which was to: *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.*

Background

The questionnaire aims to measure and document the impact of the wolf harvest program on wolf populations by monitoring CPUE. As noted in more detail on page 83, this statistic represents the amount of effort required to catch a wolf, as measured by the amount of time and energy that goes into one successful wolf hunt (e.g. distance traveled before a successful hunt).

The data used to compute CPUE is largely derived from wolf hunters, who need to report, among other points, how long they traveled before seeing a wolf. To date, this information has been collected from hunters using paper and pencil questionnaires administered at the end of a multi-day hunting trip by a hunting camp coordinator or ENR staff. These forms were designed to be lightweight, however, data collected so far has been incomplete, in some cases unreliable, or fraught with missing insights. In our experience, data quality depends on a number of factors, namely: the suitability of the data collection process, the suitability of survey instruments for the situation and population, and the timing of survey administration. In addition, GNWT asked Data Sciences to consider how best to collect information that would aid in the assessment of humaneness of harvest such as chase ties, location and number of shots, wounding loss, etc.

Identified Issues

The first issue with the current data collection process is lack of response from a sizable proportion of wolf hunters, as demonstrated by the number of registered wolf harvests that are not accounted for in the hunting survey forms.

The second is the lack of detail in the data (e.g. difficult to match the wolf sightings to days of trips, and weather on day of sighting) and concerns about data quality in the survey responses, as hunters are sometimes asked to recall information from up to 15 days ago in the current data collection approach.

The third issue is that the survey is asking about precise metrics and doesn't directly ask the hunters about their opinion regarding change in CPUE measure over time. As such, one cannot capitalize on the experience and knowledge of skilled hunters. This is unfortunate as (1) oftentimes, the average crowd-sourced response from experience respondents is highly accurate and (2) the survey respondents - hunters - are more likely to feel engaged in the wolf hunting monitoring and reporting program if they feel that their opinions are valued and actually used as a way to monitor progress. In both cases data quality will likely benefit from inclusion of a few subjective rating questions.

Finally, given that different hunters have different levels of expertise and reporting styles, it is also crucial that we keep track of hunter experience measures. In doing so, we are able to ensure that we make relevant comparisons year to year, and relative differences across these years are more likely to be due to changes in wolf population, and not natural differences in data. This will simply help to reduce error and noise in the data, as the accuracy of year-to-year comparisons depends on the low variability of factors extraneous to the phenomenon measured, such as respondents' wolf-hunting experience.

Challenges

The main challenge in dealing with the issues outlined above is that the obvious fix for each issue recommends opposing action. Improving the completion rate of a survey is usually achieved through length of interview reduction and by simplifying the questions asked. On the other hand, increasing the number of insights (e.g. by introducing subjective ratings) does the opposite; it lengthens the survey and increases the effort required to fill in the instrument, thereby increasing the risk that hunters do not provide quality responses or answer the survey at all.

Fortunately, these different issues are more prevalent among different groups of hunters, so we may be able to solve both at the same time by eliminating a “one size fits all” survey model and personalizing the survey to different harvesting groups. We also recommend the use of creative design solutions (e.g. see template below; Appendix C) to simplify the process of filling the survey, allowing us to gather more information with less effort required from hunters.

Improving Survey Completion Rates

Looking solely from a survey design perspective and disregarding any potential external incentives, the only way to get more hunters to fill in the survey is to simplify the questionnaire. This can be achieved by minimizing the number of open-ended responses and opting for more option-select type responses, breaking down hard to answer questions into simplified steps, and overall minimizing the amount of effort hunters have to exert to fill the survey. While this is bound to decrease the amount of data collected on any given survey, the tradeoff of improving response rates and accuracy will overall improve the accuracy of the CPUE measure. It is recommended that ENR check in with statistical specialists on a regular basis to ensure that crucial information continues to be captured using this new survey instrument, and that any drawbacks related to a new survey instrument are minimized.

Improving Data Accuracy

Naturally, increasing the length of time between hunting activity and survey completion will also decrease accuracy of data obtained about the hunt. Therefore, instead of asking hunters to fill out a survey at the end of a multiple day trip and recall information from days past, we recommend a partial daily completion model, where hunters fill out smaller amounts of information at the end of every day of their trip. We suggest booklets with tear outs pages that can be easily collected or photographed and texted to the department by hunters or a coordinator. It is important for this reason that booklets contain booklet IDs at the top of each page so the department can easily identify respondents associated with daily pages that have been removed from the larger booklet. Please see attached template for example (Appendix C).

It would be prudent to make an assumption that not all hunters will complete the surveys daily, and instead decide to fill answers in at the end of the trip instead, at which point it would be unrealistic to expect hyper-accurate responses about daily events, especially when asking them to report on quantitative measures like time spent hunting or distance traveled. However, we recommend an approach to collect as much data as possible from these hunters regardless, but that we favour asking for averages and approximations instead of precise metrics.

Recommendations for Survey Content and Design

Building on our review from the previous section, we recommend the following changes to the current survey:

- Switch from a single page survey to a logbook model, where each hunter gets their own journal on day 1 of their trip and fills a page at the end of each hunting day (see Appendix C for example). Each booklet will have a unique identifying number.
- The required daily input should be the minimum required for accurate analysis, we should keep in mind that the more information we ask for, the less responses we will get.
- At the end of the trip, ask hunters about their overall experience on the trip and how it fared in comparison to previous hunting seasons, as well as to fill in a brief section about their experience.
- Design a more compact version of the survey for hunters who did not complete responses daily.
- Minimize the number of open-ended responses, and when possible, employ option-based answer formats.
- If data can be accurately deduced from other sources by matching names or tags (location of wolf hunt, time of hunt, etc.), avoid asking this information directly from the hunter in their logbook. Note that reliable means of matching data from other sources to the questionnaire data will be required (e.g. inclusion of carcass tags).
- Make use of icons and small graphics instead of text when possible.

- Break down complex questions into multiple simple steps, e.g. instead of asking hunters directly how long they spent actively hunting, which requires them to do calculations and account for breaks and preparation time, ask about all these elements individually: when did you start hunting, when did you end, how many breaks did you take, how long were they on average?
- Be flexible when it comes to requirements for different groups of hunters. Any data is better than no data. Comparing CPUEs across years within the same hunting groups, instead of as an aggregate of all hunting groups, will enable more suitable data collection processes that can be tailored to each group.
- When asking for markings on a map, it will be beneficial to have individualized maps for each group of hunters, focused on the area they actively hunt in.

Recommendations for Survey Delivery

Aside from the content of the survey, we recommend the following to increase quality and engagement with the data collection process:

- Ask respondents to take a picture of their pages in the logbook with their smartphone, when possible, to create 'backups' and facilitate sharing of data.
- Make a version of the survey available online so group leaders can text or email this survey to hunters and hunters can easily fill them out on their phones, tablets or computers.
- Have an example page already filled so hunters can tell what format of information they are required to fill in.
- To minimize discrepancies between hunter responses, field coordinators should go over the survey with hunters to standardize response formats.
- When turning in a filled survey or logbook filled by a representative on behalf of the hunter, the representative should indicate so.
- Unless we're able to track precisely who is traveling with whom, daily pages should be filled by a single person from the group.
- We do not recommend external rewards (i.e., money) as incentives for filling out the logbooks, as data quality may suffer as a result render data unusable for data from such a small population as the wolf harvesters. However, other incentives for sharing their data should be considered. Specifically, sharing results with hunters in a community public setting, at a catered event once a year is more likely to motivate quality responses among wolf harvesters. By sharing the results of their work, the department has an opportunity to publicly acknowledge their efforts, skill and dedication to conservation and stewardship. Engaging communities and hunters in the research this way is more likely to lead to favourable outcomes.
- In the case of use of monetary incentives, we do not recommend penalizing hunters for poor quality or slightly incomplete responses as long as there is clear effort to answer and

data can still be extrapolated from their submission. Such penalties will likely have a negative impact on their willingness to answer future surveys and discourage other hunters from filling in their surveys as well.

CARIBOU HERD AFFILIATION OF WOLF MORTALITIES

The "*Joint Proposal on Management Actions for Wolves on the Bathurst and Bluenose-East Barren-ground Caribou Herds (2021-2024)*" acknowledges the uncertainty in how wolves are associated with barren-ground caribou herds on an annual basis and whether it provides a basis for defining wolf populations for management purposes. Wolves are known to associate with and have similar patterns of movement as barren-ground caribou on winter ranges (Walton et al. 2001, Hansen 2013); the largest and most variable seasonal range (Klazcek et al. 2015) with the highest potential for overlap among caribou herds. In contrast, wolves display fidelity to den site locations at or near the treeline which are not overlapped with spring and summer distribution of caribou, even as caribou ranges contracted with declining herd sizes (Klazcek et al. 2015). During spring and summer wolves appear to defend ranges that are much more restricted in size (Klazcek et al. 2015) and situated to intersect with caribou migration paths during fall movements prior to the rut in late October (Hansen et al. 2013). While these general patterns are known it is not clear the extent to which wolf seasonal movements are affiliated with specific caribou herds. The following section discusses our previous approach to defining herd affiliation to harvested wolves and how that approach is influenced by recent wolf movement analyses based on GPS collared wolves.

Assigning Wolf Harvest to Herd

Using our initial approach (see Nishi et al. 2020) to assign wolf harvest locations to one of three barren-ground caribou herds (i.e., Bluenose-East, Bathurst or Beverly), we applied a KDE to estimate UD isopleths for each of the three caribou herds by month from January to April 2021. For each month we used available caribou collar data to map the 50%, 80%, 90%, and 95% UD isopleths.

The monthly UD isopleth maps were then used to estimate caribou herd assignments for each recorded wolf harvest location through the following steps:

- Wolf harvest locations were aggregated by month so that the mortality locations would be compared to the appropriate monthly UD isopleth map (see Figures 31-34).
- Using ArcMap, wolf harvest locations were assessed relative to the monthly herd-specific UD isopleths. Each harvest location was scored on a scale of 1-4 depending on the herd-specific UD isopleth within which it occurred.
- The 95%, 90%, 80%, and 50% UD isopleths had scores of 1, 2, 3, and 4 respectively.
- Wolf locations were assigned based on its highest herd-specific isopleth score.
- For wolf locations that had the same UD isopleth score from two or three overlapping herd ranges, herd assignments were ranked as two or three-way ties. In these cases of overlap,

closest distance to a higher scoring isopleth was not used as a criterion to break ties.

When a wolf harvest location did not overlap with a caribou herds' monthly range, we established herd assignment based on closest distance to a caribou range UD map. This was done for one wolf harvest location in February 2021 (see Figure 37).

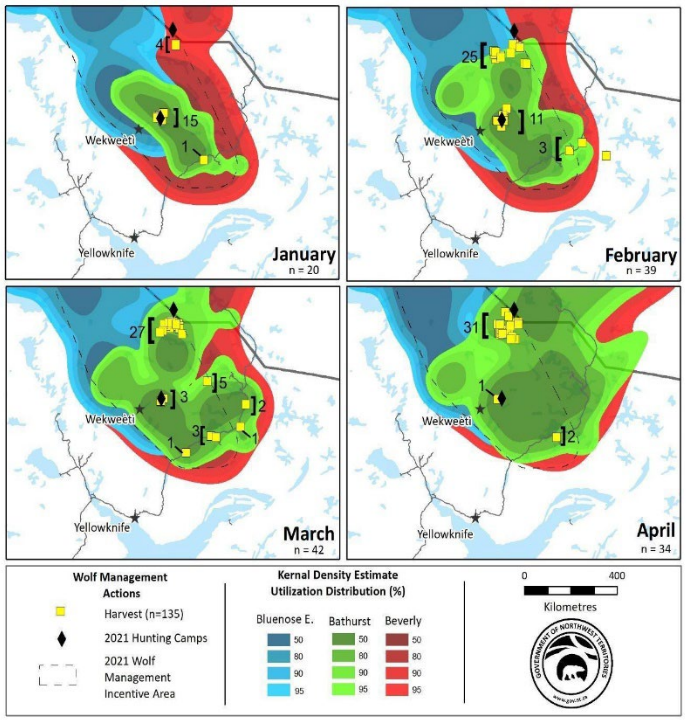


Figure 37. Monthly wolf harvest with KDE UDs of the Bathurst, Bluenose-East and Beverly caribou herds.

In applying this approach to wolf harvest locations in winter 2021, results showed that a majority of assignments were uncertain due to the high spatial and temporal overlap of collared caribou from each of the three herds in the winter months. A total of 135 wolf harvest locations were overlaid with monthly winter range areas of caribou estimated from daily locations of collared cows (Table 28, Figure 37). Average monthly counts of harvested wolves, was 33.4 with a range of 20 to 42. Based on patterns of spatial-temporal overlap with herd-specific collared caribou distributions, only 64 (47%) of the 135 harvested wolves could be attributed to a single herd. Of these 64 occurrences most (n= 62) wolf harvest locations had the strongest overlap with collared Beverly caribou, and only two wolf locations overlapped closely with the Bathurst caribou. Most wolf harvest locations (n=71, 53%) overlapped with equivalent UD isopleths of two herds (n=44, 33%), or all three herds (n=27, 20%) (Table 28).

Table 28. Spatial overlap of wolf harvest locations in winter 2021 with distributions of collared caribou from Bluenose-East, Bathurst and Beverly herds.

Winter 2021	1 Herd*			2 Herds			3 Herds	Count	%
	BNE	BAT	BEV	BNE-BAT	BNE-BEV	BAT-BEV	BNE-BAT-BEV		
January	0	0	5	0	0	0	15	20	15%
February	0	0	17	0	10	3	9	39	29%
March	0	2	28	0	0	9	3	42	31%
April	0	0	12	0	17	5	0	34	25%
Count	0	2	62	0	27	17	27	135	100%
Sum	64			44			27	135	
%	47%			33%			20%	100%	

*BNE = Bluenose-East caribou; BAT = Bathurst caribou; BEV = Beverly caribou

Herd Affiliation Summary

In 2020, we acknowledged the approach to assigning caribou herd affiliation to a harvested wolf was based on a simple assessment of overlap between wolf mortality locations and statistical inference of collared caribou data, and that herd-level inference is dependent on sample size of collars. We also recognize that the statistical inference needs to be matched with an ecological understanding of caribou and wolf interactions that should be verified by other lines of empirical data (i.e., wolf movement and spatial use patterns from collars, and patterns in genetic variability and structure).

The movement analysis in Wolf Management Patterns shows that wolves found on the winter range of Bathurst and Bluenose-East caribou herds predominantly display East-West movements associating with two or more caribou herds throughout the annual cycle. Similarly, Hansen et al. (2013) found wolves mimicked caribou movement patterns on the Bathurst caribou winter range that were predominantly directed East-West. Of the 2021 collar deployments 61% have initially been assigned East-West movement group (associated with all three herds equally), 28% stationary (only affiliated with caribou on the winter range) and 11% North-South (both associated with Bluenose-East) (Table 16 in Wolf Movement Patterns section). Under this scenario, a small proportion of wolves could reasonably be considered to affiliate strongly with either the Bathurst or Bluenose-East caribou and a larger proportion would only be affiliated seasonally.

In light of the recent wolf movement analysis, we propose the approach used previously to assign a wolf to a single herd based on a point location on the winter range is a weak assumption when herds are overlapped for two reasons. Firstly, wolves are more often associating with more than one herd and secondly wolves exhibiting the three differing movement patterns are mixed during the winter.

As mentioned in Wolf Movement Patterns, wolves appear to display fidelity to den sites (Walton et al. 2001), and movement analyses show some indication for affiliation to a single caribou herd during summer months. We suggest this may provide the basis for an alternate approach to defining wolf affiliation to caribou herd. As an initial exploration, we looked at the summer 2021 affiliation of collared wolves and then extrapolated those proportions to harvested wolves (Table 29). This exploration does not account for wolves that are not denning and as such displaying more extensive and less clustered movements.

Table 29. Exploratory caribou herd affiliation of harvested wolves by applying the proportional summer affiliation of collared wolves in summer (June 2021) to caribou herd.

Herd affiliation in June 2021 (from Caslys Table 7, Appendix D)			Extrapolated herd affiliation
	Collared wolves		Harvested wolves proportional herd affiliation*
	#	%	%
BNE	4	18	25
BAT	5	23	31
BEV	6	27	37
none	7	32	43
	22	100	135

*this doesn't account for wolves that might not be denning

Further analyses and additional data from a full complement of 30 wolf collars, ten each on Bluenose-East, Bathurst and Beverly, will aid us in further understanding seasonal affiliation and its potential application for allocating wolf harvest.

NECROPSY OF HARVESTED WOLVES

A Wolf Technical Feasibility Assessment (WFATWG 2017) identified the importance of monitoring wolf removal activities to evaluate their impacts on humaneness and welfare outcomes of wolf harvest, highlighting that detailed ground-based harvest information be recorded 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'èezhìı). 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 injuries and humaneness of death in harvested wolves (Figure 38).

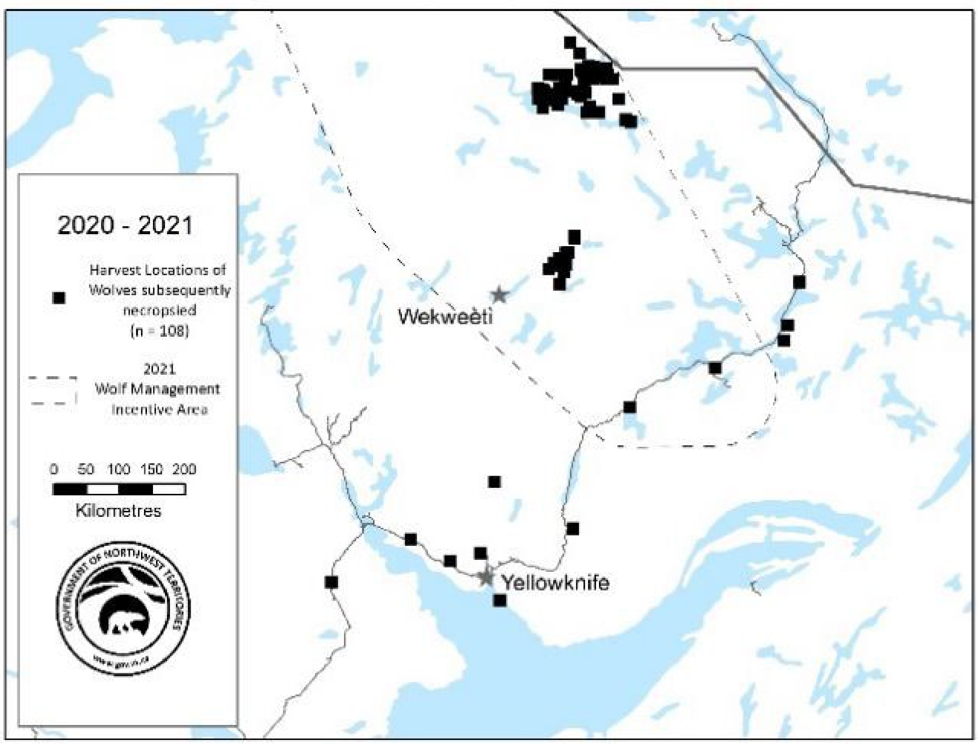


Figure 38. Map depicting locations of 108/110 harvest locations for wolves necropsied for humaneness and welfare assessment. Three wolf carcasses submitted were not accompanied by spatial data. 100/110 wolves were harvested within the North Slave Wolf Harvest Incentive Area. One of the necropsied wolves was found dead, and therefore not included in the humaneness assessment.

Methods

Between February 3, 2021 and June 30, 2021, 160 carcasses of grey wolves were submitted by 41 different harvesters to the North Slave Regional Lab. Wolves were harvested by either ground-based shooting or trapping methods. Of these, 111 carcasses were randomly selected to be examined through a full necropsy by a wildlife veterinarian which included an assessment of health, condition and injuries associated with harvesting (see Injury Documentation Form in Appendix E), in addition to standard biological monitoring. The remainder of carcasses (49/160) were examined by ENR wildlife biologists and technical staff for biological monitoring and standard health sampling. Wolves were accompanied by a tag which had spaces for the harvester to indicate the location, date and method of, submitter name, and animal sex. Carcasses were submitted between September 2020 and May 2021 to ENR and were stored frozen at -20˚C until examination. Storage conditions between harvest in the field and submission were unknown.

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

General Necropsy and Wolf Health Investigation

All necropsies followed standard protocols recognized for wild or domestic canids and were conducted by or under the direct supervision of the ENR 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 hanging scale and recorded to the nearest tenth 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 (using measuring tape), and rump fat depth (millimetres; using laboratory grade electronic calipers, CARMA, 2008; see Figure 39). 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 was collected to 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 (external body condition score) on a semi-quantitative rank scale of 0-4 (with 0 being poorest and 4 being best condition) based upon coverage and thickness of subcutaneous fat stores was assigned. Similarly, an internal body condition rank score was assigned based on abdominal visceral fat deposits. An average of external and internal rank scores provided an overall coarse subjective body 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); these samples were taken from wherever available on the already-skinned body, typically the perianal region or tail.

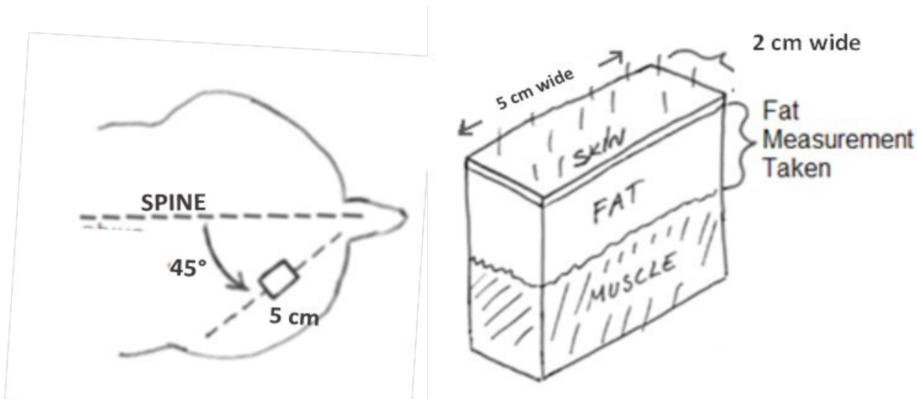


Figure 39. Visualization of location used to measure rump fat depth as an indicator of wolf body condition status.

Necropsies were performed in right lateral recumbency. All four 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 ten 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 condition (adapted from Lajeunesse and Peterson 1993; Lefebvre et al. 1999; CARMA 2008). 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 left rib cage was removed with large shears at the level of the spine and costochondral junctions. Photographs were taken of the internal cervical, 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), which was photographed separately and outside the pericardium dorsoventrally and ventrodorsally. 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, and tongue were collected from the pluck. Kidneys were removed with peri-renal fat per methods described in 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, a 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 later 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 and fixed in 10% buffered formalin along with ovarian tissue for later analysis.

Results

In total, 111 carcasses were necropsied, and of these, 100 were from the 2021 North Slave Wolf Harvest Incentive Area (Figures 19 and 38). One carcass submitted was indicated as 'found dead' and had no evidence of being shot or trapped, and therefore was not included in the humane assessment. On necropsy, this carcass was heavily autolyzed but had evidence of extensive intrathoracic haemorrhage and bruising on the external chest – cause of death was suspected blunt force trauma perhaps from a vehicle collision. Tags associated with carcasses indicated method of harvest – 92/110 (83.6%) were recorded as 'shot', 5/110 (4.5%) were recorded as 'trapped', and 13/110 (11.8%) were not reported. Based on observations made on necropsy and consideration of tag information, we confirmed that at least three of the wolves were trapped using snares. Specific snare or trap types used were not reported.

Aside from method of harvest, location, and an indication on 94 tags of observed animal sex (accurate in 84/94 (89.4%) animals based on necropsy examination), no antemortem data (Appendix K of Feasibility Assessment; Hampton et al. 2015) was documented.

Decomposition or tissue damage suspected to be from freeze-thaw cycles and post-mortem scavenging was present to some degree on 100% of the carcasses examined and hindered complete examinations; many animals were missing the limbs, head, and/or other appendages (Table 30); and the majority of carcasses (110/111) were already skinned at time of presentation and presented with varying degrees of skinning artifact, which also impacted interpretation of injuries at necropsy. One individual was too severely autolyzed to examine for wound tracts.

Table 30. Documentation of body parts removed prior to submission of carcasses for examination (total carcasses, n = 111).

Missing Body Part	# Carcasses (frequency count)
Head	8
Distal Forelimbs	31
Proximal + Distal Forelimbs	2
Distal Hindlimbs	18
Hind Paws	89
Fore paws	74
Tail	56

General Health and Sex-Age Composition of Harvested Wolves

The sample of wolves examined was widely distributed across sex and subjective age classes (Table 31). Results are pending for aging by cementum annuli analysis.

Table 31. 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) (n=111).

	Observed Frequency	Relative Proportion (%)
Sex		
Male	58	52.3%
Female	53	47.7%
Subjective Age Class		
Juvenile	32	28.8%
Adult	57	51.4%
Geriatric	19	17.1%
Unknown	3	2.7%

Internal and external body condition scores assigned ranged from 0.5 to 4.0. The average coarse (internal and external combined) body condition score across all 111 examined wolves was 2.58, or considered in good body condition. Rump fat depth, measured as a quantitative indicator of body condition, was on average 7.13 mm (range: 0 mm – 20.8 mm; n=111). Mean femur marrow fat percentage was 88.3% (range: 44.7-96.3%; n=108).

Of the female wolves examined (n = 53), 8 (15.1%) had fetuses or implantations, 15 (28.3%) had uterine scars from pregnancies in previous years, 20 (37.7%) were immature or appeared unbred, and 10 (18.9%) were unknown (often due to tissue damage or autolysis). Fetuses were developed enough to document crown-rump lengths and fetal weights in one case only. The number of pups being produced by females, as indicated by either number of scars, implantations, or fetuses in utero, ranged from two to 12, with a mean litter size of 6.4.

Most stomachs contained ingesta (83 of 111; 74.5%) compared to the proportion that were empty (28 of 111; 25.5%). Of the stomachs sampled for ingested contents at necropsy, 86.8% contained barren-ground caribou tissue. Findings are described further in Table 32. It should be noted that the stomach contents only represent the most recent meal of the wolf and does not represent the overall diet of wolves. Further, digestibility, and therefore detectability, of prey remains in the stomach may bias the diet composition reported here.

Table 32. Composition of stomach contents gross analysis results. Contents were described based on direct observation during necropsy, and then confirmed by high resolution photograph and/or physical analysis of stomach content subsample by a contracted expert. Results were summarized to reflect likely prey species in the sample of ingesta.

Composition of Stomach Contents	Percentage (n=83)
Caribou	86.8%
Other*	10.8%
Human food material/garbage	2.4%

*Other includes vegetation, ptarmigan, grouse, fish, marten, and snowshoe hare.

Thirteen (11.7%) wolves had nematodes present free in the abdominal cavity, likely due to gastrointestinal leakage due to injury, autolysis, scavenging, or necropsy artifact. In six (5.4%) cases, we detected notable incidental pathological findings unrelated to cause of death (i.e., tumors, congenital anomaly, signs of chronic inflammation or past infection, etc.). Fixed and frozen tissues sampled from these cases are to be analyzed by the Canadian Wildlife Health Cooperative Western/Northern Node at the Western College of Veterinary Medicine. These cases appeared to have relevance on an individual health level, but not necessarily a population level – case details will be reported when further results are available.

Wolf Health Assessment Summary

One hundred (100) of the 111 wolves harvested within the North Slave Wolf Harvest Incentive Area were examined for several parameters, including wolf health, condition, demographics, and cause of death. These wolves were shot by hunters and carcasses submitted as part of coordinated efforts to support Bathurst and Bluenose-East caribou population recovery. The necropsy findings from the submitted wolf carcasses show that overall wolves are in good health (average coarse body score index of 2.58). Rump fat depth was on average 7.13 mm with mean femur marrow fat percentage of 88.3%. Analysis of the stomach contents showed that 25.5% of the harvested wolves had empty stomachs. Of those stomachs with ingesta, 86.8% were comprised predominantly of caribou.

The subjective age class assessment is likely representative of a relatively un-harvested wolf population given that the majority of carcasses were adults (approximately 68%). Kelsall (1968) demonstrated a shift from less than 15% immature wolves in an un-harvested population to approximately 45% in two years and over 70% in six years of intensive wolf management. The sample of wolves harvested in 2021 represents age structure after only one year of removal and is confounded by in-migration of wolves from the adjacent Beverly herd.

DISCUSSION AND LESSONS LEARNED

A total of 135 wolves were harvested by Tłįchǫ, Inuit and other Indigenous and NWT resident harvesters within the North Slave Wolf Harvest Incentive Area in 2021 on the winter ranges of the Bathurst and Bluenose-East caribou herds. An interim trigger level for 2020/2021 was set at 114 or 80% of the estimated 142 wolves associated with the Bathurst and Bluenose-East caribou herds to evaluate wolf harvest levels over the season and to allow for adjustments if observations from harvesters and aerial survey crew members suggested there were high numbers of wolves. As the reported harvest approached the interim trigger level in late March, wolf harvest was continued, as there was no indication of declining wolf harvest rates, other than the Tłıchǫ dìga harvester camp which likely represented localized reduction in wolves. Therefore, wolves appeared to remain relatively abundant across the winter range through the harvest season.

The harvest of 135 wolves in 2021 compares to a total of 54 wolves taken by hunters in the North Slave Wolf Harvest Incentive Area in 2019-2020. All harvesting groups increased their take of wolves in 2021. The Tłįchǫ dìga harvest camp at Roundrock Lake in particular was far more successful than last year, resulting in twice as many wolves harvested; Inuit hunters almost tripled their harvest from the previous year. Higher success rates are most likely due to increased abundance of wolves on the winter ranges of Bathurst and Bluenose-East caribou herds due to extensive overlap of the Beverly caribou herd in combination with better placement of hunting camps, especially in the case of the Tłįchǫ dìga harvest camp.

Trends in harvest rates as measured through aggregated CPUE across all harvesters did not show a declining trend within the winter harvest season suggesting wolves were not being depleted as the harvest season progressed. However, localized depletion of wolves did appear to occur at the Tłıchǫ dìga harvester camp. Sighting rates for the aerial survey crews was substantially lower than the collaring crew with both indicators likely being skewed. The aerial survey crews probably had lower sighting rates than expected as they were flying both low and high density survey blocks. The higher CPUE for harvesters and sighting rates for collaring and removal crews in 2021 than 2020 was consistent with our expectation of higher numbers of wolves associated with the extensive overlap of winter ranges among the Bathurst, Bluenose-East and Beverly caribou herds. Winter ranges of caribou herds in 2020 did not have the same degree of overlap. Eighteen recommendations have been made for improvements to the wolf harvester questionnaire for improving our ability to effectively calculate and track CPUE. In addition, establishing consistent methods for reporting wolf sighting rates by aerial survey crews should reduce sightability bias and improve our ability to detect actual variation in wolf abundance and distribution patterns.

In examining, through necropsy, the submitted wolf carcasses, we found that overall wolves were in good health, predominantly feeding on caribou (86.8%) and comprised primarily of adults

(68%) based on subjective age class. Age class structure should comprise more immature individuals in heavily harvested wolf populations after a few years and is a useful indicator of the impact of removal programs on carnivore populations (Kelsall 1968, Robinson et al. 2008). The sample of harvested wolves from 2021 would not be expected to show this response as it follows just one year of wolf removals on the winter range. However, age structure effects may be diluted by immigration of wolves associated with adjacent caribou herds.

A wolf abundance survey was conducted to derive an empirical estimate of wolves on the winter range of the Bathurst caribou herd. Wolves are difficult to survey due to issues of reduced sightability especially when stationary, bedded or within treed habitat and their inherent low densities and clumped distribution. A Geospatial survey design was tested for its applicability for estimating wolves on the winter range of Bathurst caribou herd in 2021. The derived estimate of 89 wolves (31-147, 95% confidence limits) on the Bathurst winter range in March 2021 had low precision (CV=33.4) and therefore has low ability to detect numerical change. High variance was likely the result of several factors. Stratification of the wolf survey based on caribou density likely did not adequately characterize wolf density due to the high amount of overlap of the Beverly caribou herd, the low numbers of collars on that herd and its roughly ten times larger size than that of the Bathurst herd. Also, collared wolves showed movement into and out of the survey area as well as between grid cells, which would have violated an assumption for a closed population during the timing of the survey. We will continue to review and evaluate survey design options for reducing variation in wolf abundance estimates or alternative approaches to stratification.

Results from a movement analysis of collared wolves showed that a small proportion of wolves associate with a single herd (North-South movers); a small proportion is stationary; and most wolves associate with multiple herds (East-West movers) on an annual basis. It also showed that association among wolves and barren-ground caribou ranges varies seasonally with high overlap in winter and summer with little overlap in seasonal ranges in spring. Tundra wolves in the central mainland NWT are known to show strong fidelity to den sites or denning areas (Walton et al. 2001). Along major caribou migration routes wolves may be more influenced by fall migration of Bathurst caribou (for example) than spring migration (Klazcek et al. 2015), which may optimize access to caribou during late summer and early fall. As a result, summer affiliation may provide a basis for considering wolf affiliation to caribou herd. Additional analyses of the wolf collars deployed in 2021 and those planned for deployment in 2022 will further our understanding of seasonal affiliation and its potential application for allocating wolf harvest to a caribou herd. In year one of the wolf management program we used an approach to assign a single caribou herd affiliation to harvested wolves as a way to estimate the potential reduction in predation on either the Bluenose-East or Bathurst caribou herd. In light of this new information, assigning herd affiliation to a harvested wolf in years with overlap or close proximity of caribou herds will continue to be assessed.

The influence of high winter spatial overlap among caribou herds of disparate numerical abundance contributes to increased variability in association of wolf and caribou populations. During winters of high overlap in caribou herd distributions there may be more interchange of caribou and wolves across populations in comparison to winters with minimal to no spatial overlap. However, targeting wolves across the winter range of multiple caribou herds assumes that reducing predation, even seasonally, may have a meaningful effect on caribou productivity. Dynamic patterns of seasonal range overlap among caribou herds also increases uncertainty in our ability to assess management effectiveness by linking wolf removals to a demographic response in a caribou herd. We have begun engaging a statistician to incorporate measures of predation into an Integrated Population Model to examine possible outcomes for caribou herd demographics of the levels of reduction in predation we may be exerting on the Bathurst and Bluenose-East caribou herds. These analyses will be an important tool for evaluating potential effectiveness of the program upon its completion.

Revised Wolf-Centred Objectives

GNWT and TG committed to providing measurable wolf-centred objectives as part of the 2021 annual report and in response to WRRB's recommendation (#1-2020). Measurable caribou-centred objectives have been provided previously.

Appendix L of the Wolf Feasibility Assessment (WFATWG 2017) provides guidance on monitoring for evaluating numerical targets for wolf removal. Many of these are incorporated into the current program including monitoring number of wolves harvested, assessing the health, reproductive status and condition, age and sex composition of the wolf harvest as well as measures of effort or sighting rates of harvesters and aerial survey crews. Establishing measurable wolf (dìga)-centred objectives or benchmarks 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.

Considering this complexity and associated uncertainty we do not propose any change to the first two objectives. We have provided a measurable benchmark for the third objective based on shifts in age structure of a harvested wolf population reported in Kelsall (1968). We provide additional perspective on wolf-centered objectives below that we will discuss further with WRRB technical staff and other co-management partners.

1. **The number of wolves (dìga) removed annually through the five-year program.** If this number declines significantly over five years with consistent effort, this will provide some evidence that the wolf (dìga) population on the winter range of the Bathurst and Bluenose-East herds has decreased. Conversely, if the number of wolves (dìga) removed does not change or even increases with consistent effort, this would suggest that the wolf (dìga) removals were done at sustainable harvest levels, and wolves removed were replaced

relatively quickly either through immigration or reproductive output.

2. **CPUE metrics for wolf (dìga) removals**. This includes hours flown per wolf (dìga) removed, hours flown per wolf sighted by aerial survey crews and effort by ground-based hunters (distance or time) per wolf (dìga) removed. If these metrics show that there is an increasingly greater effort needed to find wolves (dìga), either through a harvest season or over the five-year period, this would provide evidence that wolf (dìga) numbers are decreasing and that removals have contributed to additive mortality in wolves. Conversely, if CPUE shows no clear trend within a season or over five years, this would also suggest that the wolf (dìga) removals were a sustainable harvest and wolves (dìga) removed were replaced relatively quickly either through immigration or reproduction.

3. **Age structure of wolves (dìga) harvested.** Modeling and empirical evidence showed that a heavily harvested wolf (dìga) population should shift from an age structure of mostly adults (85%) to mostly young wolves (dìga) (30% adults) (Kelsall 1968). Based on the shifts in age structure after six years of wolf removal reported in Kelsall (1968) we propose a benchmark of 30-40% proportion of adults in the harvested wolf sample at the end of the five-year program. If the age composition of harvested wolves (dìga) shifts in this way from primarily adults to primarily young wolves (dìga), this would indicate a decrease in the wolf (dìga) population, while the absence of such a trend would indicate that the removal rates have not sufficiently reduced the wolf (dìga) population. In 2021, after one year of wolf removals the proportion of adult wolves in the harvest is 68% (n=111).

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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 ɂekwǫ̀ 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 Kǫ̀k'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 Kǫ̀k'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 Kǫ̀k'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 Tłı̨chǫ elders and their families have observed to the dìga and ɂekwǫ̀ relationship through time, and in the present considering other animal behaviour, climate change, loss of habitat, and population declines.
#14-2020	ACCEPT	TG collect Tłı̨chǫ stories about dìga and ɂekwǫ̀, 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 ɂekwǫ̀ and how it has changed through time.
#15-2020	VARY	GNWT and TG explore possibilities and develop an approach undertake field studies and modeling to determine causes of death of collared ɂekwǫ̀ 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.

APPENDIX B – HARVESTER QUESTIONNAIRE

2021 Wolf Harvester Survey - North Slave Region

Name of hunter: ______________________

E-mail: ______________________ Phone: ______________

Type of Licence/Hunter Residency: ______________________

Are you willing to share a GPS track file of your trip? **Y** or **N** ☐

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**:

1	2	3	4	5	6	7
8	9	10	11	12	13	14

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

1	2	3	4	5	6	7
8	9	10	11	12	13	14

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

   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 or No? ☐

12. Did weather (i.e. blowing snow, or visibility) affect your hunting?

    Please describe: ______________________

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

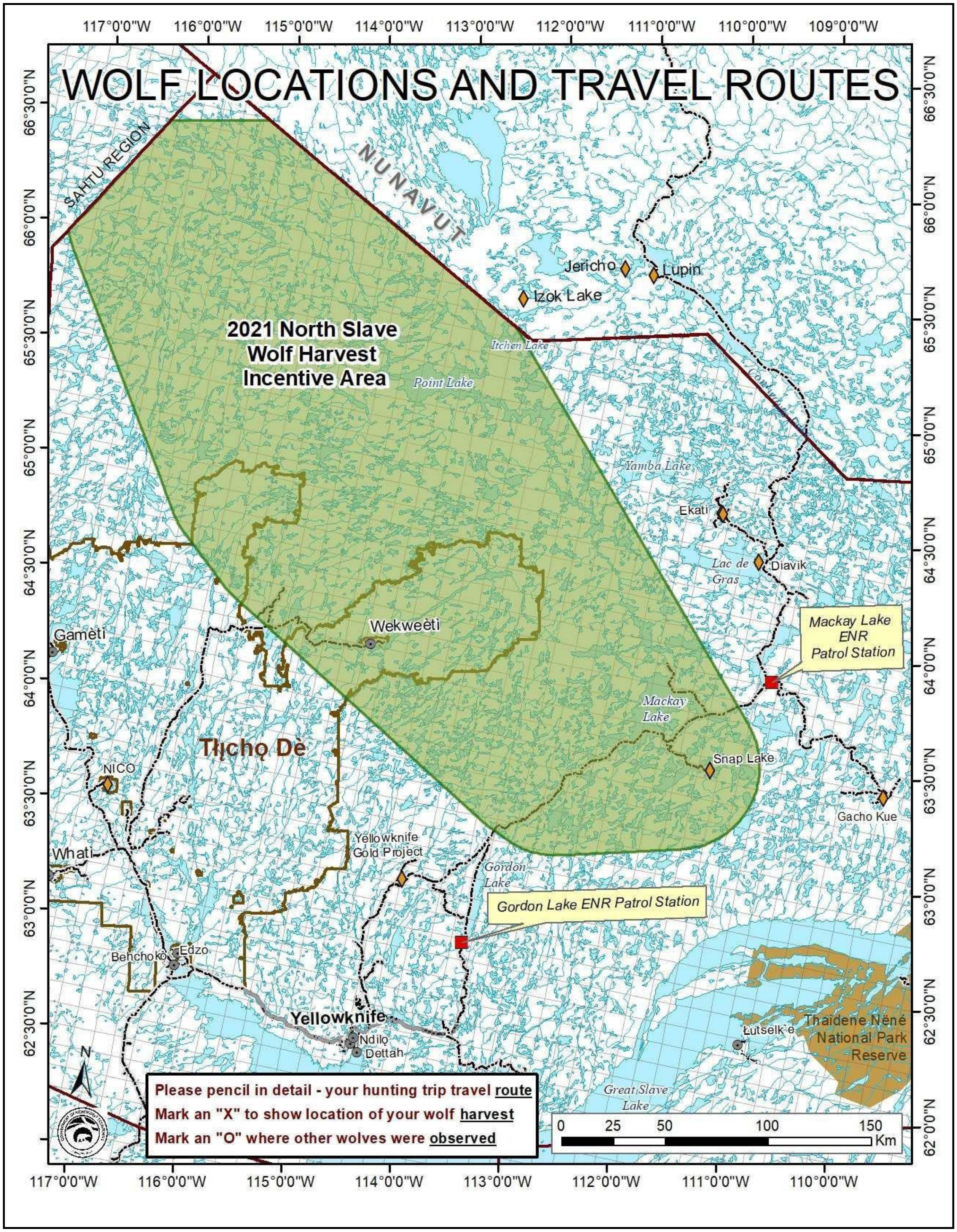
14. On the back of this sheet is a **MAP** of the winter roads in the North Slave Region. Please mark down your **travel route, wolf harvest** & **wolf observation locations**.

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 the North Slave Regional Office at 1-867-767-9238.*

Please return this completed survey to an ENR office or check station for a $50 gift card!

Government of Northwest Territories | Gouvernement des Territoires du Nord-Ouest



WOLF LOCATIONS AND TRAVEL ROUTES
2021 North Slave
Wolf Harvest
Incentive Area
NUNAVUT
SAHTU REGION
Jericho
Lupin
Izok Lake
Itchen Lake
Point Lake
Yamba Lake
Ekati
Lac de Gras
Diavik
Mackay Lake ENR Patrol Station
Wekweètì
Gamètì
Mackay Lake
Snap Lake
Tłįchǫ Dè
NICO
Gacho Kue
Whati
Yellowknife Gold Project
Gordon Lake
Gordon Lake ENR Patrol Station
Behchokǫ̀
Edzo
Yellowknife
Ndilǫ
Dettah
Łutselk'e
Thaidene Nëné National Park Reserve
Great Slave Lake
Please pencil in detail - your hunting trip travel route
Mark an "X" to show location of your wolf harvest
Mark an "O" where other wolves were observed
0 25 50 100 150 Km
117°0'0"W 116°0'0"W 115°0'0"W 114°0'0"W 113°0'0"W 112°0'0"W 111°0'0"W 110°0'0"W 109°0'0"W
66°30'0"N 66°0'0"N 65°30'0"N 65°0'0"N 64°30'0"N 64°0'0"N 63°30'0"N 63°0'0"N 62°30'0"N 62°0'0"N

APPENDIX C - SAMPLE HARVESTER LOGBOOK

HUNTING DIARY

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.

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.

HIS 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

NAME OF ORGANIZATION
123 STREET NAME
A1B 2C3, CANADA

OR TEXT OR EMAIL A PHOTO OF EACH PAGE TO
NAME@ORGNAME.CA

Questions? Contact: Name of Organization
123 Street Name
A1B 2C3, Canada
name@orgname.ca
123-456-7890

Name of hunter:...
If not filled by the hunter himself, name of the person filling this logbook:
....
Email:..
Phone:...
Type of Licence/Hunter Residency:...
Carried firearms: .... **Bullet types:** ....

Unique booklet ID: XXXXXXX

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

How many **wolves** have you:

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

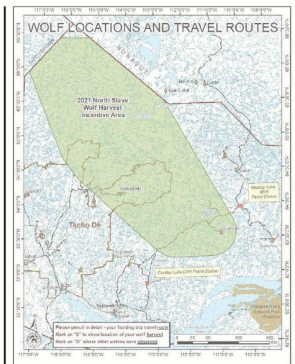
Wounded ☐
On the map, please mark with X the location and number of wolves wounded.

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

How many **caribou** have you seen:

Alive ☐

Dead ☐

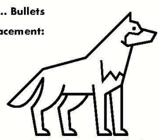


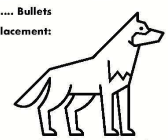
How was the weather?

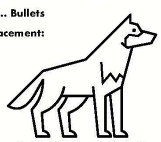
Perfect for hunting | Good for hunting | Bad for hunting | Very bad for hunting

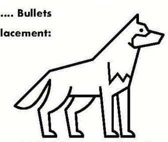
---

You shot at any wolves today, please fill this section with details about each wolf hit:

☐ **Wounded** ☐ **Harvested**
...... **Bullets**
Placement:

Mark with X placements of bullets hit
Time from first shot to death: ....mn
Chase time: ......mn **Pack size:** ....
Firearm: .... **Bullet type:** ....

☐ **Wounded** ☐ **Harvested**
...... **Bullets**
Placement:

Mark with X placements of bullets hit
Time from first shot to death: ....mn
Chase time: ......mn **Pack size:** ....
Firearm: .... **Bullet type:** ....

☐ **Wounded** ☐ **Harvested**
...... **Bullets**
Placement:

Mark with X placements of bullets hit
Time from first shot to death: ....mn
Chase time: ......mn **Pack size:** ....
Firearm: .... **Bullet type:** ....

☐ **Wounded** ☐ **Harvested**
...... **Bullets**
Placement:

Mark with X placements of bullets hit
Time from first shot to death: ....mn
Chase time: ......mn **Pack size:** ....
Firearm: .... **Bullet type:** ....

If more than 4 wolves were hit, fill this section on the next page leaving the left page empty.

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

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

Before turning in this logbook, we would like to ask you a couple of questions to get your opinion as a professional in this area.

Any information you provide will remain confidential.

We would like to know your overall impression of this hunting trip, please circle the option that best reflects your opinion:

How much harder was it to find wolves, compared to previous hunting seasons?

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

How did the amount of time travelled to find wolves compare to previous hunting seasons?

Had to travel much further | Had to travel a bit farther | Same distance | Less travel was needed | Much less travel was needed

When you saw wolves, how big would you say the pack sizes were compared to previous years?

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

Finally, we would like to ask you about your lifetime experience hunting wolves:

Approximately how many wolves have you harvested in your lifetime (including this trip)?...

Approximately, how many years have you been hunting wolves (including this season)?..

APPENDIX D – WOLF MOVEMENT ANALYSIS

GNWT WOLF MOVEMENT ANALYSIS

Summary Report - Draft

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1.0 INTRODUCTION

To support the recovery of the Bathurst and Bluenose East barren-ground caribou herds, GPS collars were deployed on wolves within the herds' ranges to better understand caribou-wolf dynamics in these areas. The goal of this project was to complete an exploratory analysis of the wolf telemetry data with the following objectives:

- Develop annual movement profiles for barren-ground caribou and wolves to determine if there are any commonalities and to explore seasonal changes in wolf movement behaviours;
- Generate occupancy models from wolf telemetry data to explore annual and seasonal space-use patterns; and,
- Conduct a sensitivity analysis that provides guidance (justification) on an appropriate number of wolf collars to have deployed across these three herds.

2.0 DATA

Telemetry locations for March to November 2020 were acquired to explore wolf movement patterns relative to barren-ground caribou movements and seasonal distributions. Collars were deployed on both male and female wolves and collected locations across a range of frequencies. Table 1 summarizes the number of locations collected by each collar by month. During May, all collars collected locations at four-hour intervals; however, from June to November four collars collected locations at eight-hour intervals and seven collars collected locations at 12-hour intervals. To account for differences in collection frequencies between collars, three datasets were generated for the analyses: a daily dataset where all data were resampled to 24-hour intervals, an eight hour dataset, and a 12 hour dataset. The two subdaily datasets contained only the collars that collected data at the corresponding intervals. Maps of the individual collar locations are available in Appendix A.

Table 1. Wolf collar telemetry data summary. The values presented in the table represent the number of locations collected for each month.

Collar ID	Gender	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
WF-NS20-01	M		20	158	87	87	89	90	93	90
WF-NS20-02	F		14	101	70	89	93	90	93	90
WF-NS20-12	M	54	120	172	90	78				
WF-NS20-13	F	44								
WF-NS20-18	M	49	120	169	90	89	8			
WF-NS20-19	M	49	72							
WF-NS20-21	F		88	165	60	55	60	60	62	60
WF-NS20-22	F		13	155	57	42	55	51		
WF-NS20-23	F		4	42	59	60	61	59	62	59
WF-NS20-26	M	37	90	165	60	54	60	27		
WF-NS20-27	M	46	90	166	60	59	60	60	62	60
WF-NS20-29	F	55	89	114	59	58	61	60	62	60
WF-NS20-30	M	43	90	165	59	59	61	60	62	60

Telemetry data for the three barren-ground caribou herds (i.e., Bluenose East, Bathurst, and Beverly Ahiak) with ranges that overlapped the wolf distributions were also obtained, as the objective of these analyses was to explore wolf movement patterns relative to barren-ground caribou. 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 the analysis. Data were further restricted to include only collars that had at least ten locations per month. These restrictions ensure that only collars that had a representative sample of locations for a given month were being used to characterize range use and movement patterns. Table 2 summarizes the number of collars used in the analysis by herd and month.

Table 2. Barren-ground caribou collar summary. The values presented in the table represent the number of collars used in the analyses by month.

Herd	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Bathurst	45	59	59	56	56	54	52	50	49
Beverly Ahiak	30	22	22	22	22	22	19	19	19
Bluenose East	66	58	56	55	54	54	52	50	48

3.0 MOVEMENT ANALYSES

To explore wolf movement patterns relative to barren-ground caribou, variation in seasonal movement for each species were 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 subdaily 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 but then averaged across individuals belonging to the same herd to provide a herd level estimate of seasonal movement patterns. For the wolf analysis, 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. Net-squared displacement (NSD) is calculated as the squared displacement between a location in a trajectory and the first location in that trajectory (Figure 1). 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.

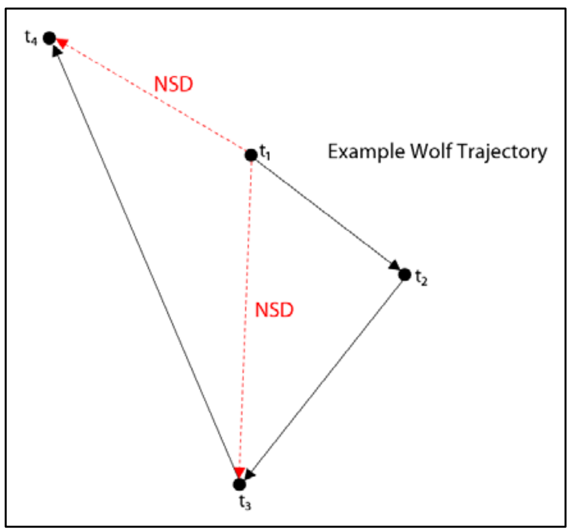

Figure 1. Example of net-squared displacement (NSD). The black line represents an example wolf movement trajectory. The red lines represent the NSD distance. For t_1 NSD= 0 as there is no relative movement. For t_2 NSD is the squared displacement between t_1 and t_2.

4.0 OCCUPANCY MODELS

To explore seasonal space-use patterns by wolves relative to barren-ground caribou, two approaches for developing occupancy models were applied: Brownian bridge movement models and grid cell counts. These two approaches were selected as they characterize space-use at two different spatial 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.

4.1.1 Brownian Bridge Occupancy Models

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 will be using 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 eight-hour and 12-hour datasets were used for this analysis. 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 28.85 metres based on error estimates calculated for a previous telemetry study (Horne et al. 2007).

BBOM UDs were calculated for two different scales: the whole trajectory (March to November) and for four shorter time periods April 1 – May 31(Spring), June 1 – June 30 (Calving), July 1 - August 31(Summer), September 1 – November 30 (Fall). 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. BBOM were only generated for the wolf data and the results compared to the location of the caribou as defined by the telemetry data.

4.1.2 Relative Herd Distributions

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-kilometre fishnet raster was created for the study area to act as a baseline surface. The one-kilometre 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 kilometre binary use rasters were aggregated to a 10 kilometre grid to match with a previous seasonal range use analysis performed for the Bathurst, Bluenose East, and Beverly Ahiak herds (Nishi *et al.* 2020). A 10 kilometre 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 kilometres, 10 kilometres, 15 kilometres and 20 kilometres. Once aggregated, 10 kilometre 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). The coding scheme applied to the use rasters is outlined in Table 3. 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.

Table 3. Relative distribution classes

Weighted Cumulative Value	Monthly Range Use
0	No recorded use
1	Beverly Ahiak only
10	Bathurst only
100	Bluenose East only
1000	Wolf use

5.0 RESULTS

5.1 Movement Analysis

Characterizing movement patterns for wolves using daily movement rate revealed no apparent seasonal trends. Movement rate varied between successive days providing no indication of seasonal changes in movement behaviours (i.e., denning or dispersal). Some wolves (e.g., WF-NS20-01, WF-NS20-26) had periods of low movement rates April through June indicating spatially restricted movements possibly associated with denning; however, the pattern was not consistent across collars, so was not considered to be an indication of a biological season.

Characterizing movement patterns for wolves using NSD was a more appropriate metric for capturing changes in movement behaviour. When the NSD values were graphed for each collar, almost every collar 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. Daily average movement rate and NSD graphs for all collars are available in Appendix B.

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 4). The north-south movers were generally characterized by north-south movements occurring from March to November, interactions with only one barren-ground caribou herd, area restricted movement March to June, and a return south in September/October matching the return of the caribou to their winter ranges. 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. The stationary wolves displayed no seasonal movement and remained in the same area March through to November. These collars generally were located south of the Bathurst range.

Table 4. General wolf movement groupings

North – South	East-West	Stationary
WF-NS20-01	WF-NS20-12	WF-NS20-02
WF-NS20-18	WF-NS20-21	WF-NS20-23
WF-NS20-19	WF-NS20-27	WF-NS20-29
WF-NS20-22	WF-NS20-30	
WF-NS20-26		

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 Ahiak 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. Low movement rates were present in March, April, and November characteristic of winter range use. A complete set of barren-ground caribou movement profiles are available in Appendix C.

5.2 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 2 shows the BBOM UD for north-south mover WS-N20-01 with pockets of high use spread across three different areas in a north-south direction. Figure 3 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 shows the BBOM UD for stationary wolf WS-N20-02 with only one major area of high use. Visualizing the occupancy models at such a high level allows for the differentiation of annual space-use strategies adopted by wolves within barren-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. 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 (Figure 5). However, the potential for interaction decreases during the calving period as the caribou move further away from the location of the clustered wolf distributions (Figure 6).

During the summer period, there was a dramatic shift in space-use and movement patterns by the non-stationary wolves away from spatially restricted movements to long dispersal movements followed by areas of high intensity use that overlapped with summer caribou distributions (Figure 7). For example, WF-NS20-01 travelled directly north with high use areas overlapping with collared Bluenose East caribou; while WF-NS20-27, travelled directly east with high use areas overlapping with collared Bathurst caribou. For stationary wolf WF-NS20-02, there was also a shift in use patterns with the large contiguous high use area observed during the spring and calving seasons splitting into multiple smaller clusters.

Wolf space-use patterns for the fall continued to be more variable than those observed during the spring and calving periods (Figure 8). Again, the non-stationary wolves followed a pattern of travelling between high use areas which overlapped with collared caribou distributions. WF-NS20-01 appeared to follow the Bluenose East caribou down from the summer range to their winter range and WF-NS20-27 travelled west returning from the Bathurst summer range to interact with Bluenose East. Interestingly, the timing of wolf WF-NS20-27 travelling west corresponds to the timing of collared Bathurst individuals leaving the area around Lupin and movement south by Bluenose East individuals returning to their winter range.

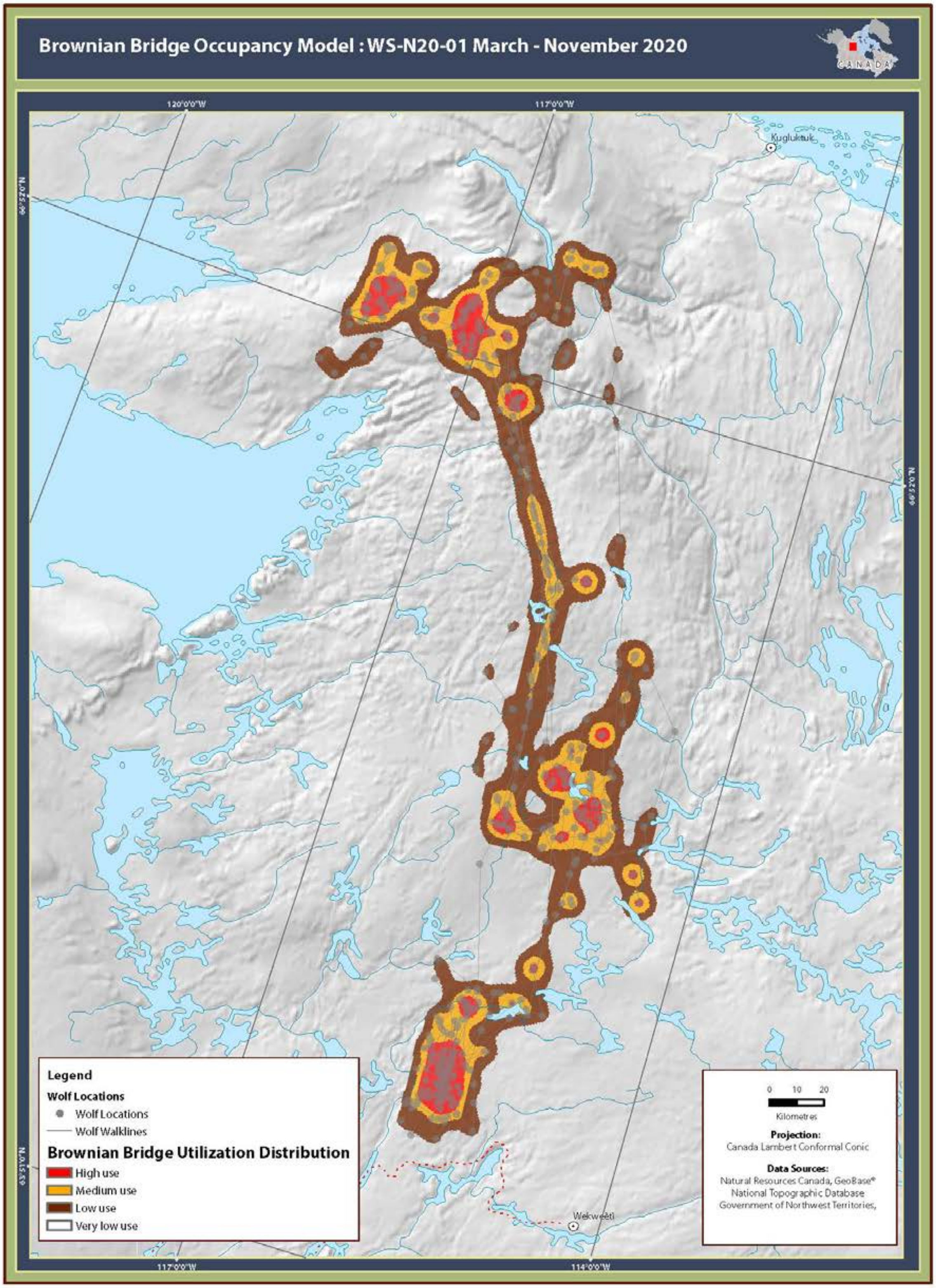

Figure 2. Brownian bridge utilization distribution for WF-NS20-01

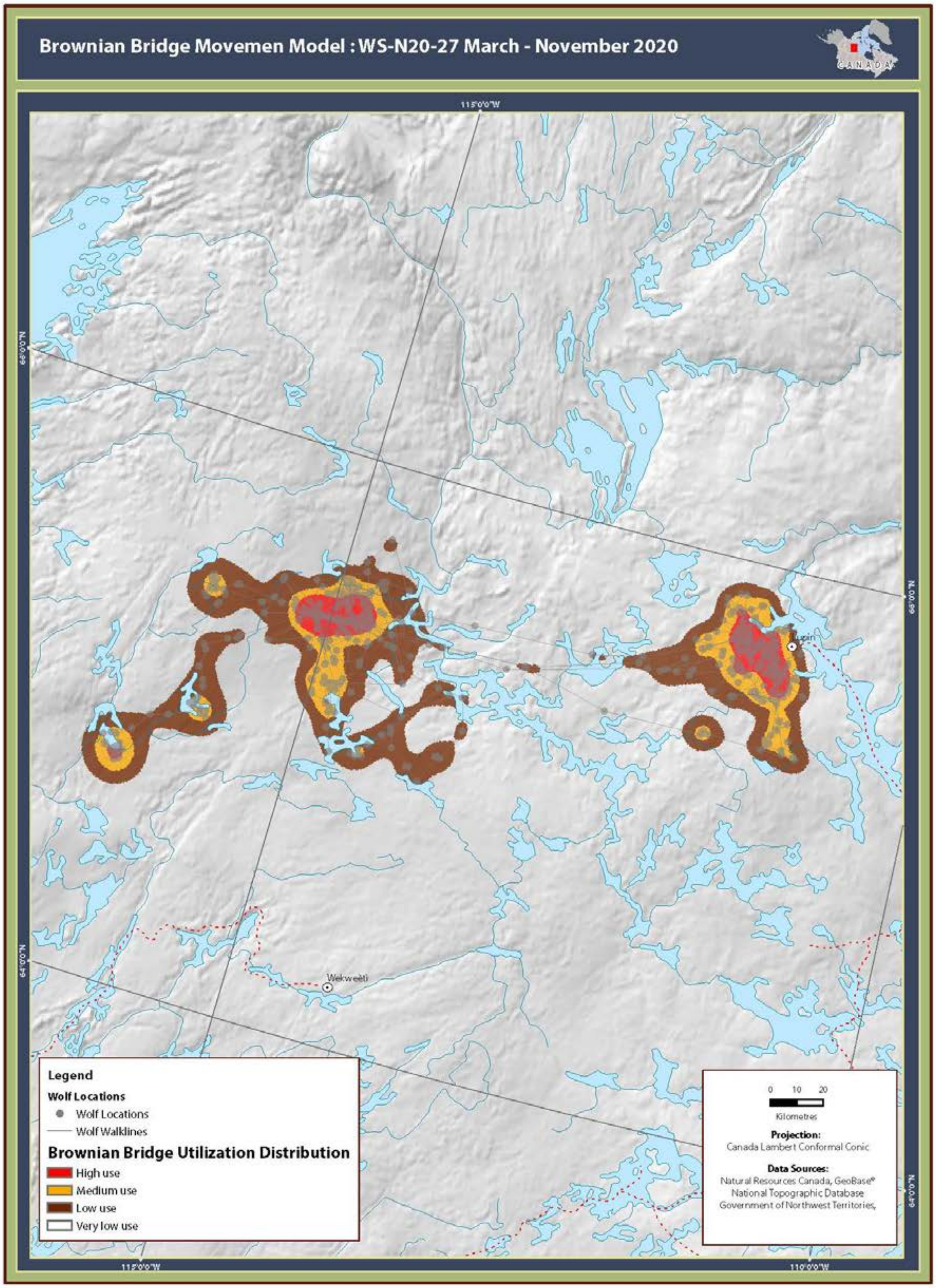

Figure 3. Brownian bridge utilization distribution for WF-NS20-27

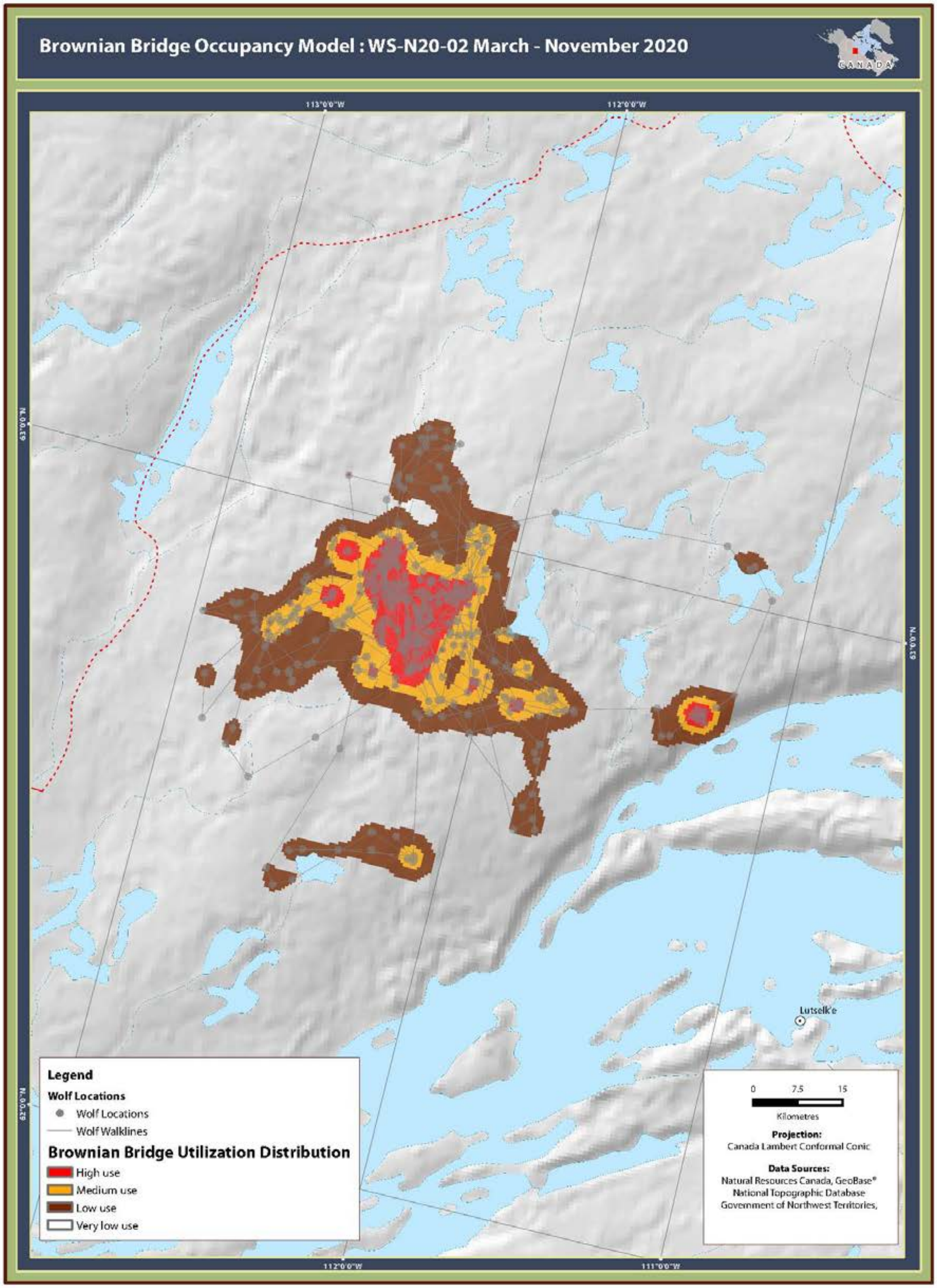

Figure 4. Brownian bridge utilization distribution for WF-NS20-02

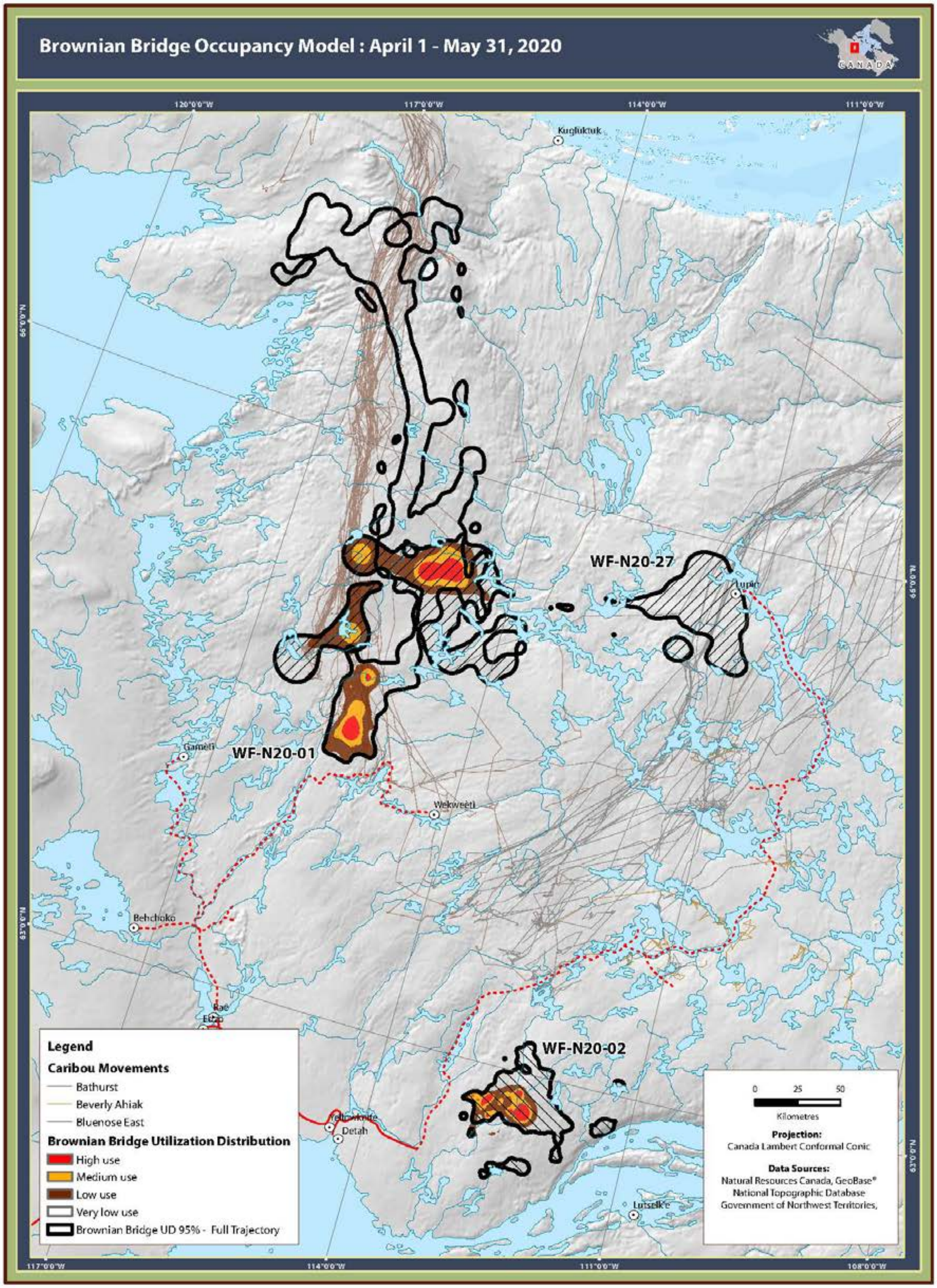

Figure 5. Brownian bridge utilization distribution for the spring period. Caribou movement for the same date range have been mapped to explore the location of the caribou relative the high use wolf areas.

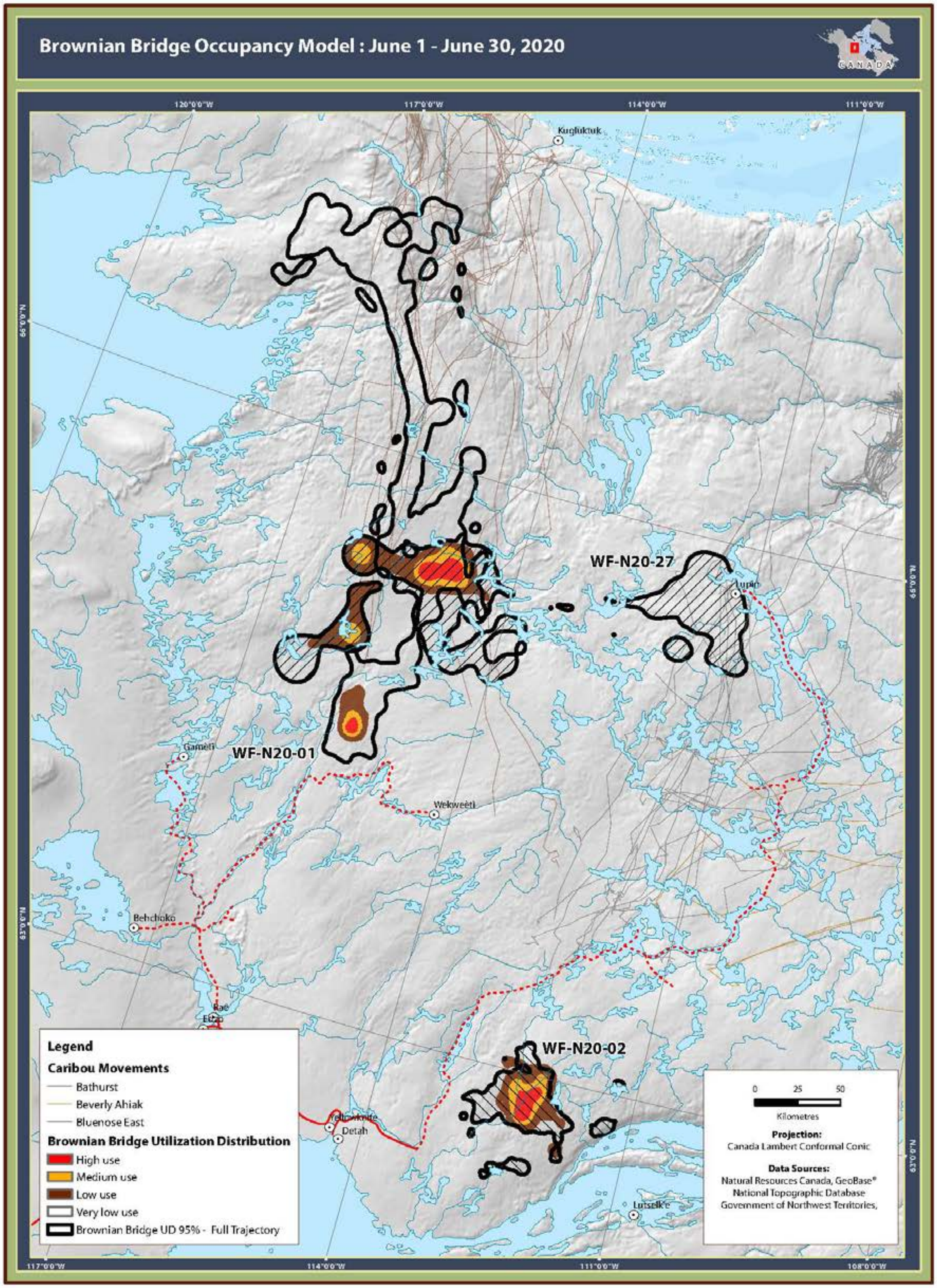

Figure 6. Brownian bridge utilization distribution for the calving period. Caribou movement for the same date range have been mapped to explore the location of the caribou relative the high use wolf areas.

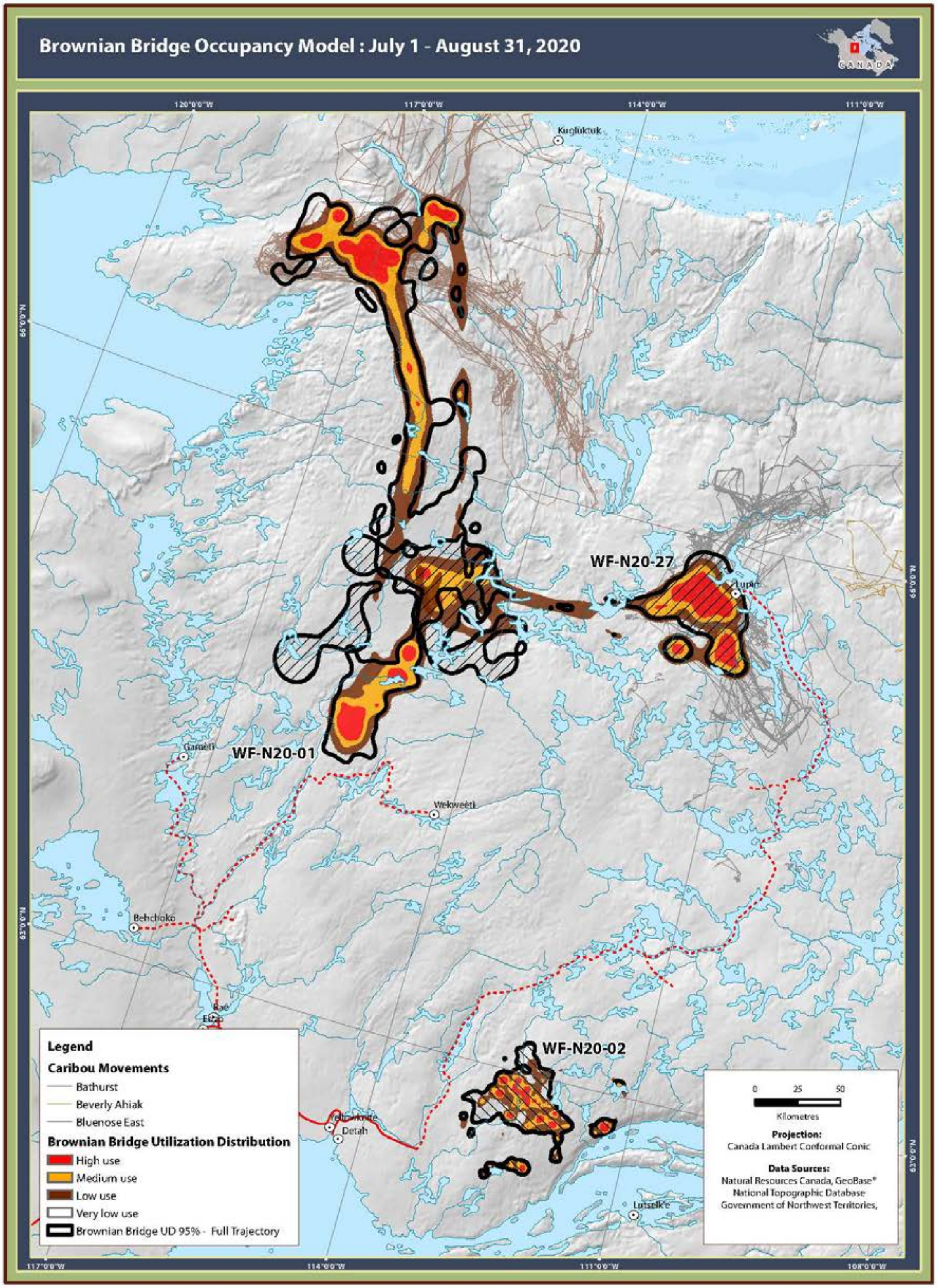

Figure 7. Brownian bridge utilization distribution for the summer period. Caribou movement for the same date range have been mapped to explore the location of the caribou relative the high use wolf areas.

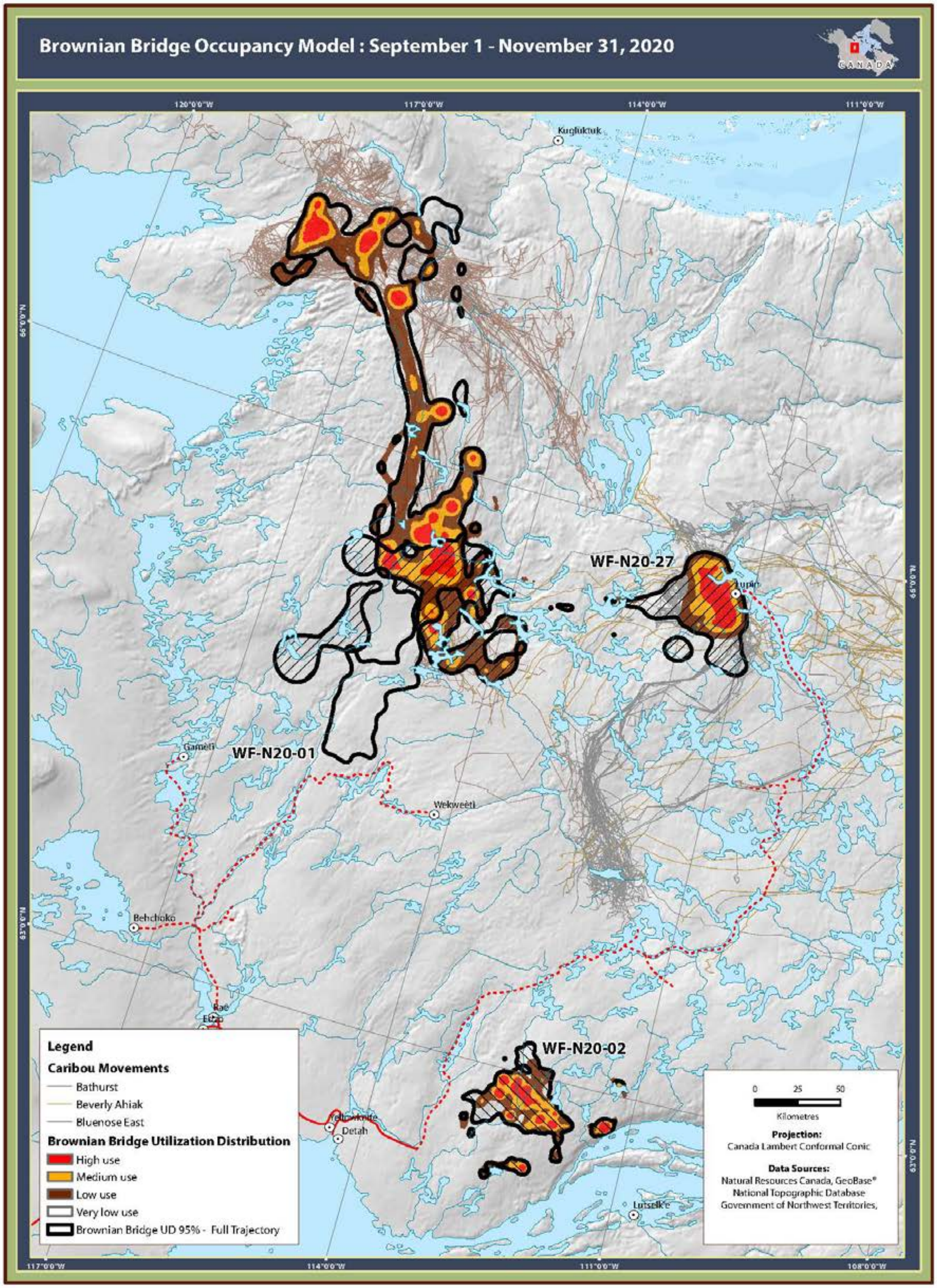

Figure 8. Brownian bridge utilization distribution for the fall period. Caribou movement for the same date range have been mapped to explore the location of the caribou relative the high use wolf areas.

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 potentially be used to identify high use areas associated with denning or for assigning wolves to specific caribou herds for management purposes. 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.

5.3 Grid Cell Counts

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 (March, April, November), areas of potential wolf-caribou interactions were primarily located in areas of overlap between caribou herds. For example, in November, 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 9). In contrast, during the summer months, potential wolf-caribou interactions appeared to be tied to individual herd distributions rather than areas of herd overlap. For example, in July, one set of wolf-caribou shared use areas were located within the Bluenose East summer distribution and another within the Bathurst summer distribution (Figure 10). A complete set of grid cell count maps are available in Appendix D.

The regional grid cell count approach is a useful analysis tool as its data requirements are far more flexible than those of the BBOM. Using data collected at a daily intervals 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. For example, when the monthly grid cell counts are reviewed as a time series, no shared wolf-caribou use is recorded for the Beverly Ahiak herd. This probably indicates a gap in the wolf telemetry data given the relationship observed between collared wolves and the Bluenose East and Bathurst herds. Identifying data gaps in the wolf collaring data spatially could be used to inform future collaring programs and deployments.

As the grid cell count approach uses a consistent grid for analysis, occupancy models 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.

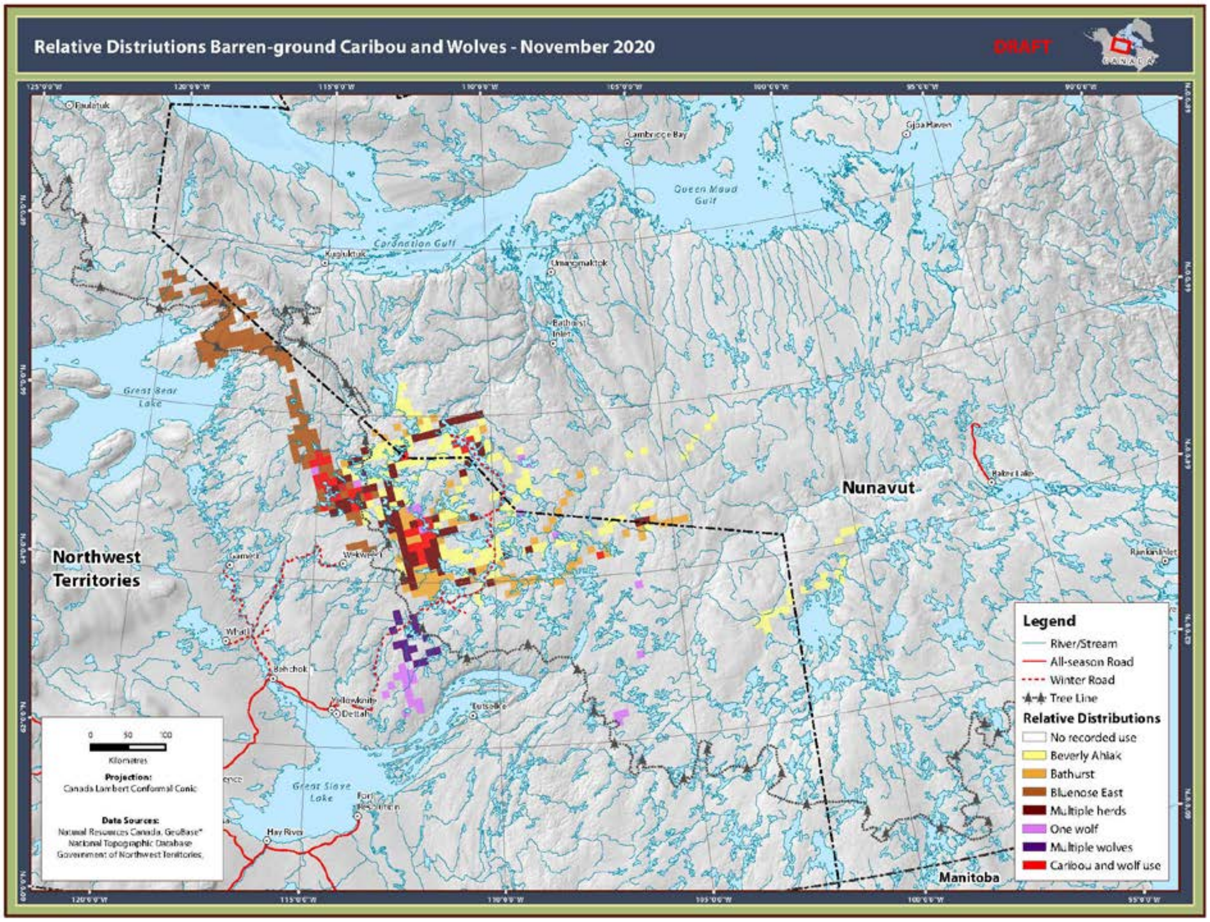

Figure 9. Grid cell count results for November showing concurrent wolf-caribou use in areas of caribou range overlap.

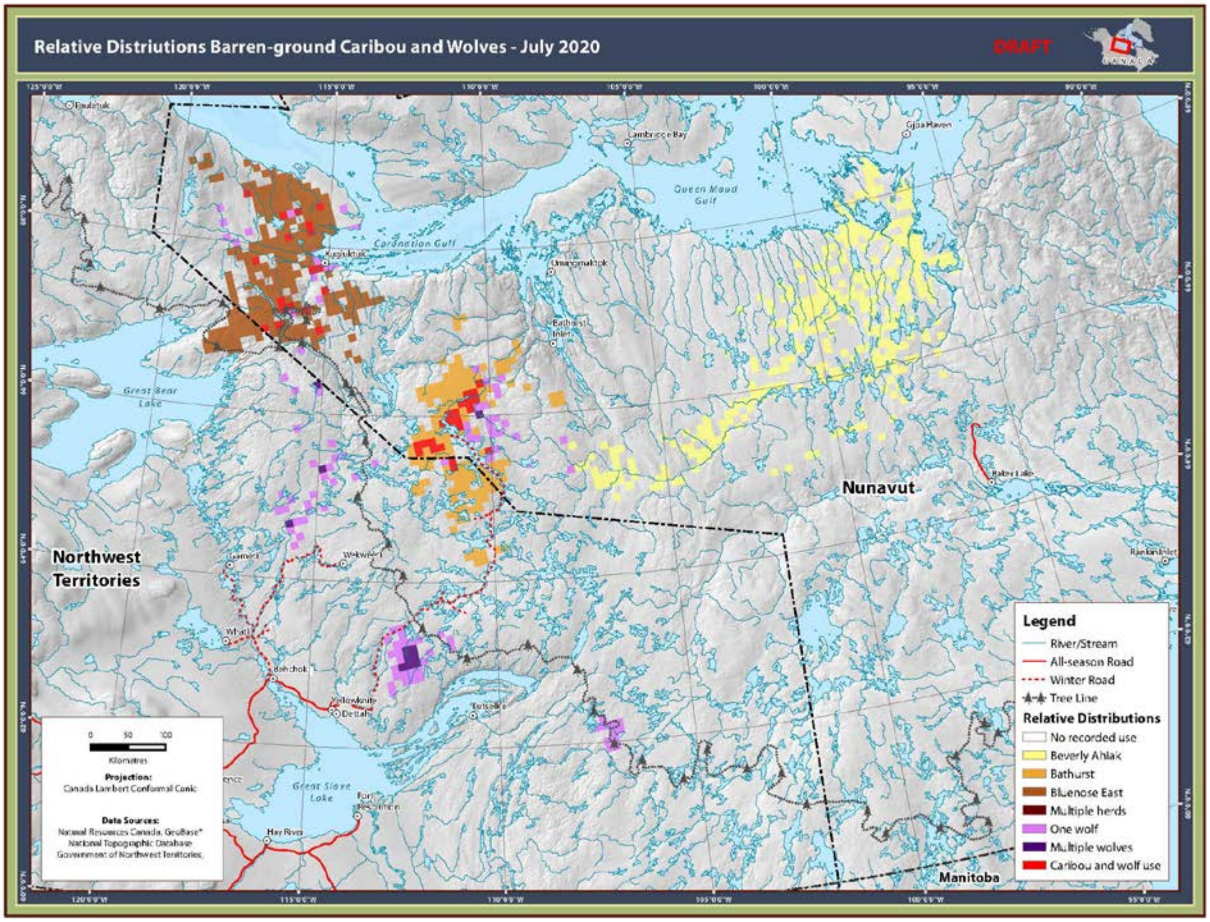

Figure 10. Grid cell count results for July showing concurrent wolf-caribou use tied to individual herds.

6.0 RECOMMENDATIONS

Based on the results of these exploratory analyses, we have the following recommendations.

6.1 Future Analyses

Incorporating the wolf telemetry data for November 2020 to March 2021 into the existing analysis would provide a complete annual characterization of wolf movement and space-use patterns. Incorporating these months would be particularly interesting for the occupancy models as the gird cell analysis highlighted areas of concurrent wolf and caribou use in November primarily in regions where there was intermixing between herds. As the three barren-ground caribou herds have overlapping winter ranges, exploring patterns of potential wolf-caribou interactions would be critical during these months. Expanding the BBOM analysis to include new data would add further detail, as finer scale space-use patterns by wolves in the areas of winter range overlap could be quantified and potentially used to inform management program planning for the following year. For example, a the BBOM generated for December 2020 – April 2021 (i.e., the barren-ground caribou winter season) would provide a characterization of both wolf movement and space use patterns during a season when we would expect caribou movement to be relatively low. It would be interesting to determine if wolf movement was correspondingly low with BBOM UDs appearing as large contiguous areas of high use, or if wolf movement was more varied with wolves alternating between travelling and area restricted movements.

With seven collars still active on the landscape, there will be the opportunity to look at spatial-temporal patterns of wolf movement and space-use between 2020 and 2021. 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. For example, WF-NS20-01 appeared to follow a north-south movement pattern that was related to the movement of the Bluenose East caribou; while WF-NS20-27 followed an east-west movement pattern that brought it into contact with both the Bluenose East and Bathurst herds. As both these wolves are active in roughly the same region, will they adopt similar strategies in 2021 or will there be a shift in movement patterns and space-use?

6.2 Data Structure

The two occupancy modelling approaches explored in this project represent methods with different data requirements. The BBOM is a data intensive method that requires sub-daily telemetry data with very few missing locations, while the grid cell count method is suited to coarser data resolutions. 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.

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 Ahiak 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 four to thirty collars have been used to ask questions pertaining to wolf caribou dynamics in the past (Hayes and Russel 1998; James 1999; Walton *et al.* 2001; Courbin *et al.* 2009; Latham et al. 2011; Hansen 2013). 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 wolf collars five-7 collars per herd may be more important to the analysis than a large number of collars deployed for just one herd.

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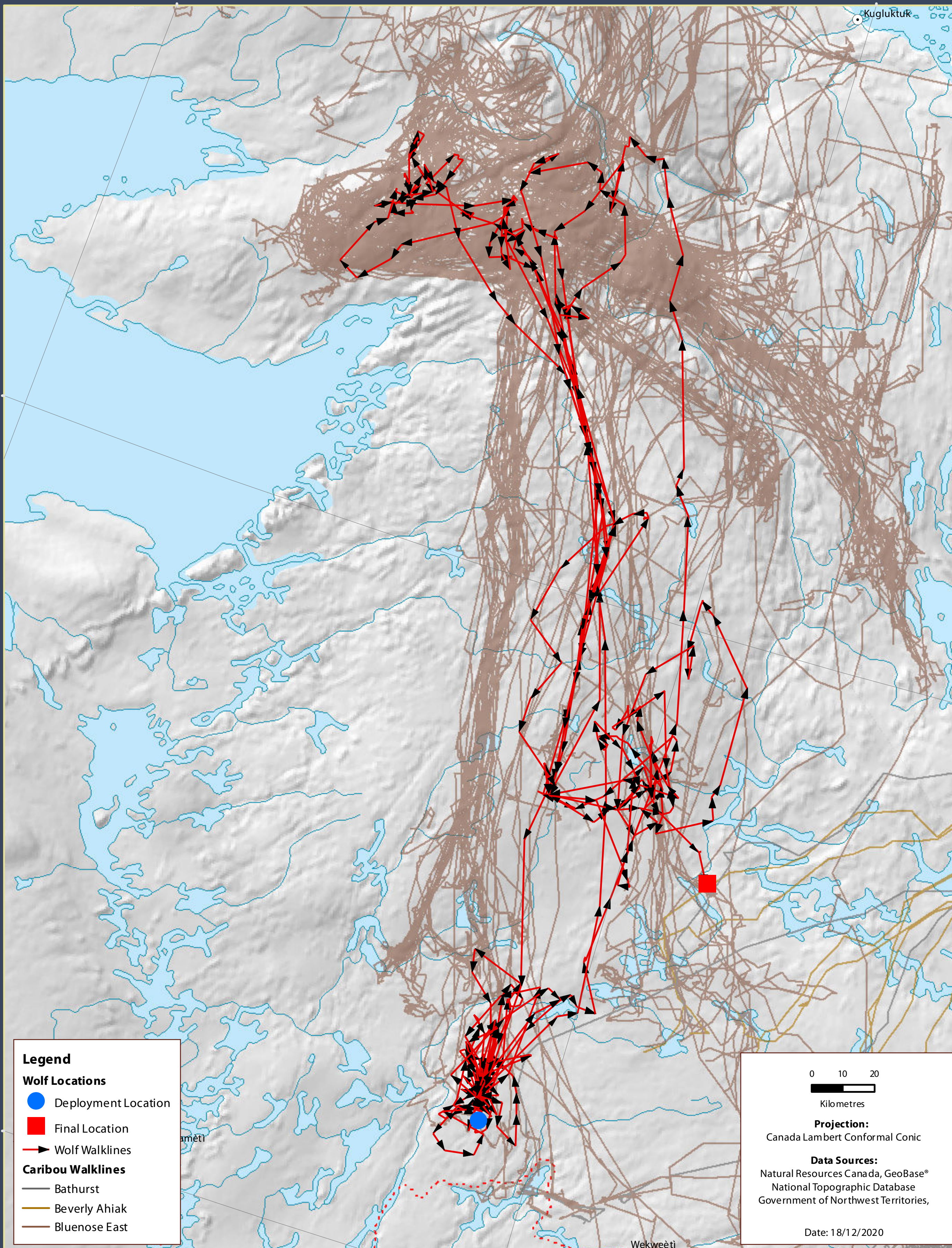
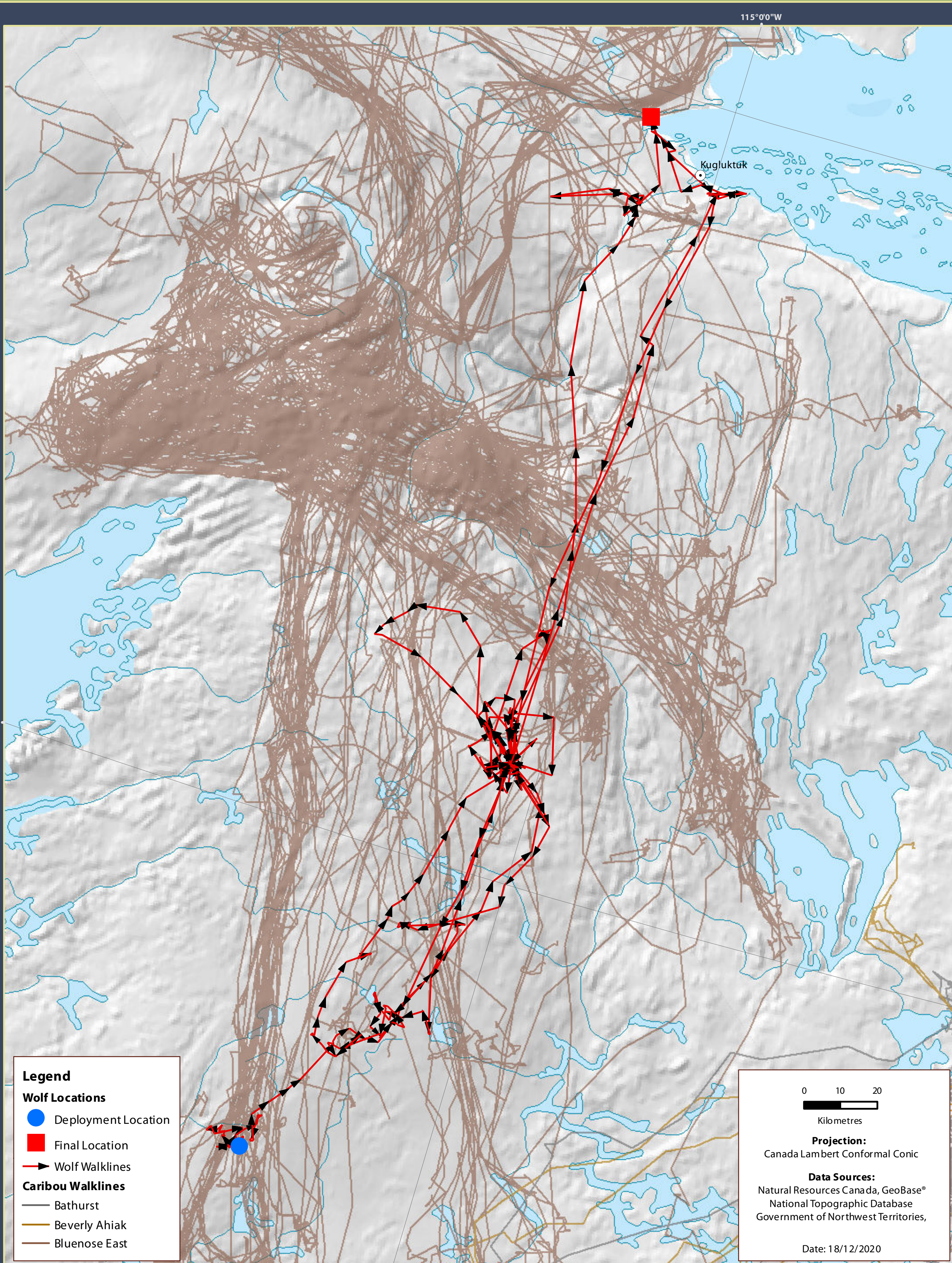
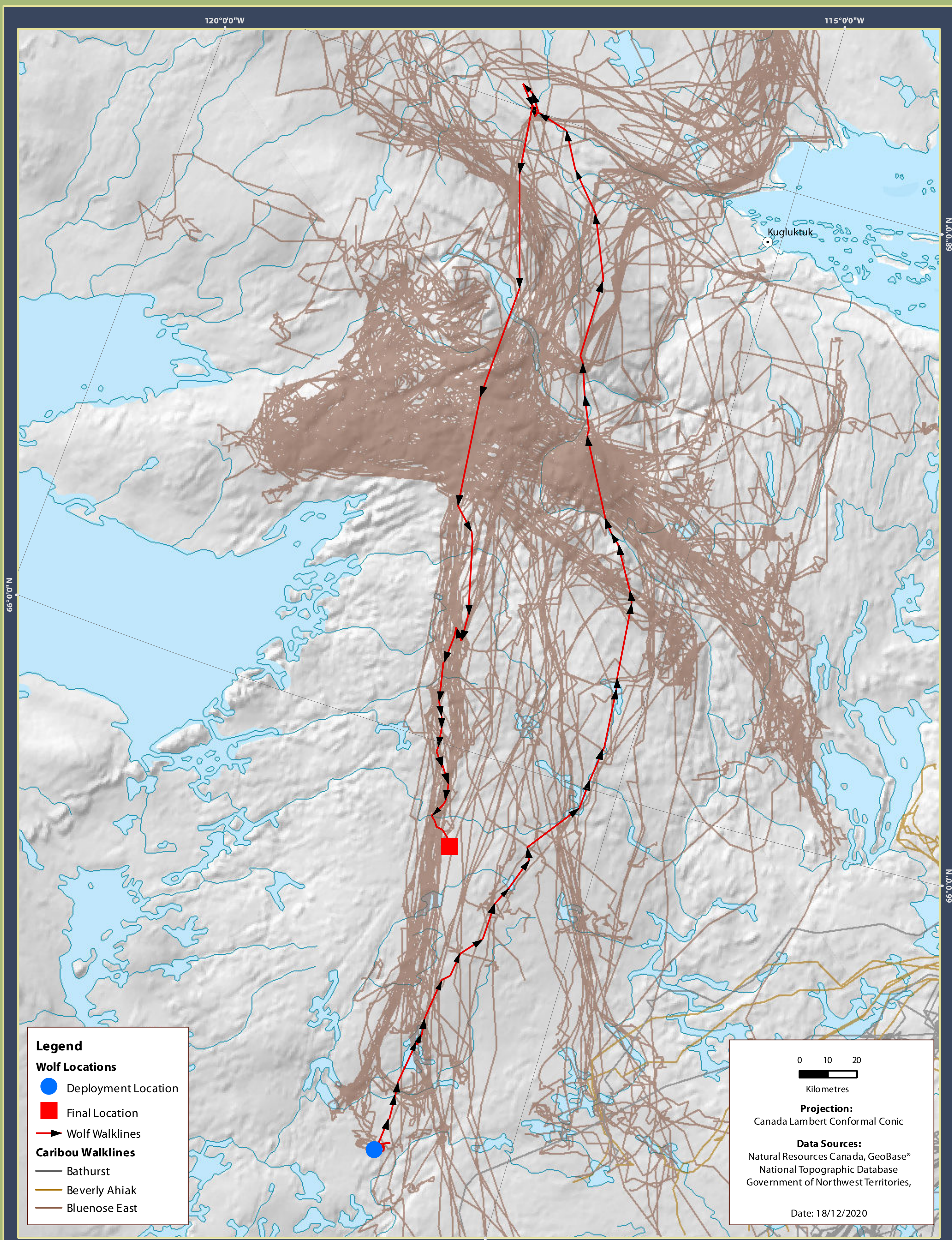
GNWT 2020 Wolf Colloring Program: WF-NS20-01



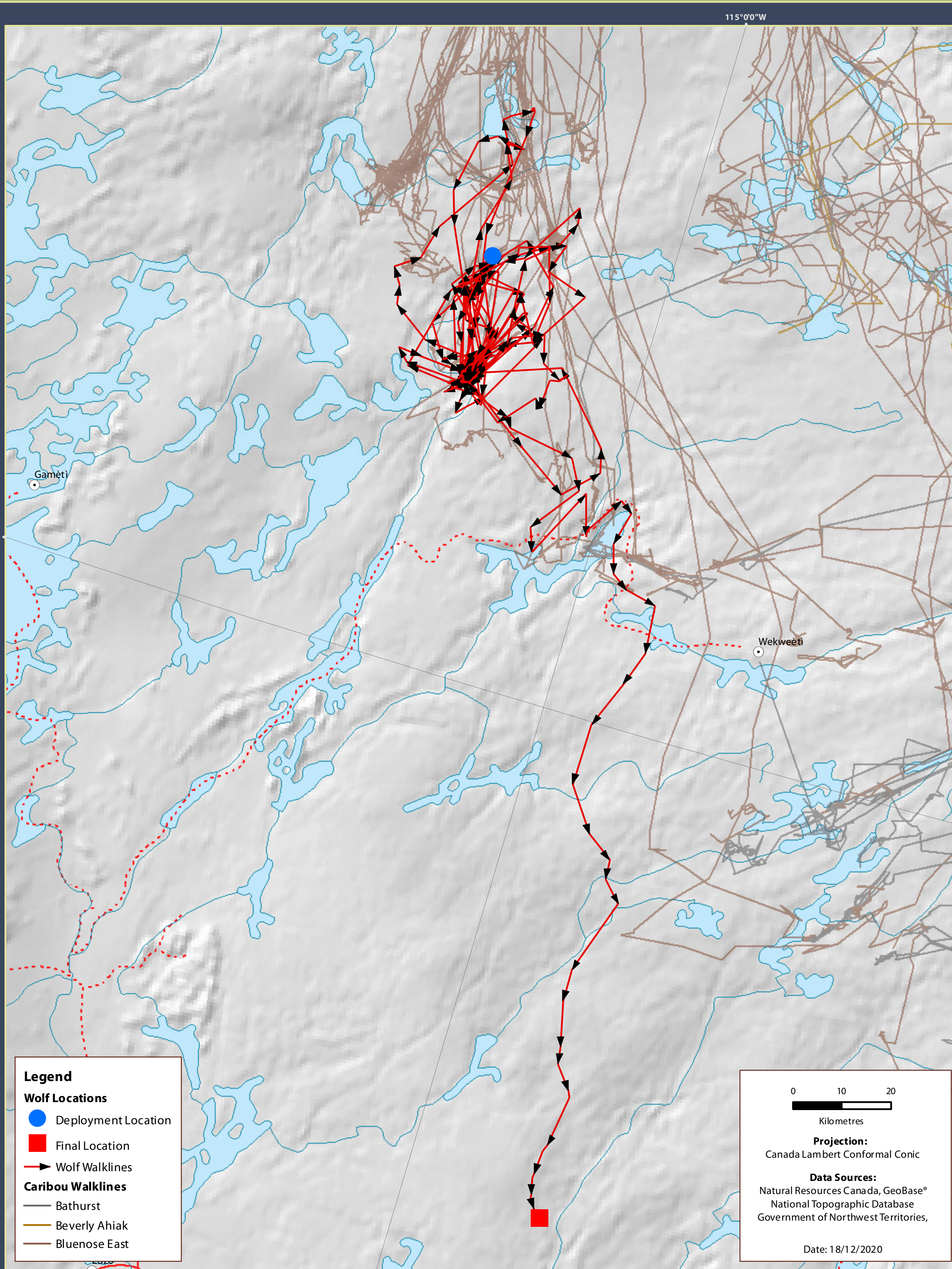
GNWT 2020 Wolf Colloring Program: WF-NS20-18

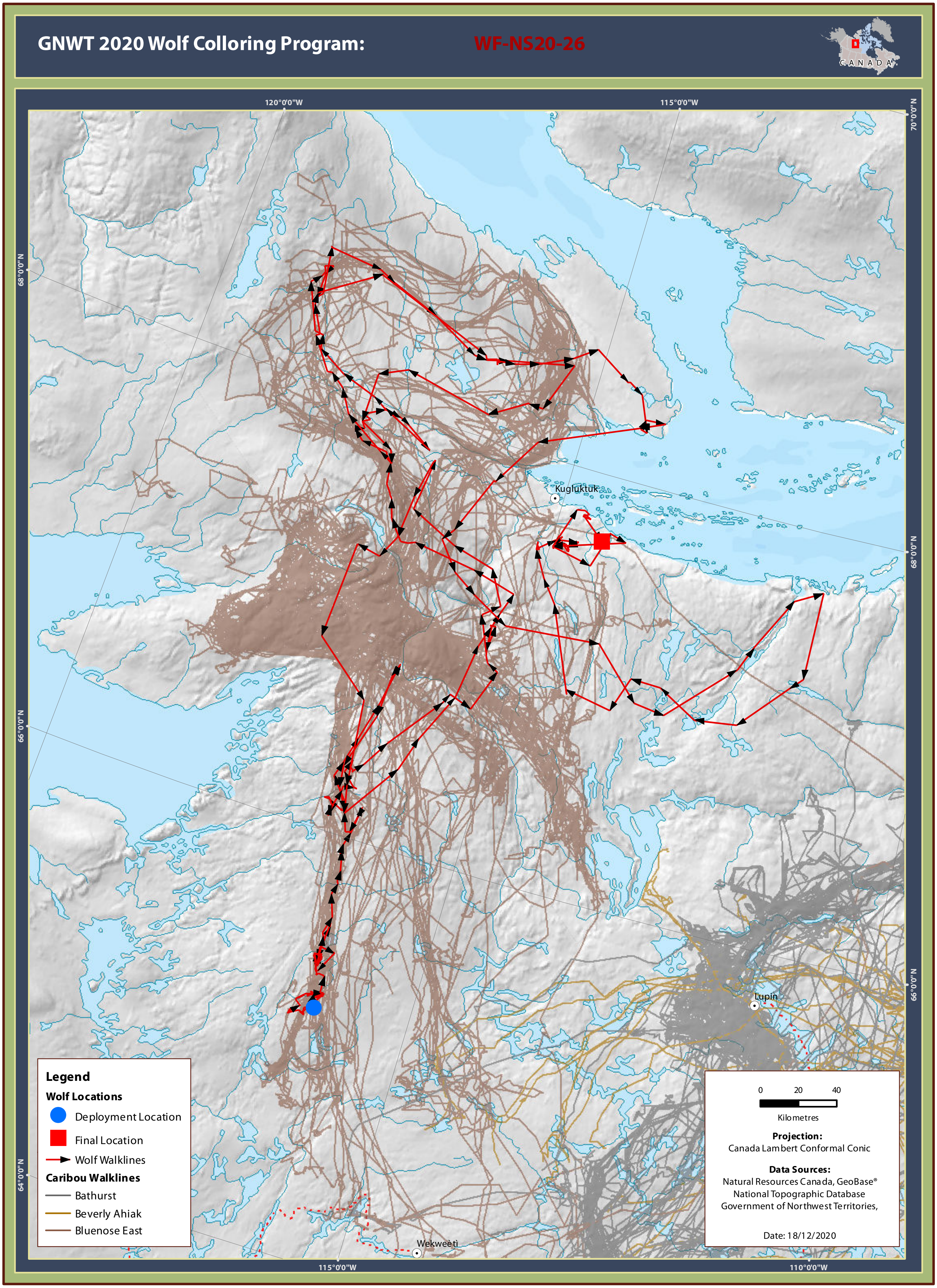


GNWT 2020 Wolf Colloring Program: WF-NS20-19



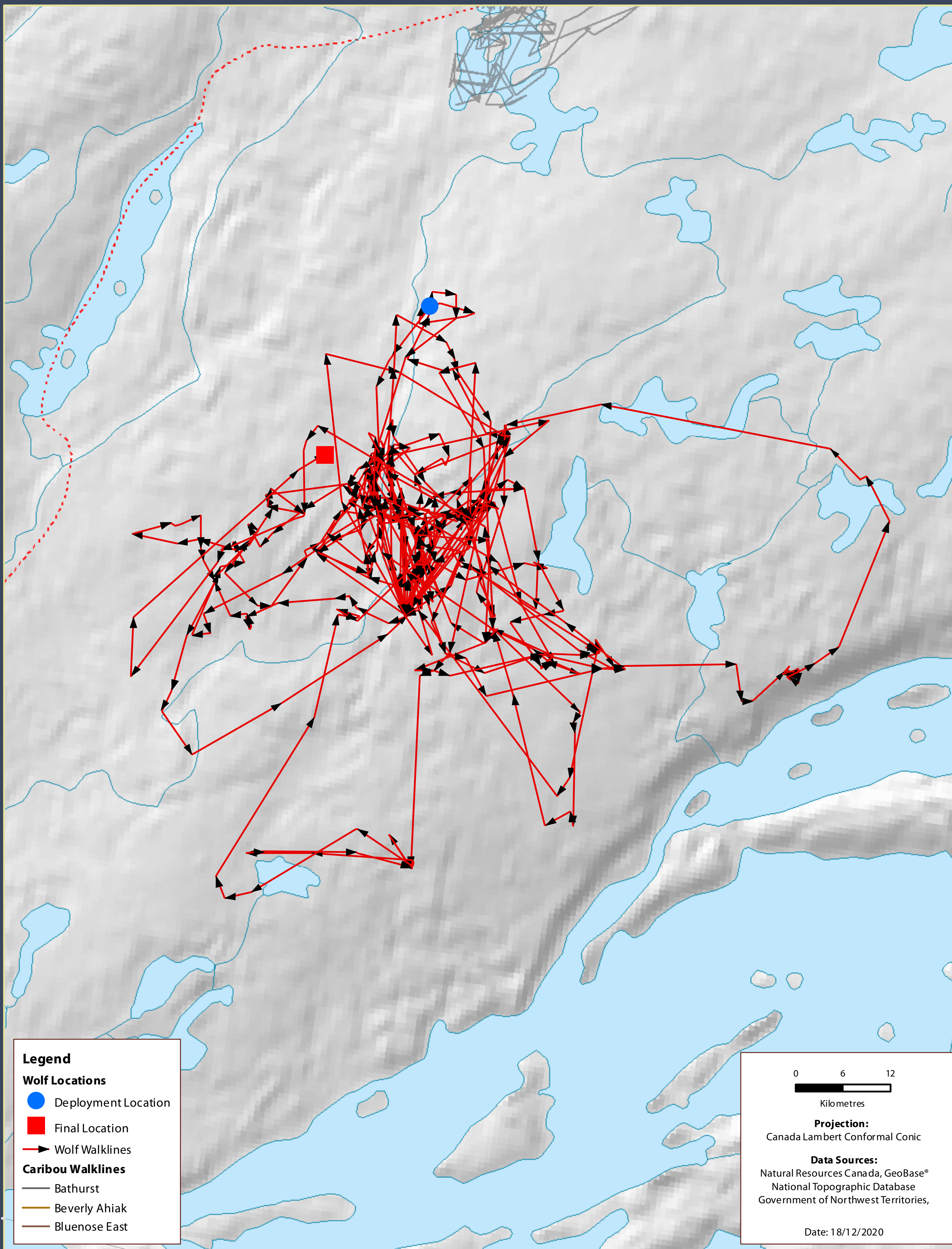
GNWT 2020 Wolf Colloring Program: WF-NS20-22



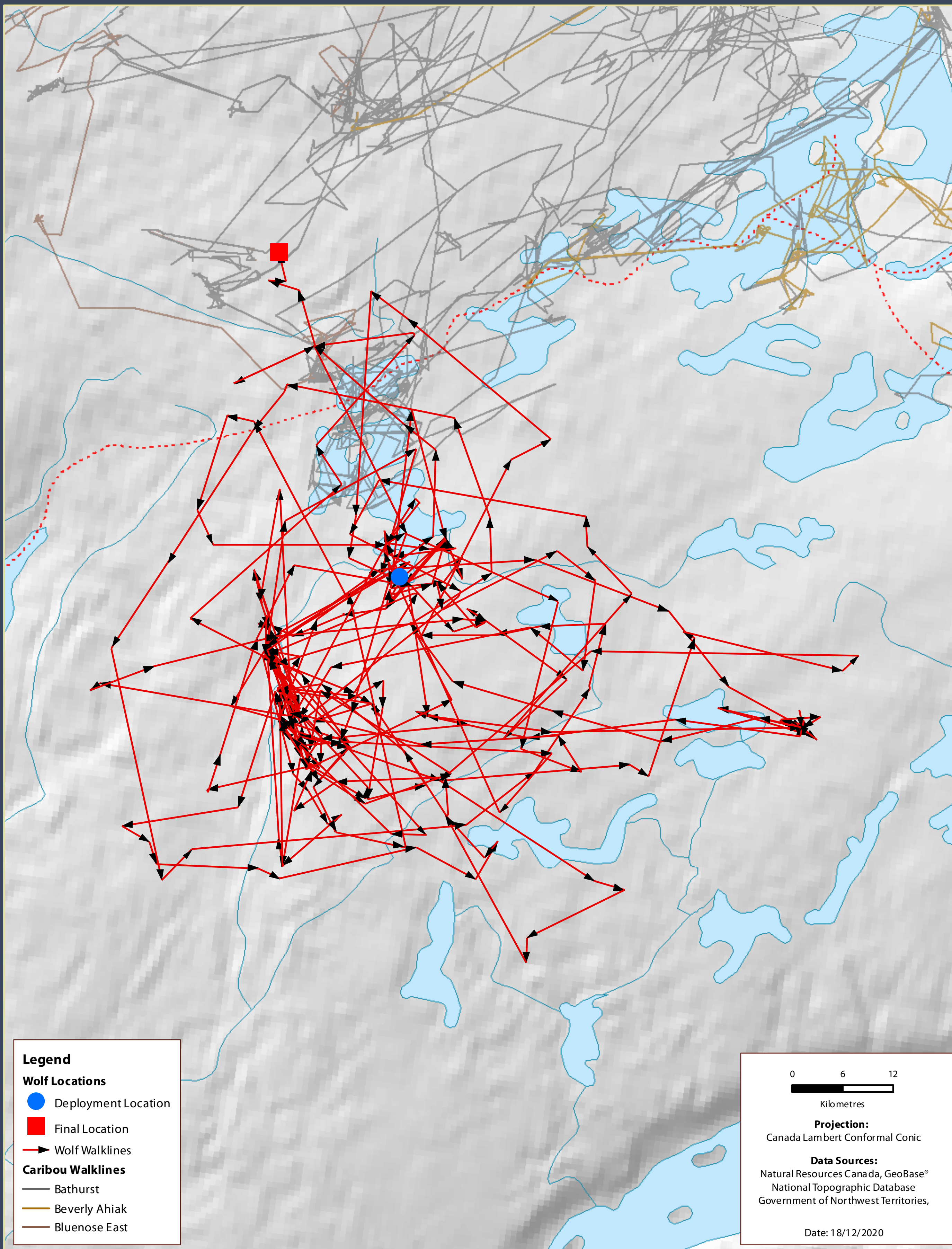


GNWT 2020 Wolf Colloring Program:
WF-NS20-26
CANADA
120°0'0"W
115°0'0"W
110°0'0"W
70°0'0"N
68°0'0"N
66°0'0"N
64°0'0"N
Kugluktuk
Lupin
Wekweètì
Legend
Wolf Locations
Deployment Location
Final Location
Wolf Walklines
Caribou Walklines
Bathurst
Beverly Ahiak
Bluenose East
0
20
40
Kilometres
Projection:
Canada Lambert Conformal Conic
Data Sources:
Natural Resources Canada, GeoBase®
National Topographic Database
Government of Northwest Territories,
Date: 18/12/2020

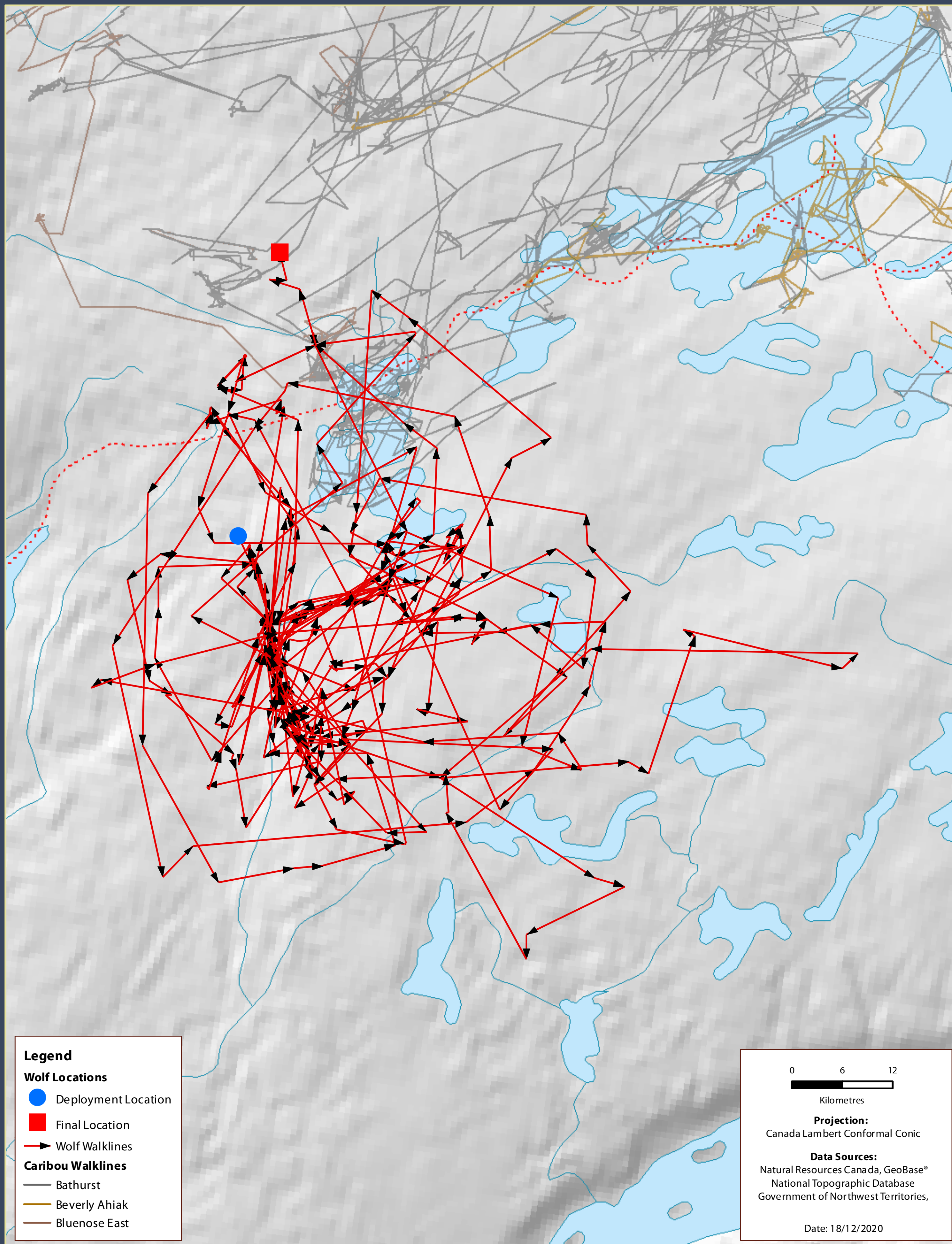
GNWT 2020 Wolf Colloring Program: WF-NS20-02

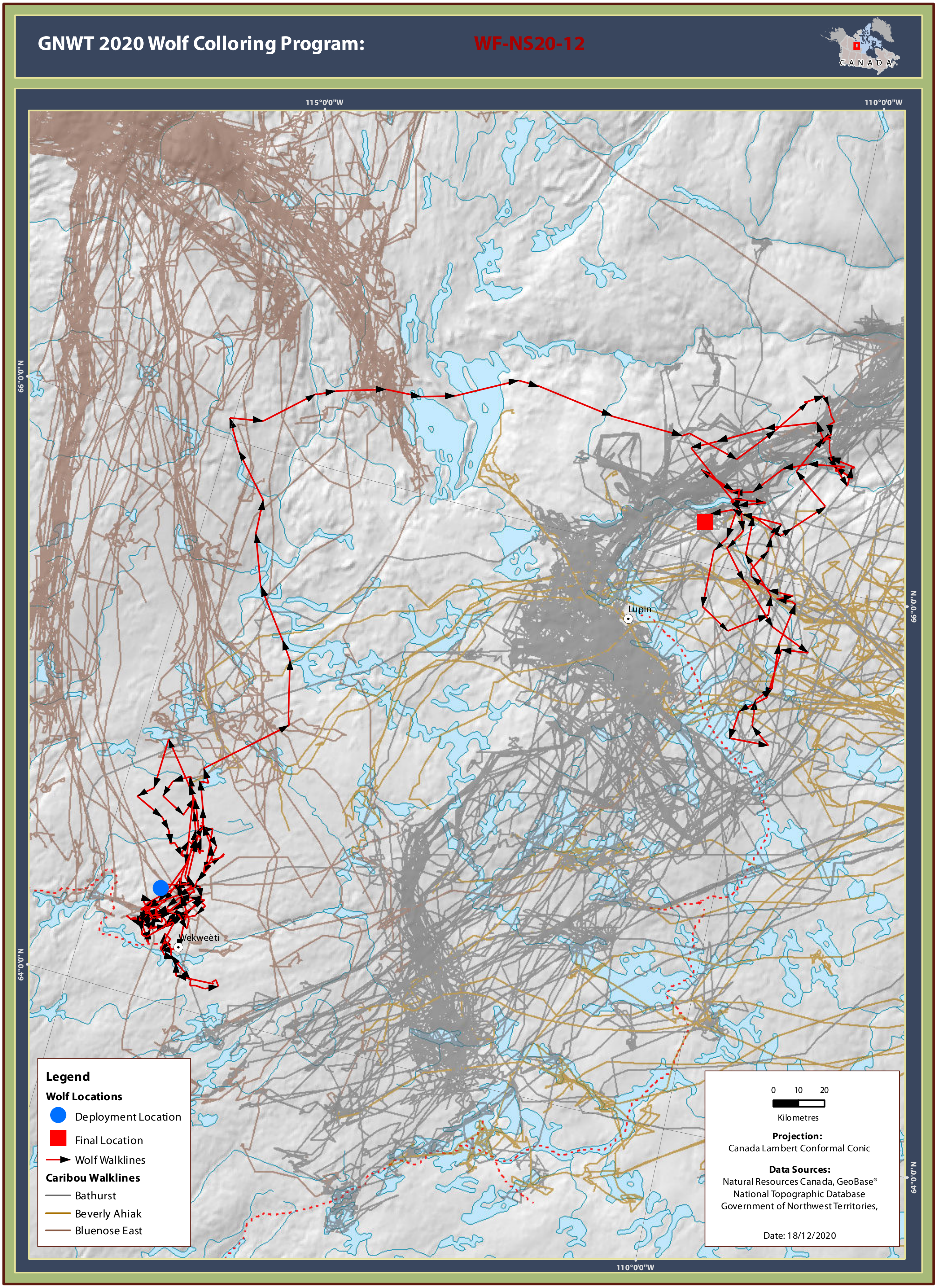


GNWT 2020 Wolf Colloring Program: WF-NS20-23



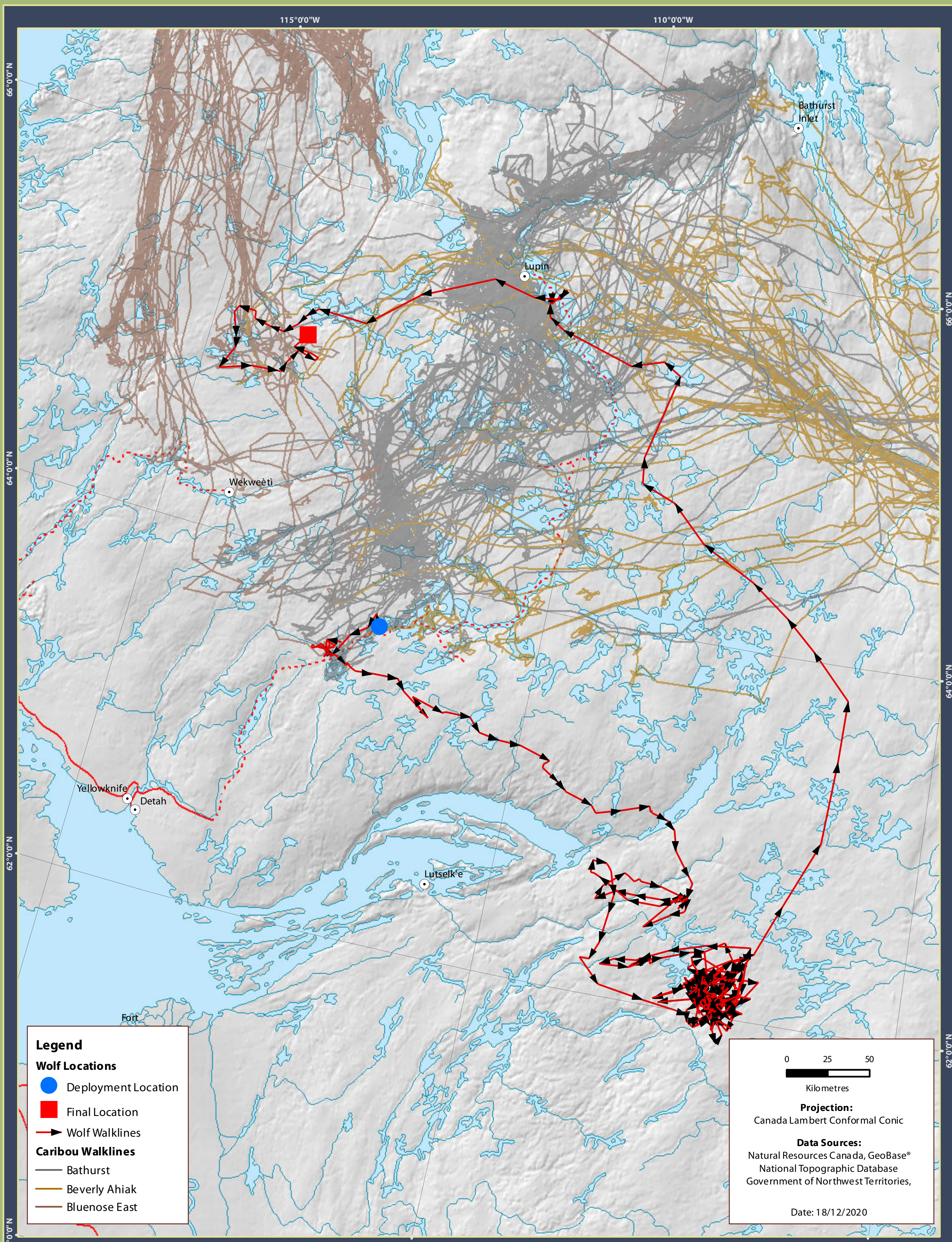
GNWT 2020 Wolf Colloring Program: WF-NS20-29

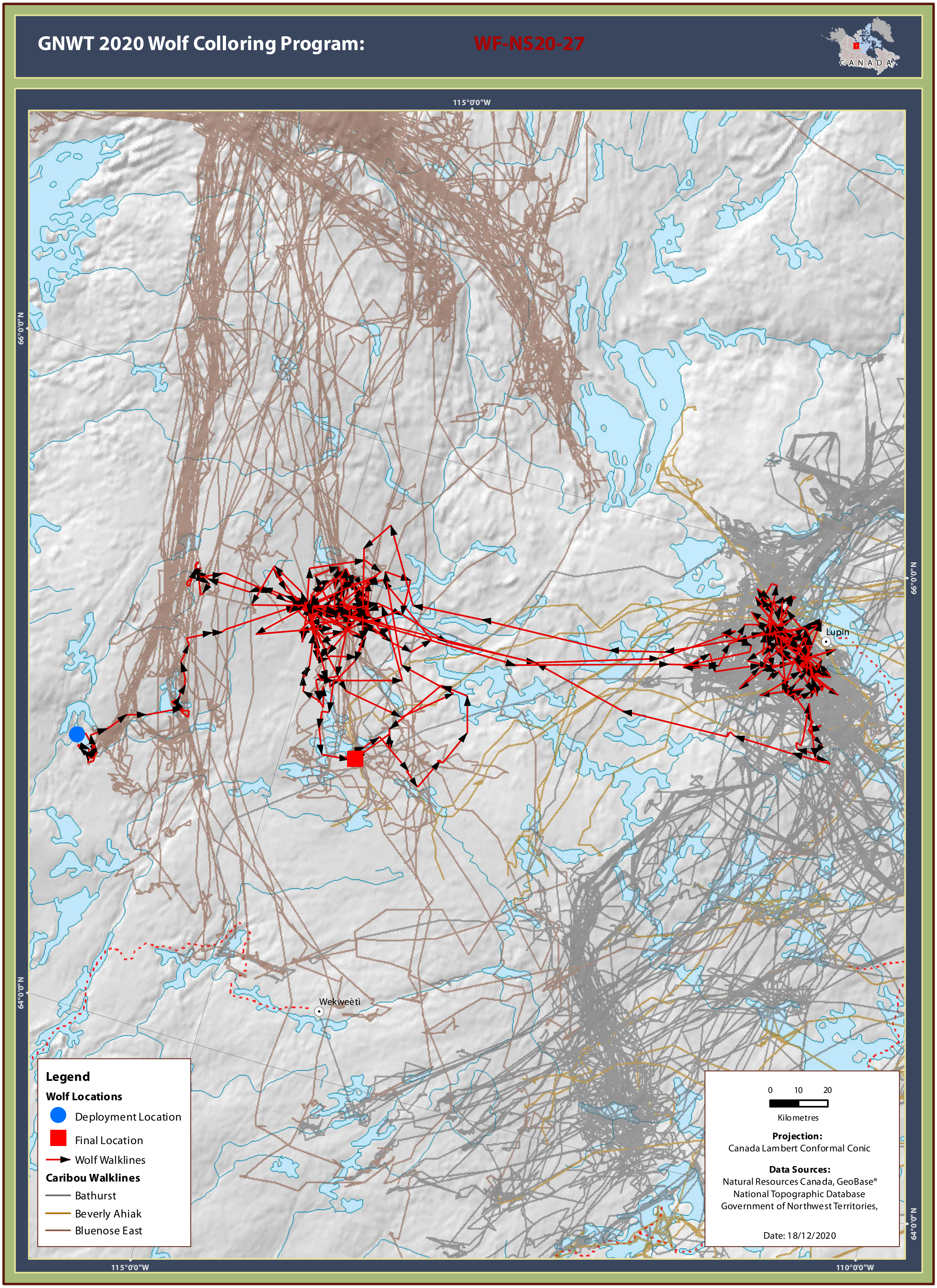


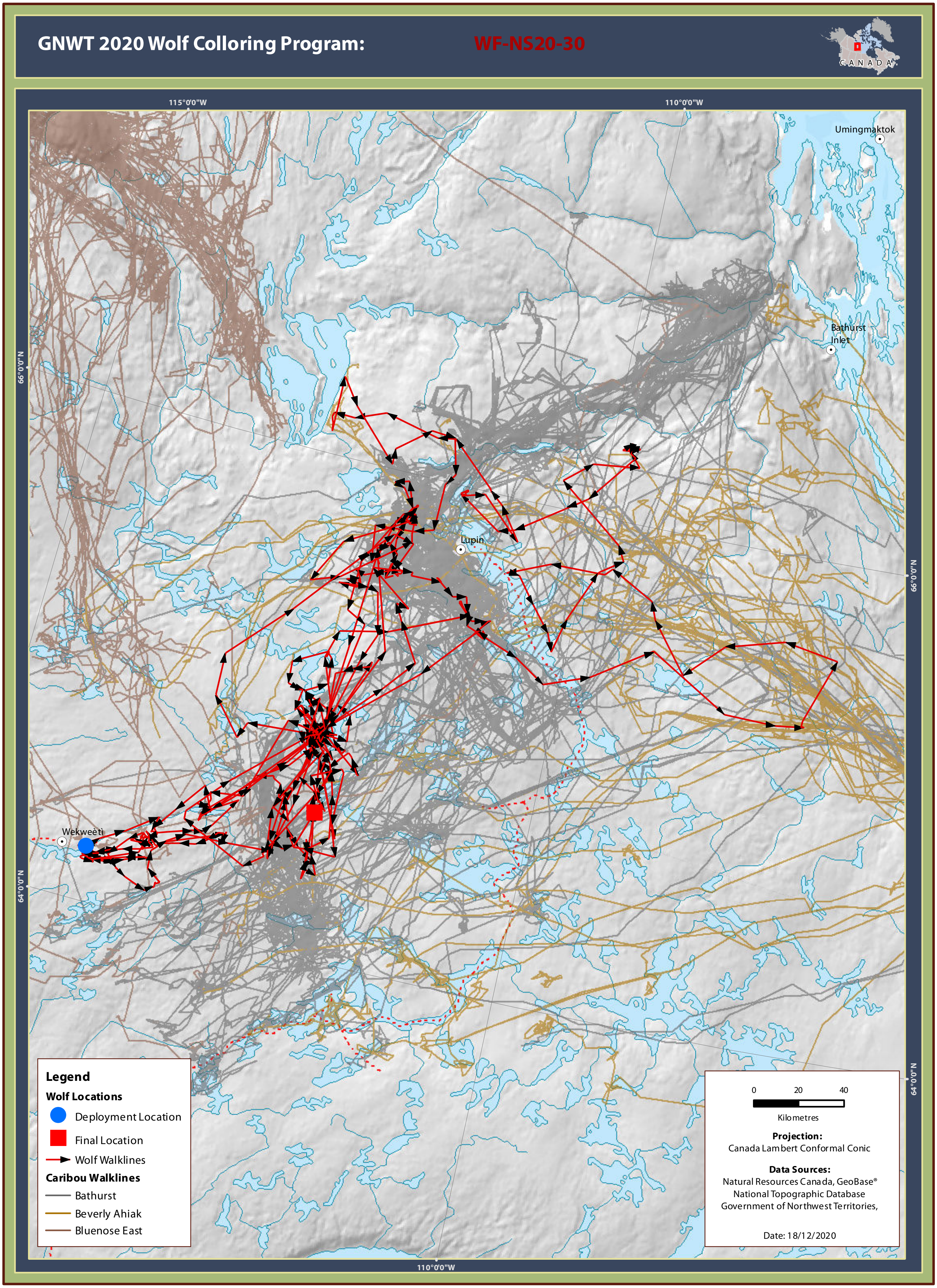


GNWT 2020 Wolf Colloring Program:
WF-NS20-12
CANADA
115°0'0"W
110°0'0"W
66°0'0"N
64°0'0"N
Lupin
Wekweètì
Legend
Wolf Locations
Deployment Location
Final Location
Wolf Walklines
Caribou Walklines
Bathurst
Beverly Ahiak
Bluenose East
0 10 20
Kilometres
Projection:
Canada Lambert Conformal Conic
Data Sources:
Natural Resources Canada, GeoBase®
National Topographic Database
Government of Northwest Territories,
Date: 18/12/2020

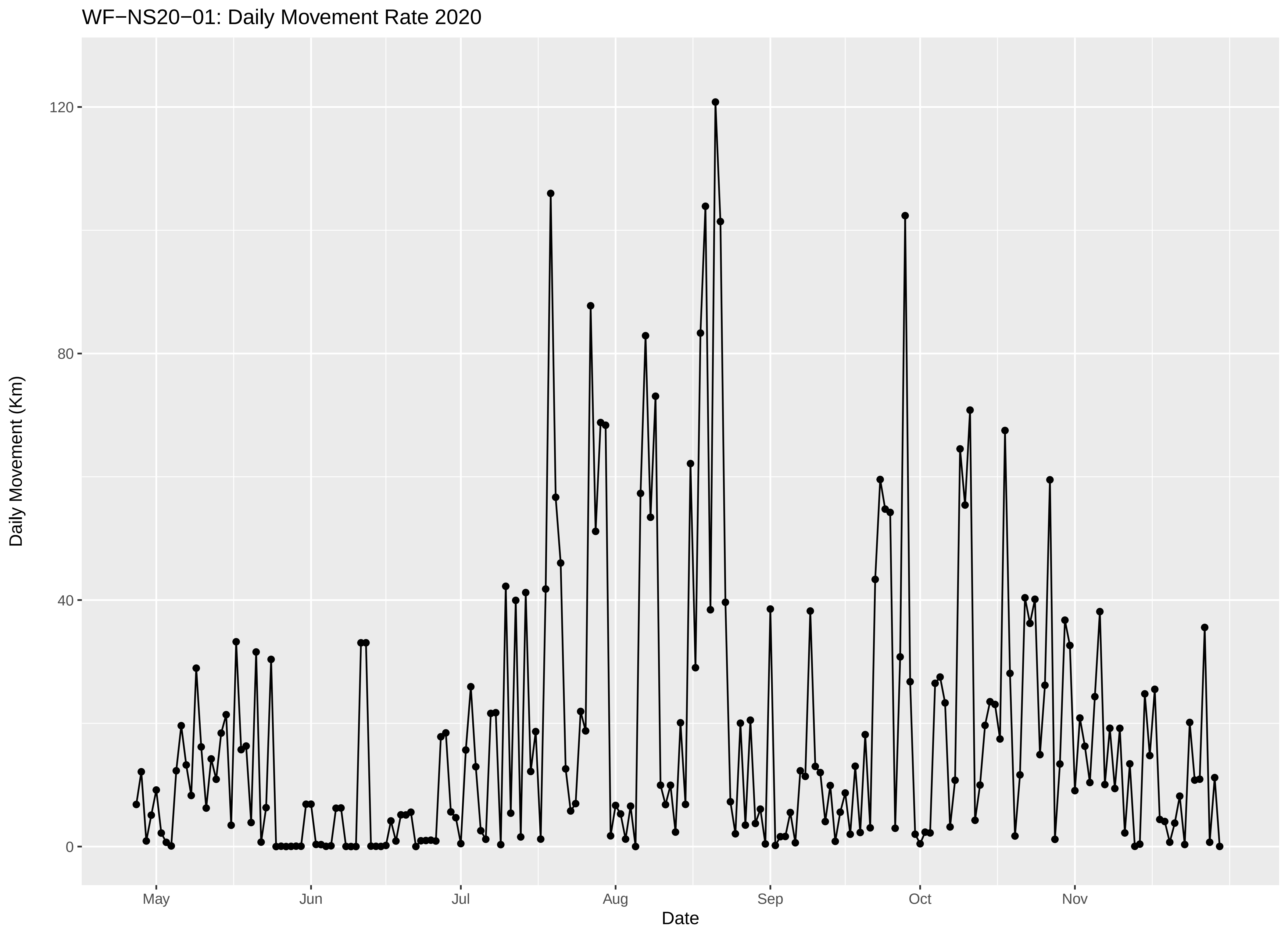
GNWT 2020 Wolf Colloring Program: WF-NS20-21



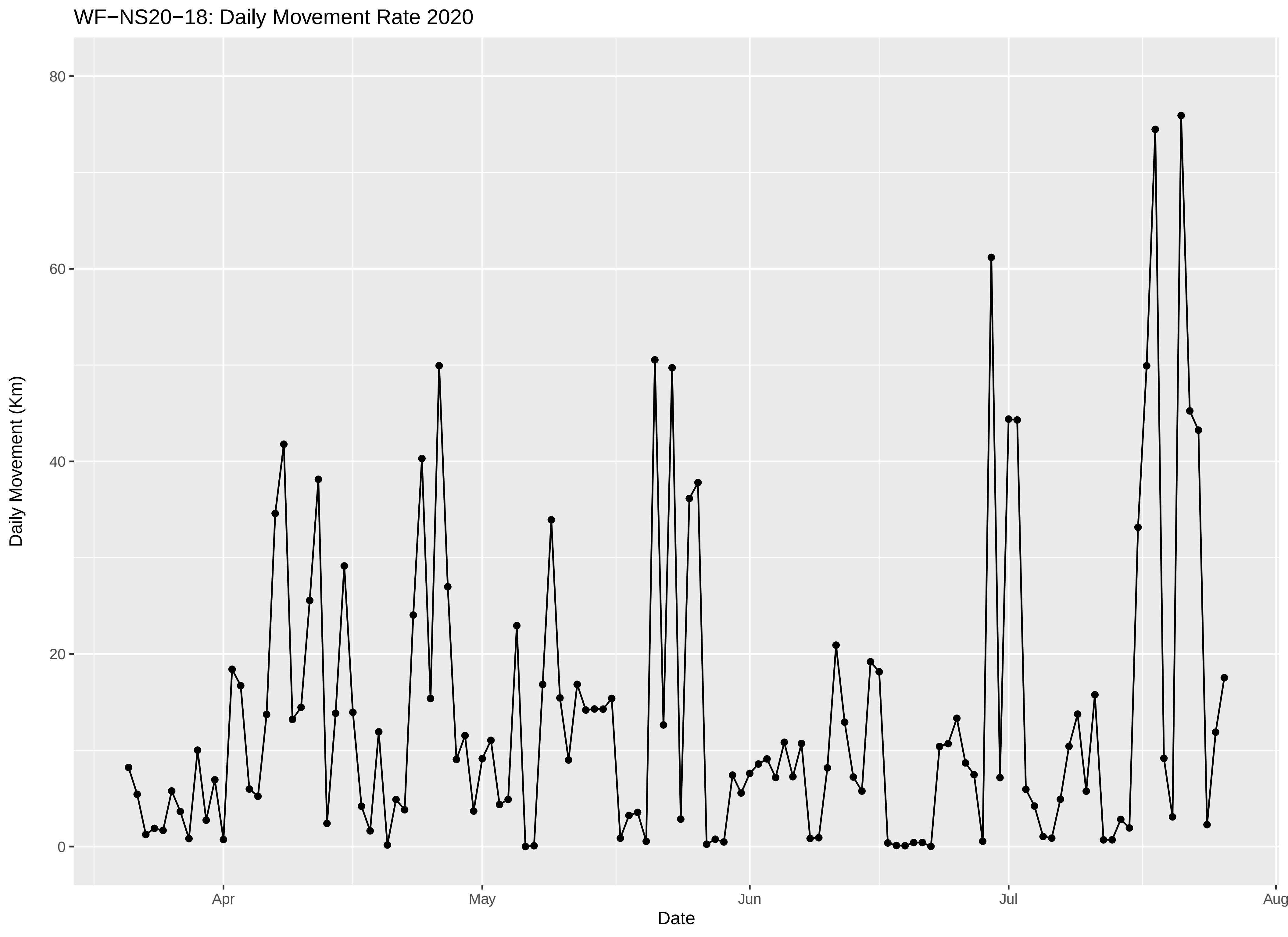

GNWT 2020 Wolf Colloring Program:
WF-NS20-27
CANADA
115°0'0"W
66°0'0"N
64°0'0"N
110°0'0"W
Lupin
Wekweètì
Legend
Wolf Locations
Deployment Location
Final Location
Wolf Walklines
Caribou Walklines
Bathurst
Beverly Ahiak
Bluenose East
0 10 20
Kilometres
Projection:
Canada Lambert Conformal Conic
Data Sources:
Natural Resources Canada, GeoBase®
National Topographic Database
Government of Northwest Territories,
Date: 18/12/2020

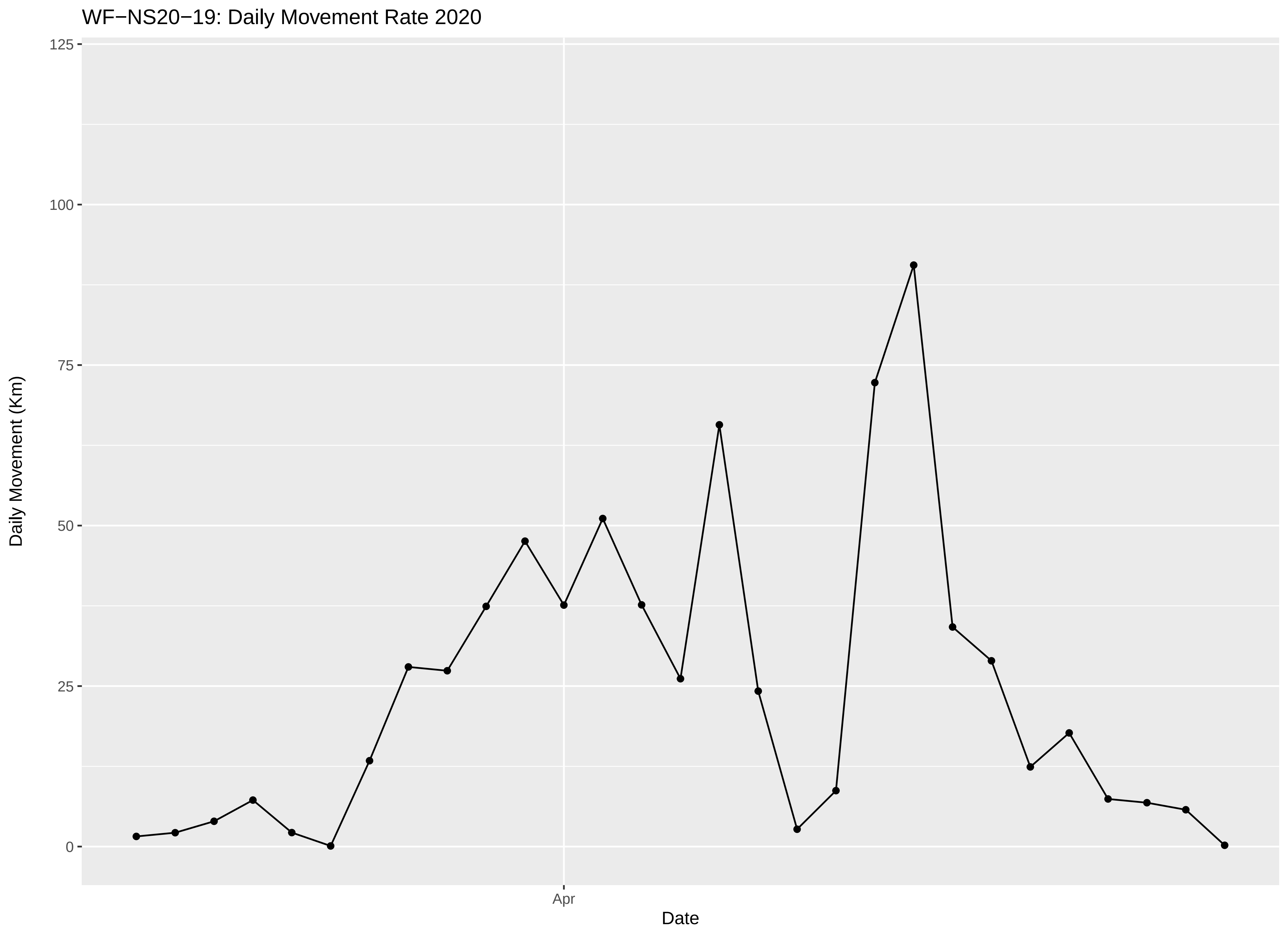


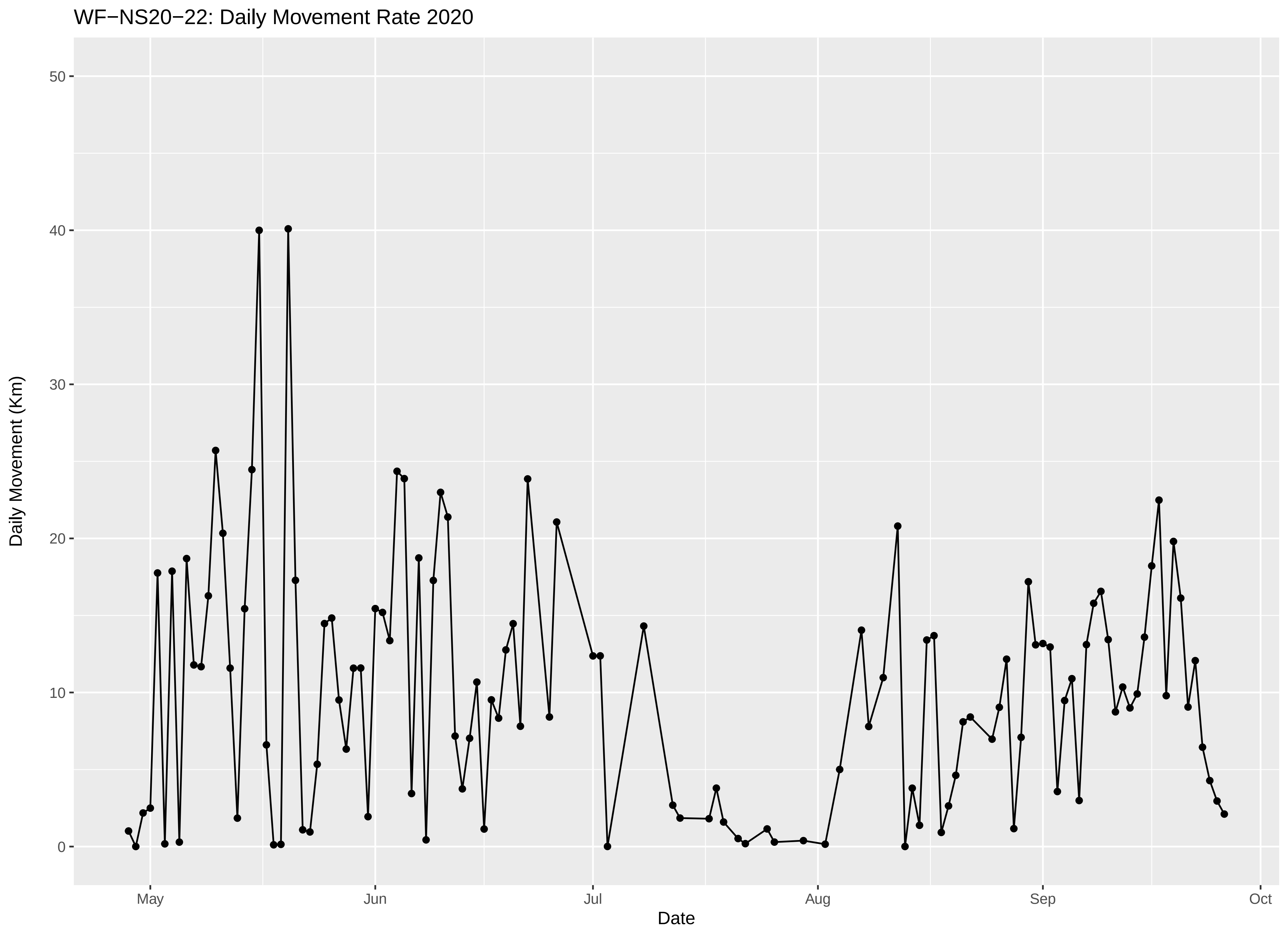
GNWT 2020 Wolf Colloring Program:
WF-NS20-30
CANADA
115°0'0"W
110°0'0"W
Umingmaktok
Bathurst Inlet
66°0'0"N
Lupin
Wekweètì
64°0'0"N
Legend
Wolf Locations
Deployment Location
Final Location
Wolf Walklines
Caribou Walklines
Bathurst
Beverly Ahiak
Bluenose East
0 20 40
Kilometres
Projection:
Canada Lambert Conformal Conic
Data Sources:
Natural Resources Canada, GeoBase®
National Topographic Database
Government of Northwest Territories,
Date: 18/12/2020

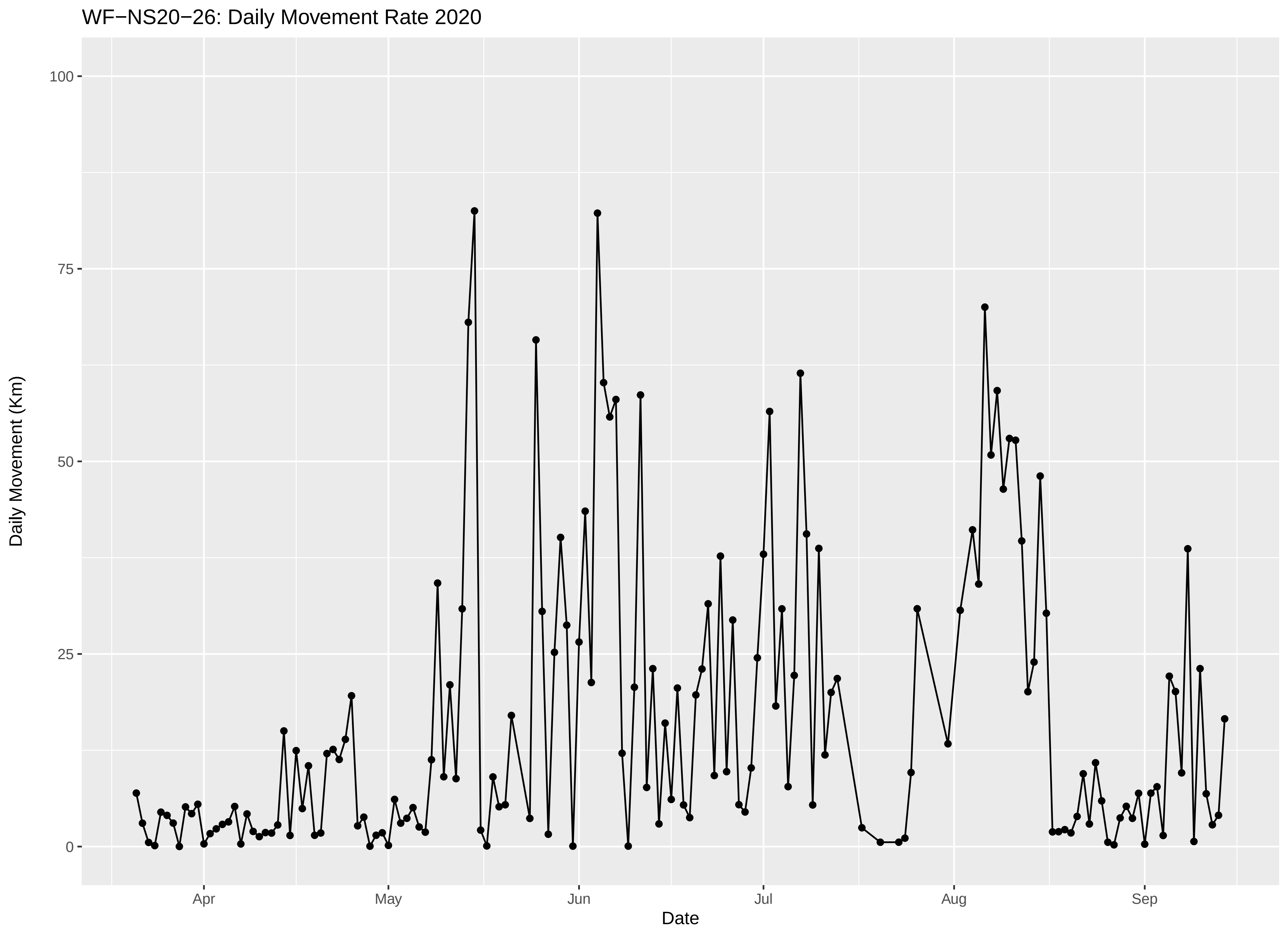


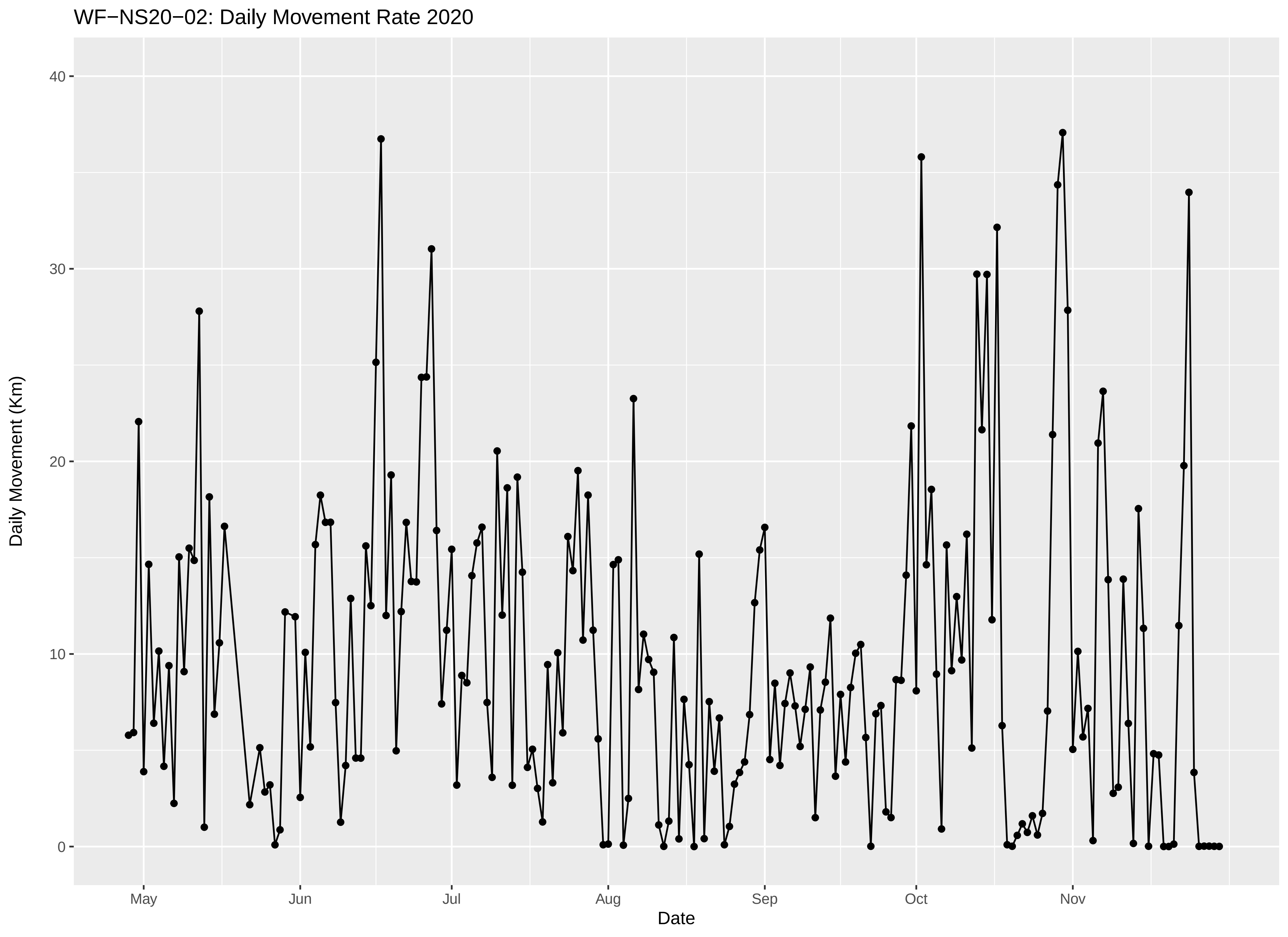
WF−NS20−01: Daily Movement Rate 2020
Daily Movement (Km)
0
40
80
120
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

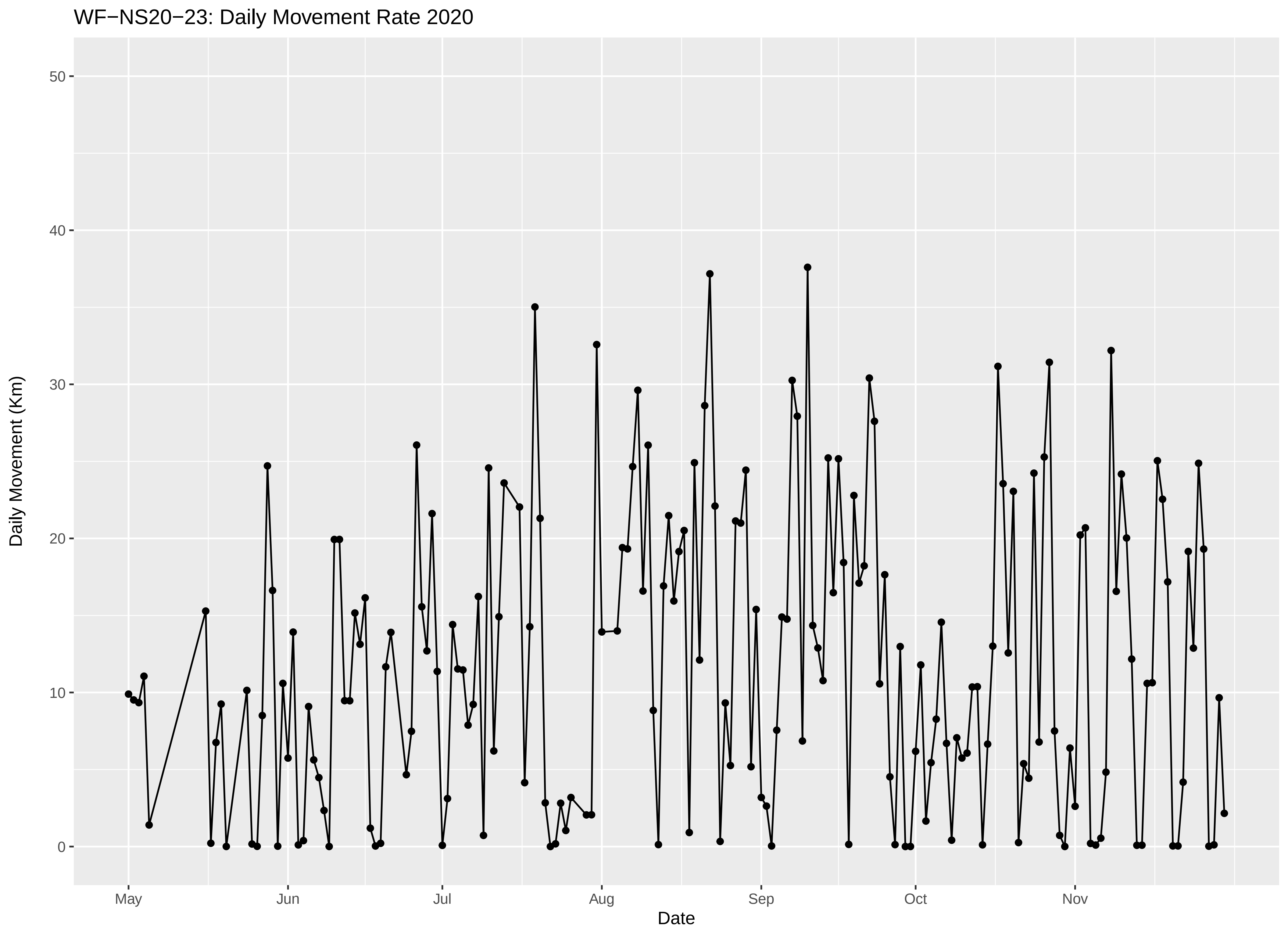

WF−NS20−18: Daily Movement Rate 2020
Daily Movement (Km)
0
20
40
60
80
Apr
May
Jun
Jul
Aug
Date

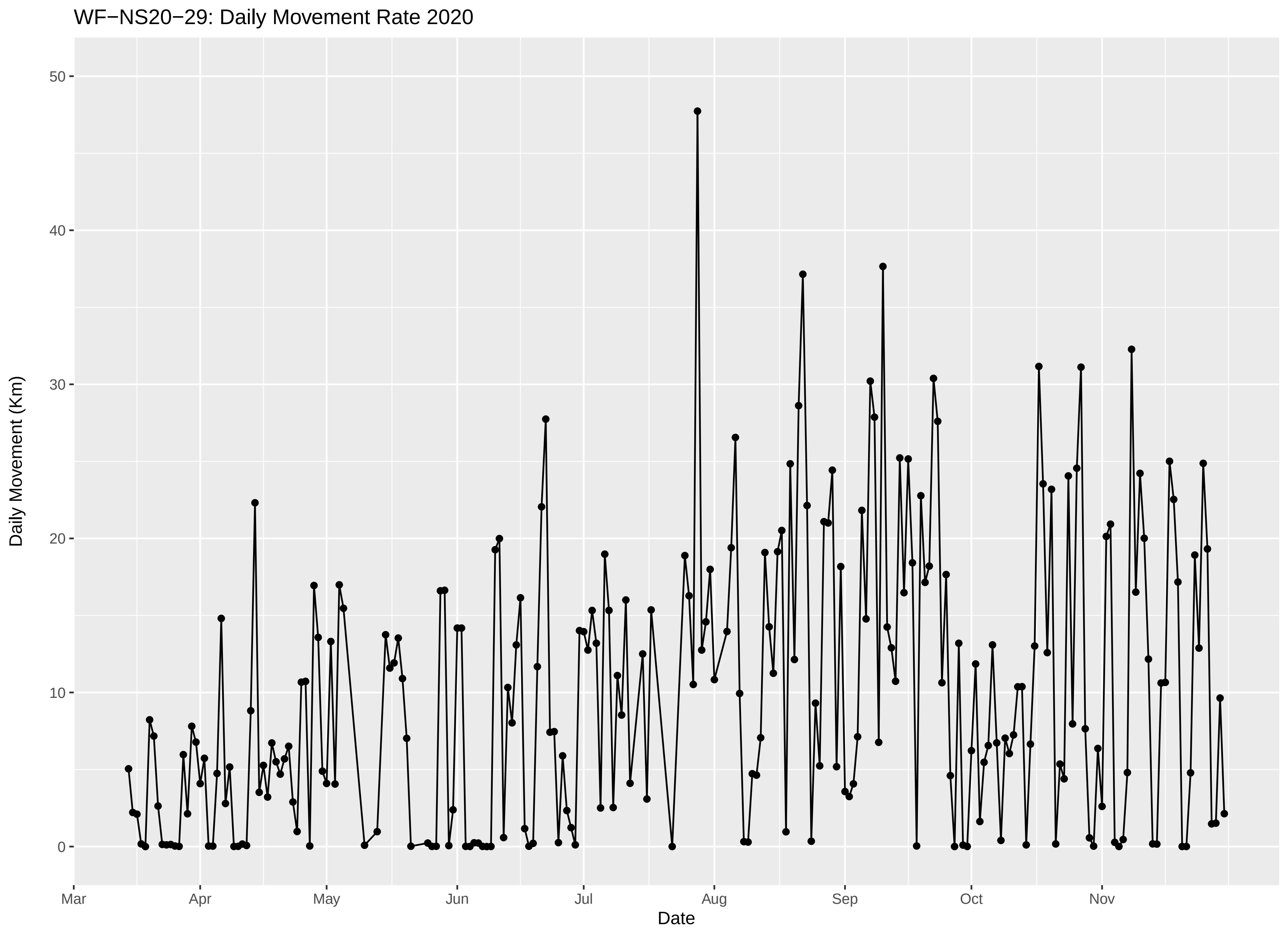

WF−NS20−19: Daily Movement Rate 2020
125
100
75
50
25
0
Daily Movement (Km)
Apr
Date


WF−NS20−22: Daily Movement Rate 2020
Daily Movement (Km)
50
40
30
20
10
0
May
Jun
Jul
Aug
Sep
Oct
Date

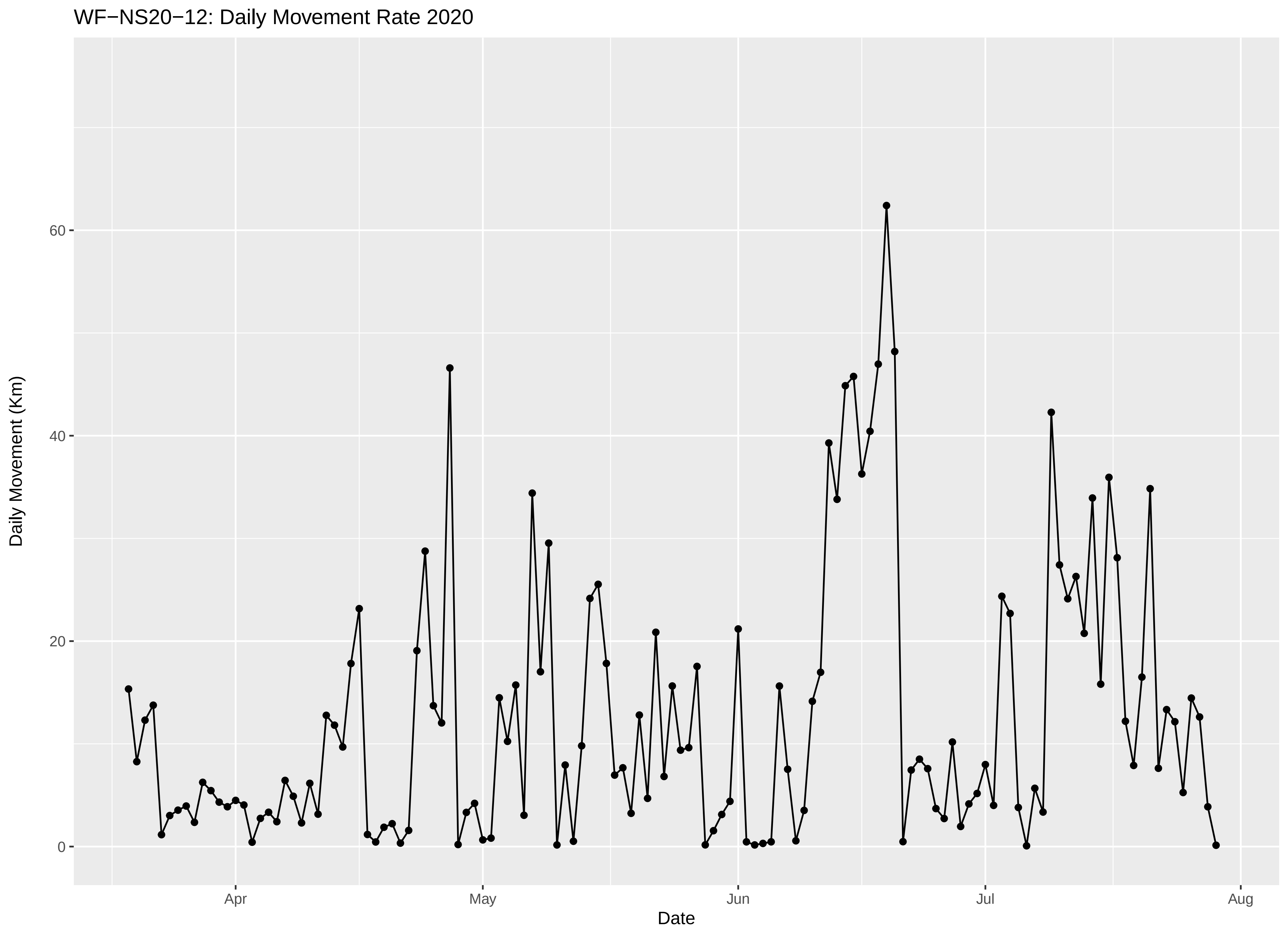

WF−NS20−26: Daily Movement Rate 2020
Daily Movement (Km)
100
75
50
25
0
Apr
May
Jun
Jul
Aug
Sep
Date

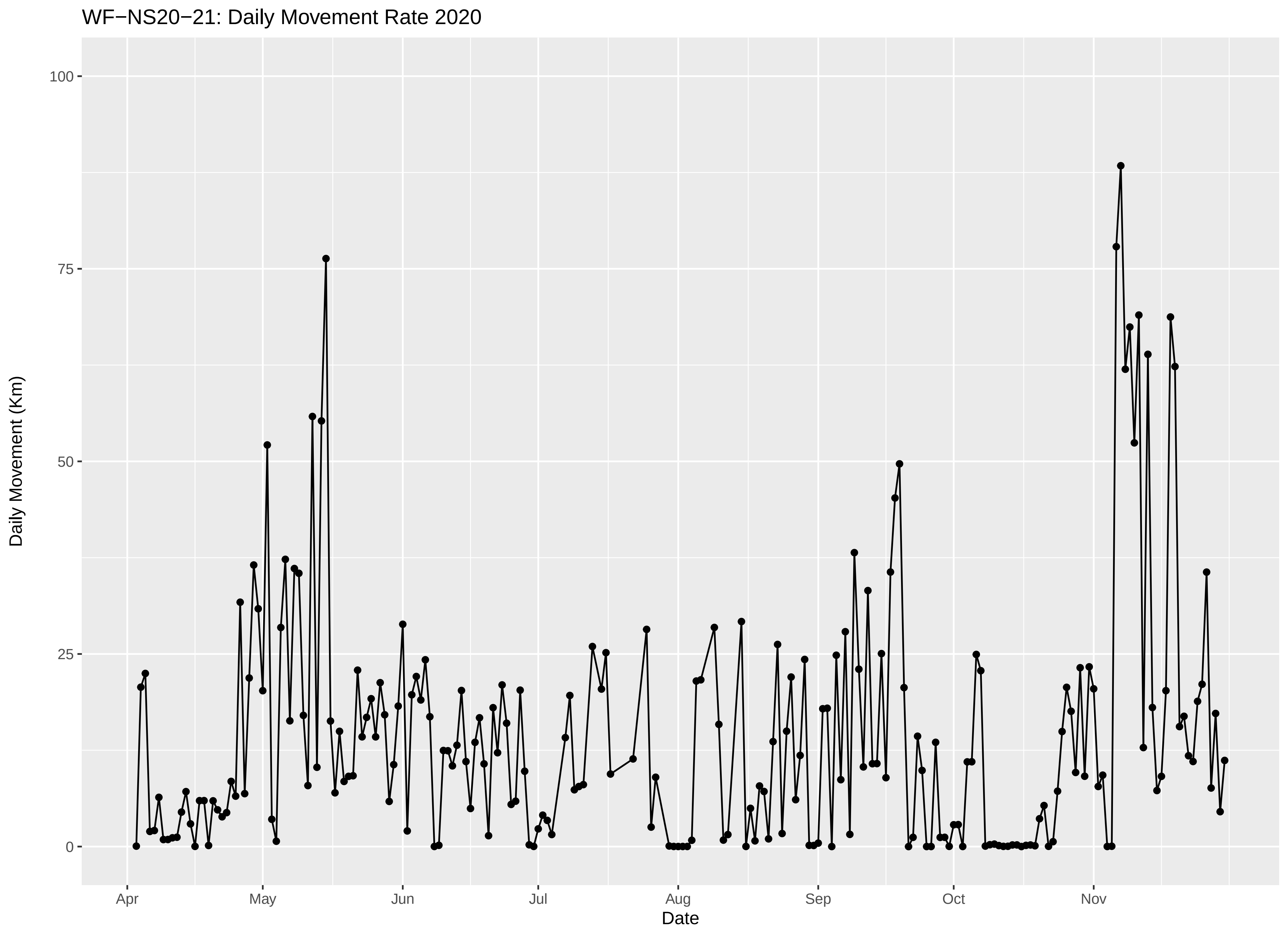

WF−NS20−02: Daily Movement Rate 2020
Daily Movement (Km)
40
30
20
10
0
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

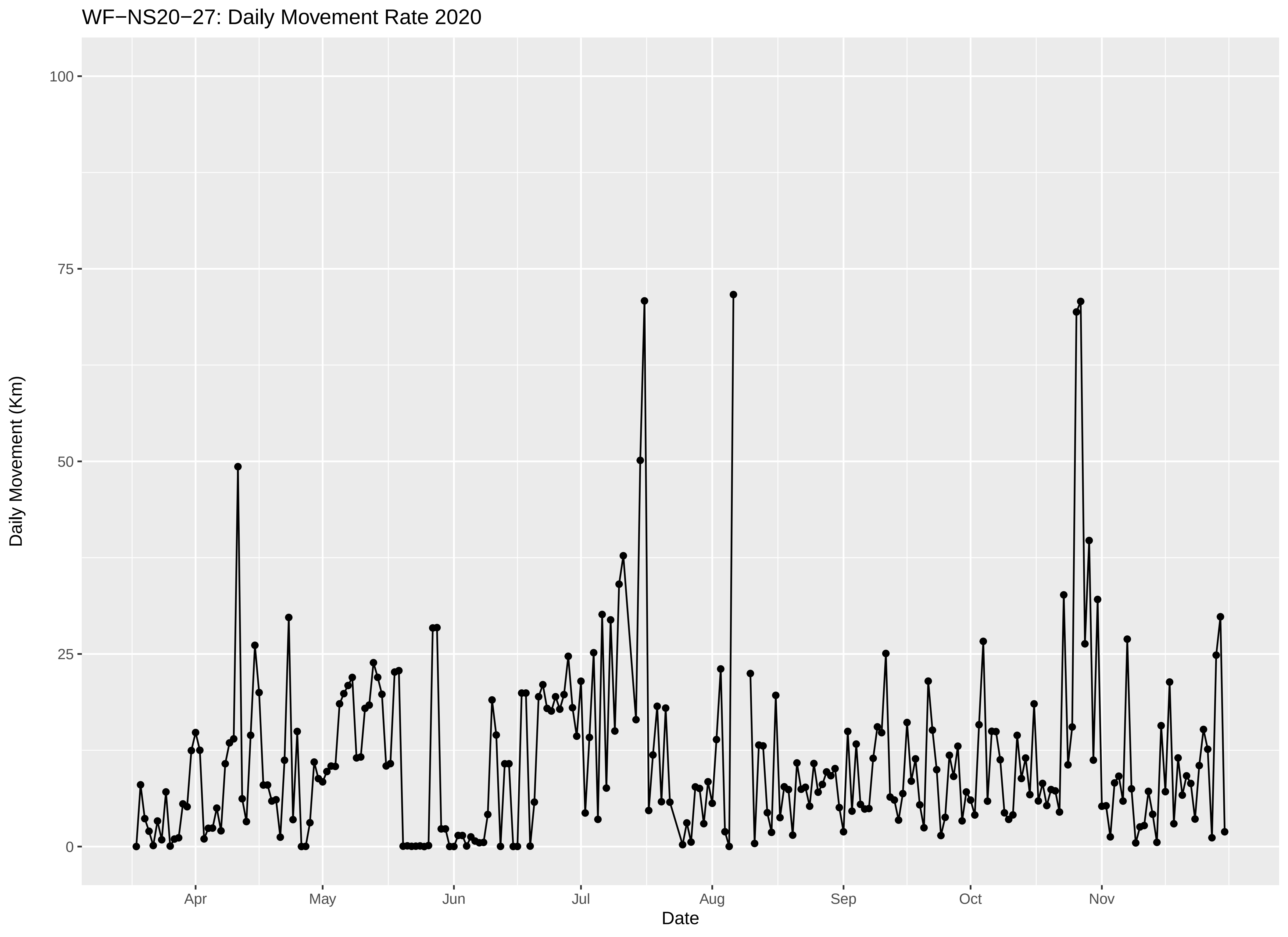

WF−NS20−23: Daily Movement Rate 2020
Daily Movement (Km)
0
10
20
30
40
50
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

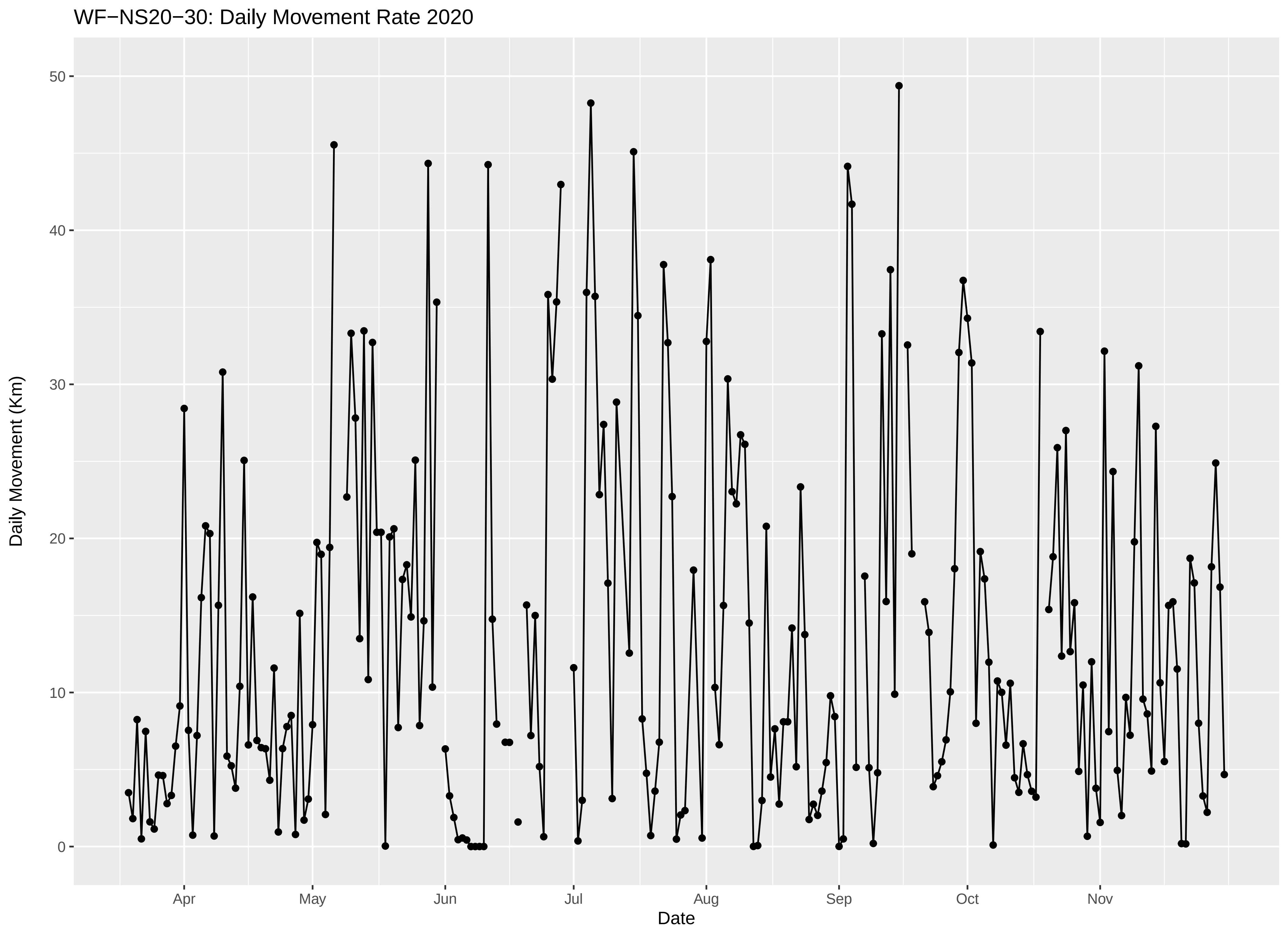


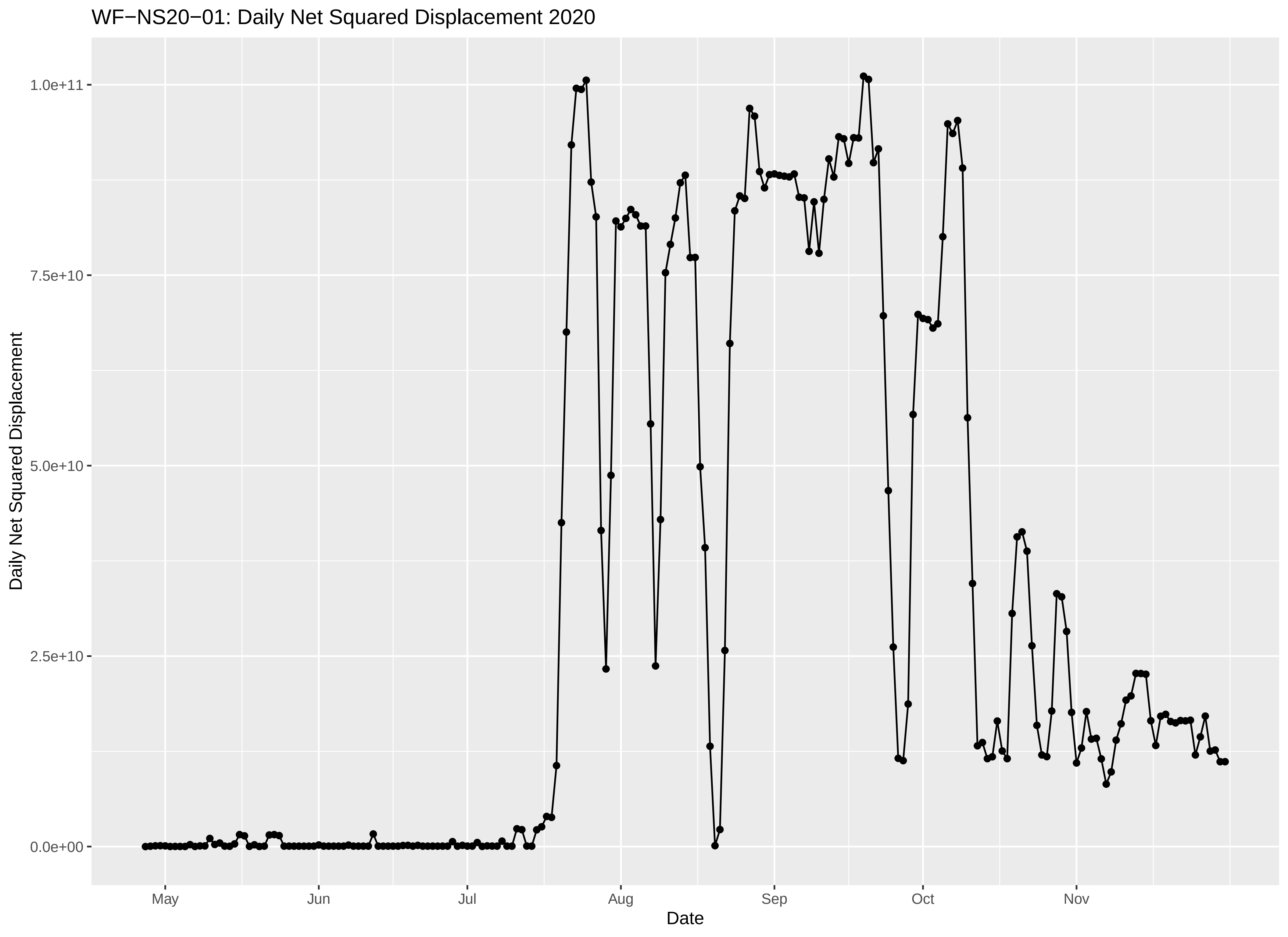
WF−NS20−29: Daily Movement Rate 2020
Daily Movement (Km)
50
40
30
20
10
0
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

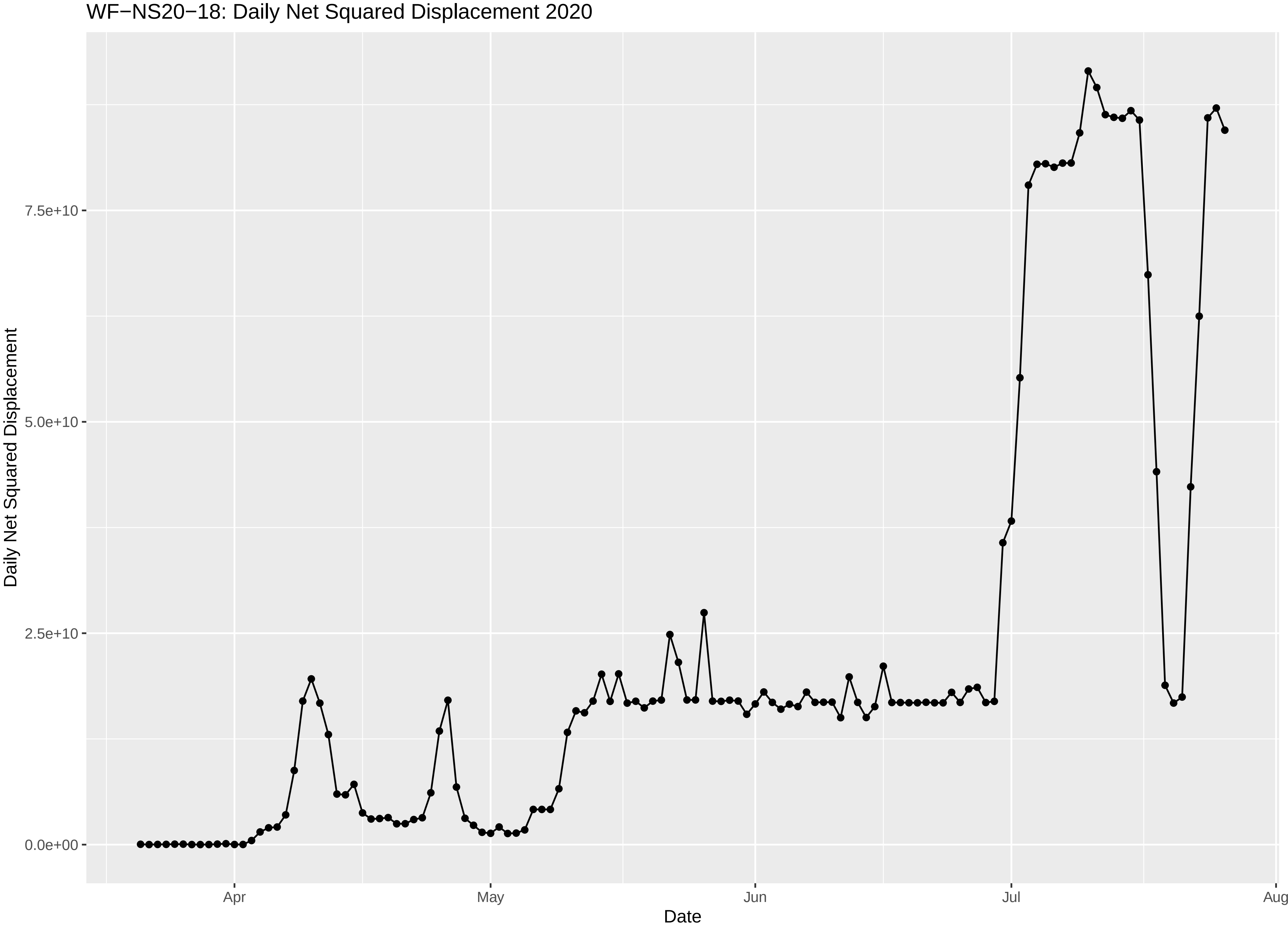

WF−NS20−12: Daily Movement Rate 2020
Daily Movement (Km)
0
20
40
60
Apr
May
Jun
Jul
Aug
Date


WF−NS20−21: Daily Movement Rate 2020
Daily Movement (Km)
100
75
50
25
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

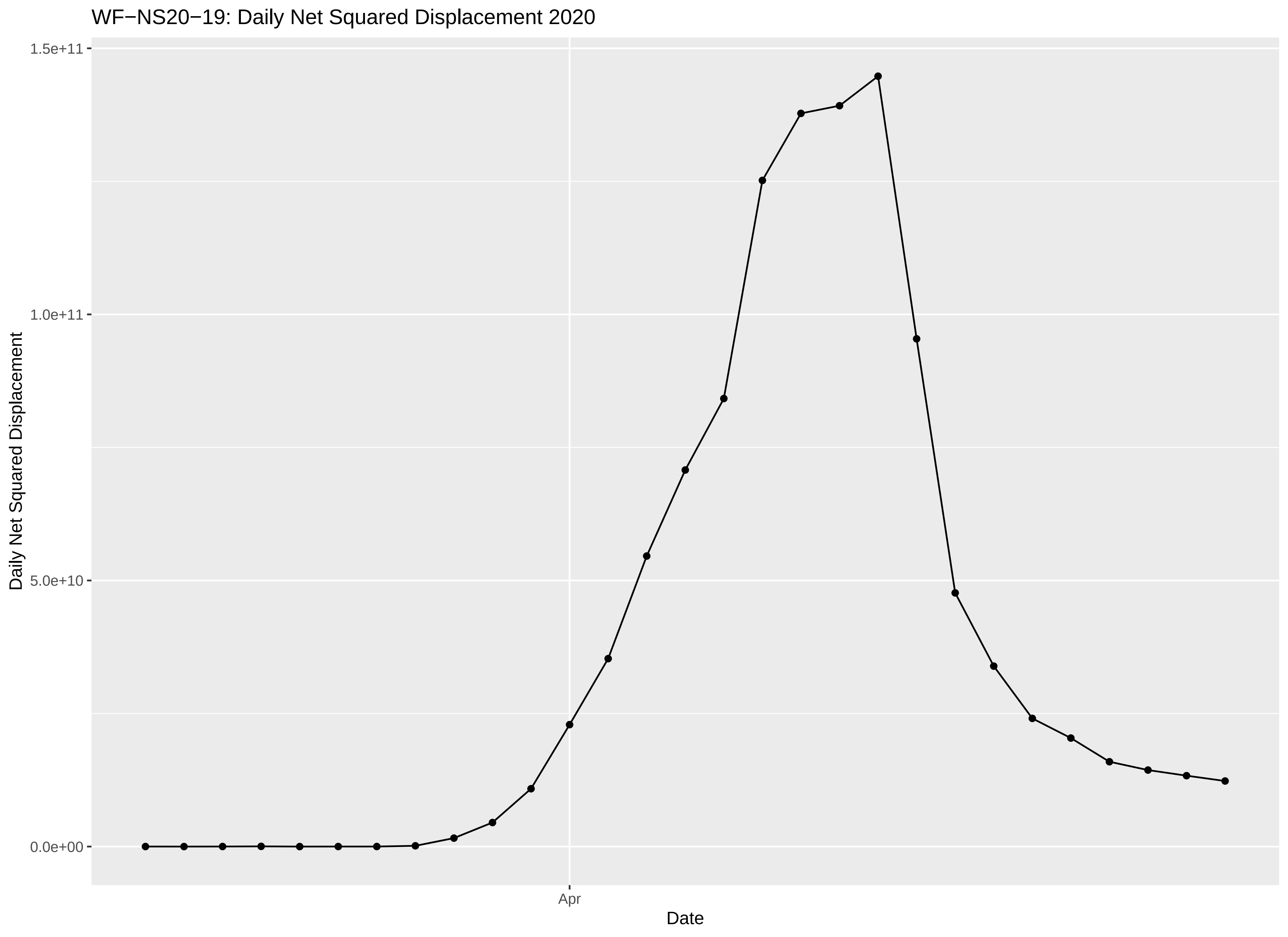

WF−NS20−27: Daily Movement Rate 2020
Daily Movement (Km)
100
75
50
25
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date


WF−NS20−30: Daily Movement Rate 2020
Daily Movement (Km)
0
10
20
30
40
50
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

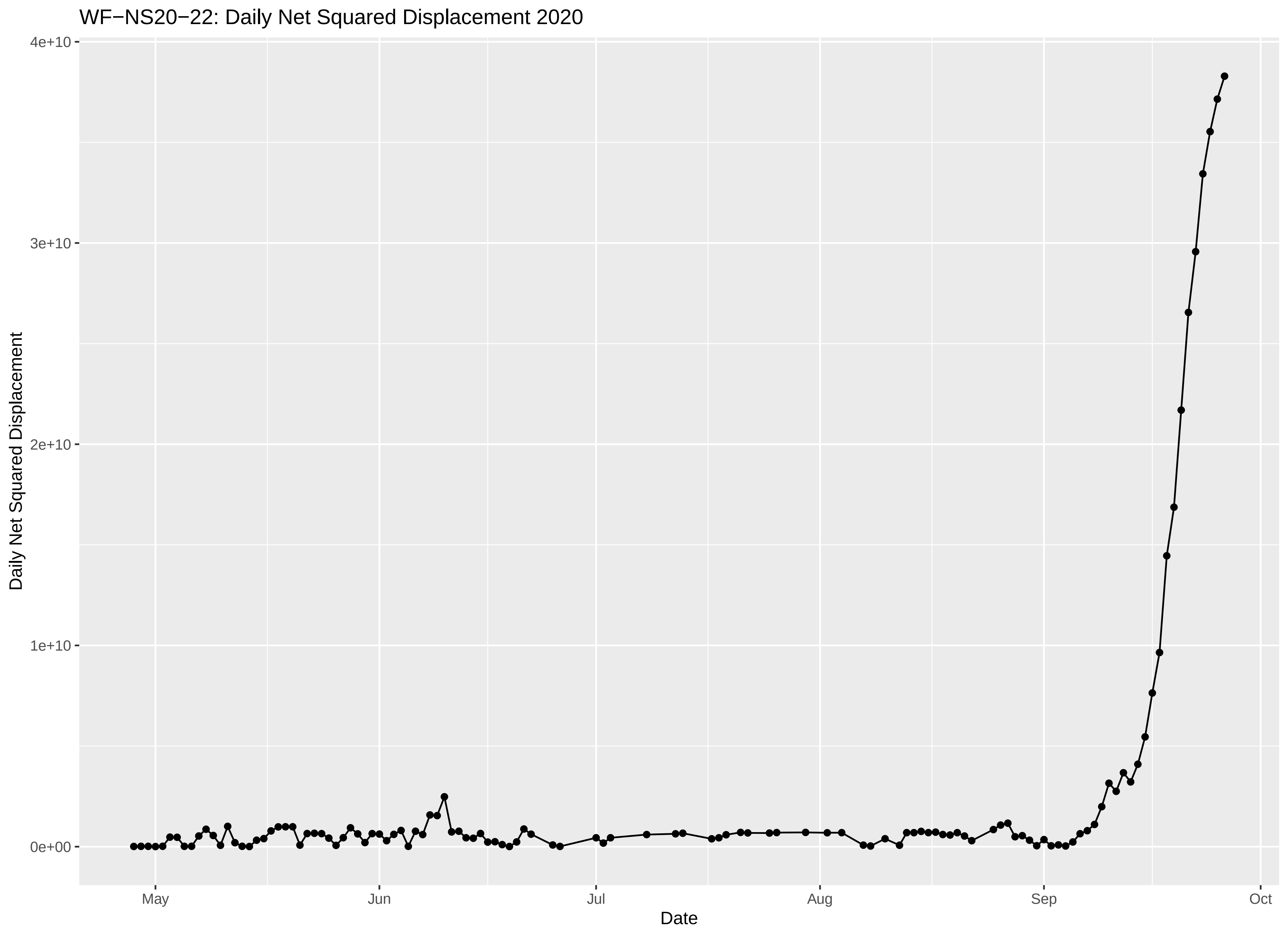

WF−NS20−01: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
1.0e+11
7.5e+10
5.0e+10
2.5e+10
0.0e+00
May
Jun
Jul
Aug
Sep
Oct
Nov
Date



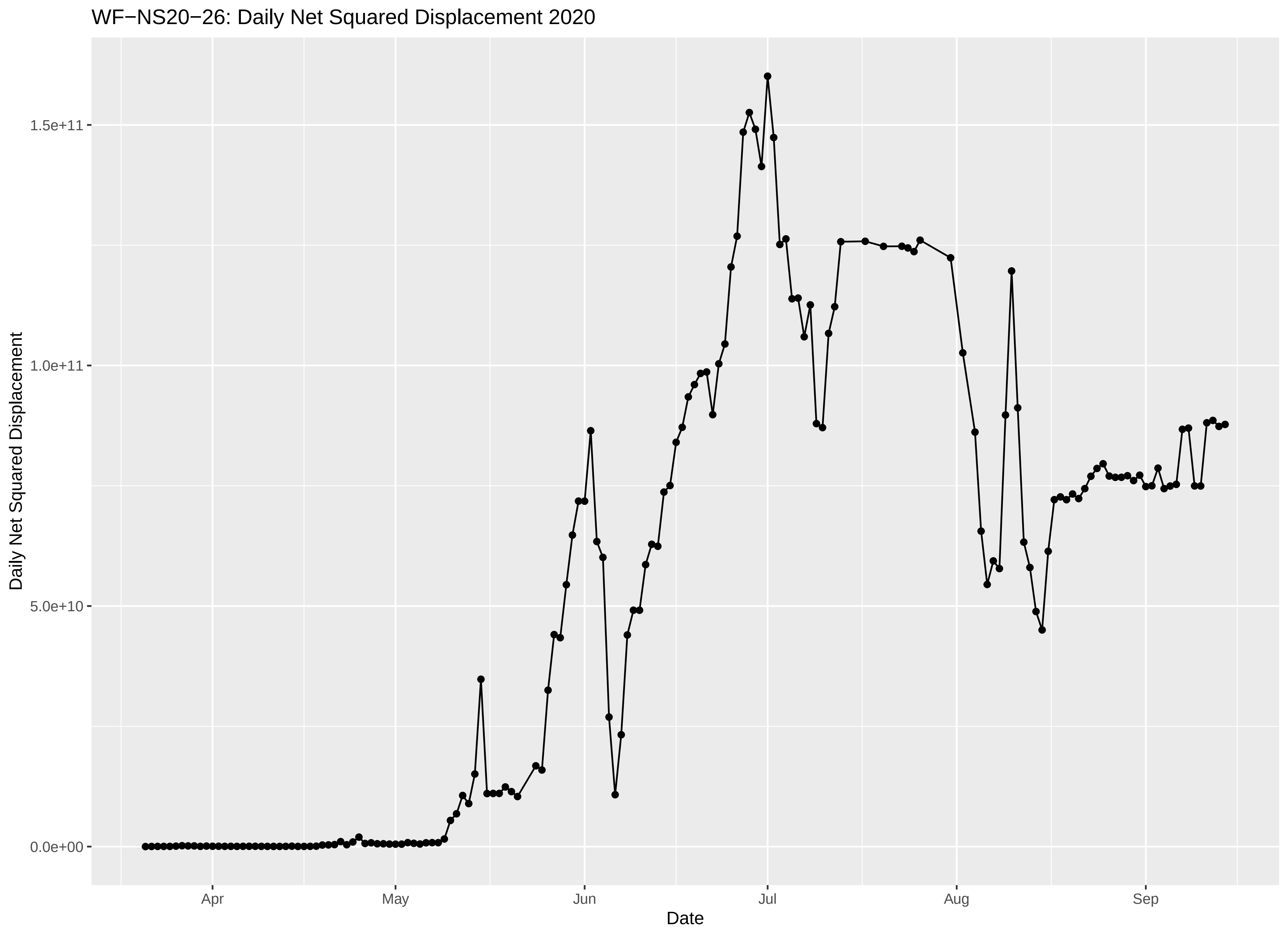
WF−NS20−18: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
7.5e+10
5.0e+10
2.5e+10
0.0e+00
Apr
May
Jun
Jul
Aug
Date

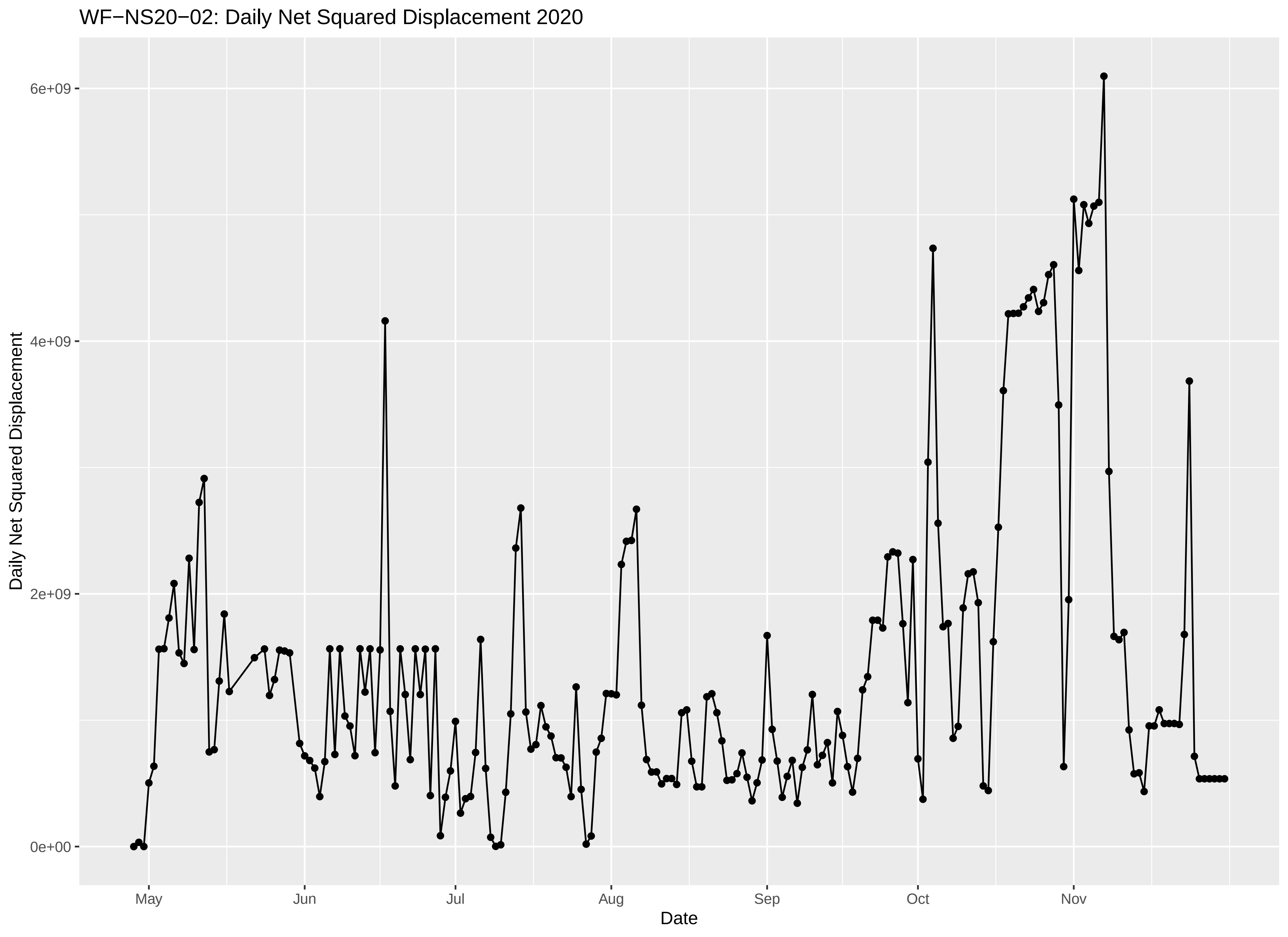


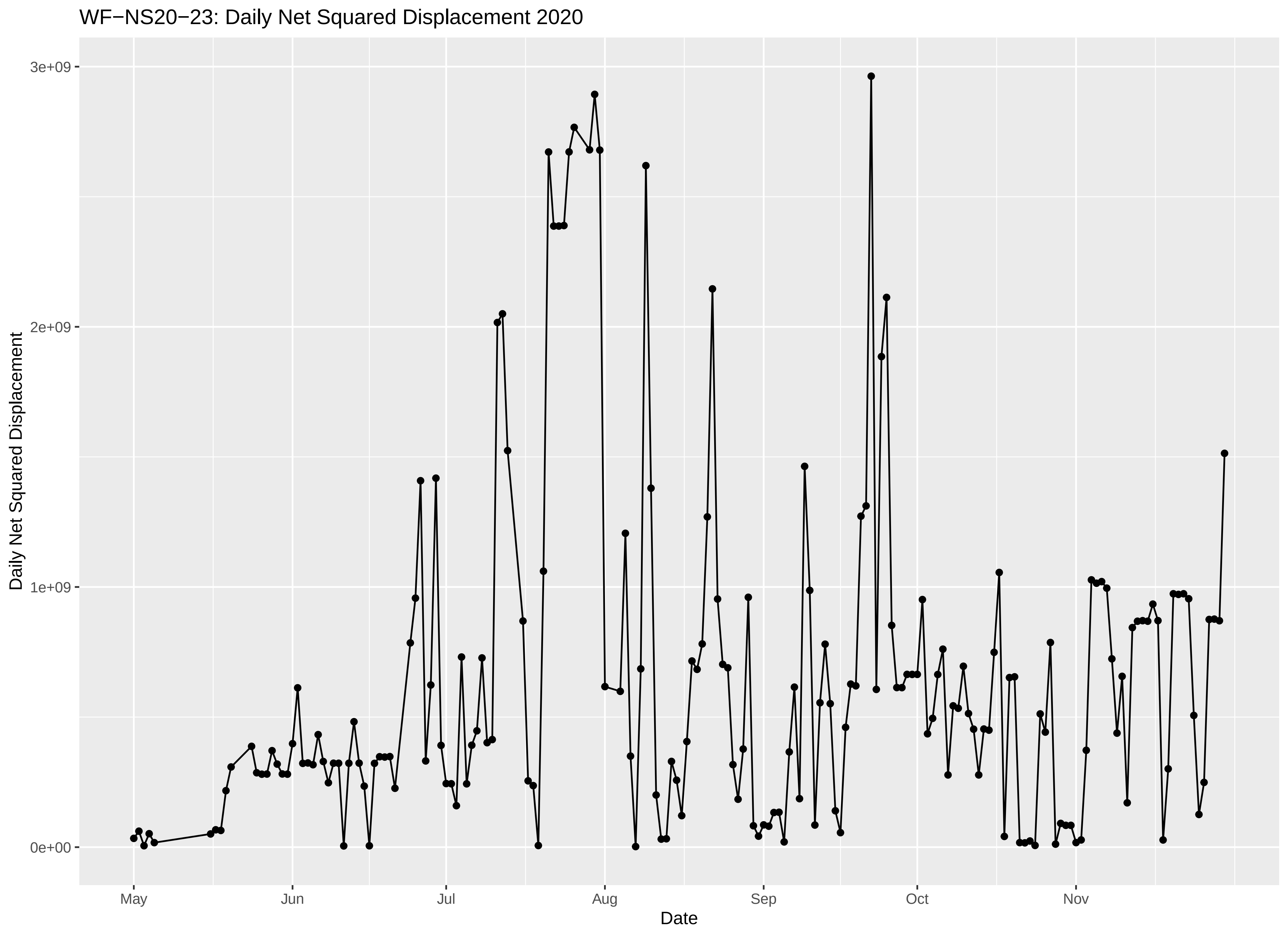
WF−NS20−19: Daily Net Squared Displacement 2020
1.5e+11
1.0e+11
5.0e+10
0.0e+00
Daily Net Squared Displacement
Apr
Date

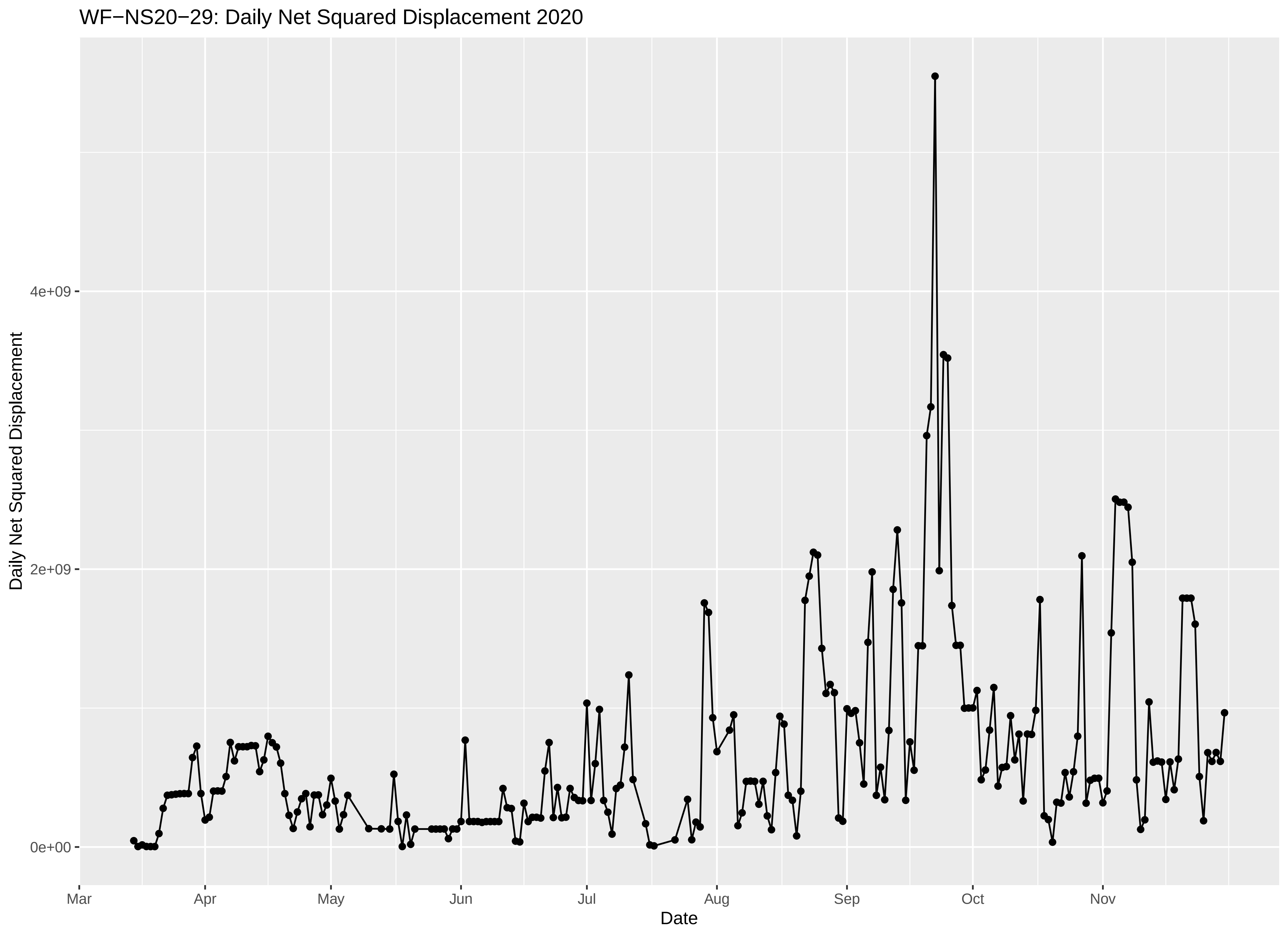


WF−NS20−22: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
4e+10
3e+10
2e+10
1e+10
0e+00
May
Jun
Jul
Aug
Sep
Oct
Date

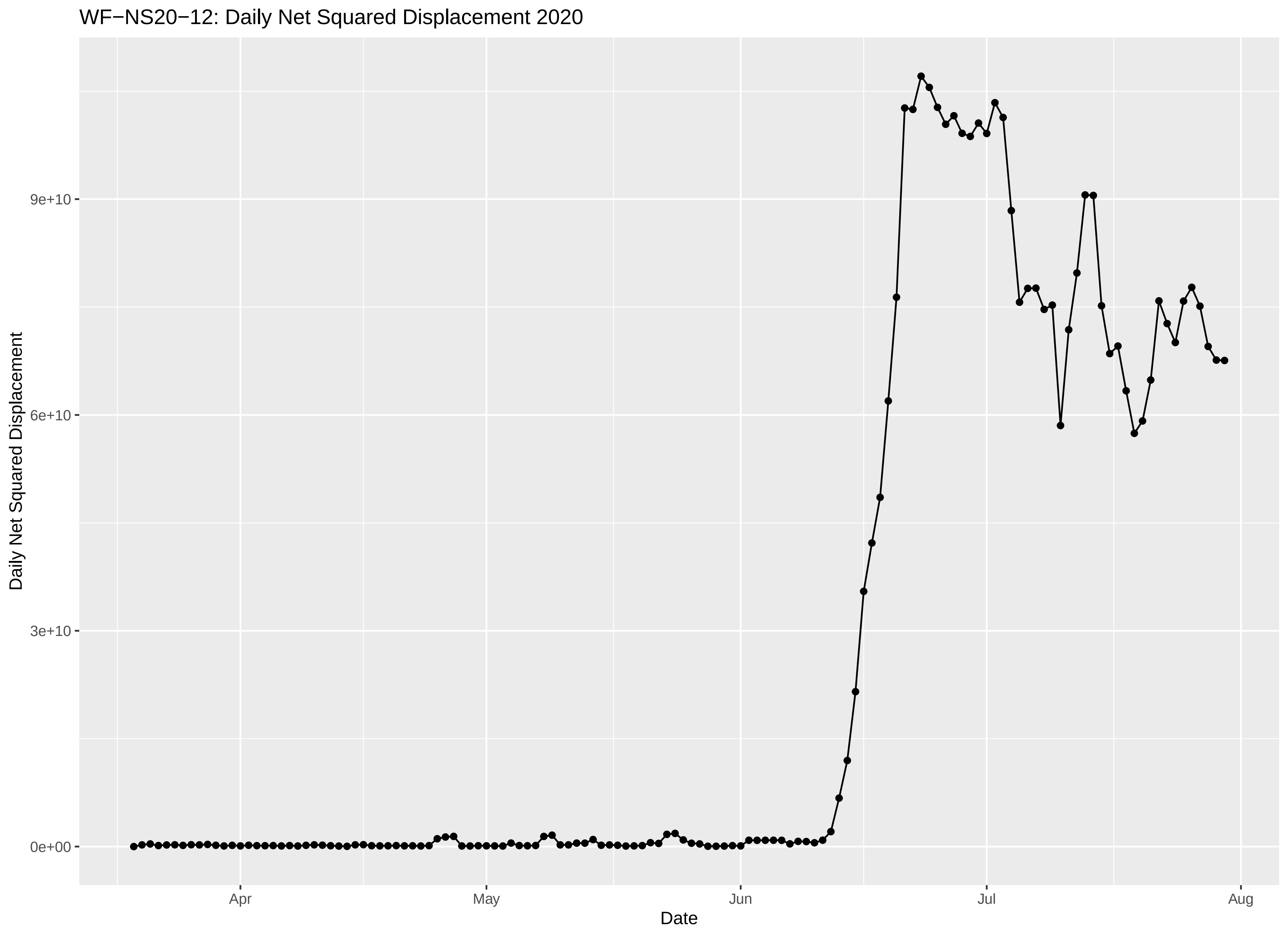

WF−NS20−26: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
1.5e+11
1.0e+11
5.0e+10
0.0e+00
Apr
May
Jun
Jul
Aug
Sep
Date

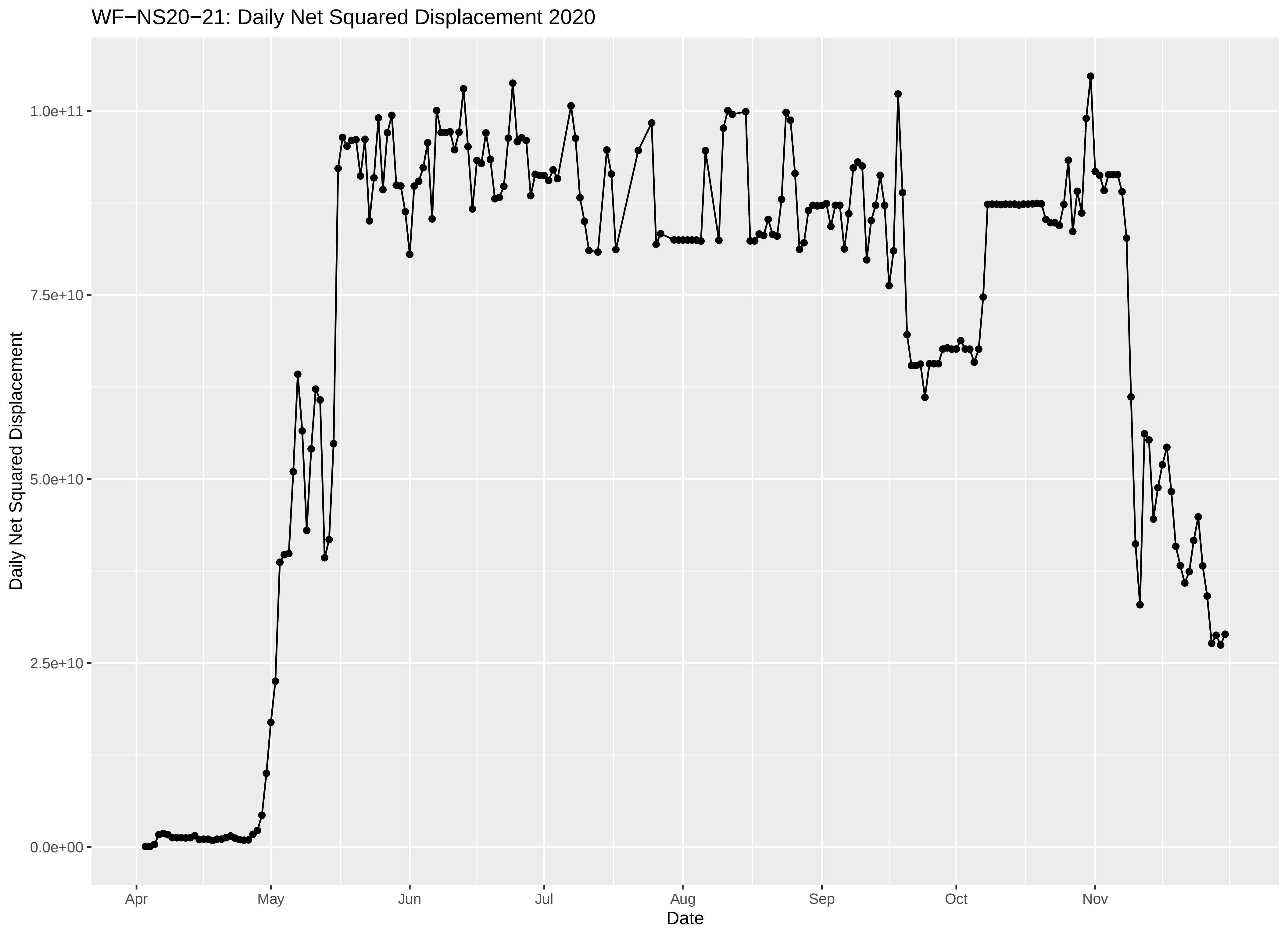

WF−NS20−02: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
6e+09
4e+09
2e+09
0e+00
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

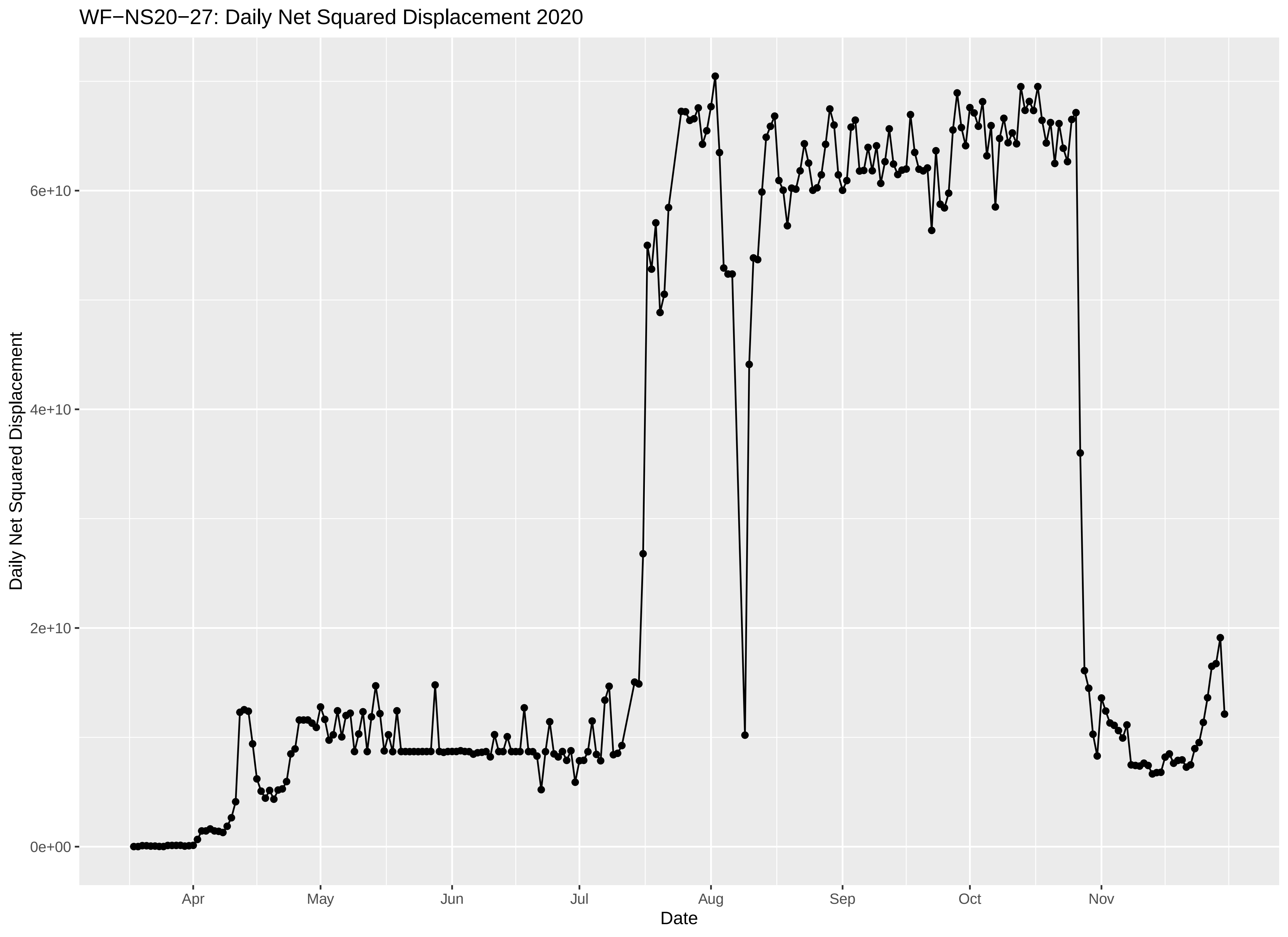

WF−NS20−23: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
3e+09
2e+09
1e+09
0e+00
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

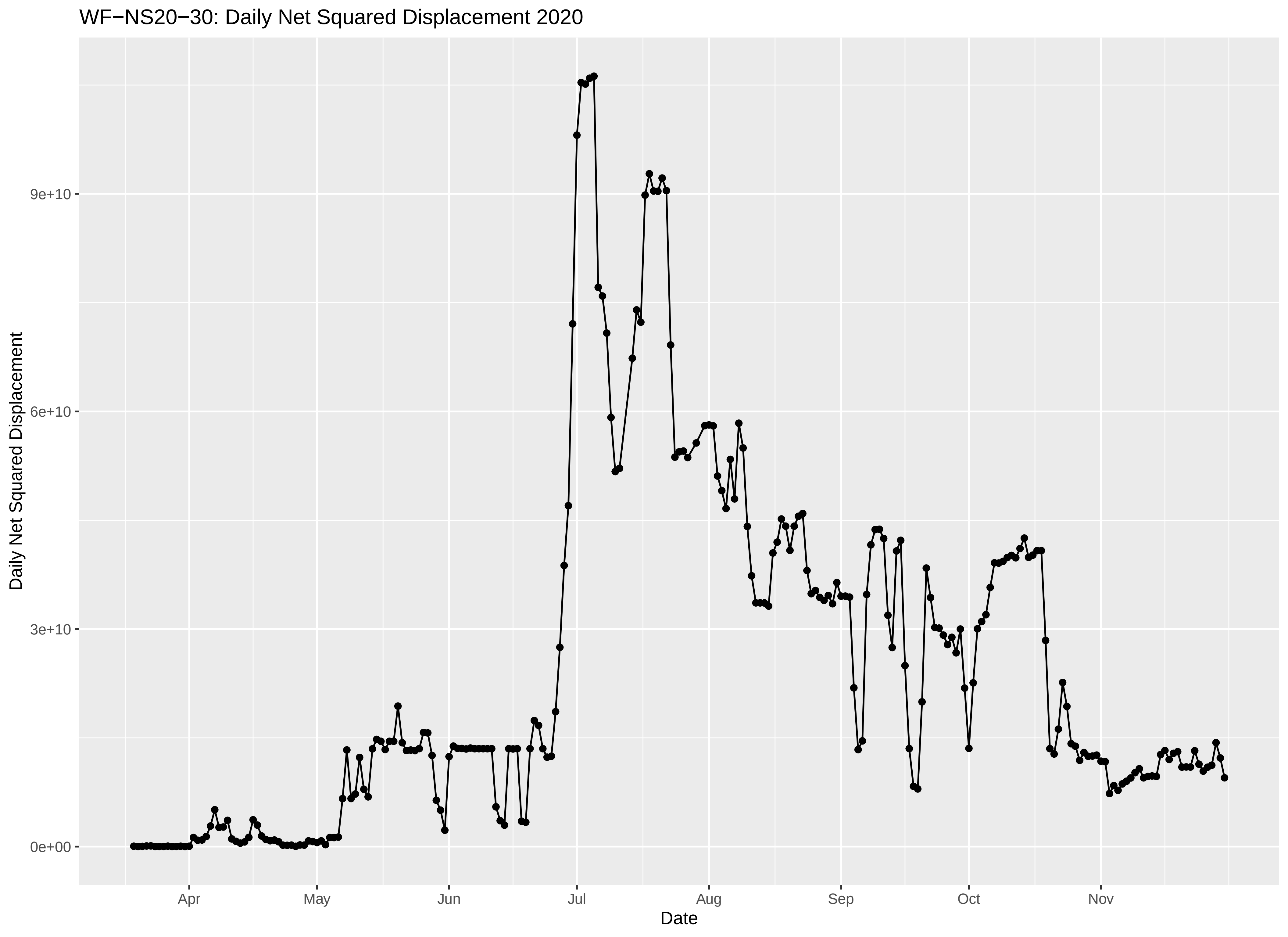


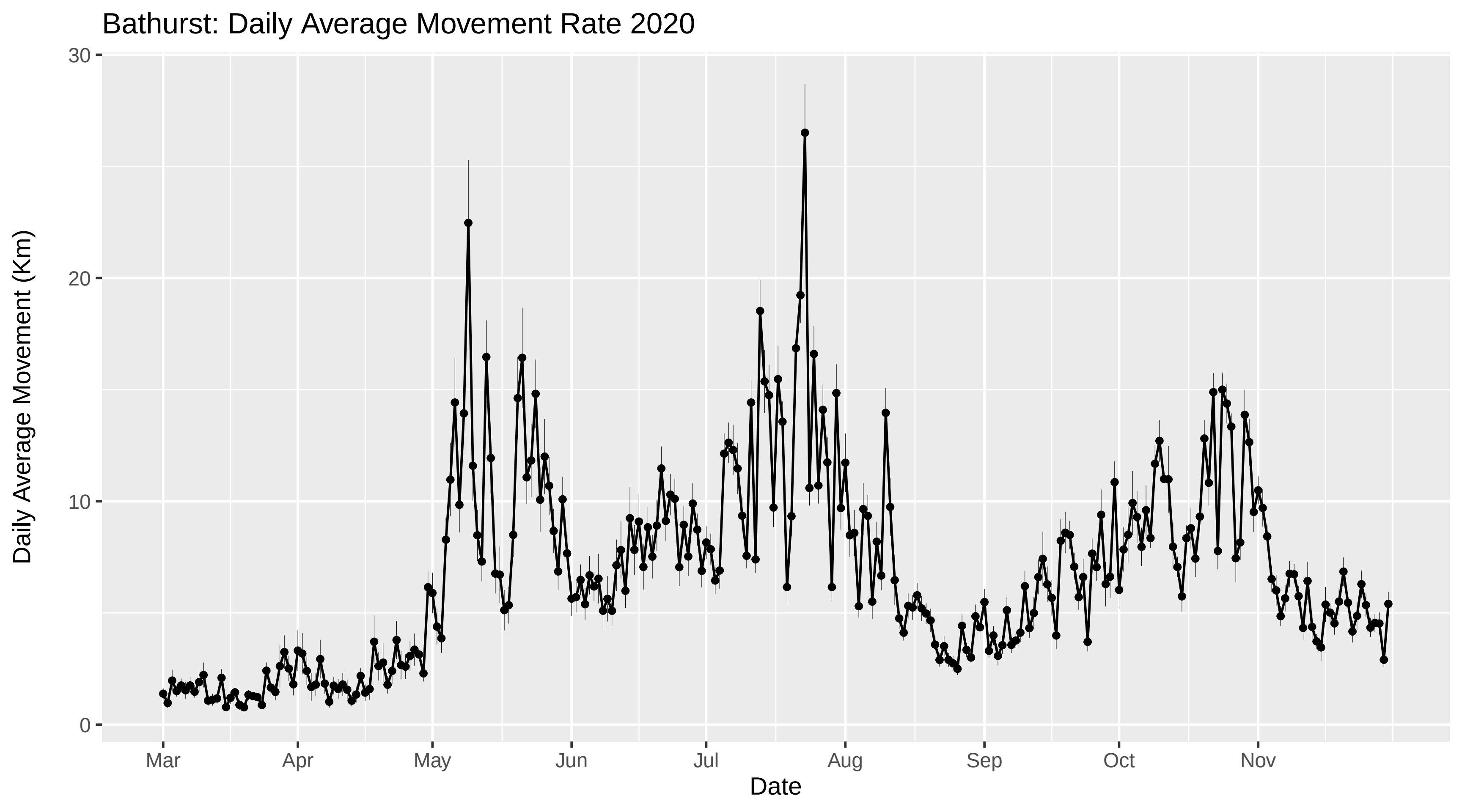
WF−NS20−29: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
4e+09
2e+09
0e+00
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

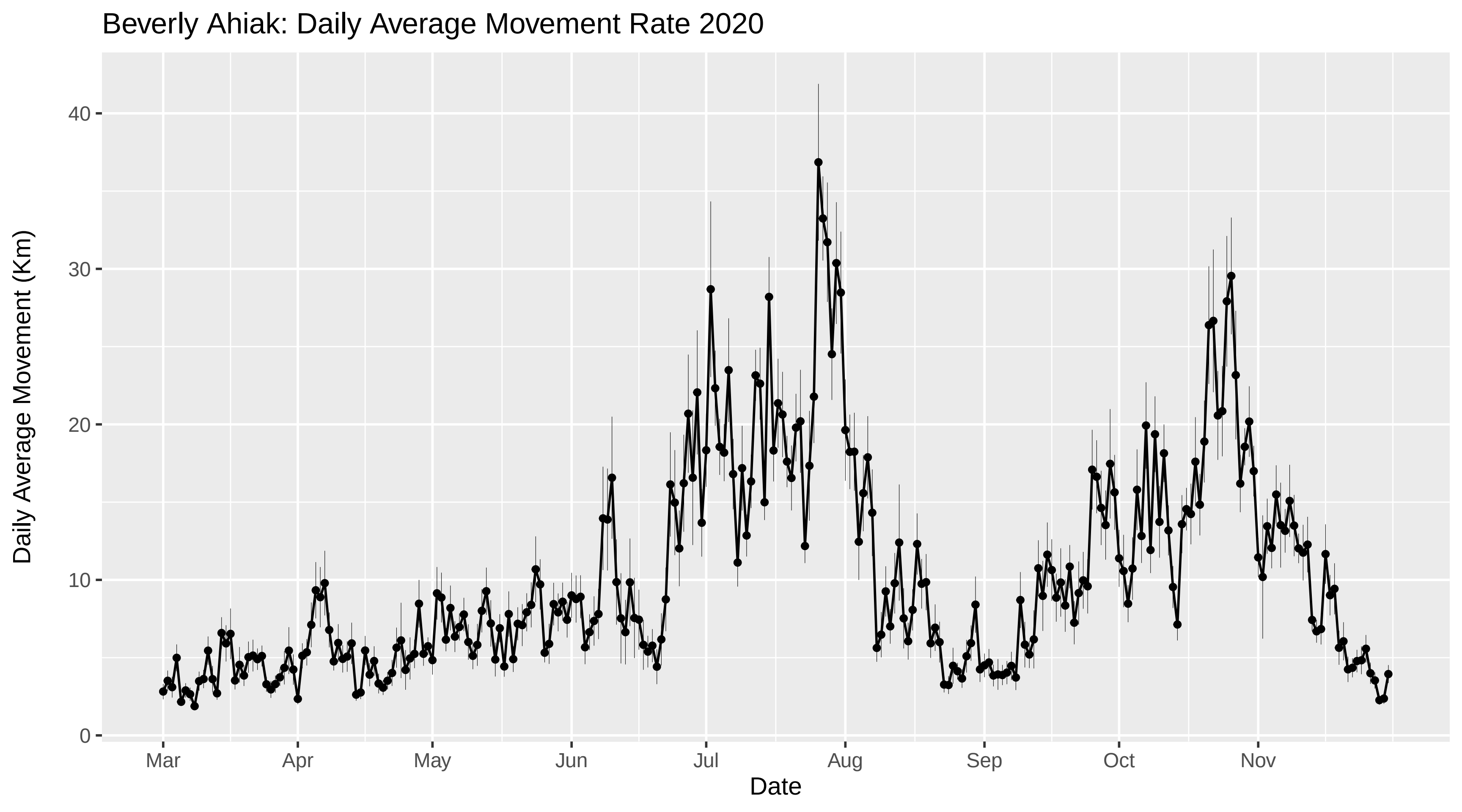

WF−NS20−12: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
9e+10
6e+10
3e+10
0e+00
Apr
May
Jun
Jul
Aug
Date

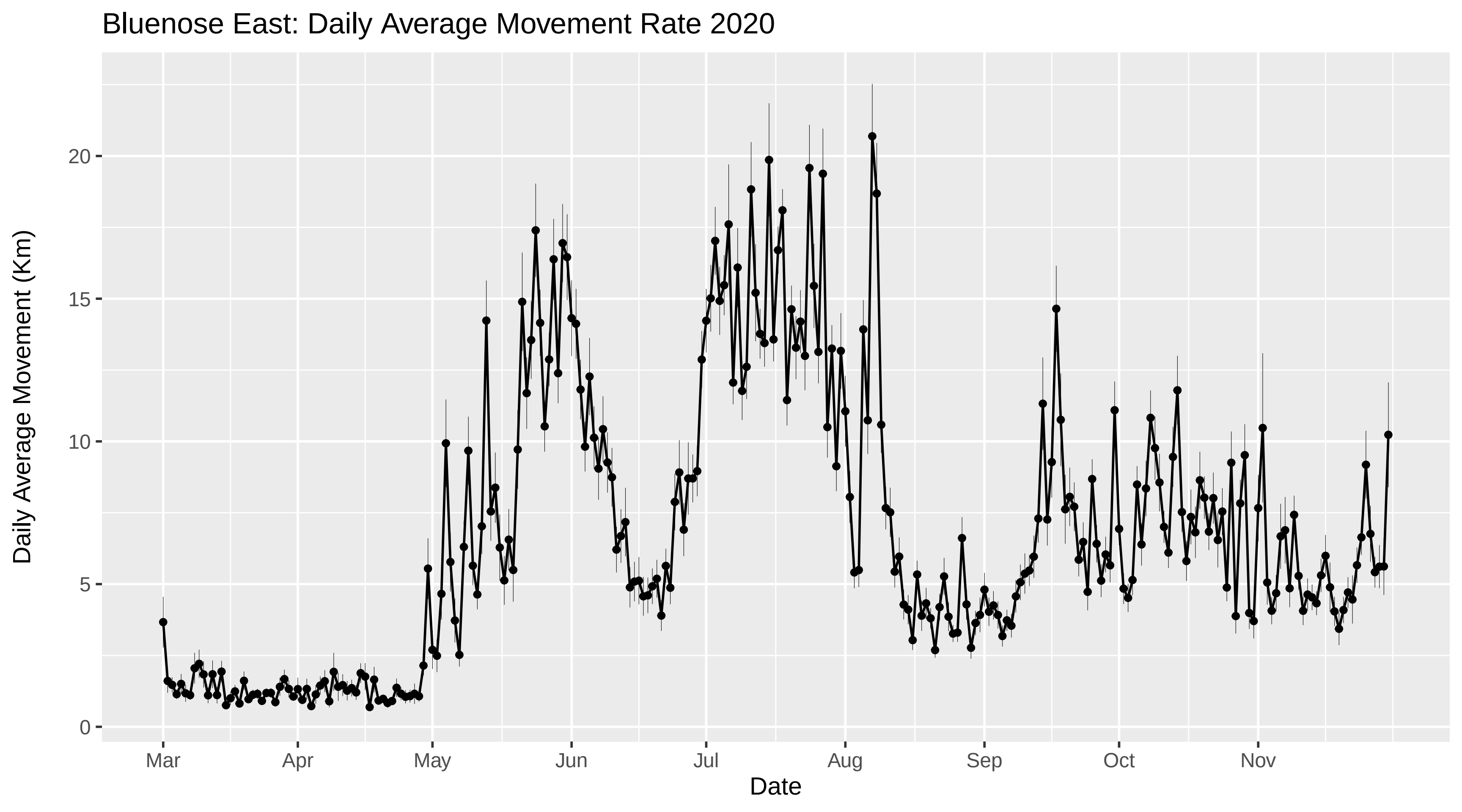

WF−NS20−21: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
1.0e+11
7.5e+10
5.0e+10
2.5e+10
0.0e+00
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date


WF−NS20−27: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
6e+10
4e+10
2e+10
0e+00
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date


WF−NS20−30: Daily Net Squared Displacement 2020
Daily Net Squared Displacement
9e+10
6e+10
3e+10
0e+00
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date


Bathurst: Daily Average Movement Rate 2020
Daily Average Movement (Km)
0
10
20
30
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

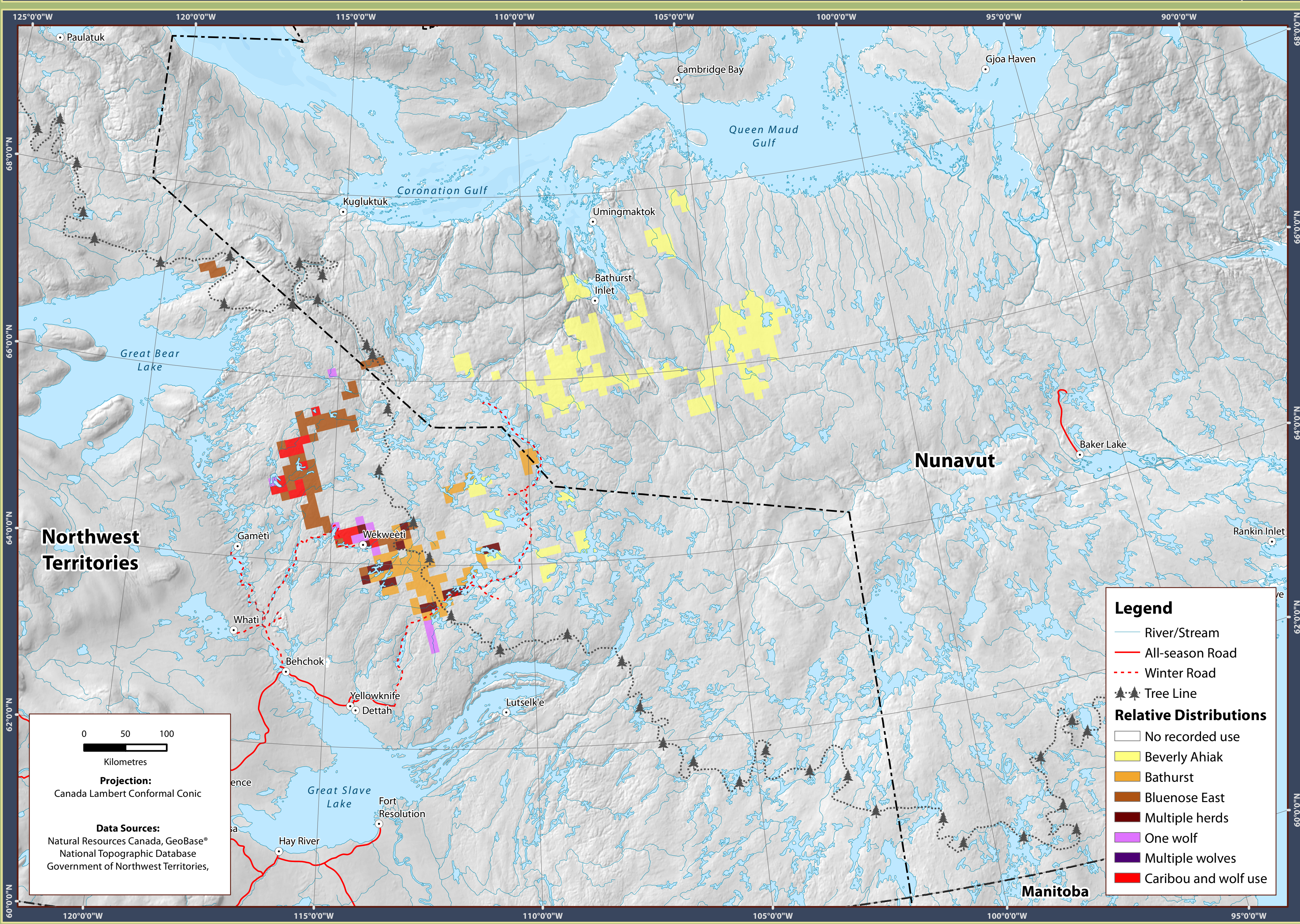

Beverly Ahiak: Daily Average Movement Rate 2020
Daily Average Movement (Km)
0
10
20
30
40
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date



Bluenose East: Daily Average Movement Rate 2020
Daily Average Movement (Km)
0
5
10
15
20
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Date

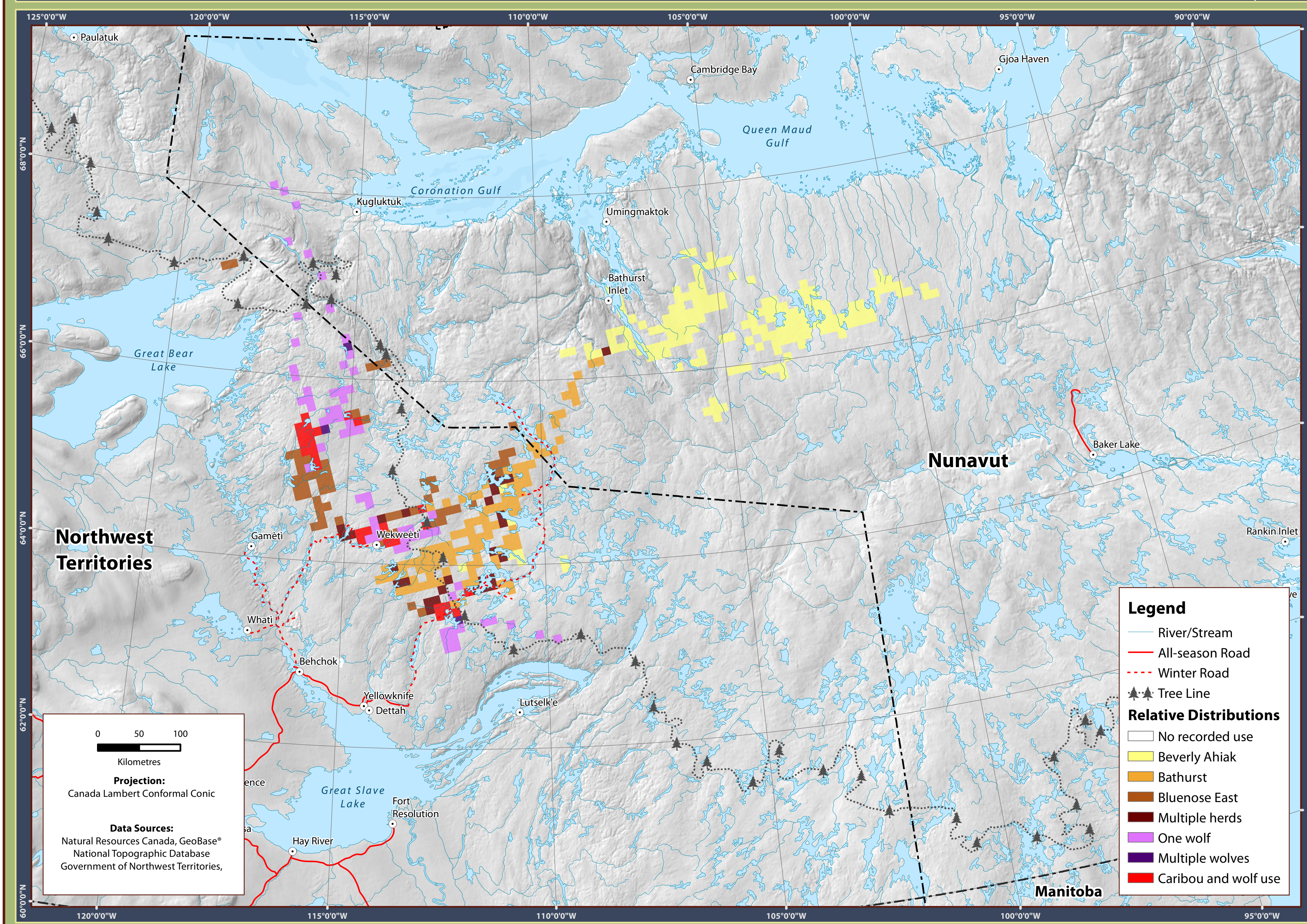
Relative Distriutions Barren-ground Caribou and Wolves - March 2020

DRAFT



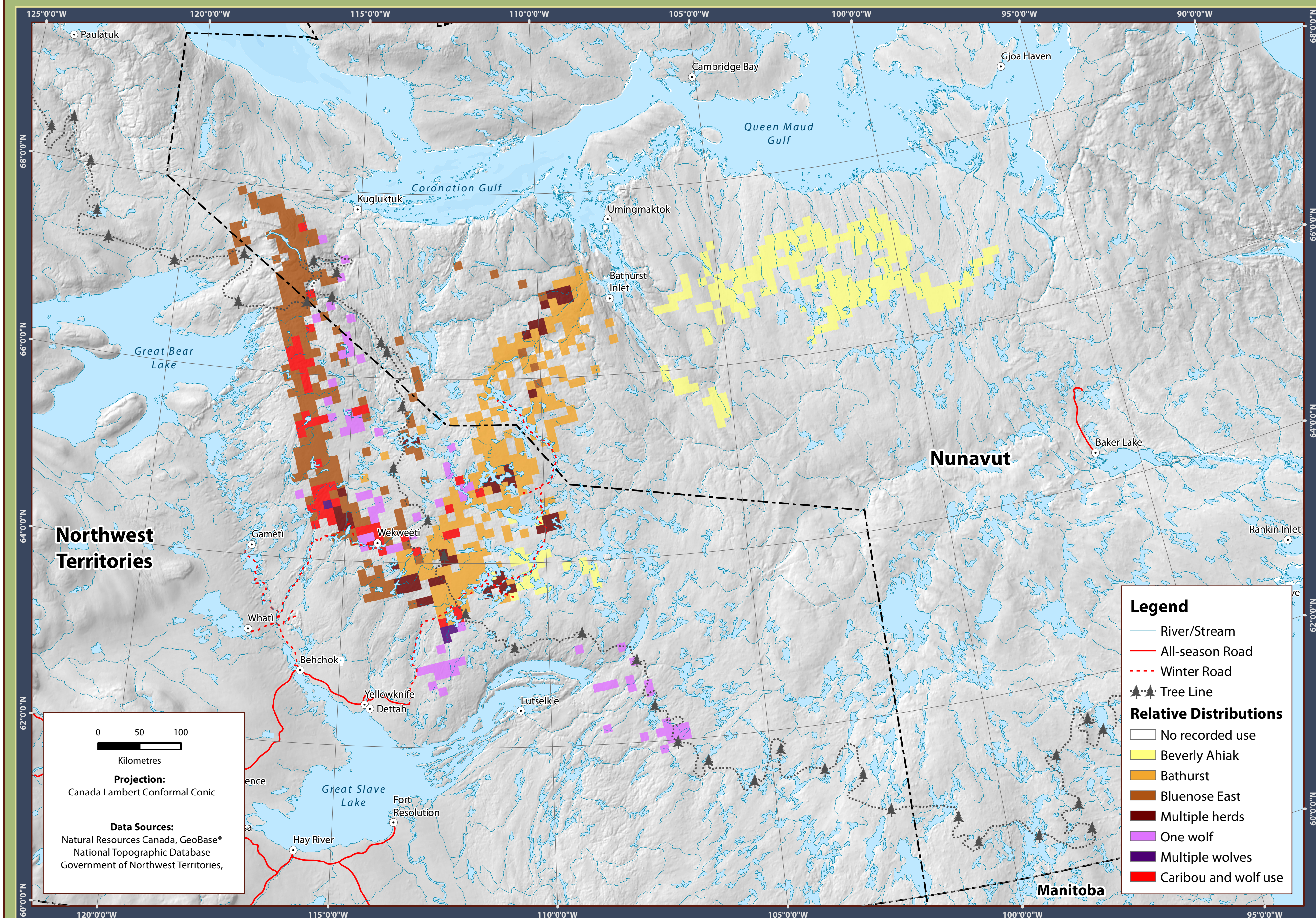
Relative Distriutions Barren-ground Caribou and Wolves - April 2020

DRAFT



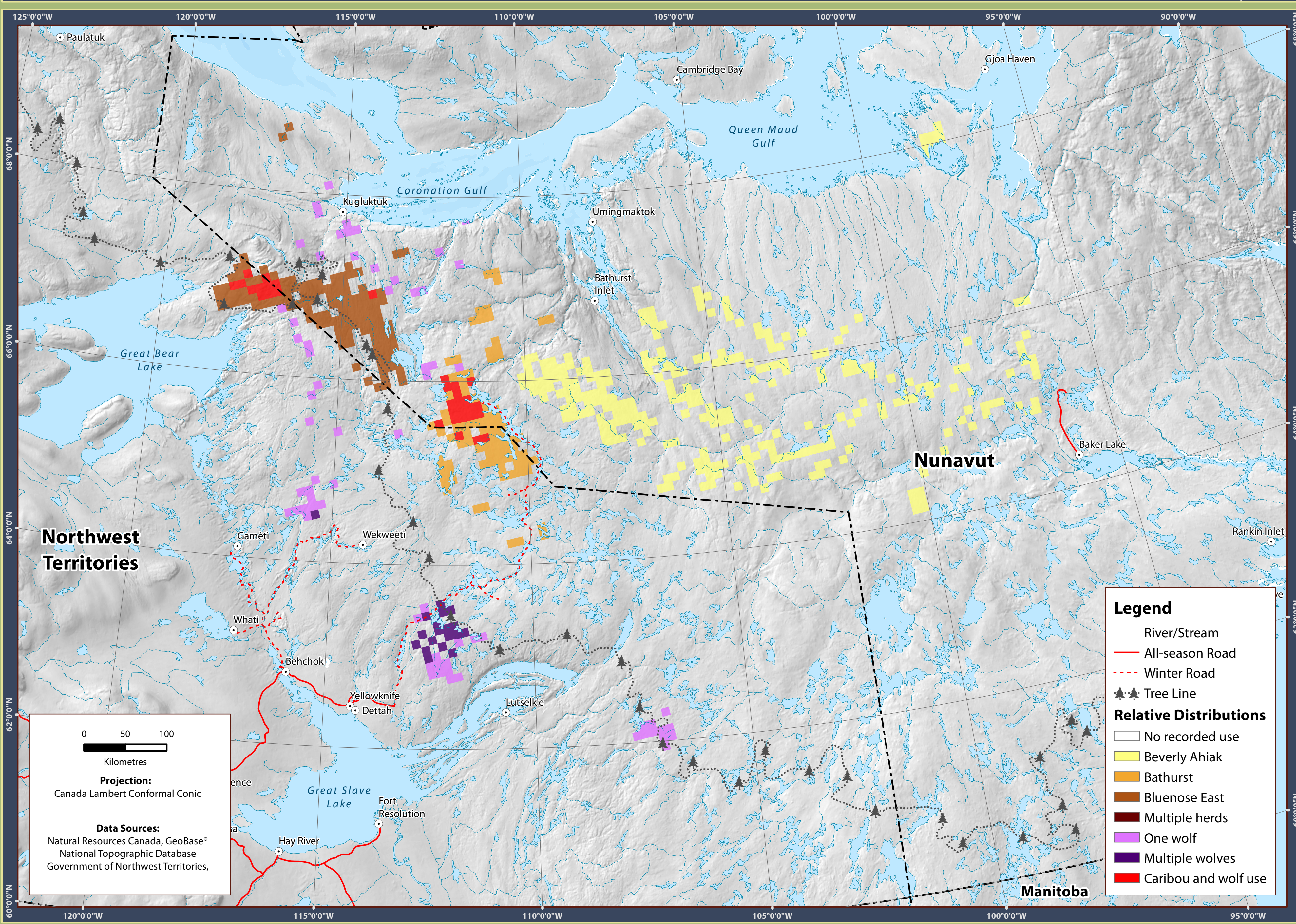
Relative Distriutions Barren-ground Caribou and Wolves - May 2020

DRAFT



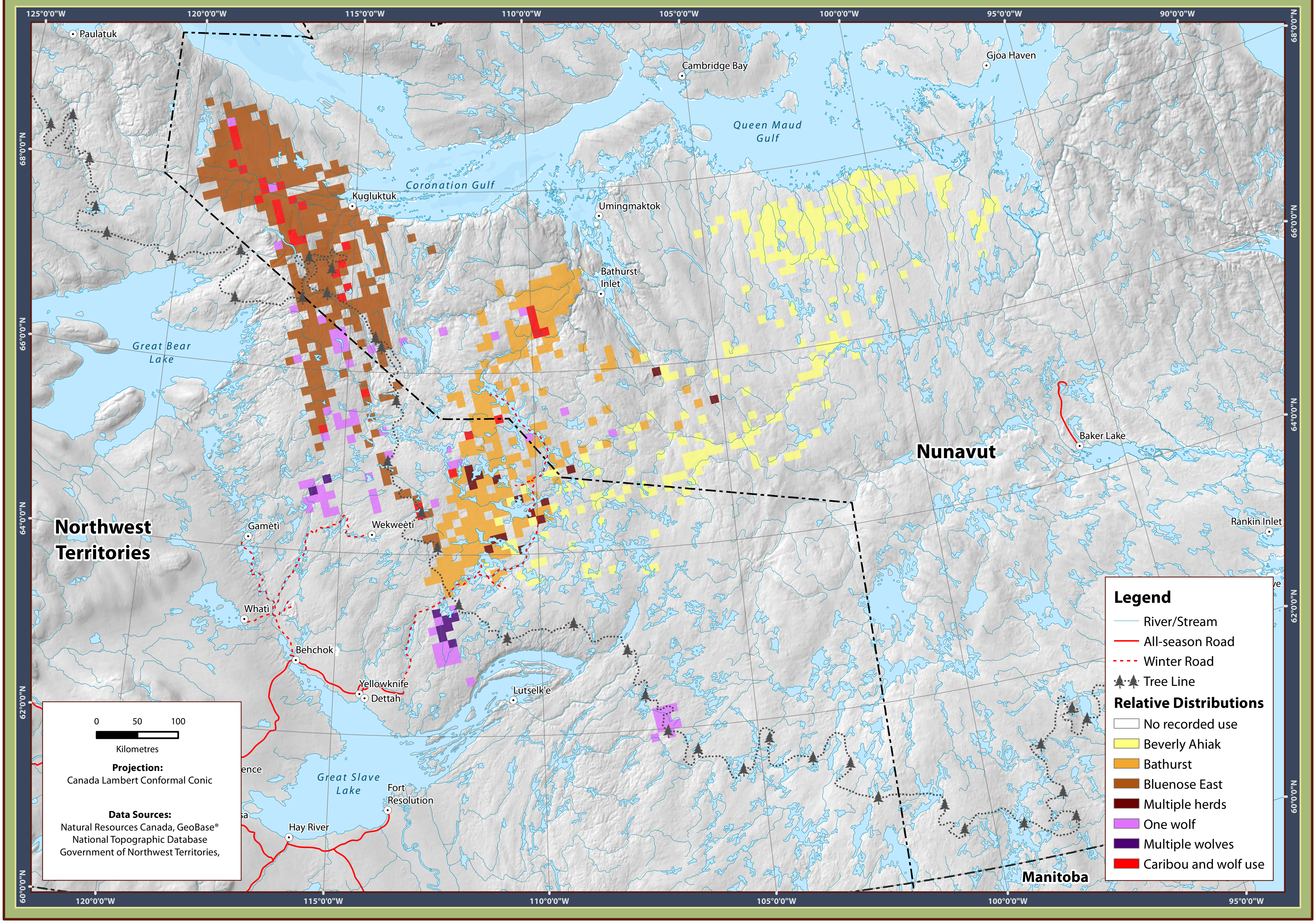
Relative Distriutions Barren-ground Caribou and Wolves - August 2020

DRAFT



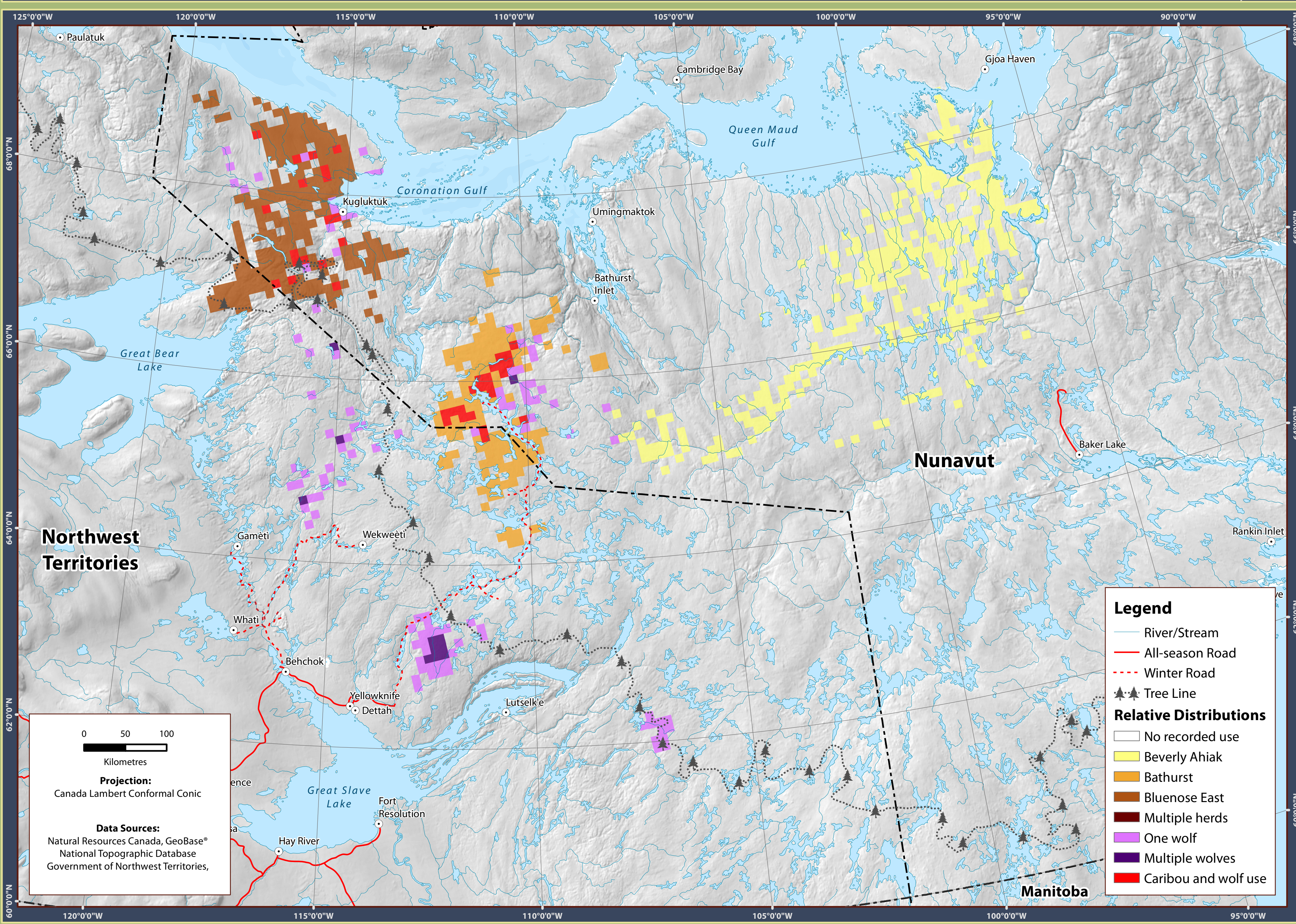
Relative Distriutions Barren-ground Caribou and Wolves - June 2020

DRAFT



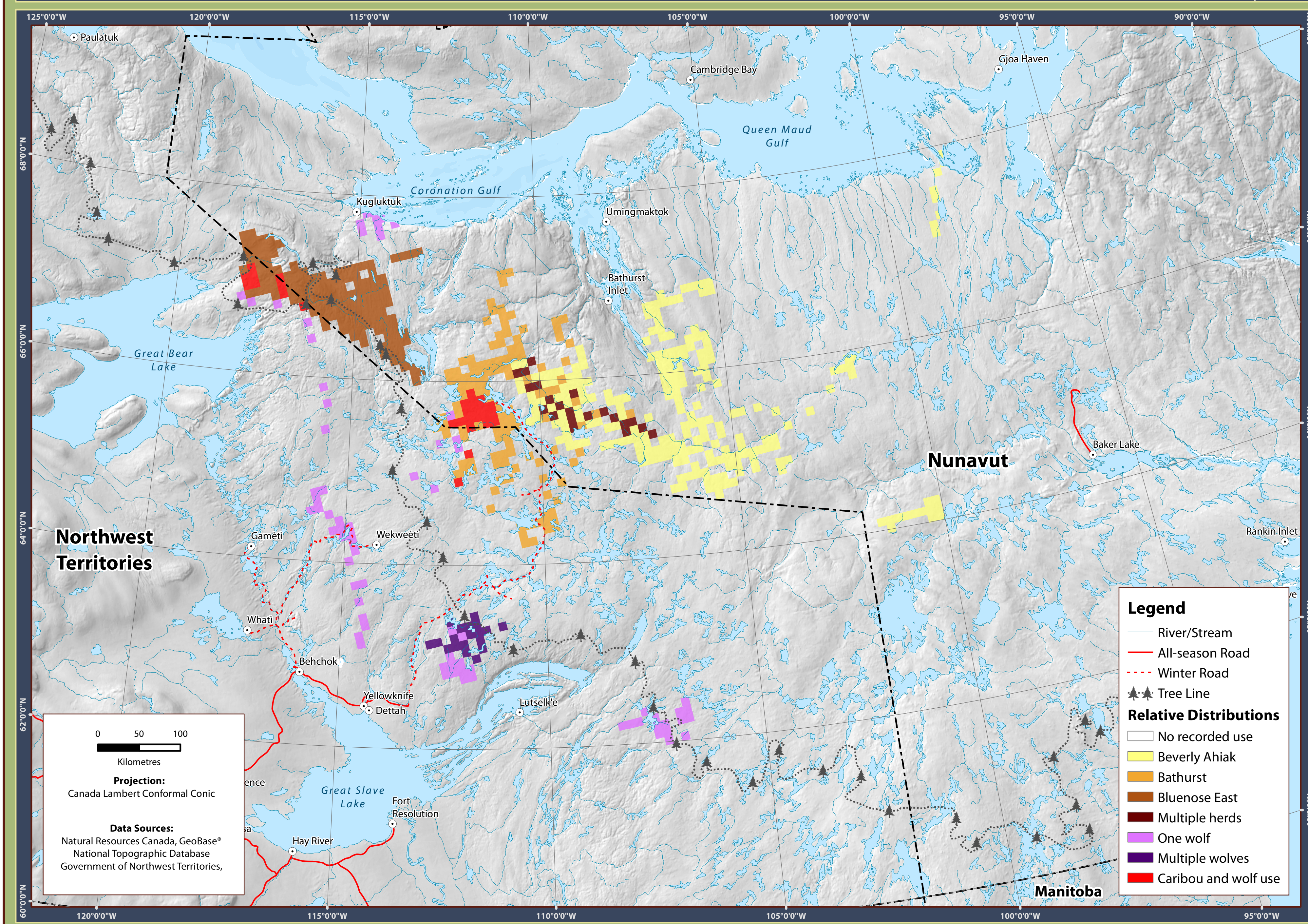
Relative Distriutions Barren-ground Caribou and Wolves - July 2020

DRAFT



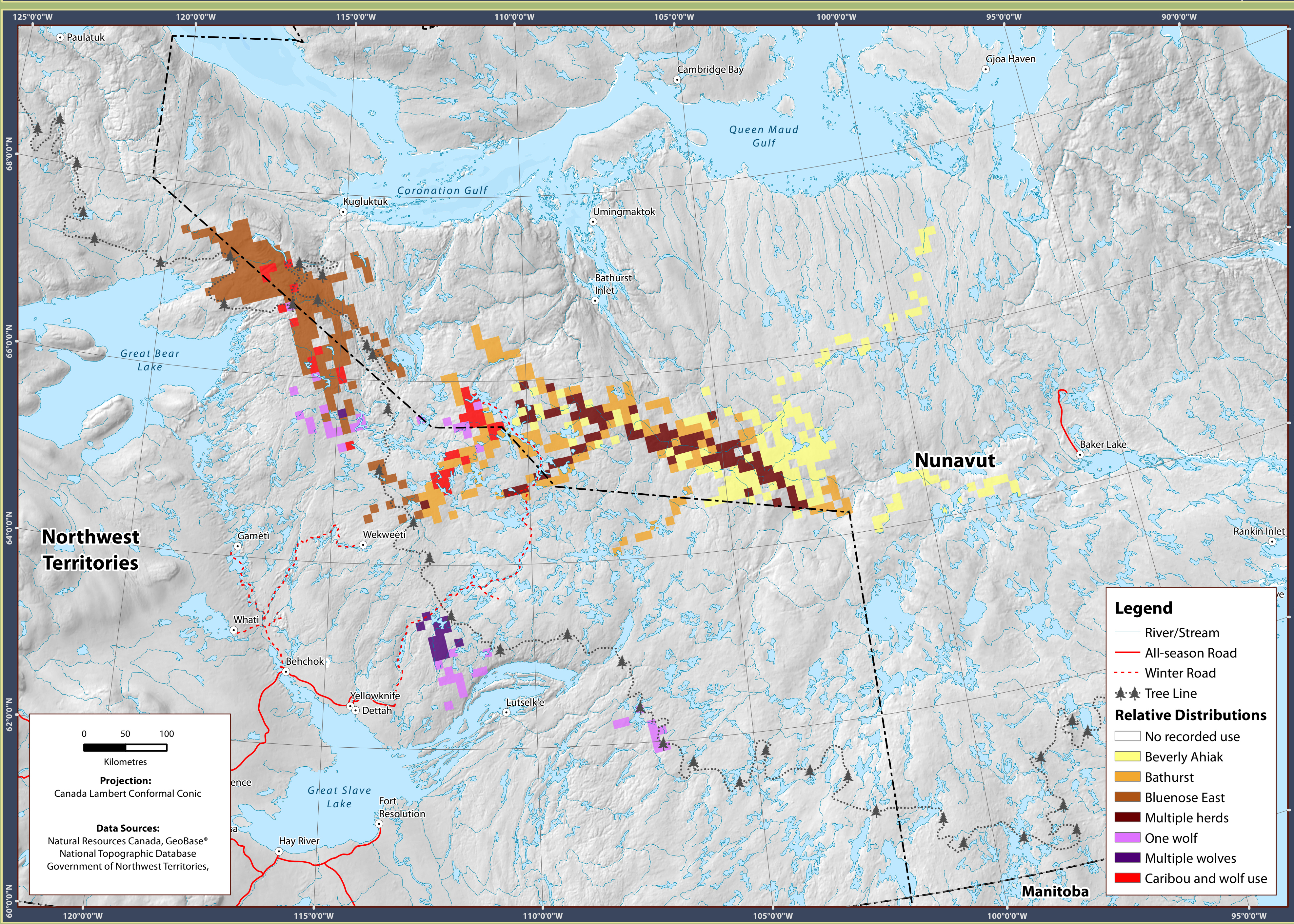
Relative Distriutions Barren-ground Caribou and Wolves - September 2020

DRAFT



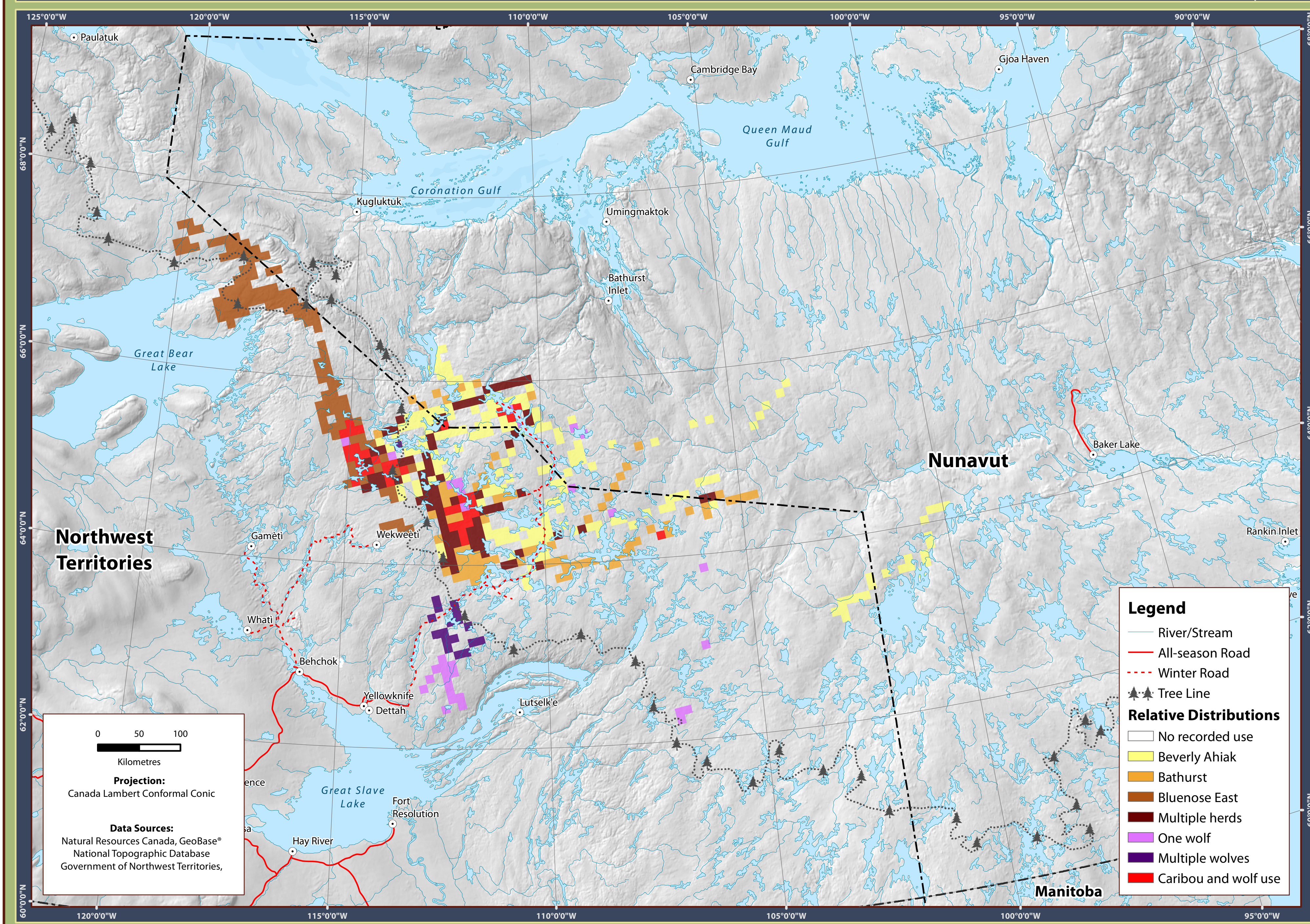
Relative Distriutions Barren-ground Caribou and Wolves - October 2020

DRAFT



Relative Distriutions Barren-ground Caribou and Wolves - November 2020

DRAFT



APPENDIX E - WOLF INJURY DOCUMENTATION FORM

Location	H.	B.	Fractures	Puncture wounds (ex; en)	Other
Head					
Neck					
L Shoulder					
R Shoulder					
L Forelimb					
R Forelimb					
L Flank (external)					
R Flank (external)					
Chest/thorax (internal)					
Abdomen (internal)					
L Hindlimb					
R Hindlimb					
Tail					

Wolf Injury Documentation

NSR number ______________

Volume of blood in chest:

Volume of blood in abdomen:

Total number of bullet holes:

Likely killing shot/injury:

Fetuses/Feti	Crown-rump length	Weight