REPORT

Commitment 38 Analyses

Caribou Movements Relative to Meliadine Mine and Other Factors

Submitted to:

Manon Turmel and Jennifer Range

Agnico Eagle Mines Ltd.

Submitted by:

WSP Canada Inc.

16820 - 107 Avenue, Edmonton, AB, T5P 4C3 Canada

+1 780 483 3499

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1 electronic PDF: Agnico Eagle Mines Ltd.

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1.0 INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) owns and operates Meliadine Gold Mine (the Project), which is located approximately 25 km north of Rankin Inlet, and 80 km southwest of Chesterfield Inlet in the Kivalliq Region of Nunavut. During technical discussions for the Meliadine Waterlines Project, the Kivalliq Inuit Association (KivIA) requested that Agnico Eagle complete an analysis of collared barren-ground caribou (*Rangifer tarandus groenlandicus*) movements relative to the Meliadine Mine (Mine) and All-weather Access Road (AWAR). Agnico Eagle committed (Commitment 38) to this analysis and to also include the KivIA, Ghotelnene Kohtineh Dene First Nation (GKD), and the Government of Nunavut (GN) for input into the study design.

Key points regarding the analysis for Commitment 38 include:

- A study area that reflects Zone of Influence (ZOI) around the Meliadine mine and mine roads.
- A definition of “deflection” that accounts for the observed behaviour of caribou paralleling the road or adjusting their course away from the road at any angle of movement.
- Agnico Eagle will consult with the interested parties on the size of the study area, the definitions of deflection and no crossing potential (using both Inuit Qaujimajatuqangit [IQ] and technical criteria and incorporating a definition that accounts for caribou paralleling the road), and incorporating other relevant covariates (e.g., insect harassment, daily traffic levels).

At the Terrestrial Advisory Group (TAG) meeting on 15 December 2022 (Agnico Eagle 2023a), Agnico Eagle solicited input on the study design to fulfill Meliadine Waterlines Commitment 38 (i.e., the ‘Commitment 38 study design’). Additional groups participating included the Baker Lake Hunters and Trappers Organization (BHTO) and the Nunavut Tunngavik Incorporated (NTI). Some of the items identified by TAG members at the meeting (Agnico Eagle 2023a) included defining the study objectives, defining the study area, and incorporating movement behaviours, such as paralleling, deflection, and crossing into the study design. The TAG also expressed interest in evaluating the AWAR and Mine ZOI using the proposed analyses, as well as including natural factors that influence caribou behaviour, such as insect harassment (Weladji et al. 2003; Witter et al. 2012).

At the TAG meeting on 13 April 2023, Agnico Eagle presented its study design proposal, which included inputs provided at the December TAG meeting and throughout the Waterline NIRB Review Process and solicited further input on the Commitment 38 study design. On 13 April 2023, Agnico Eagle obtained support from the TAG to proceed with execution of the Commitment 38 study (WSP 2023).

The main study objectives identified by the TAG in the 15 December 2022 (Agnico Eagle 2023a) and 13 April 2023 meetings are as follows:

- <u>Objective 1:</u> Evaluate caribou movement behaviours, including speed and directionality, in response to the AWAR and Mine. Evaluate caribou response to the AWAR and Mine, including deflection, crossing, and paralleling.
- <u>Objective 2:</u> Evaluate the presence and, if present, the spatial extent of a ZOI surrounding the AWAR and Mine on caribou.

2.0 METHODS

2.1 Telemetry Data Review

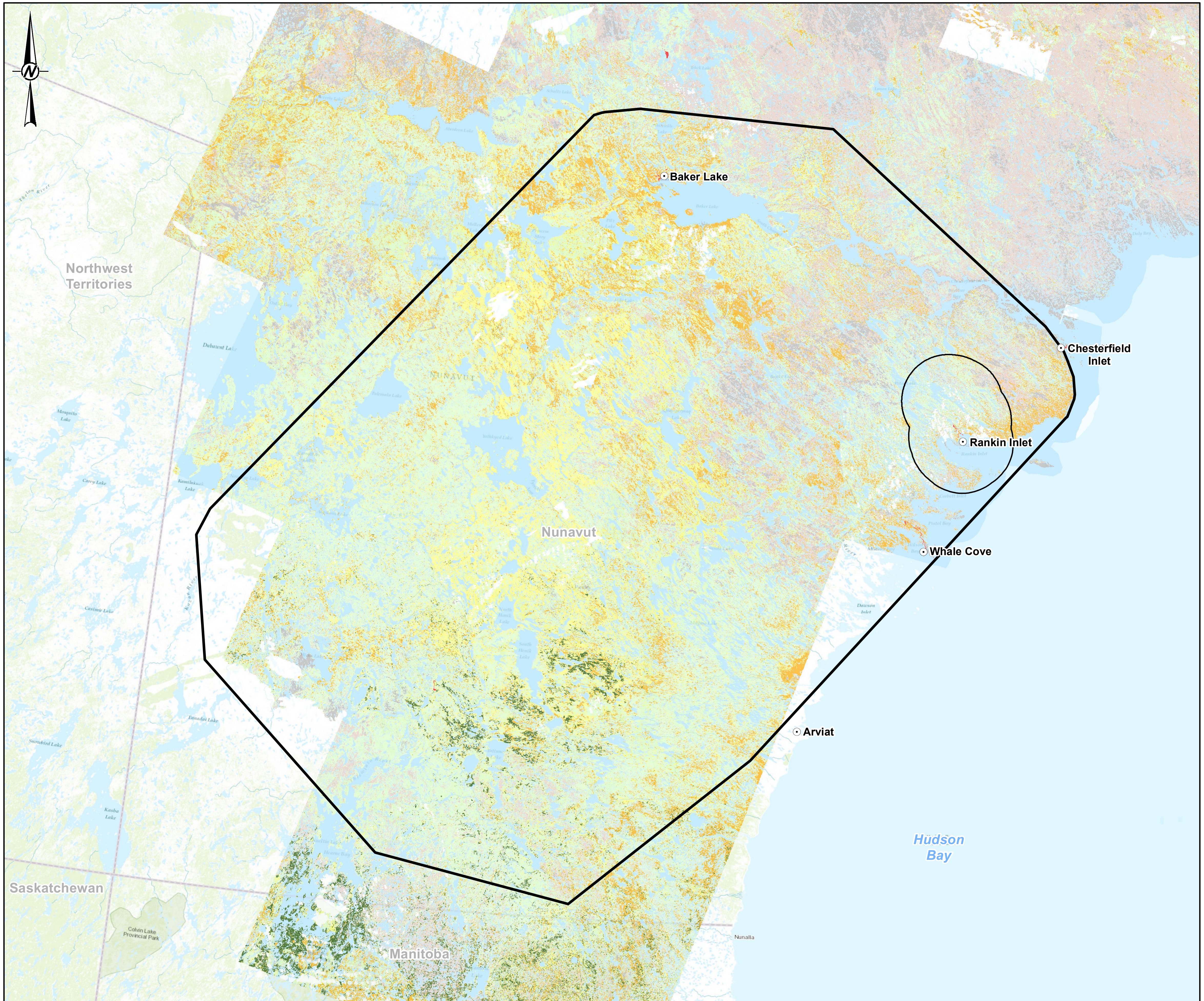
Caribou telemetry data (i.e., collar data) used in Commitment 38 analyses were provided by the GN. Telemetry data were first constrained to the Qamanirjuaq (QAM) herd. Because caribou capture dates were not provided, the first 14 days of data for each caribou were excluded to remove potential capture effects (Jung et al. 2019). Fix rates programmed to collars varied by year and/or collar and were not specified in the dataset. Thus, telemetry data were first reviewed to estimate the expected fix rate per caribou-year. The mode (i.e., most common) fix rate (i.e., interval of time between two subsequent relocations) was calculated then assigned to each caribou-year. Fix rates varied within the QAM herd; collars deployed from 2012 to 2022 usually collected fixes every four or six hours, but some collars deployed from 2012 to 2017 collected fixes every 12 or 24 hours. Once expected fix rates could be assigned to each caribou year, expected fix rates were used to resample telemetry data with the *amt* package (Signer et al. 2019) in *R* (R Core Team 2023), which cleans the telemetry data such that only one relocation is available per fix interval (e.g., four- or six-hour period) and removes any duplicate relocations. Finally, resampled movement trajectories for each QAM caribou-year were visualized using the *amt* package (Signer et al. 2019) in *R* (R Core Team 2023) to screen for erroneous locations.

2.2 Study Area

The study area for Commitment 38 analyses was defined using a two-part approach. The study area began as the 30-km buffered area surrounding the current delineation of the AWAR and Mine footprint, and the community of Rankin Inlet, then was updated to include areas where caribou cows and calves may be sensitive to disturbance (described below). The 30-km buffered area incorporated areas adjacent to the AWAR, Mine, and Rankin Inlet into the study area.

TAG members recommended that the study area also be biologically informed by calf age and the period when cows and calves may be vulnerable to disturbance (i.e., the three-week period following parturition, or giving birth to a calf). Calf age was considered in the study area definition by estimating caribou parturition dates for the QAM herd using methods established by DeMars et al. (2013) and Cameron et al. (2018), then subsetting QAM telemetry data to include relocations from the earliest date of parturition to 21 days after the latest date of parturition. Then, these subset data were used to create a 100% minimum convex polygon (called the 'post-parturition MCP'), which defined areas where QAM cows may have young calves susceptible to disturbance.

The maximum extent of the combined buffered 30-km study area and post-parturition MCP was merged to represent the Commitment 38 study area (Figure 1). All QAM caribou telemetry locations within the study area were considered in analyses.



LEGEND

- COMMUNITY
- COMMITMENT 38 STUDY AREA
- 30 km BUFFER OF AWAR/CURRENT MINE FOOTPRINT

ECOLOGICAL LAND CLASSIFICATION

- CLOUD/SHADOW
- DISTURBANCE
- GRAMINOID
- HEATH-FORB
- LICHEN
- NON-VEGETATED
- SHRUB
- TREED
- WATER

0 50 100
1:2,500,000 KILOMETRES

REFERENCE(S)

1. TOPOGRAPHIC MAP © ESRI AND ITS LICENSORS. USED UNDER LICENSE, ALL RIGHTS RESERVED.
2. DATUM: NAD83 PROJECTION UTM ZONE 15

CLIENT
AGNICO EAGLE
AGNICO EAGLE MINES LIMITED

PROJECT
MELIADINE GOLD PROJECT
NUNAVUT

TITLE
COMMITMENT 38 STUDY AREA

CONSULTANT

YYYY-MM-DD	2023-07-11
DESIGNED	MB
PREPARED	CDB
REVIEWED	MB
APPROVED	DC

PROJECT NO.	CONTROL	REV.	FIGURE
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2.2.1 Parturition Predictions

To create a biologically informed study area, predicted parturition dates were used to estimate a study area used by QAM caribou, post-calving. A method has previously been developed for barren-ground caribou (i.e., sometimes called the 'Individual-Based Method' or IBM; DeMars et al. 2013; Cameron et al. 2018), which allows information gathered using collars to be leveraged to predict parturition. Importantly, these methods do not actually measure or estimate pregnancy; rather, the IBM is based on female movement rates (DeMars et al. 2013; Cameron et al. 2018) in relation to expected parturition dates.

Female movement rates have been shown to decrease substantially when a calf is born (Nagy 2011). This sudden reduction in movement between collar locations (called a 'breakpoint') provides an estimate of a calving event (i.e., parturition) because the distance travelled between successive collar locations (i.e., 'step lengths') remains very small for several consecutive days. If the step length remains small after a breakpoint, then the calf likely survived the birth or neonatal period because the cow will typically remain in place to protect her newborn calf. If movement rate increases quickly after the breakpoint and to pre-breakpoint patterns, the calf likely died during the neonatal period (Nagy 2011; DeMars et al. 2013).

The IBM fits two models to caribou movement data (DeMars et al. 2013; Cameron et al. 2018): a constant mean movement model and a breakpoint model that identifies an apparent parturition event and followed by a mean linear increase in movement rate back to the cow's pre-breakpoint movement rate. Additionally, the breakpoint model can also identify an apparent neonate mortality event. Figure 2 provides examples of possible cow movement patterns, which correspond to a no-calving event, a calving event, and a neonate mortality event. Each model is evaluated for its relative fit to the data using Akaike's Information Criterion (AIC; Burnham and Anderson 2002). Information-theoretic approaches are described in the following paragraphs and, specifically, in Section 2.8.

Following Cameron et al. (2018), two sets of constraints were stipulated when executing the IBM for QAM female caribou: (1) the minimum number of sequential locations before and after a breakpoint could be assigned (referred to as *'int'*); and (2) the minimum and maximum number of locations it takes a cow to return to the pre-parturition movement rate (referred to as minimum '*kcon'* and maximum '*kcon'*). To estimate parturition for the QAM herd, an *int* = three days, minimum *kcon* = five days, and maximum *kcon* = 21 days were applied. Following Cameron et al. (2018), the telemetry data used as input in the IBM were constrained to 19 May to 15 July, each year. Because collars with fix rates up to 24 hours can reliably estimate parturition, all caribou-years from 2004 to 2022 (i.e., with fix rates varying from 4, 6, 12, to 24 hours) were used to estimate parturition, where sample sizes allowed.

For each QAM caribou-year, AIC values for each fitted model (i.e., no-calving event [M0], calving event [M1], and calf mortality event [M2]) were compared to understand the certainty surrounding parturition predictions. A competing top model was defined as any model within 2 AIC values (i.e., $\Delta AIC \leq 2.0$) of the top model (i.e., the model with the lowest AIC value; Burnham and Anderson 2002). If M0, M1, and M2 were all competing top models (i.e., $\Delta AIC \leq 2.0$), it was assumed that the data did not support parturition predictions because there was no certainty on which of the three potential outcomes occurred. If M0 and M1 were competing top models, it was assumed that parturition could not be determined. If M1 and M2 were competing top models, it was assumed that parturition occurred but whether there was a neonate mortality event was uncertain; estimated parturition dates from these models were carried forward to inform the study area. If M1 or M2 were not competing with another model, it was assumed that the predicted event (i.e., calving or mortality, respectively) occurred; estimated parturition dates from these models were also carried forward to inform the study area. If M0 was not competing with another model, it was assumed that no parturition occurred (this distinction was important for assessing mean daily movement as a function of parturition status; see Appendix A).

The study design (WSP 2023) indicated that where parturition could not be estimated from the movement data, a daily movement rate of five km/day would be used to determine whether cows had young calves, based on an assumption presented by the KivIA that cows with young calves move less than five km/day and that at around 21 days of age, calves are able to move more than five km/day. This assumption was tested using QAM telemetry data and results are presented in Appendix A. Because cows with calves were found to exceed five km of daily movements within a week of parturition, the five km/day movement threshold was not applied to inform which caribou may have calved or not.

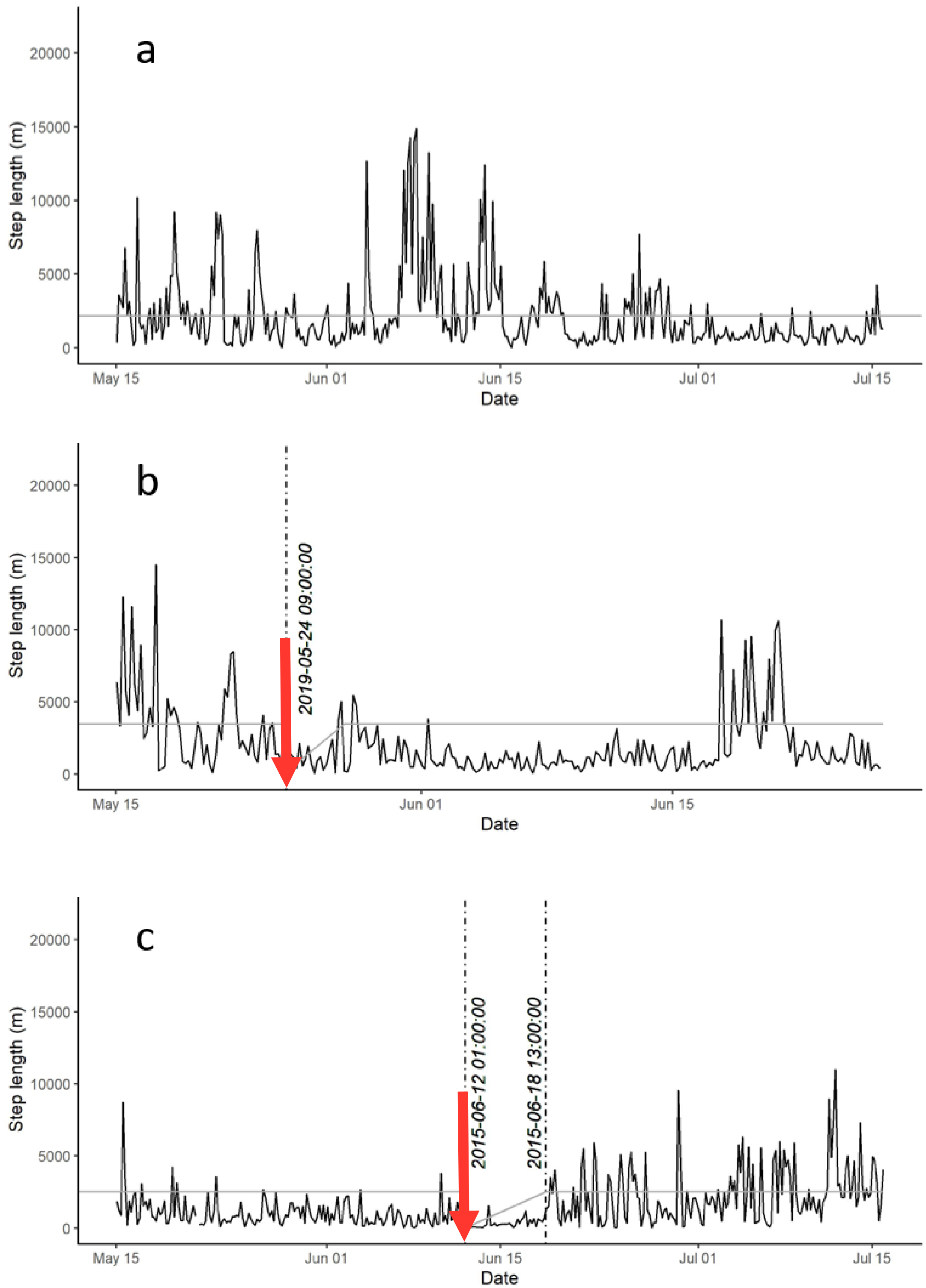

Figure 2: Examples of Individual Based Model predictions, including no-calving event (a), calving event (b), and neonate mortality event (c) from movements of collared caribou cows. Breakpoints are indicated with red arrows.

2.3 Modelling Approach: Integrated Step Selection Analysis

Integrated step selection analyses (iSSA; Avgar et al. 2016) were applied to meet the Commitment 38 study objectives. An iSSA is a type of movement analysis that relaxes the assumption that movement attributes (i.e., velocities and temporal autocorrelation) are independent from resource selection (Avgar et al. 2016). As such, an iSSA can simultaneously estimate movement and resource selection (Avgar et al. 2016, Prokopenko et al. 2017), which allows for greater flexibility in the types of hypotheses that can be tested. An iSSA uses a conditional logistic regression to model used and available steps, where available steps are informed by distributions of step length and turning angles made by an individual (Avgar et al. 2016). Informing available locations by step lengths and turning angles that an individual could realistically make is one of the unique benefits of an iSSA.

An iSSA is also unique in that movement parameters, including turning angle and step length, are included as covariates (i.e., variables) in models. The inclusion of these parameters allows the influence of habitat characteristics on movement parameters (e.g., step length, turning angle) to be quantified and evaluated. Specifically, responses to different habitat characteristics are quantified by comparing steps taken (i.e., 'used' steps, assigned use = '1') with steps that the caribou could have taken (i.e., 'available' steps, assigned use = '0'). These responses are presented as beta (β) coefficient estimates, where a positive beta coefficient indicates that caribou habitat selection is positively associated with the covariate of interest and a negative beta coefficient indicates that caribou habitat selection is negatively associated with the covariate of interest. A beta coefficient of zero indicates that caribou habitat selection is not related to the covariate of interest.

Although the study area and QAM parturition predictions were informed by caribou-years with any fix rate (i.e., 4, 6, 12, or 24-hour fix rates), iSSA were informed by only caribou-years with four-hour fix intervals. This is because the step length parameter depends on consistent fix intervals between relocations (i.e., inferring speed from step length is only possible when the time between fixes is constant). Thus, used steps were informed by telemetry locations from caribou-years with four-hour fix intervals within the study area and were defined as straight line distances between two consecutive relocations. Turning angle and step length distributions for an individual caribou-year were informed from mean headings and mean step lengths, calculated over a 28-hour period. This period represented the general direction and speed of the caribou and included the 20 hours preceding (i.e., five steps preceding), the step itself, and the four hours following (i.e., one step following) each step. For every used location, 10 random available steps were created.

2.4 Season

Telemetry data used in iSSA were constrained to post-calving and summer seasons. Calving can occur as early as 21 May in the QAM herd, so iSSA included data from 21 May to 22 August (i.e., the end of summer; Caslys 2015), each year.

2.5 Population Estimates

The iSSA models within each candidate set were estimated for each caribou-year (i.e., at the individual level as recommended by the TAG) using conditional logistic regression from the *survival* package (Therneau and Grambsch 2000; Therneau 2023) in *R* (R Core Team 2023). The resulting candidate set was ranked from best-fitting model to least-fitting model, where the top model and any competing models (i.e., ΔAIC ≤ 2.0) were ranked best-fitting. The number of occurrences as a competing top model was calculated for each model in a candidate set; the model with the most occurrences as a competing top model across all individual caribou-years was considered the population model. The population model, regardless of whether it was a top model or not for a particular caribou-year, was fit to all caribou-years using the *survival* package (Therneau and Grambsch 2000; Therneau 2023), then bootstrapped with 5,000 replicates to generate population-level beta coefficients and 95% confidence intervals (CI) from individual caribou-years using the *boot* package (Canty and Ripley 2022) in *R* (R Core Team 2023). Where possible population-level estimates were generated using at least three caribou-years and a cut-off of 20 used steps; however, the cut-off was decreased for some candidate sets to a minimum of 10 used steps due to data limitations. The proportion of caribou-years that qualitatively followed the population trend (i.e., the same direction of response as the population mean) was then calculated per model coefficient.

2.6 Covariates

Movement and spatial-temporal covariates were developed for iSSA (Table 1, Table 2) and were extracted spatially or temporally to the endpoints of each used and available step, based on geographic coordinates or rounded hourly timestamps, respectively. Some spatial-temporal covariates were available daily, in which case these covariates were extracted to used and available steps based on the day. Covariates without adequate spatial and/or temporal coverage were not considered in iSSA models. All covariates were assessed for multicollinearity and if covariates were highly correlated ($R \geq 0.70$), only one highly correlated covariate was retained for analyses.

Table 1: Proposed Movement Covariates for Inclusion in Integrated Step Selection Analyses (iSSA)

Covariate(s)	Covariate Code	Source	Brief Description and/or Definition	Expected Relationship with Caribou
Deflection step	DeflectionStep	Calculated from telemetry data, in reference to AWAR and Mine	▪ Coded as a binary covariate, which describes whether step was a deflection step (1) or not (0). ▪ Both used and available steps were assigned a 0 or 1 for deflection. ▪ Occurs only within five km of the AWAR and/or Mine. ▪ Deflection is defined as a turning angle ≥ 60° between the heading of the step and the average heading of the individual caribou's movement. ▪ The general direction of the individual caribou's movement was calculated using a moving window, over the 20-hour period preceding and four-hour period following each step and reflect the mean turning angle during this period (i.e., moving window).	Whether a caribou deflects from the AWAR and Mine may be influenced by: ▪ whether the alternative (i.e., available steps) would require the caribou to cross the AWAR or Mine, ▪ how long the caribou has been in the vicinity of the AWAR or Mine, ▪ distance to AWAR and Mine (e.g., the caribou selects habitat further from the disturbance), ▪ land cover (e.g., the caribou wants to move away from poor forage or the caribou selects good forage).
Paralleling step	ParallelStep	Calculated from telemetry data, in reference to AWAR and Mine	▪ Coded as a binary covariate, which describes whether step was a paralleling step (1) or not (0). ▪ Both used and available steps were assigned a 0 or 1 for paralleling. ▪ Occurs only within five km of the AWAR and/or Mine. ▪ Paralleling is defined as a turning angle of either 0° or 180° (± 10°) between the heading of the step and the general heading of the AWAR or Mine infrastructure. ▪ The general heading of the AWAR or Mine was estimated by creating ordered points every 250 m along the AWAR and Mine footprint perimeter, then estimating a straight line with a heading from north between two subsequent perimeter points. The nearest AWAR or Mine perimeter segment to each used or available step was used to calculate paralleling steps.	Whether a caribou parallels the AWAR and Mine may be influenced by: ▪ whether the alternative (i.e., available steps) would require the caribou to cross the AWAR or Mine, ▪ land cover (e.g., the caribou wants to move away from poor forage or the caribou selects good forage).
Crossing step	CrossingStep	Calculated from telemetry data, in reference to AWAR and Mine	▪ Coded as a binary covariate, which describes whether step was a crossing step (1) or not (0). ▪ Both used and available steps were assigned a 0 or 1 for crossing. ▪ Occurs only within five km of the AWAR and/or Mine. ▪ Crossing steps are defined as a step that intersected the AWAR and/or Mine.	Whether a caribou crosses the AWAR or Mine may be influenced by: ▪ land cover (e.g., the caribou wants to move away from poor forage or the caribou selects good forage), ▪ how long the caribou has been in the vicinity of the AWAR or Mine, ▪ how many other crossing events have taken place (i.e., by other caribou in the herd).
Step length	StepLength	Calculated from telemetry data	▪ Straight line distance between two consecutive relocations (Avgar et al. 2016). ▪ Transformed as the natural logarithm (ln) of step length for use in iSSA. ▪ Indicates movement rate (i.e., speed) when fix rates are constant. ▪ Longer steps between consecutive relocations are the result of caribou moving at higher speeds vs. shorter steps between consecutive relocations.	▪ Inclusion of step length supports iSSA modelling (Avgar et al. 2016). ▪ Can interact with other covariates (e.g., distance to AWAR and Mine) to understand how speed varies with distance from AWAR and Mine.

Table 1: Proposed Movement Covariates for Inclusion in Integrated Step Selection Analyses (iSSA)

Covariate(s)	Covariate Code	Source	Brief Description and/or Definition	Expected Relationship with Caribou
Turning angle	TurnAngle	Calculated from telemetry data	▪ Angular deviations between the headings of two consecutive steps (Avgar et al. 2016). ▪ Transformed as the cosine of turning angle for use in iSSA. ▪ By using cosine transformation, circular measure becomes a linear correlation factor between -1 and 1, where a negative value indicates moving backwards from the previous relocation and a positive value indicates moving forwards from the previous relocation. Zero indicates a random walk. ▪ Indicates directionality of movement.	▪ Inclusion of turning angle supports iSSA modelling (Avgar et al. 2016). ▪ Can interact with other covariates (e.g., distance to AWAR and Mine) to understand how turning angles vary at increasing distance from AWAR and Mine.

AWAR = All-weather Access Road

Table 2: Proposed Spatial-Temporal Covariates for Inclusion in Integrated Step Selection Analyses (iSSA). Covariates retained for iSSA are bolded.

Covariate(s)	Covariate Code	Source	Brief Description and/or Definition	Expected Relationship with Caribou	Retained for Analyses
▪ **All-terrain vehicle (ATV) traffic[a]**	▪ **ATVTraffic**	▪ Remote camera data (ERM 2023)	▪ Remote camera data were available for June and July 2020 to 2022 (*n* cameras = 23 in 2020; *n* = 4 in 2021; *n* = 3 in 2022). ▪ Maximum daily counts of ATVs, pooled across cameras, were calculated each year. ▪ ATV traffic was included as an estimate of daily harvest-related traffic; however, not all ATVs are related to harvest.	▪ Caribou movement may be influenced by harvest-related traffic.	Yes
▪ **AWAR and Mine closure status**	▪ NA	▪ Meliadine Mine caribou advisory data	▪ Open vs. closed status of AWAR and Mine. ▪ Any form of restriction or closure on the AWAR or at the Mine was assumed to represent a closure[b]. ▪ Temporal covariate that determines which data occur in Treatment Group 2 vs. Treatment Group 3 (see Section 2.7).	▪ Caribou movement may be influenced by closures and restrictions on the AWAR and at the Mine. ▪ Caribou may move faster and more directionally when no closures or restrictions are in place.	Yes – to inform treatment groups
▪ Calf age	▪ NA	▪ Estimated based on parturition dates, which were predicted using telemetry data	▪ Where sufficient data existed, predicted parturition dates (Section 2.2.1) were used to estimated calf age to a maximum age of 21 days. ▪ Refer to Appendix A for more information.	▪ Female caribou with young calves may stop more frequently to allow calves to rest, which impacts mobility/movement.	No – see Appendix A
▪ **Caribou hunter harvest[a]**	▪ **Harvest**	▪ Hunter harvest survey data (Agnico Eagle 2023b)	▪ Hunter harvest survey data were available for certain spatial grid cells, 2021 and 2022. ▪ Hunter harvest was included as a spatial and temporal estimate of harvest pressure.	▪ Caribou may move differently when hunter harvest is high, or in areas where hunter harvest is high, compared to when and where harvest is lower.	Yes

Table 2: Proposed Spatial-Temporal Covariates for Inclusion in Integrated Step Selection Analyses (iSSA). Covariates retained for iSSA are bolded.

Covariate(s)	Covariate Code	Source	Brief Description and/or Definition	Expected Relationship with Caribou	Retained for Analyses
▪ **Cumulative growing degree days above 0°C**	▪ **GrowingDays**	▪ Meliadine Mine and Rankin Inlet weather monitoring station data ▪ CARMA MERRA (Russell et al. 2013)	▪ Included based on feedback from TAG. ▪ Both linear and quadratic terms were considered. A quadratic term was considered based on relationship between calf age and cumulative daily movement, presented in Appendix A. ▪ Cumulative growing degree days above 0°C, calculated daily (equation available in Russell et al. 2013). ▪ Due to spatial and temporal resolution of CARMA MERRA data, hourly weather data from Meliadine Mine and Rankin Inlet weather monitoring stations were used to calculate this covariate. ▪ Data were assigned to steps based on whichever weather station was closer. ▪ Considered in base habitat model (see Section 2.8.1).	▪ If there have been more growing degree days, vegetation should be greener and caribou should move less directionally and more slowly.	Yes
▪ **Days since entering AWAR and Mine vicinity**	▪ **DaysVicinity**	▪ AWAR and Mine footprint ▪ Telemetry data	▪ Days since first entering the AWAR and Mine vicinity, where the vicinity was defined as a 5-km buffer surrounding the AWAR and Mine, calculated per caribou-year. ▪ Once a caribou entered the vicinity, all subsequent steps were assigned a number of ‘days since entering the AWAR and Mine vicinity’, regardless of whether the caribou exited and re-entered the vicinity. ▪ The maximum number of days that was applied was based on the day that the caribou left the vicinity and did not re-enter that summer season.	▪ Caribou may be more likely to cross the AWAR and Mine (and less likely to deflect or parallel) if they have been within five km of the AWAR and Mine for many days.	Yes
▪ Distance to AWAR ▪ **Distance to AWAR-Mine** ▪ Distance to Mine ▪ Distance to Rankin Inlet	▪ DistanceAWAR ▪ **DistanceAWARMine** ▪ DistanceMine ▪ DistanceRankin	▪ Mine footprint ▪ Settlement data for Nunavut	▪ Multiple covariate options considered, based on feedback from TAG.	▪ Caribou may move faster and more directionally when near the Mine and/or AWAR. ▪ Caribou may deflect from Mine and/or AWAR. ▪ Caribou may exhibit paralleling behaviour in response to Mine and/or AWAR. ▪ Caribou may cross AWAR after deflecting or paralleling. ▪ Nearby settlements (e.g., Rankin Inlet) may influence caribou movement.	Yes, however, some covariates were highly correlated (see Appendix B)

Table 2: Proposed Spatial-Temporal Covariates for Inclusion in Integrated Step Selection Analyses (iSSA). Covariates retained for iSSA are bolded.

Covariate(s)	Covariate Code	Source	Brief Description and/or Definition	Expected Relationship with Caribou	Retained for Analyses
▪ Elevation ▪ Terrain Ruggedness Index ▪ Topographic Position Index ▪ Vector Terrain Ruggedness	▪ Elevation ▪ TerrainRuggedness ▪ TopoPosition ▪ VectorRuggedness	▪ Canadian Digital Elevation Model (DEM)	▪ Topographic covariates were considered based on feedback from TAG. ▪ Elevation was measured in metres above sea level. ▪ Two terrain ruggedness indices were applied: Terrain Ruggedness Index (TRI; which indicates the amount of elevation difference between adjacent cells of a DEM) and Vector Terrain Ruggedness (VTR; which measures ruggedness as the variation in three-dimensional orientation of grid cells within a neighbourhood while accounting for slope and aspect). ▪ Topographic Position Index helps differentiate between being on top of a hill vs. in a concave low-lying area. ▪ Covariates were considered in base habitat model (see Section 2.8.1).	▪ Topography may influence levels of insect harassment, energy expenditure, and caribou line of sight (e.g., ability to visualize AWAR and Mine, predators).	No (see Appendix B)
▪ Enhanced vegetation index (EVI) ▪ **Normalized difference vegetation index (NDVI)**	▪ EVI ▪ **Greenness**	▪ United States Geological Survey (USGS)	▪ Included based on feedback from TAG. ▪ Indices of vegetation greenness. ▪ Covariates were considered in base habitat model (see Section 2.8.1). ▪ All NDVI or EVI images (with sufficiently low cloud and snow cover) available between 9 June and 22 August, each year, were averaged to calculate a mean NDVI and mean EVI, per year.	▪ Caribou track green up in early summer and are expected to select more green areas during the post-calving period.	Yes, however, some covariates were highly correlated (see Appendix B)
▪ **Mosquito Index** ▪ Oestrid Index	▪ **MosquitoIndex** ▪ OestridIndex	▪ Meliadine Mine and Rankin Inlet weather monitoring station data ▪ CARMA MERRA (Russell et al. 2013)	▪ Included based on feedback from TAG. ▪ Insect harassment indices based on weather and temperature and calculated hourly (equations available in Russell et al. 2013). ▪ Due to spatial and temporal resolution of CARMA MERRA data, hourly weather data from Meliadine Mine and Rankin Inlet weather monitoring stations were used to calculate this covariate. ▪ Data were assigned to steps based on whichever weather station was closer. ▪ Considered in base habitat model (see Section 2.8.1).	▪ Caribou are expected to move faster when insect harassment is high.	Yes; however, some covariates were highly correlated (see Appendix B)
▪ **Land cover**	▪ **Graminoid** ▪ **HeathForb** ▪ **Lake** ▪ **Lichen** ▪ **NonVegetated** ▪ **Shrub**	▪ Kivalliq Land Cover Data	▪ Ecological land cover reclassified into six relevant groupings based on reclassifications used by Boulanger et al. (2020; Appendix C). ▪ Reclassified land cover covariates were calculated based on proportion of each target land cover within a 250-m moving window. ▪ Land cover was considered in base habitat model (see Section 2.8.1). ▪ Note that Kivalliq Land Cover Data were not available for some portions of the study area (see Appendix C), so telemetry data in these regions could not be included in analyses.	▪ Caribou are expected to select land cover where preferred forage is available (e.g., heath/forb) and avoid land cover where movement is more difficult (e.g., lakes) or where forage is not available (e.g., non-vegetated).	Yes

Table 2: Proposed Spatial-Temporal Covariates for Inclusion in Integrated Step Selection Analyses (iSSA). Covariates retained for iSSA are bolded.

Covariate(s)	Covariate Code	Source	Brief Description and/or Definition	Expected Relationship with Caribou	Retained for Analyses
▪ **Number previous AWAR and/or Mine crossings**	▪ **CumulCrossings**	▪ AWAR and Mine footprint ▪ Telemetry data	▪ Temporal movement covariate representing the daily cumulative number of AWAR or Mine crossings by collared caribou per year.	▪ Caribou may be more likely to cross the AWAR and Mine (and less likely to deflect from or parallel) if many others have already crossed the AWAR and/or Mine.	Yes
▪ **Total AWAR traffic[(a)]** ▪ Project AWAR traffic ▪ Local AWAR traffic	▪ **AWARTrafficTotal** ▪ AWARTrafficProject ▪ AWARTrafficLocal	▪ Meliadine Mine traffic counter data	▪ Considered based on feedback from TAG. ▪ Daily Project-related and non-Project-related (i.e., local) vehicle traffic on the AWAR.	▪ Caribou movement may be influenced by traffic rates on the AWAR. ▪ Caribou may move faster and more directionally when traffic is high, compared to when traffic is low.	Yes, however, some covariates were highly correlated (see Appendix B)

AWAR = All-weather Access Road; CARMA = CircumArctic *Rangifer* Monitoring and Assessment; MERRA = Modern Era Retrospective Analysis for Research and Applications

a) These covariates had a limited spatial and/or temporal extent and were therefore tested in a subset candidate set (more information in Section 2.8).

b) This assumption was made to conservatively assign AWAR closure status and, subsequently, treatment groups. Further, this assumption allowed for a more balanced sample size of caribou-years in Treatment Groups 2 and 3 (more information on treatment groups in Section 2.7).

2.7 Treatment Groups

Caribou were classified into four treatment groups based on their potential to interact with the AWAR and Mine, whether they interacted with the AWAR during Advanced Exploration and Construction and Operations development phases, and whether they interacted with the AWAR while it was open or closed to Project traffic (Table 3). This approach is consistent with the recommendations of Flydal et al. (2019), which highlights the importance of including reference and/or baseline data to strengthen inferences about effects from development disturbance.

Caribou locations that occurred within (and up to) 15 km from the AWAR and Mine had the potential to interact with the AWAR and/or Mine (‘AWAR and Mine interactors’; Table 3). Caribou were assigned to treatment groups based on whether they interacted with the AWAR during one of two development phases: Advanced Exploration (i.e., from 2012 to 2017, when AWAR had mostly public use) or Construction and Operations (i.e., from 2018 to 2022, when AWAR had public and Project use). All AWAR and Mine interactors in the Construction and Operations phase were assigned an AWAR closure status (i.e., ‘open’ or ‘closed’; Table 3). Treatment Group 4 (‘Control’) included caribou telemetry locations farther than 15 km from the AWAR and Mine (Table 3), but within the study area.

Caribou-years were assigned to each treatment group to account for individuals that were in one group in year *t* and in another group in year *t*+1. For example, an individual caribou could be in Treatment Group 2 in year 2019 and Treatment Group 4 in 2020. The sample size of caribou-years and telemetry locations available for Treatment Group 1 depended on how many caribou interacted with the AWAR and Mine during Advanced Exploration. The sample size of caribou-years and telemetry locations in Treatment Group 2 depended on how many caribou interacted with the AWAR and Mine while the AWAR was ‘open’, acknowledging that the AWAR was closed to Project traffic once 50 or more caribou were observed within 100 m of the road. The sample size of caribou-years and telemetry locations in Treatment Group 3 depended on the cumulative duration of AWAR closures between 2018 and 2022. The sample size of caribou-years and telemetry locations for Treatment Group 4 depended on the maximum extent of the study area.

Table 3: Spatial and temporal subsets of caribou-years, based on potential for caribou to interact with the All-Weather Access Road (AWAR) and Mine, AWAR and Mine development phase, and AWAR and Mine closure status, resulting in four treatment groups.

Potential to Interact with AWAR and Mine	Temporal Subsets		Resulting Treatment Groups
	AWAR and Mine Development Phase	AWAR and Mine Closure Status	
AWAR and Mine interactors (i.e., comprised of telemetry locations ≤ 15 km of the AWAR and/or Mine; when caribou were in this area, they had the potential to interact with the AWAR and/or Mine)	**Advanced Exploration** (i.e., primarily public use; 2012 to 2017)	NA	**Treatment Group 1:** AWAR and Mine interactors × Public use
	Construction and Operations (i.e., public and Project use; 2018 - 2022)	**Open**	**Treatment Group 2:** AWAR and Mine interactors × Public and Project use × Open
		Closed	**Treatment Group 3:** AWAR and Mine interactors × Public and Project use × Closed
Control (i.e., comprised of telemetry locations > 15 km from the AWAR and/or Mine; when caribou were in this region, they had no potential to interact with the AWAR and/or Mine)	NA; data spanned same time period as AWAR and Mine interactors (i.e., Treatment Groups 1 to 3, or 2012 to 2022)	NA	**Treatment Group 4:** Control

2.8 Candidate Models

Candidate sets of models were developed *a priori* and applied to relevant treatment groups to meet Commitment 38 study objectives. In general, candidate sets of models included a base habitat model, which was developed to account for general habitat selection (Section 2.8.1), and several numbered test models, which were developed to test specific hypotheses related to explaining why caribou likely exhibit certain movement patterns.

An information-theoretic approach was used to evaluate the candidate sets of models (Burnham and Anderson 2002). Information theory is based on the concepts of simplicity and parsimony, which suggest that the simplest explanation is probably the most likely. AIC balances explanatory value with the number of covariates when evaluating a model by assigning a penalty for the number of model parameters. Each candidate set was ranked by delta AIC (ΔAIC), or the difference between the AIC of the best fitting model (i.e., top model) and each model in the set. A competing top model was defined as any model within two AIC values (i.e., ΔAIC ≤ 2.0) of the top model (Burnham and Anderson 2002).

2.8.1 Base Habitat Model

Table 4 presents the candidate set of models used to develop a base habitat model. Each model included the two standard iSSA movement parameters, StepLength and TurnAngle (defined in Table 1), and a single habitat covariate, and were estimated for each caribou-year, regardless of treatment group. Each caribou-year's candidate set was ranked from smallest to largest ΔAIC (i.e., from best-fitting to least-fitting model) and the four models that occurred most often in the top five were used to inform the covariates included in the base habitat model.

Table 4: Candidate set of models used to select habitat covariates for the base habitat model.

Model Name	Model Structure[a]
Habitat 1	Greenness + StepLength +TurnAngle
Habitat 2	MosquitoIndex + StepLength +TurnAngle
Habitat 3	Lichen + StepLength +TurnAngle
Habitat 4	HeathForb + StepLength +TurnAngle
Habitat 5	Graminoid + StepLength +TurnAngle
Habitat 6	Shrub + StepLength +TurnAngle
Habitat 7	Lake + StepLength +TurnAngle
Habitat 8	NonVegetated + StepLength +TurnAngle
Habitat 9	GrowingDays*StepLength + StepLength +TurnAngle
Habitat 10	TerrainRuggedness + StepLength +TurnAngle
Habitat 11	VectorRuggedness + StepLength +TurnAngle
Habitat 12	TopoPosition + StepLength +TurnAngle
Habitat 13	$GrowingDays^2$*StepLength + StepLength +TurnAngle

a) An asterisk (*) indicates an interaction between two covariates.

2.8.2 Caribou Movement: Influence of All-Weather Access Road and Mine

Table 5 presents the candidate set of models used to evaluate changes to caribou movement, including speed and directionality, in response to the AWAR and Mine, while also considering additional natural factors. The caribou movement candidate set was applied to caribou-years from Treatment Groups 1 to 3 (i.e., 2012 to 2022, ≤ 15 km of AWAR and/or Mine) to compare model results for caribou that interacted with the AWAR and Mine between two development phases (i.e., Advanced Exploration and Construction and Operations) and while the AWAR and Mine were open and closed. Population-level beta coefficients and 95% CI were informed by caribou-years with at least 20 used steps.

Table 5: Candidate models to evaluate influence of the All-Weather Access Road (AWAR) and Mine and land cover on caribou movement, 2012 to 2022, within 15 km of the AWAR and/or Mine.

Model Name	Model Structure[a]	Hypotheses Being Tested
Habitat	Lake + Greenness + HeathForb + GrowingDays*StepLength + TurnAngle	Accounts for basic covariates expected to influence caribou habitat selection, regardless of AWAR and Mine, during post-calving and summer seasons.
Model 1	Habitat + DistanceMineAWAR*TurnAngle + DistanceMineAWAR*StepLength	Tests hypothesis that caribou speed and directionality varies as a function of distance to AWAR and Mine.
Model 2	Habitat + Lake*TurnAngle + Lake*StepLength	Caribou appear to avoid lakes, which may cause movement patterns that may look like avoidance of the AWAR and Mine (if lakes are close to the Mine). This model tests the hypothesis that speed and directionality will vary as a function of lake land cover in area.
Model 3	Habitat + Graminoid*TurnAngle + Graminoid*StepLength	These models test the hypothesis that speed and directionality will vary as a function of different land cover classes. Caribou are expected to have less directional movement and shorter steps when foraging such as when in heath-forb or lichen land cover. Caribou are expected to have more directional movement and longer steps where forage is not available, such as in non-vegetated land cover.
Model 4	Habitat + Shrub*TurnAngle + Shrub*StepLength	
Model 5	Habitat + Lichen*TurnAngle + Lichen*StepLength	
Model 6	Habitat + NonVegetated*TurnAngle + NonVegetated*StepLength	
Model 7	Habitat + HeathForb*TurnAngle + HeathForb*StepLength	
Model 8	Habitat + Greenness*DistanceMineAWAR + HeathForb*DistanceMineAWAR + Lichen*DistanceMineAWAR	These models test the hypothesis that caribou movement behaviours vary while foraging as a function of distance to AWAR and Mine. If proximity to AWAR and Mine influences caribou, caribou should vary step length and directionality when foraging and/or when moving through non-vegetated areas. Comparing these models with Models 3–7 will help to understand the interaction of land cover and proximity to the Project.
Model 9	Habitat + NonVegetated*DistanceMineAWAR	

a) An asterisk (*) indicates an interaction between two covariates.

2.8.3 Caribou Movement: Influence of Harvest and Traffic

Table 6 presents the candidate set of models used to evaluate changes to caribou movement, including speed and directionality, in response to the AWAR and Mine, while also evaluating changes in movement due to caribou harvest pressure, ATV traffic, and total AWAR traffic. The caribou harvest candidate set was applied using a subset of telemetry data from June and July 2021, within 15 km of the AWAR and/or Mine, when harvest and traffic data were available, and for Treatment Groups 2 and 3. Data were insufficient to constrain population-level beta coefficients to caribou-years with ≥ 20 used steps, so the cut-off of ≥ 15 used steps was used.

Table 6: Candidate models to evaluate influence of the All-Weather Access Road (AWAR) and Mine, caribou harvest, and AWAR traffic on caribou movement in June and July 2021, within 15 km of the AWAR and/or Mine.

Model Name	Model Structure[(a)]	Hypotheses Being Tested
All candidate models from Table 5 plus the following three models		
Model 10[(b)]	Habitat + AWARTrafficTotal*TurnAngle + AWARTrafficTotal*StepLength	This model tests the hypothesis that caribou speed and directionality is influenced by traffic volume on the AWAR.
Model 11[(b)]	Habitat + ATVTraffic*TurnAngle + ATVTraffic*StepLength	This model tests the hypothesis that caribou speed and directionality is influenced by ATV traffic on the AWAR.
Model 12[(b)]	Habitat + Harvest*TurnAngle + Harvest*StepLength	This model tests the hypothesis that caribou speed and directionality is influenced by harvest pressure.

a) An asterisk (*) indicates an interaction between two covariates.

b) For a subset of time when AWARTrafficTotal, ATVTraffic, and Harvest data were available (i.e., June and July 2021), Models 1 to 12 were estimated.

2.8.4 Crossing, Deflection, and Paralleling Steps: Influence of All-Weather Access Road and Mine

Specific movement responses, including crossing, deflection, and paralleling, were defined collaboratively by the TAG and described in Table 1. Candidate sets of models presented in Tables 7 to 9 were designed to test hypotheses related to how specific movement responses (i.e., crossing, deflection, paralleling) vary as a function of land cover and proximity to AWAR and Mine. Crossing, deflection, and paralleling candidate sets were applied to Treatment Groups 1 to 3, within five km of the AWAR and/or Mine (described in Table 1). Data were insufficient to constrain population-level beta coefficients to caribou-years with ≥ 20 used steps, so the cut-off of ≥ 10 used steps was used.

Table 7: Candidate models to evaluate caribou crossing behaviour, in response to the All-Weather Access Road (AWAR) and Mine, 2012 to 2022, within five km of the AWAR and/or Mine.

Model Name	Model Structure[(a)]	Hypotheses Being Tested
Habitat	Lake + Greenness + HeathForb + GrowingDegreeDays*StepLength + TurnAngle	Accounts for basic covariates expected to influence caribou habitat selection, regardless of AWAR and Mine, during post-calving and summer.
Model 1	Habitat + DistanceMineAWAR*CrossingStep	This model tests whether caribou crossing the AWAR and/or Mine is a function of proximity to AWAR and/or Mine.
Model 2	Habitat + NonVegetated*CrossingStep	These models test whether caribou cross the AWAR and/or Mine as a function of land cover at the end of their step. For example, a caribou may cross to avoid non-vegetated land cover or lakes, or may cross to seek out forage (e.g., heath-forb, lichen).
Model 3	Habitat + Lake*CrossingStep	
Model 4	Habitat + Shrub*CrossingStep	
Model 5	Habitat + Graminoid*CrossingStep	
Model 6	Habitat + HeathForb*CrossingStep	
Model 7	Habitat + Lichen*CrossingStep	
Model 8	Habitat + DaysVicinity*CrossingStep + CumulCrossings*CrossingStep	This model tests whether caribou cross the AWAR and/or Mine because they have been in the vicinity for longer and because many other caribou from the QAM herd have already crossed.

a) An asterisk (*) indicates an interaction between two covariates.

Table 8: Candidate models to evaluate caribou deflection behaviour, in response to the All-Weather Access Road (AWAR) and Mine, 2012 to 2022, within five km of the AWAR and/or Mine.

Model Name	Model Structure[(a)]	Hypotheses Being Tested
Habitat	Lake + Greenness + HeathForb + GrowingDegreeDays*StepLength + TurnAngle	Accounts for basic covariates expected to influence caribou habitat selection, regardless of AWAR and Mine, during post-calving and summer.
Model 1	Habitat + DistanceMineAWAR*DeflectionStep	This model tests whether caribou deflection is a function of proximity to AWAR and/or Mine. For example, caribou may be more likely to deflect from their general path of movement if they are closer to the AWAR and/or Mine.
Model 2	Habitat + NonVegetated*DeflectionStep	These models test whether caribou deflection is related to land cover. For example, a caribou may deflect to avoid non-vegetated land cover or lakes, or may deflect to seek out forage (e.g., heath-forb, lichen).
Model 3	Habitat + Lake*DeflectionStep	
Model 4	Habitat + Shrub*DeflectionStep	
Model 5	Habitat + Graminoid*DeflectionStep	
Model 6	Habitat + HeathForb*DeflectionStep	
Model 7	Habitat + Lichen*DeflectionStep	
Model 8	Habitat + CrossingStep*DeflectionStep	This model tests whether caribou deflection is related to whether the caribou has to the cross the AWAR and/or Mine. For example, a caribou may deflect to avoid crossing the AWAR and/or Mine.

a) An asterisk (*) indicates an interaction between two covariates.

Table 9: Candidate models to evaluate caribou paralleling behaviour, in response to the All-Weather Access Road (AWAR) and Mine, 2012 to 2022, within five km of the AWAR and/or Mine.

Model Name	Model Structure[(a)]	Hypotheses Being Tested
Habitat	Lake + Greenness + HeathForb + GrowingDegreeDays*StepLength + TurnAngle	Accounts for basic covariates expected to influence caribou habitat selection, regardless of AWAR and Mine, during post-calving and summer.
Model 1	Habitat + DistanceMineAWAR*ParallelStep	This model tests whether caribou paralleling is a function of proximity to AWAR and/or Mine. For example, caribou may be more likely parallel the AWAR and/or Mine if they are closer to the AWAR and/or Mine.
Model 2	Habitat + NonVegetated*ParallelStep	These models test whether caribou paralleling is related to land cover. For example, a caribou paralleling the AWAR and/or Mine may not be related to the AWAR and/or Mine but instead related to avoiding non-vegetated land cover or seeking out forage (e.g., heath-forb, lichen).
Model 3	Habitat + Lake*ParallelStep	
Model 4	Habitat + Shrub*ParallelStep	
Model 5	Habitat + Graminoid*ParallelStep	
Model 6	Habitat + HeathForb*ParallelStep	
Model 7	Habitat + Lichen*ParallelStep	
Model 8	Base + CrossingStep*ParallelStep	This model tests whether caribou paralleling is related to whether the caribou has to the cross the AWAR and/or Mine. For example, a caribou may parallel the AWAR and/or Mine to avoid crossing the AWAR and/or Mine.

a) An asterisk (*) indicates an interaction between two covariates.

2.8.5 Zone of Influence

A ZOI, if present, is expected to result in observable changes to caribou habitat selection, movement, or both, as a function of distance from AWAR and Mine. The candidate set of models presented in Table 10 were applied for Treatment Groups 1 to 3 to assess the presence of a ZOI due to the Mine and introduction of Mine traffic on the AWAR.

The ZOI candidate set was designed to test caribou movement parameters split at different distances (i.e., breakpoints, or potential ZOI extents) from the AWAR and Mine. Ten breakpoints were selected by the TAG. The first breakpoint occurred at one km, the next at two km, the third at three km, and the farthest at 10 km (Table 10). To test each potential ZOI extent, a binary covariate representing steps within the breakpoint (i.e., within one km, within two km, …, within 10 km) vs. steps farther than the breakpoint (i.e., farther than one km, farther than two km, …, farther than 10 km) was included in candidate models. The binary breakpoint covariate was interacted with movement parameters (i.e., StepLength, TurnAngle) to test whether caribou movement differs on either side of the breakpoint and evaluate whether a ZOI may be present.

Table 10: Candidate models to evaluate the presence and, if present, the extent of a Zone of Influence surrounding the All-Weather Access Road (AWAR) and Mine, 2012 to 2022, within 15 km of the AWAR and/or Mine.

Model Name	Model Structure[(a)]	Hypotheses Being Tested
Habitat	Lake + Greenness + HeathForb + GrowingDegreeDays*StepLength + TurnAngle	Accounts for basic covariates expected to influence caribou habitat selection, regardless of AWAR and Mine, during post-calving and summer.
Model 1	Habitat + BreakPt1km*TurnAngle + BreakPt1km*StepLength	If a ZOI existed at (or near) a particular breakpoint (i.e., buffered distance from the AWAR and Mine), caribou movement patterns were expected to differ on either side of the breakpoint/buffer. For example, if a ZOI existed around six km from the AWAR and Mine, caribou steps within this buffer may be directional and quick, whereas steps outside this buffer may be less directional and slow.
Model 2	Habitat + BreakPt2km*TurnAngle + BreakPt2km*StepLength	
Model 3	Habitat + BreakPt3km*TurnAngle+ BreakPt3km*StepLength	
Model 4	Habitat + BreakPt4km*TurnAngle+ BreakPt4km*StepLength	
Model 5	Habitat + BreakPt5km*TurnAngle + BreakPt5km*StepLength	
Model 6	Habitat + BreakPt6km*TurnAngle+ BreakPt6km*StepLength	
Model 7	Habitat + BreakPt7km*TurnAngle+ BreakPt7km*StepLength	
Model 8	Habitat + BreakPt8km*TurnAngle + BreakPt8km*StepLength	
Model 9	Habitat + BreakPt9km*TurnAngle + BreakPt9km*StepLength	
Model 10	Habitat + BreakPt10km*TurnAngle + BreakPt10km*StepLength	

a) An asterisk (*) indicates an interaction between two covariates.

2.8.6 Comparison with Control Group

Lastly, Table 11 includes a candidate set of models applied to all four treatment groups. The control candidate set of models was limited in that it could not include covariates related to the AWAR or Mine because caribou in Treatment Group 4 did not interact with the AWAR or Mine. The purpose of this candidate set was to compare baseline caribou movement and selection among the treatment groups.

Table 11: Candidate models to compare baseline movement metrics between 'interactor', 'non-interactor', and 'control' caribou, between 2012–2022, for the entire study area where land cover data were available (Appendix C).

Model Name	Model Structure[a]	Hypotheses Being Tested
Habitat	Lake + Greenness + HeathForb + GrowingDegreeDays*StepLength + TurnAngle	Accounts for basic covariates expected to influence caribou habitat selection, regardless of AWAR and Mine, during post-calving and summer.
Model 1	Habitat + HeathForb*StepLength + HeathForb*TurnAngle	Model tests whether caribou movement speed and directionality is predominantly related to forage (e.g., heath-forb land cover).
Model 2	Habitat + Lake*StepLength + Lake*TurnAngle	Model tests whether caribou movement speed and directionality is predominantly related to avoidance of water (e.g., lake land cover).
Model 3	Habitat + Greenness*StepLength + Greenness*TurnAngle	Model tests whether caribou movement speed and directionality is predominantly related to vegetation green-up.

a) An asterisk (*) indicates an interaction between two covariates.

3.0 RESULTS

3.1 Parturition Predictions

A total of 630 caribou-years, from 2004 to 2022, were used to predict parturition dates for the QAM herd. Of these caribou-years, 84 had insufficient data to predict parturition (i.e., too many missing fixes). Thus, the IBM was used to estimate parturition for 546 caribou-years. A total of n = 12 caribou-years did not support parturition predictions (all three parturition models were competing). Parturition could not be determined for n = 7 caribou-years, where 'no-calving' (i.e., M0) and 'calving' models (i.e., M1 and M2) were competing. Calving was certain but calf mortality was uncertain for n = 419 caribou-years. Calf survival and calf mortality were predicted for n = 2 and n = 38 caribou-years, respectively. Finally, no calving was predicted for n = 68 caribou-years.

The earliest and latest dates of calving within the QAM herd were Julian day 142 (or 21 May, in 2020) and Julian day 174 (or 23 June, in 2009). The resulting temporal window used to constrain the Commitment 38 study area was Julian day 142 to Julian day 195 (i.e., latest parturition date plus 21 days [Section 2.2]; 14 July).

3.2 Base Habitat Model

A total of 393 caribou-years, from 2012 to 2022, were available for informing a base habitat model. Model 7 (Lake), Model 1 (HeathForb), Model 4 (Greenness), and Model 9 (GrowingDays*StepLength) had 389, 384, 355, and 282 occurrences as competing top models, respectively (Table 4; Figure 3). Thus, lakes, heath-forb land cover, greenness, and cumulative growing degree days > 0°C were included as covariates in the base habitat model to account for general caribou habitat selection during post-calving and summer seasons. Movement parameters (i.e., step length and turning angle) were also included as covariates in the base habitat model.

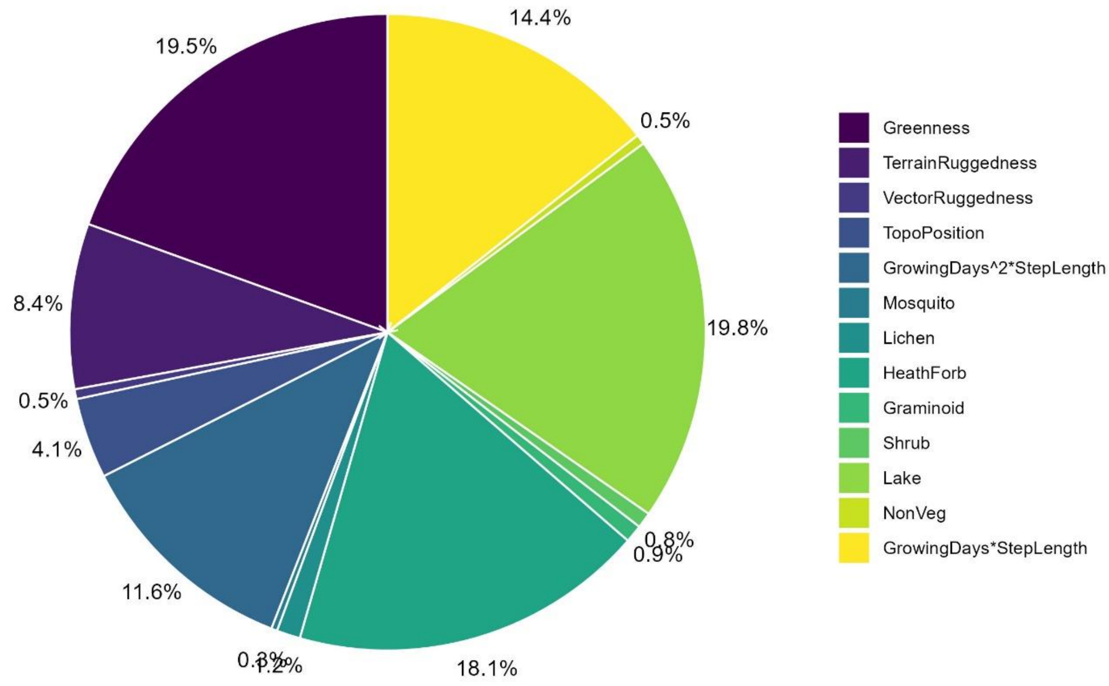

Figure 3: Results of base habitat model selection. A total of 393 caribou-years, from 2012 to 2022, were used to inform a base habitat model.

3.3 Caribou Movement: Influence of All-Weather Access Road and Mine

Models testing the influence of the AWAR and/or Mine on caribou movement and directionality (Table 5) converged for 97%, 82%, and 80% of caribou-years within Treatment Groups 1, 2, and 3, respectively. The base habitat model was the population model for all three treatment groups (Figure 4). Specifically, the base habitat model was a competing top model for 23%, 24%, and 23% of caribou-years within Treatment Groups 1, 2, and 3, respectively.

Based on bootstrapped population means, caribou selected habitats that were greener, had more heath-forb land cover, and had less lake land cover, regardless of treatment group (Figure 5; Table 12). Approximately 74.1%, 68.4%, and 75.0% of caribou-years in Treatment Groups 1, 2, and 3, respectively, exhibited the population response to greenness (Table 13). Similarly, 85.2%, 65.8%, and 66.7% of caribou-years in Treatment Groups 1, 2, and 3, respectively, exhibited the population response to heath-forb land cover (Table 13). Lastly, 74.1%, 94.7%, and 90.0% of caribou-years in Treatment Groups 1, 2, and 3, respectively, responded to lake land cover like the population (Table 13).

The population mean of the interaction between step length and growing degree days > 0°C was positive for all treatment groups, indicating that movement was faster as growing degree days increased (Figure 5; Table 12). Approximately 66.7%, 78.9%, and 85% of caribou-years in Treatment Groups 1, 2, and 3 followed this pattern, respectively (Table 13).

The population mean of the coefficient for turning angle was negative, indicating non-directional movement, regardless of treatment group (Figure 5; Table 12). Regardless of treatment group, 100.0% of individual caribou-years followed this pattern (Table 13). The population mean for step length was negative, indicating slower movement, regardless of treatment group (Figure 5; Table 12). Over 63% of individual caribou-years followed this pattern, regardless of treatment group (Table 13).

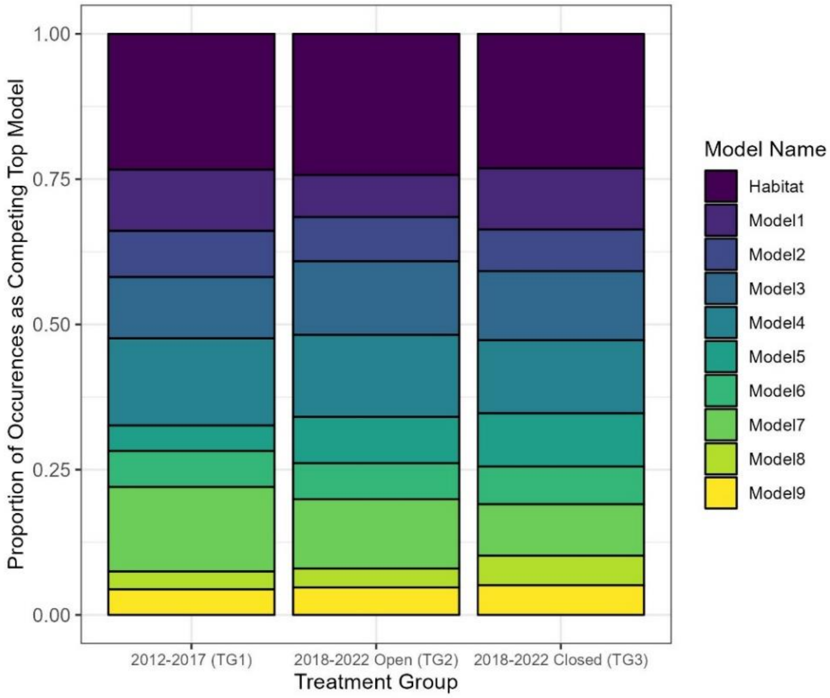

Figure 4: Proportion of occurrences as a competing top model for the caribou movement candidate set (presented in Table 5). Treatment Groups 1, 2, and 3 were comprised of *n* = 107, 146, and 155 caribou-years, respectively.

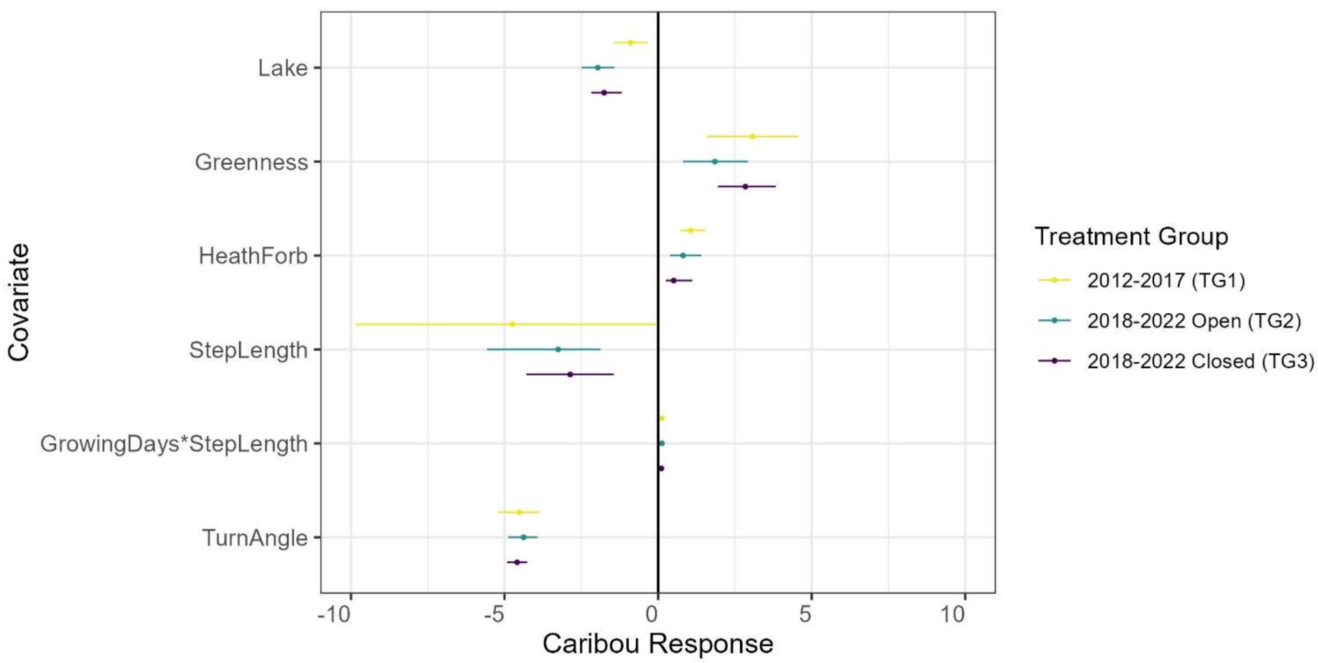

Figure 5: Predicted population response for covariates included in population models for Treatment Groups 1 to 3, based on results from the caribou movement candidate set. Predicted population responses (symbolized with circles) were informed by caribou-years with *n* ≥ 20 used steps. Horizontal lines indicate bootstrapped 95% confidence intervals (CIs). CIs that overlap 0 indicate no, or zero, population-level response.

Table 12: Beta coefficient estimates (β) and upper and lower 95% confidence interval limits for covariates included in population models, per treatment group. Population estimates were informed from results of the caribou movement candidate set and included caribou-years with *n* ≥ 20 used steps.

Covariate[a]	Treatment Group 1			Treatment Group 2			Treatment Group 3		
	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit
Lake	-0.89	-1.43	-0.34	-1.97	-2.49	-1.42	-1.76	-2.18	-1.18
Greenness	3.07	1.58	4.57	1.85	0.81	2.93	2.84	1.94	3.83
HeathForb	1.06	0.72	1.54	0.81	0.39	1.41	0.51	0.25	1.11
StepLength	-4.75	-9.84	-0.07	-3.25	-5.57	-1.88	-2.86	-4.29	-1.45
GrowingDays*StepLength	0.12	0.04	0.21	0.12	0.07	0.21	0.11	0.06	0.15
TurnAngle	-4.52	-5.21	-3.85	-4.38	-4.88	-3.93	-4.59	-4.92	-4.26

a) An asterisk (*) indicates an interaction between two covariates.

Table 13: Percentage (%) of caribou-years with positive (+) and negative (–) responses to covariates included in the population model, per treatment group. Population estimates were informed from results of the caribou movement candidate set and included caribou-years with *n* ≥ 20 used steps.

Covariate[a]	Treatment Group 1		Treatment Group 2		Treatment Group 3	
	+	–	+	–	+	-
Lake	25.9	74.1	5.3	94.7	10.0	90.0
Greenness	74.1	25.9	68.4	31.6	75.0	25.0
HeathForb	85.2	14.8	65.8	34.2	66.7	33.3
StepLength	37.0	63.0	15.8	84.2	20.0	80.0
GrowingDays*StepLength	66.7	33.3	78.9	21.1	85.0	15.0
TurnAngle	0.0	100.0	0.0	100.0	0.0	100.0
Total caribou-years with *n* ≥ 20 used steps	**27**		**38**		**60**	

a) An asterisk (*) indicates an interaction between two covariates.

3.4 Caribou Movement: Influence of Harvest and Traffic

Models testing the influence of caribou harvest and AWAR traffic on caribou movement and directionality, for June and July 2021 (Table 6), converged for 82% and 73% of caribou-years within Treatment Groups 2 and 3, respectively. The base habitat model was the population model for both treatment groups, representing a competing top model for 26% and 18% of caribou-years within Treatment Groups 2 and 3, respectively (Figure 6). Because the base habitat model has been described above in Section 3.3 it will not be presented again in this section.

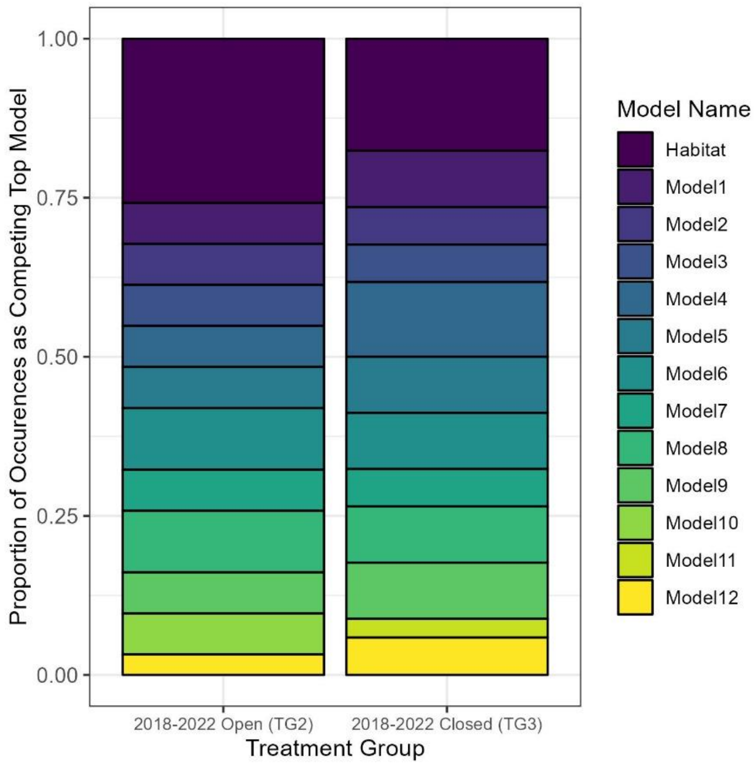

Figure 6: Proportion of occurrences as a competing top model for the caribou harvest candidate set (presented in Table 6). Treatment Groups 2 and 3 were comprised of *n* = 36 and 46 caribou-years, respectively.

3.5 Crossing Steps: Influence of All-Weather Access Road and Mine

Models testing how crossing steps varied as a function of land cover and proximity to AWAR and/or Mine, within five km of the AWAR and/or Mine (Table 7), converged for 82%, 73%, and 68% of caribou-years within Treatment Groups 1, 2, and 3, respectively. Model 8 was the population model for both Treatment Groups 1 and 3; the base habitat model was the population model for Treatment Group 2 (Figure 7). Specifically, Model 8 was a competing top model for 35% and 51% of caribou-years within Treatment Groups 1 and 3, respectively, and the base habitat model was a competing top model for 35% of caribou-years within Treatment Group 2.

Based on bootstrapped population means from population models, caribou within five km of the AWAR and/or Mine selected habitats that had less lake land cover (Figure 8; Table 14). Generally, caribou within five km of the AWAR and/or Mine did not respond to heath-forb land cover or greenness, as indicated by beta estimates that were close to zero and 95% CIs that overlapped zero (Figure 8; Table 14). Similar to results presented for the base habitat model within 15 km of the AWAR and/or Mine (Figure 5), caribou within five km of the AWAR and/or Mine moved less directionally (Figure 8 Table 14).

For Treatment Group 3, where Model 8 was the population model, the interaction term between DaysVicinity and CrossingStep was positive, indicating that caribou are more likely to cross the AWAR and/or Mine when they have been in the vicinity of the AWAR and/or Mine for longer. For approximately half of caribou-years in Treatment Group 3 (i.e., 52.0%), whether a caribou crossed the AWAR and/or Mine was positively related to the number of days the caribou had been in vicinity of the AWAR and/or Mine (Table 15). The bootstrapped population mean for the interaction term between CumulCrossings and CrossingStep was positive for Treatment Group 3, indicating that caribou are more likely to cross the AWAR and/or Mine when more caribou in the herd have crossed (Table 14). However, the population trend was observed for only 35.0% of caribou-years (Table 15).

Although Model 8 was the population model for Treatment Group 1, the 95% CIs for both interaction terms (i.e., DaysVicinity*CrossingStep and CumulCrossings*CrossingStep) overlapped zero, indicating that whether caribou crossed the AWAR and/or Mine was unrelated to the number of days that caribou had been in the vicinity or number of previous caribou crossings.

Model 1, which included the ‘Distance to AWAR and/or Mine’ covariate interacted with crossing steps (Table 7), was the top model for three caribou-years in Treatment Group 3, among the 227 caribou-years across the three treatment groups (i.e., 1.3% of caribou-years). However, all beta coefficient estimates for DistAWARMine*CrossingStep were either zero or had 95% CI that overlapped zero.

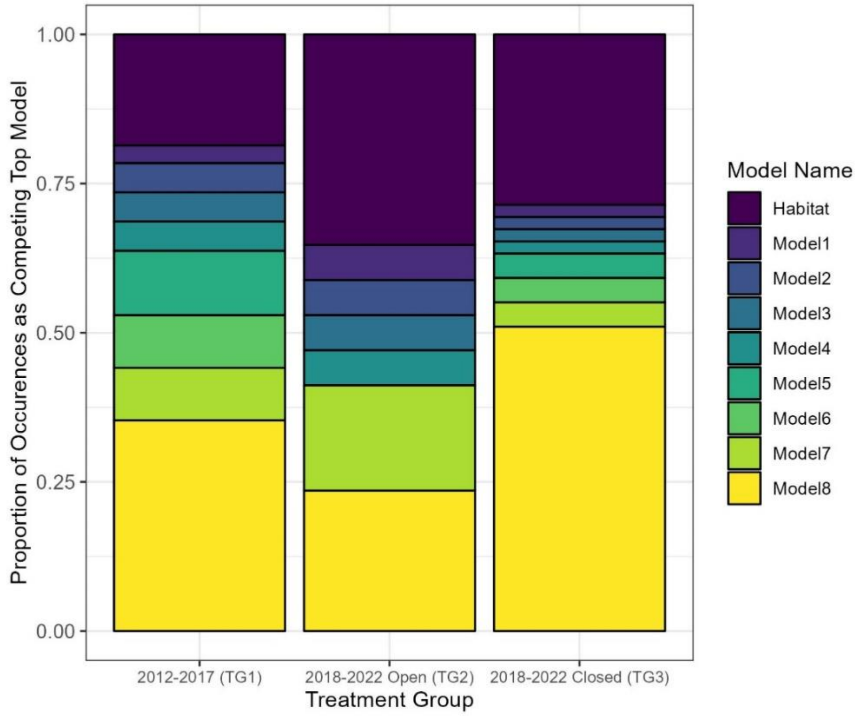

Figure 7: Proportion of occurrences as a competing top model for the crossing candidate set (presented in Table 7). Treatment Groups 1, 2, and 3 were comprised of *n* = 94, 77, and 155 caribou-years, respectively.

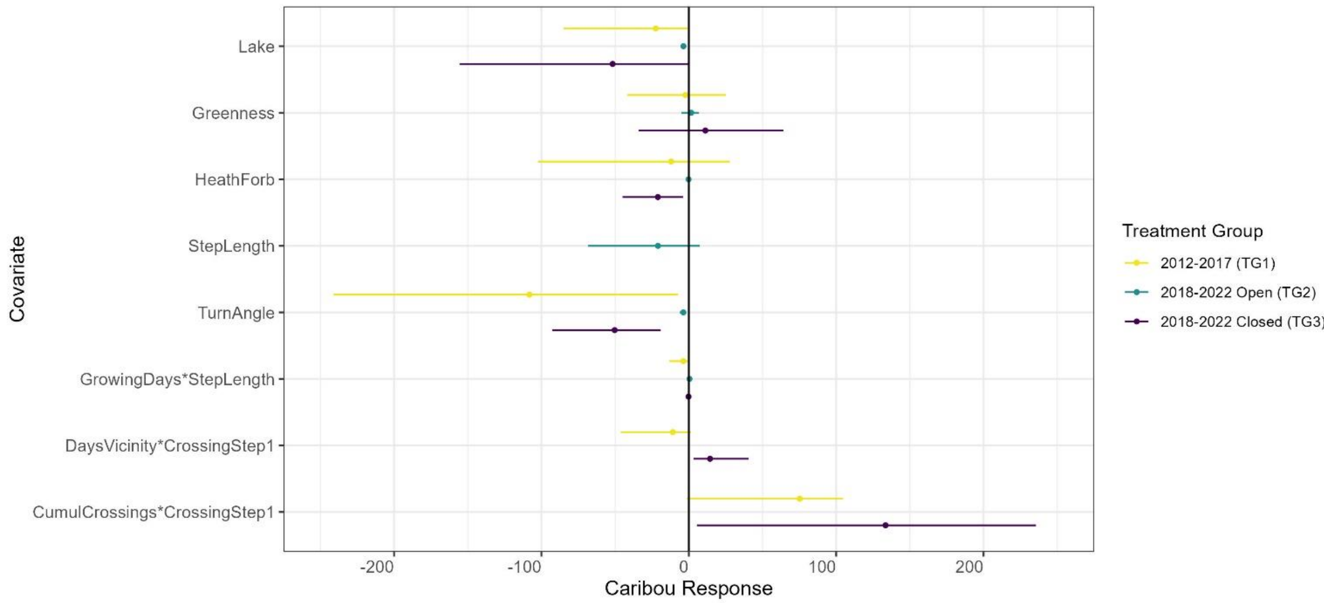

Figure 8: Predicted population response for covariates included in population models for Treatment Groups 1 to 3, based on results from the crossing candidate set. Predicted population responses (symbolized with circles) were informed by caribou-years with *n* ≥ 10 used steps. Horizontal lines indicate bootstrapped 95% confidence intervals (CIs). CIs that overlap 0 indicate no, or zero, population-level response. CrossingStep = '1' was used as the reference category. Beta coefficient estimates for Treatment Group 1 and 3 StepLength were too large to include in the figure but are reported in Table 14.

Table 14: Beta coefficient estimates (β) and upper and lower 95% confidence interval limits for covariates included in population models, per treatment group. Population estimates were informed from results of the crossing candidate set and included caribou-years with *n* ≥ 10 used steps. Model 8 was the population model for Treatment Groups 1 and 3; the base habitat model was the population model for Treatment Group 2.

Covariate[a]	Treatment Group 1			Treatment Group 2			Treatment Group 3		
	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit
Lake	-22.45	-85.09	-0.67	-3.64	-4.38	-2.95	-51.71	-155.59	-0.16
Greenness	-2.32	-41.79	25.12	1.66	-4.97	6.96	11.24	-33.95	64.18
HeathForb	-11.98	-102.29	27.81	-0.18	-0.88	0.43	-20.98	-44.98	-3.86
StepLength	576.09	-118.59	1830.83	-20.94	-68.31	7.34	-508.57	-1462.89	-117.11
TurnAngle	-108.11	-241.03	-7.24	-3.70	-6.06	-2.31	-50.30	-92.53	-19.09
GrowingDays*StepLength	-3.72	-13.13	-0.43	0.48	-0.33	1.10	-0.19	-1.08	0.01
DaysVicinity*CrossingStep[b]	-10.80	-46.21	1.57	NA			14.39	3.40	40.70
CumulCrossings*CrossingStep[b]	75.31	-1.24	104.72				133.48	5.51	235.52

a) An asterisk (*) indicates an interaction between two covariates.

b) CrossingStep = '1' was used as the reference category.

Table 15: Percentage (%) of caribou-years with positive (+) and negative (–) responses to covariates included in the population model, per treatment group. Population estimates were informed from results of the crossing candidate set and included caribou-years with *n* ≥ 10 used steps.

Covariate[a]	Treatment Group 1		Treatment Group 2		Treatment Group 3	
	+	–	+	–	+	–
Lake	18.8	81.3	0.0	100.0	23.3	76.7
Greenness	59.4	40.6	33.3	66.7	66.7	33.3
HeathForb	50.0	50.0	33.3	66.7	60.0	40.0
StepLength	43.8	56.3	33.3	66.7	33.3	66.7
TurnAngle	3.1	96.9	0.0	100.0	0.0	100.0
GrowingDays*StepLength	59.4	40.6	66.7	33.3	70.0	30.0
DaysVicinity*CrossingStep[b]	77.8	22.2	NA		52.0	48.0
CumulCrossings*CrossingStep[b]	28.6	71.4			35.0	65.0
Total caribou-years with *n* ≥ 10 used steps	**32**		**3**		**30**	

a) An asterisk (*) indicates an interaction between two covariates.

b) CrossingStep = '1' was used as the reference category.

3.6 Deflection Steps: Influence of All-Weather Access Road and Mine

Models testing how deflection steps varied as a function of land cover and proximity to AWAR and/or Mine, within five km of the AWAR and/or Mine (Table 8), converged for 93%, 79%, and 73% of caribou-years within Treatment Groups 1, 2, and 3, respectively. The base habitat model was the population model for all treatment groups (Figure 9) and was a competing top model for 29%, 19%, and 23% of caribou-years within Treatment Groups 1, 2, and 3, respectively. Because the base habitat model has been described above in Section 3.3 it will not be presented again in this section.

Model 1, which included the 'Distance to AWAR and/or Mine' covariate interacted with deflection steps (Table 8), was a top model for 4.4% of caribou-years (*n* = 10 caribou-years) among the three treatment groups. However, all beta coefficient estimates for DistAWARMine*DeflectionStep were either zero or had 95% CI that overlapped zero, except for one caribou-year. In 2021, caribou 'UK2018033' was more likely to exhibit deflection movement behaviour as she got further from the AWAR and/or Mine (i.e., distance to AWAR and/or Mine increased; $\beta = 0.63$, 95% CI = 0.61 – 0.65).

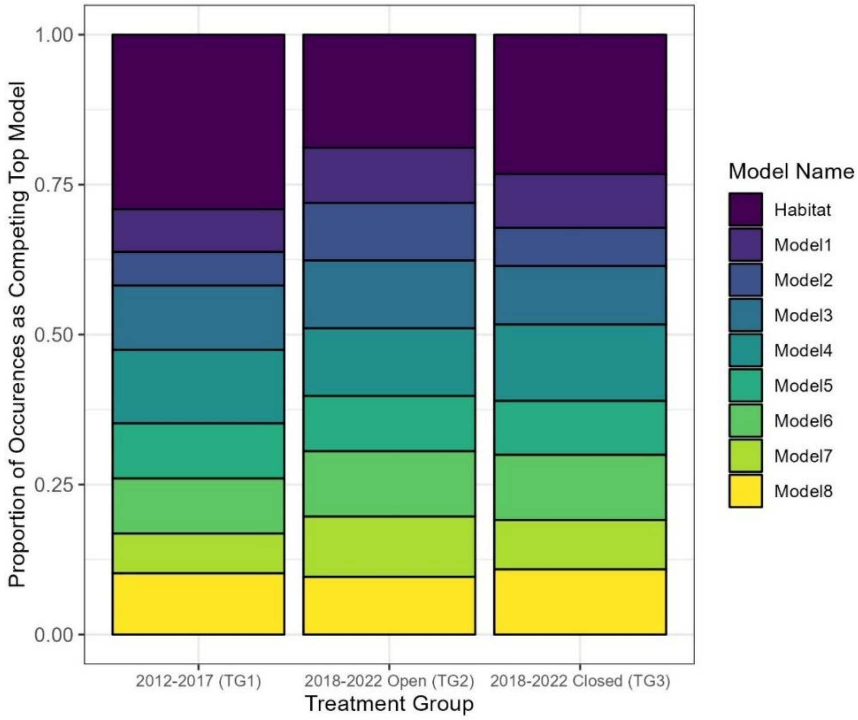

Figure 9: Proportion of occurrences as a competing top model for the deflection candidate set (presented in Table 8). Treatment Groups 1, 2, and 3 were comprised of *n* = 94, 77, and 155 caribou-years, respectively.

3.7 Paralleling Steps: Influence of All-Weather Access Road and Mine

Models testing how paralleling steps varied as a function of land cover and proximity to AWAR and/or Mine (Table 9) converged for 84%, 79%, and 73% of caribou-years within Treatment Groups 1, 2, and 3, respectively. The base habitat model was the population model for all treatment groups (Figure 10) and was a competing top model for 30%, 23%, and 25% of caribou-years within Treatment Groups 1, 2, and 3, respectively. Because the base habitat model has been described above in Section 3.3 it will not be presented again in this section.

Model 1, which included the ‘Distance to AWAR and/or Mine’ covariate interacted with paralleling steps (Table 9), was a top model for 6.2% of caribou-years (*n* = 14 caribou-years) among the three treatment groups. Beta coefficient estimates for DistAWARMine*ParallelStep were zero or had 95% CI that overlapped zero for 12 of these caribou-years and were negative for two of these caribou years. Specifically, in 2016 and 2017 (Treatment Group 2), caribou ‘QM1670415’ and caribou ‘QM1690415’ were more likely to exhibit paralleling movement behaviour if they were closer to the AWAR and/or Mine, respectively
(QM1670415 in 2016: β = -0.43, 95% CI = -0.45 – -0.40; QM1690415 in 2017: β = -0.06, 95% CI = -0.06 – -0.05).

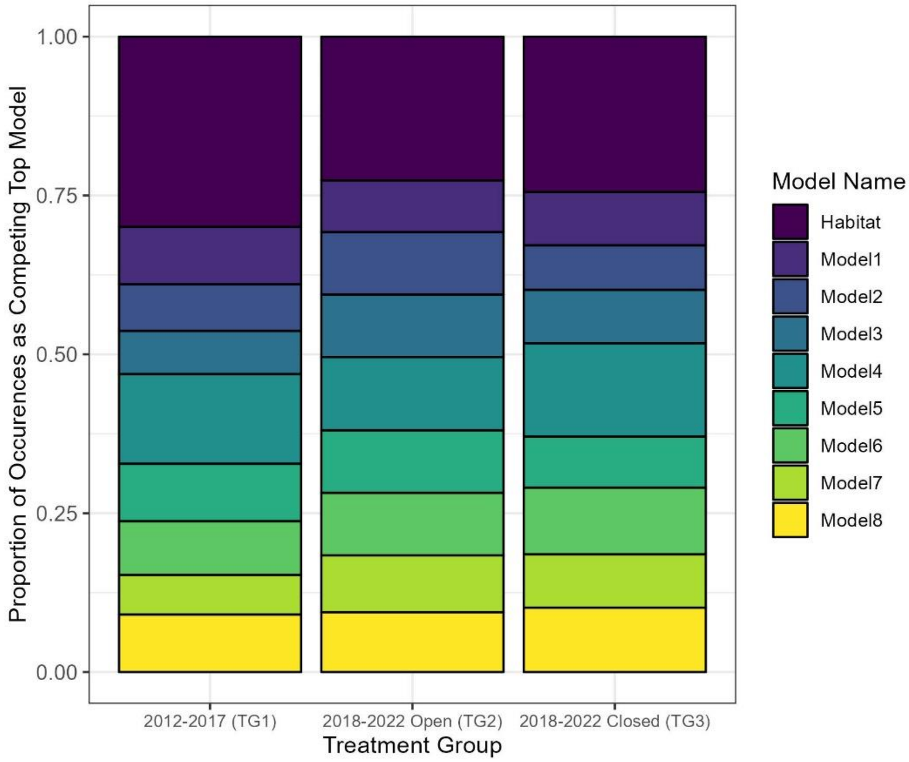

Figure 10: Proportion of occurrences as a competing top model for the paralleling candidate set (Table 9). Treatment Groups 1, 2, and 3 were comprised of *n* = 94, 77, and 155 caribou-years, respectively.

3.8 Zone of Influence

Models testing for the presence of a ZOI (Table 10) converged for 97%, 81%, and 80% of caribou-years within Treatment Groups 1, 2, and 3, respectively. The base habitat model was the population model for all treatment groups (Figure 11) and was a competing top model for 19%, 13%, and 16% of caribou-years within Treatment Groups 1, 2, and 3, respectively. Because the base habitat model has been described above in Section 3.3 it will not be presented again in this section.

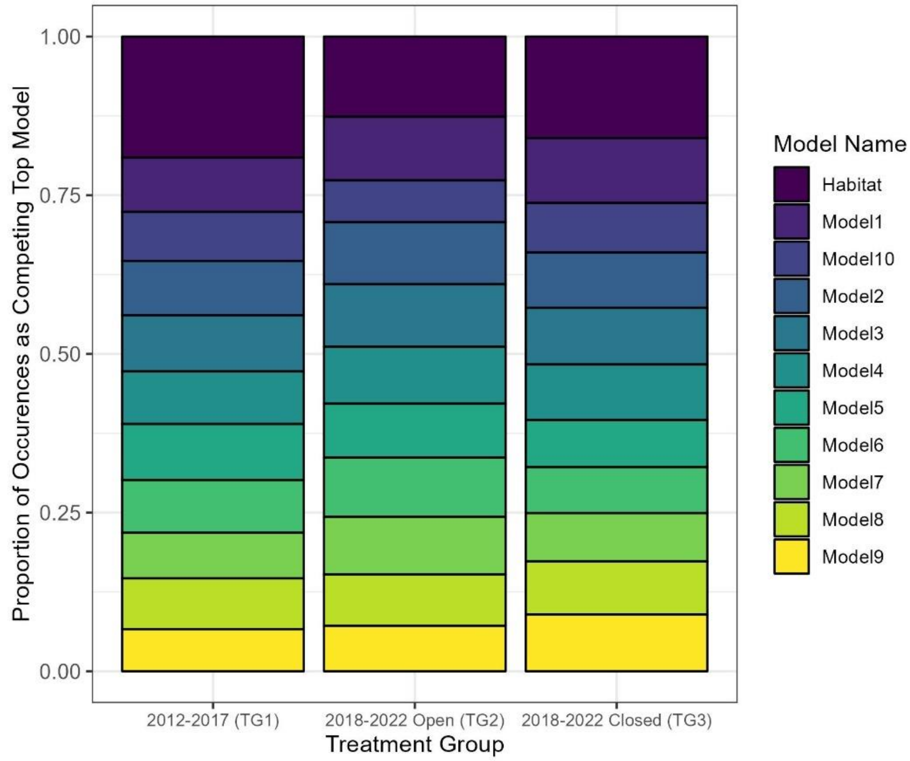

Figure 11: Proportion of occurrences as a competing top model for the zone of influence (ZOI) candidate set (presented in Table 10). Treatment Groups 1, 2, and 3 were comprised of *n* = 107, 146, and 155 caribou-years, respectively.

3.9 Comparison with Control Group

Models comparing all four treatment groups (Table 11) converged for 97%, 81%, 80%, and 100% of caribou-years within Treatment Groups 1, 2, 3, and 4, respectively. The base habitat model was the population model for Treatment Groups 1 to 3 (Figure 12 and was a competing top model for 43%, 43%, and 47% of Treatment Groups 1, 2, and 3, respectively. Model 1 was the population model for Treatment Group 4 (Figure 12) and represented a competing top model for 23% of caribou-years.

Caribou in the three test treatment groups (i.e., Treatment Groups 1 to 3) exhibited similar population-level responses to land cover as caribou in the Control Group (i.e., Treatment Group 4). For instance, based on bootstrapped population means, caribou in all treatment groups selected habitats that were greener and had less lake land cover (Figure 13; Table 16). Over 68% and 74% of caribou-years in test treatment groups exhibited a positive response to greenness and negative response to lake land cover, respectively. These trends were stronger in the Control Group, where almost all caribou-years exhibited the population-level responses to lake land cover (i.e., 98.2% exhibited a negative Lake coefficient) and greenness (i.e., 94.4% exhibited a positive Greenness coefficient; Table 17). Caribou in test treatment groups selected habitats with more heath-forb landcover whereas caribou in the Control Group selected habitats with less heath-forb landcover (Figure 13; Table 16).

However, the CIs for the Control Group HeathForb coefficient were wide, indicating uncertainty about how caribou in the Control Group (i.e., further than 15 km from the AWAR and/or Mine) respond to heath-forb landcover. Response to growing degree days > 0°C interacted with step length was similar across treatment groups and caribou across all treatment groups moved non-directionally and slowly during the post-calving and summer seasons (Figure 13; Table 16).

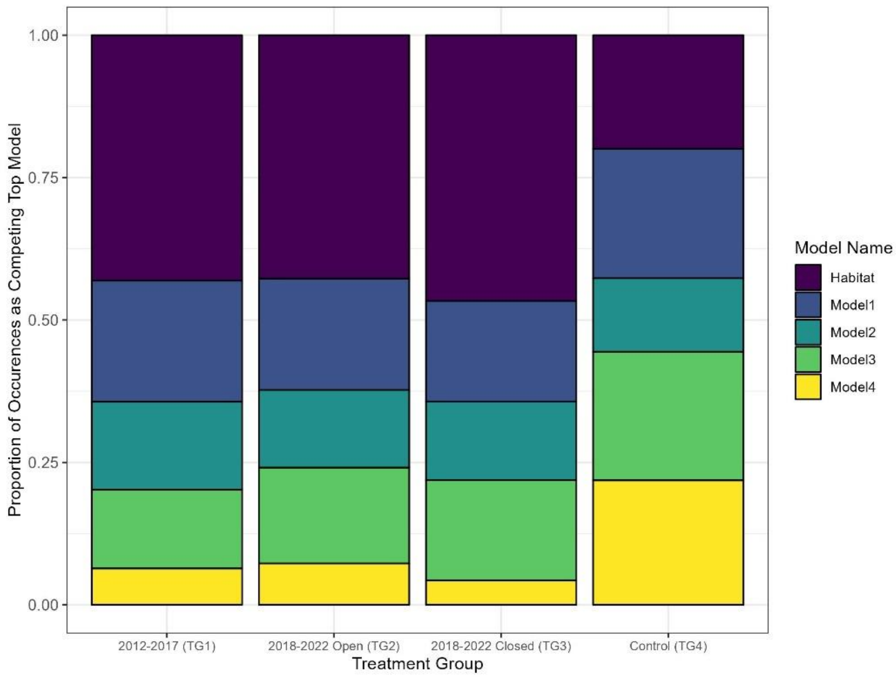

Figure 12: Proportion of occurrences as a competing top model for the control candidate set (presented in Table 11). Treatment Groups 1, 2, 3, and 4 were comprised of *n* = 107, 146, 155, and 393 caribou-years, respectively.

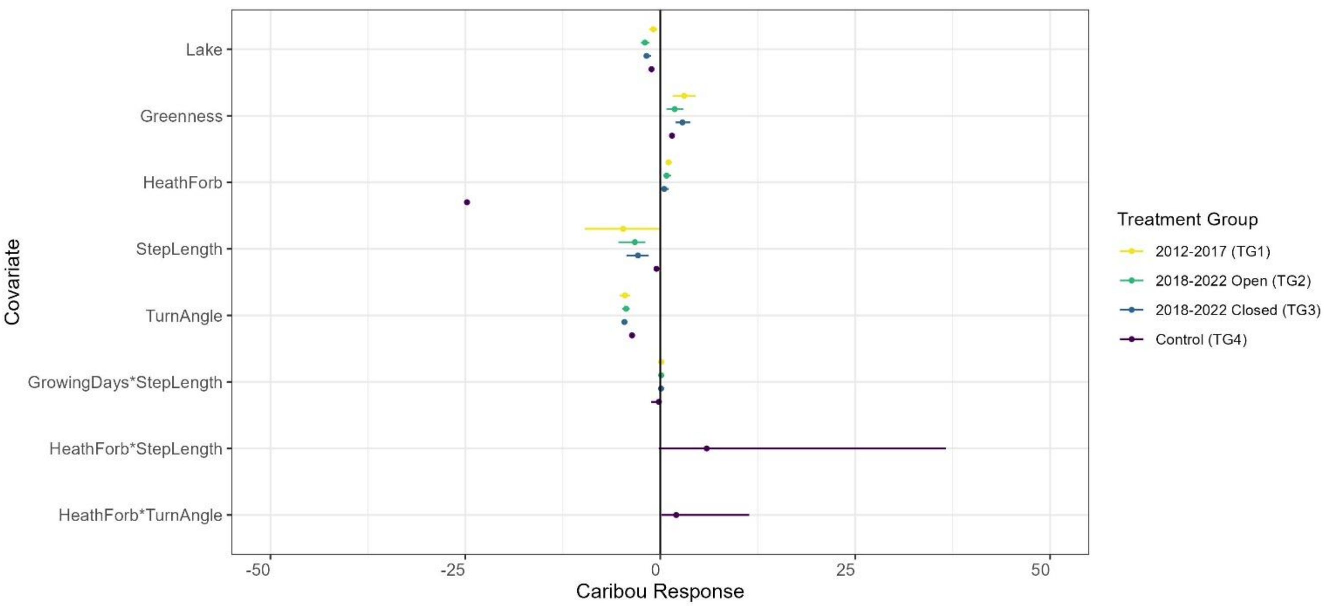

Figure 13: Predicted population response for covariates included in population models for Treatment Groups 1 to 4, based on results from the control candidate set. Predicted population responses (symbolized with circles) were informed by caribou-years with *n* ≥ 20 used steps. Horizontal lines indicate bootstrapped 95% confidence intervals (CIs). CIs that overlap 0 indicate no, or zero, population-level response. Treatment Group 4 HeathForb CIs were too wide to include in the figure but are reported in Table 16.

Table 16: Beta coefficient estimates (β) and upper and lower 95% confidence interval limits for covariates included in population models, per treatment group. Population estimates were informed from the control candidate set results and included caribou-years with *n* ≥ 20 used steps. The base habitat model was the population model for Treatment Groups 1 to 3; Model 1 was the population model for Treatment Group 4.

Covariate[a]	Treatment Group 1			Treatment Group 2			Treatment Group 3			Treatment Group 4		
	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit	β	Lower 95% Limit	Upper 95% Limit
Lake	-0.89	-1.42	-0.36	-1.97	-2.47	-1.41	-1.76	-2.16	-1.17	-1.12	-1.18	-1.07
Greenness	3.07	1.58	4.54	1.85	0.79	2.94	2.84	1.95	3.84	1.51	1.35	1.62
HeathForb	1.06	0.70	1.50	0.81	0.38	1.42	0.51	0.24	1.10	-24.78	-142.60	-0.66
StepLength	-4.75	-9.71	-0.01	-3.25	-5.37	-1.90	-2.86	-4.34	-1.49	-0.48	-0.53	-0.43
TurnAngle	-4.52	-5.23	-3.87	-4.38	-4.88	-3.92	-4.59	-4.94	-4.28	-3.62	-3.71	-3.53
GrowingDays* StepLength	0.12	0.03	0.22	0.12	0.07	0.20	0.11	0.06	0.15	-0.18	-1.15	0.02
HeathForb* StepLength	NA									5.95	-0.21	36.64
HeathForb* TurnAngle										2.05	0.17	11.42

a) An asterisk (*) indicates an interaction between two covariates.

Table 17: Percentage (%) of caribou-years with positive (+) and negative (–) responses to covariates included in the population model, per treatment group. Population estimates were informed from results of the control candidate set and included caribou-years with *n* ≥ 20 used steps.

Covariate[a]	Treatment Group 1		Treatment Group 2		Treatment Group 3		Treatment Group 4	
	+	–	+	–	+	–	+	–
Lake	25.9	74.1	5.3	94.7	10.0	90.0	1.8	98.2
Greenness	74.1	25.9	68.4	31.6	75.0	25.0	94.4	5.6
HeathForb	85.2	14.8	65.8	34.2	66.7	33.3	38.9	61.1
StepLength	37.0	63.0	15.8	84.2	20.0	80.0	14.0	86.0
TurnAngle	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
GrowingDays* StepLength	66.7	33.3	78.9	21.1	85.0	15.0	87.0	13.0
HeathForb* StepLength	NA						65.9	34.1
HeathForb* TurnAngle							42.7	57.3
Total caribou-years with *n* ≥ 20 used steps	**27**		**38**		**60**		**393**	

a) An asterisk (*) indicates an interaction between two covariates.

4.0 DISCUSSION

The base habitat model included several covariates that were important for predicting general caribou habitat selection and movement in the study area. Regardless of treatment group, caribou selected habitats with higher greenness and lower lake land cover, which has also been observed in other caribou herds (Boulanger et al. 2012; Golder 2021). Caribou in the three test treatment groups selected habitats with higher heath-forb land cover, whereas caribou in the Control Group selected habitats with lower heath-forb land cover. This difference may be related to the broad spatial extent of the Commitment 38 study area and the much smaller area within 15 km of the AWAR and/or Mine, especially if other land cover types (e.g., lichen, graminoid) provide more forage for caribou in the Control Group. Generally, caribou in all treatment groups moved less directionally and more slowly, which supports that caribou in post-calving and summer seasons are likely exhibiting foraging movement patterns.

In many cases, 95% CI for bootstrapped population means were wide. Wide CI may be due to low sample sizes of telemetry points, which would corroborate the lower model convergence for test treatment groups and the variety of models arising as a top competing model per candidate set. Where possible, only those caribou-years with at least 20 used steps were used to bootstrap population means, which increased the precision of population-level responses.

Alternatively, uncertainty in population-level responses may also be related to high variability among individuals of the QAM caribou herd. High intra-population variability was apparent in the results of the Control Group candidate set, which had several potential population models. Individual variation could be due to several factors, including sex, whether a caribou cow has a calf or not, and/or locations of an individual's range within the Commitment 38 study area. Intra-population variability was also apparent in the diversity of models supported in each analysis as multiple models were supported by different caribou-years. The presence of intra-population variability was also demonstrated by both positive and negative responses to the same covariates, including natural covariates among caribou-years, as previously noted. Intra-population variability illustrates that populations may be plastic and resilient to environmental change (Reed et al. 2003), which has been shown in QAM caribou (Mallory et al. 2020). Although individuals may vary in their response to different land cover or habitat variables, QAM telemetry data were representative of QAM herd movements (see results of assumption test in Appendix D).

The base habitat model was the population model for both the caribou movement candidate set and caribou harvest candidate set, which supports that the addition of AWAR and/or Mine, harvest, and AWAR traffic covariates in the iSSA did not improve model fit and are therefore not likely to be significant predictors of caribou directionality and speed. Likewise, the base habitat model was the population model for the deflection candidate set and paralleling candidate set. These results support that, at the population level, including proximity to AWAR and/or Mine and different land cover types as a function of deflection or paralleling steps did not improve model fit. For a small proportion of the population, deflection (4.4%) and paralleling (6.2%) movement behaviours were best represented by models that included proximity to AWAR and/or Mine but for most individuals, there was no measurable effect. One caribou, in 2021, was more likely to exhibit deflection movements when further from the AWAR and/or Mine and two caribou, before the construction of the Mine (i.e., 2016 and 2017), were more likely to exhibit parallel movements when closer to the AWAR and/or Mine. These two caribou's paralleling behaviours are therefore unlikely to be related to Mine activity.

Also, the base habitat model was the population model for the ZOI candidate set, indicating that the addition of breakpoints (or potential ZOI distances) did not improve model fit. Results do not support the presence of a ZOI on caribou movements due to the AWAR and Mine. Overall, several lines of evidence predict that the presence of the AWAR and Mine is not having a strong adverse influence on caribou habitat selection (i.e., indirect effects to habitat) or movement in the surrounding area.

The population-level model for Treatment Group 3 (i.e., telemetry data from 2018 to 2022 when the AWAR and/or Mine was closed) indicated that caribou were more likely to cross the AWAR and/or Mine if they had been in the vicinity for longer and if more caribou from the herd had crossed already. However, less than 10% of caribou-years demonstrated this population-level trend. For most (i.e., 90% or more) caribou-years, crossing steps were unrelated to time spent in the vicinity before crossing or whether other caribou had crossed the AWAR and/or Mine.

Several factors made estimating population-level models challenging. Few individuals within the QAM herd interact with the AWAR and/or Mine, which limited sample sizes available for testing effects of the AWAR and/or Mine on caribou movement and likely contributed to imprecise estimates (i.e., wide CIs) in population-level models. For instance, 32% of QAM caribou-years came within 5 km of the AWAR/Mine and 28% of QAM caribou-years interacted with (i.e., crossed) the AWAR and/or Mine. When individuals from the QAM herd did interact with the AWAR and/or Mine, they usually did not linger in the vicinity, which further reduced the telemetry data available for Treatment Groups 2 and 3. Specifically, 99% of caribou-years that encountered the AWAR and/or Mine interacted for less than 24 hours between 21 May and 22 August each year. The separate effects of the AWAR, Mine, and Rankin Inlet could not be disentangled; rather, the 'distance to AWAR and/or Mine' covariate should be interpreted as 'distance to AWAR, Mine, or Rankin Inlet' because these three covariates were perfectly correlated ($r = 1.00$; Appendix B). Similarly, local and Project-related AWAR traffic were also highly correlated, which prevented the separate effects of local (i.e., public) and Mine-related traffic to be tested. While sample sizes were low or time spent near the AWAR and/or Mine was short, this also means that only a small portion of the QAM herd experience possible effects from the AWAR and/or Mine and over a short duration.

The results presented herein support that QAM caribou movements during post-calving and summer seasons are best predicted by a combination of habitat variables, including vegetation greenness, cumulative growing degree days > 0°C, and nearby lakes and heath-forb forage. The lack of support for models that included distance to AWAR and/or Mine suggest that proximity to Mine-related disturbances are unlikely to influence caribou speed and directionality during post-calving and summer seasons.

5.0 CONCLUSIONS

Agnico Eagle collaborated with the KivIA, GKD, BHTO, NTI, and GN to develop a study design to fulfill Commitment 38. The collaboration included key considerations for the study design, such as an ecological definition of the study area to represent a sensitive time for QAM caribou and definitions for deflection and paralleling steps made by collared caribou. Other contributions from the KivIA, GKD, and GN included which natural factors (including those identified by IQ) and anthropogenic factors should be considered as covariates in analyses to explain collared QAM caribou movement behaviour in response to the AWAR and/or Mine. The KivIA, GKD, and GN also determined how a ZOI should be analyzed.

Making inferences about caribou movement behaviour based on visualization alone ignores the underlying process of habitat selection. Caribou movement and selection are linked, both in the relation to the landscape and their relationship with one another (Avgar et al. 2016; Prokopenko et al. 2017). Thus, collared QAM caribou data were analyzed using iSSA (Avgar et al. 2016), which was the approach developed collaboratively by the KivIA, GKD, and GN. The iSSA provided a robust framework for comparing observed caribou movements with available caribou movements, while accounting for underlying habitat selection. Ultimately, the iSSA allowed the fine-scale direct and indirect spatiotemporal effects of the AWAR and Mine on caribou movement and selection to be estimated simultaneously (Avgar et al. 2016; Prokopenko et al. 2017).

The results of Commitment 38 analyses indicated intra-population variability by collared QAM caribou in response to different environmental factors, that collared caribou movement behaviour is best predicted by natural factors, and no measurable presence of an adverse response by collared caribou to the AWAR or Mine. Less than one-third of collared QAM caribou occurred within 5 km of the AWAR and/or Mine and 99% of these individuals were present for less than 24 hrs, which may partially explain why anthropogenic factors were not supported as predictors of collared caribou movement behaviour at the population level. Results of the analyses indicate that the Mine's Final Environmental Impact Statement (FEIS; Agnico Eagle 2014) residual effects predictions were conservative and support the assessment conclusion of non-significant impacts to caribou. For example, predictions of indirect effects to caribou habitat made in the FEIS assumed the presence of 5 km and 14 km ZOIs for the AWAR and Mine, respectively, whereas the results of Commitment 38 analyses failed to detect a ZOI within 10 km. Commitment 38 results further support that the indirect effects to caribou habitat for the Meliadine Extension assessment have been over-estimated because the same FEIS ZOI assumptions were carried forward in the FEIS Addendum for the Extension as well as larger AWAR ZOIs assumptions as requested by the GN (Agnico Eagle 2023c).

Agnico Eagle appreciates the contributions by the KivIA, GKD, NTI, BHTO, and GN, and IQ holders that participated in meetings leading to the development and fulfillment of the Commitment 38 study design and analyses. While Commitment 38 is now complete, Agnico Eagle looks forward to future caribou collaborations and discussions with the KivIA, GKD, BLHTO, NTI, GN, and IQ holders.

Signature Page

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

WSP Canada Inc.

Meghan Beale, M.Sc., R.P.Bio.
Senior, Wildlife Biologist

Daniel Coulton, Ph.D. R.P.Bio.
Lead, Wildlife Biologist

John Virgl
Senior Principal, Ecologist

MB/DC/CDLM/jr

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APPENDIX A

Daily Movement vs. Calf Age Assumption Test

Methods of Assumption Test

The age at which calves should no longer influence cow movement was tested to inform the use of a calf age covariate in iSSA and the use of a five-km/day threshold for determining when a caribou may have calved. The KivIA suggested that cows with calves up to 21 days of age move less than five km/day and once calves are older than 21 days of age, move more than five km/day. To test this assumption, total distance moved (km) was calculated by summing step lengths per day for caribou where it was confirmed that parturition occurred and neonate mortality did not occur (i.e., M1 was top parturition model and was not competing with either M0 or M2). Then, based on the predicted parturition date for each caribou-year, daily movement was assigned a calf age, in days. Mean daily movement was calculated per day of calf age, across caribou-years. Mean daily movement was plotted as a function of calf age (Figure A-1).

To understand daily distances moved by caribou without calves as a function of day of year, total distance moved was summed per day for caribou where it was confirmed that parturition did not occur (i.e., M0 was the top parturition model and was not competing with either M1 or M2). Using the mean calving date for the QAM herd (i.e., Julian day 157, or 6 June for non-leap years), mean daily movement was assigned a 'calf age', then plotted as a function of calf age (Figure A-1).

Results of Assumption Test

Linear trendlines were plotted up to peak daily movement (i.e., up to calf age = 37 days) for caribou with calves and caribou without calves (Figure A-1). Linear trendlines for caribou with calves and caribou without calves had similar slopes (0.59 for caribou without calves; 0.62 for caribou with calves; Figure A-1) and different y-intercepts (3.87 for caribou without calves; 1.14 for caribou with calves; Figure A-1). Ultimately, daily movement increased as calf age increased for both caribou with calves and caribou without calves (representing an increase in daily movement as Julian day or day of year increased) but the minimum daily movement varied based on whether caribou had a calf or not (Figure A-1). Minimum daily movement for caribou with calves was 2.16 km, whereas minimum daily movement for caribou without calves was 6.26 km (Figure A-1). Caribou with calves moved further than five km/day when calves were 6.25 days old (Figure A-1).

Key Takeaways from Assumption Test

Results presented in Figure A-1 support that caribou with calves in the QAM herd reach the daily movement threshold of five km earlier than 21 days post-parturition and calves may only present a limitation to a cow's daily movement while the calf is less than seven days old. Figure A-1 shows that daily caribou movement decreases after approximately July 13 (i.e., Julian day 194), which coincides with peak vegetation green-up and, subsequently, reduced caribou movement while foraging. Based on the strong linear relationships between day of year and daily movement, Julian day was considered as a covariate in iSSA. However, Julian day was highly correlated with growing degree days > 0°C, so the latter covariate was included in base habitat model selection to account for variation in caribou movement as a function of day of post-calving/summer season.

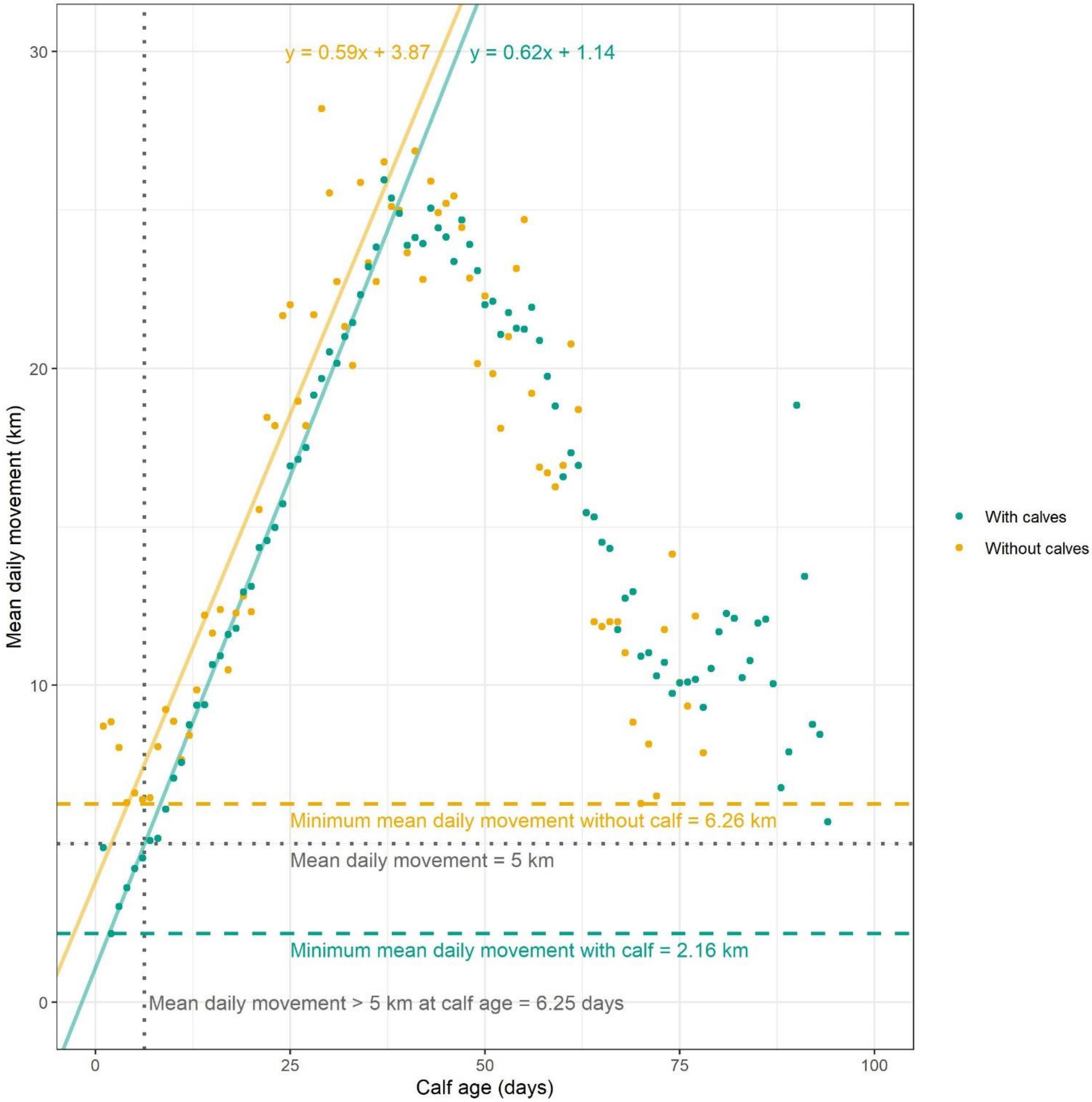

Figure A-1: Mean daily movement (km) as a function of calf age (days) for caribou with calves (teal) and caribou without calves (orange). Linear trendlines were fit to the data before peak daily movement, which occurred around a calf age of 37 days.

APPENDIX B

Correlated Covariates

Table B-1: Correlation coefficients (*r*) between pairs of spatial covariates considered in Integrated Step Selection Analyses (iSSA). Highly correlated covariates (*r* ≥ 0.70) are bolded and shaded grey.

Covariate	DistAWAR	DistAWARMine	DistMine	DistRankin	Elev	TerrainRug	TopoPos	VectorTerr	EVI	NDVI	Graminoid	HeathForb	Lichen	NonVeg	Shrub	Lake
DistAWAR	1.00	**1.00**	**1.00**	**1.00**	**0.84**	-0.02	0.03	-0.05	0.40	0.39	-0.13	0.21	-0.28	-0.16	0.33	-0.07
DistAWARMine		1.00	**1.00**	**1.00**	**0.84**	-0.02	0.03	-0.05	0.40	0.39	-0.13	0.21	-0.29	-0.17	0.33	-0.07
DistMine			1.00	**1.00**	**0.84**	-0.02	0.03	-0.05	0.40	0.39	-0.13	0.21	-0.29	-0.17	0.33	-0.07
DistRankin				1.00	**0.85**	-0.02	0.03	-0.05	0.39	0.38	-0.13	0.20	-0.27	-0.16	0.33	-0.07
Elev					1.00	0.00	0.06	-0.04	0.37	0.34	-0.13	0.17	-0.14	-0.06	0.24	-0.14
TerrainRug						1.00	0.04	0.31	0.09	0.06	-0.03	0.06	0.05	0.04	0.00	-0.12
TopoPos							1.00	0.04	0.10	0.11	0.00	0.06	0.03	0.02	0.01	-0.11
VectorTerr								1.00	-0.01	-0.02	-0.03	0.00	0.03	0.03	-0.03	0.00
EVI									1.00	**0.90**	0.07	0.51	-0.08	-0.15	0.33	-0.69
NDVI										1.00	0.09	0.46	-0.11	-0.18	0.31	-0.59
Graminoid											1.00	-0.20	-0.02	-0.10	-0.08	-0.23
HeathForb												1.00	-0.38	-0.27	-0.12	-0.40
Lichen													1.00	0.11	-0.21	-0.23
NonVeg														1.00	-0.12	-0.15
Shrub															1.00	-0.17
Lake																1.00

Table B-2: Correlation coefficients (*r*) between pairs of spatial-temporal covariates considered in Integrated Step Selection Analyses (iSSA). MosquitoIndex and OestridIndex were moderately correlated; MosquitoIndex was retained.

Covariate	MosquitoIndex	OestridIndex	GrowingDays
MosquitoIndex	1.00	0.58	0.06
OestridIndex		1.00	0.05
GrowingDays			1.00

Table B-3: Correlation coefficients (r) between pairs of covariates used in caribou movement candidate set (Table 5). Highly correlated covariates (r ≥ 0.70) are bolded and shaded grey.

Covariate	DistAWARMine	Greenness	Graminoid	HeathForb	Lichen	NonVegetated	Shrub	Lake	Julian	MosquitoIndex	GrowingDays
DistAWARMine	1.00	0.49	-0.16	0.21	-0.29	-0.16	0.33	-0.09	0.58	-0.01	0.59
Greenness		1.00	-0.03	0.39	-0.27	-0.29	0.32	-0.38	0.33	-0.01	0.31
Graminoid			1.00	-0.29	-0.03	-0.11	-0.10	-0.15	-0.05	0.01	-0.05
HeathForb				1.00	-0.49	-0.31	-0.18	-0.27	0.20	0.00	0.20
Lichen					1.00	0.12	-0.23	-0.14	-0.26	0.00	-0.25
NonVegetated						1.00	-0.12	-0.11	-0.17	-0.01	-0.17
Shrub							1.00	-0.13	0.21	0.00	0.21
Lake								1.00	-0.11	-0.01	-0.11
Julian									1.00	0.06	**0.96**
MosquitoIndex										1.00	0.06
GrowingDays											1.00

Table B-4: Correlation coefficients (*r*) between pairs of covariates used in caribou harvest candidate set (Table 6). Highly correlated covariates (*r* ≥ 0.70) are bolded and shaded grey.

Covariate	DistAWARMine	Greenness	Graminoid	HeathForb	Lichen	NonVegetated	Shrub	Lake	Julian	MosquitoIndex	GrowingDays	Harvest	AWARTrafficLocal	AWARTrafficProject	AWARTrafficTotal	ATVTraffic
DistAWARMine	1.00	-0.01	0.03	-0.20	0.05	0.20	0.17	0.05	0.45	0.00	0.47	-0.22	0.38	0.38	0.38	-0.02
Greenness		1.00	0.04	0.45	-0.12	-0.41	0.11	-0.22	-0.10	0.01	-0.11	-0.01	-0.06	-0.06	-0.06	-0.03
Graminoid			1.00	-0.35	-0.13	-0.17	0.02	-0.18	0.04	0.00	0.06	-0.06	-0.03	-0.03	-0.03	-0.01
HeathForb				1.00	-0.39	-0.32	-0.06	-0.20	-0.20	0.00	-0.22	0.13	-0.13	-0.13	-0.13	0.01
Lichen					1.00	0.03	-0.08	-0.14	0.14	0.02	0.13	-0.07	0.17	0.17	0.17	0.03
NonVegetated						1.00	-0.04	-0.07	0.06	0.01	0.06	-0.06	0.06	0.06	0.06	-0.01
Shrub							1.00	-0.02	0.12	-0.02	0.12	-0.03	0.10	0.10	0.10	0.00
Lake								1.00	0.11	-0.01	0.11	0.04	0.09	0.09	0.09	-0.01
Julian									1.00	0.01	**1.00**	-0.12	**0.84**	**0.84**	**0.84**	0.07
MosquitoIndex										1.00	0.01	0.02	-0.03	-0.03	-0.03	-0.01
GrowingDays											1.00	-0.12	**0.83**	**0.83**	**0.83**	0.08
Harvest												1.00	-0.10	-0.10	-0.10	-0.03
AWARTrafficLocal													1.00	**1.00**	**1.00**	0.28
AWARTrafficProject														1.00	**1.00**	0.28
AWARTrafficTotal															1.00	0.28
ATVTraffic																1.00

APPENDIX C

Ecological Land Cover Groupings and Extent of Kivalliq Land Cover Data

Table C-1: Reclassification of Kivalliq ecological land cover into six reclassified groups

Original Land Cover Classification	Reclassified Land Cover Groupings
Graminoid heath tundra	Graminoid
Graminoid tundra	
Wet graminoid	
Forb tundra	Heath-forb
Heath tundra	
Heath upland	
Shrub heath tundra	Lichen
Heath upland rock complex	
Lichen rock complex	
Lichen tundra	
Boulder gravel	Non-vegetated
Rock	
Sand	
Graminoid shrub tundra	Shrub
Shrub thicket	
Shrub tundra	
Ice	Water
Water	

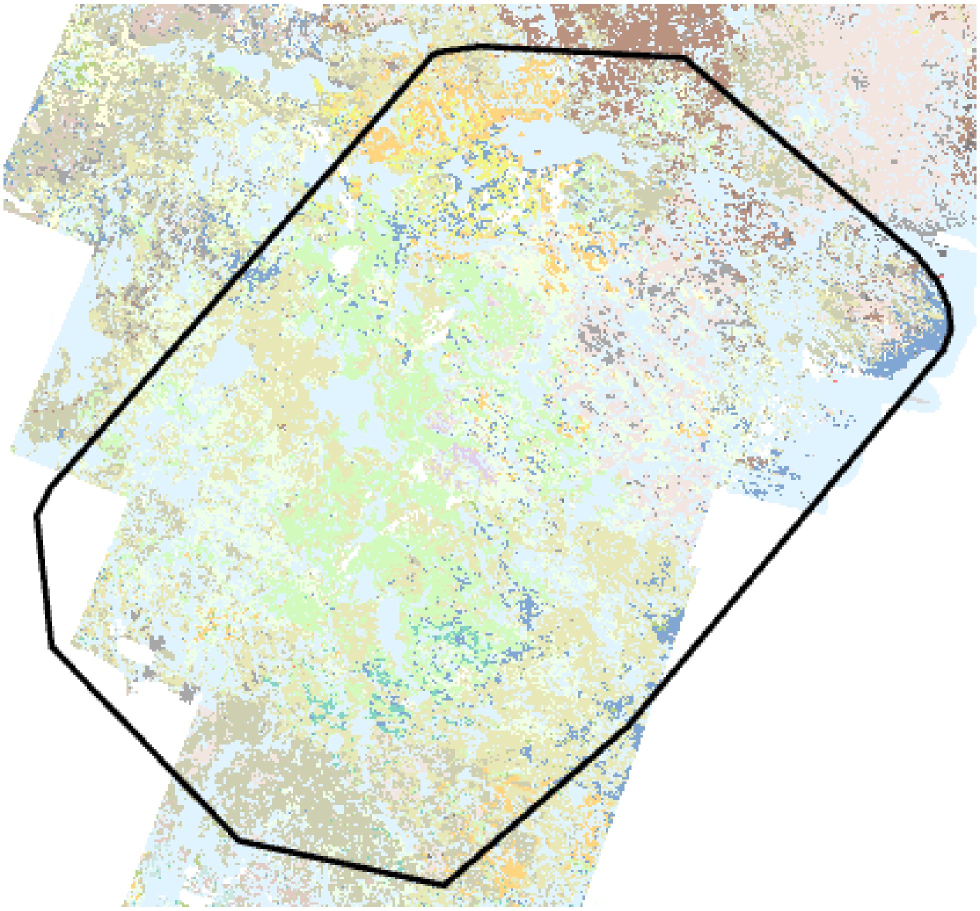

Figure C-2: Spatial coverage of Kivalliq Land Cover Data compared to Commitment 38 study area (black outlined polygon)

APPENDIX D

Ground-Based Observations vs. Telemetry Data Assumption Test

Methods of Assumption Test

Based on feedback from the TAG, observations of caribou from telemetry data were compared to ground-based observations of caribou to determine whether individuals being monitored with GPS collars are representative of the movements and migrations made by the QAM herd. Ground surveys were conducted on and/or near the AWAR and Mine between 19 June and 23 July 2022. Telemetry data were constrained to the same date range (i.e., 19 June to 23 July 2022) and to only locations of caribou collected within five km of the AWAR and/or Mine. The total number of caribou observed were summed per day for each data source, then compared using a Spearman rank correlation test, which produced a Spearman rank correlation coefficient (r).

Results of Assumption Test

Caribou were observed for 20 of the 35 days when ground surveys were conducted between 19 June and 23 July 2022. Ground-based observations ranged from 0 to 135,000 individuals, and telemetry observations ranged from 0 to 17 individuals. Maximum counts of caribou from ground surveys and telemetry data occurred on 12 July and 11 July, respectively. Caribou observed via ground surveys and telemetry data were highly correlated ($r = 0.74$; $p = < 0.005$; $n = 35$ days; Figure D-1).

Key Takeaways from Assumption Test

Daily caribou observations from collars and ground-based surveys were significantly highly correlated over the 35-day period when both types of data were available. The results of this assumption test support that the collared subset of QAM caribou are representative of the broader movements and migrations being made by the QAM herd. Specifically, collared QAM caribou are migrating through the AWAR and/or Mine vicinity at the same time as the QAM herd.

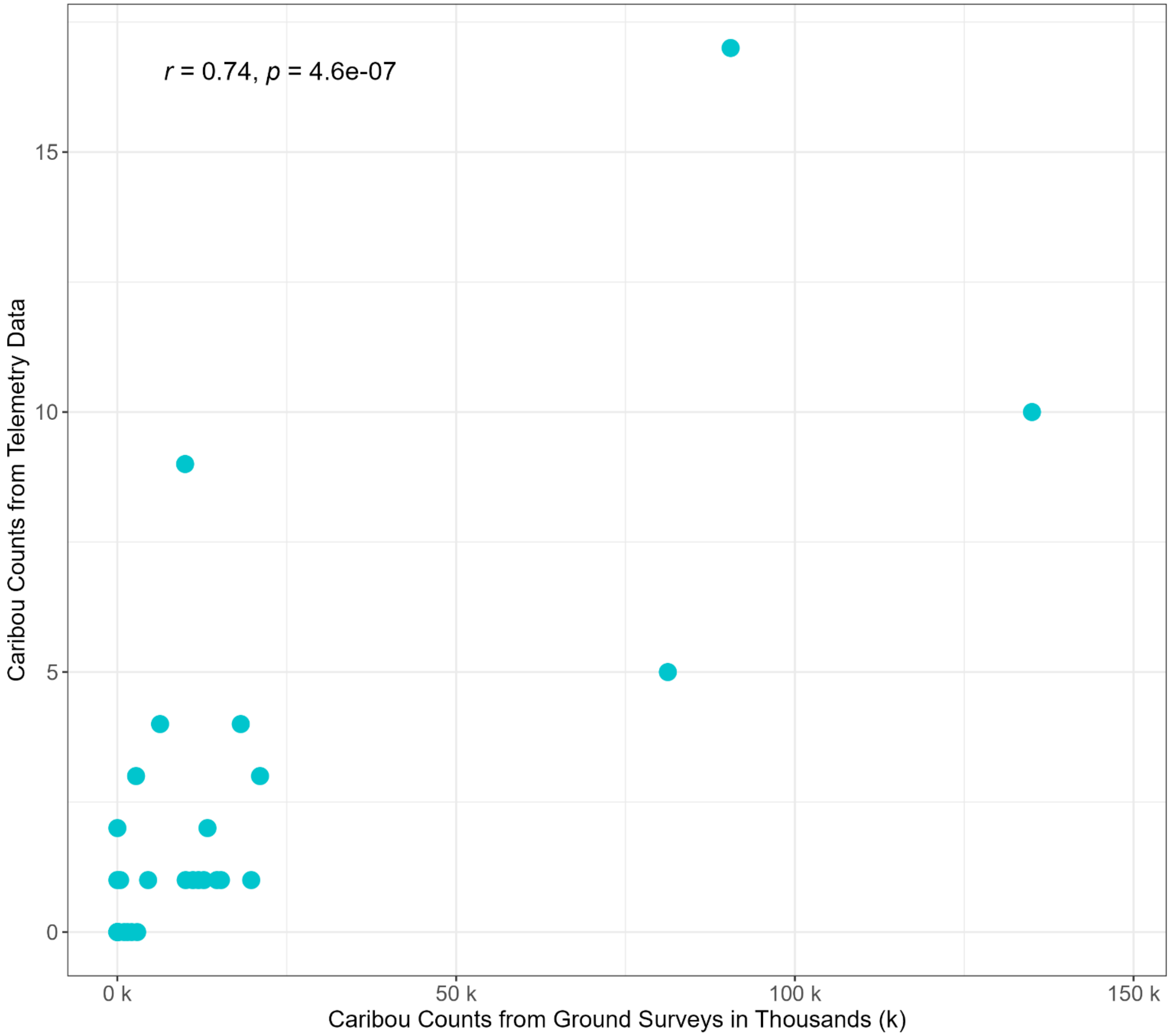

Figure D-1: Daily caribou counts from ground-based surveys, measured in thousands (k) of individuals, compared to caribou counts from telemetry collars, within five km of the All-Weather Access Road (AWAR) and Mine. Data were collected between 19 June and 23 July 2022. A Spearman rank correlation coefficient (r) and p-value is presented.

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