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20 June 2022

**Re: Diavik Exploratory Collared Caribou Movement Analysis Technical Memorandum**

Diavik Diamond Mine (2012) Inc. (DDMI) is pleased to submit the attached Exploratory Collared Caribou Movement Analysis Technical Memorandum as an addendum to DDMI's 2021 Wildlife Management and Monitoring Report (WMMR) that was submitted on April 1, 2022. This technical memorandum is in response to the Government of the Northwest Territories Environment and Natural Resources (GNWT-ENR) comment ENR-WMMP-17 on DDMI's Tier 3 Wildlife Management and Monitoring Plan (WMMP).

If you have any questions regarding this submission, please contact the undersigned at kofi-boa.antwi@riotinto.com or Kyla Gray at kyla.gray@riotinto.com or (867)-445-4922 at your convenience.

Yours sincerely,

Kofi Boa-Antwi
Superintendent, Environment

Cc: John McCullum, EMAB
Dylan Price, EMAB
EANorthNWT@ec.gc.ca, ECCC

Attachment: Exploratory Collared Caribou Movement Analysis Technical Memorandum

# DIAVIK DIAMOND MINES (2012) INC.

## TECHNICAL MEMORANDUM

**DATE** 14 June 2022

**Reference No.** 21452119-2380-TM-Rev0-13000

**DIAVIK WORK PLAN No. 716 Rev. 0**

**DIAVIK PO No. 3104889168**

**TO** Kofi Boa-Antwi, Superintendent Environment
Diavik Diamond Mines (2012) Inc.

**FROM** Grace Enns, Dan Coulton, and John Virgl

**EMAIL** Grace_Enns@golder.com, Daniel_Coulton@golder.com, John_Virgl@golder.com

**EXPLORATORY COLLARED CARIBOU MOVEMENT ANALYSIS**

## 1.0 INTRODUCTION

Since 2015, Diavik Diamond Mines (2012) Inc. (DDMI) and other mines have contributed funding for the purchase and deployment of geo-fence collars for deployment on Bathurst caribou by the Government of the Northwest Territories, Department of Environment and Natural Resources (GNWT-ENR). Geo-fence collars are programmed to generate a higher rate of telemetry locations once they encounter and remain within an arbitrary 30 km geo-referenced boundary around the Diavik and Ekati mines and other developments in the NWT. The purpose of deploying geo-fence collars was to provide finer-resolution data about how caribou interact with developments. Poole et al. (2021) provided the first exploratory analysis of geo-fence collar data and caribou interactions with the Ekati mine. DDMI committed to completing an exploratory analysis of geo-fence collar data in the Diavik Mine draft Tier 3 Wildlife Management and Monitoring Plan (WMMP) as part of caribou zone of influence monitoring (DDMI 2021). This memorandum fulfils the commitment.

Methods used in this exploratory analysis incorporate those documented in the previous analysis completed by Poole et al. (2021), but also include additional ecologically-based movement metrics and comparisons. A main objective of the Poole et al. (2021) report was to characterize movement behaviours of caribou from the Bathurst and Beverly/Ahiak herds within potential areas of influence of the Ekati mine, and to investigate possible changes in caribou movement in response to the Ekati mine. Poole et al. (2021) focussed their analysis on collared caribou from the Bathurst and Beverly/Ahiak herds from 2010 to 2019 occurring within 30 km of the Ekati mine. Movement metrics evaluated in their analysis included residency time, speed, and the proportion of hard turns (relative turning angles ≥ 60°) within consecutive 3 km buffer zones around the Ekati mine up to a 30 km radius. Their conclusions were based mostly on caribou that encountered the Ekati mine within a 3 km buffer zone and characterizing responses of caribou to the Sable and Misery roads.

The purpose of this exploratory analysis was to assess movement behaviours of caribou from the Bathurst and Beverly/Ahiak herds that approached the Diavik Mine (Mine) using caribou collar data from 2010 to 2021. A 3 km buffer zone was chosen as the focal area to evaluate movement metrics. In order to compare movement metrics of collared caribou paths within the 3 km buffer zone to population-level estimates, a reference group was defined for each herd as collared caribou paths located outside the 30 km buffer zone around the Diavik and Ekati mine complex. Movement metrics calculated from paths in the 3 km buffer zone were evaluated to determine if they overlapped estimates from the reference group. As a result, this analysis identified whether movement metrics were within the expected population movement metrics or if they differed closer to the Mine. It is important to note that inference made from collar data is assumed because it is not possible to observe the environmental conditions present and identify what the collared individual is actually doing along its movement path. For example, it is possible that decreased speed and high rates of turning may reflect a response to anthropogenic disturbance (Poole et al. 2021), foraging (Loureiro et al 2007; Hammerschlag et al. 2012; Hodges et al. 2014) or predators. To help understand the movement behaviours of collared caribou, additional caribou behaviour monitoring, Mine activities, and land cover data were considered.

The overall purpose of this technical memorandum was to evaluate movement metrics of collared caribou paths around the Mine to better understand movement behaviours of caribou near the Mine. The objectives for this exploratory analysis were to:

- Summarise caribou collar data within the 3 km buffer zone around the Mine.
- Calculate residency metrics based on methods used in Poole et al. (2021), as well as a residency metric that accounts for seasonal duration.
- Calculate and compare caribou speed (km/hour) within a 3 km buffer zone around the Mine to that of the reference group outside the 30 km buffer zone around the Diavik and Ekati mine complex.
- Compare the proportion of hard turns (relative turning angles of ≥ 60°) within a 3 km buffer zone around the Mine to that of the reference group outside a 30 km buffer zone around the Diavik and Ekati mine complex.
- Investigate correlations between collared caribou movements on East Island and West Island with caribou behavioural surveys, landcover, and available Mine activity data.
- Discuss implications of the findings from this analysis on monitoring and mitigation at the Mine.

# 2.0 METHODS

## 2.1 Caribou telemetry data

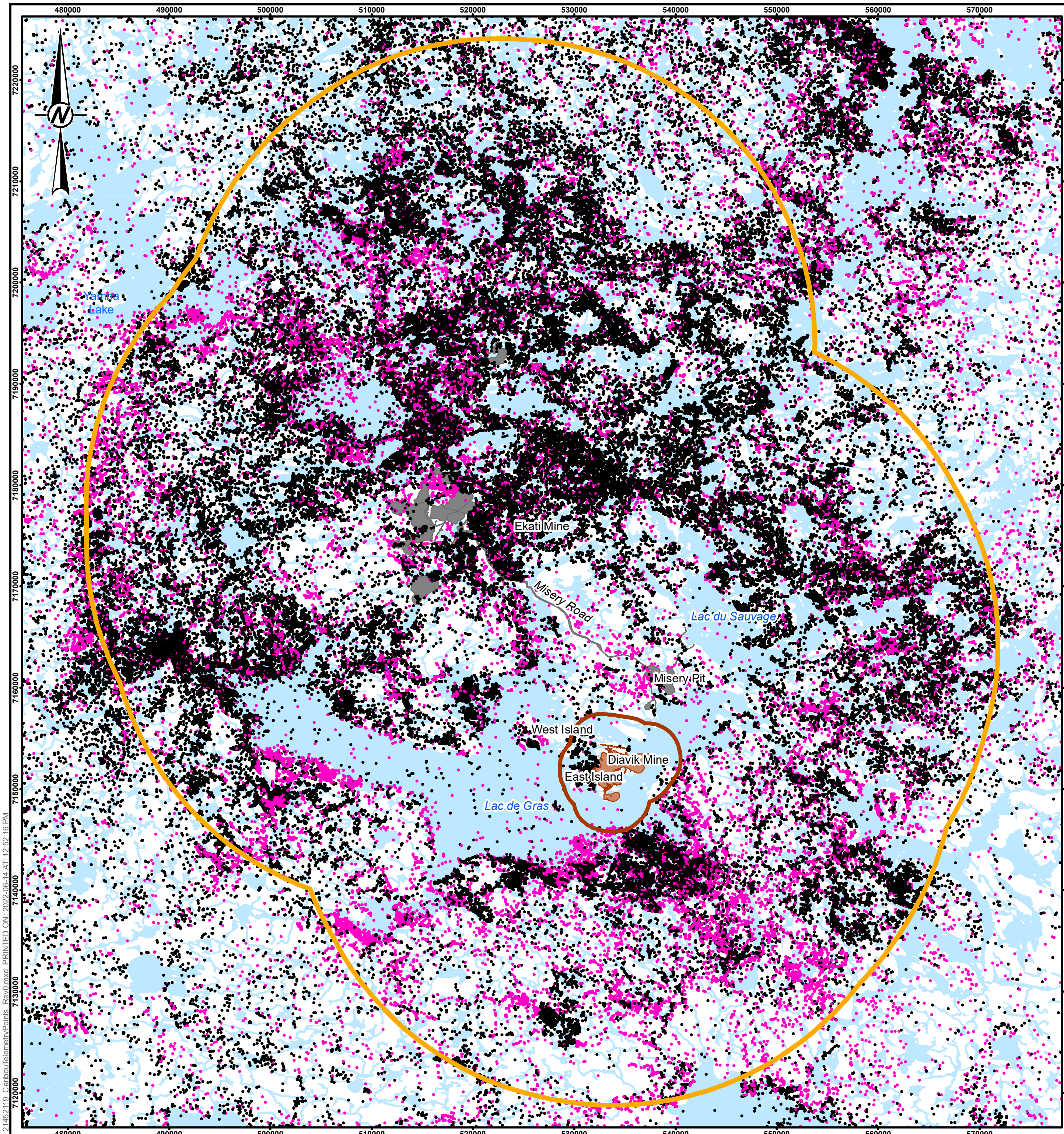
Caribou telemetry data from 1995 to November 2021 were provided by the GNWT-ENR. Telemetry data were collected from both male and female caribou from the Bathurst and Beverly/Ahiak herds; however, a higher proportion of female caribou were equipped with collars throughout the duration of the study. The collars deployed from 1995 to 2005 were satellite collars that were mostly programmed to collect location data at fix rates greater than 24 hours. In some cases, satellite collars collected location data more frequently (8 to 24 hr fix rates), but this was not common. After 2006, GPS collars were more commonly deployed, which usually yield more accurate location estimates than satellite collars. Most of the collars deployed from 2008 to 2015 were programmed to collect one location per day (24 hr fix rate), while some collars had an 8-hour fix rate, and a few had a fix rate of 1 to 3 hours during specific seasons. Almost all collars deployed after 2015 were geo-fence collars. Most geo-fence collars were programmed to collect location data at 8-hour fixes, but increased the fix frequency to every one hour when a caribou triggered the ‘geo-fence’ by travelling within a 30 km radius of the Diavik and Ekati mine complex.

To remove behavioural effects from capture events, the first two weeks of data from each collar were removed from all analyses. Duplicate locations were removed from the dataset (29,445 locations). Following the methods of Poole et al. (2021), all telemetry locations collected before 2010 were removed and collars that collected location data at a fix rate greater than 24 hours were also excluded from analyses. Unlike Poole et al. (2021), this analysis included male caribou and location data collected from satellite collars. A limited number of collared caribou were observed in the 3 km buffer zone around the Mine, which was the focal area of this study. Inclusion of male caribou and satellite collar locations helped provide more understanding of caribou movement behaviours around the Mine. Figure 1 depicts the filtered telemetry locations from caribou in the Bathurst and Beverly/Ahiak herds from 2010 to 2021.

After the telemetry data were filtered according to the criteria above, it was sorted into biological years and seasons. A biological year was defined as the time between spring migration until the end of winter the following year (20 April – 19 April). For example, a caribou location collected on 16 January 2020 would be classified from the 2019 biological year. Sorting by biological year rather than calendar year was important so that the data collected during the same winter season could be evaluated, rather than being split into two separate years. Data were sorted into six seasons that were defined in Poole et al. (2021). The six seasons and the corresponding dates are presented in Table 1.

**Table 1: Dates of caribou seasons defined by Poole et al. (2021)**

| Season | Dates |
|---|---|
| Spring migration | 20 Apr – 1 Jun |
| Calving | 2-16 Jun |
| Post-calving | 17-28 Jun |
| Summer | 29 Jun – 6 Sep |
| Fall | 7 Sep – 30 Nov |
| Winter | 1 Dec – 19 Apr |




**LEGEND**

- DIAVIK FOOTPRINT
- DIAVIK FOOTPRINT 3 KILOMETRE BUFFER
- 30 KILOMETRE BUFFER ZONE AROUND THE DIAVIK AND EKATI MINE COMPLEX
- EKATI FOOTPRINT
- WATERCOURSE
- WATERBODY
- BATHURST TELEMETRY LOCATION
- BEVERLY/AHIAK TELEMETRY LOCATION

0 10 20
1:550,000 KILOMETRES

**REFERENCE(S)**

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

RioTinto

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

**FILTERED TELEMETRY LOCATIONS COLLECTED FROM COLLARED BARREN-GROUND CARIBOU IN THE BATHURST AND BEVERLY/AHIAK HERDS, 2010 – 2021**

CONSULTANT

wsp GOLDER

| | |
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| YYYY-MM-DD | 2022-06-14 |
| DESIGNED | NM |
| PREPARED | ANK |
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## 2.2 Movement Metrics of Caribou Movement Paths

A main goal of this analysis was to provide more understanding of the behaviour of caribou near the Mine using similar caribou collar data and derived movement metrics as Poole et al. (2021). To evaluate caribou movements around the Mine, different metrics were estimated from movement paths of caribou within a 3 km buffer zone around the Mine. Poole et al. (2021) derived movement metrics from caribou movement paths that occurred across multiple consecutive 3 km buffer zones around the Ekati mine from a 0 to 30 km radius. The 30 km buffer zone was chosen by Poole et al. (2021) because it was approximately double the mean distance or zone of influence (i.e., 7 to 14 km) that caribou responded to the Diavik and Ekati mine complex (Boulanger et al. 2012, 2021). However, many of the conclusions in the analysis by Poole et al. (2021) were focussed on collar movements within the first 3 km buffer zone around the Ekati mine because the 3 km buffer zone is where caribou were close enough to interact with the Ekati mine. The focus of this analysis was to explore movement behaviours of caribou in close proximity to the Diavik Mine, and therefore, the 3 km buffer zone was the focal area that movement metrics were evaluated for the Bathurst and Beverly/Ahiak herds. In order to compare movement metrics of caribou paths within the 3 km buffer zone to population-level estimates, a reference group for each herd was defined as all caribou movement paths located outside a 30 km buffer zone around the Diavik and Ekati mine complex. This assumed that movement metrics from the reference group would not be affected by activities at the Diavik and Ekati mines and is consistent with the scale used by Poole et al. (2021).

The filtered telemetry dataset was input into a Geographic Information System (GIS; ESRI 2011), and movement paths were created for each caribou as spatial polylines using the XY to line tool in ArcGIS (ESRI 2011). Metrics of residency time, speed, and turning angles were then calculated as described below.

### Movement path residency, speed and turning angle

Caribou telemetry data were input into R and raw movement metrics were generated using the ‘make_track’ function in the ‘amt’ package (Signer et al. 2019) in R v. 4.0.3 (R Core Team 2020). This tool provided the step lengths (Euclidean distance between consecutive telemetry locations), turning angles, and the start and end times of each step. A step is the straight line connecting two consecutive telemetry locations. In this analysis, multiple steps by an individual caribou constitute a movement path. Additional movement metrics, including two metrics of residency (time spent in an area), speed, and proportion of hard turns, were calculated from these raw metrics for all movement paths within the 3 km buffer zone and for each reference group when possible.

Residency time was investigated using two different metrics. Residency Metric 1 was calculated as the summed amount of time each caribou path remained in the 3 km buffer zone and was provided as a unit of hours per square kilometre (hr/km$^2$) following the approach demonstrated in Poole et al. (2021). While it was important to standardize across the increasing amount of area for each distance zone evaluated in Poole et al. (2021), the amount of time (hours) was not standardized across the different durations of each season, which is necessary to allow for comparisons across seasons. To account for this, an additional metric of residency time was estimated as the percent of time per season (defined in Table 1) that each caribou spent in the 3 km buffer zone and was referred to as Residency Metric 2. Residency metrics could not be estimated for the reference groups outside the 30 km buffer zone because there is no defined area to calculate these metrics. As a result, a population-level comparison was not made for residency metrics in this analysis.

Speed (movement rate) of caribou were provided as estimates of distance per hour (km/hr). Speed was calculated by dividing the step length by the time difference of each step (time between start and end points of a step). A mean speed was presented for each season per biological year that was averaged across individual caribou within the 3 km buffer zone. Additionally, mean speed was presented for each reference group (i.e., outside the 30 km buffer zone).

The turning angle of caribou paths was identified as the relative difference in headings of consecutive steps. Turning angles were first calculated in radians but were converted to degrees for easier interpretation. For simplicity, only the absolute value of turning angles (positive value) were presented, because it was not of interest whether caribou turned to the left or right, but rather if they deviated from heading in a straight line (Poole et al. 2021). Following Poole et al. (2021), turning angles were identified as a hard turn if they had a relative angle greater than or equal to 60 degrees. The proportion of hard turns were presented for each caribou within the 3 km buffer zone, and as a mean for the reference group for each season per biological year.

After the movement metrics were calculated for each movement path, the paths were joined with the movement metric dataset in GIS. Movement paths that intersected the 3 km buffer zone around the Mine were exported into a separate dataset for further evaluation. Movement paths that occurred outside the 30 km buffer zone were also exported into a separate dataset to represent the reference group of each herd.

The sample size of caribou that occurred within the 3 km buffer zone was less than three collared caribou per herd for each season in each biological year. As a result, the movement metrics should not be interpreted as representative of the population's movement behaviours around the Mine, but rather as exploratory insights into the behaviour of collared individuals near the Mine.

## 2.3 Distance from the Mine

The closest distance of each caribou movement path within the 3 km buffer zone was estimated from the nearest feature of the Mine footprint in GIS (ESRI, 2011). The movement paths were also visually inspected to identify if any crossed the Mine footprint, including roads.

## 2.4 Qualitative correlation analysis

Movement paths within the 3 km buffer zone of the Mine were classified based on whether the path overlapped East Island and West Island (or East/West Islands) for the purpose of qualitatively correlating these data with other Mine-related data sources. Movement paths that did not overlap East/West Islands were excluded because they briefly entered and exited the 3 km boundary and never came closer to the Mine. For each path that met criteria for inclusion, start and end dates were identified for the time the individual spent in the 3 km buffer zone. Movement metrics were summarized for each path, including residency time (Residency Metric 1), percent of the season (Residency Metric 2), speed, and proportion of hard turns (see Section 2.2 for details).

Caribou behavioural group scan data presented in the 2021 Wildlife Management and Monitoring Report (Golder 2022) were evaluated for inclusion in the qualitative correlation analysis based on the survey date and location. For each movement path, behavioural group scan surveys were selected if the survey date was within the movement path date range and the behavioural survey location was in the general vicinity of the path. There was no way to confirm if a collared individual was part of the caribou groups observed during the behavioural surveys. Instead, it was assumed that a caribou with a movement path near the behavioural survey was experiencing similar conditions and stimuli similar to those animals recorded in the behavioural scan surveys. Once behavioural scan surveys were identified as having occurred at similar times and areas of each movement path, observed caribou behaviours were compared to the movement metrics of the collared individual. For example, the behaviours of caribou in selected scan surveys were compared to the residency time, speed, and proportion of hard turns from the adjacent movement path. Caribou behavioural group scan data included the proportion of counts for a defined activity type (i.e., bedded, feeding, standing, alert, walking, trotting, running) for the duration of a survey. In cases where multiple behavioural surveys aligned with a movement path, activity budget values were averaged across surveys.

Mine activity information was evaluated and included blast dates, mine phases (i.e., underground and open pit), and general activity levels at various areas at the Mine (e.g., vehicle traffic and heavy equipment operation in a few general areas on the west side of the Mine). Caribou movement patterns were qualitatively compared to Mine activities based on general locations as well as dates when available.

Caribou paths were qualitatively correlated with landcover (habitat) data. Landcover data included the Ecological Landscape Classification (ELC) using remote sensing techniques for the Slave Geological Province (Matthews et al. 2001) and the newly updated landcover classifications based on satellite imagery as described in Section 3.1 of the 2021 Wildlife Management and Monitoring Report (Golder 2022). Habitat classifications were updated only in the area immediately surrounding the current Mine footprint to assess Mine-related landscape changes. This updated area included all of East Island and the south-eastern portion of West Island but did not include the entire 3 km buffer zone surrounding the Mine. Habitat data were extracted to caribou locations within the 3 km buffer zone of the Mine. Once extracted, habitat use percentages were calculated for each caribou based on the number of locations that occurred in each habitat type relative to the total number of locations for each movement path. The proportion of ELC types available were not assessed as part of this analysis, so there were no inferences made on habitat selection by caribou.

# 3.0 RESULTS

## 3.1 Caribou telemetry data

Of the 212 collared caribou from the Bathurst herd that had telemetry data collected, ten caribou had movement paths that occurred within the 3 km buffer zone around the Mine (Table 2, Figure 2). Seven caribou (eight caribou-years) from the Beverly/Ahiak herd had movement paths within the 3 km buffer zone out of the total 218 collared caribou in this analysis (Table 2). More females were observed within the 3 km buffer zone, but this is likely due to the greater number of females collared compared to males in each herd throughout the study.

**Table 2: Number of collared caribou and caribou-years from the Bathurst and Beverly/Ahiak herds with paths inside the 3 km buffer zone around the Mine and outside the 30 km buffer zone surrounding the Diavik and Ekati mine complex, 2010 – 2021**

| Herd | Count type | Count within 3 km buffer[a] | | | Count of reference groups (outside 30 km buffer[a]) | | | All collared caribou | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | M | Total[b] | F | M | Total[b] | F | M | Total[b] |
| Bathurst | Caribou | 7 | 3 | 10 (4.7%) | 153 | 57 | 210 (99%) | 154 | 58 | 212 (100%) |
| | Caribou-years | 8 | 3 | 11 (2.2%) | 333 | 113 | 446 (99%) | 336 | 115 | 451 (100%) |
| Beverly/ Ahiak | Caribou | 5 | 2 | 7 (3.2%) | 154 | 64 | 218 (100%) | 154 | 64 | 218 (100%) |
| | Caribou-years | 6 | 2 | 8 (1.6%) | 375 | 126 | 501 (100%) | 375 | 126 | 501 (100%) |

(a) Refers to the 3 km buffer zone around the Mine and the 30 km buffer zone around the Diavik and Ekati mine complex.

(b) Total proportion of collared caribou in the herd.

Abbreviations: F = female; M = male; km = kilometres.

The number of caribou with movement paths inside the 3 km buffer zone varied from one to three caribou across biological years, seasons, and herds, and remained below 12% of total collared caribou for all seasons each year (Table 3). Across the entire study period, the average percent of collared caribou from each herd observed in the 3 km buffer zone per year was 2.8% of the Bathurst herd and 0.8% of the Beverly/Ahiak herd. Most caribou were observed within the 3 km buffer zone in recent biological years from 2017, 2018, 2019 and 2021; however, one caribou was observed during 2010. Caribou were found to occur within 3 km of the Mine more commonly in the winter season, followed by spring migration, and one caribou was observed during the fall of 2010 (Table 3). No caribou had movement paths within 3 km of the Mine during the calving, post-calving, and summer seasons.

**Table 3: Number of collared caribou from the Bathurst and Beverly/Ahiak herds with paths inside the 3 km buffer zone around the Mine, outside 30 km of the Diavik and Ekati mine complex, and in total cleaned dataset, 2010-2021**

| Herd | Biological year | Season | Collared caribou within 3 km buffer[a] | Collared caribou in reference group (outside 30 km[a]) | Total collared caribou |
|---|---|---|---|---|---|
| Bathurst | 2010 | Fall | 1 (11%) | 9 | 9 |
| | 2016 | Winter | 1 (2%) | 46 | 46 |
| | 2017 | Winter | 3 (7%) | 41 | 44 |
| | 2018 | Winter | 2 (5%) | 39 | 40 |
| | 2020 | Winter | 2 (4%) | 56 | 56 |
| | 2021 | Spring migration | 2 (4%) | 55 | 55 |
| Beverly/Ahiak | 2016 | Winter | 2 (4%) | 51 | 53 |
| | 2017 | Spring migration | 1 (2%) | 47 | 47 |
| | | Winter | 2 (3%) | 61 | 63 |
| | 2018 | Winter | 3 (3%) | 60 | 61 |

(a) Refers to the 3 km buffer zone around the Mine and the 30 km buffer zone around the Diavik and Ekati mine complex.

Abbreviations: km = kilometres; "%" = percent.

The mean length of time that location data were collected from collared caribou during the study period was 531 days (1.5 years) and 587 days (1.6 years) for the Bathurst and Beverly/Ahiak herds, respectively. The mean number of telemetry locations collected from collared caribou in the Bathurst herd was 1,162 locations and from the Beverly/Ahiak herd was 1,075 locations during the study period.

Most caribou that were equipped with a satellite collar had fix rates that surpassed 24 hours (Table 4). Because caribou with fix rates over 24 hours were excluded in this analysis, most caribou with satellite collars were excluded, except for one individual from the Bathurst herd that had fix rates that remained below 24 hours. All caribou from the Beverly/Ahiak herd that had a path in the 3 km buffer zone were equipped with GPS collar (none were equipped with a satellite collar). Most caribou from the Bathurst herd had locations collected at 1-hour fixes (n=9; Table 4). One caribou from the Beverly/Ahiak herd had 1-hour fixes and the remaining had a fix rate of 8 hours. Generally, fix rates varied from 8 to 24 hours for caribou outside of the 30 km buffer zone that were included in this analysis.

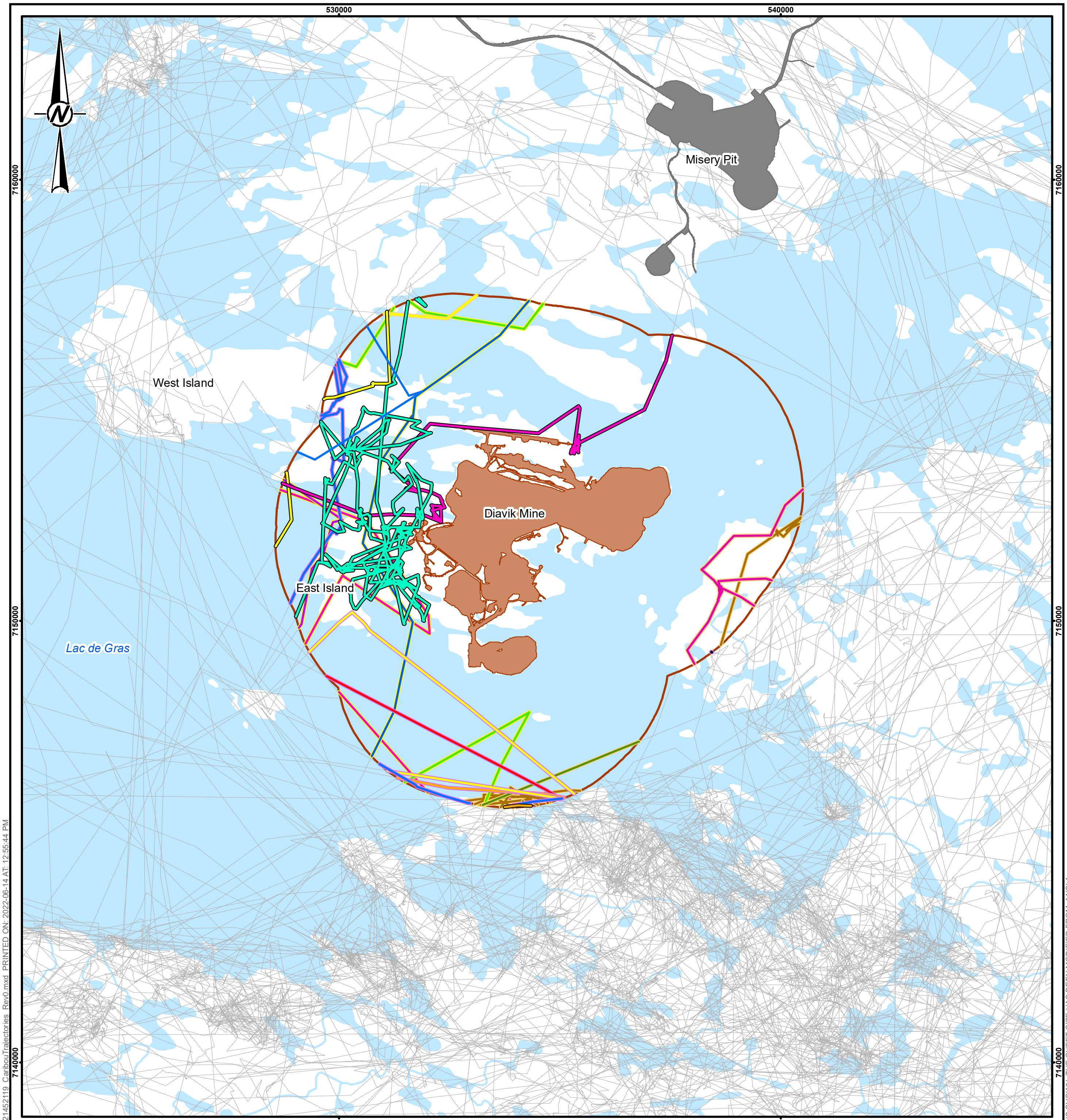
**Table 4: Number of collared caribou with approximated fix rates from the Bathurst and Beverly/Ahiak herds**

| | Collared caribou within 3 km[(a)] | | | Reference group outside 30 km[(b)] | | |
|---|---|---|---|---|---|---|
| | 1 hr fixes[(b)] | 8 hr fixes | 24 hr fixes | ≤ 8 hr fixes | 9 to 23 hr fixes | ≥ 24 hr fixes |
| Bathurst | 9 | 0 | 1 | 129 | 74 | 7 |
| Beverly/Ahiak | 1 | 8 | 0 | 133 | 34 | 51 |

(a) Refers to the 3 km buffer zone around the Mine and the 30 km buffer zone around the Diavik and Ekati mine complex.

(b) Fix rate of geo-fence collars increases to 1hr frequency when a caribou approaches within 30 km of mining infrastructure, resulting in few 1 hr fixes outside of the 30 km buffer zone around the Diavik and Ekati mine complex.

Abbreviations: km = kilometre; hr = hour; “ ≤ ” = less than or equal to; “ ≥ ” = greater than or equal to.




**LEGEND**

- DIAVIK FOOTPRINT
- DIAVIK FOOTPRINT 3 KILOMETRE BUFFER
- EKATI FOOTPRINT
- WATERCOURSE
- WATERBODY

**CARIBOU ID - YEAR INTERSECTING 3 KM BUFFER**

- BGCA20143-2021
- BGCA20144-2021
- BGCA20113-2020
- BGCA21160-2020
- BGCA14717-2018
- BGCA17155-2018
- BGCA18116-2018
- BGCA18138-2018
- BGCA18148-2018
- BGCA19322-2018
- BGCA14717-2017
- BGCA17105-2017
- BGCA15315-2017
- BGCA16102-2017
- BGCA17100-2017
- BGCA18121-2017
- BGCA14723-2016
- BGCA17100-2016
- BGCA227-2010
- CARIBOU TRAJECTORY OUTSIDE OF 3 KM BUFFER

0 2 4

1:125,000 KILOMETRES

**REFERENCE(S)**

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

RioTinto

PROJECT

DIAVIK DIAMOND MINES INC.

TITLE

**PATHS OF CARIBOU-YEARS THAT INTERSECT WITH THE 3KM BUFFER ZONE AROUND THE MINE FROM THE BATHURST AND AKIAK/BEVERLY HERDS**

CONSULTANT

wsp GOLDER

| | |
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## 3.2 Caribou movement paths and metrics

### Residency

#### *Annual Residency*

Caribou varied in their residency time within 3 km of the Mine by herd, season, and biological years (Figure 3; Table 5). The mean residency time (Metric 1) was greatest for caribou from the Bathurst herd in the winter during the 2017 and 2021 biological years. Due to low sample size for each season and biological year and the inability to calculate residency times outside of the 30 km buffer zone (Section 2.2), it is unknown if the residency times of individuals within 3 km are different than the population. However, collared caribou were spending much less than one hour per km$^2$ within 3 km the Mine (Table 5).

Residency Metric 1 did not account for the duration of time per season that individual caribou spent within the 3 km buffer zone. Residency Metric 2 provided the percentage of time per season that movement paths were observed within 3 km of the Mine. The mean percent of time per season was below 7% for all seasons across biological years and herds (Figure 3, Table 5). To provide context, a mean of 7% of the season during the winter would indicate that caribou resided in the 3 km buffer zone for 9.7 days out of a possible 138 days, during spring migration this would be 2.9 out of 42 days, and the fall would be 5.9 out of 84 days. The highest mean percentages of seasons spent within the 3 km buffer zone were observed from caribou in the Bathurst herd during winter 2020 (6.8%; n=2), fall 2010 (4.8%, n=1), and then spring migration (3.6%; n=2) (Table 5). Highest mean percentages of seasons for the Beverly/Ahiak herd were observed in winter 2017 (3.9%; n=2).

**Table 5: Residency metrics of movement paths from the Bathurst and Beverly/Ahiak herds within 3 km of the Mine**

| Herd | Year(a) | Season | n | Residency Metrics | |
|---|---|---|---|---|---|
| | | | | Metric 1 | Metric 2 |
| | | | | Mean residency ± 1SD (hr/km$^2$)(b) | Percent of season ± 1SD (%)(b) |
| Bathurst | 2010 | Fall | 1 | 0.0 | 4.8 |
| | 2016 | Winter | 1 | 0.0 | 0.2 |
| | 2017 | Winter | 3 | 0.0 ± 0.0 | 0.4 ± 0.6 |
| | 2018 | Winter | 2 | 0.0 | 1.0 |
| | 2020 | Winter | 2 | 0.1 | 6.8 |
| | 2021 | Spring migration | 2 | 0.0 | 3.6 |
| Beverly /Ahiak | 2016 | Winter | 2 | 0.0 | 2.3 |
| | 2017 | Spring migration | 1 | 0.0 | 0.9 |
| | | Winter | 2 | 0.0 | 3.9 |
| | 2018 | Winter | 3 | 0.0 ± 0.0 | 0.3 ± 0.2 |

(a) Biological year.

(b) Standard deviation provided for estimates with sample sizes ≥ 3 caribou.

Abbreviations: n = number of caribou; hr = hour; km = kilometre; "%" = percent, SD = standard deviation.

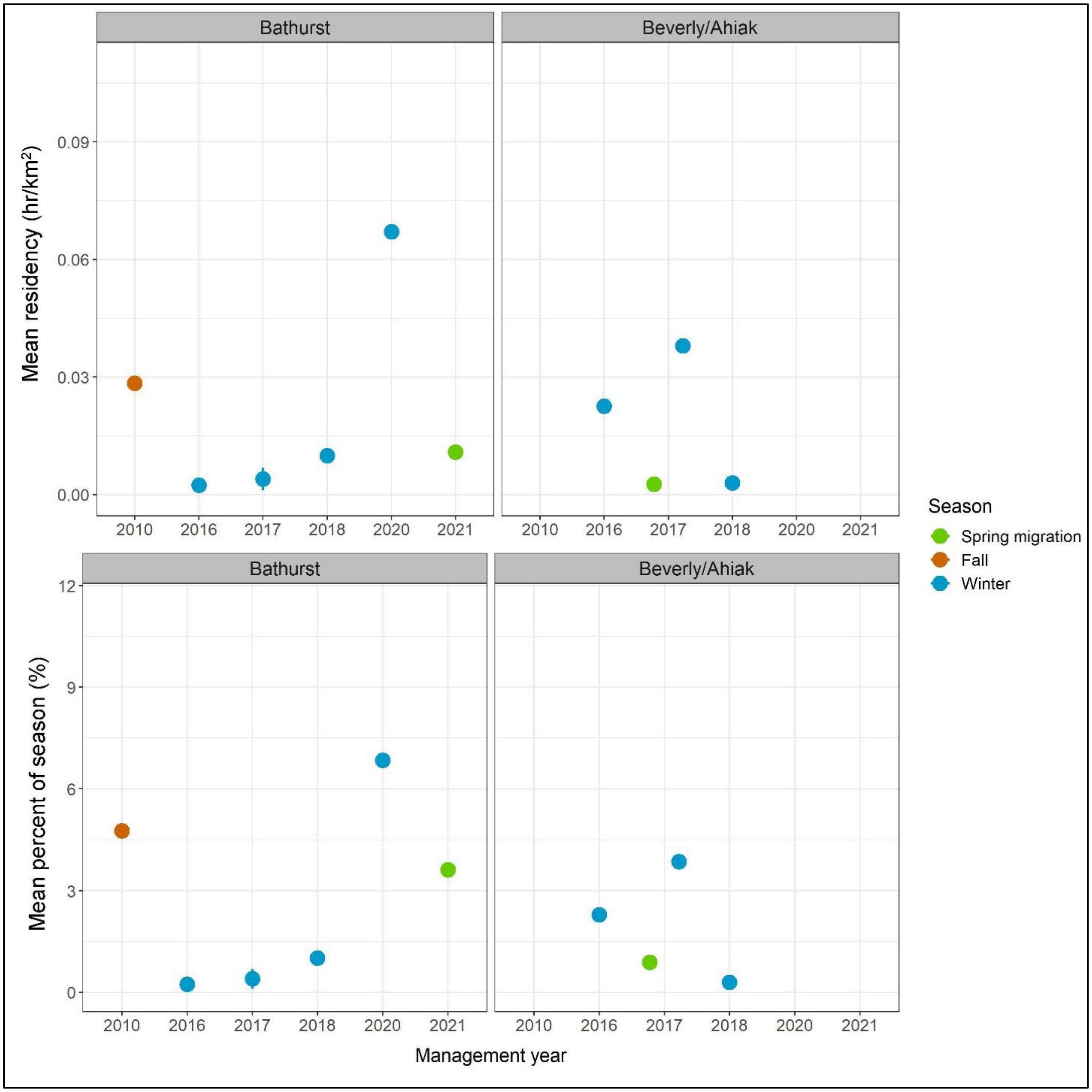



**Figure 3 : Mean residency (hr/km²) and mean percent of the season of collared caribou movement paths within the 3 km buffer zone around the Mine, 2010-2021. Error bars represent standard deviation for seasons with >3 caribou. Note: all seasons had limited sample sizes ranging from one to three individual caribou.**

### Mean Seasonal Residency

Residency metrics shown in Table 5 were combined across management years to evaluate overall seasonal residency throughout the study period (Table 6). Caribou from both herds varied in residency times across seasons. Most caribou were observed within the 3 km buffer zone during the winter season (n=15). Summed residency time (Metric 1) was greatest in winter and lowest during spring migration for both herds (Table 6).

The greatest mean percent of a season (Metric 2) spent in the 3 km buffer zone was 4.8% (Table 6), indicating caribou spent limited time in the 3 km buffer zone across all seasons. Caribou in the Bathurst herd spent the greatest duration of fall and spring seasons within the 3 km buffer zone (Table 6), although this remained below 5% of a season. Caribou in the Beverly/Ahiak herd spent the greatest duration in the winter season.

**Table 6: Mean seasonal residency metrics of collared caribou from the Bathurst and Beverly/Ahiak herds on East and West Islands in the 3 km buffer zone**

| Herd | Season | n | Residency Metrics | |
|---|---|---|---|---|
| | | | Metric 1 | Metric 2 |
| | | | Summed residency (hr/km$^2$) | Mean percent of season ± 1SD (%)[(a)] |
| Bathurst | Fall | 1 | 0.0 | 4.8 |
| | Spring migration | 2 | 0.0 | 3.6 |
| | Winter | 8 | 0.2 | 2.3 ± 4.5 |
| Beverly/Ahiak | Spring migration | 1 | 0.0 | 0.9 |
| | Winter | 7 | 0.1 | 0.6 ± 0.6 |

(a) Standard deviation provided for estimates with sample sizes ≥ 3 caribou.

Abbreviations: n = number of caribou; hr = hour; km = kilometre; SD = standard deviation.

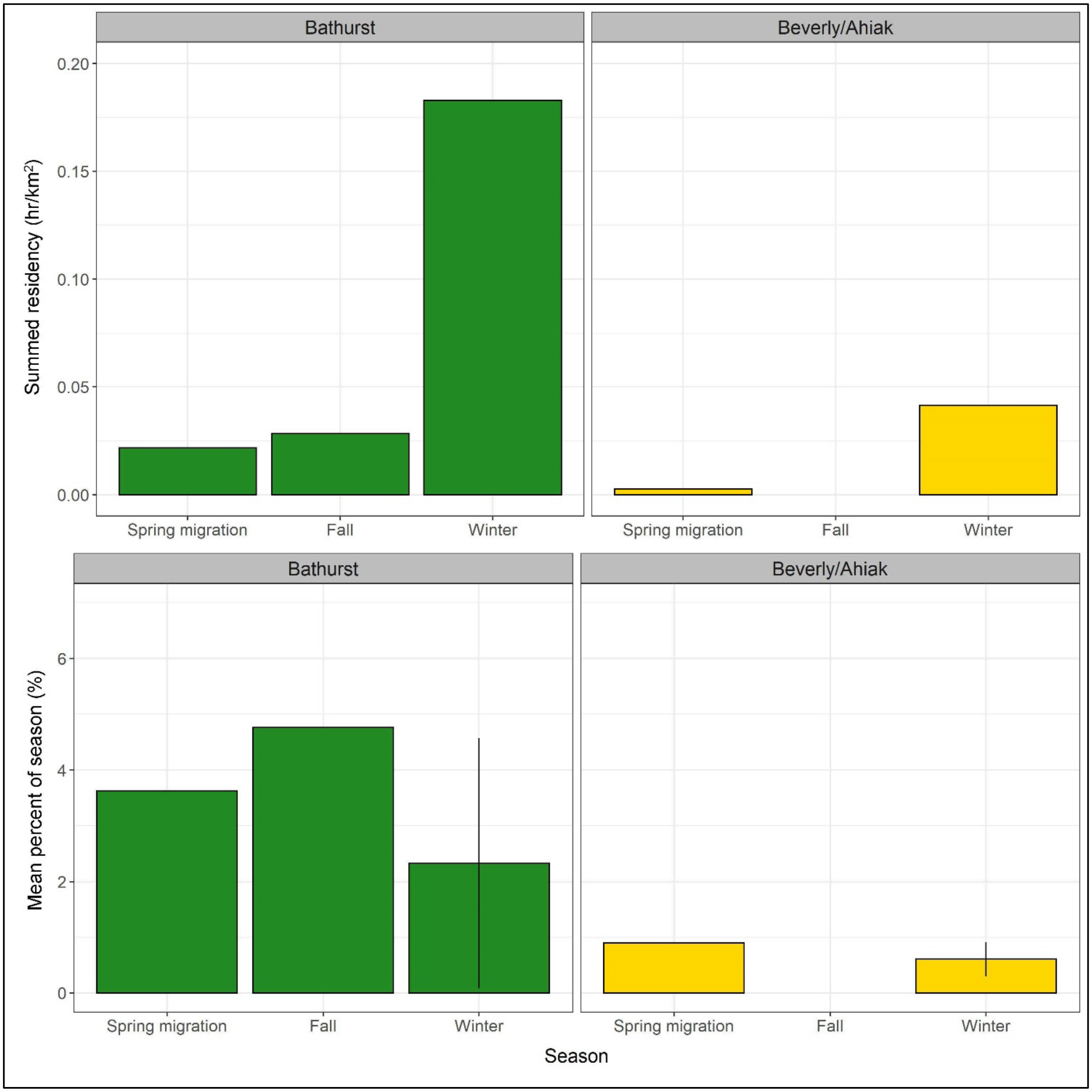



**Figure 4 : Summed residency (hr/km$^2$) and mean percent of the season that caribou movement paths were observed within the 3 km buffer zone around the Mine from caribou in the Bathurst and Beverly/Ahiak herds, 2010-2021. Error bars represent standard deviation for seasons with ≥3 caribou. Note: all seasons had limited sample sizes ranging from one to seven individual caribou.**

## Speed

The mean speed (km/hr) of caribou varied across seasons, biological years, and herds. The fastest mean speed was 1.7 km/hr and was observed from a caribou in the Beverly/Ahiak herd during spring migration 2017 (Table 7). The mean speed from caribou paths outside the 30 km buffer zone varied slightly across herds, seasons, and biological years, but remained within a narrow range of 0.2 to 0.5 km/hr. The highest mean speeds of the reference groups were observed during the spring migrations in 2017 and 2021 for the Beverly/Ahiak herd and the Bathurst herd, respectively. Most of the mean speeds estimated from caribou within the 3 km buffer zone overlapped with the variation (i.e., SD) of the estimated speed of the associated reference group (Figure 5). This indicates that the mean speeds of caribou in the 3 km buffer zone were generally similar to the reference groups outside of the 30 km buffer zone. Three speed metrics, two from winter and one from spring migration did not overlap with the SD of the speed of reference group.

**Table 7: Mean speed (km/hr) of collared caribou from the Bathurst and Beverly/Ahiak herds**

| Herd | Year (a) | Season | Within 3 km buffer zone(b) | | Outside 30 km buffer zone(b) | |
|---|---|---|---|---|---|---|
| | | | n | Mean speed ± 1SD (km/hr)(c) | n | Mean speed ± 1SD (km/hr)(c) |
| Bathurst | 2010 | Fall | 1 | 0.1 | 9 | 0.3 ± 0.3 |
| | 2016 | Winter | 1 | 0.8 | 46 | 0.2 ± 0.4 |
| | 2017 | Winter | 3 | 0.5 ± 0.7 | 41 | 0.3 ± 0.5 |
| | 2018 | Winter | 2 | 0.4 | 39 | 0.2 ± 0.4 |
| | 2020 | Winter | 2 | 0.2 | 56 | 0.2 ± 0.4 |
| | 2021 | Spring migration | 2 | 0.3 | 55 | 0.5 ± 0.6 |
| Beverly/Ahiak | 2016 | Winter | 2 | 0.3 | 51 | 0.3 ± 0.4 |
| | 2017 | Spring migration | 1 | 1.7 | 47 | 0.5 ± 0.7 |
| | | Winter | 2 | 0.8 | 61 | 0.3 ± 0.5 |
| | 2018 | Winter | 3 | 1.3 ± 1.3 | 60 | 0.2 ± 0.5 |

(a) Biological year.

(b) Refers to the 3 km buffer zone around the Mine and the 30 km buffer zone around the Diavik and Ekati mine complex.

(c) Standard deviations provided for mean estimates with ≥ 3 caribou.

Abbreviations: n = number of caribou; km = kilometres; hr = hour; SD = standard deviation.

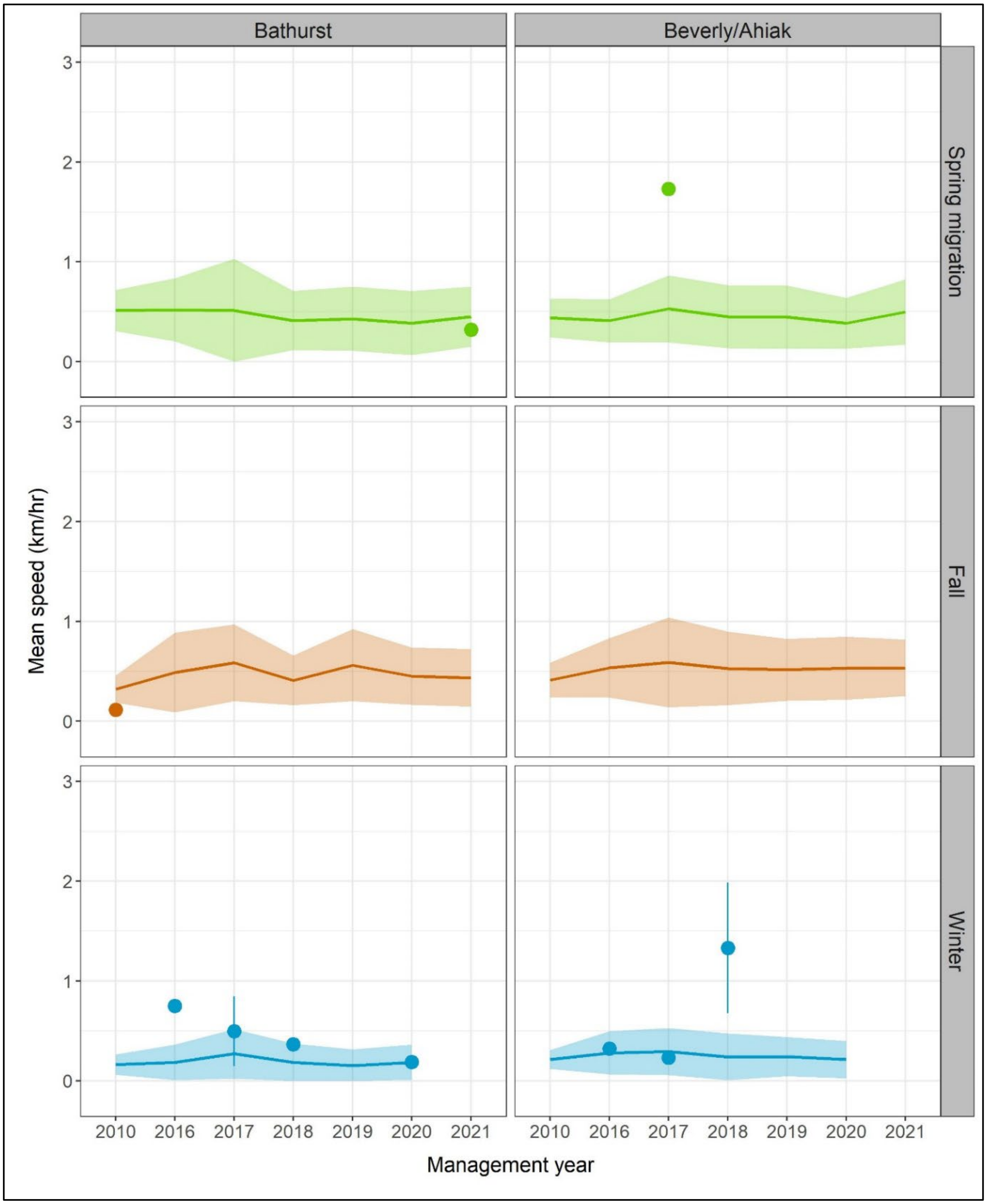



**Figure 5 : Mean speed (km/hr) of caribou from the Bathurst and Beverly/Ahiak herds within the 3 km buffer zone of the Mine and outside the 30 km buffer zone around the Diavik and Ekati mine complex, 2010-2021. Error bars on points and shading around the line represent 1 SD and are provided for estimates with sample size ≥ 3 caribou. Note: all seasons had sample sizes ranging from one to seven individual collared caribou.**

## Turning angles

The distribution of turning angles for all caribou within the 3 km buffer zone and outside the 30 km buffer zone around the Diavik and Ekati mine complex are presented on Figure 6. Both herds exhibited similar patterns in their frequency of turning angles within the 3 km buffer zone when compared to turning angles of their reference group. Caribou from the Beverly/Ahiak herd in the 3 km buffer zone had lower frequencies of turning angles because fewer collared individuals from this herd were observed in the 3 km buffer zone.

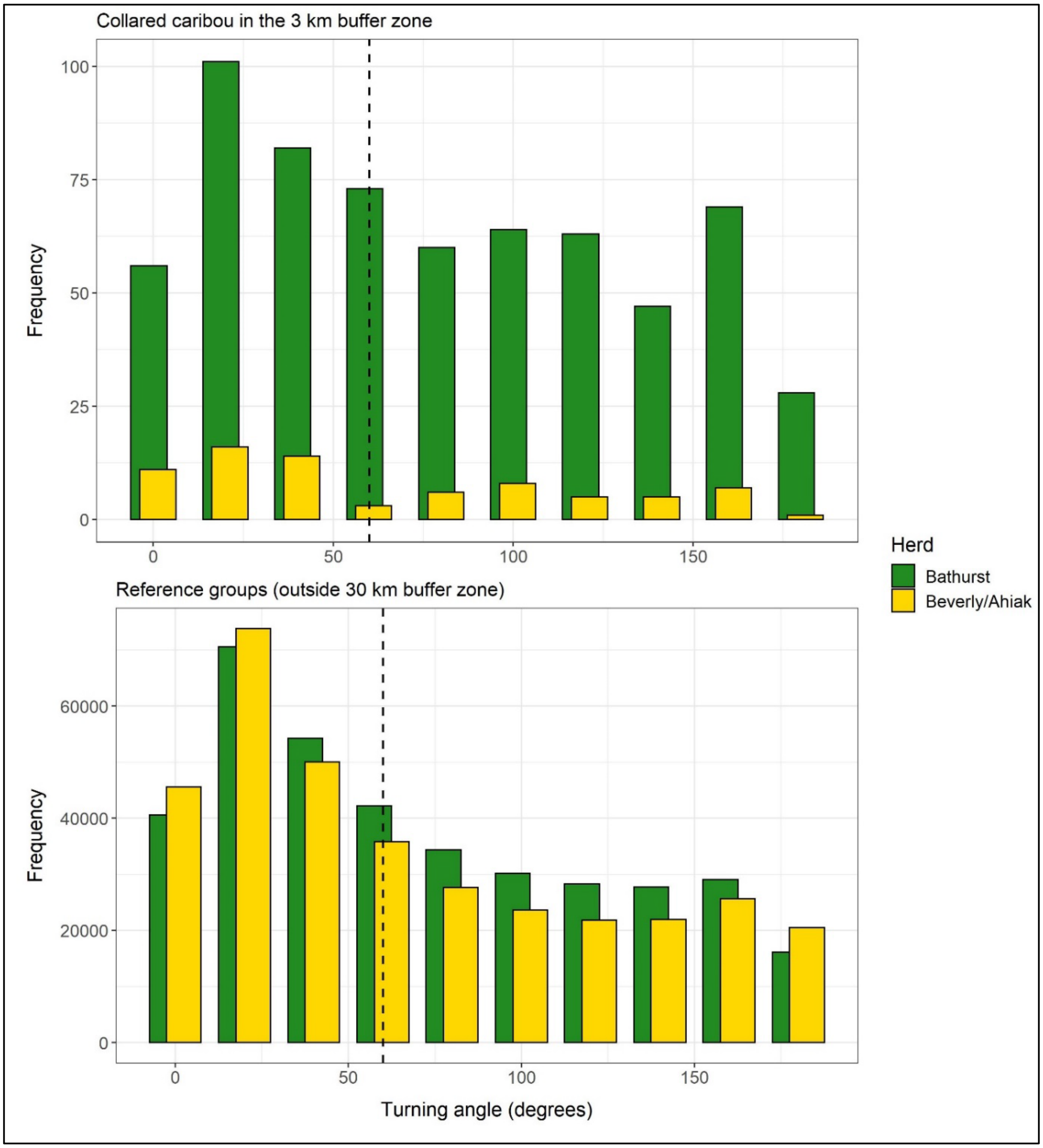



**Figure 6 : Frequency of relative turning angles (transformed to positive absolute degrees) for collared caribou in the Bathurst and Beverly/Ahiak herds. Dashed line indicates the threshold for a hard turn (≥60 degrees).**

During most seasons and years, nearly half of the turns exhibited by the reference groups were hard turns (≥ 60˚) (Table 8; Figure 7). This indicates that on average caribou in the reference groups were almost equally as likely to exhibit hard turns (≥ 60˚) as they were to exhibit non-hard turns (< 60˚). The proportion of hard turns varied across individuals in the 3 km buffer zone (Figure 7, Table 8). Most of the caribou had proportion of hard turns that were below or within the variation exhibited by the reference group (i.e., within 1 or 2 SD). The proportion of hard turns for one caribou in the fall 2010 was estimated from four telemetry locations collected with a satellite collar at 24 hr fix rates, and thus, the metrics estimated for this caribou are expected to be less accurate than other caribou in this analysis.

**Table 8 : Mean proportion of hard turns (≥60˚) from collared caribou from the Bathurst and Beverly/Ahiak herds within the 3 km buffer zone around the Mine and outside the 30 km buffer zone around the Diavik and Ekati mine complex, 2010-2021.**

| Herd | Year (a) | Season | Within 3 km buffer zone(b) | | Outside 30 km buffer zone (b) | |
|---|---|---|---|---|---|---|
| | | | n | Mean proportion of hard turns ± 1SD (≥ 60˚)(c) | n | Mean proportion of hard turns ± 1SD (≥ 60˚)(c) |
| Bathurst | 2010 | Fall | 1 | 0.75 | 9 | 0.4 ± 0.1 |
| | 2016 | Winter | 1 | 0.38 | 46 | 0.5 ± 0.1 |
| | 2017 | Winter | 3 | 0.17 ± 0.3 | 41 | 0.5 ± 0.1 |
| | 2018 | Winter | 2 | 0.24 | 39 | 0.5 ± 0.1 |
| | 2020 | Winter | 2 | 0.58 | 56 | 0.5 ± 0.1 |
| | 2021 | Spring migration | 2 | 0.27 | 55 | 0.4 ± 0.1 |
| Bev/Ahiak | 2016 | Winter | 2 | 0.59 | 51 | 0.4 ± 0.1 |
| | 2017 | Spring migration | 1 | 0.22 | 47 | 0.3 ± 0.1 |
| | | Winter | 2 | 0.57 | 61 | 0.5 ± 0.1 |
| | 2018 | Winter | 3 | 0.3 ± 0.4 | 60 | 0.5 ± 0.1 |

(a) Biological year.

(b) Refers to the 3 km buffer zone around the Mine and the 30 km buffer zone around the Diavik and Ekati mine complex.

(c) Standard deviation provided for estimates with sample sizes ≥ 3 caribou.

Abbreviations: n = number of caribou; “>” = greater than; “ ° ” = degrees; SD = standard deviation.

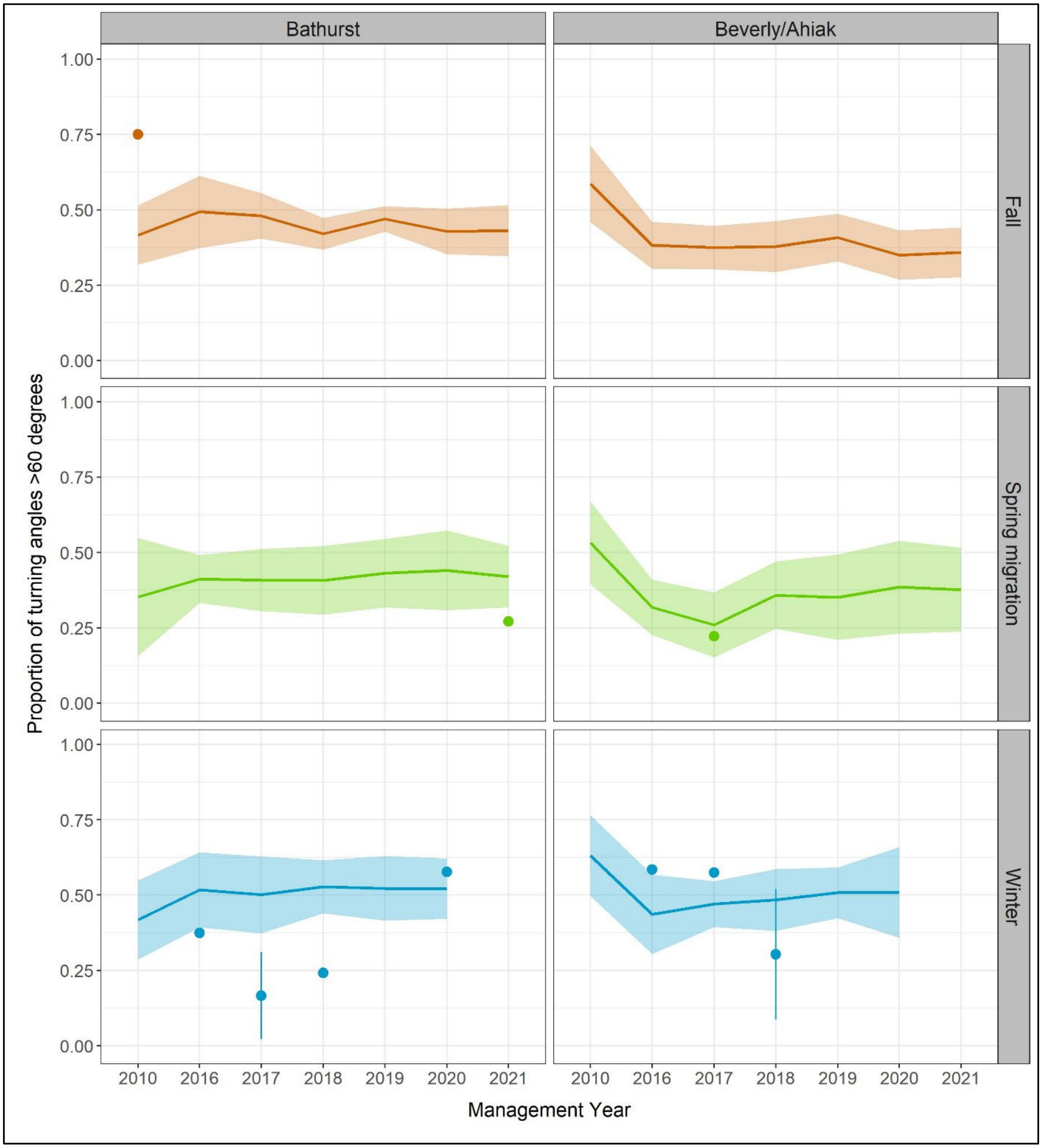



**Figure 7 : Proportion of hard turns (relative turns ≥60º) of caribou paths within the 3 km buffer zone around the Mine and outside the 30 km buffer zone around the Diavik and Ekati mine complex. Error bars on points and shading around the line represent 1 SD and are provided for estimates with sample size ≥ 3 caribou.**

## 3.3 Distance from the Mine

Of the 19 caribou-years that were observed within the 3 km buffer zone around the Mine, the mean nearest distance to the Mine boundary was 1,509 m (SD=991 m). Few caribou travelled within 500 m of the Mine boundary (18%; n=3), and even fewer approached within 250 m (12%; n=2) (Figure 8). However, these distances were estimated from the nearest segment of a movement path, rather than the known telemetry locations. As a result, these distances may overestimate or underestimate the true nearest distance that each caribou approached the Diavik Mine boundary. Of the caribou observed within 3 km of the Mine, only one caribou (caribou BCGA21160) had a movement path that crossed a segment of a road located in the windfarm area.

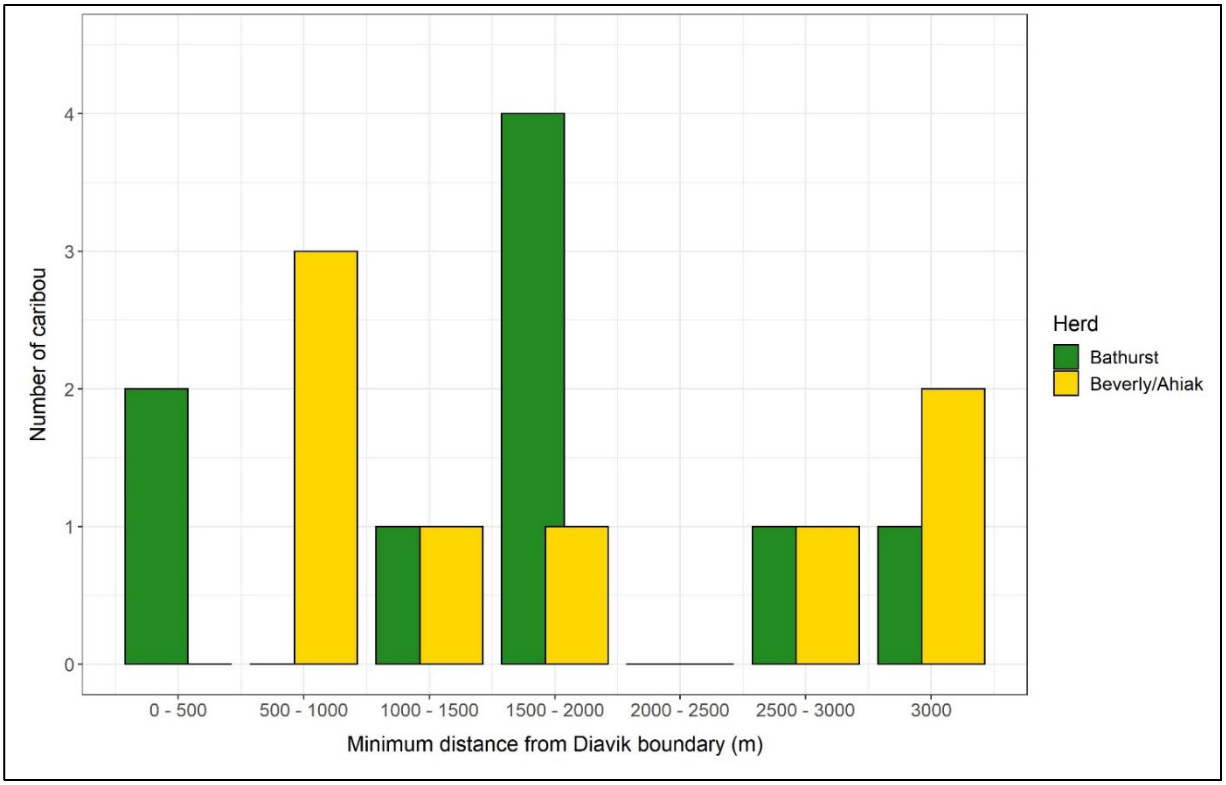



**Figure 8: Number of collared caribou in the 3 km buffer zone with nearest distances (m) of movement paths from the Mine footprint pooled into 500 m bins.**

## 3.4 Qualitative correlation analysis

Five caribou from the Bathurst herd and three caribou from the Beverly/Ahiak herd had movement paths within the 3 km buffer zone and on East/West Islands that could be included in the correlation analysis (Table 9). These movement paths were evaluated for correlations with other data sources, including behavioural survey data, Mine activity (i.e., blast dates, Mine phases and relative vehicle activity) and habitat.

## *Behavioural surveys*

Of the eight movement paths, five (three Bathurst, two Beverly/Ahiak) could be associated with behavioural survey data and occurred during the spring migration (n=2) and winter (n-3). For these paths, the number of behavioural surveys ranged from one to five (Table 9). Figure 9 shows two examples of caribou movement paths that had corresponding behavioural survey data used. Caribou BGCA20143 (female) was present within the 3 km buffer zone around the Mine during the spring migration of 2021 from 27 April to 30 April, and there was one behavioural survey associated with this path (Figure 9). Caribou BGCA21160 (male) was located within the 3 km buffer zone around the Mine during the winter of 2020 from 27 March to 15 April, and there were five behavioural surveys associated with this path (Figure 9).

Considering all behavioural surveys associated with movement paths, the most frequently observed behaviours on East/West Islands included bedded, feeding, standing, and walking. Average proportion of time spent bedding ranged from 0% to 49%, feeding ranged from 0% to 69%, standing ranged from 0% to 36%, and walking ranged from 5% to 75% (Table 9). Running was less common (i.e., 0% to 14%). The average percentage of time caribou were identified as ‘alert’ was 0%. These behavioural surveys did not specifically identify caribou responses to mine activity such as blasting, but some potential sources of stress were identified, including vehicles and wolves.

For paths with associated behavioural data, residency time (Residency Metric 1) ranged from 0 to 0.1 hr/km$^2$, and percent of the season (Residency Metric 2) ranged from 1 to 13% (Table 9). Mean speed ranged from 0.2 to 1.7 km/hr, and the proportion of hard turns ranged from 0.2 to 0.6. In most cases, the residency, speed and turning angles estimated for caribou on East/West Islands remained within 1 to 2 SD of the estimates for the associated reference group. Caribou BGCA21160 (male) exhibited the greatest residency time (0.13 hr/km$^2$) and the greatest percent of the season spent within the 3 km buffer zone (13.3%) during the winter of 2020. Caribou exhibited the greatest mean speeds in winter of 2018 and the spring migration of 2017, while the lowest mean speed was observed in the fall 2010. Proportion of hard turns varied across caribou on East/West Islands; however, all caribou except one had a proportion of hard turns that overlapped with 2 SD of the reference group. This indicates proportion of hard turns on East/West Islands were consistent with the population reference groups.

The greatest proportions of hard turns were exhibited by BGCA227 (female) in fall 2010, which was the only caribou equipped with a satellite collar with 24 hr fix rates. The coarse resolution of these data could have influenced estimated movement metrics. The two caribou with the next largest proportion of hard turns were BGCA21160 (male) in winter 2020 and BGCA20143 (female) in spring migration 2021. The movement of these caribou are depicted in Figure 9. Caribou movements that had relatively low speeds and higher proportion of hard turns were mostly associated with feeding, bedded and walking behaviours (see caribou BGCA21160 and BGCA20143; Table 9). One caribou (caribou BGCA17105; female) that exhibited higher speed and lower proportion of hard turns was associated with walking and standing behaviours (Table 9).

### Table 9: Caribou movement metrics and potential behaviour data correlations

| Caribou ID | Herd | Year[(a)] | Season | Movement metrics | | | | Number of behaviour surveys | Average percentage of behaviour survey activity budgets[(f)] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Residency[(b)] | Percent of Season[(c)] | Mean speed[(d)] | Proportion of hard turns[(e)] | | Bedded | Feeding | Standing | Alert | Walking | Trotting | Running |
| BGCA227 | Bathurst | 2010 | Fall | 0.03 | 4.76 | 0.11 | 0.75 | 0 | - | - | - | - | - | - | - |
| BGCA17100 | Bathurst | 2016 | Winter | 0.00 | 0.06 | 0.75 | 0.38 | 0 | - | - | - | - | - | - | - |
| BGCA18148 | Bathurst | 2018 | Winter | 0.02 | 1.93 | 0.29 | 0.48 | 2 | 49 | 6 | 36 | 0 | 5 | 0 | 6 |
| BGCA20143 | Bathurst | 2021 | Spring migration | 0.02 | 7.04 | 0.28 | 0.54 | 1 | 40 | 33 | 0 | 0 | 14 | 0 | 14 |
| BGCA21160 | Bathurst | 2020 | Winter | 0.13 | 13.3 | 0.17 | 0.61 | 5 | 19 | 56 | 11 | 0 | 13 | 0 | 1 |
| BGCA17105 | Beverly/ Ahiak | 2017 | Spring migration | 0.00 | 0.89 | 1.73 | 0.22 | 1 | 0 | 0 | 25 | 0 | 75 | 0 | 0 |
| BGCA14717 | Beverly/ Ahiak | 2016 | Winter | 0.02 | 2.66 | 0.35 | 0.48 | 5 | 18 | 69 | 0 | 0 | 12 | 0 | 0 |
| BGCA18138 | Beverly/ Ahiak | 2018 | Winter | 0.00 | 0.27 | 2.00 | 0.11 | 0 | - | - | - | - | - | - | - |

(a) Biological year.

(b) Residency Metric 1 provided as an estimate of hours per $km^2$.

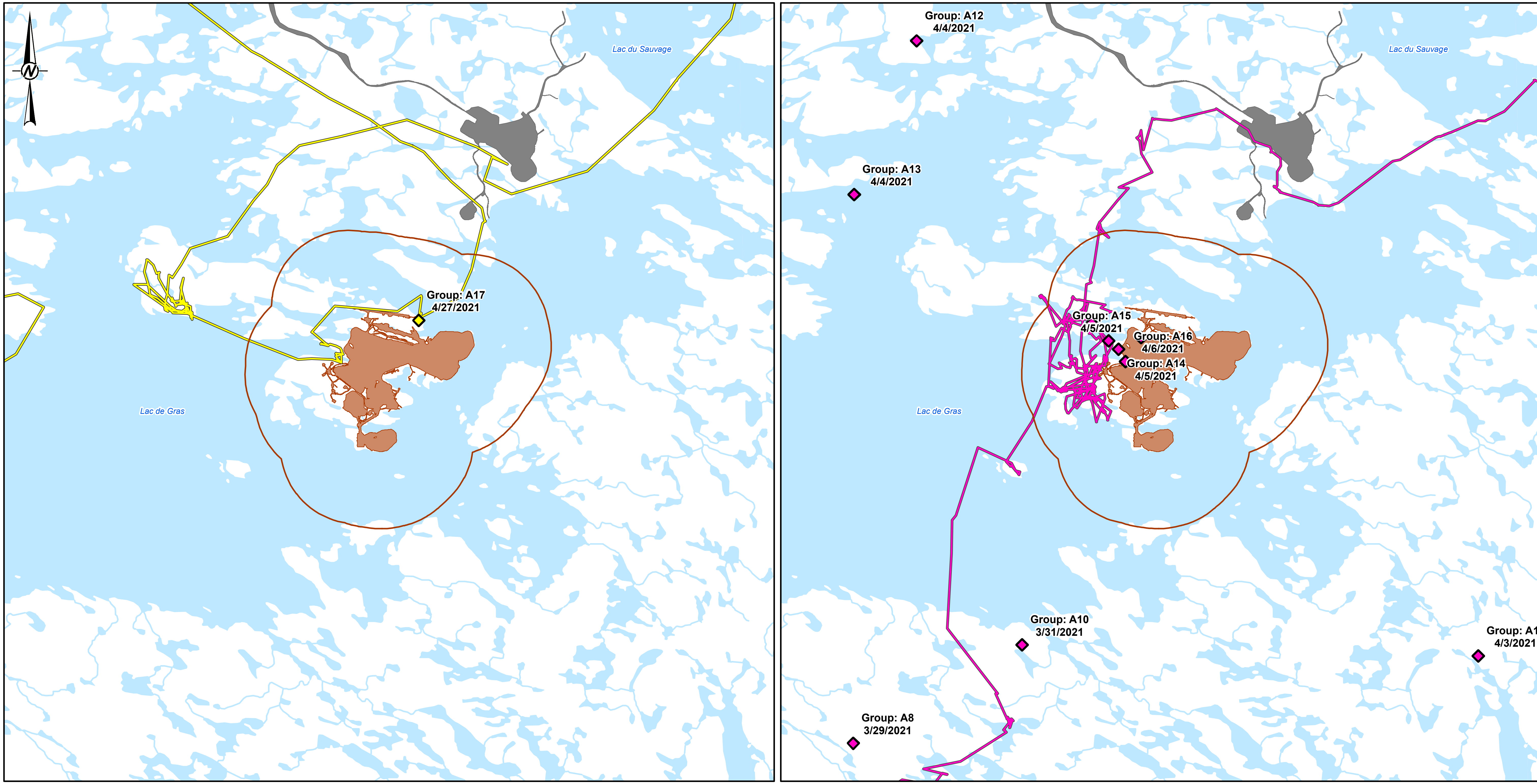
(c) Residency Metric 2 provided as an estimated percentage (%).

(d) Unit of estimate is km/hr.

(e) Hard turns defined as relative turning angles greater or equal to 60º.

(f) Activity budgets from caribou behavioural group scan dataset. In cases with multiple behavioural surveys associated with a movement path, proportions from behavioural survey activity budgets were averaged across surveys.

Abbreviations: ID = identification.




**LEGEND**

- DIAVIK FOOTPRINT
- DIAVIK FOOTPRINT 3 KILOMETRE BUFFER
- EKATI FOOTPRINT
- BGCA20143
- BGCA21160

**CARIBOU ID - YEAR**

- BGCA20143-2021
- BGCA21160-2020

0 3,000 6,000

1:150,000 METRES

**REFERENCE(S)**

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

| | | | |
|---|---|---|---|
| CLIENT | RioTinto | PROJECT | DIAVIK DIAMOND MINES INC. |
| CONSULTANT | YYYY-MM-DD | 2022-06-14 | TITLE |
| WSP GOLDER | DESIGNED | GE | EXAMPLES OF CARIBOU PATHS ON EAST AND WEST ISLANDS IN THE 3 KM BUFFER ZONE AND LOCATIONS OF BEHAVIOUR SURVEYS USED IN CORRELATION ANALYSIS |
| | PREPARED | ANK | |
| | REVIEWED | GE | |
| | APPROVED | DC | |

| PROJECT NO. | CONTROL | REV. | FIGURE |
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## Blast Dates

Four caribou from the Bathurst herd were within 3 km of the Mine when blasting occurred (Table 10). Most of the blasts occurred at the A21 site (14 out of 16 blasts) and two blasts occurred at the North Country Till Pile. The closest distance between a caribou telemetry location and the coinciding blast site (A21 or North County Till Pile) on the day of a blast event was 2,223 m, though distances during blasting cannot be confirmed without the time of day of the blast event. Because blasting times were not available, the reactions of caribou to blasting are difficult to infer based on changes in collared caribou movement. However, based on the daily movement behaviours of these four caribou on blast dates, there did not appear to be large changes to movement behaviours (e.g., hard turns, increased speed) that could indicate potential reactions to blasting.

**Table 10: Caribou paths and associated blasting**

| Caribou ID | Herd | Year(a) | Season | Number of blasts | Blast locations(b) |
|---|---|---|---|---|---|
| BGCA20143 | Bathurst | 2021 | Spring migration | 4 | A21 (qty=3), NCTP |
| BGCA21160 | Bathurst | 2020 | Winter | 10 | A21 (qty=9), NCTP |
| BGCA17100 | Bathurst | 2016 | Winter | 1 | A21 |
| BGCA18148 | Bathurst | 2018 | Winter | 1 | A21 |

(a) Biological year.

(b) For quantities not specified, number of blasts = 1.

Abbreviations: ID = identification; NCTP = North County Till Pile; qty = quantity of blast occurrences.

## Mine Phases and Activity

Mine phases during the period of this analysis included the underground mining and A21 Pit development (Table 11). The number of caribou-years with paths in the 3 km buffer zone and on East/West Islands during each Mine phase are displayed in Table 11. Most of the caribou movement paths within the 3 km buffer zone were observed during the A21 Pit development (n=17) from 2017 to 2021. During the underground mining phase (2010 – 2016), four caribou were observed within 3 km of the Mine in 2010 and 2016. There were no movement paths observed in the 3 km buffer zone from 2011 to 2015.

**Table 11: Number of caribou movement paths observed during Mine Development Phases, 2010-2021**

| Mine Phase | Years | Caribou-years in 3 km buffer zone | Caribou-years on East and/or West Islands |
|---|---|---|---|
| Underground Mining | 2010 – 2016 | 4 | 3 |
| A21 Pit Development | 2017 – 2021 | 17 | 5 |

Abbreviations: km = kilometre.

Mine activity was compared to the eight caribou movement paths observed on East/West Islands. Data were not available for vehicle traffic and heavy equipment operation (such as specific locations, times, traffic volume), so movement paths were qualitatively compared to information about relative mine activity in four different areas on the west side of the Mine (where paths on East/West Islands mostly occurred). Collared caribou that used East Island were most frequently observed in natural areas located to the west of the four areas of the Mine described below (such as the wind farm).

The first of the four areas (referred to as Area 1) is located west of the PKC West Dam, an area with occasional snow clearing but generally low vehicle traffic. One caribou, (BGCA20143; female), was observed using Area 1 during spring migration of 2021. The second of the four areas described was the windfarm and ammonium nitrate storage area (referred to as the windfarm; Area 2). The windfarm generally receives low vehicle traffic, except for during February and March when ammonium nitrate deliveries take place. One caribou (BCGA21160; male) frequented the windfarm area during winter over a period of more than two weeks (i.e., March and April 2021). Of note is that the windfarm is continuously operational so blade motion and subsequent noise is continuous. During this time, the individual crossed twice over one road in the windfarm area, and was the only caribou observed to cross a section of the Mine footprint. Additionally, caribou BGCA20143 (female) used areas just north of the wind farm after travelling south from the airstrip.

Area 3 included Emulsion Road and the Emulsion Plant, an area that experiences relatively higher vehicle use than Area 1 and Area 2 (up to ~60 trips per week). One movement path was observed just west of the Emulsion Road and Plant. Area 4 included the lake located just south of the Emulsion Plant. While Area 4 is not accessible by vehicle, it is near the Waste Rock Storage Area - South County Rock Pile (WRSA-SCRP) that has nearly continuous vehicle activity. Two caribou movement paths, BGCA14717 (female) and BGCA21160 (male) were observed on the western and southern sides of the lake in Area 4, but no paths were observed on the eastern portion, closer to the WRSA-SCRP.

### *Habitat Types*

Habitat (i.e., ELC) types were extracted to caribou locations from the eight caribou paths observed on East/West Islands in the 3 km buffer zone. The number of locations varied between the eight caribou paths, ranging from 3 to 439 locations per path. Weighted averages of habitat use ranged from 0.2% in riparian tall shrub and esker habitats to 39.4% in heath tundra (Table 12). The combined category of heath tundra (heath tundra, heath tundra [30-68% bedrock], and heath tundra [30-68% boulder]) was the most used habitat for all seasons and years and had a combined weighted average of 66% caribou use (Table 12). Other highly used habitats include sedge wetlands and birch seep and shrub. Habitat types that were infrequently used included tussock/hummock (1.4%), deep water (0.9%), bedrock complex (0.8%), and boulder complex (0.7%).

**Table 12: Percentage of caribou fix locations in each Ecological Landscape Classification (ELC) for each path**

| Season | Caribou ID | Herd | Year(a) | Sample size(b) | Percentage of fix locations in each ELC | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Heath Tundra | HT & 30% to 68% Bedrock | HT & 30% to 68% Boulder | Sedge Wetlands | Birch Seep & Shrub | Tussock /Hummock | Riparian Tall Shrub | Deep Water | Esker | Bedrock Complex | Boulder Complex |
| Spring migration | BGCA17105 | Beverly/ Ahiak | 2017 | 8 | 38 | 0 | 25 | 0 | 12 | 0 | 0 | 12 | 12 | 0 | 0 |
| Spring migration | BGCA20143 | Bathurst | 2021 | 69 | 45 | 10 | 22 | 13 | 3 | 0 | 0 | 0 | 0 | 7 | 0 |
| Fall | BGCA227 | Bathurst | 2010 | 3 | 67 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 |
| Winter | BGCA14717 | Beverly/ Ahiak | 2016 | 4 | 50 | 0 | 25 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter | BGCA17100 | Bathurst | 2017 | 7 | 43 | 0 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter | BGCA18138 | Beverly/ Ahiak | 2018 | 5 | 60 | 0 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Winter | BGCA18148 | Bathurst | 2018 | 55 | 55 | 4 | 5 | 9 | 20 | 5 | 2 | 0 | 0 | 0 | 0 |
| Winter | BGCA21160 | Bathurst | 2020 | 439 | 36 | 10 | 18 | 17 | 16 | 1 | 0 | 1 | 0 | 0 | 1 |
| **Average Percentage Weighted by Sample Size(c)** | | | | | **39.4** | **9.0** | **17.8** | **15.2** | **14.5** | **1.4** | **0.2** | **0.9** | **0.2** | **0.8** | **0.7** |

(a) Biological year.

(b) Number of caribou fix locations per caribou path.

(c) Percentage of each landcover type were averaged across all caribou paths (including all seasons and years) and weighted by sample size(b).

Abbreviations: ID = identification; HT = heath tundra; ELC = Ecological Landscape Classification.

# 4.0 DISCUSSION

Few caribou paths were observed within 3 km of the Mine during the study period. The average percent of collared individuals in each herd that encountered the 3 km buffer zone per year was 2.8% of the Bathurst herd and 0.8% of the Beverly/Ahiak herd. Most collared caribou with paths in the 3 km buffer zone were observed from 2017 to 2021 during the A21 Pit development phase. Few caribou were observed in the 3 km buffer zone during the underground mining phase in 2010 and 2016, and no collared caribou occurred within the 3 km buffer zone from in the underground phase from 2011 to 2015. However, the increase in collared caribou observations may not be related to the change in Mine phases, but instead due to the shift in seasonal ranges of the Bathurst herd and increased deployment of GPS collars in recent years. Historically, the Mine was not located within the winter range of the Bathurst herd (Gunn et al. 2002), but recent shifts in seasonal ranges after 2015 have now overlapped with the Lac de Gras area (Virgl et al. 2017; Poole et al. 2021). Most of the caribou paths were observed during the winter from 2016 to 2021, which coincides with the recent overlap of the winter range of the Bathurst herd with the Mine. Although caribou paths were observed more frequently in recent years, there were still very few collared caribou observed around the Mine during this study. This may indicate that only small portions of the Bathurst and Beverly/Ahiak herds used areas within 3 km of the Mine (such as on East Island).

Throughout the duration of this study, the spring migration, summer and fall seasonal ranges of the Bathurst and Beverly/Ahiak herds largely overlapped with the Lac de Gras area (Virgl et al. 2017; Golder et al. 2021; Poole et al. 2021). However, few caribou paths were observed within the 3 km buffer zone around the Mine during these seasons, and no collared caribou were observed during the summer season and only one in fall 2010. During spring migration, pregnant cows from the Bathurst and Beverly/Ahiak herds often use the Lac de Gras area during their northern migration to calving grounds to calf. However, during spring migration, a limited number of collared caribou were observed in the buffer zone around the Mine. This was unlike the study of Poole et al. (2021) who documented multiple caribou paths travelling through the buffer zones around the Ekati mine and often crossed the Ekati haul roads on their spring migration to calving grounds. The Mine is located on East Island in Lac de Gras, which would be frozen during spring migration. There may be little incentive for caribou to move across islands where snow conditions might be deeper and softer and decrease speed and prolong migration to calving areas. Winter was the most frequent season that collared caribou were present within the 3 km buffer zone around the Mine. This is consistent with the contraction of seasonal ranges during the Bathurst caribou decline phase (Virgl et al. 2017; Poole et al. 2021). This pattern may also be partly due to increased numbers of collars deployed from historic levels. Similar to Poole et al. (2021), there were no paths observed during the calving and post-calving periods, which was expected considering the calving and post-calving ranges are located farther to the northeast of the Mine (237 to 257 km from the Ekati Mine in 2019; Poole et al. 2021).

When estimating residency time (the amount of time an animal spends in an area) it is important to choose a metric that is suitable for the comparisons that will be made in the analysis. In this analysis, two residency metrics were calculated: Residency Metric 1 (hr/km$^2$) following the approach by Poole et al. (2021), and Residency Metric 2 (percent of time in a season). Residency Metric 1 accounts for differences in area (km$^2$) and allows for comparisons across areas of interest that vary in size (e.g., comparisons between different size buffer zones). Residency Metric 2 accounts for differences in the duration of seasons and is therefore more appropriate for comparisons *across* seasons. The seasons defined in this analysis were based on the ecology of barren-ground caribou and resulted in seasons that spanned different lengths of time throughout the year (e.g., spring migration lasted 42 days while winter lasted 138 days). Figure 4 demonstrates the need to account for season duration when comparing across seasons. In Figure 4 the summed residency time from Residency Metric 1 (hr/km$^2$) is depicted for each season, but because it does not standardize across the differing lengths of each season, across season estimates are misleading because residency is confounded with season duration.

Poole et al. (2021) calculated only residency metric, the hours spent per squared kilometre (referred to as Residency Metric 1 in this analysis). In their analysis, it was necessary to standardize the residency metric by area to correctly compare residency times across the different size buffer zones (as shown in Figure 7 of Poole et al. 2021). When they compared residency estimates *within* the same season (see Figure 7 in Poole et al. 2021), it was sufficient to use Residency Metric 1 (hr/km$^2$) because the duration of any particular season was invariable. However, this metric was less appropriate for comparing caribou residency times across different seasons as shown in Figures 8 and 9 (Poole et al. 2021), because it did not account for differences in seasonal duration. Comparing Residency Metric 1 across different seasons does not represent a biologically meaningful comparison. For example, two seasons may have the same value for Residency Metric 1, but in reality, a caribou may have used the area for 100% of a shorter season (e.g., spring migration) and only a small percentage of a longer season (e.g., winter); a distinction that is necessary for understanding how caribou use the area across different seasons. In this analysis, all residency time estimates were calculated within one buffer zone (i.e., 3 km around the Diavik Mine); therefore, it was not necessary to standardize residency metrics across area. Residency Metric 2 (percent of the season) was the only residency metric necessary for this analysis.

In most cases, collared caribou exhibited speeds and proportions of hard turns that were within the range of estimates for the associated reference group. Speeds within the 3 km buffer zone tended to be slightly faster than the mean speeds of the reference groups, but mostly overlapped with the variation of the estimate for reference groups (i.e., within 1 or 2 SD). Only one caribou (BGCA18138; female) in the winter of 2018 had a mean speed that exceeded the variation the Beverly/Ahiak reference group. This caribou also exhibited very low proportion of hard turns, indicating it travelled mostly in a straight line. The animal travelled from the mainland south of the Mine toward the south of East Island, remained on the southwest portion of East Island for less than a day, and then travelled south back toward the mainland at an elevated speed. There were no available behavioural survey data or blasting activity that correlated with this caribou's path, so it was not possible to assess potential explanations for this observed movement on East Island.

Caribou can exhibit increased movement rates for a variety of reasons that were not investigated in this analysis, including encounters with predators, seasonal insect harassment, herd dynamics, and travel through different habitat types and landscape configurations. For example, a behavioural survey documented the response of a group of caribou in winter 2020 to an approaching wolf. After seeing the wolf, the caribou ran in the opposite direction, aggregated together, and continued to watch the approaching wolf. A limitation of this analysis was that additional factors that can influence caribou behaviours (such as predators) were not investigated for potential correlations with caribou paths, other than those described in behavioural surveys and known mining activities. Nevertheless, almost all caribou with paths in the 3 km buffer zone, excluding caribou BGCA18138 (female), were consistent with the speeds exhibited by the reference groups. Additionally, most speed estimates in this analysis were comparable to those reported for collared caribou around the Ekati mine (Poole et al. 2021). However, Poole et al. (2021) suggested that the speeds of collared caribou were generally lower in areas closer to the Ekati mine (such as within the 3 km buffer zone).

Similar to speed, most turning angle distributions and proportion of hard turns exhibited by collared caribou near the Mine were similar to those of the reference groups, especially for caribou paths on East/West Islands. When caribou exhibited high proportions of hard turns and low speeds, the correlated behaviours from scan data mostly included feeding, bedding down, and standing. When hard turns are exhibited in a cluster by an ungulate this often indicates that the individual is moving back and forth within a small area (e.g., to feed in areas within a patch of forage) (Loureiro et al. 2007; Hammerschlag et al. 2012; Hodges et al. 2014). For example, caribou BGCA21160 (male) had many hard turns that were clustered within natural areas to the west of the Mine on East Island (movement path depicted on Figure 9). This individual resided on East Island for over two weeks during the winter of biological year 2020 and exhibited high proportions of hard turns and relatively low to moderate speeds. Multiple behavioural scans correlated well with the times that caribou BGCA21160 (male) occurred in heath tundra and heath boulder habitats on the western side of East Island.

Heath tundra and heath boulder are considered highly suitable habitats that provide forage for caribou (DDMI 1998; Golder et al. 2021). The behavioural surveys indicated that caribou in these areas spent most of their time feeding, walking, standing and bedded down. No caribou were observed reacting to a mining or human disturbance during behaviour scans. Based on the correlated behaviour scans, it is likely that the hard turns and lower speeds of this caribou were associated with foraging behaviours in suitable habitats on East Island. In contrast, Poole et al. (2021) assumed hard turns and lower speeds exhibited by caribou near a road were indicative of a delayed response to cross an active haul road. Unlike the Ekati mine, the Diavik Mine does not have haul roads that connect satellite pits to the core mine facilities (i.e., the Mine footprint is highly compressed and aggregated relative to the Ekati mine). Collared caribou that exhibited high proportions of turns around the Mine were not assumed to have a negative interaction with a road, but instead, were hypothesized to be carrying out normal daily activities such as foraging. The use of additional sources of information such as behaviour data and habitat information can help with the interpretation and understanding of collared caribou movement patterns.

Caribou on East Island mostly used natural areas dominated by suitable habitats of health tundra, health boulder and sedge wetland located to the west of the Mine. Caribou used natural areas adjacent to the PKC west dam, the windfarm/ammonium nitrate storage area, the west side of the Emulsion Road, and the southwest sides of a lake located south of the Emulsion Plant (see Figure 9 for depicted paths of caribou BGCA21160 (male) and BGCA20143 (female) that used these four areas). Caribou BGCA21160 (male) used the windfarm area and adjacent areas to the west over multiple days and again exhibited high proportions of hard turns likely associated with foraging behaviours (based on behavioural surveys). The windfarm area and other areas to the west of the Mine are predicted to provide suitable habitats for caribou on East Island and should not be physically altered by the Mine. The operations phase of the Mine is approaching completion (i.e., 2025) and expansion of the spatial boundary of the footprint is expected to be negligible.

Unsurprisingly, no caribou paths were observed near areas immediately adjacent to the Mine pits. Two pits on the north end of the Mine, A154 and A418, are adjacent to Lac de Gras and are mostly surrounded by deep water with little adjacent land. The land area just south of A418 and the North Winter Road Approach is dominated by heath tundra, heath boulder, and heath bedrock, the first two of which have high suitability for caribou, while heath bedrock has low suitability for caribou (Section 4.1.2 of the 2021 WMMR). The A21 Pit is mostly surrounded by deep water, but on the west side has adjacent land dominated with suitable habitat (heath tundra). Collared caribou did not approach this area despite the presence of highly suitable habitat. No collared caribou approached the undeveloped areas near the WRSA-SCRP. The natural areas adjacent to the WRSA-SCRP are dominated by heath tundra and heath boulder, both highly suitable caribou habitat. It is unknown if caribou did not approach the WRSA-SCRP to avoid the increased amount of haul traffic and other disturbances at this location, or if other factors influenced their lack of use in this area. Future monitoring of these areas for collared caribou and caribou observed in behavioural scans would help understand caribou movements around the Mine pits and WRSA-SCRP, provided caribou are present in these areas.

Four caribou were present on East/West Islands during blasting events. Nine blasting events took place while caribou BGCA21160 (male) resided on East Island and three blasts occurred when caribou BGCA20143 (female) was on East Island and West Island. On the dates of blasts, there did not appear to be large changes in caribou movements that would imply an adverse reaction to a blasting event (such as increased speeds, and reduced proportions of hard turns indicating fleeing behaviour). Because the closest distance a caribou was to the corresponding pit on a blast date was 2,223 m, it is possible that the individuals were far enough away to not exhibit a strong reaction or not experience the blast. However, the times of blasting events were not available, so it is possible that the caribou had a negative response to blast events, but this was not identifiable through movement metrics derived from fix frequencies at 1 to 8-hours. Thus, further investigation would need to be conducted using the specific times that blasting took place to identify whether caribou movements were influenced by blasting; however, it may still be challenging to correlate movement with blasts unless fix frequency is increased.

## Conclusions

Geo-fence collar data can be an effective tool to investigate movement behaviours of caribou near the Mine. However, the low sample sizes of caribou across biological years and seasons that used the area within 3 km of the Mine limited the inferences that could be made about caribou movement patterns. The low number of individuals that used areas near the Mine indicates that a small proportion of the Bathurst and Beverly/Ahiak herds interacted with the Mine and adjacent habitats. While geo-fence caribou collar data can help identify movements through the landscape surrounding the Mine, its application to assessing mitigation effectiveness is limited by fix rate and lack of on-the-ground detail about the environment experienced by the collared individual (e.g., vehicle traffic). For example, Poole et al. (2021) assumed that a higher proportion of turns ≥60º represented an adverse response to active haul roads at the Ekati mine. However, this analysis showed that often the patterns within 3 km were similar to the reference group, and when information on caribou behaviour and habitat was available, hard turns with lower speeds may alternatively indicate feeding behaviour. It is expected that collared caribou will continue to be observed near the Mine in future years as long as seasonal ranges continue to overlap with the Mine during the closure and post-closure phases. It is possible that geo-fence collar data could be used during closure and post-closure phases to inform on interactions with the reclaimed Mine site, which is a program included in the WMMP (DDMI 2021).

The correlations that were completed in this analysis were largely descriptive and limited because time-specific data were not available for the mining activities. More rigorous and possibly statistical correlations could be made with caribou movement paths during the closure and post-closure phases if the time of day and level of activity associated with flights, traffic, and other disturbances are collected. Additionally, recording time-specific data on type of traffic and volumes at areas of interest during closure and post-closure could improve future correlation analyses. Correlations with behavioural surveys proved helpful in understanding the associated behaviours of some caribou movements. Recording the presence of collared animals during behaviour scan surveys would increase confidence in the correlation of caribou movement with scanning behaviour data.

# 5.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

Yours Truly,

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https://golderassociates.sharepoint.com/sites/140080/project files/6 deliverables/issued/2380-tm-rev0-13000-caribou collar analysis/21452119-2380-tm-rev0-13000-ddmi_tm_caribou collar analysis 14jun_22.docx

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