26 February 2024

To: Distribution List (attached below):

Re: Barren-ground caribou movement and habitat selection analyses from telemetry data Report

Arctic Canadian Diamond Company Ltd. (Arctic Canadian) became a wholly owned subsidiary of Burgundy Diamond Mines Ltd. (Burgundy) in June 2023 and is pleased to provide a copy of the Barren-ground caribou movement and habitat selection analyses from telemetry data for Ekati Diamond Mine Wildlife Effects Monitoring for review.

The Wildlife Effects Monitoring Plan for the Ekati Diamond Mine that was in effect from 2017 to 2023 included a number of different monitoring and mitigation programs. One of those programs was a commitment to provide funding for the Government of the Northwest Territories' radio-collaring program for the Beverly and Bathurst caribou herds. Arctic Canadian Diamond Company Ltd. made a commitment to use the resulting data to examine the effects of the Ekati Diamond Mine on caribou behaviour.

This report addresses concerns about the effect of the Ekati Diamond Mine on caribou behaviour when the animals are within 30 km of the mine roads and mine infrastructure (including things like open pits, camps, waste rock storage areas, and settling ponds). More specifically, this report is a detailed analysis of radio-collar location data to examine the responses of caribou to mines and mine roads after accounting for the distribution of waterbodies, eskers, landcover categories (mostly vegetation types), and insect abundance.

Burgundy has included a formal schedule and distribution of the first draft of the telemetry report and the following proposed schedule is below:

- Burgundy to provide formal schedule and distribute telemetry report draft- February 26th , 2024
- Burgundy proposed meeting workshop on Telemetry Report Draft – date to be determined (April 8-9th or April 11th, 12th 2024)
- Burgundy to receive final stakeholder comments on Telemetry Report Draft – April 22nd, 2024
- Burgundy to address comments and responses in final draft of Telemetry Report- May 31st , 2024

Burgundy Diamond Mines Limited
Level 25, South 32 Tower, 108 St Georges Terrace, Perth WA 6000, AUSTRALIA | Ph: +61 8 6313 3945
Suite 900, 606 Fourth Street S.W., Calgary, Alberta, T2P 1T1, CANADA | Ph: +1 403 910 1933
Schupstraat 15, 2018 Antwerp, Belgium

Burgundy trusts that you will find this information to be clear and informative. Please contact the undersigned at 403-910-1933 ext. 2408 or Adam.Scott@burgundydiamonds.com or Kurtis Trefry, Acting Manager – Environmental Reporting and Permitting at 403-650-1310 or Kurtis.Trefry@burgundydiamonds.com if you have any comments or questions.

Adam Scott

Environment Advisor- Wildlife

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Date: 26-February-24

Distribution List:

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Shawn McKay – Environment Coordinator- frmcenvironment@northwestel.net

Tas-Tsi Catholique – Manager – Wildlife, Lands and Environment Department

Violet Camsell-Blondin – Manager, Lands Regulatory Department, Tłįchǫ Government

Burgundy Diamond Mines Limited
Level 25, South 32 Tower, 108 St Georges Terrace, Perth WA 6000, AUSTRALIA | Ph: +61 8 6313 3945
Suite 900, 606 Fourth Street S.W., Calgary, Alberta, T2P 1T1, CANADA | Ph: +1 403 910 1933
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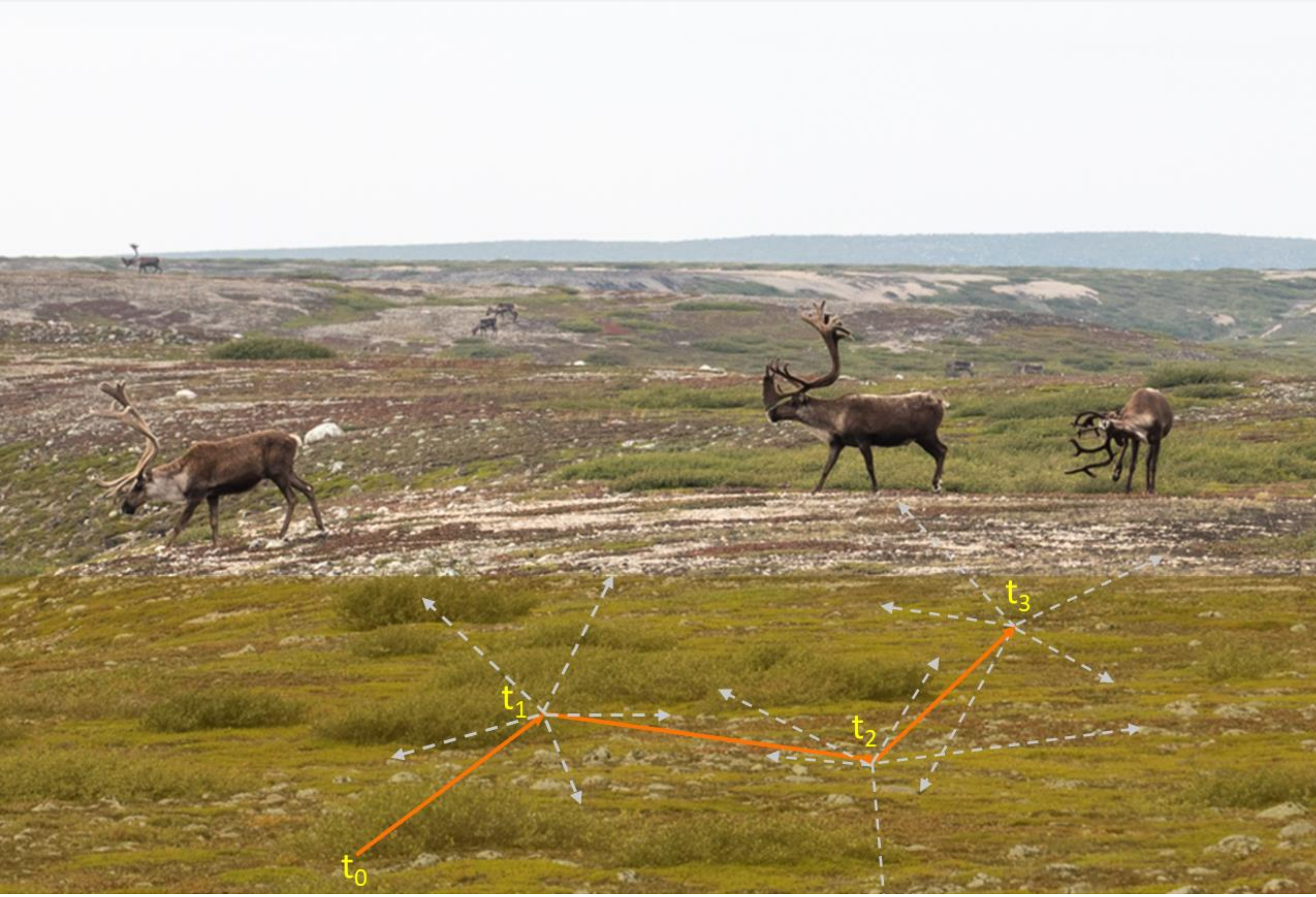


Barren-ground caribou movement and habitat selection analyses from telemetry data

Ekati Diamond Mine Wildlife Effects Monitoring

February 2024

Project No.: Arctic 22-04

Barren-ground caribou movement and habitat selection analyses from telemetry data

Ekati Diamond Mine Wildlife Effects Monitoring

February 2024

Project No.: Arctic 22-04

W. James Rettie, Robert S. Rempel, and Laurie M. Ainsworth

Paragon Wildlife Research and Analysis Ltd.

30 River Road
Winnipeg, MB
Canada, R2M 3Z2

Email: jim.rettie@paragonwildlife.com
Phone: 204-801-7176

CONTENTS

PLAIN LANGUAGE SUMMARY

The Wildlife Effects Monitoring Plan for the Ekati Diamond Mine that was in effect from 2017 to 2023 included a number of different monitoring and mitigation programs. One of those programs was a commitment to provide funding for the Government of the Northwest Territories' radio-collaring program for the Beverly and Bathurst caribou herds. Arctic Canadian Diamond Company Ltd. made a commitment to use the resulting data to examine the effects of the Ekati Diamond Mine on caribou behaviour.

This report addresses concerns about the effect of the Ekati Diamond Mine on caribou behaviour when the animals are within 30 km of the mine roads and mine infrastructure (including things like open pits, camps, waster rock storage areas, and settling ponds).

In 2021, the Independent Environmental Monitoring Agency (IEMA) summarized some of the movement data from the Beverly and Bathurst herds for animals within 30 km of the Ekati Diamond Mine and raised some questions requiring more detailed examination. The questions of interest were about local effects of mines and mine activity on caribou behaviour: essentially, how do caribou respond in time periods of less than a day to mining activities when caribou are close enough to sense the effect of the mine (for example, by sound, sight, scent, vibrations). The potential area around the Ekati and Diavik diamond mines where caribou might respond to sensory disturbances is large, and separate measurements for potential disturbances at each location in the area do not exist. Instead, the distance to the nearest point along a mine road and the nearest point to mine infrastructure was measured for every caribou location within 30 km. While the analyses can identify when animals preferred to be close to the mine (positive response to the mine) or avoided the mine (negative response to the mine), they do not tell us what specifically caused any of the observed responses.

Caribou are known to have seasonal preferences for habitat features. Earlier studies on the Beverly and Bathurst herds and on other migratory caribou have suggested or shown that roads, mine infrastructure, and mining activity can affect how caribou behave. This report is a detailed analysis of radio-collar location data to examine the responses of caribou to mines and mine roads after accounting for the distribution of waterbodies, eskers, landcover categories (mostly vegetation types), and insect abundance.

As responses may be different in different seasons and may be different for male and female caribou, the movements were examined separately for each sex in each season. The Beverly and Bathurst herds were initially considered for separate analyses, but the results supported combining data from the two herds.

The time period and the area included in the study

The goal was to understand caribou habitat selection and movement behaviour in short time intervals, so the years included in the study began with the winter of 2015-2016 when radio-collar locations collected once every 8-hours became available throughout the year for both the Bathurst and Beverly herds.

The radio-collar locations showed the large ranges used each year by the Beverly and Bathurst herds and those areas guided the selection of the study area. To define the regional study area, the ranges of both herds were considered and the area chosen is shown in Figure 1. The 212,000 km^2 area contains over 90% of all Bathurst herd locations collected between December 2015 and December 2022 and nearly 70% of Beverly herd locations for the same time period.

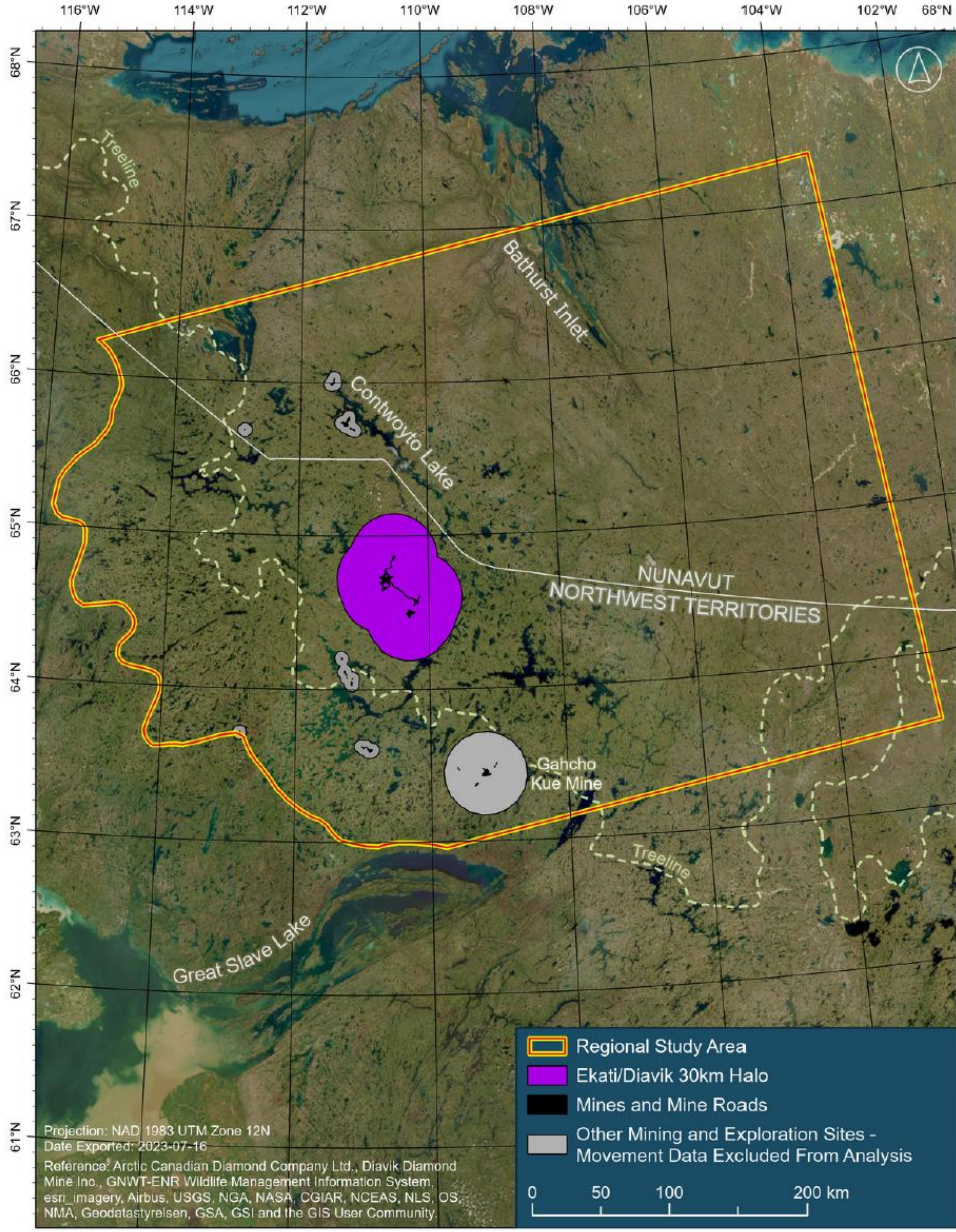


Figure 1: The areas containing caribou locations used in the analyses.

Understanding caribou habitat use when they are far from mines

Before trying to understand the effects of the Ekati and Diavik diamond mines on caribou behaviour, caribou locations were first used to determine how animals responded to natural environmental features when there were no mines nearby.

The locations from near the Gahcho Kué Diamond Mine and other mining and exploration sites (within the grey shapes on Figure 1) were excluded completely, while locations from within 30 km of the Ekati and Diavik diamond mines (the purple shape on Figure 1, the "Ekati/Diavik 30 km halo") were kept separate. All of the other locations from inside the regional study area were used to examine caribou habitat selection by each sex in each season when they were more than 30 km away from the mines.

Overall, there was a general pattern for caribou to prefer to be within about 1.3 km of a body of water, but not right next to it. In most seasons, both male and female caribou chose locations with higher amounts of tussock tundra and shrubs within 100 m. Of the nine seasons examined separately for males and females, all but one (female summer) showed that caribou made decisions about where to move over an 8-hour period using habitat information from the area within 100 m of their location as well as other habitat information within distances up to 1.3 km away (the farthest distance examined).

Testing how caribou change how they use habitat when they are close to mines

Using the knowledge learned from how caribou responded to natural features away from the mines, the natural features within 30 km of the mines were used to predict the value of the habitat to caribou (ignoring how close they were to the mines).

Then the caribou locations from within the Ekati/Diavik 30 km halo were used to test if the predictions were correct, or if caribou habitat selection was affected by the mine roads or the mine infrastructure. Like the other analysis, this was done separately for each season for male and for female caribou. Calving season and post-calving season were not included for this analysis because there were too few locations recorded near the mines in those seasons.

For most seasons of the year, male caribou selected habitat the same way they did in the large regional study area – there was no difference related to how close they were to mine roads and mine infrastructure. There were two seasons where there was an effect of mines on male caribou habitat selection: during summer, male caribou preferred to be farther away from mine infrastructure, out to about 14 km; and during the rut, they preferred to be closer to mine infrastructure.

During winter (December to April) and summer, late summer, and pre-rut (a continuous period from the beginning of July to mid-October) female caribou preferred areas farther away from mine infrastructure than was predicted from their habitat preferences in the larger region.

As an example, Figure 2 provides a view of how female caribou responded to habitat in the pre-rut period. The map on the left of Figure 2 is the prediction of how females would respond to habitat based on their behaviour when they are far from the mines; it shows how, based on the natural environmental features, higher and lower value habitat is spread throughout the Ekati/Diavik 30 km halo. When the behaviour of caribou inside the halo is considered (the map on the right of Figure 2), there is a reduction in habitat value closer to mine infrastructure. In seasons when there was no effect of mine infrastructure on behaviour, the two maps are identical, indicating no apparent difference in habitat value.

There were not any seasons of the year where either male or female caribou 8-hour movement behaviour was best explained by how far they were from mine roads.

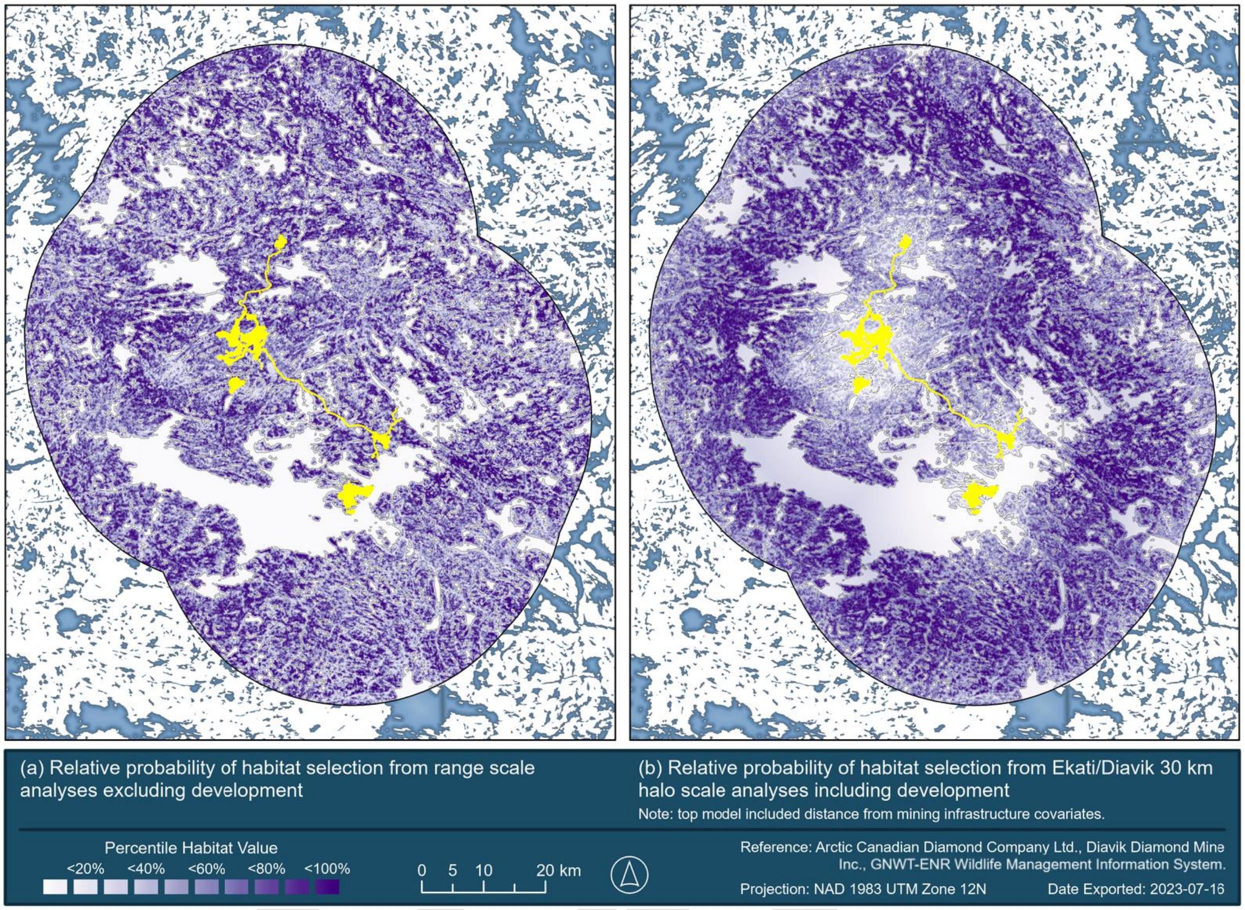


Figure 2: The predicted habitat value (left-hand panel) for female caribou in the pre-rut season in the Ekati/Diavik 30 km halo and the effect of distance to mining infrastructure (included in right-hand panel) on the predicted habitat value.

How caribou respond to habitat and mines when they make 1-hour movements

Starting in 2017 (Bathurst herd) and 2018 (Beverly herd) locations were collected every hour when a radio-collared caribou was within about 30 km of the mines. These were the same animals that provided the locations 8-hours apart, but when close to the mines they produced locations that allowed 1-hour behaviour to be determined.

When locations are only 1-hour apart, animals have less to choose from – the habitats they have available to them are closer together than when they have 8-hours between locations. The 1-hour habitat selection decisions by animals were dominated by the environmental features within 100 m of their locations.

With their 1-hour movement steps, male caribou preferred habitat closer to mine roads in summer; habitat selection by male caribou was not affected by distance to mine roads or mine infrastructure in any other season. The results from 1-hour interval analyses for female caribou suggest they preferred habitat closer to mine roads in summer and during the rut. Female caribou avoided habitat closer to mine roads during winter and spring migration and avoided areas closer to mine infrastructure during post-rut.

Overall effects of mine roads and mine infrastructure on habitat selection by caribou

When their 8-hour movements were examined, male caribou avoided habitat closer mine infrastructure in the summer; however, their 1-hour movement preferences in summer were to be closer to mine infrastructure. Eight-hour interval analyses showed that male caribou preferred habitat closer to mine infrastructure during the rut. There were no other selection or avoidance responses to habitat near mine roads or infrastructure observed for male caribou in any season at either the 1-hour or 8-hour movement scale.

Combined with 8-hour results, female habitat selection was to avoid habitat near mine infrastructure or roads at both 1-hour and 8-hour movement scales in winter, and at one scale but not the other in every other season except the rut. Female caribou 1-hour interval habitat selection included a preference for habitat closer to mine roads during summer and the rut.

Effect of encountering mines on total seasonal movement distance and delays in seasonal range arrival

Regardless of their individual pathways and movement patterns, caribou that spend time near the Ekati and Diavik diamond mines are not typically travelling farther than animals that do not encounter the mine complex. Some comparisons (11%) of seasonal travel by each sex in each herd showed longer travel distances when the mining complex was encountered by caribou, but more comparisons (17%) showed shorter seasonal pathways; the remaining 72% of season/sex/herd combinations showed no effect of mine encounter on total travel distance in the season.

One of the characteristics of barren-ground caribou is that they use different ranges in different seasons. To address a concern that encountering the Ekati and Diavik diamond mines might delay movement across the landscape, the arrival times on each seasonal range were compared with whether or not the animal had spent time in the 30 km halo around the mines. There was no evidence that indicated animals were delayed from arriving at their next seasonal range on time after encountering the Ekati and Diavik diamond mines in the previous season.

EXECUTIVE SUMMARY

The objective of this study was to determine the effects of the Ekati Diamond Mine on fine-scale behaviour of Beverly and Bathurst herd caribou. The telemetry location data available at a scale of less than 24-hour intervals defined the study period as 2016 to 2022. In the study period, data were collected every 8-hours throughout the range of both herds. Additionally, 1-hour interval data collection within an area of approximately 30 km around the Ekati and Diavik mines began with spring migration in 2017 for the Bathurst herd, and spring migration in 2018 for the Beverly herd. The 8-hour and 1-hour time intervals were adopted as the coarser- and finer-scales for habitat selection analyses.

Habitat selection analyses were conducted in three distinct phases. In Phase 1, data collected on an 8-hour interval within the region, but outside the influence of development, were analyzed and used to predict relative habitat selection value within 30 km of the Ekati and Diavik mines. In this way, behaviour of animals removed from the effects of development was used to predict habitat selection that might be expected if development was not present. In Phase 2 analyses, relative habitat selection values predicted from Phase 1 results were combined with the caribou location data from inside the 30 km buffer and used to assess the effect of the proximity of mine infrastructure and mine roads on seasonal habitat selection by caribou of each sex. The analyses of 8-hour interval data for male caribou suggested that areas closer to mine roads or mine infrastructure had reduced habitat selection value only during summer. During rut, 8-hour analyses indicated that habitat selection value for male caribou was higher in areas closer to mine infrastructure. For female caribou, the analyses indicated that areas closer to mine infrastructure had reduced habitat selection value in winter, summer, late summer and pre-rut.

The Phase 3 analyses used data collected on a 1-hour interval, limited to an area within approximately 30 km of the Ekati and Diavik mines. Results from 1-hour movement analyses of male caribou data showed no significant influence of mine roads or mine infrastructure on habitat selection or movement behaviour in any season except summer (where predicted relative habitat selection value was higher closer to mine roads), reinforcing the conclusion reached from 8-hour scale results. Overall, the results from 1-hour interval analyses for female caribou suggest that relative habitat selection values were reduced closer to mine roads or mine infrastructure in three seasons of the year; in two other seasons the opposite effect was observed with relative habitat selection value increased closer to the road. Combined with 8-hour results, relative habitat selection values were reduced for female caribou at both scales in winter, and at one scale of the two in every other season examined except the rut.

The results provide evidence that proximity to mine infrastructure and mine roads affects habitat selection by male caribou in summer and during the rut, and by female caribou throughout the year, with the exception of the calving and post-calving seasons when they are not within 30 km of the mines.

Analyses were also conducted to evaluate the effects of proximity to mines on seasonal caribou movement. Specifically, exposure to the 30 km buffer around the Ekati and Diavik mines was examined for its effect on total seasonal movement path length and on delayed arrival in the seasonal range for the next season. In 26 of 36 comparisons (independent for each herd by sex by season) there were no differences in total seasonal movement path length related to how long an animal had been within 30 km of the Ekati and Diavik mines. Of the remaining 10 results, four showed longer movement paths related to increased residency within 30 km of Ekati and Diavik, while the other six showed shorter movement paths associated with increased time near the mines. There were no seasons in which any level of exposure to the 30 km buffer around the Ekati and Diavik mines resulted in caribou arriving late to the next seasonal range. The results did not generally support concerns of exposure to diamond mining infrastructure and roads yielding deflected, longer movements by caribou, nor delays in range-scale movements.

ACKNOWLEDGEMENTS

This project was initiated and managed by Tommy Thorsteinsson and Harry O'Keefe of Arctic Canadian Diamond Company Ltd. This report was prepared for Arctic Canadian Diamond Company Ltd. by Paragon Wildlife Research and Analysis Ltd. (Paragon). James Rettie (Paragon) led the project and collaborated on analyses with Robert Rempel of FERIT Consulting and Laurie Ainsworth of PhiStat Research & Consulting. Mapping was completed by Daniel Phalen.

Proprietary spatial data used in this report were provided by: Arctic Canadian Diamond Company Ltd. (mine and mine road footprints); Diavik Diamond Mines Inc. (mine footprint); and the Government of the Northwest Territories Department of Environment and Natural Resources - Northwest Territories Wildlife Management Information System (exploration and development layer).

The Government of the Northwest Territories Department of Environment and Natural Resources provided all barren-ground caribou radio-collar locations through its Northwest Territories Wildlife Management Information System.

Don Russell of the CircumArctic Rangifer Monitoring and Assessment (CARMA) network kindly provided daily insect harassment index values for the period of the analyses.

Suggested citation for this report:

Rettie, W.J., R.S. Rempel, and L.M. Ainsworth. 2024. Barren-ground caribou movement analyses from telemetry data. Ekati Diamond Mine Wildlife Effects Monitoring. Report prepared by Paragon Wildlife Research and Analysis Ltd., Winnipeg, MB for Arctic Canadian Diamond Company Ltd. xx pp.

ACRONYMS AND ABBREVIATIONS

AIC	Akaike's Information Criterion
BCRP	Bathurst Caribou Range Plan
BIC	Bayesian Information Criterion
BRT	Boosted regression tree
CARMA	CircumArctic Rangifer Monitoring and Assessment network
CRMP	Caribou Road Mitigation Plan
GF112N	Geofence 112 North
GIS	Geographic Information System
GNWT	Government of the Northwest Territories
GNWT-ENR	Department of Environment and Natural Resources of the GNWT
GPS	Global Positioning System
ha	hectare
HSA	Habitat Selection Analysis
HSF	Habitat Selection Function
IEMA	Independent Environmental Monitoring Agency
iSSA	integrated Step Selection Analysis
iSSF	integrated Step Selection Function
km	kilometre
LSL	Landscape Scripting Language
m	metre
mm	millimetre
NTS	National Topographic System
NU	Nunavut
NWT	Northwest Territories
RSA	Regional Study Area
RSF	Resource Selection Function
SSA	Step Selection Analysis

SSF	Step Selection Function
UD	Utilization Distribution
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WEMP	Wildlife Effects Monitoring Plan
VIF	Variance Inflation Factor
ZOI	Zone of Influence

GLOSSARY

Animal-season	A period of a single season in a single year for a single animal. Data collected in each animal-season were considered independent in the analyses in this report.
Available locations	Geographic locations generated during analyses that represent plausible alternative end points for each real movement step that each caribou took. In step selection analyses and integrated step selection analysis, the analytical processes employed in this report, a set of 5 available locations were generated for each real location acquired for each radio-collared caribou.
Delayed arrival	For the purposes of characterizing an animal's movement over a period of time, the delayed arrival of an individual in a seasonal range was defined as the number of days between the first telemetry location recorded for the individual in the season and the first location recorded for the individual within the 90% utilization distribution (UD) seasonal range.
Ekati/Diavik halo	A geographic area defined as being within 30 km of the area occupied by the Diavik and Ekati mine infrastructure and mine roads in 2021. In the 8-hour interval habitat selection analyses, data from within this area were separated from data in the broader regional study area. This is the geographic area used in Phase 2 analyses. The spatial extent of the Ekati/Diavik halo is similar to GF112N described below.
Extent	See "Spatial extent" and "Temporal extent" below.
Geofence 112 North (GF112N)	A geographic area defining the limits of 1-hour telemetry data analysed in this report. Three geofence areas were established by GNWT-ENR to increase the frequency of telemetry location acquisition from radio-collars near areas of human disturbance. Geofence 112 includes the area around the Ekati and Diavik mines. In this report data were restricted to the portion of geofence 112 north of 64°12' North latitude. GF112N is the geographic area used in Phase 3 analyses. The spatial extent of GF112N is similar to the Ekati/Diavik halo described above.
Grain	The spatial area or temporal period associated with individual observations in an analysis. Its potential upper and lower limits are set by covariate data resolution (at the finest level) and by spatial and temporal data extents (at the coarsest level). Functionally, the analyst will choose one or more grains between the upper and lower limits. Ecologically, animals may simultaneously respond to covariates measured at different grains.
Habitat	The set of resources and risk conditions at each location in environmental space. The resources and risks vary for each species and are likely influenced by other factors such as season, sex, and reproductive status. Habitat is approximated by the set of environmental covariates measured and included in an analysis. However, the full suite of relevant resources and risks are rarely known or measured at all appropriate spatial and temporal extents and resolutions.

Habitat selection	The process through which individual animals differentially use habitats relative to their availabilities. Typically determined through comparison of habitat attributes at available locations and used locations.
Regional Study Area	The spatial extent of environmental and caribou location data included in analyses of 8-hour movement and habitat selection. Phase 1 analyses were based on data within the regional study area, excluding data both within the Ekati/Diavik halo (described above) and within buffers around some other select development features.
Relative habitat selection value	The exponentiated result when a selection function is applied to the covariates in a discrete cell (e.g., a 3.1-ha hexagonal unit as used in the analyses reported here). The habitat selection value is relative to the values of other cells, rather than being an absolute likelihood that a cell will be selected by an animal.
Resolution	How finely a resource unit is measured: the minimum spatial or temporal unit of data (e.g., pixel size of raster data; fix-interval of telemetry locations; frequency of updated measurement of environmental covariates).
Scale (of selection)	The size of a geographic space or the length of a period of time. In the context of habitat selection, it is generally accepted that selective behaviour may differ when examined over finer or coarser scales. The spatial and temporal scales are linked: behaviour occurring over larger areas is likely to occur over longer periods of time, and vice versa.
Selection analysis	An analytical process used to characterize preferential use or avoidance of environmental features by an animal. In this report selection analyses were based on conditional logistic regression of sets of candidate models for each sex by season. In this report it is referred to generically as habitat selection analysis (HSA) or specifically as step-selection analysis (SSA) or integrated step-selection analysis (iSSA). When completed, the top model covariates and their coefficients become the elements of the selection function (below)
Selection function	A weighting function applied to environmental covariates to estimate the relative probability of an animal selecting a location (a 3.1-ha hexagonal unit in the case of the analyses presented here). Selection functions are the end product of selection analyses. In this report they are the top models resulting from selection analyses (see above) for each sex by season. In this report they are referred to generically as habitat selection functions (HSFs) or specifically as step-selection functions (SSFs) or integrated step-selection functions (iSSFs).
Spatial extent	The entire geographic area represented by a data layer or an analysis.
Temporal extent	The entire time period represented by a data set or an analysis.

Total movement pathway	For the purposes of characterizing an animal's movement over a period of time, the total movement pathway is defined as the sum of the length of straight-line steps implied by the sequence of 8-hour interval telemetry locations for the individual.
Used locations	Geographic locations obtained via telemetry from radio-collared caribou.
Utilization Distribution (UD)	The UDs described in this report represent the seasonal distribution of caribou in each year – separately for each sex in each herd. Based on telemetry data.

1. INTRODUCTION

The Ekati Diamond Mine and its surrounding mining leases are located approximately 200 km south of the Arctic Circle and 300 km northeast of Yellowknife, Northwest Territories (NWT; Section 2.1 below)). The mine is situated within the Exeter Lake, Koala, Lac de Gras, and Lac du Sauvage watersheds at the headwaters of the Coppermine River drainage basin, which flows north to the Arctic Ocean. It is also within the annual ranges of the Bathurst and Beverly herds of migratory barren-ground caribou (*Rangifer tarandus groenlandicus*).

The 2017 Ekati Diamond Mine Wildlife Effects Monitoring Plan (WEMP, Golder 2017), including the Caribou Road Mitigation Plan (CRMP), was applied site-wide at the Ekati Diamond Mine to the end of the study period in 2022. The Ekati WEMP program included a commitment by Arctic Canadian Diamond Company Ltd. to provide funding to the Government of the Northwest Territories Department of Environment and Natural Resources (GNWT-ENR) for radio-collaring programs and to incorporate the radio-telemetry data in its assessment of the effect of the Ekati Diamond Mine on barren-ground caribou.

In a recent report on caribou movement prepared for the Independent Environmental Monitoring Agency (IEMA), Poole et al. (2021) described movement attributes of barren-ground caribou relative to the Ekati Diamond Mine. Their review was limited to movement of female caribou that came within 30 km of mine infrastructure, examining movement speed, turning angles, time spent in concentric distance buffers around the mine infrastructure, and crossings of two of the mine roads. They included a qualitative assessment of habitat but recognized that more thorough analyses would likely provide a better understanding of the relationship between caribou movement and ecological covariates. The summary concluded that fine-scale movement step-lengths and turning angles were affected by proximity to Ekati Diamond Mine infrastructure and its operations.

Arctic Canadian Diamond Company Ltd. identified two broad objectives that to address through formal analyses:

- to conduct detailed analysis of caribou telemetry data to identify and evaluate the movement of caribou through the mine site; and
- to conduct analyses that will contribute to the body of knowledge utilized by the GNWT and others to manage the herd.

This document reports on Arctic Canadian Diamond Company Ltd.'s analyses to address their commitments, and to respond to the concerns raised by Indigenous Governments, regulators, and others regarding the potential effects of the Ekati Diamond Mine on fine-scale behaviour of caribou. The analyses reported here used telemetry data from the Bathurst and Beverly herds to examine the effects the Ekati Diamond Mine has on caribou behaviour in the vicinity of the mine. Habitat selection is always a scale-dependent process, as available habitat is context-dependent. Locations that an animal may select are constrained to what is within the area that the animal may encounter over the time interval of selection, given its movement abilities and its established behaviour. That selective behaviour may be measured over any time interval of interest (e.g., annual, seasonal, sub-seasonal, daily, etc.). The spatial and temporal resolution of telemetry location data for the Beverly and Bathurst herd caribou was set by GNWT-ENR as one location (with approximately 10-m accuracy; E. DiMarco – Telonics, personal communication March 15, 2023) every 8-hours throughout the range of both herds, increasing to one location every 1-hour when animals were within specific geographic areas near development – areas that include a buffer of approximately 30 km around the Ekati Diamond Mine. Those temporal resolutions (1-hour and 8-hour) were adopted to define the two, relatively fine scales of analyses in this report.

Animal movement and habitat selection are linked to each other and to ecological attributes including topography, vegetation communities, and human disturbance (Passoni et al. 2021). For that reason, the analytical approaches for this project were step-selection analyses to model movement steps in relation to ecological covariates (Thurfjell et al. 2014, Passoni et al. 2021) including land cover classes, insect harassment indices, and proximity to mine infrastructure and mine roads

1.1 Objectives

The broad questions addressed in this report are:

1. Are there effects of the Ekati Diamond Mine on fine-scale barren-ground caribou behaviour?
2. What are the effects and what are their causes?
3. At what scale do the effects occur?
4. Are effects specific to different seasons or sexes? and
5. What is the magnitude of the effects?

Important variables of interest for these analyses were identified with input from Indigenous Governments, regulators, and IEMA. They included landcover types, mine roads, other mine infrastructure, insect harassment, sex, season, herd, and year. Other factors were mentioned for future work.

To address those key questions, the analyses in this report sought to remove the confounding effects of differential distribution of habitat. While Boulanger et al. (2012, 2021) attempted to address the effects of habitat availability on caribou distribution, this report includes explicit habitat selection analyses (HSA) spatially separated and independent from the effects of development to provide seasonal habitat selection functions (HSFs) for each sex (Phase 1 analyses). In the iterative development of a set of sex by season HSFs, multiple grains of habitat were measured to characterize used and available locations rather than relying on a default assumption of the importance of habitat within a specific distance of a point.

The Phase 1 HSFs were used to predict relative habitat selection values in proximity to the Ekati and Diavik mine, providing controls for relative habitat selection value independent of the influence of distances to mining infrastructure and activities. Having accounted for relative habitat selection values, the Phase 2 HSAs at the 8-hour interval scale then moved forward to address the role of proximity of mine infrastructure and mine roads on caribou behaviour. The integration of habitat selection, movement behaviour, and behavioural responses to mine roads and infrastructure was considered to be a detailed, ecologically sound approach to examine the effects of industry on caribou.

Data collected at 1-hour intervals were used for finer scale Phase 3 HSAs, though the data acquisition frequency was limited to areas close to the mines, precluding the ability to control for habitat selection absent of mining influence.

Additionally, the analyses in this report test the season-specific effect of exposure of caribou to the area within 30 km of the Ekati and Diavik mines on:

6. Total distance moved within the season; and
7. Delay in arrival time on the next seasonal range.

Though known to be affected by habitat composition, the effects of distance to mining features on movement step lengths and turning angles were examined for both 1-hour and 8-hour intervals to provide quantitative analyses for direct comparison with summary information in Poole et al. (2021).

Given the proximity of the Diavik Diamond Mine to the Ekati Diamond Mine and the reported distances of effects on caribou distribution (zones of influence [ZOIs]: Boulanger et al. 2012, 2021; Poole et al. 2021) the analyses in this report include both the Ekati and Diavik mines and their roads and other infrastructure; no attempt was made to separate the effects of the individual mines on caribou.

2. METHODS

This report examines behavioural responses of caribou to infrastructure and roads at the Ekati and Diavik diamond mines at two different scales. At the coarse scale, 8-hour interval data were used to characterize habitat selection by each sex in each season throughout the ranges of the Beverly and Bathurst caribou herds. The results of those analyses were used to predict relative habitat selection values within 30 km of the two mines where movement characteristics, and proximity to mining features were used to examine responses of caribou to the mines, while accounting for predicted relative habitat selection values. At the fine scale, 1-hour interval data were used to examine habitat selection and proximity to mine effects for each sex in each season within an area extending out approximately 30 km from the Ekati and Diavik mines. It was not possible to predict relative habitat selection value for 1-hour interval data in the absence of mining effect, as 1-hour interval data were not collected except in proximity to human developments.

2.1 Regional description

The region containing the study area is the Coppermine River Upland Ecoregion of the Taiga Shield Ecozone in the south and west, and two ecoregions of the Southern Arctic Ecozone: the Garry Lake Lowland in the east; and the Takijua Lake Upland which stretches from the margin of Bathurst Inlet to west of Lac de Gras, including the Ekati and Diavik diamond mines. Much of the surface of the Takijuaq Lake Upland is unvegetated rock outcrops of the Canadian Shield (Ecological Stratification Working Group 1996). Soils in the ecoregion are predominantly Cryosols and permafrost is continuous and deep across the region (Ecological Stratification Working Group 1996). The mean summer and winter temperatures are +6°C and -26°C, respectively, and annual precipitation is between 200 mm and 300 mm. Low Arctic shrub tundra dominates the study area with boreal forest-tundra transition in the Taiga Shield to the west. The vegetation communities are further discussed in Sections 2.5 and 3.4 below.

Besides caribou, large mammals in the region include grizzly bears (*Ursus arctos*), wolves (*Canis lupus*), wolverine (*Gulo gulo*), muskoxen (*Ovibos moschatus*), and moose (*Alces alces*).

2.1.1 Ekati Diamond Mine

The Ekati Diamond Mine is located in the Northwest Territories, approximately 200 kilometres (km) south of the Arctic Circle and 100 km north of the tree line on the tundra (Figure 2-1). The Diavik Diamond Mine is situated on an island in Lac de Gras approximately 30 km south-southeast of the Ekati Main Camp (Figure 2-2).

The local terrain near the mine is characterized by boulder fields, tundra, wetlands, eskers, and numerous lakes with interconnecting streams. There are more than 8,000 lakes within the 266,300 hectare (ha) claim block. While extreme winter temperatures dominate the majority of the year, there are generally four months (June through September) that experience daytime temperatures above freezing.

The Ekati mine began construction in 1997 and opened in October 1998. During the period of the study the following developments occurred at the Ekati Diamond Mine:

- The Misery Road power distribution line construction began in September 2014. The final portion of construction occurred between March 3, 2016 and the completion of construction on August 2, 2016 - during the period defined for analyses in this report;

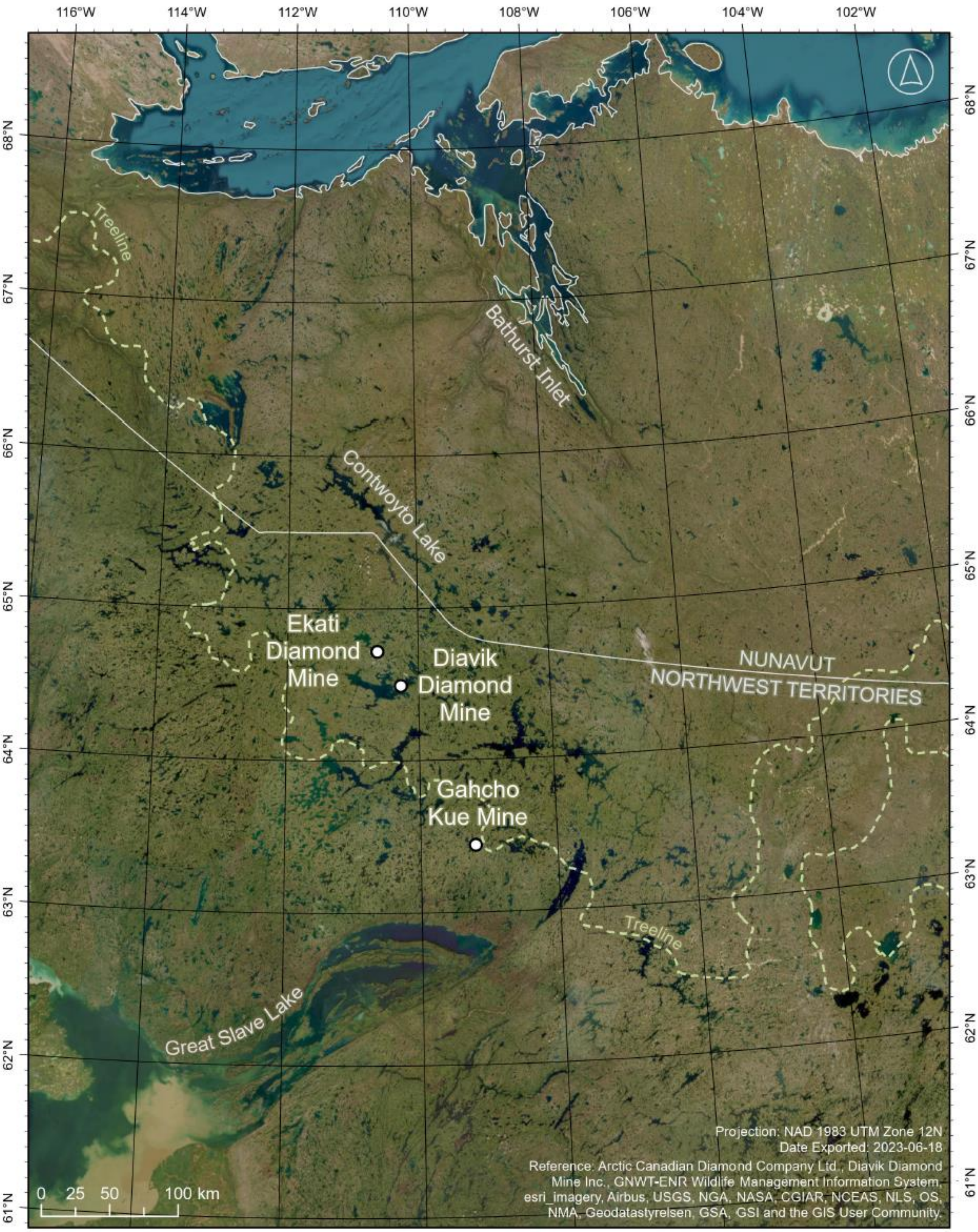


Figure 2-1:
Ekati Diamond Mine Location

ARCTIC CANADIAN DIAMOND COMPANY
Naturally Beautiful. Mined Right.
PARAGON WILDLIFE RESEARCH AND ANALYSIS

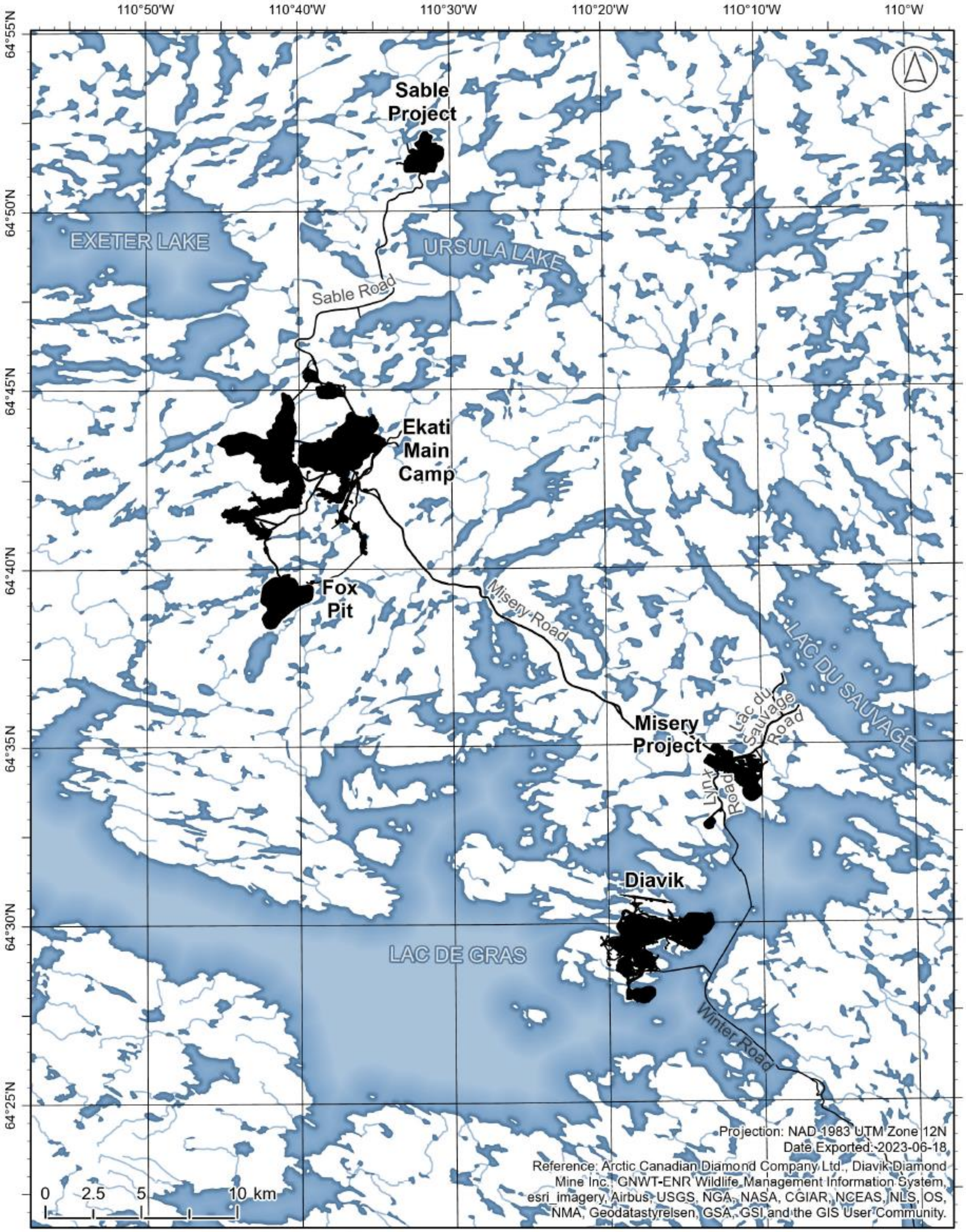


Figure 2-2: Local Detail of the Ekati Diamond Mine and Diavik Diamond Mine

ARCTIC CANADIAN DIAMOND COMPANY
Naturally Beautiful. Mined Right.
PARAGON WILDLIFE RESEARCH AND ANALYSIS

- The portion of Sable Road from km 2.8 to 19.8 was under construction during 2016, with construction completed on September 30, 2016;
- The Lac du Sauvage Road was built in 2017, with completion on October 10, 2017;
- Operations were suspended at the Ekati Diamond Mine from March 20, 2020 until December 31, 2020 and the mine was in care and maintenance;
- Dewatering of Point Lake occurred between June 10, 2022 and October 1, 2022. During this period a pipeline was in place on top of the Lac du Sauvage Road and Lac du Sauvage Spur Road between Point Lake and Lac du Sauvage. For reference, Point Lake was approximately 2 km northeast of the Misery Project, 650 m east-southeast of the Lac du Sauvage Road.

2.2 Data projection for analyses in this report

Environmental data layers used in the analysis were projected to Canada Atlas Lambert (EPSG:3978) as calculation of area-based statistics and linear edge require an area-based projection. Universal Transvers Mercator (UTM) and Lambert are commonly used area-based projections. The Canada Atlas Lambert projection (EPSG:3978) was selected as multiple UTM zones are included in the study area and the Canada Atlas Lambert projection is commonly used in map production in Canada.

Caribou location data were provided as latitude/longitude (WGS84/CRS4326), and these were also transformed to Canada Lambert to properly overlay with the environmental data, and as area-based projection is necessary for calculating movement distance in metres (m).

Source: NAD83 / Canada Atlas Lambert - EPSG:3978

2.3 Caribou location data

Radio-collars were first deployed on female Bathurst herd caribou in 1996 and on males in 2015. The earliest data for the Beverly herd were from radio-collars deployed on female caribou in 2006; available data for male caribou began in 2015. The number of radio-collars on each sex from each herd varies annually, depending on mortalities, collar failure, and operational decisions regarding collar deployment. The location fix rate (the frequency of locations being obtained for each individual) has also varied over time. Within each time period these factors dictate the number of locations available per animal, per season, and per herd.

Each radio-collared caribou is assigned to a herd by GNWT-ENR based on its range use, a classification that GNWT-ENR reviews annually – retroactively reassigning animals to different herds if the animal changed the calving ground it used.

All caribou location data used in this report were acquired from radio-collars using a global positioning system (GPS) to determine the locations. Location dates and time were received and stored in Coordinated Universal Time (UTC) and all analyses were conducted based on UTC time, i.e., without correction to local time.

Spatially, the telemetry locations have been used to define the extent of the ranges used by each herd over time. The location-fix rates set by GNWT-ENR determined the finest temporal resolution possible for examinations of movement and other behavioural patterns.

2.3.1 Geofence delineation and effect on data collection

Beginning with radio-collars deployed in early 2016, the GNWT-ENR began collecting location data on 1-hour intervals when caribou were within pre-defined geographic areas, areas referred to as being “geofenced”. One of those geofenced areas (geofence 112) included an approximately 30 km buffer around the Ekati and Diavik mines and the Ekati Mine roads (Section 2.7.2).

2.3.2 Telemetry data screening

- Following receipt of data from GNWT-ENR, the following screening steps were applied:
- Each location was assigned a code for the season in which it was collected; season dates being specific to the herd to which the animal was assigned in the GNWT database (Section 2.4.1);
- Data were then screened to remove duplicate locations from the same animal at the same time on the same date;
- As large sets of remotely acquired data have the potential to include GPS location data that are incorrect, the next step was to screen data for outliers – locations that are likely to be incorrect. Data were screened for outliers using a combination of techniques of Bjørneraas et al. (2010, as employed by van Beest et al. [2013]) and those of Keating (1994). These techniques use one or more of: interval movement speed; turn angle between two steps; absolute distance and equivalence of distance of adjacent movement steps; and comparison with the distribution of those values against the entire set of movement steps in the data set over the same time interval;
- To determine the distribution of time intervals between locations for each animal, data were next examined for time of data collection and the time interval between sequential locations, with the minimum interval set at 56 minutes;
- After cleaning the data to remove location duplicates, movement outliers, and data from short time intervals, the data were summarized by time of data collection, inter-location time interval, and years of data availability for different time intervals between locations; and
- Data were then reduced to the range of years and location acquisition times when adequate and comparable data were available to address the project objectives.

2.4 Seasonal caribou ranges

2.4.1 Season delineation

Nagy (2011) delineated 12 seasons for each barren-ground caribou herd in the NWT. Nagy’s seasons (Nagy 2011 p. 92) were as short as 12 to 14 days for the calving, post-calving, and rut seasons (Table 2-1). In previous analyses of NWT barren-ground caribou data (e.g., Caslys 2016; GNWT 2019; Poole et al. 2021) some of Nagy’s seasons were combined to yield between 5 and 9 seasons for analyses. In early years, data collection was as infrequent as one location every 5 to 7 days. The post-2015 data for the Bathurst and Beverly herds and used in the analyses in this report included multiple locations per animal per day. The sets of seasons and season dates adopted for these analyses appear in Table 2-1. Winter data spanned periods from December of one year to April of the following year (Table 2-1); the winter data for each animal were retained as a set for analysis and nominally assigned to the analysis year corresponding to the January to April period (e.g., data from December 2017 to April 2018 were assigned to the nominal 2018 analysis year).

Table 2-1: Season dates used in this report for the Bathurst and Beverly barren-ground caribou herds

Season	Bathurst Herd[1]	Length in days	Beverly Herd[1]	Length in days
Winter	December 1 to April 19	140	December 16 to April 9	115
Spring migration	April 20 to June 1	43	April 10 to June 5	57
Calving	June 2 to June 16	15	June 6 to June 19	14
Post-calving	June 17 to June 28	12	June 20 to July 8	19
Summer	June 29 to August 17	50	July 9 to August 12	35
Late Summer	August 18 to September 6	20	August 13 to September 11	30
Pre-rut	September 7 to October 16	40	September 12 to October 20	39
Rut	October 17 to October 31	15	October 21 to November 3	14
Post-rut	November 1 to 30	30	November 4 to December 15	42

[1] Season dates follow Nagy 2011 (p. 92).

2.4.2 Seasonal range utilization distribution (UD) analyses

Seasonal ranges were estimated at the herd level, using 90% fixed kernel utilization distributions (90% UDs) as recommended and employed in previous studies (e.g., Fieberg and Kochanny 2005; Börger et al. 2006; van Beest et al. 2013). For each herd, the sex-specific UDs were estimated for each season in each year from data pooled across animals using the package adehabitatHR in the R statistical package (R Core Team 2022). Data for each winter spanned two calendar years: winter began in December and ended the following April.

The use of kernel density estimators to delineate seasonal ranges is dependent on the quantity of data (i.e., number of locations), the underlying spatial grid used in the analyses and the smoothing factor that affects the size and shape of UDs based on known locations of animal use; consistency in spatial grid and smoothing factors used for UDs is necessary for comparability among years and among seasons. A 500 m grid was used for all UD analyses and the ad hoc approach (Kie 2013; Morellet et al. 2013; Bastille-Rousseau et al. 2015; Newton et al. 2017) was used to determine the best smoothing parameter for each herd; in the initial stage, smoothing parameters were varied iteratively in 1,000 m increments for each female seasonal range in each year in each herd to determine the minimum value needed to yield a single contiguous 90% UD. Following the initial analyses for each seasonal range, the herd-specific median of the smoothing parameters for all female seasonal 90% UDs in all years was selected and applied prior to the recalculation of all UDs (all seasons, all years, and each sex) for each herd.

2.4.3 Location data screening for seasonal range delineations

In addition to considerations of UD estimation parameters it is important that there be a relatively equal weighting in the amount of available data. To give each animal equal weight in pooled-animal UD analyses, each individual radio-collared animal must provide a similar, ideally identical, number of locations to the data set within a season (Börger et al. 2006). Prior to confirming methods for range delineation available location data were screened and summarized for abundance and distribution of data through the season and across animals. This was conducted in two steps:

- Morellet et al. (2013) (i) reduced the number of locations per animal to match the coarsest time interval in data collection (e.g., one location per animal per day or one location per animal per 12 hours); and (ii) set a minimum number of locations per animal for inclusion in the data set for range analysis. For the purpose of delineating seasonal ranges in this study, the Beverly and Bathurst herd data were screened to produce a subset of the data with a single location per animal per day.

- Within the single-location-per-day subset, summaries of the number of locations per animal per season per year were generated. Following established principles for screening data (van Beest et al. 2011; Morellet et al. 2013; Avgar et al. 2015; Nicholson et al. 2016) the animal by season by year summaries were screened for a minimum number of locations in a season; animals whose data sets contained the minimum or greater were retained and included in the analyses, locations from other animals were removed. The minimum threshold for inclusion was one location per day on at least 75% of days in a season.

2.5 Landcover and associated data layers

Spatial analyses of caribou behaviour require detailed information on environmental variables that reflect ecological value at the spatial and temporal scale associated with animal location data. Previous works on barren-ground caribou in the study area have reported the various importance of vegetation communities, eskers, water, topography (elevation, slope, aspect), human development, and insect harassment (Johnson et al. 2005; Witter et al. 2012; Boulanger et al. 2012, 2021; Dominion Diamond 2014; Golder Associates 2014, 2016; ERM 2021). Available environmental data were examined for relevant detail, and against the spatial and temporal extent and resolution for this study.

2.5.1 Available landcover data layers considered

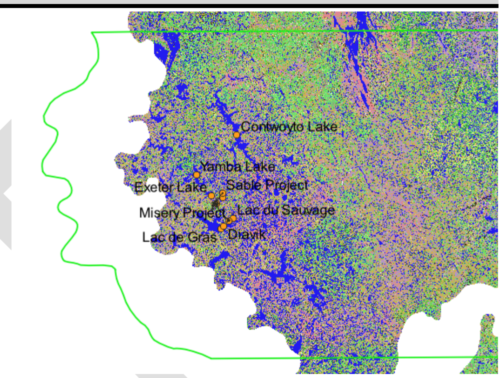
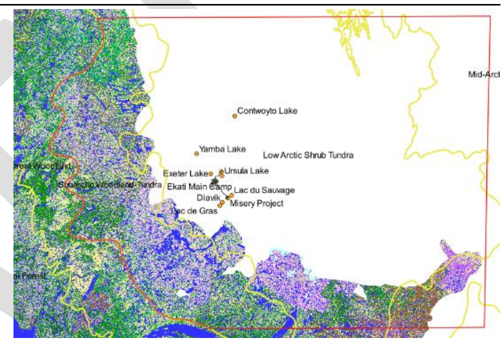
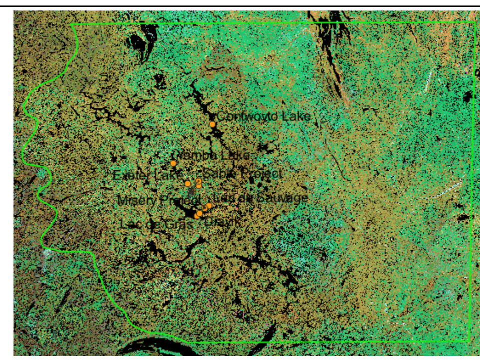
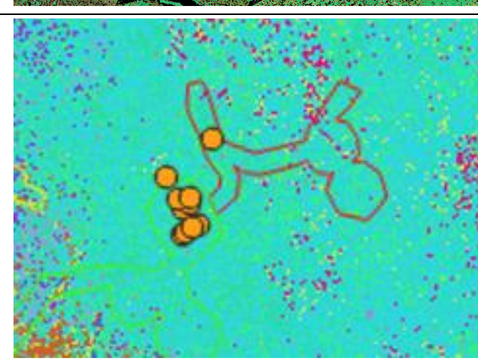
Five available landcover Geographic Information System (GIS) layers were considered (Table 2-2), nominally termed LC2009 (Olthof et al. 2009), EOSD (Wulder et al. 2003), LC2000-ETM+ (Olthof et al. 2005), CanLC2015 (Latifovic et al. 2017), and WKSS (Matthews et al. 2001). Layers were evaluated in terms of extent of coverage relative to the study area, focus and detail of the landcover classification relative to the Tundra and Woodland vegetation zones and known caribou habitat relationships, pixel size, and general impression of classification quality. A combination of LC2009 and EOSD data layers were used in two published studies incorporating caribou RSF modeling by Boulanger et al. (2012) and Boulanger et al. (2021). The WKSS data layer was used to develop the first barren-ground caribou resource selection function (RSF) in the region by Johnson et al. (2005) and was later used for RSF analyses by Dominion Diamond (2014) and for landcover classification by ERM (2021) in an examination of the methodology of Boulanger et al. (2012). In their analyses of the Bathurst herd winter RSF, Golder (2016) combined LC2000 data above the treeline with additional data sources in areas below the treeline.

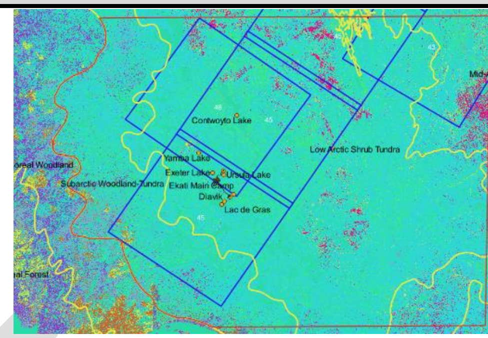
For this project, LC2009 was assessed as a high-quality mapping product, it covered the initially defined study area, had good spatial resolution (30 m), and sufficient classification detail for caribou RSF estimation in the Arctic Tundra vegetation zone (Table 2-2). LC2000 (ETM+) was considered the second choice in that it had appropriate spatial extent; however, it had lower spatial resolution (90 m) and more classes defined (43) than were likely to be accurately mapped. The unsupervised approach to classification LC2000 (ETM+) (which produced an initial group of 150 classes that were then labelled into 43 classes) led to the potential for higher classification error rates.

Following engagement with Indigenous Governments, regulators, and other project participants on September 15, 2022, the initial study area was extended further to the west into the Sub-Arctic Woodland Tundra, beyond the extent of LC2009 coverage. Consideration was given to retain LC2009 for the main portion of the study area (Arctic Tundra vegetation zone) and use either the EOSD or LC2000

(ETM+) classification for the Sub-Arctic Woodland Tundra portion of the study area in the western portion of the revised study area.

Table 2-2. Available landcover data layers that were considered, with comments on suitability.

Description and comments	Extent relative to study area
LC2009: 30 m raster; 15 classes. Circa-2000 Northern Land Cover of Canada. This dataset was generated to provide spatially and thematically consistent land and vegetation cover of Northern Canada above the tree line at medium (30 m) Landsat resolution. Nominally called LC2009 based on publication date. This classification had both good spatial and classification resolution for the Arctic Tundra vegetation zone but did not extend into the Boreal Forest & Woodland zone, which falls in the western portion of the study area. Olthof, I., R. Latifovic, and D. Pouliot. 2009. Development of a circa 2000 land cover map of northern Canada at 30 m resolution from Landsat. Canadian Journal of Remote Sensing 35:152-165.	
EOSD: 25 m raster; 37 classes. This mosaic created for the forested ecozones of Canada. The classification was focused on forested areas, and did not extend into the Arctic Tundra zone. Also, when overlayed, gaps occurred between the extents of this coverage and the LC2009 coverage. There is also a vector version created from a smoothed raster that provides even less spatial resolution. Wulder, M.A., J.A. Dechka, M.A. Gillis, J.E. Luther, R.J. Hall, A. Beaudoin, and S.E. Franklin, 2003; Operational mapping of the land cover of the forested area of Canada with Landsat data: EOSD land cover program. Forestry Chronicle 79:1075-1083.	
LC2000 (ETM+): 90 m raster; 43 classes. Circa 2000 Landsat ETM+ mosaic of northern Canada above the tree line. This map covered the extents of the study area, but was based on an unsupervised classification approach, which was of lower quality than the LC2009 product. Also, spatial resolution was 90 m versus 30 m for the LC2009. There were more classes than the LC2000 map, but accuracy is not well defined. Olthof, I., C. Butson, R. Fernandes, R. Fraser, R. Latifovic, and J. Orazietti. 2005. Landsat ETM+ mosaic of northern Canada. Canadian Journal of Remote Sensing 31:412-419.	
CanLC2015: 30 m raster; 19 classes. Canada Landcover 2015. Classification resolution above the tree line was very low, with most of the study area comprised of only 2 land cover classes. Latifovic, R., Pouliot, D., and Olthof, I. 2017. Circa 2010 Land Cover of Canada: Local Optimization Methodology and Product Development. Remote Sensing, 2017, 9:1098.	

Description and comments	Extent relative to study area
WKSS Map. 30 m raster; 22 classes. This map covered only a portion of the study area (blue lines), so was not considered further. Matthews, S., H. Epp, and G. Smith. 2001. Vegetation Classification for the West Kitikmeot/Slave Study Region. Final Report to West Kitikmeot/Slave Study Society. Yellowknife, NWT, Canada.	

2.5.2 Additional landcover and topography data layers

In addition to the raster based landcover data layer, covariates for elevation (m), slope (degrees), and aspect (degrees) were derived from the Canadian Digital Elevation Model (CDEM) mosaic (Natural Resources Canada 2013); aspect was later eliminated as a covariate in the absence of calculated values for parts of the study area. The CanVec 1:250,000 Series Hydrographic Features layer (Natural Resources Canada 2019) was used to determine waterbody areas (overwriting the water coverage included in the landcover layers) and land/water edge density. Eskers were derived from 1:50,000 National Topographic System (NTS) map layers for the regional study area (RSA; Section 2.7); esker polygons were created as 200 m (total width) polygons centred on the esker polylines on the NTS map layers. In all cases, data layers from NWT and NU were merged when necessary.

2.5.3 Resolution and multi-grain assessment of landcover covariates

Habitat selection analyses based on sets of telemetry point locations (rather than movement pathways) include various analytical frameworks to define available habitat based on telemetry locations. However, analytical methods do not specify the grains (the spatial scales of measurement) at which habitat covariates are best quantified to characterize locations in the used and available data sets; these are at the discretion of the analyst.

At minimum, the characterization of habitat associated with each location is limited by the spatial resolution of the covariate data sets (e.g., raster size). Telemetry locations are a sample of selective behavioural outcomes for the entire inter-location movement interval; in an area where habitat is characterized by multiple covariates, each location should be evaluated for its relationship not only to a set of covariates, but also to the grains of covariate measurement that are potentially relevant to decision making by wildlife. Rettie and McLoughlin (1999) recommended that in habitat selection studies, habitat be characterized following the examination of habitat associations defined at multiple radii around each location. The inter-location interval or movement rate, and the patch characteristics and arrangement of landcover types are expected to influence the appropriate size of buffers placed around each location to optimally describe its habitat characteristics (Rettie and McLoughlin 1999; Northrup et al. 2022). In an empirical example, Laforge et al. (2015) explored multiple grains of habitat measurement (based on concentric radii around each location) in their analyses of habitat selection by white-tailed deer (*Odocoileus virginianus*). They concluded that white-tailed deer habitat selection was best explained by a model where the grain of measurement was allowed to vary for each environmental covariate.

To facilitate spatial analyses, a 3.1-ha hexagon grid (approximately equal in area to a circle with 100 m radius) was superimposed on the regional study area (Section 2.7). Each topographic covariate and the proportional cover of each landcover covariate was determined for every 3.1-ha cell in the study area. The 3.1-ha cell was the landscape unit for habitat selection analyses. To examine the spatial extent around each location that influenced habitat selection in this study, landcover covariates were also measured for a range of spatial extents (i.e., multiple grains) centred on each 3.1-ha cell in the hexagon grid. Rather than generating new coarse-grain measures of covariates based on a moving window, spatial averaging was used to calculate values through the specialized GIS program LSL (Kushneriuk and Rempel 2011). For a large study area with 30 m raster coverage, LSL offered a computational efficiency that was orders of magnitude faster than raster-centred assessment. Beginning with 3.1-ha hexagon values, spatial averaging in LSL was used to generate measures of covariates at four different grain sizes, and record the nested set of measures for each cell in the 3.1-ha hexagon-based shapefile for the RSA. Exact dimensions of the coarser grain pseudo-hexagons are constrained by nesting from the base 3.1-ha hexagon; beyond 3.1-ha, the three grains were 58.9-ha, 524-ha, and 5137-ha. The LSL program employs a hierarchy of hexagons and offsets (for spatial averaging) to capture layer attributes within each hexagon (e.g., area and proportion of tundra, tussock, and water; Sections 2.5.1 and 2.5.2), as well as length and density of the edge between water and land (Section 2.5.2). An example of the LSL spatial averaging process from 3.1-ha grain to 5137-ha grain is illustrated in Figure 2-3.

The process produced a measurement for each covariate in a set of near-concentric nested hexagons and pseudo-hexagons centred on each 3.1-ha cell. This provided data to examine multiple grains of covariate measurement on habitat selection at each of the 1-hour and 8-hour movement interval scales. Published uses of LSL include developing and applying range specific resource selection functions for caribou in northern Ontario (Hornseth and Rempel 2016), developing an indicator of ecological integrity for songbirds (Rempel et al. 2016), and conducting scenario analysis of forest management options (Rempel et al. 2007). The program is also used in Ontario for mapping caribou Category 2 conservation habitat. Though they did not mix grains within models, Hornseth and Rempel (2016) conducted a study of caribou habitat selection in northern Ontario that compared habitat selection with a set of nested pseudo-hexagons ranging from 16 ha to 10,000 ha; they determined a 5,000-ha scale was almost always the best predictor.

Analyses in this study include multiple grains of measurement for most covariates and allow the analytical processes (Section 2.8) to identify the appropriate grains to describe ecological relationships. The implementation of multi-grain habitat characterization for each used and random location is described in Section 2.8.5. The analyses here most closely correspond to multi-variable multi-scale modelling as described by McGarigal et al. (2016, p. 1173) who recommended measuring covariates at multiple scales (i.e., multiple grains sensu Northrop et al. 2022), allowing data from different grains to compete in modelling processes, and identifying the optimal grain for each covariate.

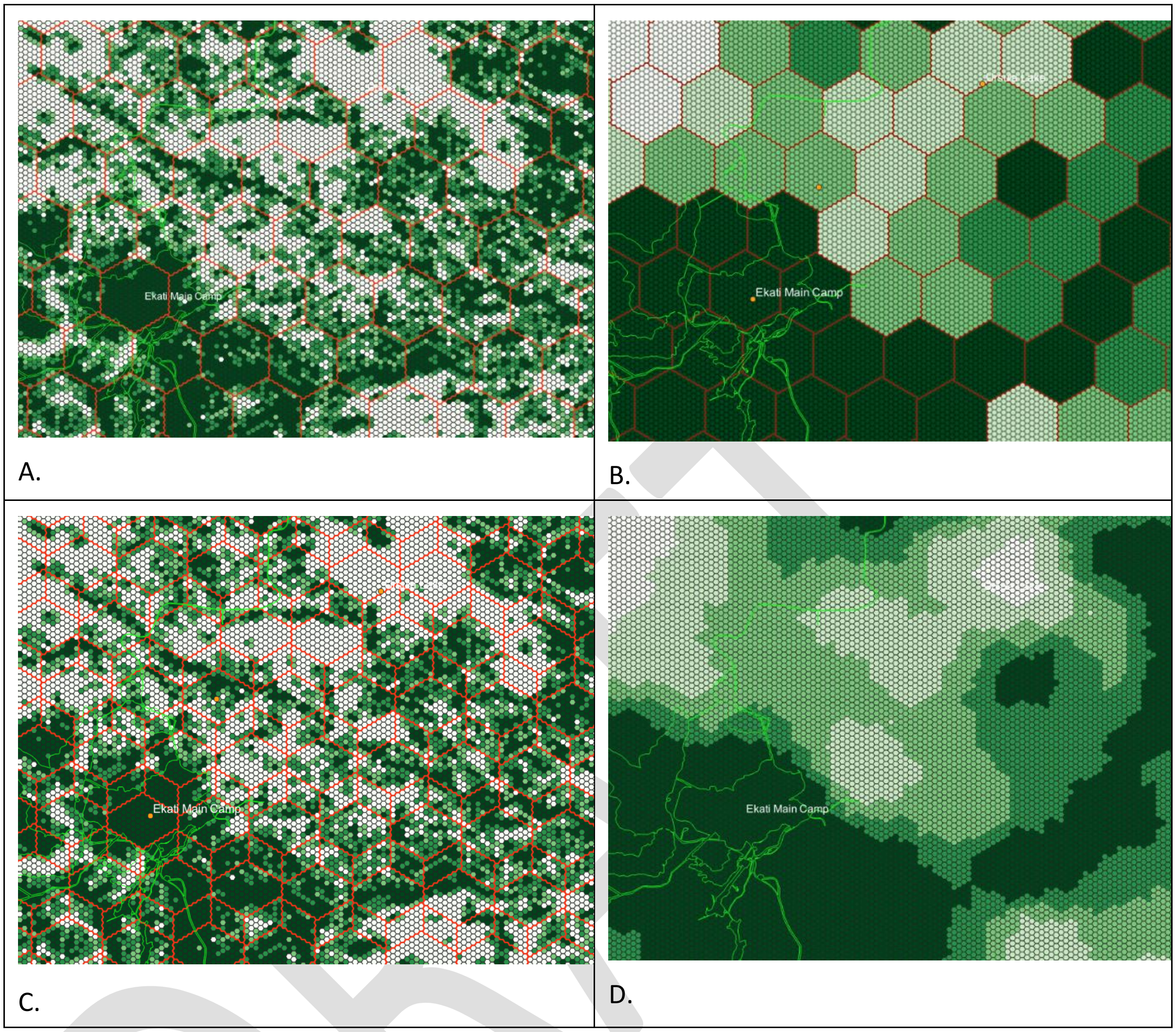


Figure 2-3. Illustration of spatial data capture and smoothing using LSL. A) Proportion tundra with 3.1-ha hexagons, where hexagons with higher proportions are darker green. 5137 ha pseudo-hexagons are overlayed in red; B) Average proportion of tundra within 5137 ha pseudo-hexagons, where values are transferred back to the 3.1-ha hexagon; C) Overlay of two 5137 ha pseudo-hexagons offsets in red; operationally, 12 offsets were specified at the 5137-ha grain. D) Average of the average offset values of tundra at the 5137-ha grain. Note how spatial averaging (smoothing) of the offsets compares to the result in B where no offset averaging is used. Note also the coarser grain at which D presents the information originally plotted in A.

2.6 Environmental covariates

2.6.1 Insect harassment indices

The CircumArctic Rangifer Monitoring Agency (CARMA) established five overlapping geographic regions for each of the Bathurst and Beverly ranges in which they calculate region-wide daily and cumulative harassment indices for oestrids (bot flies) and for mosquitoes. The CARMA harassment indices are based on remotely sensed weather variables from NASA's Modern Era Retrospective Analysis for Research and Applications (MERRA) dataset (Russell et al. 2013). CARMA's processing of the MERRA data largely relies on established relationships of insect abundance with temperature and wind speed and direction (Russell et al. 2013). While the five regions for each herd were based on historical seasonal distributions, they are effectively fixed polygons for which daily harassment index values have been determined. After examination of annual cycles of CARMA's oestrid and mosquito harassment index values it was concluded that the potentially affected seasons during the 2016 to 2022 period were calving, post-calving, summer, and late summer.

The screened 8-hour-interval caribou location data (Section 2.3.2) for each sex of each herd for each of the four seasons of each year were independently intersected with the 10 CARMA regional polygons and the best fit between the caribou location data and the regional polygons was used to select the insect harassment data sets to use as covariate data for each sex and herd in each season of each year. The appropriate oestrid and mosquito daily harassment index values were appended to each 1-hour and 8-hour caribou step record (Section 2.8) in each data set for each of the four seasons with insect harassment.

The conditional logistic regression approach (Section 2.8) used for habitat selection in this report relies on comparisons of the characteristics of each real caribou movement step and a number of random steps beginning at the same location. In every instance, the insect harassment index values are identical for the actual (TRUE) movement step and the random (FALSE) movement steps. Consequently, neither oestrid nor mosquito harassment could be incorporated as a stand-alone covariate in models; instead, they were incorporated in interaction terms with landcover covariates. Given that the insect harassment covariates themselves did not differ between TRUE and FALSE steps, the interaction term was used to determine if landcover selection varied in response to insect harassment index values. Witter et al. (2012, p. 293) summarised insect relief terrain for reindeer and caribou as variously including eskers, areas of higher elevation, and coastal areas. Hagemoen and Reimers (2002) included snow patches, marshes, hilltops, ponds, and windy mountaintops as oestrid relief areas.

In analyses for this report, when the preliminary top model for any of the four seasons with potential insect harassment included select landcover covariates (water edge; waterbody area proportional cover; esker proportional cover; or mean elevation), interactions were created between oestrid and mosquito daily harassment indices and those covariates and new candidate models were created including insect harassment (See Sections 2.8.5.3 and 2.8.8.2 below for details).

2.6.2 Human development and distance to feature measurements

Polygon coverages of mining developments and mine roads were produced from data provided by Arctic Canadian Diamond Company Ltd. and Diavik Diamond Mines Inc. Winter road locations were based on the shapefile of the Tibbitt to Contwoyto Winter Road (polyline file provided by Arctic Canadian Diamond Company Ltd.); the Tibbitt to Contwoyto Winter Road was plotted as a line feature terminating at the Ekati Diamond Mine, the limit of its construction during the study period.

Additional mines, exploration sites, and other human developments within the range of the Bathurst caribou herd were provided as shapefiles by GNWT-ENR (ENR 2022), who maintain the development layer for the Bathurst Caribou Range Plan.

Using the Landscape Scripting Language (LSL, Kushneriuk and Rempel 2011), distances from the centroid of the 3.1-ha hexagon containing each real or random caribou location were calculated to:

- the nearest point on the nearest Ekati mine road polygon;

- the nearest point on the nearest Ekati or Diavik mine infrastructure polygon;
- the nearest point on the winter road; and
- the nearest point on the nearest human development or exploration area polygon > 10 ha, and not accounted for in three human development categories immediately above.

When the distance from the caribou location to a feature was > 30 km it was given a value of 30,001 m. Distance to winter roads were considered only in winter season analyses.

2.7 Study period and study area delineation

As the objective of the analyses was to examine fine-scale effects of the Ekati Diamond Mine on barren-ground caribou behaviour, the study period was defined by the period for which telemetry location data were collected multiple times per day. For 8-hour interval analyses the period was winter 2015/2016 through post-rut 2022. For 1-hour analyses the period was spring migration 2017 through post-rut 2022 as it was dependent on the deployment of radio-collars set to acquire locations on 1-hour intervals in the geofence areas (Section 2.3.1).

The spatial delineation of the study area was jointly determined by the area of potential influence of mining infrastructure and operations on caribou behaviour (see Section 2.8.4) and by the ranges used by the two herds during the study period.

2.7.1 Regional study area

At the coarser movement scale examined (8-hour interval) the first objective was to characterize seasonal habitat selection based on landcover, topography, and insect harassment within the ranges of the Bathurst and Beverly caribou herds but beyond the influence of development infrastructure and operations (Regional study area, Figure 2.4). After estimating seasonal habitat selection by caribou beyond the influence of development, the resulting seasonal habitat selection functions were used to predict relative habitat selection values within 30 km of the Ekati and Diavik mines and mine roads.

Predicted relative habitat selection value, movement characteristics, and distances to mine infrastructure and roads were then jointly analysed to determine the apparent effects of the proximity of mine infrastructure or mine roads on seasonal habitat selection at 8-hour time-step intervals.

Predicted relative habitat selection value, movement characteristics, and distances to mine infrastructure and roads were then jointly analysed to determine the apparent effects of the proximity of mine infrastructure or mine roads on seasonal habitat selection at 8-hour time-step intervals.

2.7.2 Geofence 112 North (GF112N)

At the fine interval scale the objective was to examine behavioural responses that occur in short periods of time (1-hour intervals) and at the associated spatial resolution (a few hundred metres) – in an area within approximately 30 km of mining infrastructure (the approximate buffer around the Ekati and Diavik mines. The 1-hour data included in analyses in this report data were restricted to the portion of geofence 112 north of 64°12’ North latitude (hereafter: GF112N; Figure 2.4).

As there were no 1-hour interval data collected beyond the areas expected by GNWT-ENR to be affected by human development (i.e., the geofenced areas), it was not possible to estimate relative habitat selection values beyond the influence of human development as done for 8-hour interval data. Instead, landcover (Section 2.5), insect harassment (Section 2.6.1), human development (Section 2.6.2), and movement step (Section 2.8) covariates were modelled together.

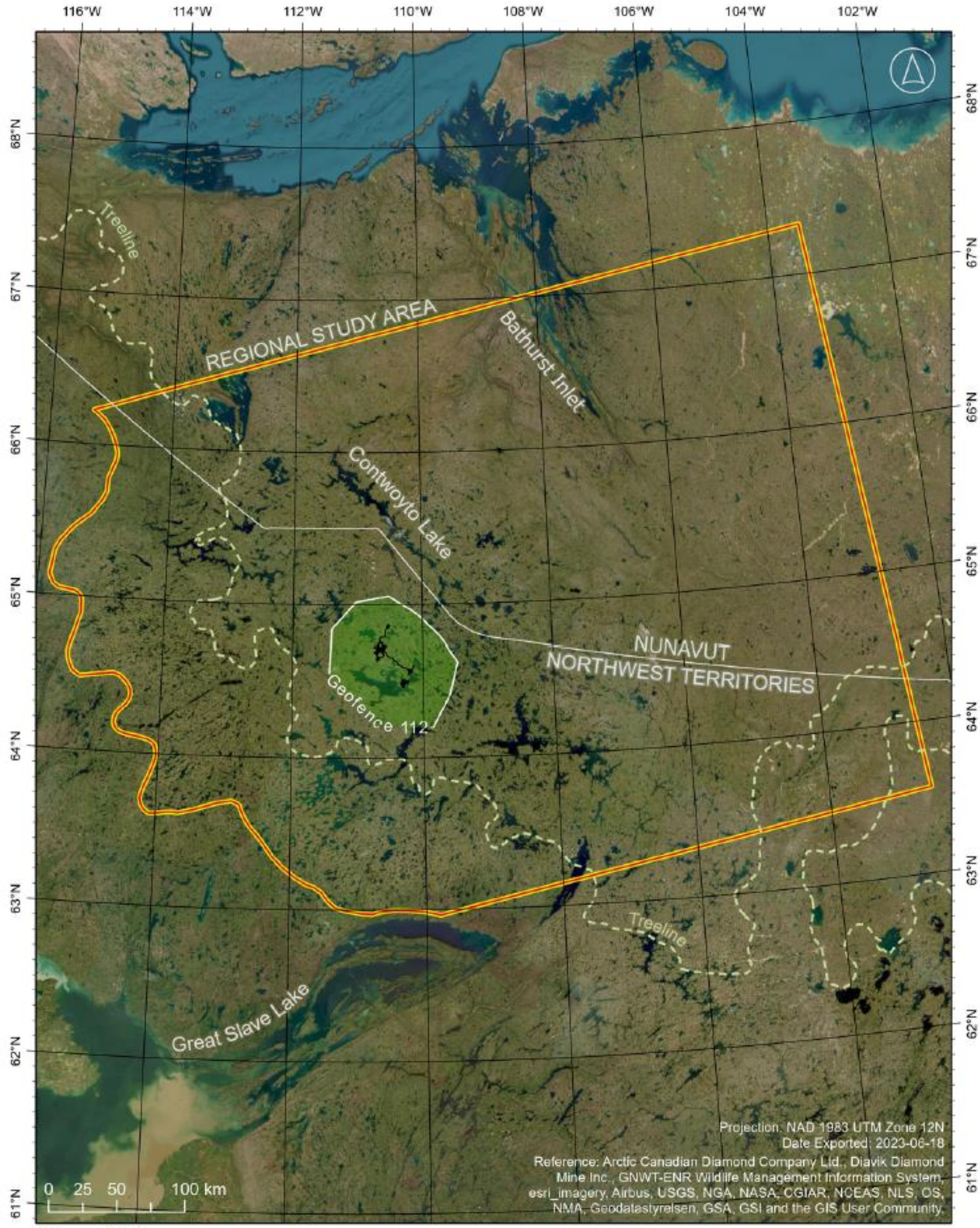


Figure 2-4
Regional and Local Study Areas

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2.8 Habitat selection analysis (HSA)

Throughout this report, the analytical approach will be generally referred to as habitat selection analysis (HSA) and the end products of analyses will be referred to as habitat selection functions (HSFs), following Fieberg et al. (2021) and Northrup et al. (2022). Specifically, the HSAs used were step selection analysis (SSA; when step-length and turning angle were excluded as covariates) and integrated step selection analysis (iSSA; when step length and turning angle were included as covariates). The analyses yielded step selection functions (SSFs) and integrated step selection functions (iSSFs), respectively.

The scale dependence in habitat selection (Johnson 1980; Wiens 1989) has influenced the development of data collection and HSA techniques for several decades. The research objectives of this study are to create HSFs over short time periods (i.e., 1-hour and 8-hour intervals); fine temporal scales that imply parallel fine-scale spatial scales and behaviour that requires available habitat to be re-defined with each movement. This follows the hierarchical interpretation of habitat selection first described by Johnson (1980). Older reports of HSA for caribou (e.g., Rettie and Messier 2000; Johnson et al. 2005) incorporated a significant advance in HSA introduced by Arthur et al. (1996): the location-specific definition of available habitat in a circular buffer centred on each location. An important drawback of generating random locations in circular buffers to define available habitat is that it implies that an individual perceives habitat as more available when it is further away from the starting location (Rhodes et al. 2005). Fortin et al (2005) further advanced the dynamic assessment of available habitat when they developed SSA in which each real movement step is matched with a number of random locations based on step lengths and turning angles observed in the real movement data, resulting in available random locations that reflect an animal’s movement patterns. Forester et al. (2009) showed that incorporating movement into analyses would reduce bias in the resulting SSFs.

The development of iSSA (Avgar et al. 2016; Signer et al. 2019; Fieberg et al. 2021) incorporated both movement covariates and habitat covariates in the analysis of habitat selection. Consequently, iSSA was chosen for this examination of 8-hour (Phase 2 analyses) and 1-hour (Phase 3 analyses) habitat selection by caribou in the vicinity of the Ekati and Diavik diamond mines. This follows the recommendation of Northrup et al. (2022, p. 12) to use iSSA for selection analyses over short time intervals. In the examination of short-interval movements, it is important to reiterate the conditional nature of selective behaviour; habitat selection in a 1-hour or 8-hour interval is conditional on patches of habitat with specific attributes being accessible to an animal within a typical movement step during that time period. Step selection functions are scale dependent (Fieberg et al. 2021) and differences are expected between model results from different time intervals, including between the 1-hour and 8-hour intervals in this study.

The iSSAs in this study examine two scales of selection (i.e., 1-hour and 8-hour interval movements). Together, telemetry data collection and the random step generation process included in SSA and iSSA determine the TRUE location (telemetry point) and the set of FALSE locations (random points) for each stratum. However, the grain at which the attributes of each point are measured to determined the characteristics of the locations is variable and is specified by the analyst. Analyses in this study include multiple grains of measurement for most covariates and allow the analytical processes to identify the best grains of measurement for covariates to fit the best model. The importance and implementation of multiple-grain habitat characterization for each used and random location are described in Section 2.5.3.

Conditional logistic regression models were fit in all SSAs and iSSAs using the clogit function in the survival package in R (R Core Team 2022). Following Boyce et al. 2002), all models took the log-linear form:

$$w(x) = exp(\beta_1 x_1 + \beta_2 x_2 + \cdots \beta_k x_k)$$

where:

w(x) is the relative habitat selection value for 3.1-ha cell x;

(x_i) is the measure of covariate i for hexagon x; and

(β_i), is the coefficient for covariate i.

Following the recommendation of Northrup et al. (2022 p. 14) key factors were identified prior to the start of modelling. Of the four factors considered (herd, year, sex, and season), a priori expectations of sex and season effects in habitat selection made those two factors priorities. Consequently, all habitat selection modelling was conducted separately for each sex within each of the nine seasons, yielding 18 separate sets of models, depending on data availability. The steps outlined below were followed for each of the 18 data sets.

2.8.1 Random step generation

2.8.1.1 8-hour movement steps (for Phase 1 and Phase 2 analyses)

Following the reduction of the 8-hour caribou location data to fixed collection times and the establishment of a fixed time period for the study, the locations were reduced to those that fell inside the established RSA during the study period. Animal movement step lengths were calculated in the traipse package in R (R Core Team 2022); locations with prior steps of 0 m length were removed. Remaining data were then divided into the nine seasons established for analyses.

Using the amt package in R (Signer et al. 2019; R Core Team 2022), data were processed as follows:

- The movement interval was set to 8 hours ± 6 minutes;
- Animal-seasons with fewer than 20 locations were excluded from analyses. A minimum number of locations is necessary as each animal in each season in each year must have sufficient data to properly characterize the distribution of its movement step lengths and turning angles;
- In all analyses, step lengths and turning angles were determined for each individual animal-season of data. Data for each animal-season were used to create movement tracks; track data were then summarized and turning angles were fit to a Von Mises distribution while step-lengths were fit to a gamma distribution (Avgar et al. 2016; Signer et al. 2019);
- For each real movement step, five random locations were generated from the step-length and turning angle distributions. Each stratum for analyses consisted of one real (TRUE) location and five random (FALSE) locations with a common starting location and stratum identifier;
- All animal identification information and the insect harassment index values were copied from the real location to the random locations in each stratum; and
- A single file was written for each season. It contained all sets of real and random locations for both sexes from all years.

2.8.1.2 1-hour movement steps (for Phase 3 analyses)

Preparation of the 1-hour data inside GF112N around the Ekati and Diavik mines followed the same process used for 8-hour data. Data were reduced to the time period selected for the study. There were two differences in the processing of 1-hour data:

- Spatial screening to the limits of GF112N was applied in LSL as a precaution, though the 1-hour data were constrained by the geofence perimeter that resulted in the collection of data on a 1-hour interval; and
- The movement interval was set to 1 hour ± 6 minutes.
- As with 8-hour data, a single file was written for each season for 1-hour interval data. It contained all sets of real and random locations for both sexes from all years.

2.8.2 Addition of environmental covariate data for 8-hour and 1-hour step data

The resulting locations from 8-hour and 1-hour amt step generation were intersected with the LSL 3.1-ha hexagon data layer. The environmental covariate data for the hexagon containing the end point of each step were attached to each of the real and random steps in each file. These data consisted of the landcover proportions at each of the nested spatial grains (Section 2.5), topographic data (Section 2.5), insect harassment data (Section 2.6.1). Distances to human developments were calculated from each location to mine roads, mine infrastructure, and winter roads (Section 2.6.2).

For the 8-hour interval data, distance to human development data values of 30,001 m were used to screen data but not used in distance-to-feature analyses (Section 2.8.4).

2.8.3 Exploratory analyses, data transformation, and scaling

After defining covariates, exploratory analyses included examinations of data at each of the four grains of landcover measurement. Key results were:

- model sensitivity (true positive rates) and specificity (true negative rates) varied across grains, with the 59 ha (_S2) grain being poorest overall;
- two transformations of covariates were examined, logit and square root. In each case, proportional cover covariates were first transformed, after which they were centered and scaled using z-deviates (mean = 0, standard deviation = 1.0). Regardless of the transformation applied to proportional cover covariates, non-proportional continuous covariates (e.g., elevation and slope) were scaled, but not transformed. In almost every case the logit transformation of the explanatory covariates resulted in better model performance than the square root transformation. Scaling was applied to facilitate the interpretation of coefficients of covariates measured with different units; and
- analyses tested the relative performance of boosted regression tree (BRT) models (Section 2.8.5.1 below) that included quadratic form (squared versions of covariates). The models with quadratic terms performed better than those without.

These analyses supported three decisions regarding the data:

- The 59 ha grain (_S2 versions of covariates) were eliminated from further consideration at this point;
- All landcover covariates at all grains for all data records (real and random) were logit transformed and then scaled as z-deviates; and
- The transformed and scaled values were then squared to provide a second version of each of the covariates, to provide data to allow for nonlinear effects through quadratic forms of models (Fieberg et al. 2021).

Additionally, all distances to mine roads, mine infrastructure, and winter roads were rescaled from m to km. Factors were created for herd, year, and binary classification of the 3.1-ha hexagon as Boreal Forest and Woodland vegetation (1) or not (0).

Prior to iSSA modelling of 1-hour and 8-hour interval data, movement step covariates were transformed in R: step turn angles were transformed to cosine of the turn angle (cos.ta) and step lengths were transformed as the natural log of step length (log.sl) following recommendations of Avgar et al. (2016) and Prokopenko et al. (2017). Log transformed versions of distance to feature covariates were also created and used in some candidate models.

Following transformation and scaling, landcover covariates were analyzed for collinearity (and multicollinearity) among explanatory covariates at each grain using the variance inflation factor (VIF). The VIF was calculated using the function ols_vif_tol in the R package olsrr. The VIF measures the inflation in the variances of the parameter estimates due to collinearities that exist among the predictors (Belsley et al. 2005). A VIF of 1 means that there is no correlation, values between 1 and 5 suggest moderate correlation, and values exceeding 10 are signs of serious multicollinearity requiring correction. In preliminary analyses, collinearity was initially detected, with some VIF values approaching 20, but when proportional cover by water derived from landcover layers was replaced with proportion waterbody area derived from CanVec Series - Hydrographic Features (Natural Resources Canada 2019), collinearity (VIF) was greatly reduced.

Attributes common to all step selection analyses appear in Table B-1. The set of covariates used in 8-hour interval SSA outside a 30 km buffer around the Ekati and Diavik mine roads and mine infrastructure (hereafter: Ekati/Diavik halo, see Section 2.8.4 below) appear in Table B-2. Two interaction terms at the 3.1-ha grain were also added to the basic set of covariates (Table B-2). Covariates used in 8-hour interval iSSA inside the Ekati/Diavik halo appear in Table B-3.

The covariates used for 1-hour SSA and iSSA inside GF112N appear in Table B-4.

2.8.4 Separation of 8-hour interval data for modelling

Boulanger et al. (2021, p. 11) indicated 30 km as the likely limit of the effect of the Ekati and Diavik mines on caribou habitat selection, accounting for the selection of 30 km as the buffer used for the Ekati/Diavik halo (Section 8.4.3). Other distances of effects of human disturbances on Bathurst caribou have been estimated and applied in a number of previous analyses. In the Bathurst Caribou Range Plan (GNWT 2019, Appendix A, Table 2) zones of influence around active mines were buffered by 14 km while other polygonal features and linear features were buffered by ≤ 5 km. In the environmental assessment for the Jay Project (Dominion Diamond 2014, Table 12.4-15) the maximum extent of influence around communities and active mines was 15 km while all other development features were considered to have effects ≤ 5 km.

Eight-hour interval data for each season (with covariates attached as listed in Tables B-1 and B-2) were divided spatially:

- All records from strata whose TRUE step ended in the Ekati/Diavik halo (30 km buffer; Figure 2-5) were removed and retained for the Phase 2 analyses of 8-hour interval data; and
- From remaining data, all strata were removed if their TRUE step ended within 30 km of the centroid of the Gahcho Kué mine (active during the study period), or within 5 km of any other development, mine, or exploration site polygon > 10 ha found in the GNWT-ENR human disturbance data set for the Bathurst herd (Figure 2-5; GNWT-ENR 2022). These data were not used for any subsequent analyses.

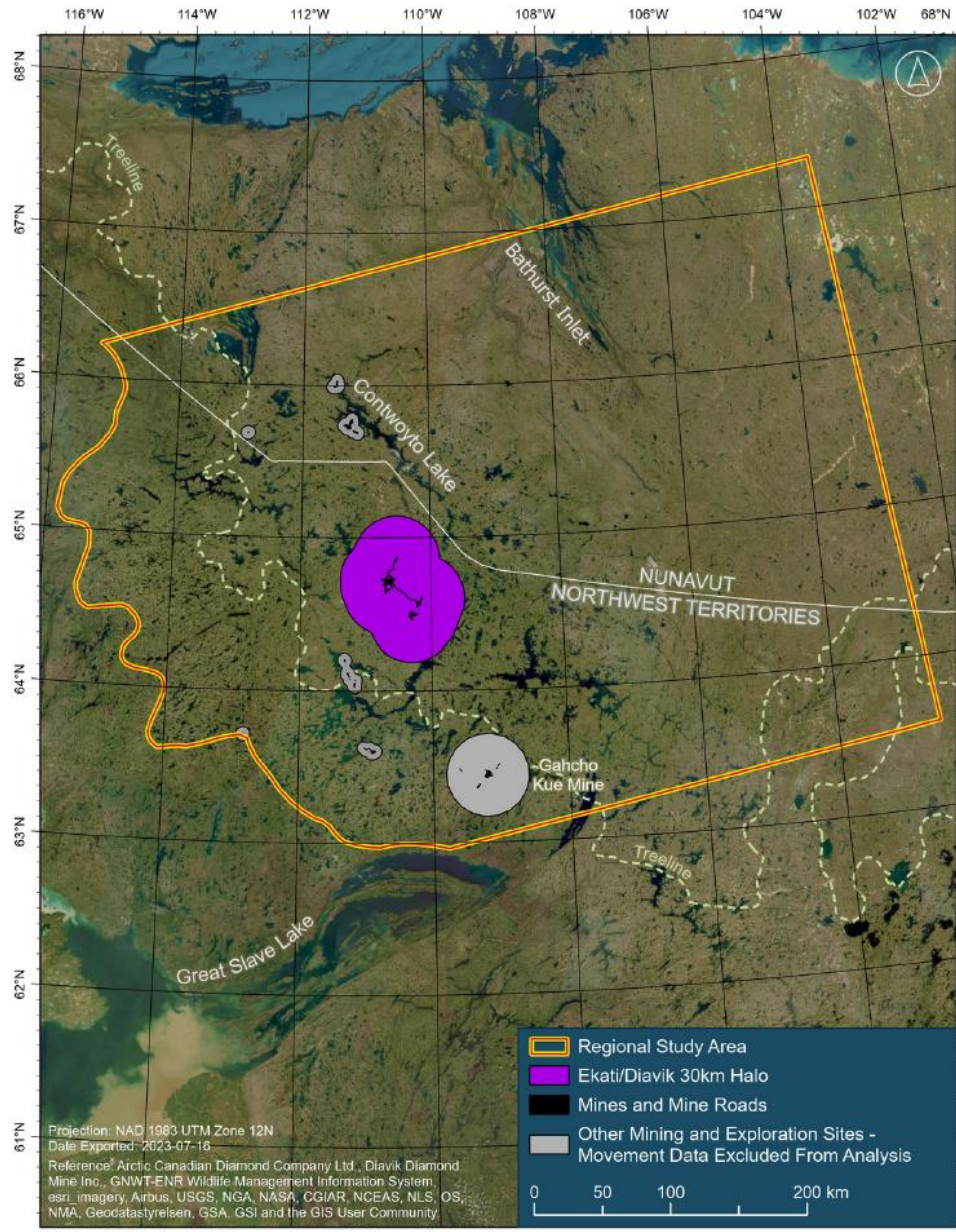

Figure 2-5: Spatial Screening of 8-hour Interval Data Prior to Integrated Step Selection Function Modelling.

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The remaining data were strata with TRUE steps ending in the RSA but outside the influence of development (i.e., the Ekati/Diavik halo, the buffered Gahcho Kué mine, and the other buffered developments, mines, and exploration areas; Figure 2-5). These data were used in the Phase 1 analyses of 8-hour interval habitat selection.

Each of the seasonal Phase 1 data sets were divided by sex and the data for each sex were then divided into train (70% of data) and test (30% of data) data sets. Rather than randomly splitting data pooled among all animals, data from each animal-season were kept together. This better accounted for inter-animal and inter-annual variation.

2.8.5 Phase 1 analyses: 8-hour interval SSA outside the Ekati/Diavik halo

The objective of the Phase 1 analyses (8-hour movement analyses outside the Ekati/Diavik halo) was to identify the best models of habitat selection for each sex by season. The exponentiated versions of the resulting habitat selection functions (HSFs) were then used to predict relative habitat selection values for each 3.1-ha hexagon inside the Ekati/Diavik halo, a pre-cursor to Phase 2 analyses. To properly account for movement patterns, predicting relative habitat selection values from iSSAs requires extensive simulations of movement, analytical processes that are not advanced in their development (Signer et al. 2017; Fieberg et al. 2021; Northrup et al. 2022). Consequently, SSA was chosen for Phase 1 analyses, and movement covariates for turning angle and step length were excluded from candidate models.

The steps outlined below were followed for each of the 18 sex by season data sets.

2.8.5.1 Generalized boosted regression models

The selection and measurement of multi-grain landcover and topographic covariates (Section 2.5.3), followed by their transformation, scaling, and squaring (Section 2.8.3) yielded an expansive set of covariates. To identify the covariates with the greatest relationship to caribou movement steps, the data were first explored (separately for each sex by season) with a boosted regression tree (BRT) model in R (R Core Team 2022) using the package gbm. Gradient BRT modelling is a sequential machine learning process that works to construct a predictive model with high accuracy.

The BRT models used for analyses in this report specified a Bernoulli distribution, as recommended for logistic regression, a 10-fold cross validation, and a maximum of 250 trees (iterations). The covariates included in BRT analyses are those listed in Table B-2 (Appendix B), excluding the last two items in the table, which are the insect harassment indices. The relative influence was calculated for each covariate and those covariates with relative influence values ≥ 1.0 were passed forward to stepAIC modelling (Section 2.8.5.2).

2.8.5.2 StepAIC modelling

The list of BRT covariates with relative influence values ≥ 1.0 were defined as the candidate covariates for the full model in the stepAIC modelling. Generalized linear models (glm) were fit using stepAIC in the MASS package (Venables and Ripley 2002) in R (R Core Team 2022). The glm model used a forward/backward selection approach, where Akaike’s Information Criterion (AIC) values were used to select the best model. Two performance measures were used. The first was deviance ratio (1 – (model deviance/null deviance)), which represents the proportion of variance explained. The second was AIC value, which assigns a penalty based on number of covariates included in the model to meet the objective of removing unnecessary information (Burnham and Anderson 2002).

2.8.5.3 Conditional logistic models

The final model from the stepAIC process (separate process for each sex by season) was accepted as the set of candidate covariates from which candidate model sets were constructed (Table 2-3). Candidate model development followed the rule set described in Table 2-3 and produced four models for most seasons, with two additional models added in four seasons (calving, post-calving, summer, and late summer) to account for insect harassment.

Table 2-3: Phase 1 conditional logistic model development for 8-hour SSAs outside the Ekati/Diavik halo

Model name	Seasons	Origin and general characteristics of models
Mixed Grain 1	All	Inherited set of covariates from stepAIC process.
Mixed Grain 2	All	Inherited set of covariates from stepAIC process, then modified: a. removed all covariates where $p > 0.10$ [1]; b. where both grain 3 and 4 version of any covariate remained, they were reduced to a single covariate for coarser grains; first, broadly by significance, and, if significance was approximately equal then defaulted to grain 3; and c. when there was a squared version of any covariate, the base version of the covariate was added if it was not already in the model. This functionally developed a quadratic function for the covariate.
Fine Grain	All	Inherited set of covariates from Mixed Grain 2, then modified: when both grain 0 and grain 3 or 4 values of one or more covariates were included in Mixed Grain Model 2, then a fine grain model was created with only the grain 0 version of those covariates. Any model covariates contained in the Mixed Grain 2 model at only one grain were retained.
Coarse Grain	All	Inherited set of covariates from Mixed Grain 2, then modified: when both grain 0 and grain 3 or 4 values of one or more covariates were included in Mixed Grain Model 2, then a coarse grain model was created with the grain 0 version of those covariates removed (similar to the process applied to yield the Fine Grain Model). Any model covariates contained in the Mixed Grain 2 model at only one grain were retained.
Oestrid	calving, post-calving, summer, late summer	The top AIC model among the Mixed Grain, Fine Grain , and Coarse Grain models was modified by adding interaction terms between the OestIndx_1 and each of: ELEVATION, P_ESKER, WBAREA, and WAT_EDGE, when they occurred in the model, and at their finest grain of occurrence (Section 2.6.1). This was then included as an additional candidate model.
Mosquito	calving, post-calving, summer, late summer	The top AIC model among the Mixed Grain, Fine Grain , and Coarse Grain models was modified by adding interaction terms between the MosqIndx_1 and each of: ELEVATION, P_ESKER, WBAREA, and WAT_EDGE, when they occurred in the model, and at their finest grain of occurrence (Section 2.6.1). This was then included as an additional candidate model.

[1] a cut-off of $p > 0.10$ rather than $p > 0.05$ was chosen to include additional covariates from the stepAIC process in the candidate model sets.

The function clogit in the survival package in R (R Core Team 2022) was used to fit conditional logistic regression models to the data for each of the candidate models. Following Burnham and Anderson

(2002) and the recommendation of Aho et al. (2014), AIC was used to select the best model from the complex candidate model set for each sex in each season. Aho et al. (2014) noted that AIC evaluation of candidate models is likely to favour increased model complexity, i.e., include more covariates.

The overall performance of the top SSA models was assessed using Rho^2_{adj}. A Rho^2_{adj} value of 1.000 indicates perfect correlation between the model predictions and the observed data, declining to independence of the data sets when Rho^2_{adj} = 0.000. To validate the train model, coefficients from the train model were applied to the test data to get predicted values, and train model cut-points were used to assess accuracy. Model fit and predictive accuracy were assessed using Rho^2_{adj}, percent correct classification (PCC, presented here as a proportion); model sensitivity (the proportions of true positives that are correctly identified by the model); model specificity (the proportion of true negatives that are correctly identified by the model); and Kappa (a measure of the agreement between predicted and true values).

By definition, the top ranked model from the SSA for each sex by season are the Step Selection Functions (SSFs); the SSF is the set of covariates and their coefficients that is used to calculate the relative habitat selection value for each 3.1 ha hexagon.

2.8.6 Phase 2 analyses: 8-hour interval iSSA inside the Ekati/Diavik halo

The objective of the Phase 2 analyses was to identify the best iSSFs for each sex by season within 30 km of the Ekati and Diavik mines that integrated movement parameters, predicted relative habitat selection values determined from SSFs in Phase 1, and distance to mining features.

The steps outlined below were followed for each of the sex by season data sets.

2.8.6.1 Relative 8-hour interval selection probability for 3.1-ha hexagons within the Ekati/Diavik halo based on Phase 1 SSFs

The 8-hour SSF models from outside the Ekati/Diavik halo (Section 2.8.5), were used to predict relative habitat selection values w(x) for each 3.1- ha hexagon inside the Ekati/Diavik halo. The prediction was conducted in R (R Core Team 2022) by exponentiating the linear combination of the *K* SSF covariates (x_i) and their coefficients (β_i), excluding the intercept (Boyce et al. 2002; Fieberg et al. 2021; Northrup et al. 2022). When the SSF for a season included insect harassment covariates, the mean seasonal insect harassment index value was substituted as its coefficient in the equation for each hexagon.

$$\mathrm{w}(x) = exp(\beta_1 x_1 + \beta_2 x_2 + \cdots \beta_k x_k)$$

For visual presentation, the predicted 8-hour SSF relative habitat selection values in the Ekati/Diavik halo were mapped for each sex by season. Prior to mapping values for each 3.1-ha hexagon in the Ekati/Diavik halo, the predicted relative habitat selection values were rescaled to between 0 and 1 with a linear stretch (DeCesare et al. 2012):

$\widehat{w}(x) = \left(\frac{\mathrm{w}(x) - w_{min}}{w_{max} - w_{min}}\right)$,

where:

w(x) is the unscaled relative habitat selection value for 3.1-ha cell x;

w_{min} is the minimum 3.1-ha cell value within the Ekati/Diavik halo;

w_{max} is the maximum 3.1-ha cell value within the Ekati/Diavik halo; and

$\widehat{w}(x)$ is the new, rescaled relative habitat selection value for 3.1-ha cell x.

The re-scaling process yields a set of relative habitat selection values that has the same total value on each map. This should not be interpreted to suggest that overall selection is equal among seasons.

2.8.6.2 Conditional logistic models

The 8-hour movement step data from inside the Ekati/Diavik halo were analysed with iSSAs, similar to the SSAs used in Phase 1 analyses, but with the addition of transformed movement covariates. Each candidate model included the predicted relative habitat selection values from Phase 1 SSFs as covariates. Candidate model development followed the rule set described in Table 2-4 and produced eight models for most seasons, with three additional models added in winter to address the effect of proximity to the winter road on habitat selection.

Table 2-4: Conditional logistic model development for 8-hour iSSAs inside the Ekati/Diavik halo

Model name	Seasons	Origin and general characteristics of models
SSF Predicted habitat value	All	3.1-ha hexagon predicted relative habitat selection value only (RSFrisk)
iSSA Base model	All	3.1-ha hexagon predicted relative habitat selection value (RSFrisk) + movement (cos.ta, log.sl)
DFMineRoads	All	Base model + distance from mine roads, distance from mine roads squared, interactions between distance from mine road covariates and 3.1-ha hexagon predicted relative habitat selection value
DFMines	All	Base model + distance from mines, distance from mines squared, interactions between distance from mines covariates and 3.1-ha hexagon predicted relative habitat selection value
LogDFMineRoads	All	Base model + log(distance from mine road), interactions between log(distance from mine road) and 3.1-ha hexagon predicted relative habitat selection value
LogDFMines	All	Base model + log(distance from mines), interactions between log(distance from mine) and 3.1-ha hexagon predicted relative habitat selection value
LinearDFMineRds	All	Base model + distance from mine roads, interaction between distance from mine road and 3.1-ha hexagon predicted relative habitat selection value
LinearDFMines	All	Base model + distance from mines, interaction between distance from mines and 3.1-ha hexagon predicted relative habitat selection value
DFWinterRoad	winter	Base model + distance from winter road, distance from winter road squared, interactions between distance from winter road covariates and 3.1-ha hexagon predicted relative habitat selection value
LogDFWinterRoad	winter	Base model + log(distance from winter road), interactions between log(distance from winter road) and 3.1-ha hexagon predicted relative habitat selection value
LinearDFWintRd	winter	Base model + distance from winter road, interaction between distance from winter road and 3.1-ha hexagon predicted relative habitat selection value

The function clogit in the survival package in R (R Core Team 2022) was used to fit conditional logistic regression models to the data for each of the Phase 2 iSSA candidate models. With large sample sizes, using the Bayesian Information Criterion (BIC) tends to yield simpler models (fewer covariates) and avoids overfitting. Aho et al. (2014) recommended the use of BIC to determine the best fitting model.

Following this recommendation, BIC was used to select the top model from each candidate model set in Phase 2 iSSA.

By definition, the top ranked models from the iSSA for each sex by season are the integrated Step Selection Functions (iSSFs); the iSSF is the set of covariates and their coefficients that is used to calculate the relative habitat selection value for each 3.1 ha hexagon when movement covariates are also included in the candidate models.

The overall performance of the iSSFs was assessed using Rho^2_{adj}. In addition, the model was applied to the test data and performance metrics (see Section 2.8.5.3) were assessed.

2.8.7 Comparative mapping of relative 8-hour interval selection probability for 3.1-ha hexagons within the Ekati/Diavik halo based on Phase 1 SSFs and Phase 2 iSSFs

For visual comparison, relative habitat selection values for each 3.1-ha hexagon within the Ekati/Diavik halo were predicted with Phase 1 SSFs (determined from landcover and topography outside the Ekati/Diavik halo). Similarly, for each sex by season, relative habitat selection values were predicted for each 3.1-ha hexagon using Phase 2 8-hour iSSFs (based on Phase 1 predicted relative habitat selection values, movement covariates, and distance to mining feature covariates). The iSSF covariates related to turning angle and step length require a starting location and prior movement pathway to be fully evaluated. It is possible to accomplish this through an emerging approach that uses simulated movements (Northrup et al. 2022, p. 22). Therefore, the Phase 2 results in this report were mapped with covariates for turning angle and step length excluded from calculations; the relative value of each 3.1-ha cell was based on the remaining covariates for the iSSF. The two equations presented in Section 2.8.6.1 were used to predict relative habitat selection values and re-scale them across the Ekati/Diavik halo for each sex by season.

For each sex by season, the predicted relative habitat selection values based on Phase 1 SSF and Phase 2 iSSF were plotted side-by-side for visual assessment.

2.8.8 Phase 3 analyses: 1-hour interval SSA and iSSA inside GF112N

2.8.8.1 Data reduction

The sample size in SSA and iSSA is the number of strata (the matched sets of 1 TRUE location and 5 FALSE [i.e., random] locations). Residence time in GF112N varied significantly among individuals: on average only 21% of animals had any 1-hour movement steps in GF112N during an animal- season. However, with hourly locations there were many individuals with hundreds of 1-hour steps in a season, and in winter there were several animal-seasons with over 1,000 1-hour steps. To limit individual influence on results, the median number of steps for each sex by season was calculated for each animal-season with 1-hour step data. Any animal with greater than the median number of 1-hour steps had its steps systematically reduced to the median (e.g., if it had 3.0 times the median number of 1-hour steps, every third stratum [i.e., the set of 1 TRUE and 5 FALSE locations] was retained in the analyses). This better balanced the sample of data used to make population inferences.

2.8.8.2 SSA for landcover, topography, and insects

Conditional logistic modelling for 1-hour interval movements within GF112N followed the process for the two phases of 8-hour modelling outlined above (Section 2.8.5; including BRT, StepAIC, and conditional logistic modelling). Initially, landcover only modelling was conducted on 1-hour movement data for each sex by season data set. The development of conditional logistic regression candidate models followed the process used for 8-hour SSA outside the Ekati/Diavik halo as outlined in Table 2-3, including the evaluation of two insect harassment models built from the top landcover model and interaction terms including mosquito and oestrid index values.

2.8.8.3 iSSA with SSA top model covariates plus movement and distance to feature covariates

The set of covariates from the top 1-hour SSA landcover/insect harassment model for each sex by season, plus cos.ta and log.sl was adopted as the landcover model for 1-hour iSSA. Distance to feature covariates were added to create six (or nine, in the case of winter) additional models as presented in Table 2-5. The differences between the Table 2-4 8-hour candidate model set and the Table 2-5 1-hour candidate model set were:

- the absence of a predicted relative habitat model in the 1-hour model set as there were no 1-hour movement interval data outside the geofence area to use as control data as was done for the 8-hour interval analyses; and consequently
- the complete set of covariates from the top 1-hour SSA landcover model for each sex by season were included in each candidate model.

Table 2-5: Conditional logistic model development for 1-hour iSSA inside GF112N

Model name	Seasons	Origin and general characteristics of models
Landcover model	All	Top 1-hour SSA covariates + movement (cos.ta, log.sl)
DFMineRoads	All	Landcover model + distance from mine roads, distance from mine roads squared
DFMines	All	Landcover model + distance from mines, distance from mines squared
LogDFMineRoads	All	Landcover model + log(distance from mine road)
LogDFMines	All	Landcover model + log(distance from mines)
LinearDFMineRds	All	Landcover model + distance from mine roads
LinearDFMines	All	Landcover model + distance from mines
DFWinterRoad	winter	Landcover model + distance from winter road, distance from winter road squared
LogDFWinterRoad	winter	Landcover model + log(distance from winter road)
LinearDFWintRd	winter	Landcover model + distance from winter road

As in Phase 2 iSSAs of 8-hour data, BIC was used to select the iSSF from each candidate model set in Phase 3 iSSA. The overall performance of each iSSF was assessed using Rho^2_{adj}. In addition, the iSSF was fit to the test data and performance metrics were assessed (see Section 2.8.5.3).

The iSSF covariates related to turning angle and step length require a starting location and prior movement pathway to be fully evaluated. In mapping the Phase 3 results, the covariates for turning angle and step length were excluded from calculations; the relative value of each 3.1-ha cell was based on the remaining covariates for the iSSF as in Section 2.8.7. The two equations presented in Section 2.8.6.1 were used to predict relative habitat selection values and re-scale them across the Ekati/Diavik halo for each sex by season.

2.9 Movement characterization

Following examination of movement data summaries, Poole et al. (2021) raised concerns regarding the relationship between diamond mines (including infrastructure, roads, and operations) and caribou movements. The simple relationship of caribou movements to the proximity of mine infrastructure is confounded by habitat selection and the spatial distribution of natural environmental features. These relationships were explicitly addressed through iSSAs as described in Section 2.8.

To examine the effects of an animal's exposure to the Ekati and Diavik mines on its behaviour at the seasonal scale, analyses were conducted on 8-hour interval data to quantify and test the relationships between time spent in the Ekati/Diavik halo and: (1) total movement pathway within a season; and (2) delayed arrival at the next seasonal range.

To satisfy requests of GNWT-ENR and IEMA, movement step-length and turn angles were examined relative to distances from mine roads and mine infrastructure for both 1-hour and 8-hour time intervals.

2.9.1 Effect of exposure time in Ekati/Diavik halo on length of seasonal movement path

The total length of the seasonal movement path for each animal-season was calculated as the sum of all 8-hour movement steps in the season (determined in R package amt; R Core Team 2022). This included all locations for each animal, regardless of whether they were in or out of the RSA.

The seasonal movement path length calculated as a sum of step lengths is affected by missing movement steps for individuals. These occur owing to failed GPS location fixes, late-season collar deployment (typically in winter), mortality, scheduled collar removal, or collar failure. To provide relative consistency among animal-season records, a minimum of 90% of the maximum number of locations possible for an animal-season was required for the data to be included in analyses; at 8-hour intervals, the maximum number of locations is 3 times the season length in days.

The number of 8-hour movement steps ending in the Ekati/Diavik halo was then determined for each animal-season of data; essentially the total number of locations in the Ekati/Diavik halo for each animal in each season in each year. This was regarded as a measure of the animal's exposure time to the effects of the mines and mine roads.

Linear regression of seasonal path length on Ekati/Diavik halo exposure time was conducted in R. These analyses compare how far each animal moves in an entire season to how long it spent in the Ekati/Diavik halo in that season. In addition to separate analyses for each sex in each season it was necessary to divide data into the two herds as the season lengths varied between the Bathurst and Beverly herds (Table 2-1). This is the one instance in this report where herd was used to divide data prior to analyses.

2.9.2 Effect of exposure time in Ekati/Diavik halo on delayed arrival in next seasonal range

As with the examination of the effect of exposure to the Ekati/Diavik halo on total movement pathway, the number of 8-hour movement steps ending in the Ekati/Diavik halo was used to address concerns regarding the effect of exposure in one season on the arrival date in the 90% UD seasonal range used in the next season.

As seasonal ranges included areas outside the RSA (Section 2.4), the entire set of 8-hour locations for each animal-season were included in these analyses. Animal-seasons included in these analyses were restricted to sets of data with locations on ≥ 75% of 8-hour location fix attempts, the same threshold for data inclusion used for calculations of seasonal UDs (Section 2.4.3).

The first 8-hour telemetry location for each animal in each season (Table 2-1) was identified as the first possible date and time the animal could have been detected in a seasonal range. Each set of animal-season 8-hour locations was intersected with the appropriate 90% UD seasonal range to identify the earliest location of the animal recorded inside the seasonal range. A delay in arrival was defined as the number of days between the first telemetry location recorded for the season and the first telemetry location recorded inside the 90% UD seasonal range. When the first location for the season was within the 90% UD seasonal range the delay was recorded as 0.00 days (i.e., no delay).

The set of animal-season records contained cases where individuals present in one season did not have any locations in the following season, likely owing to mortality, collar failure, or collar removal. These records were removed from further consideration. There were also cases where individuals had telemetry location data from both seasons but never entered the 90% UD seasonal range delineated for the later season; these records are summarized in the results section but were not analysed further.

While the length of exposure to the Ekati/Diavik halo was measured (i.e., number of 8-hour movement steps as in Section 2.9.1) and the length of any delay was calculated for each animal-season, the data were ultimately reduced to binary categories for analyses: 1. Did the location data intersect the Ekati/Diavik halo - TRUE or FALSE; and 2. Was the animal delayed in arrival on the next seasonal range - TRUE or FALSE. Fisher's exact tests were used to test the independence of Ekati/Diavik halo intersection and delayed arrival in the next seasonal range in program R (R core team 2022).

2.9.3 Proximity to mine infrastructure and mine roads on movement step length

Step-length was explicitly included in iSSAs at both the 8-hour (Phase 2 analyses, Section 2.8.6) and 1-hour (Phase 3 analyses, Section 2.8.8). In those analyses step-length was, by definition, integrated in models with habitat selection and distance to mining features, recognizing that movement patterns and habitat selection influence one another (Avgar et al. 2016; Signer et al. 2019; Fieberg et al. 2021).

Exploratory descriptions of female caribou movement were summarized in a recent document (Poole et al. 2021) that was part of the impetus for the analyses in this report. Though they did not directly analyze the relationship between step length and distance to mining features, Poole et al. (2021) expressed concern that their descriptive summaries showed step-length to be related to proximity to mining features. Consequently, direct analyses of step-length data are included in this report even though the iSSAs are considered the statistically more appropriate and stronger analyses for these data.

As described in Section 2.8, the area analyzed for the effect of Ekati and Diavik mine influence on caribou behaviour was defined as the 30 km Ekati/Diavik halo for 8-hour interval data and as GF112N for 1-hour data. The data included in the direct assessment of mining activity effects on caribou movement were the TRUE movement step data used in Phase 2 (8-hour interval inside the Ekati/Diavik halo; Section 2.8.6) and Phase 3 (1-hour interval inside GF112N; Section 2.8.8) analyses.

Independently for each of the 1-hour and 8-hour interval data sets, the natural log transformed step length data (log.sl) were regressed on the shortest distance to mine roads or mine infrastructure for all steps in the sex by season data sets (linear regression in R). As with iSSA analyses for both 1-hour and 8-hour intervals, the calving and post-calving season data were excluded; there were 28 separate regressions – 7 seasons x 2 sexes x 2 time-intervals.

2.9.4 Proximity to mine infrastructure and mine roads on movement step turn angle

The rationale for the analyses of turn angles between successive movement steps is the same as that for analyzing movement step lengths against distance to mining features in Section 2.9.3 above. As with step length analyses, the direct analyses of turn angle data are included in this report even though the iSSAs (Sections 2.8.6 and 2.8.8) are considered the more appropriate analyses for these data.

As with the relationship of movement step length to distance to mining features, the turning angle data analyses were independent for each of the 1-hour and 8-hour intervals, using the TRUE step data included in Phase 2 and Phase 3 analyses. The cosine transformed turn angle data (cos.ta) were regressed on the shortest distance to mine roads or mine infrastructure for all steps in the sex by season data sets (linear regression in R). As with iSSA analyses for 1-hour and 8-hour intervals, the calving and post-calving season data were excluded; there were 28 separate regressions – 7 seasons x 2 sexes x 2 time-intervals.

3. RESULTS

3.1 Caribou location data

Telemetry location data received from GNWT-ENR (ENR 2022) for the Bathurst herd included data from 1996 to the end of 2022. The data received from GNWT-ENR for the Beverly herd were compromised for the period prior to December 2015, restricting available data for the Beverly herd to the period from December 2015 to December 2022 (Table 3-1).

The screening of caribou location data resulted in the removal of duplicate locations, locations collected less than 55 minutes apart, and locations deemed to be movement outliers. A review of location frequency by hours of the day and minutes of the hour provided information for additional screening and resulted in the selection of 8-hour and 1-hour intervals for SSAs and iSSAs. The collection of 1-hour interval data sufficient for analyses began with spring migration 2017 for the Bathurst herd and spring migration 2018 for the Beverly herd.

Table 3-1: Number of radio-collared Bathurst Herd and Beverly Herd caribou with location data[1] considered in this study: by herd, sex, and year

	Bathurst Herd		Beverly Herd	
Year	**Male**	**Female**	**Male**	**Female**
2016	15	27	9	27
2017	19	31	16	33
2018	16	24	22	36
2019	15	28	24	33
2020	16	56	13	21
2021	16	47	25	30
2022	20	48	21	36
Total	117	261	130	216

[1] Environment and Natural Resources (2022).

3.2 Seasonal caribou ranges (utilization distributions [UDs])

Time periods with daily location data and seasonal screening criteria are presented in Table 3-2 (Bathurst herd) and Table 3-3 (Beverly herd). The available data permitted 90% UD seasonal ranges to be calculated for each sex in each herd from winter 2015/2016 to post-rut 2022; seven complete years, though the sample size for Beverly males was only 4 animals with adequate location data prior to spring migration 2017. Iterative seasonal range smoothing parameter values for female Bathurst caribou were calculated beginning with winter 2008/2009 and results were included in the determination of Bathurst herd smoothing parameters; seasonal ranges for Bathurst females prior to winter 2015/2016 are not presented in this report.

The smoothing parameter applied to analyses for all Bathurst herd 90% UD seasonal ranges was 18,000 m. Beverly herd 90% UD seasonal ranges were determined with a smoothing parameter of 38,000 m.

Seasonal ranges for each sex in each herd in each year are presented in Appendix A (Figures A-1 to A-9).

Table 3-2: Summary of Bathurst herd telemetry locations used for seasonal kernel density estimate range analyses; one location per day per animal

Season	Season length (days)	Minimum locations per animal per season for inclusion	Individual years analysed for females	Individual years analysed for males
Winter	140	105	2008/2009 to 2021/2022	2015/2016 to 2021/2022
Spring Migration	43	33	2009 to 2022	2015 to 2022
Calving	15	12	2009 to 2022	2015 to 2022
Post-Calving	12	9	2009 to 2022	2015 to 2022
Summer	50	38	2009 to 2022	2015 to 2022
Late Summer	20	15	2009 to 2022	2015 to 2022
Pre-Rut	40	30	2009 to 2022	2015 to 2022
Rut	15	12	2009 to 2022	2015 to 2022
Post-Rut	30	23	2009 to 2022	2015 to 2022

Table 3-3: Summary of Beverly herd telemetry locations used for seasonal kernel density estimate range analyses; one location per day per animal

Season	Season length (days)	Minimum locations per animal per season for inclusion	Individual years analysed for females	Individual years analysed for males
Winter	115	87	2015/2016 to 2021/2022	2015/2016 to 2021/2022
Spring Migration	57	43	2016 to 2022	2016 to 2022
Calving	14	11	2016 to 2022	2016 to 2022
Post-Calving	19	15	2016 to 2022	2016 to 2022
Summer	35	27	2016 to 2022	2016 to 2022
Late Summer	30	23	2016 to 2022	2016 to 2022
Pre-Rut	39	30	2016 to 2022	2016 to 2022
Rut	14	11	2016 to 2022	2016 to 2022
Post-Rut	42	32	2016 to 2022	2016 to 2022

3.3 Intersection of Bathurst and Beverly caribou data with RSA extent

The RSA (Figure 2-4) was defined by available landcover (Sections 2.7 and 3.3) and the distribution of Bathurst and Beverly herd telemetry locations in the study period. Its total area is 212,355 km^2. The RSA included 91% of all Bathurst caribou telemetry locations and 69% of all Beverly caribou telemetry locations collected on 8-hour intervals within the study period (Tables 3-4 and 3-5).

Table 3-4: Summary of all Bathurst herd telemetry locations collected at 00h, 08h, and 16h for the study period - by season

Season	Total Bathurst herd telemetry locations December 1, 2015 to November 30, 2022 (number of animal-seasons in parentheses)	Locations recorded inside the Regional Study Area	Percentage of total Bathurst herd 8-hour interval telemetry locations within the Regional Study Area
Total	260,495 (2610)	238,012	91.4%
Winter	82,255 (333)	75,226	91.5%
Spring Migration	36,159 (332)	28,136	77.8%
Calving	13,946 (320)	10,104	72.5%
Post-Calving	9.588 (272)	9,086	94.8%
Summer	42,852 (317)	41,445	96.7%
Late Summer	16,129 (302)	15,694	97.3%
Pre-Rut	28,836 (256)	28,185	97.7%
Rut	10,486 (242)	10,180	97.1%
Post-Rut	20,243 (236)	19,956	98.6%

Table 3-5: Summary of all Beverly herd telemetry locations collected at 00h, 08h, and 16h for the study period - by season

Season	Total Beverly herd telemetry locations December 16, 2015 to December 15, 2022 (number of animal-seasons in parentheses)	Locations recorded inside the Regional Study Area	Percentage of total Beverly herd 8-hour interval telemetry locations within the Regional Study Area
Total	257,737 (2506)	176,951	68.7%
Winter	72,287 (342)	59,810	82.7%
Spring Migration	48,122 (311)	30,400	63.2%
Calving	12,018 (296)	2,334	19.4%
Post-Calving	15,671 (296)	1,194	7.6%
Summer	27,468 (289)	14,010	51.0%
Late Summer	21,581 (270)	19,010	88.1%
Pre-Rut	25,779 (242)	21,173	82.1%
Rut	9,015 (231)	7,063	78.3%
Post-Rut	25,796 (229)	21,957	85.1%

3.4 Landcover and associated data layers

3.4.1 Selected landcover classification

As noted in the methods section, LC2009 was considered as the preferred landcover classification where it existed. Both EOSD and LC2000 (ETM+) were considered for the remainder of the study area. Attempts to merge the LC2009 with the EOSD data layer resulted in poor alignment between the two classifications, and also revealed gaps between the two coverages on the edge of the woodland/tundra vegetation zones.

Ultimately, the combination of LC2009 for the main portion of the study area (Arctic Tundra vegetation zone) and the LC2000 (ETM+) classification for the Sub-Arctic Woodland Tundra portion of the study area provided the best combination of two landcover classifications. By limiting the LC2000 (ETM+) data specifically along Vegetation Zone boundary then the demarcation between the LC2009 and LC2000 (ETM+) became explicit (Figure 3-1).

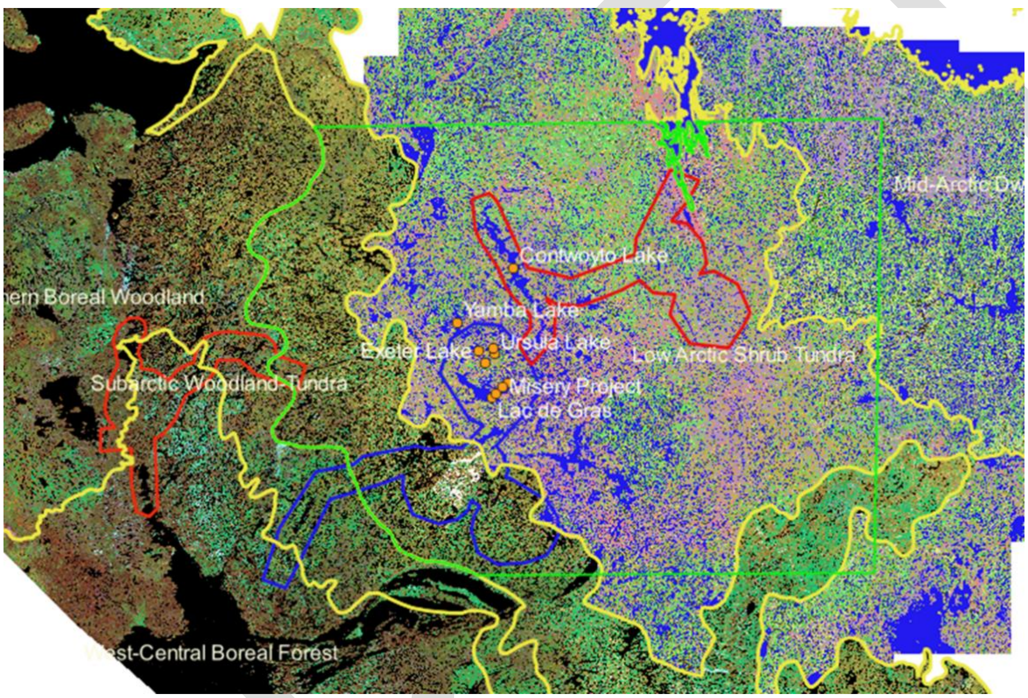

Figure 3-1: Regional Study Area Extent (green line) showing Vegetation Zone Boundaries (yellow lines). Note the exclusion of Northern Boreal Woodland and West-Central Boreal Forest that lie further to the west and south.

Grouping the 43 classes from LC2000 (ETM+) into 15 LC2009 classes provided stronger correspondence between the two classifications. The landcover classes from the two landcover products were grouped to a common classification of six categories useful for the habitat selection analyses: Bedrock-boulder, Tundra, Tussock, Sedge Wetland, Shrub, and Forest (Table 3-6). Water was initially classified from both these sources, but following preliminary analyses of collinearity among covariates it was overwritten with waterbody area classified from the CanVec Series Hydrographic Features data (see Section 3.3.2 below). During the grouping process various combinations were mapped, with the objectives of producing a relatively seamless map by landcover category. As an example, Figure 3.2 shows RSA extent maps from the final groupings for Tundra and Tussock, with abundance measured for each 3.1-ha hexagon; almost seamless maps with no evidence of strong demarcation between landcover source. Overall, the classification provided by the merged LC2000 (ETM+) and LC2009 data sets provide a landcover layer that is continuous and complete for the study area. The spatial resolution of the landcover is used to its maximum potential, with higher resolution LC2009 for the majority of the study area. The LSL processing then yielded a common resolution of 3.1-ha across the entire study area.

Table 3-6: Landcover classification, merged classes

Landcover category for analysis	LC2009	LC2000 (ETM+)
Bedrock-boulder	8, 9, 12	18, 19, 38
Tundra	3, 4, 7, 10	28, 35, 36
Tussock	1	23, 37, 41
Sedge Wetland	2, 11	25
Shrub	5, 6	15, 16, 21, 22, 24, 26, 39
Forest		1, 7, 8, 9

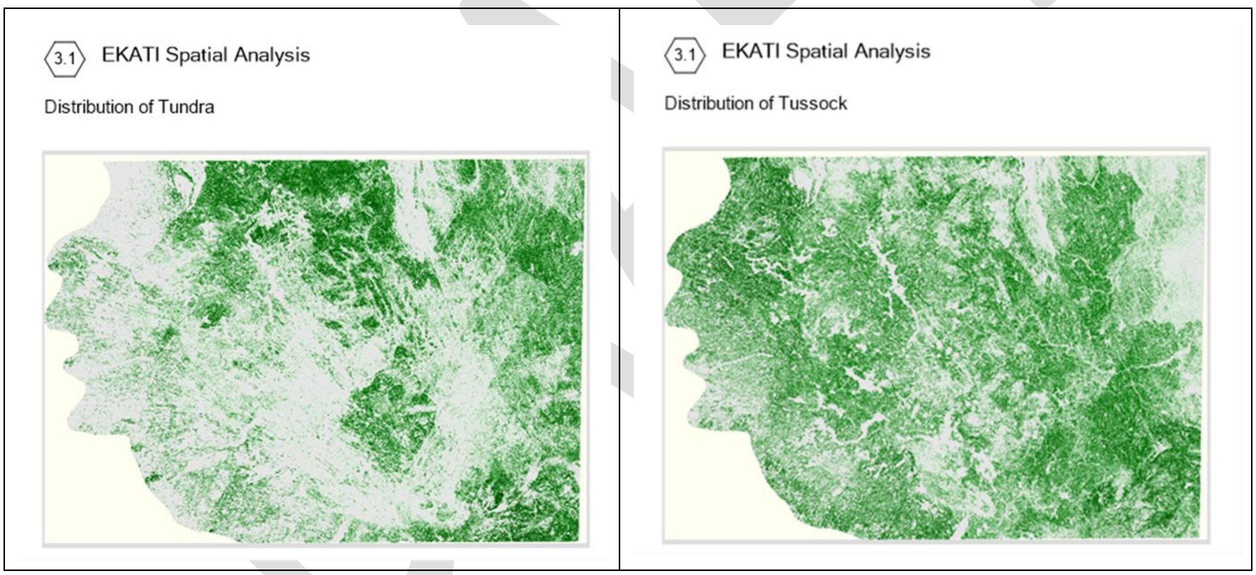

Figure 3-2. LSL output for proportion of Tundra and Tussock (3.1-ha grain) across the regional study area after grouping of LC2000 (ETM+) (west) and LC2009 (east) landcover classes. Note that there are no evident discontinuities or gaps between the landcover map sources at the map boundary.

3.4.2 Additional selected landcover and environmental attributes

The environmental attributes acquired from sources other than the raster-based landcover layers are listed in Table 3-7. They include categories for proportional coverage by water and eskers, water/land edge, topographic attributes, human disturbance, and insect harassment indices.

Table 3-7: Additional study area landcover and environmental attributes

Category for analysis	Data source	Description
Waterbody Area	Lakes, Rivers and Glaciers in Canada - CanVec Series - Hydrographic Features (Natural Resources Canada 2019)	Polygon features
Water/land edge	Lakes, Rivers and Glaciers in Canada - CanVec Series - Hydrographic Features (Natural Resources Canada 2019)	Linear measure of edge between water polygons and adjacent landcover polygons per unit area (m/ha)
Elevation	Canadian Digital Elevation Model Mosaic (Natural Resources Canada 2013)	Calculated within 3.1-ha hexagons
Slope	Canadian Digital Elevation Model Mosaic (Natural Resources Canada 2013)	Calculated within 3.1-ha hexagons
Aspect	Canadian Digital Elevation Model Mosaic (Natural Resources Canada 2013)	Calculated within 3.1-ha hexagons. Later removed from analyses.
Esker polygon	Linear Surficial Features of Canada (NTGS 2022 - Canadian Geoscience Map 195)	Esker polygons created as a 200 m wide polygon centred on esker line features appearing on 1:50,000 NTS map layer.
Mine roads	2021 Misery, Sable, Lynx, and Lac du Sauvage roads clipped from Ekati Diamond Mine shapefiles (Arctic Canadian Diamond Company Ltd.).	Polygons representing mine roads for the Ekati Diamond Mine. All Diavik Diamond Mine roads were included as mine infrastructure.
Winter roads	Shapefile of the Tibbitt to Contwoyto Winter Road provided by Arctic Canadian Diamond Company Ltd.	Polyline feature. Truncated at the Ekati Diamond Mine to reflect the limit of its construction during the study period.
Ekati and Diavik mine infrastructure	2021 Ekati Diamond Mine shapefiles excluding mine roads described above (Arctic Canadian Diamond Company Ltd.); 2021 Diavik Diamond Mine shapefiles (Diavik Diamond Mines Inc.)	No differentiation regarding type of infrastructure (e.g., pit, camp, processing site, wasterock storage area, etc.). Also includes mine roads at Diavik.
Other human developments	GNWT-ENR 2022. 2022 CIMP human disturbance layer	Historic mines, exploration sites, and other human developments up to and including 2022.
Oestrid harassment index	CircumArctic Rangifer Monitoring and Assessment (CARMA) Network	Daily index value calculated for each of five large spatial scales for each of the Beverly and Bathurst herds (Russell et al. 2013). Spatial scale with best match for seasonal caribou distribution was used. This covariate applied to Calving, Post Calving, Summer, and Late Summer data only.
Mosquito harassment index	CircumArctic Rangifer Monitoring and Assessment (CARMA) Network	Daily index value calculated for each of five large spatial scales for each of the Beverly and Bathurst herds (Russell et al. 2013). Spatial scale with best match for seasonal caribou distribution was used. This covariate applied to Calving, Post Calving, Summer, and Late Summer data only.

Polygon coverages of Ekati Mine roads and Ekati and Diavik mine infrastructure were produced to represent development for the 2016-2022 time period of the study (Figure 3-3). Ekati Diamond Mine roads (Sable, Misery, Lynx, and Lac du Sauvage roads) were grouped as the set of mine roads for analyses while all other Ekati and Diavik diamond mine features (Ekati Diamond Mine, including Misery, Lynx, and Sable projects, plus the Diavik Diamond Mine) were grouped as the set of mine infrastructure polygons for analyses. As described in the methods section, the winter road was plotted as a line feature terminating at the Ekati Diamond Mine, the limit of its construction during the study period.

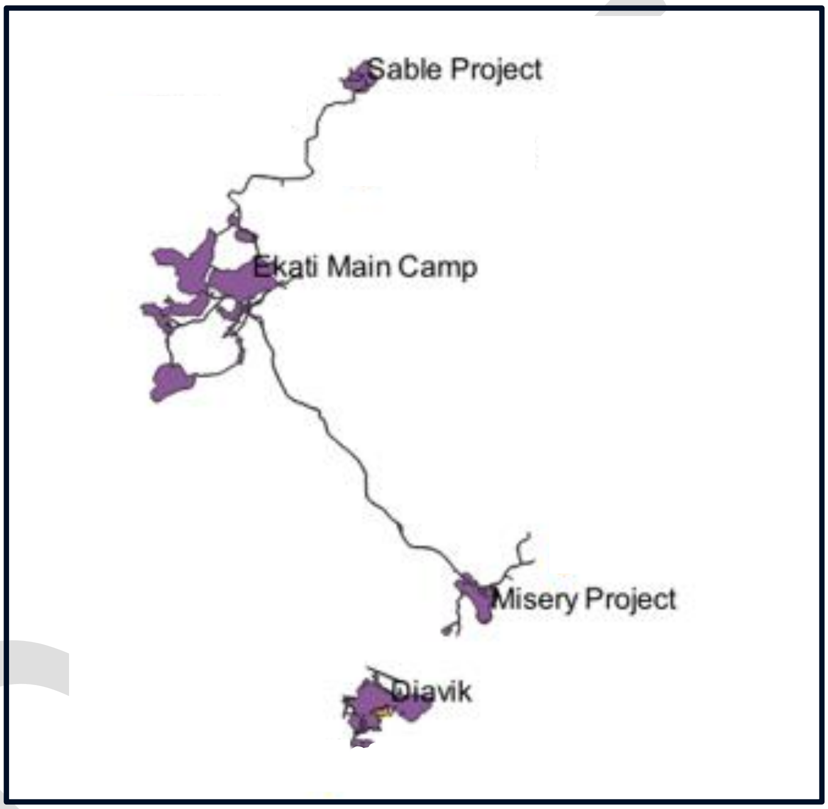

Figure 3-3. 2021 Ekati Diamond Mine roads and Diavik and Ekati Diamond mine infrastructure footprints for intersection with 2016-2022 caribou location data. Roads between sites are buffered by 25 m.

3.4.3 Resolution and multi-grain covariate data

The spatial averaging process completed in LSL results in covariate estimation to becoming progressively smoother after averaging at coarser grains (Figure 3-4). The resulting 3.1-ha hexagon shapefile for the RSA has attributes for all four grains attached to each 3.1-ha cell record and provides a structured data set for both training models and applying predictions from a multi-grain model across the entire landscape. There is a data record for each 3.1-ha hexagon in the RSA, each record with a column for each covariate (Table 3-8). Data from this shapefile were spatially joined to the telemetry location data to provide the raw input data for SSA and iSSA modelling.

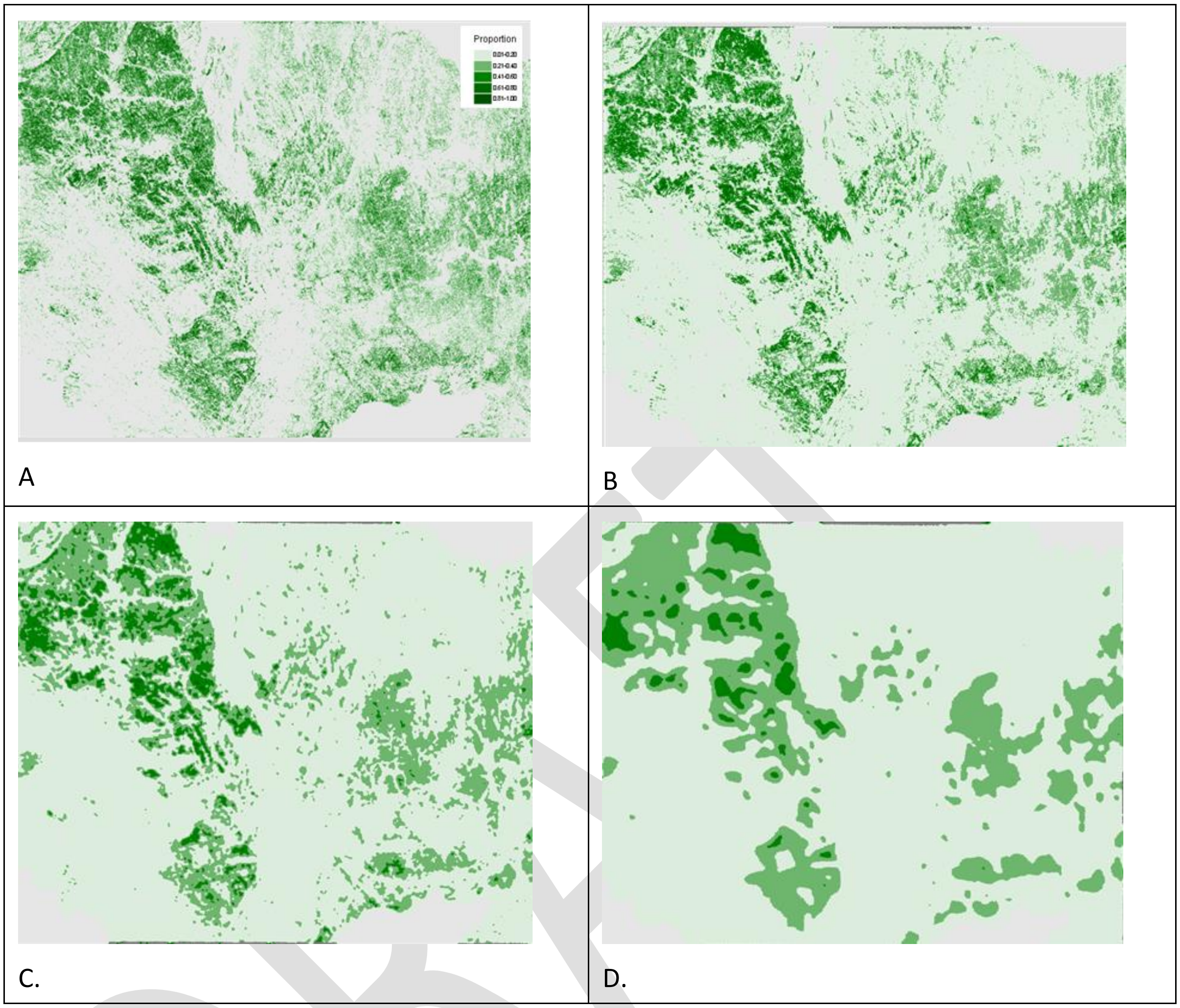

Figure 3-4. Proportion of Tundra measured across four grains. A) 3.1-ha; B) 59-ha; C) 524-ha; and D) 5137-ha. All maps are displays of 3.1-ha hexagon data records for Tundra – one at each of the four grains (See Table 3-8 for an example).

Table 3-8. Clip of LSL 3.1-ha hexagon attribute table illustrating the proportion of tundra at each of four grains (3.1-ha, 59-ha, 524-ha, and 5137-ha) for six of the hexagons in the RSA.

HEXID	DF_MINE	TUNDRA (3.1-ha)	TUNDR_S2 (59-ha)	TUNDR_S3 (524-ha)	TUNDR_S4 (5137-ha)
1001750	30001	0.230	0.495	0.509	0.464
1181262	28019	0.000	0.075	0.175	0.280
4350924	25172	0.602	0.696	0.471	0.348
4034102	30001	0.116	0.065	0.118	0.282
1650497	30001	0.691	0.378	0.287	0.183
1682329	30001	0.000	0.152	0.109	0.132

[1] *HEXID is unique for each 3.1-ha hexagon and is linked when creating a seamless habitat layer across the entire study area. DF_MINE is the proximity of 3.1-ha hexagon to the nearest Ekati or Diavik mine footprint in metres. Complete sets of attributes are listed in Tables in Appendix B. There is a record for each 3.1 ha hexagon in the RSA.*

3.5 Habitat selection analyses

3.5.1 Pre-HSA examination of collinearity of data for each landcover class

Following transformation and re-scaling (Section 2.8.3) and prior to model development, base landcover covariates in the train data sets were examined at three grains for each of the 18 sex by season combinations. The VIF was calculated using the function ols_vif_tol in the R package olsrr. Of the 432 season, sex, and covariate combinations examined, 38 (9%) had VIF > 5.00, with a maximum value of 7.21; of these, 36 were tundra and shrub covariates at the two coarsest grains. Some level of collinearity is expected among landcover classes, as some of these classes will tend to occur together. This is normal and was not considered to be an issue. Ultimately nine of these covariates were included in SSFs (Table 3-9).

Table 3-9: Covariates with variance Inflation Factors > 5.00 that were included in SSFs. Data modelled were the train data sets used for 8-hour Regional Study Area Step Selection Analyses.

Season	Sex	Covariate	Tolerance	VIF	Grain (ha)
Calving[1]	Male	TUNDR_S3	0.185	5.411	524
Calving[1]	Male	LHSHRUB_S3	0.195	5.119	524
Calving[1]	Male	TUNDR_S4	0.156	6.400	5137
Calving[1]	Male	LHSHRUB_S4	0.176	5.680	5137
Calving[1]	Female	LHSHRUB_S3	0.195	5.119	524
Rut	Male	WBAREA	0.193	5.194	3.1
Rut	Male	TUNDR_S4	0.182	5.497	5137
Rut	Female	WBAREA	0.193	5.194	3.1
PostRut	Female	LHSHRUB_S4	0.192	5.213	5137

[1] Owing to seasonal distribution of animals, there was no assessment of the effect of development on caribou behaviour during calving season.

3.5.2 Removal of records with incomplete data

During analysis it became evident that a small number of records lacked elevation data, rendering them incomplete and not possible to analyze. The locations were confined to the extreme southeast portion of the RSA (white rectangle in the lower right corner of Figure 3-5). The records lacking elevation data were removed from analyses.

Similarly, the first movement step in each movement pathway (the first step in every animal season and in each new movement burst following a missed location) did not have a turning angle and was not possible to include in iSSAs, all of which required the cosine of the turning angle as a covariate for each record.

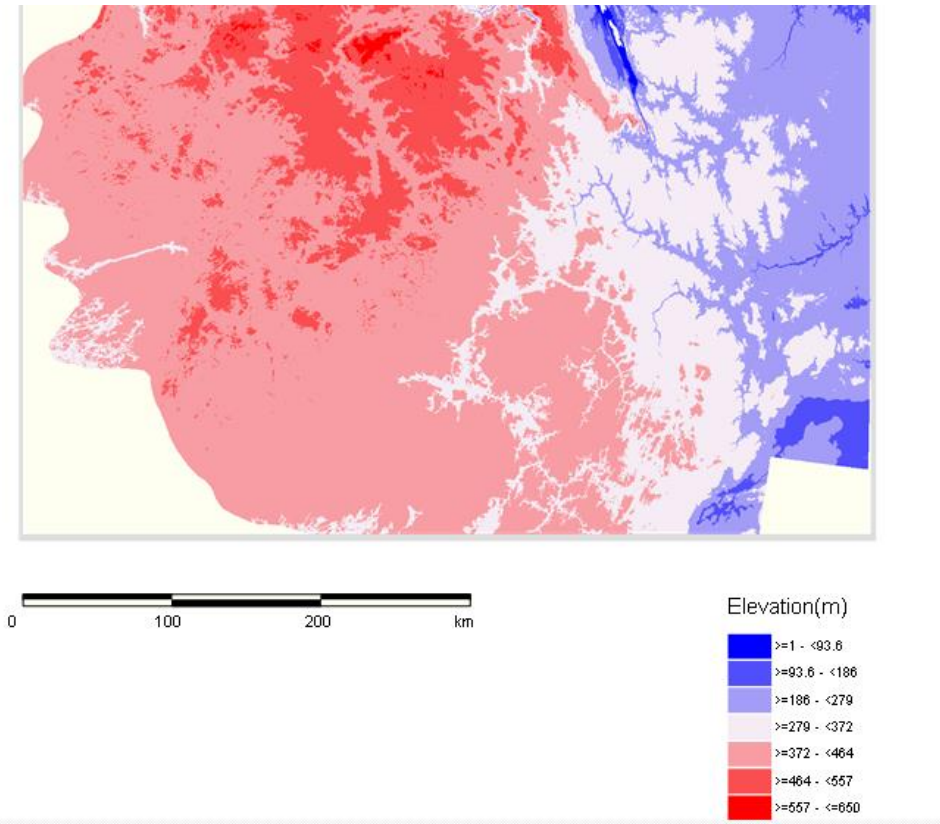

Figure 3-5. Map of elevation within the Regional Study Area (in metres above sea level) showing area in south east corner that lacked elevation data.

3.6 Phase 1 results: SSFs for 8-hour movement intervals inside the RSA but outside the influence of development

Multi-grain SSFs

The AIC value was used to identify the SSF from each sex and season set of candidate 8-hour SSA models. In seasons where the top stepAIC model included covariates at more than one grain, both fine- and coarse-grain candidate models were also created and included in the analyses. There was only one case (female pre-rut) where a fine- or coarse-grain model was selected as the SSF for a season (Appendix C, Tables C-1 to C-18). The conditional logistic model based on the top set of covariates from the stepAIC process had the lowest AIC score in 11 of 18 model comparisons; these included a period from post-rut through winter, spring migration, calving, and post-calving for both sexes. In the remaining seven cases the top conditional logistic model was an adaptation of the top stepAIC model.

With the exception of pre-rut for males, the refined versions of the mixed-grained models were the SSFs for the remaining seasons (summer through rut) for both sexes. The mixed-grain model with oestrid harassment interaction terms was the SSF for females in summer while the mixed-grain model with mosquito interaction terms was the SSF for males in late summer.

The overall result was one where SSFs revealed that 8-hour interval habitat preferences were based on landcover covariate abundances at different grains (i.e., at more than one spatial scale of assessment around the movement step end-point).

The covariates from each seasonal SSF , their coefficients, and the statistical significance of each coefficient are presented in Appendix D (Tables D-1 to D-18).

Topography

Elevation was included in the SSFs for eight sex by season combinations, always with a positive coefficient, indicating a positive relationship between locally higher elevation and the relative habitat selection value for a habitat cell in an 8-hour step interval. The seasons with a significant relationship between relative habitat selection value and elevation were spring migration, calving, post-calving, summer, and late summer for females and spring migration and summer for males.

Proportion waterbodies

There was a general pattern across seasons and sexes for fine-grain avoidance of waterbodies. The 3.1-ha grain covariate for waterbody area was included in 17 of 18 top seasonal models; it had a negative coefficient for 13 of the models and a positive coefficient in 4 others. The squared version of the same covariate appeared with a negative coefficient in all 18 of the SSFs. Overall, water was avoided in the selection of the 3.1-ha hexagon containing the step end-point. When the covariates for waterbody area at the two coarsest grains included in the analyses appeared in SSFs (seven seasons for males, four seasons for females), the coefficients were positive in 16 of 20 instances, indicating preferential selection of habitat cells near water at coarser grains.

Fine-grain landcover

At the 3.1-ha grain, two landcover types were selected by both sexes: tussock and low/high shrub. Both types had positive coefficients in top 8-hour interval SSA models for male caribou in all seasons; for female caribou, low/high shrub was included in all season models except spring migration and calving, while tussock was absent only in summer. Tundra was selected (positive coefficient) at the 3.1-ha grain by both males and females in post-rut, winter, and spring migration seasons.

Conversely, sedge wetlands were avoided (negative coefficient) by female caribou in all seasons except during the rut, and by males in 4 of the 9 seasons. Bedrock-boulder was avoided by females in 6 of 9 seasons and by males in three seasons.

Coarse-grain landcover

There were 72 coarser-grain covariates included in top seasonal SSFs compared with 111 covariates at the 3.1-ha grain (Table 3-10). The coefficients for water were generally reversed from coarse-grains (positive) to fine-grain (negative) as discussed above. Similarly, coarser-grain coefficients were negative in 4 of 6 cases for each of tussock and low/high shrub (the two landcover types most selected for at the 3.1-ha grain). The avoidance of bedrock-boulder observed at the 3.1-ha grain was reinforced at coarser-grains where it had negative coefficients in 5 of 7 cases.

Table 3-10: Numbers of significant[1] landcover and topographic covariates in top SSF models for each sex by season at the 8-hour interval scale in the RSA and the 1-hour interval scale in GF112N.

Sex	Season	8-hour SSF landcover and topography covariates in the RSA				1-hour SSF landcover and topography covariates in GF112N			
		elevation /slope	Landcover grain (ha)			elevation /slope	Landcover grain (ha)		
			3.1	524	5137		3.1	524	5137
Female	Winter	1	7	4	1	0	5	2	0
Female	Spring Migration	4	6	8	4	2	6	2	0
Female	Calving	3	5	6	5	NA	NA	NA	NA
Female	Post-Calving	2	7	5	3	NA	NA	NA	NA
Female	Summer	2	6	2	0	1	6	4	4
Female	Late Summer	2	5	1	0	1	4	0	0
Female	Pre-Rut	1	7	0	0	1	6	1	0
Female	Rut	2	4	0	2	1	5	0	1
Female	Post-Rut	2	7	0	0	1	4	0	0
Male	Winter	2	6	5	0	2	4	0	0
Male	Spring Migration	4	8	5	1	2	3	0	0
Male	Calving	1	7	1	2	NA	NA	NA	NA
Male	Post-Calving	1	5	2	1	NA	NA	NA	NA
Male	Summer	3	6	2	0	1	4	3	0
Male	Late Summer	0	5	4	0	0	7	1	0
Male	Pre-Rut	2	8	2	2	1	5	1	0
Male	Rut	1	6	1	1	0	4	0	0
Male	Post-Rut	2	6	1	1	0	3	0	0
	Totals	35	111	49	23	13	66	14	5

[1] Significance determined as $P<0.05$.

Model performance

The overall performance of the SSFs was assessed using Rho^2_{adj} (in Tables C-1 through C-18). The poorest performances for both sexes (lowest Rho^2_{adj}; 0.015 to 0.029) were for winter and spring migration seasons. Female SSF model Rho^2_{adj} ranged from 0.055 to 0.080 for post-calving through post-rut. For males, SSF model Rho^2_{adj} ranged from 0.042 to 0.069 for calving through post-rut.

The comparisons of test and train models for the SSF for each sex by season are presented in Tables C-1b through C-18b. The measures of predictive accuracy of the model: percent correct classification (PCC, presented here as a proportion); model sensitivity (the proportions of true positives that are correctly identified by the model); model specificity (the proportion of true negatives that are correctly identified by the model); and Kappa (a measure of the agreement between predicted and true values) are provided for both the train and test data sets for each model. Of these measures, PCC is viewed as the most important measure. Model validation depends on the performance of the model for the test data closely matching the performance of the train data; which was observed for all measures in all models, with test data having higher PCC scores than train data in 12 of 18 comparisons.

3.7 Phase 2 results: iSSFs for 8-hour movement intervals inside the Ekati/Diavik halo

The 2016 to 2022 8-hour interval data available for calving and post calving seasons inside the Ekati/Diavik halo were quite limited (calving season female steps = 21, male steps = 292; post-calving season female steps = 0, male steps = 151) and were not analyzed.

8-hour interval relative selection probability for 3.1-ha hexagons in the Ekati/Diavik halo

As described in Section 2.8.6, the iSSAs of 8-hour interval data within the Ekati/Diavik halo integrated SSF predicted relative habitat selection value with movement characteristics and distance-to-feature measurements. For each sex by season, the SSF was used to predict the relative habitat selection value for the 3.1-ha cell containing each real or random location for inclusion in each candidate model. Within each sex by season, the set of candidate models differed from each other in the way that distances to roads or mines were included; the set of model distance-to-feature elements for 8-hour interval iSSAs were standardized across all sex and season combinations (see Table 2.4). Model structures and evaluation for both sexes and all seasons are presented in Appendix E, Tables E-1/E-1b to E-14/E-14b.

The iSSFs were selected using BIC. In every iSSF, there was a significant positive coefficient for the SSF predicted relative habitat selection value (RSFrisk) of the 3.1-ha hexagon. In the iSSFs for male caribou in all seven seasons, RSFrisk was the only covariate with a positive coefficient; it was also the only positive covariate in female models for spring migration and post-rut.

The covariates from each seasonal iSSF, their coefficients, and the statistical significance of each coefficient are presented in Appendix F, Tables F-1 to F-14.

Step length and turning angle

The cosine of the turning angle (cos.ta) is a covariate with values between +1.000 (no change in direction from the previous step) to -1.000 (180° turn from bearing of previous step) where 0.000 represents a 90° turn in either direction. Cos.ta had a significant negative coefficient in 11 of 14 iSSFs, indicating that higher relative habitat selection values within the Ekati/Diavik halo were associated with 8-hour movement steps where the animal changed its movement direction from its previous step; i.e., 3.1-ha hexagons had higher relative selection value when caribou changed direction to get to them.

In the Phase 2 iSSFs, the natural log of the step length (log.sl) had coefficients between -0.07 and -0.17 for spring migration and summer for female caribou and for summer and pre-rut for male caribou. In these seasons, shorter steps were consistent with 3.1-ha hexagons with higher relative habitat selection values. Step length coefficients were not significant for males in any other season, while female caribou had positive coefficients associated with step length in late summer, pre-rut, rut, and winter; in these seasons 3.1-ha hexagons with higher relative habitat selection value were associated with longer steps.

Proximity to mine infrastructure and mine roads

For female caribou the DFMines (distance from mine infrastructure) model was selected as the iSSF in winter, summer, late summer, and pre-rut; the iSSA base model (SSF predicted habitat value + ln[step length] + cos[turning angle]) was the iSSF during the rut; and the SSF predicted habitat value was the iSSF for spring migration and post-rut. Though the magnitude of effect varied by season, in each of the seasons where DFMines became the iSSF, the effect of increasing distance from mine infrastructure was to increase relative habitat selection value out to some point, after which relative habitat selection value began to decline with distance. For those seasons the threshold distances were: winter 13.6 km; summer 11.8 km; late summer 15.8 km; and pre-rut 17.9 km)

For male caribou, the iSSA base model was the iSSF in four seasons (winter, spring migration, late summer, and pre-rut) while the SSF predicted habitat was the best model rut and post-rut. The top summer model (DFMines) included covariates related to distance to mining activity and the iSSF for rut was the model including linear relationship between distance to mine infrastructure and predicted relative habitat selection value (LinearDFMines). During summer the effect of increasing distance from mine infrastructure was to increase relative habitat selection value out to 13.8 km after which point, relative habitat selection value declined with distance. During the rut, relative habitat selection value steadily declined with distance from infrastructure.

There was no season for either sex where either of the distance to road models (DFMineRoads, LinearDFMineRds, or logDFMineRoads) was selected as the iSSF.

Model performance

The overall performance of the 8-hour iSSFs was assessed using Rho^2_{adj} (Tables E-1 through E-14). As with the 8-hour SSFs, the lowest Rho^2_{adj} for both sexes (0.016 to 0.043) were for winter and spring migration seasons. Female iSSF Rho^2_{adj} ranged from 0.055 to 0.154 for summer through to post-rut. For males, iSSF Rho^2_{adj} were 0.047 to 0.070 for summer through post-rut.

The comparisons of test and train models for the iSSF for each sex by season are presented in Tables E-1b through E-14b. As observed for the SSFs (from data outside the Ekati/Diavik halo), for each sex by season the PCC of the model applied to the test data closely matched the PCC of the train data used to create the model, with test data having higher PCC scores than train data in 5 of 14 instances.

3.8 Comparison of Phase 1 and Phase 2 results: the effect of Ekati and Diavik mines and mine roads on 8-hour interval habitat selection by caribou

The Phase 1 results (Section 3.6) contained general patterns of landcover selection in the RSA outside the Ekati/Diavik halo. Both tussock and low/high shrub were selected by both sexes at the 3.1-ha grain while waterbody area was generally selected at coarser-grains but avoided at the 3.1-ha grain. Within the Ekati/Diavik halo those three cover types accounted for 81% of the total area (Table 3-11).

Table 3-11: Percent cover within the Ekati/Diavik 30 km halo

Water / landcover category	Percent cover
Waterbody area	29.6
Tussock	26.8
Low / High Shrub	24.7
Tundra	9.6
Sedge wetland	8.7
Esker	0.8
Bedrock-boulder	0.4
Forest	0.0

There were two seasonal iSSFs that included only the exponentiated Phase 1 SSF (both sexes in post-rut). In post-rut for both sexes, the Rho^2_{adj} declined from the Phase 1 results to the Phase 2 results (Table 3-12), indicating that the predicted relative habitat selection value derived from the RSA analyses explained less of the variance in selective behaviour inside the Ekati/Diavik halo than outside it. In each of the other 12 iSSFs (5 distance from mine infrastructure models, 1 linear distance from mine infrastructure, and 6 iSSA base models) the Rho^2_{adj} was higher in the Phase 2 results; coinciding with the addition of movement covariates in every case, and the addition of distance-from-mine covariates in 6 of 11 cases. The PCC (percent correct classification) increased for 5 of the 6 distance from mine infrastructure iSSFs, 3 of the 6 iSSA base models, and 1 of the 2 SSF models.

Overall, the Phase 2 iSSFs provide a better fit to data inside the Ekati/Diavik halo than the Phase 1 SSFs provide to data outside the halo. Distance to mine was included in two male iSSFs (summer and rut) where four of the six distance covariates had insignificant coefficients.

Table 3-12: Model performance summary statistics for the three phases of habitat selection analyses: 8-hour SSF in the RSA outside the Ekati/Diavik 30 km halo; 8-hour iSSF inside the Ekati/Diavik halo; and 1-hour iSSF inside GF112N.

		Phase 1: 8-hr SSF in RSA		Phase 2: 8-hr iSSF in halo		Phase 3: 1-hr iSSF in GF112N	
Sex	Season	Rho^2_{adj}	PCC (test)	Rho^2_{adj}	PCC (test)	Rho^2_{adj}	PCC (test)
Female	Winter	0.016	0.426	0.016	0.589	0.005	0.445
Female	Spring Migration	0.015	0.495	0.027	0.579	0.009	0.471
Female	Summer	0.080	0.537	0.154	0.571	0.054	0.331
Female	Late Summer	0.055	0.429	0.084	0.508	0.031	0.362
Female	Pre-Rut	0.068	0.492	0.086	0.444	0.034	0.403
Female	Rut	0.066	0.510	0.093	0.415	0.039	0.265
Female	Post-Rut	0.057	0.436	0.055	0.545	0.033	0.437
Male	Winter	0.019	0.478	0.021	0.389	0.004	0.405
Male	Spring Migration	0.029	0.609	0.043	0.595	0.013	0.444
Male	Summer	0.047	0.413	0.061	0.478	0.043	0.337
Male	Late Summer	0.042	0.505	0.065	0.619	0.030	0.475
Male	Pre-Rut	0.051	0.469	0.069	0.535	0.039	0.449
Male	Rut	0.069	0.456	0.070	0.474	0.030	0.491
Male	Post-Rut	0.055	0.493	0.047	0.421	0.017	0.440

[1] Rho^2_{adj} *is a measure of the correlation of the model with the data.* PCC (test) *is the proportion of correct classification of the test data set - an overall measure of the predictive accuracy.*

Though not part of formal analyses, the predicted relative habitat selection values for all 3.1-ha hexagons in the entire Ekati/Diavik halo were plotted for all seasons for each sex, matching pairs of maps based on Phase 1 SSFs and Phase 2 iSSFs in each figure (Figures 3-6 to 3-19). There are some key items to consider in reviewing the figures:

1. All habitat values are relative to other values within that map only; the value for each cell is scaled against the values for other cells in that map. The predicted relative habitat selection values in each map were re-scaled to between 0 and 1. Depending on the distribution of un-scaled values, the map may appear to show greater or lesser habitat value overall.
2. Relative habitat selection values in each figure were calculated using the mean value for each coefficient. Each coefficient has a standard error, as presented in Appendices D and F. Accounting for standard errors of coefficients would provide estimates of uncertainty in the predicted relative habitat selection values mapped here and differences would be less apparent when mapped.
3. The maps show conditional predicted relative habitat selection values specific to the scale of analysis. In this case the scale is an 8-hour movement step. The condition is that an animal would need to already be present within a normal 8-hour movement step distance (typically a 2 to 4 km range for these data) to be able to select a cell. A useful way to think of it is that if animals were randomly placed on the landscape, they would tend to make movements that would distribute them according to the relative habitat selection values mapped.
4. The left-hand panel of each figure is the relative probability of habitat selection based on the Phase 1 analyses done outside the Ekati/Diavik halo. The SSFs from those analyses were constructed from landcover, topography, and insect harassment covariates alone. All spatial variation in relative habitat selection value is based only on those covariates, and is not related to mining and development activity. The mine footprints have been added for spatial reference but did not influence calculation of predicted relative habitat selection values shown in the figure. The left-hand panel of each pair should be used as a reference for relative habitat selection value within 30 km of the Ekati and Diavik mines for 8-hour movements for that sex in that season.
5. The right-hand panel is the relative probability of habitat selection based on Phase 2 analyses done inside the Ekati/Diavik halo, where (for each season model set) all candidate models except one included movement covariates and all but two candidate models included distance to mining infrastructure covariates. The iSSF covariates related to turning angle and step length require a starting location and prior movement pathway to be fully evaluated. In mapping the Phase 2 results the covariates for turning angle and step length were excluded from calculations; the relative habitat selection value of each 3.1-ha cell was based on the remaining covariates for the iSSF.
6. The inclusion of distance to feature and squared distance to feature covariates allowed the data to fit a quadratic distribution that shows relative habitat selection value that changes with distance. In some figures the effect is subtle (e.g., Figure 3-9b) and in others it is more pronounced (e.g., Figure 3-6b).
7. For male rut, the top model contained linear distance to feature terms (i.e., not a quadratic relationship). Figure 3-18b shows a decline in predicted relative habitat selection value with distance from infrastructure.
8. In eight of the 14 figures, the left-hand and right-hand panels are identical. This reflects the results of Phase 2 analyses that produced iSSFs that did not include mine road or mine infrastructure covariates. For reference, there is a note below the right-hand panel in each map indicating the inclusion of distance-to-feature covariates in the iSSF for that season.

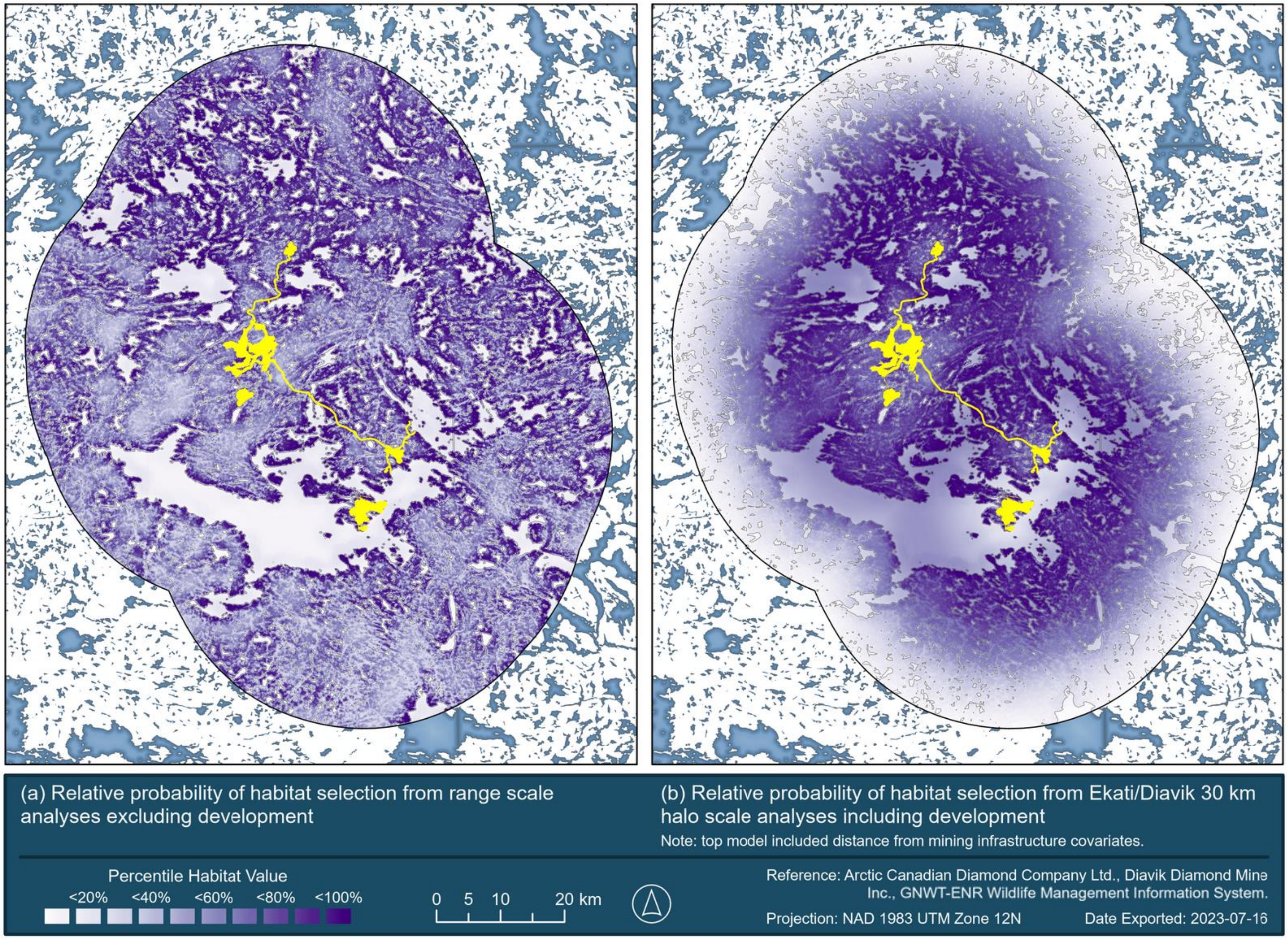

Figure 3-6: Winter 8-hour Interval Habitat Selection by Female Caribou

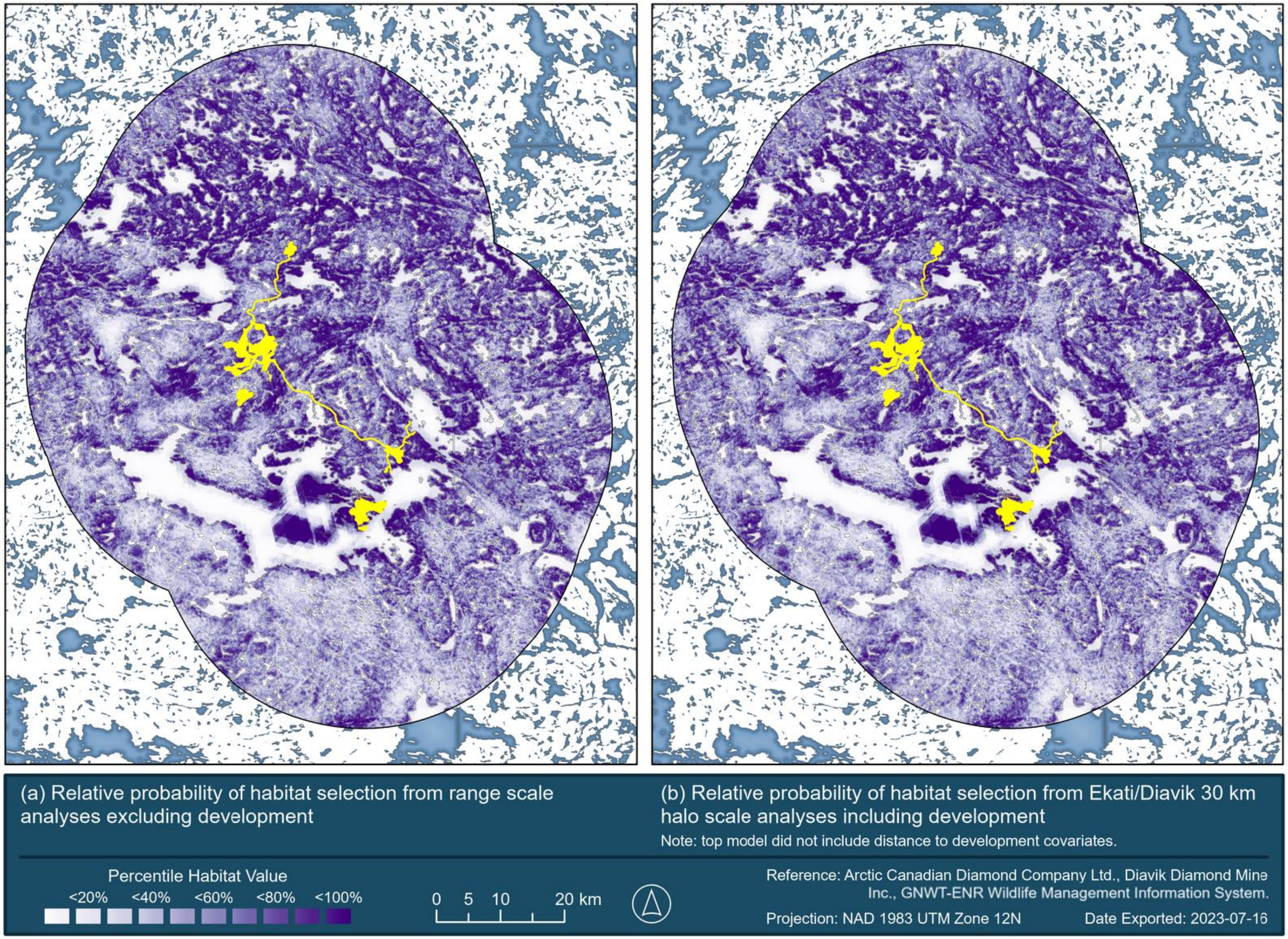

Figure 3-7: Spring Migration 8-hour Interval Habitat Selection by Female Caribou

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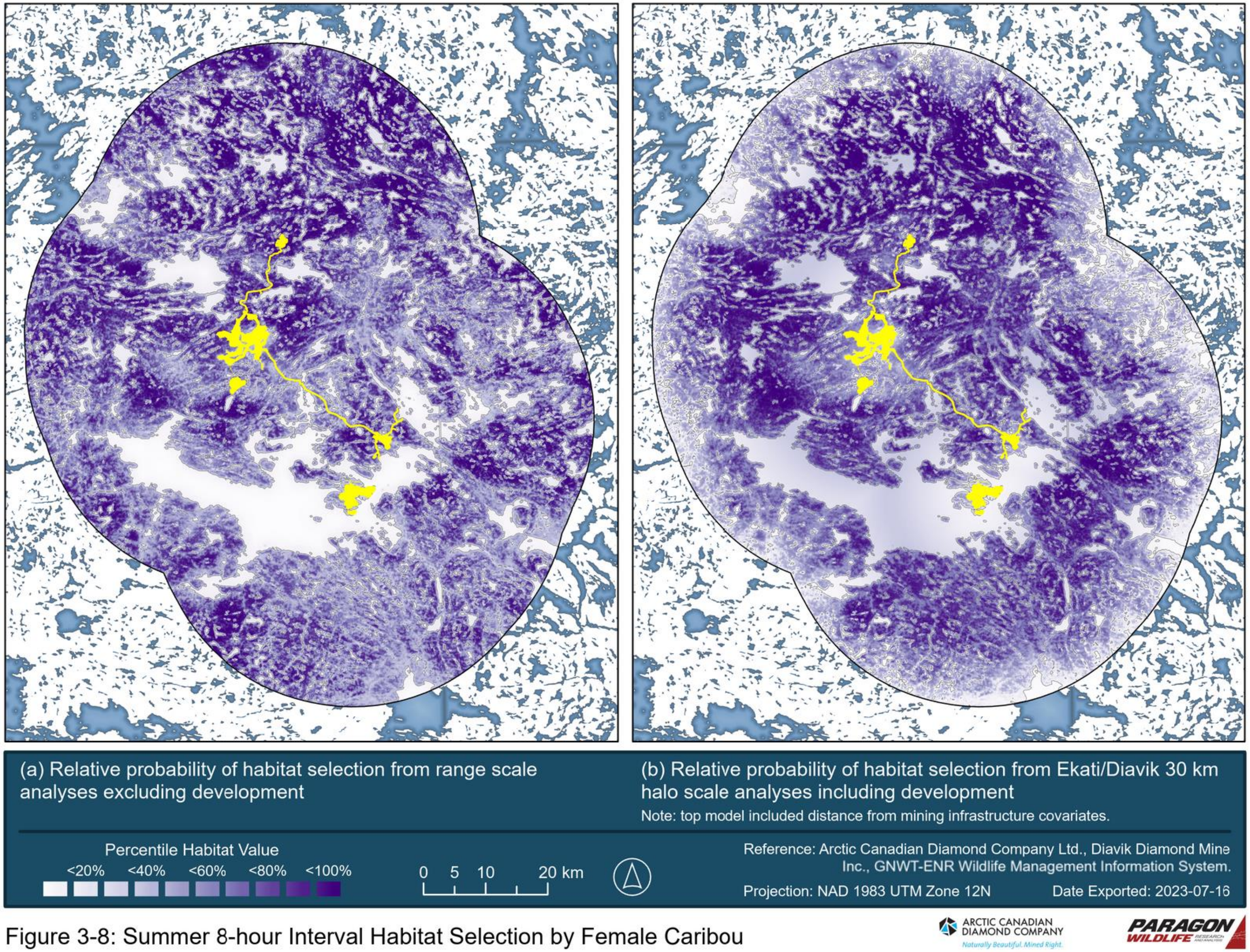

Figure 3-8: Summer 8-hour Interval Habitat Selection by Female Caribou

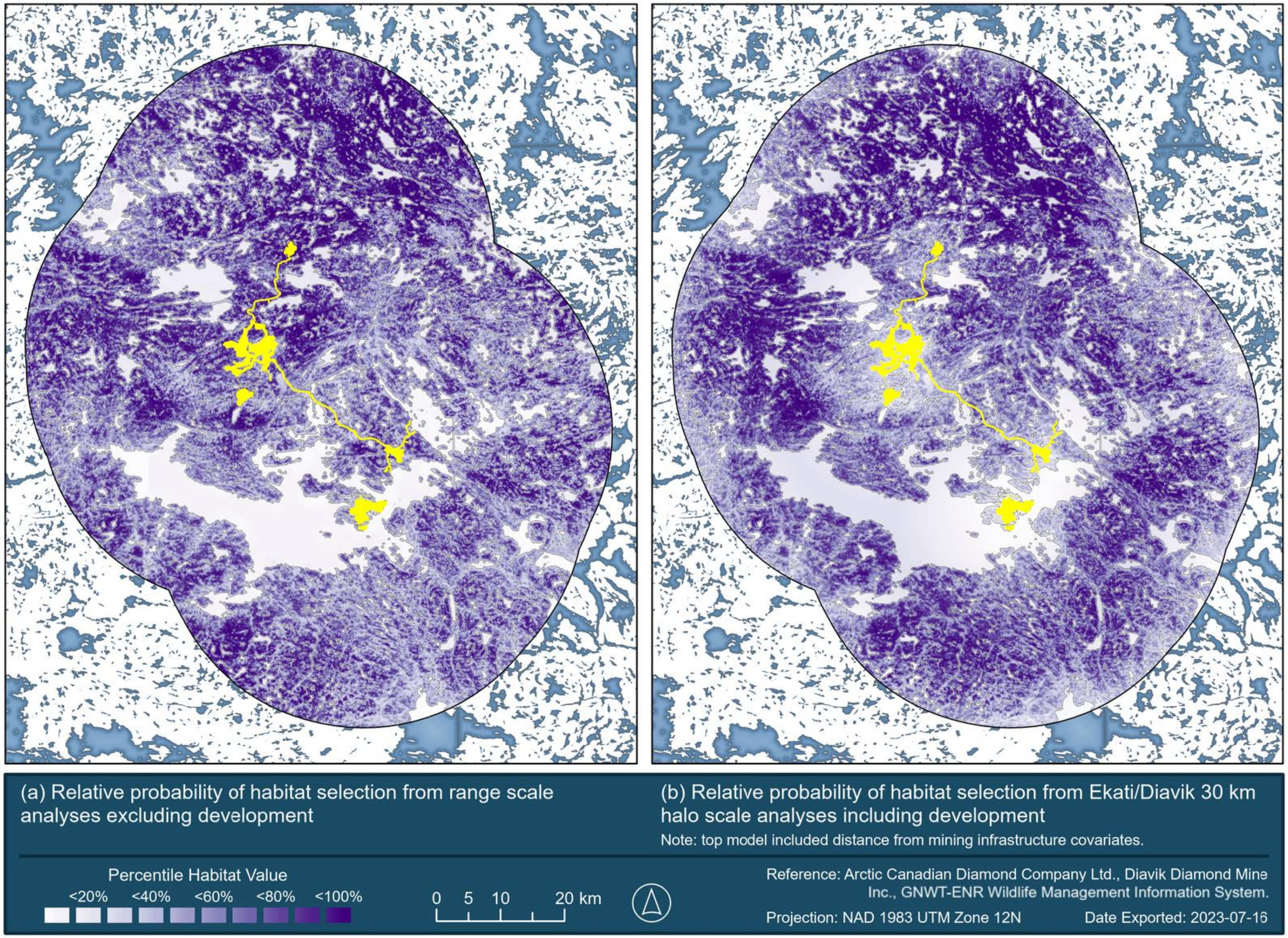

Figure 3-9: Late Summer 8-hour Interval Habitat Selection by Female Caribou

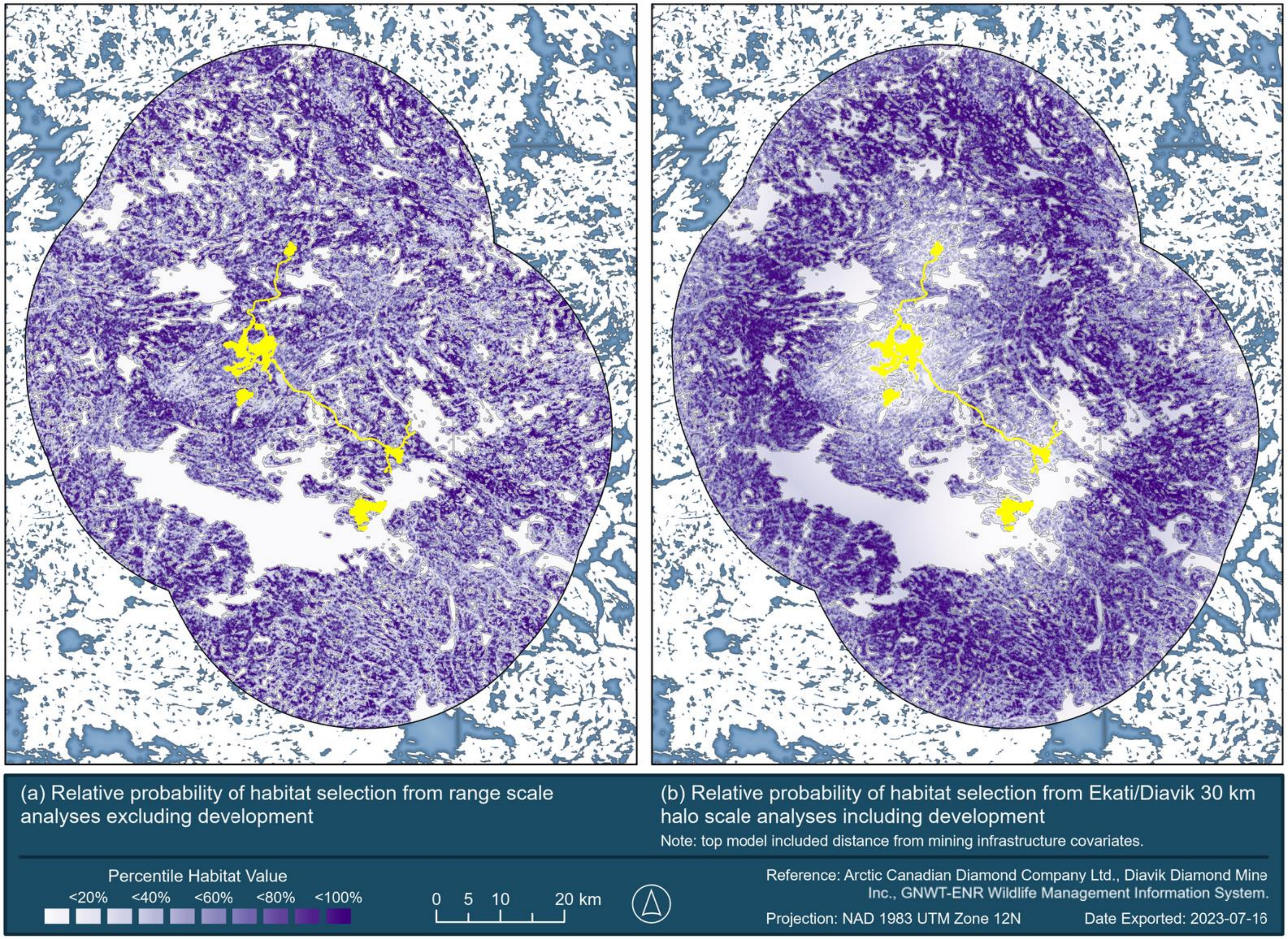

Figure 3-10: Pre-Rut 8-hour Interval Habitat Selection by Female Caribou

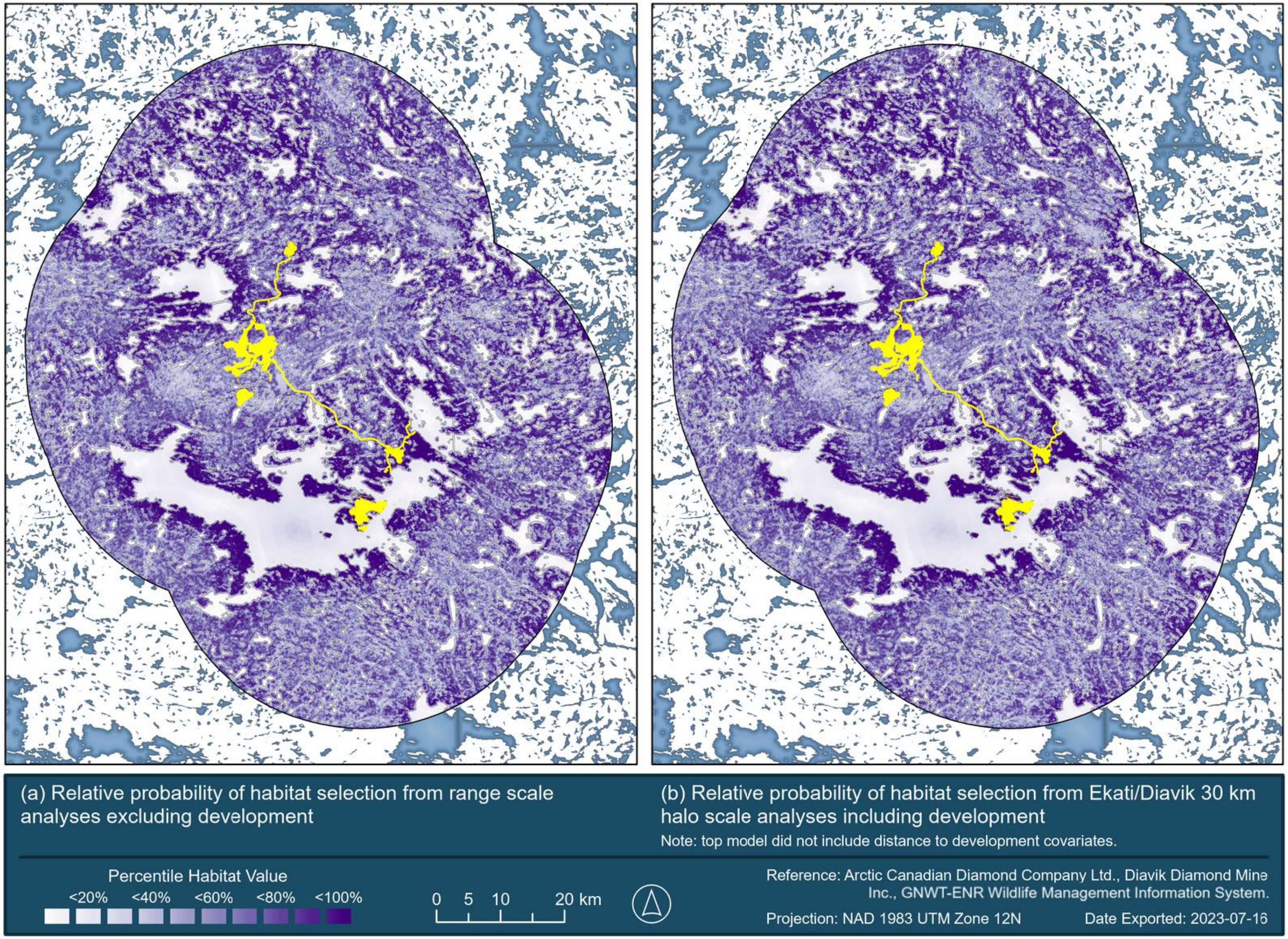

Figure 3-11: Rut 8-hour Interval Habitat Selection by Female Caribou

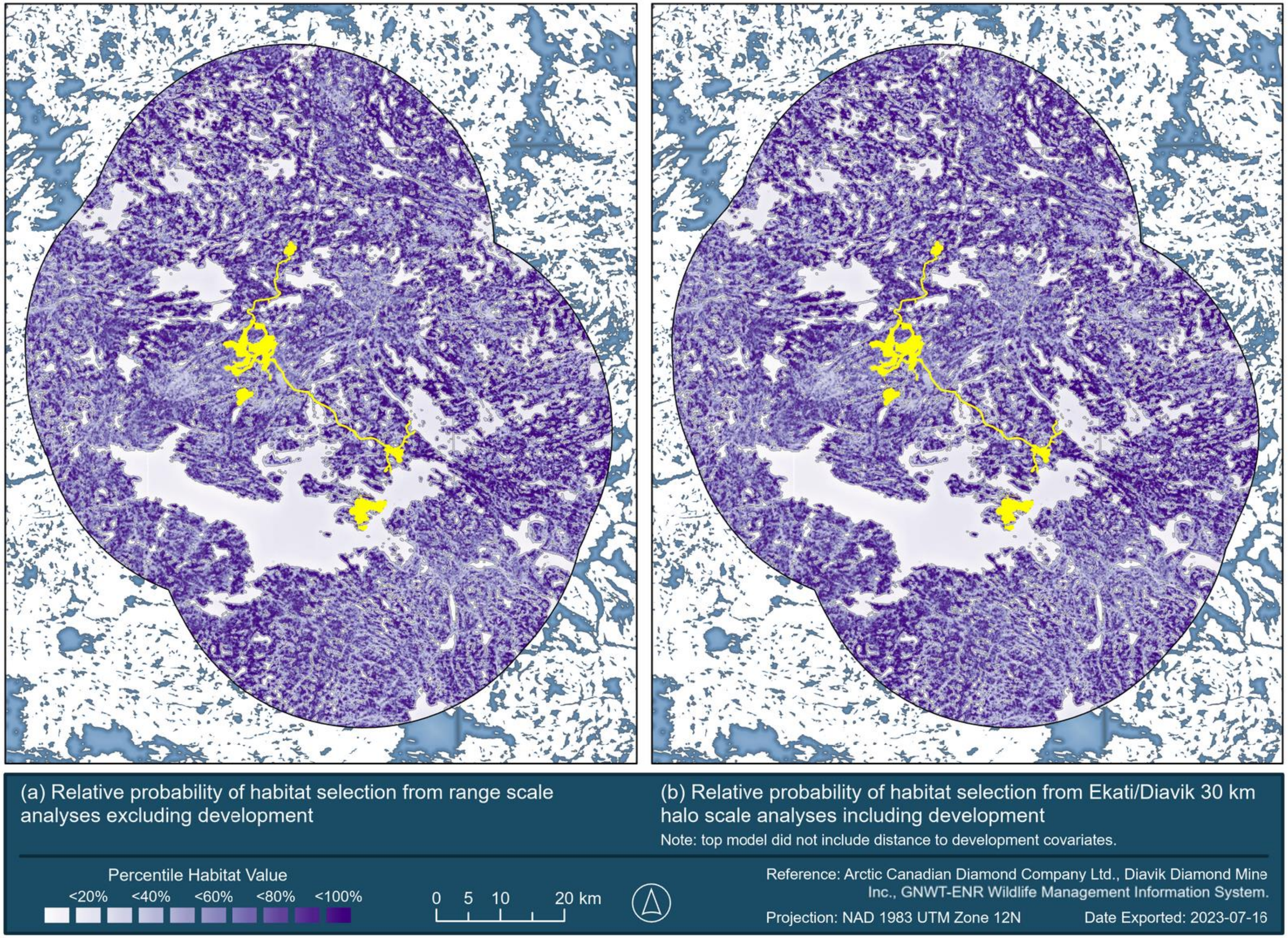

Figure 3-12: Post-Rut 8-hour Interval Habitat Selection by Female Caribou

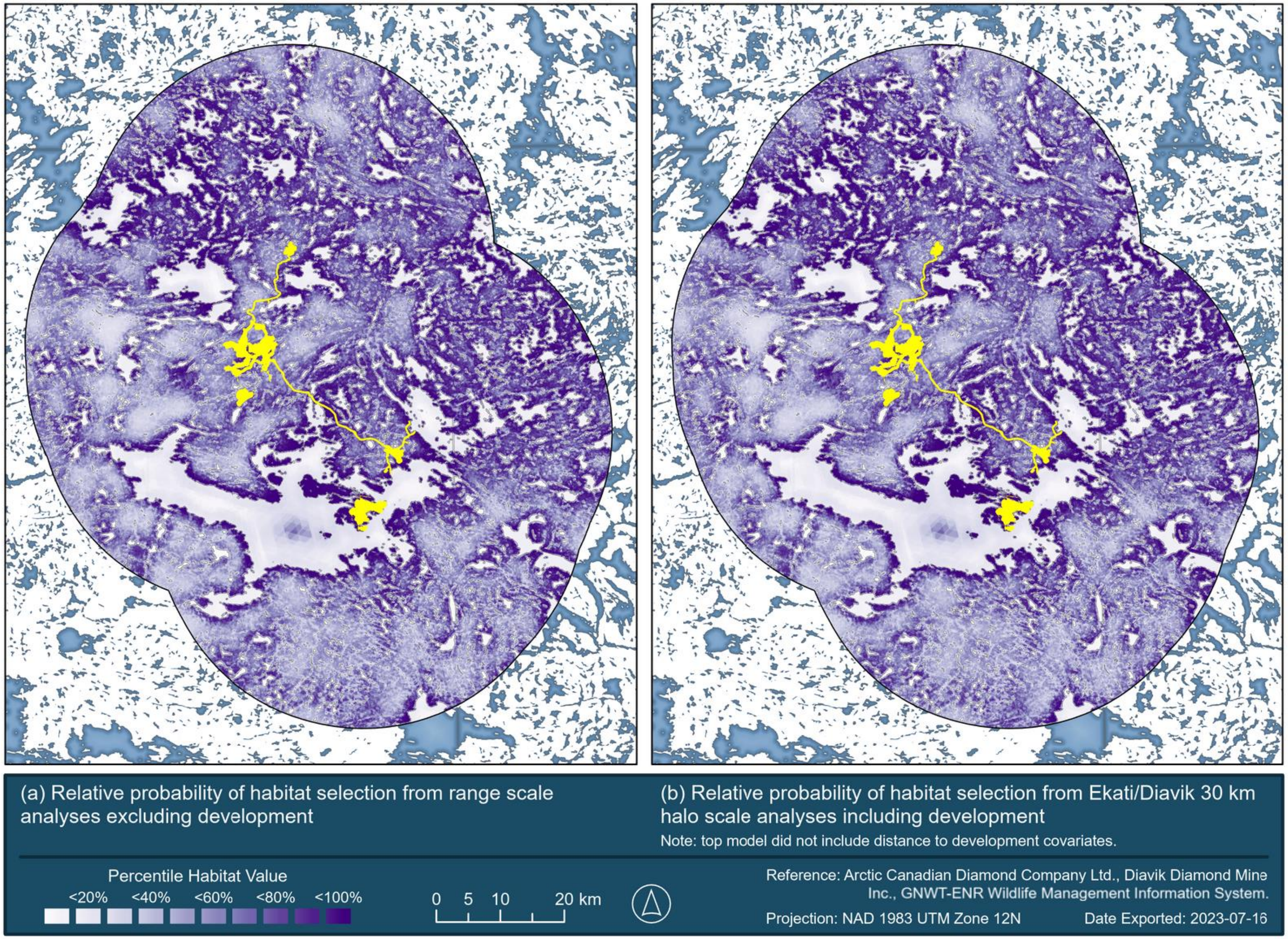

Figure 3-13: Winter 8-hour Interval Habitat Selection by Male Caribou

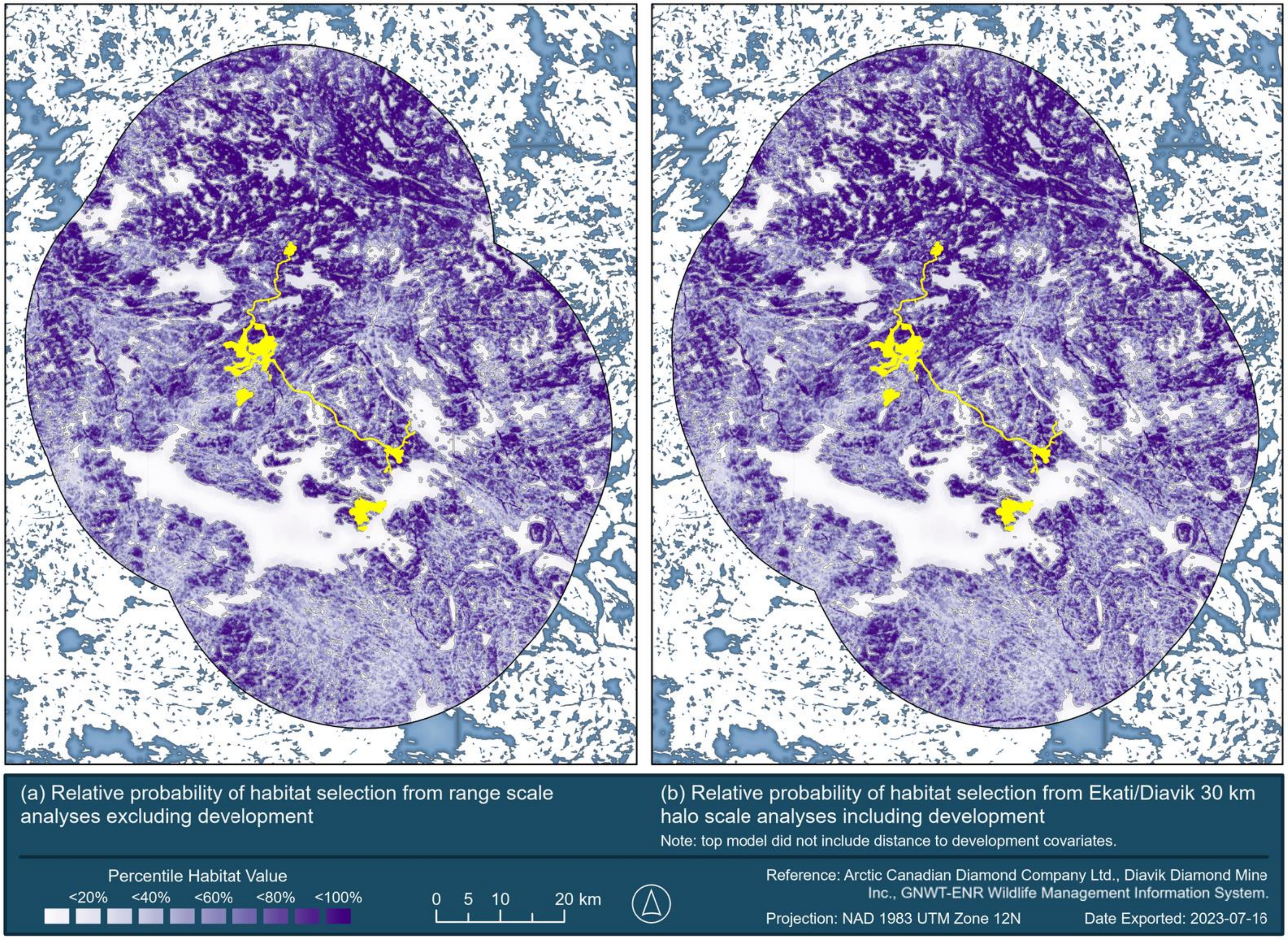

Figure 3-14: Spring Migration 8-hour Interval Habitat Selection by Male Caribou

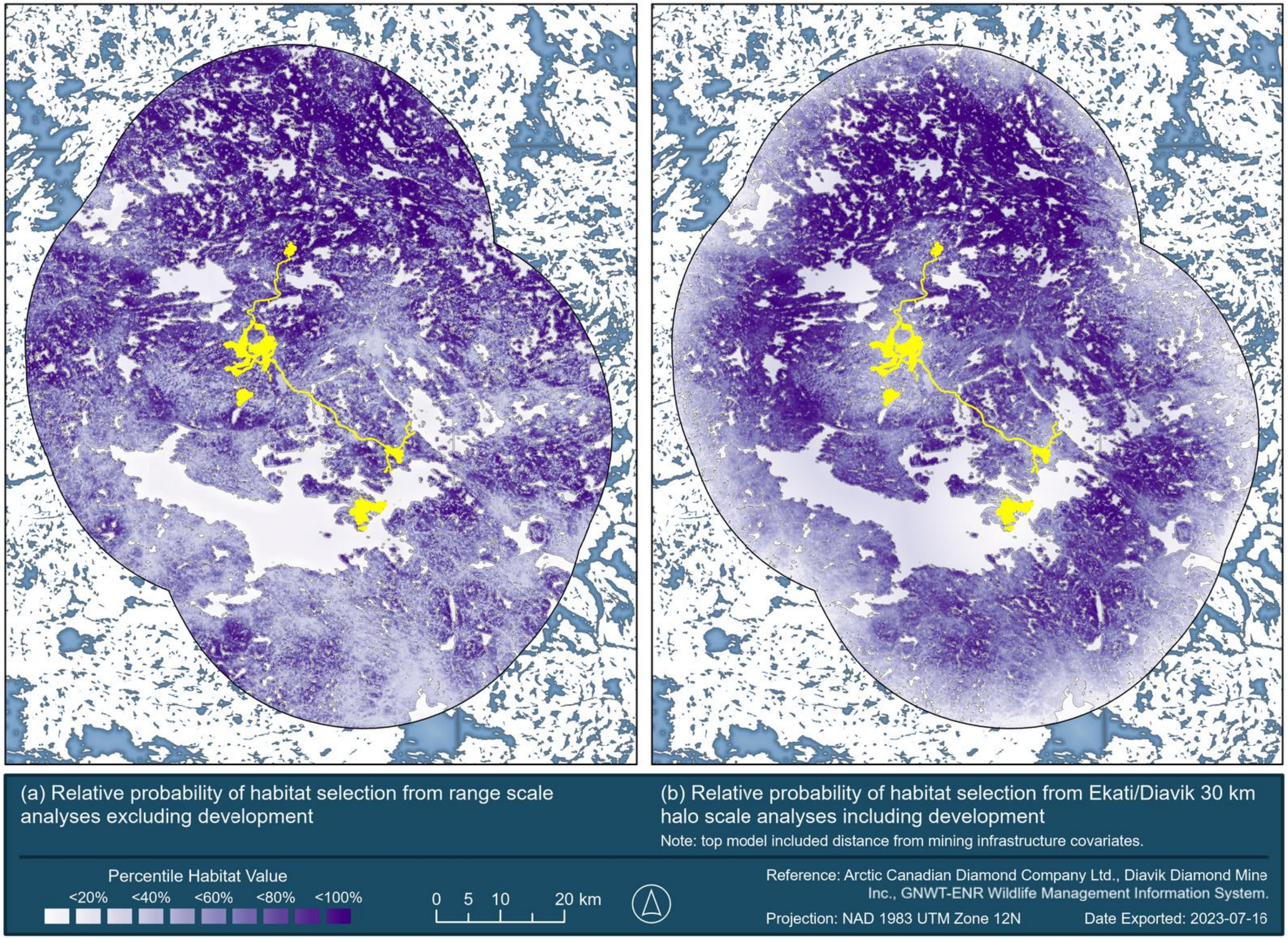

Figure 3-15: Summer 8-hour Interval Habitat Selection by Male Caribou

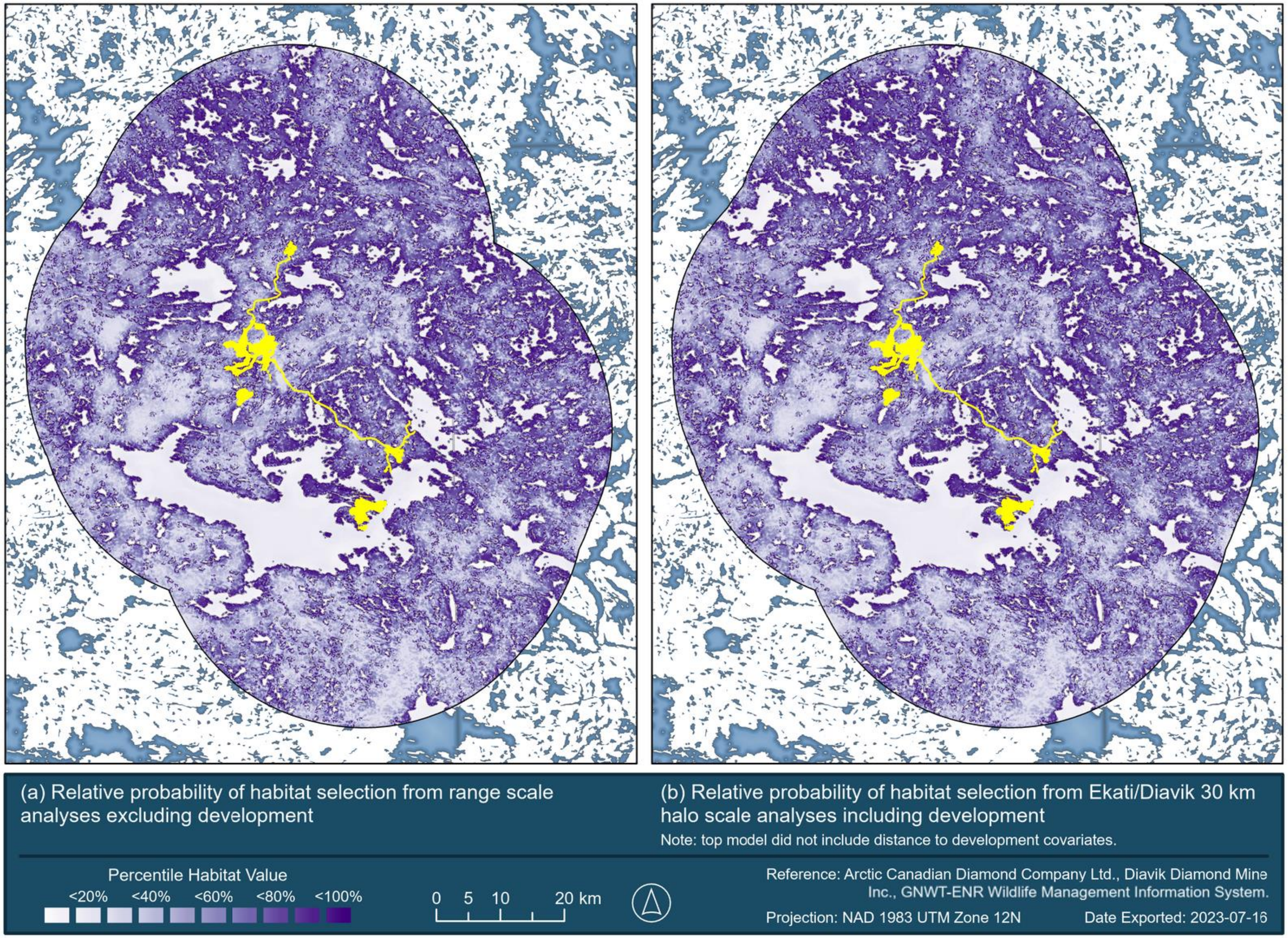

Figure 3-16: Late Summer 8-hour Interval Habitat Selection by Male Caribou

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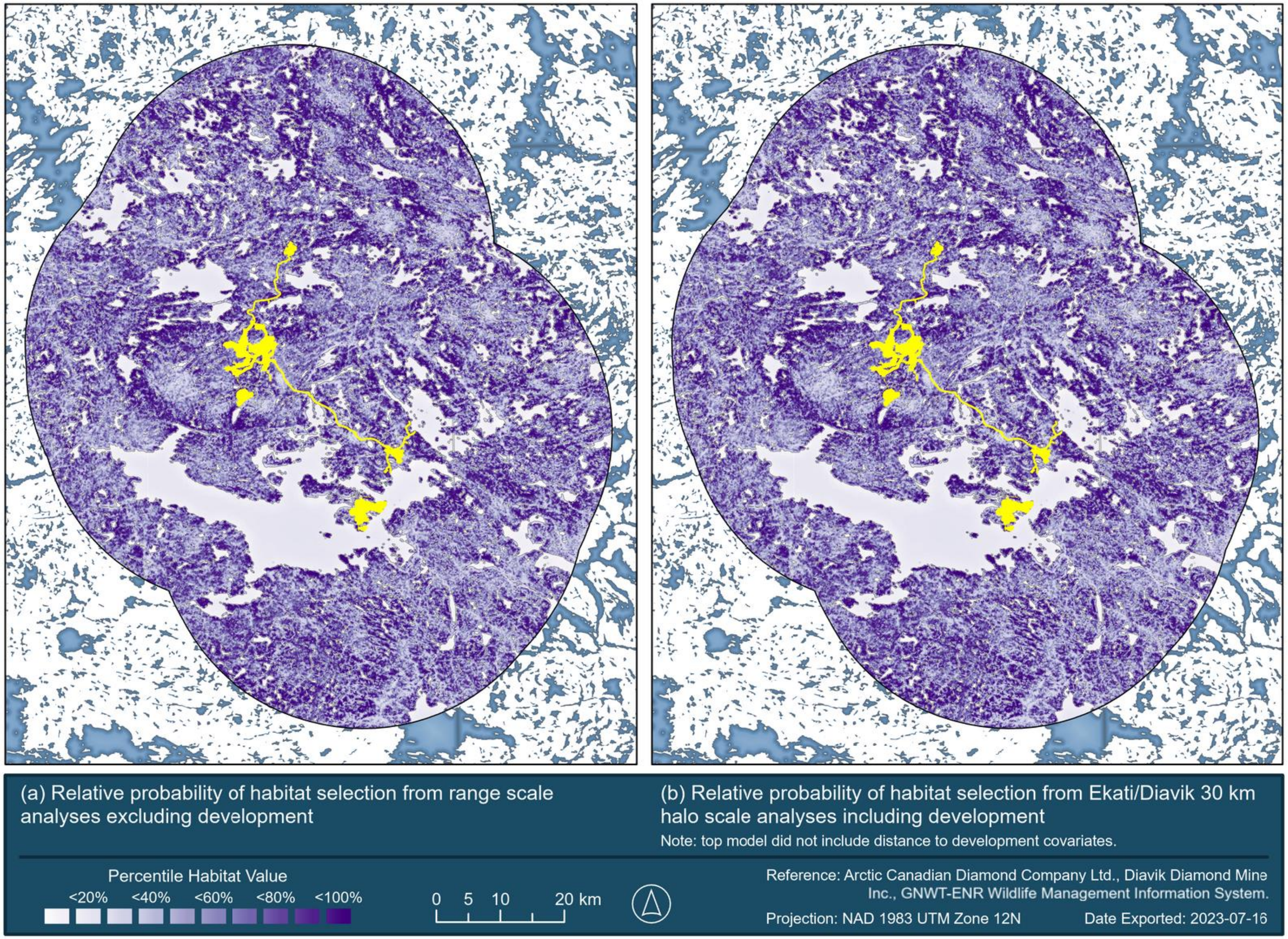

Figure 3-17: Pre-Rut 8-hour Interval Habitat Selection by Male Caribou

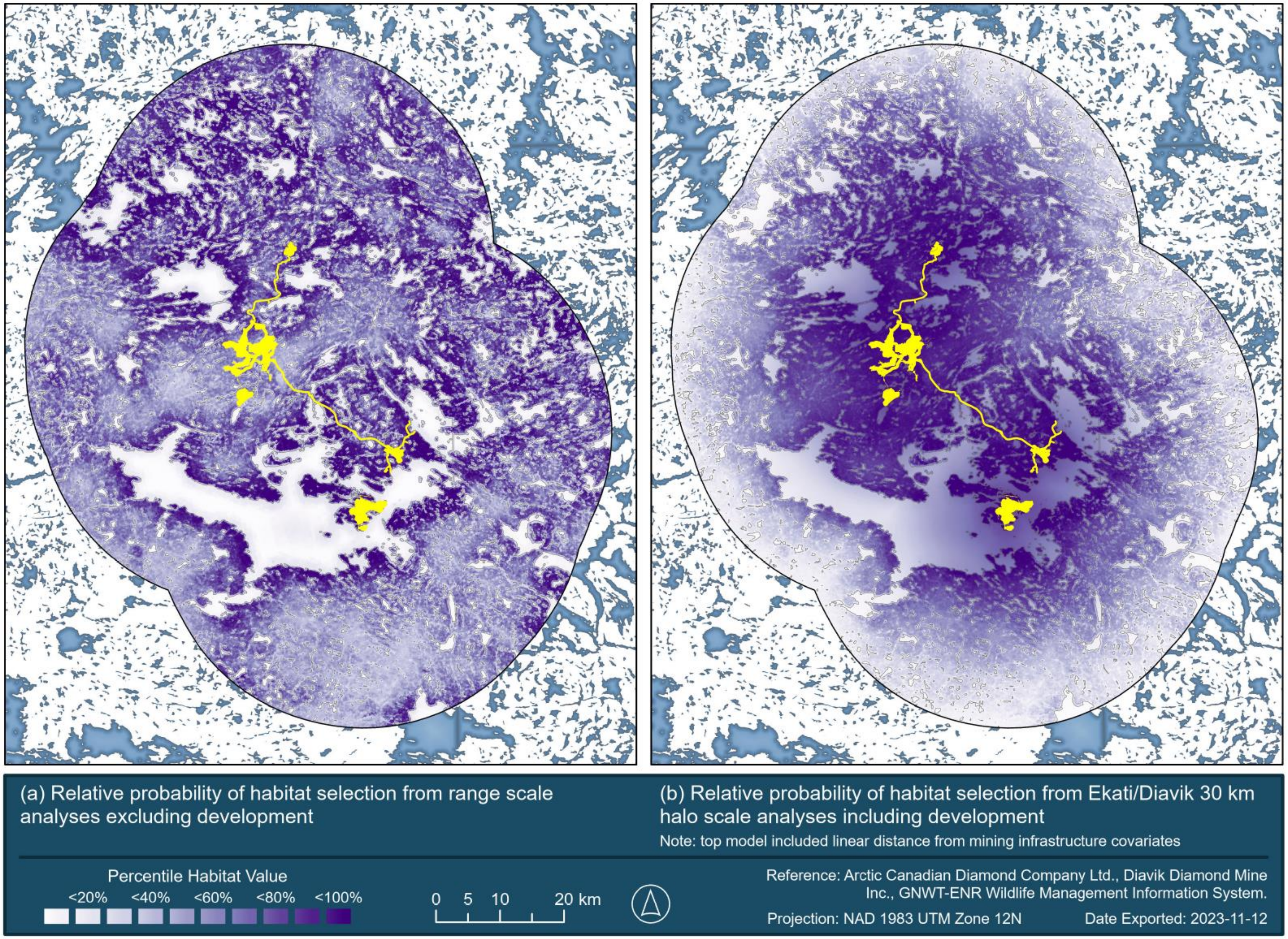

Figure 3-18: Rut 8-hour Interval Habitat Selection by Male Caribou

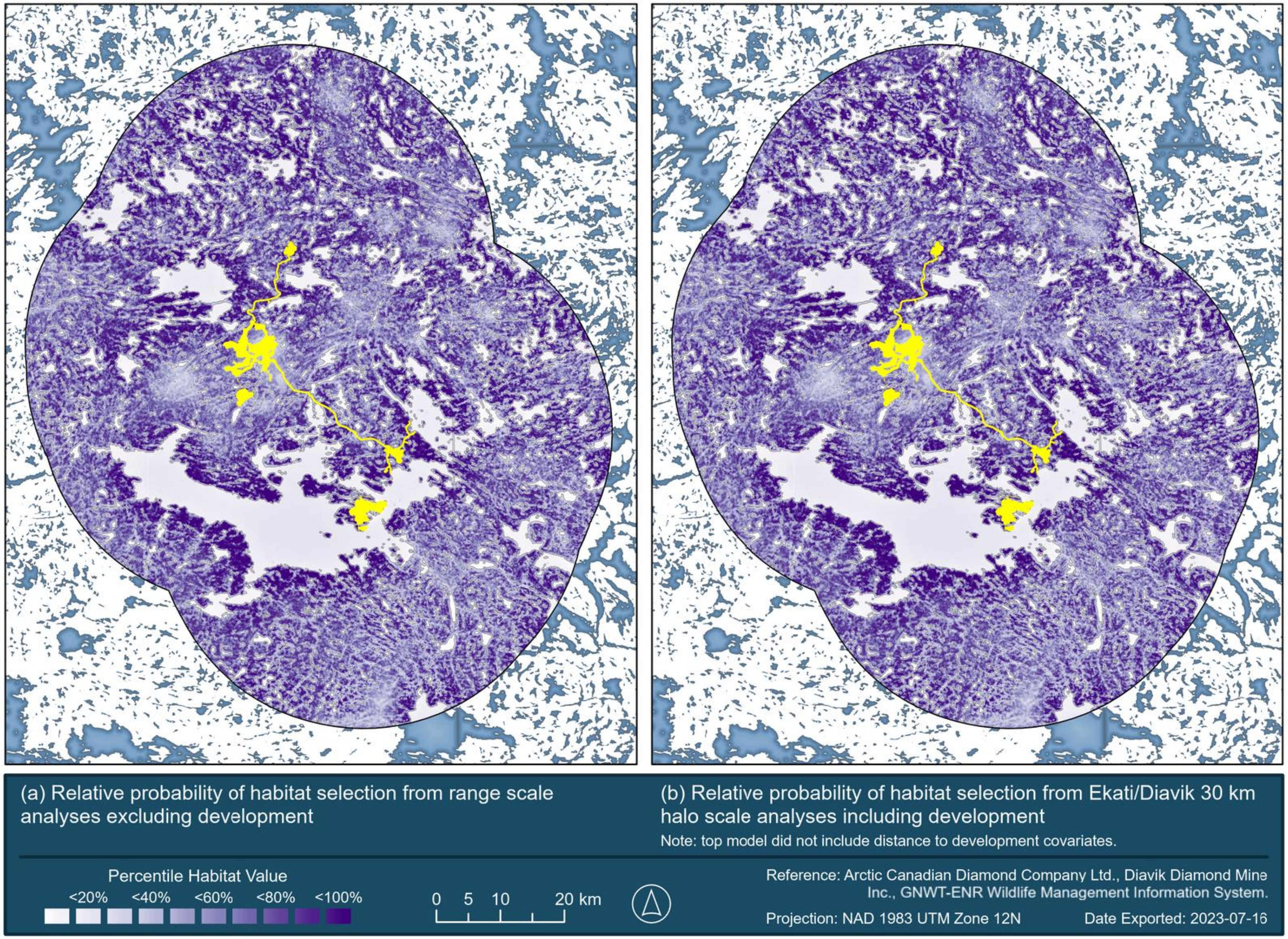

Figure 3-19: Post-Rut 8-hour Interval Habitat Selection by Male Caribou

3.9 Phase 3 results: SSA top models and iSSF for 1-hour movement intervals inside GF112N

As for the Phase 2 analyses, 1-hour interval data available for calving and post calving seasons were limited and were not analyzed.

3.9.1 1-hour SSA modelling

The initial stage of 1-hour interval modelling followed the process for 8-hour SSA modelling: BRT modelling followed by stepAIC modelling to identify the best set of landcover and topography covariates for each sex by season candidate model set. For 1-hour interval SSAs, the objective was to select the best candidate model and then pass its covariate set on to the iSSA step. Top model covariates were never joined to their coefficients in SSFs to predict relative habitat selection values.

Multi-grain SSAs

The covariates from the top stepAIC models were used to create candidate conditional logistic model sets as for 8-hour interval analyses. The stepAIC models from the 1-hour interval data contained fewer instances where there were covariates included at multiple grains; only 6 of 14 sex by season models had additional fine- and coarse-grain candidate models defined.

StepAIC analysis results for each of the sex by season candidate model sets were evaluated with AIC, and the covariates from the top model were moved forward to the iSSA stage. The conditional logistic model containing the covariate set from the stepAIC model was selected as the top model for summer for both sexes and for pre-rut and post-rut for males. The top models for all other seasons for the two sexes were the refined versions of the mixed-grained models; in no case did a fine- or coarse-grain model come out on top. The top SSA model covariates for each sex by season are explicitly included in each of the iSSA candidate model sets (Appendix G, Tables G-1 to G-14).

Insect harassment

As for 8-hour SSAs, interaction terms including oestrid and mosquito harassment indices were added to create additional models for summer and late summer for both sexes. These models failed to out-perform the candidate model versions without insect harassment included. Results for this portion of analyses are not presented.

3.9.2 1-hour iSSA modelling

In contrast to the 8-hour time interval, the absence of 1-hour data outside the geofence prevented prediction of relative habitat selection values based on observations in an area considered unaffected by development. Instead of a predicted relative habitat selection value for each 3.1-ha hexagon, the entire set of covariates from the top seasonal 1-hour SSA model was moved forward and combined with the cos.ta and log.sl covariates to create the iSSA landcover model for each season. The remaining candidate models were created from the landcover model, with the addition of movement covariates and distance to mining feature covariates.

The iSSA model structures and evaluation for both sexes and all seasons are presented in Appendix G, Tables G-1/G-1b to G-14/G-14b. Phase 3 iSSA models were evaluated with BIC and are ranked accordingly in the tables in Appendix G. While the landcover and topography were season-specific, all other candidate model elements for Phase 3 iSSA 1-hour data analyses were standardized for all sex and season combinations.

The covariates from each seasonal iSSF , their coefficients, and the statistical significance of each coefficient are presented in Appendix H, Tables H-1 to H-14.

Topography

Elevation was included in the 1-hour interval iSSFs for four seasons, always with a positive coefficient, indicating a positive relationship between higher elevation and the relative habitat selection value. The seasons with a significant relationship between relative selection value and elevation were spring migration, summer, and late summer for females and spring migration for males. The 8-hour interval SSFs for each of these seasons also contained elevation with a positive coefficient.

Proportion waterbodies

The 3.1-ha grain avoidance of waterbodies observed in 8-hour interval analyses was also present in the top 1-hour iSSFs (negative coefficients in six of seven seasons for females and all seven seasons for males). Covariates for waterbody area at the 524-ha and 5137-ha grains appeared in four iSSFs with positive coefficients in three of them.

Fine-grain landcover

At the 3.1-ha grain, the two covariates with positive coefficients by both sexes were tussock and low/high shrub; the same two 3.1-ha covariates that were common in the 8-hour SSFs for both sexes. Low/high shrub had positive coefficients in 1-hour interval iSSFs for female caribou in all seasons and for male caribou iSSFs in all seasons except summer. For female caribou, tussock was included in all 1-hour iSSFs except winter and spring migration; for male caribou tussock was absent in spring migration, summer, and pre-rut. The mean number of 3.1-ha grain covariates in 1-hour iSSFs (4.7) was 24% lower than the 6.2 covariates per model for 8-hour iSSFs (Table 3-10).

Coarse-grain landcover

The mean number of landcover covariates in 1-hour iSSFs (6.1) was 40% lower than in 8-hour iSSFs (10.2; Table 3-10). At the 524-ha and 5137-ha grains the decline was 65% from 8-hour to 1-hour iSSFs (from 4.0 to 1.4 coarser-grain covariates per model), indicating a decline in influence of coarser-grain covariates in habitat selection for the shorter time interval. There were no distinct patterns of landcover types observed, but of the 19 significant 524-ha and 5137-ha covariates included for the 14 seasonal iSSFs, 8 were in the summer iSSF for females and 3 were in the summer iSSF for males.

Step length and turning angle

The turning angle covariate (cos.ta) had a significant negative covariate in 6 of 14 1-hour iSSFs, indicating that higher relative habitat selection value was associated with 1-hour movement steps where the animal changed its movement direction from its previous step; i.e., 3.1-ha hexagons had higher relative selection value when caribou changed direction to get to them.

In the 1-hour iSSFs, the natural log of the step length (log.sl) had positive coefficients for both sexes for late summer, pre-rut and rut, as well as for females in summer; in these seasons 3.1-ha hexagons with higher relative habitat selection value were associated with longer 1-hour movement steps.

Proximity to mine infrastructure and mine roads

For female caribou (Tables G-1 to G-7) the DFMineRoads (quadratic distance from mine roads) model was the best performing model in winter, spring migration, and rut; LinearDFMines (linear distance from mine infrastructure) was the iSSF for post-rut; and LinearDFMineRds was the best performing model in summer. The landcover model was the iSSF for female caribou in late summer and pre-rut. In winter and spring migration, the effect of increasing distance from mine roads was to increase relative habitat selection value out to a threshold (winter 6.7 km; spring migration 8.0 km), after which relative habitat selection value declined with distance. In contrast, the effect was reversed during rut where relative habitat selection value was higher at mine roads, declining with distance out to 8.4 km and then increasing with distance beyond that point. In summer, the top female model showed higher predicted relative habitat selection values at the edge of mine roads, with a linear decline in predicted relative habitat selection value with increasing distance. The post-rut linear model was for predicted relative habitat selection value to steadily increase with distance from mining infrastructure.

For male caribou (Tables G-8 to G-14), the landcover model was the iSSF in all seasons except summer where the iSSF was LinearDFMineRoads. As for female caribou, predicted summer relative habitat selection value was highest at the edge of mine roads, with a linear decline in value with distance.

Model performance

The overall performance of the 1-hour iSSFs models was assessed using Rho^2_{adj} (Tables G-1 through G-14). As with the 8-hour SSFs and iSSFs, the lowest Rho^2_{adj} for both sexes (0.004 to 0.013) were for winter and spring migration seasons (Table 3-12). Phase 3 female iSSF Rho^2_{adj} ranged from 0.031 to 0.053 for summer through to post-rut. For males, iSSF Rho^2_{adj} 0.017 to 0.042 for summer through post-rut.

As for Phase 1 and Phase 2 models, the comparisons of Phase 3 test and train models for the top iSSF model for each sex by season are presented in Tables G-1b through G-14b. As observed for the Phase 1 and Phase 2 models, for each sex by season the PCC of the model applied to the test data closely matched the PCC of the train data used to create the model, with test data having higher PCC scores than train data in 7 of 14 instances. The largest declines in PCC from train to test data were 0.09 for female post-rut, 0.08 for female spring migration, and 0.06 for male spring migration.

3.9.3 1-hour iSSF mapping

As for 8-hour predicted relative habitat selection values plotted in Section 3.8, the 1-hour movement iSSF predicted relative habitat selection values for all 3.1-ha hexagons were plotted for all seasons for each sex (Figures 3-20 to 3-26). Though the 1-hr iSSF were determined from data sets from GF112N, they are plotted here for the Ekati/Diavik halo. The Ekati/Diavik halo exceeds the limits of GF112N in some directions and falls short of its limits in others, but is provides a consistent area for mapping with that completed for 8-hour iSSF results. Most of the same considerations apply to the 1-hour predicted relative habitat selection value maps as applied to the 8-hour maps:

1. All habitat values are relative to other values within that map only; the value for each cell is scaled against the values for other cells in that map. The predicted relative habitat selection values in each map were re-scaled to between 0 and 1. Depending on the distribution of un-scaled values, the map may appear to show greater or lesser habitat value overall.
2. Relative habitat selection values in each figure were calculated using the mean value for each coefficient. Each coefficient has a standard error, as presented in Appendix H. Accounting for standard errors of coefficients would provide estimates of uncertainty in the predicted relative habitat selection values mapped here and differences would be less apparent.

3. Unlike the 8-hour data, there were not 1-hour data collected throughout the RSA to permit reference habitat selection analyses with data outside the influence of mining and development. All of the figures in this set show predicted relative habitat selection values based on location data collected in GF112N while the Ekati and Diavik mines were in operation.
4. The maps show conditional predicted relative habitat selection values specific to the scale of analysis. In this case the scale is a 1-hour movement step. The condition is that an animal would need to already be present within a normal 1-hour movement step distance (typically <1 km for these data) to be able to select a cell. A useful way to think of it is that if animals were randomly placed on the landscape, they would tend to make movements that would distribute them according to the relative habitat selection values mapped.
5. Each figure shows the relative 1-hour movement predicted relative habitat selection values for a specific season: the left-hand panel of each figure is the relative probability of habitat selection by female caribou; male caribou are in the right-hand panel. For each sex by season all candidate models included movement covariates and all candidate models except one included distance to mining infrastructure covariates. The iSSF covariates related to turning angle and step length require a starting location and prior movement pathway to be fully evaluated. In these maps the covariates for turning angle and step length were excluded from calculations; the relative habitat selection value of each 3.1-ha cell was based on the remaining covariates for the iSSF.
6. The inclusion of distance to feature and squared distance to feature covariates allowed the data to fit a quadratic distribution that shows relative habitat selection value that changes with distance. This occurred in three iSSFs and the effect was obvious when mapped (i.e., Figures 3-20a, 3-21a, and 3-25a).
7. For both sexes in summer (Figures 3-22a and 3-22b) and for post-rut females (Figure 3-26a) the iSSFs contained only linear distance to feature terms (i.e., not quadratic relationships). Figures 3-22a and 3-22b show declines in predicted relative habitat selection values with increasing distance from mine roads. Figure 3-26b shows an increase in predicted relative habitat selection values with increasing distance from mine infrastructure.
8. In the other nine of the 14 panels, the results of analyses that produced iSSFs that did not include mine road or mine infrastructure covariates. For reference, there is a note below each panel in each map indicating the inclusion of distance-to-feature covariates in the iSSF for that season.

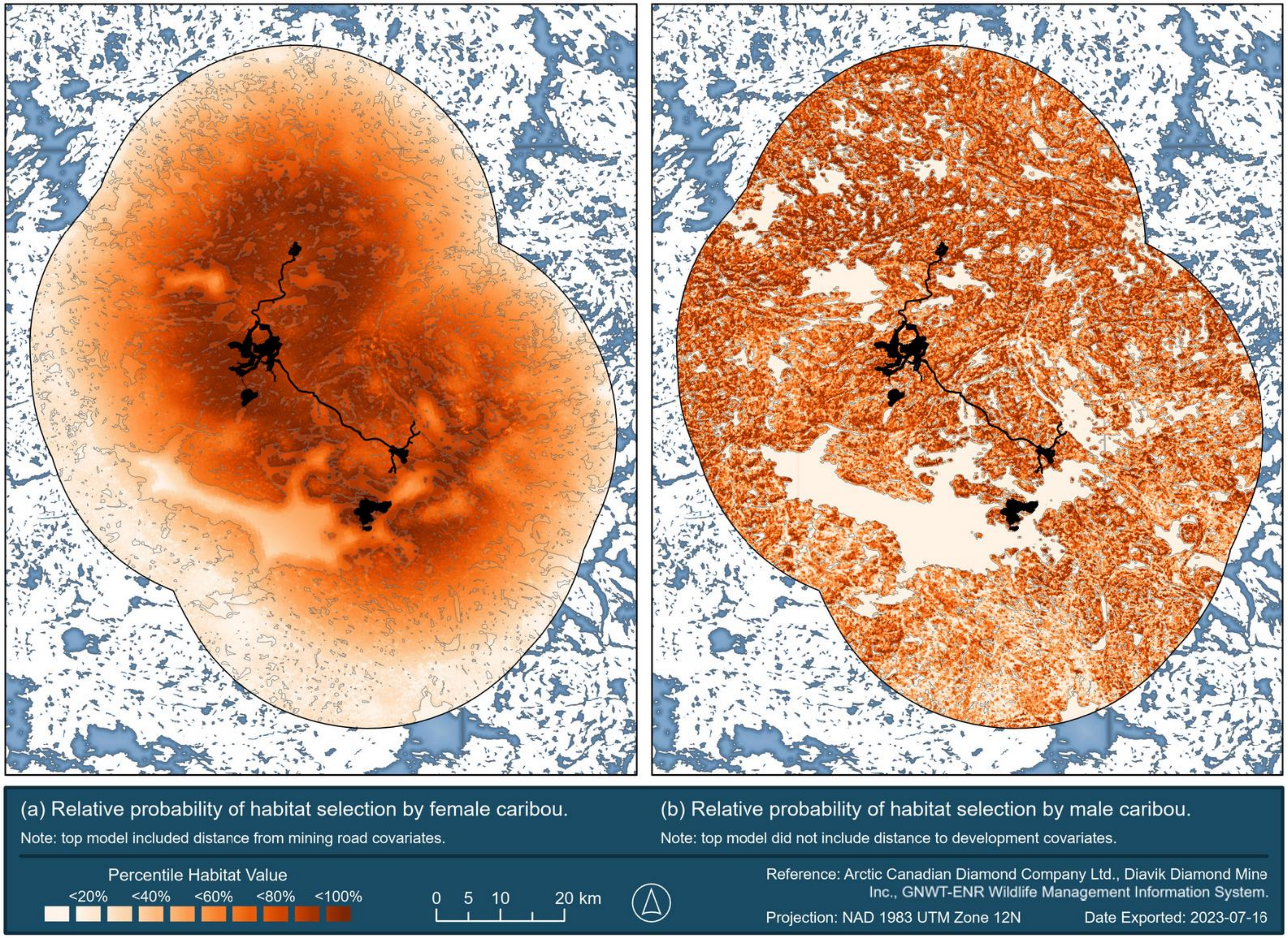

Figure 3-20: Winter 1-hour Interval Habitat Selection by Caribou

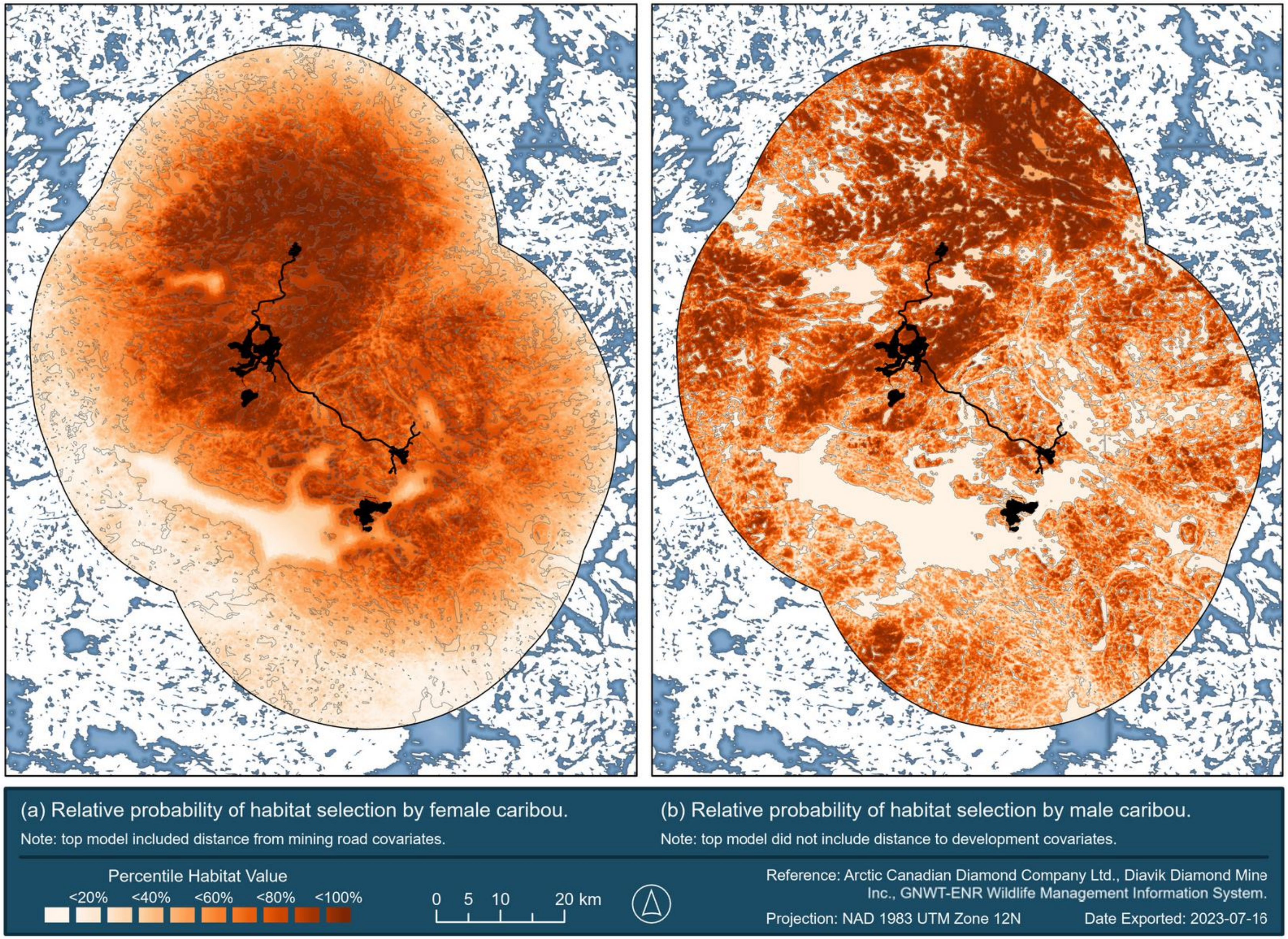

Figure 3-21: Spring Migration 1-hour Interval Habitat Selection by Caribou

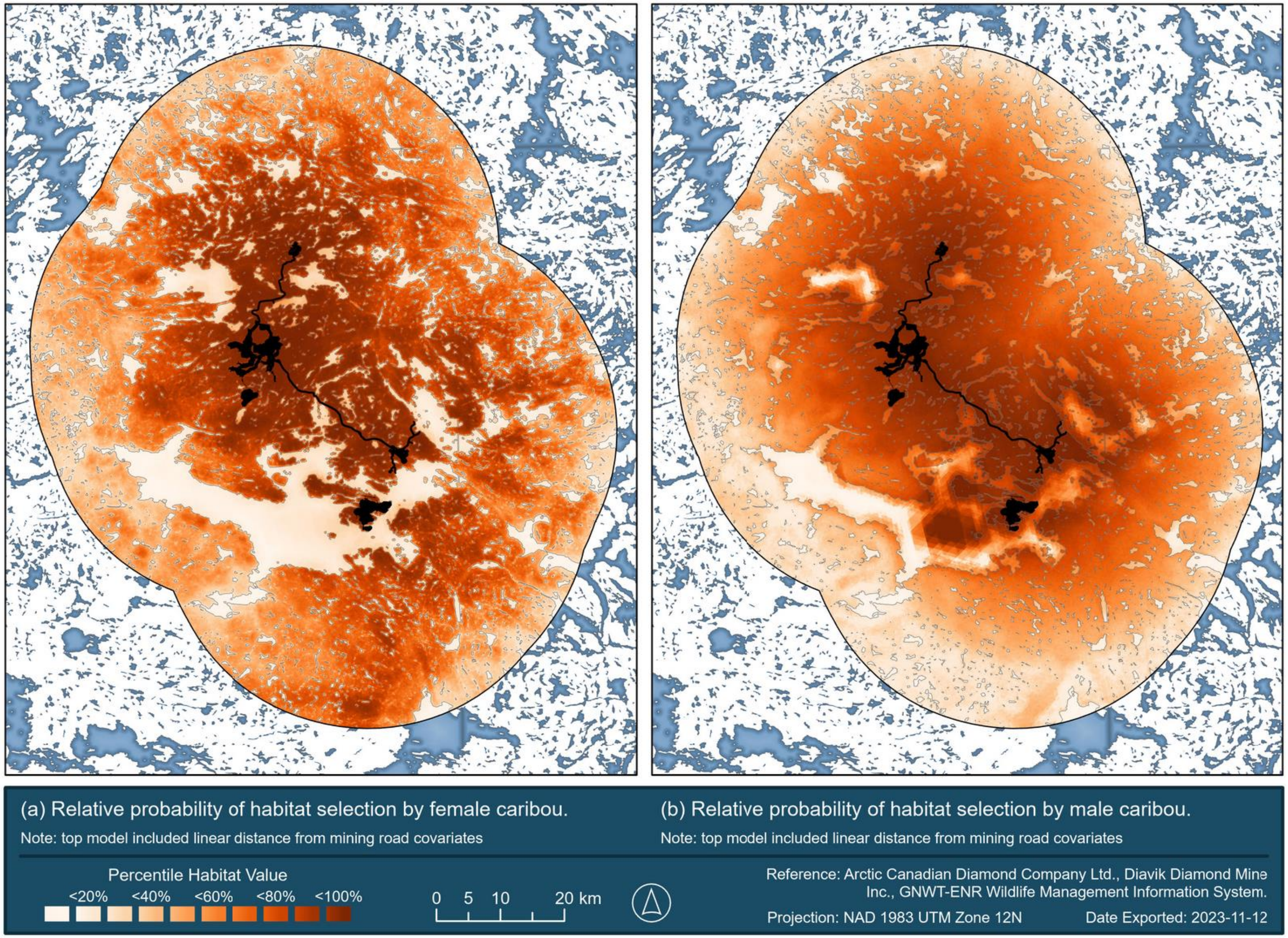

Figure 3-22: Summer 1-hour Interval Habitat Selection by Caribou

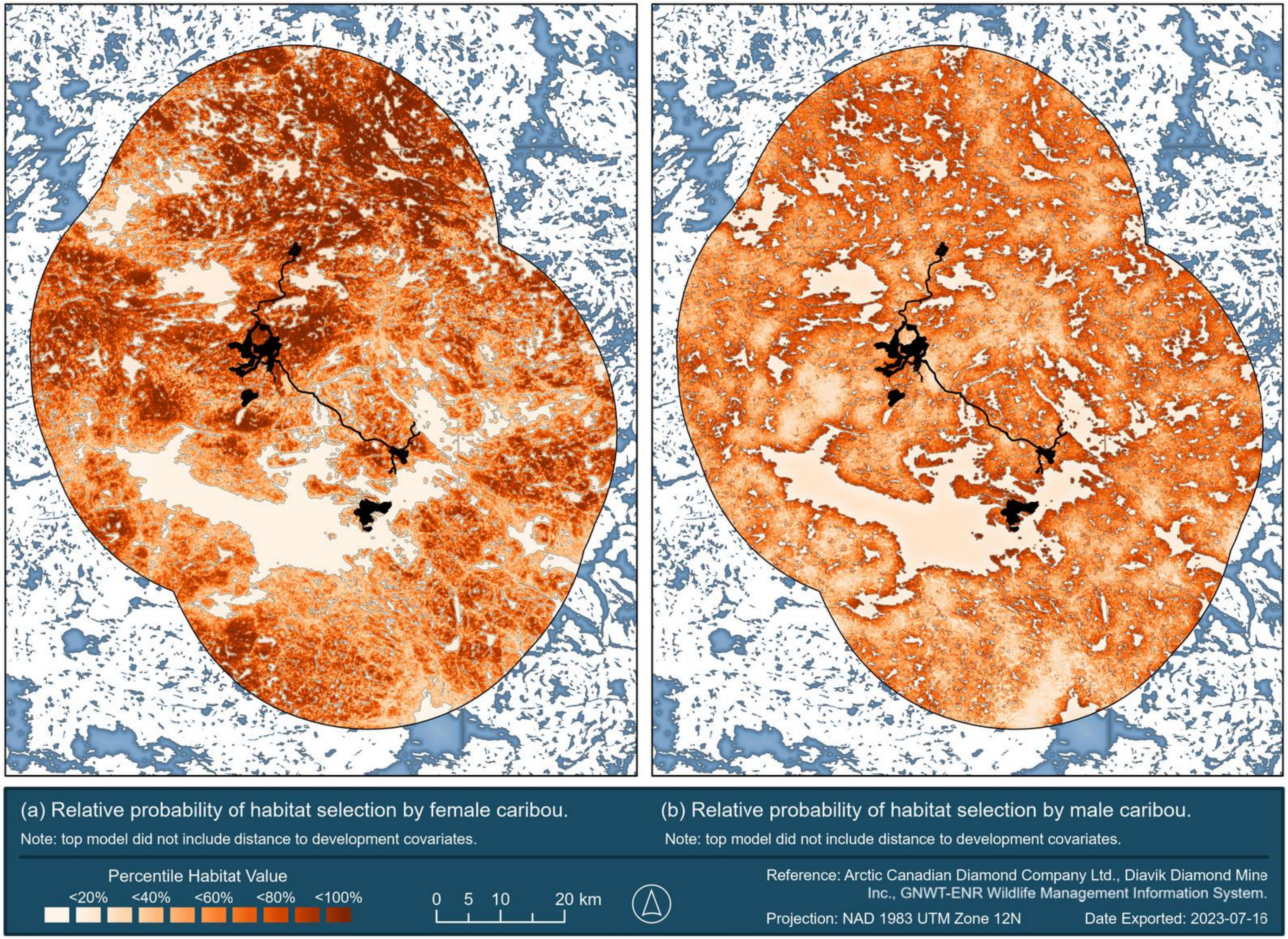

Figure 3-23: Late Summer 1-hour Interval Habitat Selection by Caribou

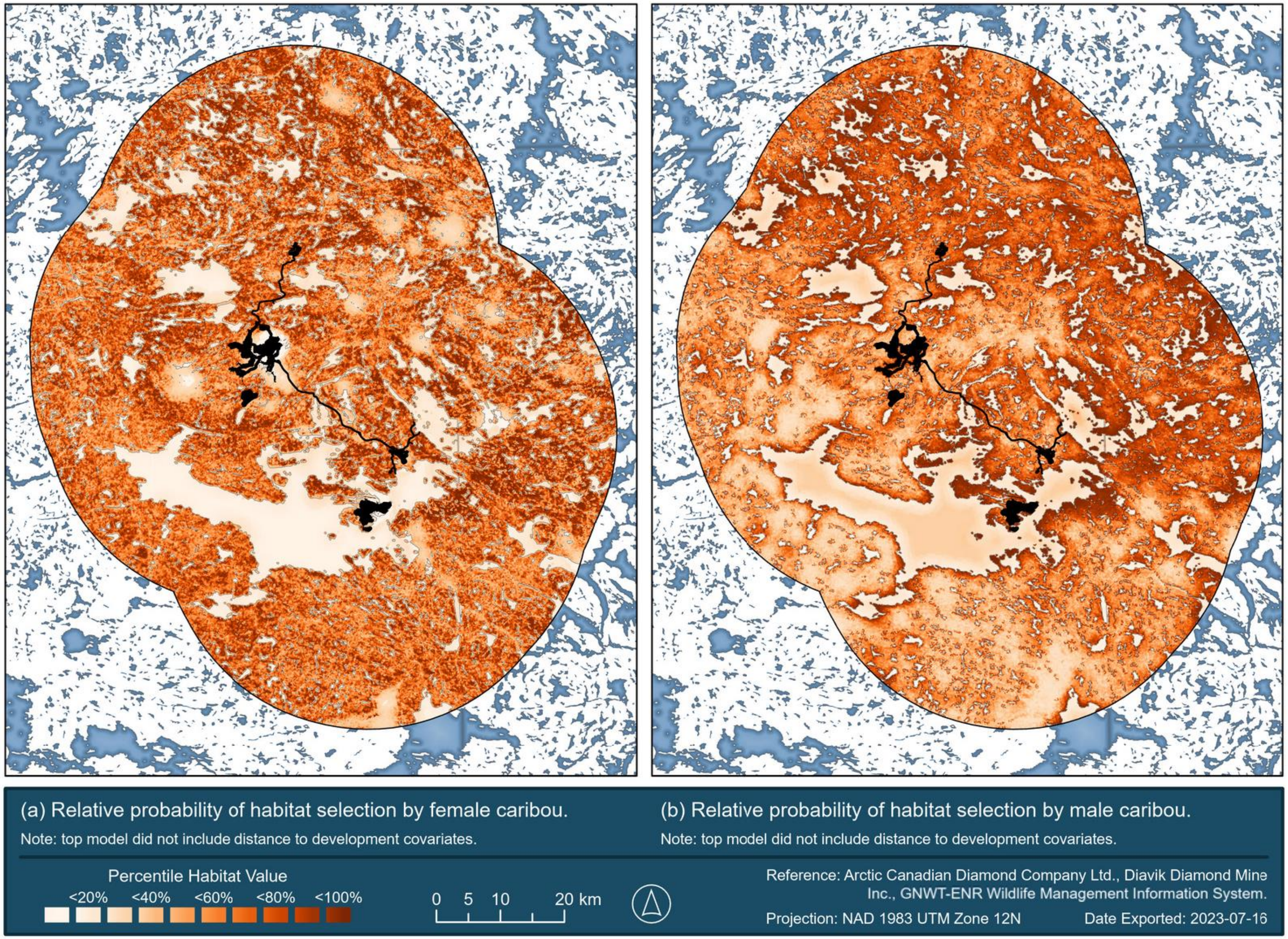

Figure 3-24: Pre-Rut 1-hour Interval Habitat Selection by Caribou

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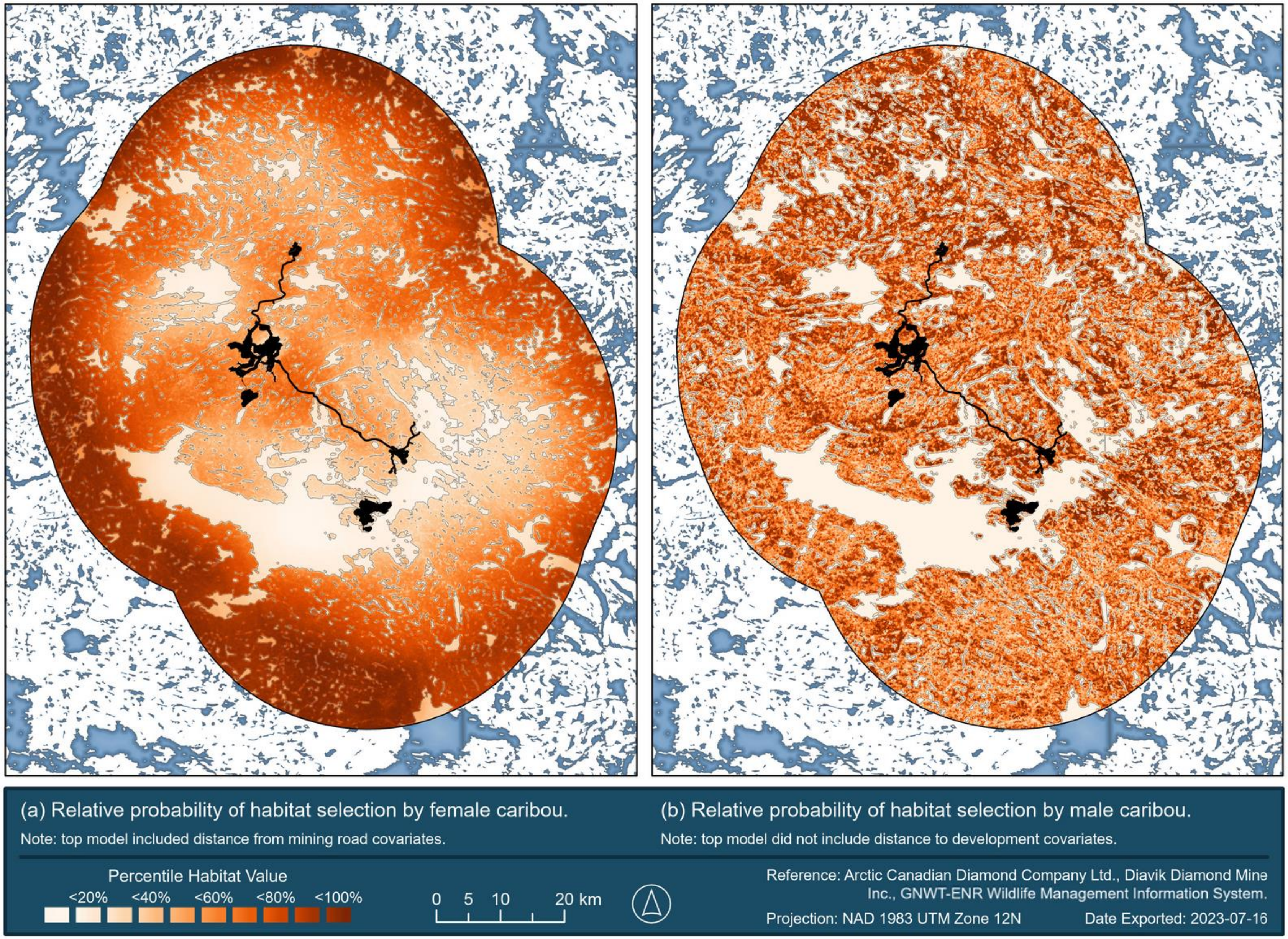

Figure 3-25: Rut 1-hour Interval Habitat Selection by Caribou

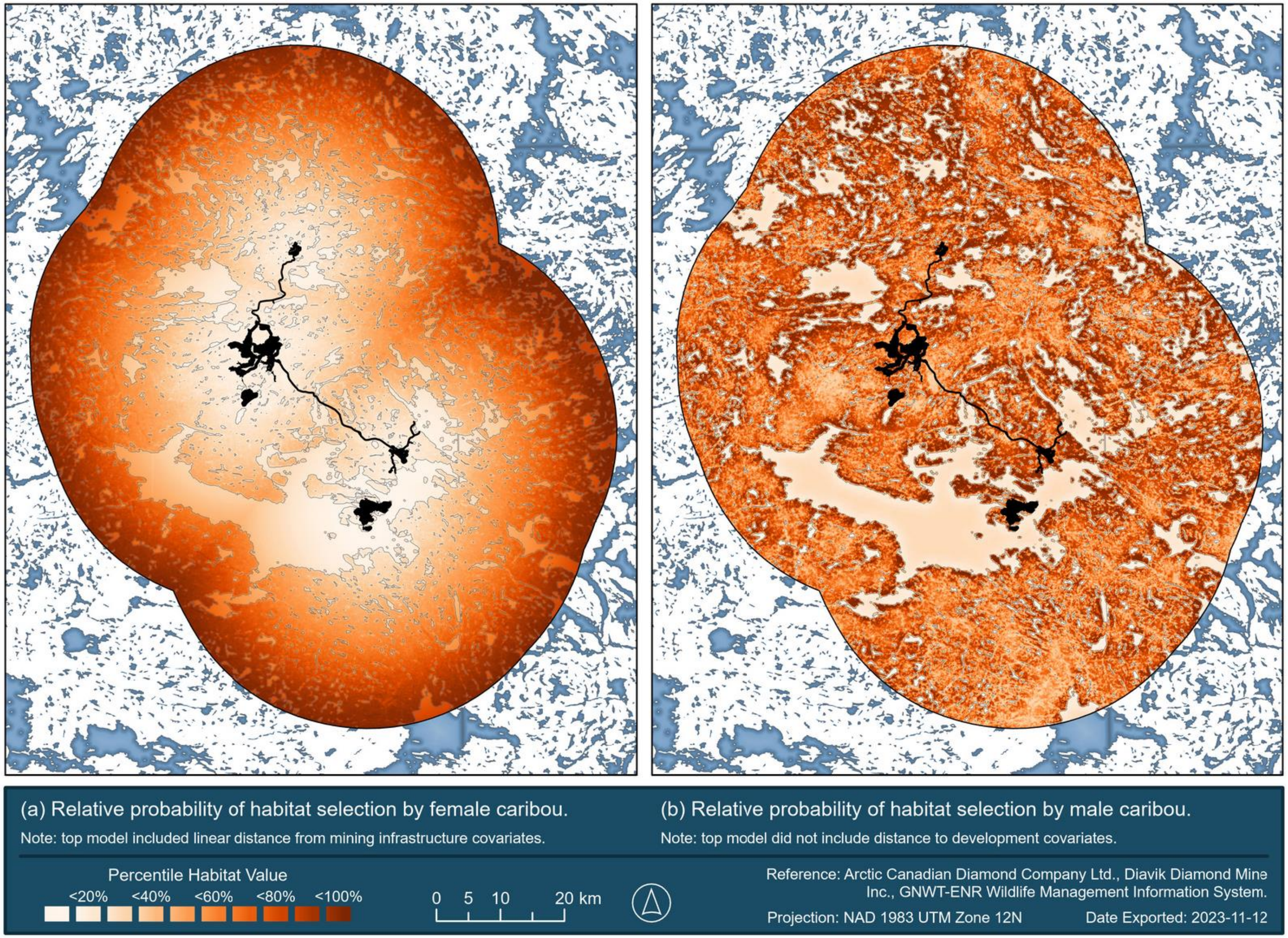

Figure 3-26: Post-Rut 1-hour Interval Habitat Selection by Caribou

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3.10 Movement characterization

3.10.1 Effect of exposure time in Ekati/Diavik halo on length of seasonal movement path

Accounting for two herds with two sexes in each of nine seasons, there were 36 separate analyses conducted, regressing total seasonal movement path length (in km) on the number of 8-hour movement steps ending in the Ekati/Diavik halo. Graphs and equations of the 36 regression lines are in Appendix J, (Figures J-1 to J-4).

Of the 36 regressions there were 11 with significant slopes indicating a relationship between the number of 8-hour movement steps in the Ekati/Diavik halo and the total path length travelled by caribou during the season. One of the 11 significant results (Bathurst female calving season) was based on 203 animal-seasons of data, only one of which intersected the Ekati/Diavik halo. The equations of the other 10 are presented in Table 3-13.

Table 3-13: Significant results of regression of exposure to the Ekati/Diavik halo on total seasonal movement path length (km)

Sex	Herd	Season	Y-int[1]	slope(β)[1]	P	n Animal Seasons
Female	Bathurst	Winter	670	+1.54	0.018	74
Female	Bathurst	Summer	729	-1.63	0.002	180
Female	Bathurst	Late Summer	158	-0.385	0.010	166
Female	Bathurst	Pre-Rut	370	-0.997	<0.001	164
Female	Beverly	Pre-Rut	516	-2.99	<0.001	116
Female	Beverly	Post-Rut	369	+1.62	0.027	96
Male	Bathurst	Winter	433	+0.83	0.047	40
Male	Bathurst	Calving	129	+2.12	0.020	98
Male	Bathurst	Summer	562	-1.77	0.021	92
Male	Bathurst	Pre-Rut	390	-0.84	0.037	71

[1] The units of measure for the equation are km: Y-intercept in km and slope in km/8-hour step ending inside the Ekati/Diavik halo.

Of the 10 herd by sex by season combinations with significant effects of exposure to the Ekati/Diavik halo on total movement path, four (11%) are positive relationships: caribou seasonal movement paths increased with greater time spent in the halo during winter for Bathurst male and female caribou, during calving for Bathurst males, and during the post-rut for female Beverly caribou. The other six (17%) results indicated that animals had shorter seasonal paths when they spent time within 30 km of the Ekati and Diavik mines.

For the other 26 (72%) herd by sex by season combinations, there were no significant relationships between time spent in the Ekati/Diavik halo and the distance travelled during the season.

3.10.2 Effect of exposure time in Ekati/Diavik halo on delayed arrival in next seasonal range

After examining the effect of exposure to the Ekati and Diavik mines of the total distance travelled in a season (Section 3.10.1 above), the other potential effect tested was delayed arrival in the next seasonal range. Following examination of available data (individual animal-season summaries), each animal-season was classified by two binary covariates: (1) did the animal's seasonal path intersect the Ekati/Diavik halo, and (2) was the animal present in the 90% UD seasonal range for the next season when its first location for the season was recorded, or was its arrival delayed.

The results of the analyses for each sex by season are presented in Table 3-14. Of the 18 sex by season combinations there were two seasons where a significant effect of exposure on delay was detected. Female caribou that did not intersect the Ekati/Diavik halo during summer were more likely to be delayed in their arrival on the late summer range than female caribou whose summer range included the Ekati/Diavik halo. The same pattern was observed for female caribou in the subsequent season, where caribou whose late summer range did not include the Ekati/Diavik halo were more likely to have a delayed arrival on the pre-rut range.

There was no season where spending time in the Ekati/Diavik halo made it more likely for animals of either sex to be delayed in arriving in the seasonal range for the next season.

There were also 62 animal-seasons where individuals had telemetry locations from both the earlier season and the later season but never entered the 90% UD seasonal range delineated for the later season (i.e., not delayed in their arrival at the next 90% UD seasonal range, but did not arrive at all). Of these, 53 were animals that had not entered into the Ekati/Diavik halo during the earlier season; the remaining nine animals had earlier season movement that included the Ekati/Diavik halo – they were from eight different sex by season combinations. They were not included in any formal analyses.

3.10.3 Proximity to mine infrastructure and mine roads on movement step length

The linear regressions of interval step lengths on distance to mine (or mine road) are presented in Appendix K, Figures K-1 and K-2. Their equations and summary statistics are presented in Table 3-15. The analyses were based on natural log transformed data. To aid in interpretation, Table 3-15 includes columns with the exponentiated values (i.e., back transformed step length data so they are expressed in metres moved per time interval) for step lengths ending 0 km from mine infrastructure (the y-intercept) and 30 km from mine infrastructure. The final column in the table is the difference in step-length between 0 and 30 km from the edge of mine infrastructure. For interpretation, steps ending 30 km from infrastructure were considered background behaviour while steps closer to the mine infrastructure may reveal an effect of development.

For 8-hour interval steps, there was a statistically significant slope ($P<0.05$) for every season for female caribou with the exception of post-rut. Other than during post-rut, the female 8-hour step length decreased closer to mine infrastructure (range: from 269 m shorter at infrastructure edge than at 30 km distance in late summer, to 1231 m shorter at infrastructure edge than at 30 km in summer). For males statistically significant differences in 8-hour step-length related to proximity to mines were observed during winter, spring migration, and late summer. In winter and late summer male caribou step-lengths were longer the closer they were to mine infrastructure (177 m longer at infrastructure edge per 8-hour interval in winter and 334 m longer per 8-hour interval in late summer), while the step-lengths were 873 m shorter per 8-hour interval step at infrastructure edge than at 30 km from infrastructure in spring migration.

For 1-hour interval steps, there were statistically significant effects for female caribou during pre-rut (35 m shorter step at edge of infrastructure than at 30 km), rut (18 m longer step at infrastructure edge than at 30 km), and post-rut (26 m longer step at infrastructure edge than at 30 km). For male caribou, distance to mine had a significant effect on 1-hour step length for all seasons except post-rut. In spring migration, the step length from the regression equation was 18 m shorter at the edge of mine infrastructure than at 30 km, while for all other seasons the step lengths were longer at infrastructure edge than at 30 km (range: 27 m longer in winter to 64 m longer in rut).

The regression equations were significant in the majority of cases. The R^2_{adj} values were < 0.01 in all but three cases: in one case R^2_{adj} = 0.01; in two cases R^2_{adj} = 0.02 (Table 3-15). The amount of variance in step length explained by the distance to mine features was very low.

Table 3-14: Results of Fisher's exact tests of the effects of caribou encountering the Ekati/Diavik halo in one season on their arrival time in their seasonal range in the next season.

Sex	Season	Total Animal Seasons	Total Animal-Seasons Intersecting Ekati/Diavik Halo		Total Animal-Seasons Not Intersecting Ekati/Diavik Halo		P
			No delay in arrival	Delayed arrival next season	No delay in arrival	Delayed arrival next season	
Female	Winter	176	45	2	117	12	0.3585
Female	Spring Migration	326	85	3	229	9	1.0000
Female	Calving	346	0	0	339	7	1.0000
Female	Post-Calving	331	0	0	313	18	1.0000
Female	Summer	312	131	1	167	13	0.0053
Female	Late Summer	297	86	1	190	20	0.0107
Female	Pre-Rut	293	77	1	207	8	0.4530
Female	Rut	291	65	9	200	17	0.2488
Female	Post-Rut	229	70	2	155	2	0.5918
Male	Winter	106	22	0	75	9	0.1987
Male	Spring Migration	200	59	6	119	16	0.6387
Male	Calving	200	20	3	172	5	0.0509
Male	Post-Calving	194	8	0	177	9	1.0000
Male	Summer	192	54	0	130	8	0.1083
Male	Late Summer	168	34	0	124	10	0.2156
Male	Pre-Rut	159	32	0	123	4	0.5839
Male	Rut	149	31	0	110	8	0.2057
Male	Post-Rut	115	28	3	76	8	1.0000
	Totals	4,084	847	31	3,023	183	

Table 3-15: Results of regression of 1-hour and 8-hour caribou step lengths on distance from the nearest Ekati or Diavik mine infrastructure (mine or mine road).

								mean step length (sl) at distance from mine (m)[1]		
Sex	**Season**	Interval	Y-int	slope(β)	R^2_{adj}	**P**	**n steps**	30 km	0 km	**Δsl (m) (30-0 km)**
Female	Winter	1-hour	4.35	-0.0001	<0.01	0.958	32,433	77	77	0
Female	Spring Migration	1-hour	4.66	-0.0014	<0.01	0.483	16,639	101	106	5
Female	Summer	1-hour	5.32	-0.0017	<0.01	0.619	7,977	194	204	10
Female	Late Summer	1-hour	5.11	-0.0027	<0.01	0.110	18,591	153	166	13
Female	Pre-Rut	1-hour	4.64	0.0098	<0.01	<0.001	21,395	139	104	-35
Female	Rut	1-hour	4.94	-0.0046	<0.01	0.045	8,791	122	140	18
Female	Post-Rut	1-hour	4.48	-0.0119	<0.01	<0.001	5,607	62	88	26
Female	Winter	8-hour	6.86	0.0108	<0.01	<0.001	6,915	1318	953	-365
Female	Spring Migration	8-hour	7.06	0.0125	<0.01	<0.001	2,722	1694	1164	-530
Female	Summer	8-hour	7.45	0.0180	0.01	<0.001	2,542	2951	1720	-1231
Female	Late Summer	8-hour	7.31	0.0055	<0.01	0.004	3,715	1764	1495	-269
Female	Pre-Rut	8-hour	6.93	0.0215	0.02	<0.001	3,917	1949	1022	-927
Female	Rut	8-hour	7.35	0.0093	<0.01	0.013	1,647	2058	1556	-502
Female	Post-Rut	8-hour	7.09	0.0076	<0.01	0.127	1,810	1509	1200	-309
Male	Winter	1-hour	4.28	-0.0159	<0.01	<0.001	22,393	45	72	27
Male	Spring Migration	1-hour	4.38	0.0067	<0.01	0.001	15,027	98	80	-18
Male	Summer	1-hour	4.83	-0.0092	<0.01	<0.001	8,186	95	125	30
Male	Late Summer	1-hour	5.11	-0.0128	<0.01	<0.001	9,953	113	166	53
Male	Pre-Rut	1-hour	4.98	-0.0098	<0.01	<0.001	8,901	109	145	36
Male	Rut	1-hour	5.21	-0.0142	<0.01	<0.001	4,002	120	183	63
Male	Post-Rut	1-hour	4.56	0.0035	<0.01	0.254	5,331	106	96	-10
Male	Winter	8-hour	6.67	-0.0085	<0.01	<0.001	3,873	611	788	177
Male	Spring Migration	8-hour	6.79	0.0228	0.02	<0.001	2,607	1762	889	-873
Male	Summer	8-hour	7.17	-0.0044	<0.01	0.284	1,684	1139	1300	161
Male	Late Summer	8-hour	7.17	-0.0099	<0.01	<0.001	1,778	966	1300	334
Male	Pre-Rut	8-hour	7.28	-0.0068	<0.01	0.075	1,494	1182	1451	269
Male	Rut	8-hour	7.59	0.0028	<0.01	0.550	676	2152	1978	-174
Male	Post-Rut	8-hour	7.11	0.0040	<0.01	0.265	1,357	1378	1224	-154

[1] The three columns on the right show the values (in metres, determined from the regression intercept and slope) for steps ending on mine infrastructure or at its edge (i.e., 0 km from the mine), at a 30 km distance from the mine (the limit of the data), and the difference in step-length between 0 km and 30 from the mine (Δsl). Negative Δsl values indicate steps ending at the edge of infrastructure are shorter than at 30 km from the mine, while positive Δsl values indicate steps are longer when at the edge of infrastructure.

3.10.4 Proximity to mine infrastructure and mine roads on movement step turn angle

The linear regressions of interval turn angles (the deviation of the bearing of the most recent step from the bearing of the previous step) on distance to mine (or mine road) are presented in Appendix L, Figures L-1 and L-2. Their equations and summary statistics are presented in Table 3-16. The analyses were based on cosine transformations of turning angles measured in radians (where a value of 1.00 meant no change in direction, a value of 0.00 corresponded to a 90° turn in either direction, and a value of -1.00 meant a reversal of direction [i.e., 180° turn]). To aid in interpretation, Table 3-16 includes columns with the turn angle values from the regression equation expressed in degrees for steps ending both 0 km from mine infrastructure (the y-intercept) and 30 km from mine infrastructure. The final column in the table is the difference in turn angle (in degrees) between steps ending 0 and 30 km from the edge of mine infrastructure; a positive value means the turn was more extreme at the edge of the mine while a negative value indicates less extreme turns closer to mine infrastructure. For interpretation, steps ending 30 km from infrastructure were considered background behaviour while steps closer to the mine infrastructure may reveal an effect of development.

For 8-hour interval turning angles, there was a statistically significant effect (each $P<0.001$) for each season for female caribou; in every season the turning angle increased closer to mine infrastructure (range: 8° more extreme at infrastructure edge in winter through 14° more extreme at infrastructure edge in spring migration to 21° more extreme in post-rut). For males, statistically significant differences in turning angles between 8-hour steps ($P<0.05$) occurred in spring migration (17° more extreme at infrastructure edge), summer (16° less extreme at infrastructure edge), late summer (7° less extreme at infrastructure edge), and post-rut (18° more extreme at infrastructure edge).

For 1-hour interval turning angles, there were statistically significant effects for female caribou during late summer (3° less extreme at the edge of mine infrastructure) and pre-rut (4° more extreme at the edge of mine infrastructure). For male caribou, distance to mine had a significant effect on 1-hour turning angles in three seasons. In each case the turning angle was less extreme at edge of infrastructure than at 30 km: 5° in winter; 14° in summer; and 7° in late summer.

Though the regression equations were significant in 11 of 14 8-hour interval analyses and 5 of 14 1-hour interval analyses, the $R^2_{adj} < 0.01$ in all but 4 cases: two cases where $R^2_{adj} = 0.01$; and two cases where $R^2_{adj} = 0.02$ (Table 3-16). The amount of variance in turning angle explained by the distance to mine features was very low.

Table 3-16: Results of regression of 1-hour and 8-hour caribou turning angles on distance from the nearest Ekati or Diavik mine infrastructure (mine or mine road).

Sex	Season	Interval	Y-int	slope(β)	R^2_{adj}	P	n	mean turn angle (ta) at distance from mine (°)[1]		
								30 km	0 km	**Δta (°) (30-0 km)**
Female	Winter	1-hour	0.218	-0.0007	<0.01	0.232	31,645	79	77	-1
Female	Spring Migration	1-hour	0.231	0.0009	<0.01	0.191	16,343	75	77	2
Female	Summer	1-hour	0.233	0.0015	<0.01	0.292	7,804	74	77	3
Female	Late Summer	1-hour	0.256	-0.0019	<0.01	0.006	18,241	78	75	-3
Female	Pre-Rut	1-hour	0.170	0.0025	<0.01	<0.001	21,062	76	80	4
Female	Rut	1-hour	0.270	0.0015	<0.01	0.063	8,623	72	74	3
Female	Post-Rut	1-hour	0.286	-0.0013	<0.01	0.255	5,422	76	73	-2
Female	Winter	8-hour	0.180	0.0048	<0.01	<0.001	6,747	71	80	8
Female	Spring Migration	8-hour	0.144	0.0080	<0.01	<0.001	2,663	67	82	14
Female	Summer	8-hour	0.216	0.0072	<0.01	<0.001	2,521	64	78	13
Female	Late Summer	8-hour	0.068	0.0054	<0.01	<0.001	3,636	77	86	9
Female	Pre-Rut	8-hour	0.063	0.0058	<0.01	<0.001	3,836	76	86	10
Female	Rut	8-hour	0.243	0.0074	0.01	<0.001	1,590	62	76	14
Female	Post-Rut	8-hour	0.250	0.0109	0.02	<0.001	1,736	55	76	21
Male	Winter	1-hour	0.183	-0.0027	<0.01	<0.001	21,854	84	79	-5
Male	Spring Migration	1-hour	0.180	0.0011	<0.01	0.110	14,784	78	80	2
Male	Summer	1-hour	0.218	-0.0079	<0.01	<0.001	7,939	91	77	-14
Male	Late Summer	1-hour	0.245	-0.0039	<0.01	<0.001	9,694	83	76	-7
Male	Pre-Rut	1-hour	0.207	-0.0006	<0.01	0.575	8,612	79	78	-1
Male	Rut	1-hour	0.272	0.0019	<0.01	0.148	3,909	71	74	3
Male	Post-Rut	1-hour	0.265	0.0017	<0.01	0.119	5,199	72	75	3
Male	Winter	8-hour	0.098	0.0013	<0.01	0.314	3,838	82	84	2
Male	Spring Migration	8-hour	0.040	0.0099	0.01	<0.001	2,580	70	88	17
Male	Summer	8-hour	0.268	-0.0094	<0.01	<0.001	1,657	91	74	-16
Male	Late Summer	8-hour	0.168	-0.0043	<0.01	0.029	1,727	88	80	-7
Male	Pre-Rut	8-hour	0.039	0.0035	<0.01	0.157	1,436	82	88	6
Male	Rut	8-hour	0.370	0.0051	<0.01	0.075	652	59	68	10
Male	Post-Rut	8-hour	0.298	0.0095	0.02	<0.001	1,327	54	73	18

[1] The three columns on the right show the turn angle values (in degrees, determined from the regression intercept and slope) for steps ending on mine infrastructure or at its edge (i.e., 0 km from the mine), at a 30 km distance from the mine (the limit of the data), and the difference in turn angle between 0 km and 30 from the mine (Δta). Negative Δta values indicate steps ending at the edge of infrastructure are closer to the bearing of the previous step than steps ending 30 km from the mine , while positive Δta values indicate steps ending at the edge of mine infrastructure have turn angles more extreme than steps ending at 30 km.

4. DISCUSSION

The objective of this study was to determine the effects of the Ekati Diamond Mine on fine-scale behaviour of Beverly and Bathurst herd caribou. The period with data available at a scale of less than 24-hour intervals defined the study period as winter 2015/2016 to post-rut 2022. In the study period, data were collected every 8-hours throughout the range of both herds; 1-hour interval data collection in the GF112N area around the Ekati and Diavik mines began with spring migration 2017 for the Bathurst herd and spring migration 2018 for the Beverly herd.

The SSAs and iSSAs are inherently spatial analyses. Non-spatial factors of interest and potential influence identified prior to analyses included herd membership, season, sex, and year; factors best addressed with separate sets of models (Northrup et al. 2022). With two herds, two sexes, nine seasons, and seven years there were 252 potential model sets, an unmanageable number. As seasonal range use and habitat selection are known to vary between the sexes and by season (see Section 3.2 and Appendix A) those two factors were considered important enough to warrant independent analyses from the outset. At both the 1-hour and 8-hour scales, herd membership was included in BRT analyses. However, herd membership was never included among important factors from the analyses, and so was not considered further.

The landcover data (LC2009) used to classify the majority of the RSA (including all of the Ekati/Diavik halo) was the same as that used in recent studies in the region by Boulanger et al. (2012, 2021). Rather than a summary of area covered in a single fixed buffer around each caribou location, landcover data in these analyses were characterized at multiple grains (Laforge et al. 2015; McGarigal et al. 2016; Northrup et al. 2022) centred on each 3.1-ha cell in the RSA. The two scales of analyses were fixed temporally at 1-hour and 8-hour intervals, with associated spatial scales dictated by the movements of animals during those intervals. Key attributes of SSFs are that they introduce time-dependency to constrain the distribution of available locations while allowing it to vary in time and space – changing with current locations and individual movement tendencies (Fieberg et al. 2021). At each of the 1-hour and 8-hour scales, multi-grain covariates competed in models assessed in SSAs and iSSAs. The resulting SSFs and iSSFs provided insight into the perceptual ranges of caribou and the influence of environmental covariates at different grains on behaviour at the two scales of analyses (Laforge et al. 2015; Bastille-Rousseau et al. 2018).

Phase 1 and Phase 2 analyses: 8-hour interval selection functions and the influence of distance to mining features on habitat selection

In Phase 1 of the analyses, 8-hour interval data were separated by proximity to development and SSAs were used to model behaviour from movements throughout the study area, but more than 30 km from development. Based on results presented here, caribou select habitat in an 8-hour interval based on a set of covariates that spans the range of nested grains included in the analyses (from 3.1-ha to 5137-ha). Overall, there was a general pattern for caribou to preferentially include waterbodies at coarser-grains and avoid them at the 3.1-ha grain. Tussock graminoid tundra and shrub landscapes were selected at the 3.1-ha grain by both sexes in most seasons. Of the 18 sex by season SSFs, all but one (female summer) contained covariates from multiple grains.

The resulting Phase 1 sex by season SSFs were then used to predict habitat selection values for Phase 2 iSSAs for each sex by season inside the Ekati/Diavik halo. The predicted values effectively represent predictions of relative, development-free, habitat selection value. Those predicted values were included in iSSA models to determine if adding movement characteristics (step length and turning angle) and distance to mining features improved predicted use.

Caution is always recommended when making predictions in areas or time periods outside the data used to generate models. However, the approach employed here was to withhold the 8-hour data from all study animals in the entire study period when they occurred in a 6,662 km^2 area centrally located in a 212,355 km^2 RSA (i.e., 3% of the RSA).

Each of the 8-hour interval iSSFs included positive coefficients for the RSFrisk covariate, the relative habitat selection value predicted with SSFs from Phase 1 analyses.

For male caribou, iSSFs suggest no significant influence of mine roads or mine infrastructure on habitat selection and movement behaviour in five of the seven seasons. The iSSA base model including turn angle and step length was selected as the iSSF in four seasons (winter, spring migration, late summer, and pre-rut) while the SSF predicted relative habitat was the best model in post-rut. The summer iSSF (DFMines) and the rut iSSF (LinearDFMines) included covariates related to distance to mining infrastructure.

For female caribou, the DFMines model was the best performing model in winter, summer, late summer, and pre-rut; the iSSA base model was the iSSF during the rut; and the SSF predicted relative habitat selection value was the iSSF for spring migration and post-rut. Overall, the 8-hour interval iSSFs for female caribou suggest that proximity to mine infrastructure reduces relative habitat selection value in four seasons of the year.

Eleven of the 12 iSSFs that included movement covariates (n=6), or movement covariates plus distance to mine infrastructure covariates (n=6) had higher Rho^2_{adj} values than the SSFs for the same sex by season, indicating a higher amount of variance explained (i.e., improved predictive value with the addition of movement and distance to feature covariates). Overall, the 8-hour scale iSSF Rho^2_{adj} values were below 0.10 with the exception of the summer female iSSF (Rho^2_{adj} = 0.15). Of these, the lowest Rho^2_{adj} values (between 0.016 and 0.043) were for winter and spring migration for the two sexes. This limited explanation of behaviour is a consequence of analyses that appropriately restricts available habitat to a plausible set of locations based on the movement time interval and the movement patterns of individual animals. Little change in relative selective value arises when observed short distance movement steps are matched with random short distance movement steps originating at the same location – available and used locations have similar attributes and selection at this scale is limited.

The maps of predicted relative probability of 8-hour habitat selection in the Ekati/Diavik halo (left-hand panels in Figures 3-6 to 3-19) represent the distribution of predicted relative habitat selection values based on sex by season SSFs outside the halo. Though relative rather than absolute, the right-hand panels of Figures 3-6, 3-8, 3-9, 3-10, 3-15, and 3-18 show the influence of mining infrastructure on relative habitat selection value evident near the Ekati Main Camp, Sable Project, and Misery Project.

There was no evidence that distance to road affected 8-hour step-selection. There was no season for either sex where a distance to road candidate model came out as the 8-hour iSSF. In considering the relative effects of distance to mine roads compared with distance to other infrastructure, the portions of the Ekati/Diavik halo where roads are the nearest mining feature were compared to those where other infrastructure is the nearer feature. Figure 4-1 shows the Ekati/Diavik halo shaded to show where roads or mine infrastructure are the closer feature, or where the difference is < 1.0 km. As there are infrastructure nodes near the terminus of each haul road, the majority of the halo (63%) is closer to mine infrastructure than to mine roads (18%), with 19% of the halo equidistant from each (within 1 km). The large light gray area on the east side of Figure 4-1 where roads are the closer feature depends on the proximity of the Lac du Sauvage Road, which is not a haul road.

Phase 3 analyses: 1-hour interval selection functions and the influence of distance to mining features on habitat selection

Compared with 8-hour analyses, the stepAIC models from the 1-hour interval data contained fewer instances where there were covariates included at multiple grains; only 6 of 14 sex by season models had additional fine- and coarse-grain candidate models defined. With the exception of summer, the 1-hour iSSFs were dominated by 3.1-ha grain covariates. Given the shorter step lengths, the set of locations in each stratum are likely to have much higher overlap, leading to similar values for coarse-grain covariates; a situation which favours differentiation between used and available locations based on 3.1-ha grain covariate measures.

Overall, the 1-hour interval iSSFs for male caribou suggest no significant influence of mine roads or mine infrastructure on habitat selection or movement behaviour of male caribou in any season except summer, where the influence was positive, with habitat selection values higher near the mine roads. For male caribou, the landcover model (landcover covariates plus turn angle and step length) was the top 1-hour model in all seasons except summer where the iSSF was LinearDFMineRds. This is similar to the 8-hour iSSF, where summer was one of two seasons that the male iSSF included covariates related to distance to mining features (in the 8-hour summer iSSF, it was distance to mine infrastructure).

The 1-hour interval iSSFs for female caribou suggest proximity to mine roads reduces relative habitat selection value in winter, spring migration, and post-rut. Conversely, relative habitat selection values were positively related to presence of mine roads in summer and during the rut. For female caribou, the DFMineRoads (distance from mine roads) model was the best performing model in winter, spring migration, and rut; LinearDFMines (linear distance from mine infrastructure) was the iSSF for post-rut; and LinearDFMineRds was the iSSF for summer. The landcover model was the iSSF for female caribou in late summer and pre-rut. The addition of interaction terms with insect harassment indices did not yield candidate models selected as the iSSF for summer or late summer for either sex at the 1-hour scale. Combined with 8-hour results, female habitat selection was affected at both scales in winter and summer, and at one scale but not the other in every other season.

The sex by season patterns generally matched at the 1-hour and 8-hour scales, with Rho^2_{adj} values for 1-hour iSSFs averaging less than half the values for 8-hour iSSFs. The 1-hour scale iSSF Rho^2_{adj} were between 0.03 to 0.04, except in summer (female Rho^2_{adj} =0.053; male Rho^2_{adj} = 0.043), and winter and spring migration (Rho^2_{adj} values between 0.004 and 0.013 for the two sexes). As noted for the 8-hour results, shorter time intervals coincide with shorter step lengths and the 1-hour interval effectively imposes further restrictions on locations available for steps from a common origin.

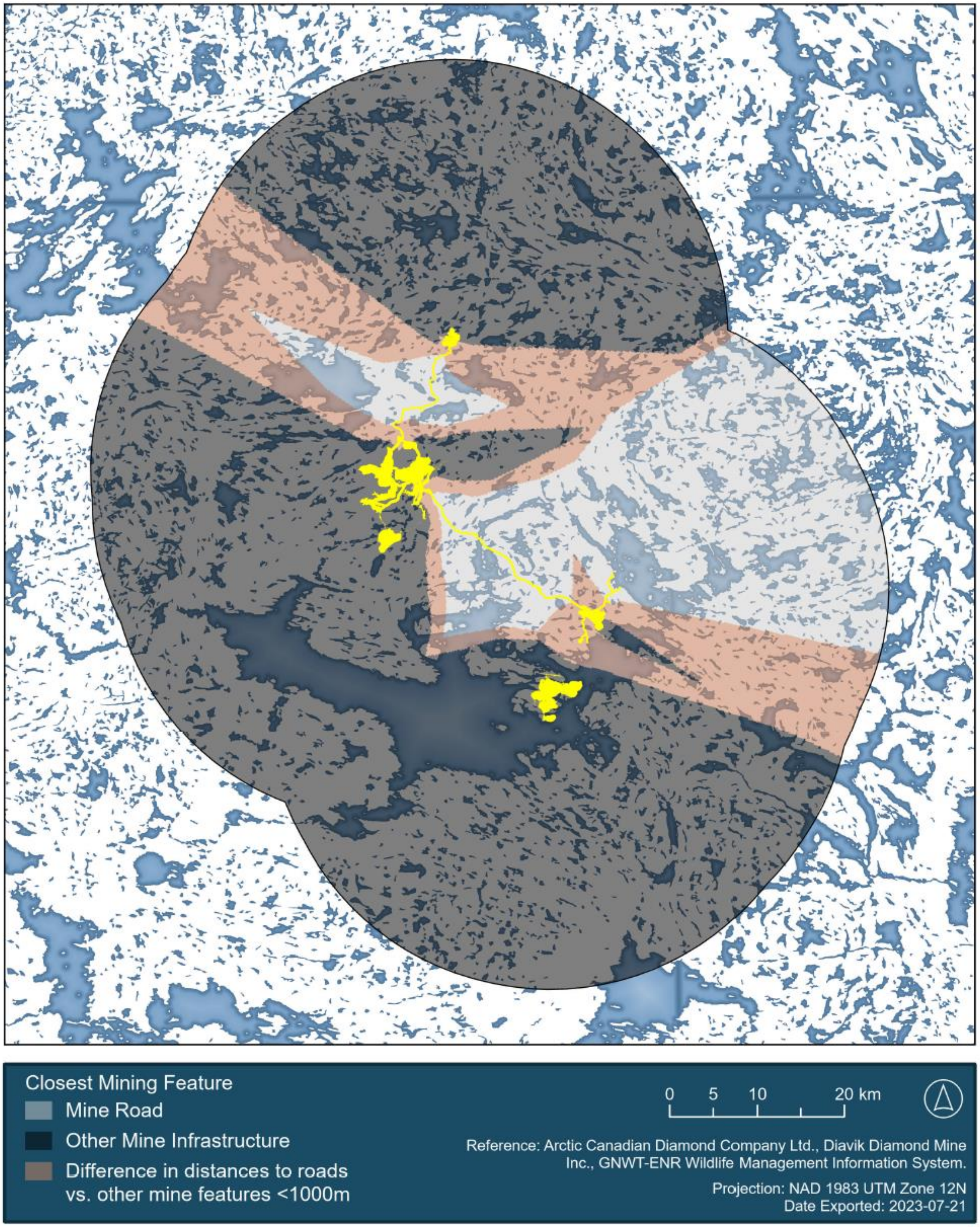

Figure 4-1: Closest mining feature type to each 3.1 ha hexagon in the Ekati/Diavik 30 km halo

Effects of exposure to the Ekati/Diavik halo on movement path length and delays in arrival to seasonal ranges

Poole et al. (2021) expressed concern over the ecological effects to caribou whose movements intersected the Ekati and Diavik mine infrastructure. The potential effects of concern included:

- delays in moving across the mine roads and mine infrastructure;
- increased energetic costs arising both from any delays and from increased movements, should an animal be deflected from its preferred line of travel;

The measures used in assessment by Poole et al. (2021) included movement speed, proportion of turns >60° (referred to as "sharp turns" or "hard turns").

The iSSF analyses conducted in this study included both movement and habitat selection, an important consideration in movement paths and turning angles not included by Poole et al. (2021). Those iSSF results indicate that relative habitat selection values closer to mine roads and mine infrastructure are reduced in some seasons.

Direct analyses of movement in the Ekati/Diavik halo, ignoring habitat distribution, were made to examine the data of concern to Poole et al. (2021). There were statistically significant differences in mean female 8-hour movement rates based on distance from mine roads and mine infrastructure in every season except post-rut. Depending on season, female caribou 8-hour movement step length was between 269 m and 1231 m shorter when they were at the edge of mine roads or mine infrastructure than when they were 30 km away from mine roads and infrastructure. When measured at a 1-hour interval there were statistically significant differences in the pre-rut, rut, and post-rut seasons of between 26 m longer and 35 m shorter step lengths at the edge of mine infrastructure than 30 km away. For male caribou, there were three seasons with statistically significant differences in step length between 334 m longer and 873 m shorter steps at the edge of mine infrastructure relative to movements at 30 km. At 1-hour intervals significant differences in step length were observed in all seasons except post-rut; all differences were between 64 m longer and 18 m shorter steps.

A similar pattern was observed in turning angles. While Poole et al. (2021) used 60° as a threshold of concern for turn angles, the results of analyses showed that only male and female caribou 8-hour movements in rut and post-rut had mean turn angles below or near this reference threshold at 30 km from the nearest mine infrastructure. There was no season for either sex where 1-hour interval movements had mean turning angles less than 70° at 30 km from mine infrastructure. At the 8-hour interval scale, for female caribou, turn angles at the edge of the mine were more extreme by between 8° and 21° (depending on season) than at 30 km, results that are significant statistically, though the amount of variance explained was low ($R^2 \leq 0.02$) in all cases. Male 8-hour interval turning angle analyses yielded three statistically significant results: more extreme turns closer to mine edge in spring migration and post-rut, and less extreme turns during summer.

In this report, the effects of exposure to the Ekati/Diavik halo on total seasonal movement path and delayed arrival in the 90% UD for the next season were adopted as measures to assess the effect of proximity to mines on seasonal caribou movement. Owing to different season lengths for each of the Beverly and Bathurst herds, movement paths were measured for each herd by sex by season. Ten of the 36 cases had statistically significant results, four with positive slopes (i.e., longer exposure in the halo yielded longer total seasonal movement paths), and six had negative slopes (longer halo exposure yielded shorter movement paths in the season).

The only significant effects of Ekati/Diavik halo exposure on delayed arrival in the next seasonal range were that female caribou that did not have any locations in the halo were more likely to be delayed on their arrival on late summer and pre-rut seasonal ranges. There was no season where spending time in the Ekati/Diavik halo made it more likely for animals of either sex to be delayed in arriving in the seasonal range for the next season.

Ecologically, the concerns of exposure to diamond mining infrastructure and roads yielding deflected, longer movements and delays in range-scale movements do not appear to be warranted. Four of 36 sex by season by herd seasonal pathway length comparisons showed significantly longer pathways related to encounter times in the Ekat/Diavik halo, compared with six of 36 comparisons showing significantly shorter seasonal pathways, and 26 of 36 showing no significant differences. Regardless of what individual pathways and movement patterns are, caribou encountering the Ekati Diamond Mine are not typically travelling farther than animals that do not encounter the Ekati/Diavik mine complex, nor are they delayed in arrival on their subsequent seasonal range.

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DATA ANALYSIS FLOWCHART

TELEMETRY LOCATION DATA

GNWT Radio-telemetry data from Bathurst and Beverly herds

Report Sections 2.3, 2.4.1, and 3.1

- coded for season
- duplicates by animal x date and time removed
- outlier movements removed
- screened for minimum time interval between locations
- distribution and abundance of data through time reviewed
- data reduced to December 2015 to December 2022

-only data collected at 00, 01, 02, or 03 minutes of any hour retained

-used to create (1) single location per animal per day data set; (2) 8-hour interval data set; and (3) 1-hour interval (geofence) data set

1-hour interval (geofence) location data

Restricted to radio-telemetry data in geofence 112 north of 64.2° collected on 1-hour time intervals.

See 1-hour interval processing page 3

Single location per animal per day location data

Report Sections 2.4.2, 2.4.3, and 3.2

-Screened for required minimum number of locations per animal in each season (for inclusion required locations on ≥75% of days in animal-season)

-Data pooled across animals and then divided by season x year x sex x herd combinations

- Pooled data used to calculate 90% UD (season x year x sex x herd)

-e.g., 2017 calving season data for all Bathurst female caribou pooled to yield a single 90% UD Maps in Appendix B

8-hour interval location data (collected at 0000h, 0800h, 1600h UTC)

8-hour interval location data (collected at 0000h, 0800h, 1600h UTC)

<u>Spatial screening</u>

Report Sections 2.7 and 3.3

-Intersected with regional study area (RSA) boundary. Data outside boundary were removed.

<u>Movement Steps</u>

Report Section 2.8.1.1

-movement steps analysed for each animal in each season in each year (animal-season)

-steps where prior-interval movement = 0 were removed

-data from animals with <20 steps in an animal-season were removed

-data processed in R package amt. Step interval set to 8 h ± 6 minutes. Turn angles fit to Von Mises distribution, steplength fit to Gamma distribution

-Based on the turning angle and steplength distributions for the animal-season, 5 random (FALSE) steps created to match each real (TRUE) step for each animal. Each matched set of one TRUE and five FALSE records became a stratum for analysis. Each stratum of six records was kept together throughout analyses.

See 8-hour locations + covariates Page 4

8-hour interval location data and 90% UDs

Report Sections 2.9.2 and 3.10.2

- Intersected each 90% UD with relevant 8-hour interval data (herd x sex x season x year) to determine arrival time of each animal on the 90% UD range

8-hour interval location and step length data

Report Sections 2.9.1 and 3.10.1

-Screened for minimum number of locations per animal in each season (for inclusion required locations on ≥90% of possible locations for the season)

-Intersected animal-season locations with 30 km Ekati/Diavik halo to determine total steps ending in halo

-Determined total pathway length for each animal-season as sum of animal-season 8-hour step lengths

-Regressed total seasonal pathway length on number of locations in halo for each herd x sex x season x year Graphs in Appendix J

ENVIRONMENTAL COVARIATE DATA

Landcover data
Report Sections 2.5.1, 3.4.1
- several landcover data sets examined
- study area delineation and landcover considered simultaneously
- Regional study area defined
- LC2009 and LC2000(ETM+) combined to provide landcover
- Landcover classes grouped and merged across the two coverages
- six categories defined

Topographic, esker, and hydrological data
Report Sections 2.5.2, 3.4.2
- elevation and slope data from Canada Digital Elevation Model
- waterbody areas and land/water edge from CanVec hydrographic features data layer
- eskers defined as 200 m wide polygons centred on esker linear features in 1:50,000 UTM Canada topographic map series

Human development data
Report Sections 2.6.2, 3.4.2
- polygon coverages of Ekati and Diavik mines

-Tibbitt to Contwoyto Winter Road shapfile
- Additional mines, exploration sites, developments from GNWT as compiled for Bathurst Caribou Range PLan

Regional Study Area environmental attribute characterization
Report Sections 2.5.2, 2.5.3, 3.4.2, 3.4.3
- 3.1-ha hexagon grid was superimposed on the study area

For each 3.1-ha hexagon, the following were determined:
- proportional areas covered by each landcover class, eskers, and waterbodies
- total linear water/land edge
- mean elevation
- mean slope

Each 3.1-ha hexagon then had each of the attributes listed above calculated at three additional, nested, coarser grains through spatial averaging. This characterized proportional coverage, land/water edge, elevation, and slope at concentric areas of 59-ha, 524-ha, and 5137-ha centred on each 3.1.-ha hexagon.

Each 3.1-ha hexagon had the following determined:
- distance to nearest Ekati mine road
- distance to nearest infrastructure > 10 ha (this includes all of Ekati and Diavik mine infrastructure plus other mining and exploration data for the study area)
- distance to nearest point on winter road

See 1-hour interval processing page 3
See 8-hour locations + covariates Page 4

Insect harassment covariate data
Report Sections 2.6.1, 3.4.2

-set of assessment area polygons provided by CARMA

-sets of daily mosquito and oestrid insect harassment index values provided for each assessment area

-Intersected 8-hour interval locations for each herd x sex x season x year data set with the set of CARMA assessment area polygons and selected the best spatial fit for that herd x sex x season x year data set.

-bound the mosquito and oestrid daily IHI value to each 8-hour and 1-hour record

See 1-hour interval processing page 3
See 8-hour locations + covariates Page 4

1-HOUR INTERVAL PROCESSING

1-hour interval (geofence) location data (from page 1)

<u>Spatial screening</u>
-Previously screened to within geofence area 112 North of 64.2°N

<u>Temporal screening</u>
-Calving and post-calving season data were excluded

<u>Movement Steps</u>
Report Section 2.8.1.2
-movement steps analysed for each animal in each season in each year (animal-season)
-steps where prior-interval movement = 0 were removed
-data from animals with <20 steps in an animal-season were removed
-data processed in R package amt. Step interval set to 8 h ± 6 minutes. Turn angles fit to Von Mises distribution, steplength fit to Gamma distribution
-Based on the turning angle and steplength distributions for the animal-season, 5 random (FALSE) steps created to match each real (TRUE) step for each animal. Each matched set of one TRUE and five FALSE records became a stratum for analysis. Each stratum of six records was kept together throughout analyses.

<u>Regional study area environmental covariates</u> (from page 2)
Section 2.8.2
-Covariate data from the 3.1 ha hexagon containing the step end point were bound to each TRUE and FALSE step. These include landcover, topography, distances from nearest mine infrastructure, mine road, winter road.

<u>Insect harassment covariate data</u> (from page 2)
Section 2.8.4
-The two IHI values were bound to each to each TRUE and FALSE step.based on sex, herd, and date.

<u>Input data characteristics based on previous steps:</u>
-There is a separate data file for each of the seven seasons
-Both sexes included in each data file
-Beverly and Bathurst data combined in each data file
-All years combined in each data file
-Data files consist of sets of 1-hour step intervals with 1 TRUE step (the actual animal movement) and 5 FALSE steps (random movements from the same starting point

<u>Data reduction to limit individual animal influence</u>
Section 2.8.8.1
-animals with greater than the median number of step for an animal-season were systematically reduced to the median number of steps

<u>Pre-analyses covariate transformation, scaling, squaring</u>
Section 2.8.3
-Landcover covariates for all records were logit transformed and z-normalized. Squared versions of the transformed and normalized data were added as additional covariates.
-Movement step covariates were transformed
-Some landcover interaction terms were added

<u>Separation into train and test data sets</u>
Section 2.8.4
-Male and female data were separated from each other and then the dataset for each sex was randomly divided into train (70% of the data) and test (30% of the data) datasets for analyses.
-In separating seasonal data into train and test data sets, entire animal-seasons of data were kept together. I.e., all data from a single animal in a single year for that season was assigned to either the test or train data set and was not divided between them.

See Phase 3 Analyses page 6

8-HOUR LOCATIONS + COVARIATES

8-hour interval location data (from page 1)

Regional study area environmental covariates (from page 2)
Section 2.8.2, 3.5
-Covariate data from the 3.1 ha hexagon containing the step end point were bound to each TRUE and FALSE step. These include landcover, topography, distances from nearest mine infrastructure, mine road, winter road.

Insect harassment covariate data (from page 2)
Section 2.8.4
-The two IHI values were bound to each to each TRUE and FALSE step.based on sex, herd, and date.

Pre-analyses covariate transformation, scaling, squaring
Section 2.8.3
-Landcover covariates for all records were logit transformed and z-normalized. Squared versions of the transformed and normalized data were added as additional covariates.
-Movement step covariates were transformed
-Some landcover interaction terms were added

Spatial screening
Section 2.8.4
-8-hour interval data from inside 30 km GK buffer or other development 5 km buffers were excluded from all habitat selection analyses
-8-hour data from outside the Ekati/Diavik 30 km halo were moved forward to phase 1 analyses.

-8-hour interval data inside the Ekati/Diavik 30 km halo were removed and reserved for Phase 2 analyses.

See Phase 2 Analyses page 5

Phase 1 SSA (8-hour interval regional study area)

Separation into train and test data sets
Section 2.8.4
-Male and female data were separated from each other and then the dataset for each sex was randomly divided into train (70% of the data) and test (30% of the data) datasets for analyses.
-In separating seasonal data into train and test data sets, entire animal-seasons of data were kept together.
-All analyses were conducted separately for each season x sex data set.

Step 1. Landcover covariate reduction
Section 2.8.5.1
-Generalized boosted regression models applied to herd (factor) and landcover and topography variables.
-Covariates with relative influence ≥ 1.0 passed on to StepAIC analyses.

Step 2. Initial candidate model development and assessment
Section 2.8.5.2, 2.8.5.3, 3.6,
-StepAIC glm modelling process applied to create a candidate top model for landcover and topography.
-StepAIC top model covariates used as base for other candidate models.
-Competing conditional logistic regression models were run with train data then compared with AIC, identifying the top model for each sex x season
-For four seasons, added models with interaction terms including mosquito index values and oestrid index values.
-Following addition of insect models, competing models were then re-run with train data and compared with AIC, identifying the top model for each sex x season combination
-The top model for each season was moved forward as the Step Selection Function and used to predict relative habitat selection value for Phase 2 analyses.

See Phase 2 Analyses page 5

PHASE 2 ANALYSES

8-hour interval integrated Step Selection Analyses

-The iSSA inside the Ekati/Diavik 30 km halo did not include calving and post-calving seasons for either sex

Step 1. Relative habitat selection value from SSF

Section 2.8.6.1, 3.6

-For each sex x season the relative habitat selection value was predicted for each hexagon using the SSF equation from the Phase 1 analyses

Step 2. candidate model development and assessment

Section 2.8.6.2, 3.7,3.8

-the SSF predicted habitat value was used together with movement covariates became the base model for other candidate models.
-Other candidate models created with distance-to-feature covariates
-Competing conditional logistic regression models were run with train data then compared with BIC, identifying the top model for each sex x season
Top model selected as the iSSF for the sex by season

Candidate model evaluation tables in Appendix E
iSSF (top model) covariates and coefficients in Appendix F

PHASE 3 ANALYSES

1-hour interval Step Selection Analyses and integrated Step Selection Analyses

Step 1. Landcover covariate reduction

Section 2.8.5.1, 2.8.8.2

-Generalized boosted regression models applied to herd (factor) and landcover and topography variables.

-Covariates with relative influence ≥ 1.0 passed on to StepAIC analyses.

Step 2. Initial candidate model development and assessment

Section 2.8.5.2, 2.8.6.2, 3.9.1

-StepAIC glm modelling process applied to create a candidate top model for landcover and topography.
-StepAIC top model covariates used as base for other candidate models.
-Competing conditional logistic regression models were run with train data then compared with AIC, identifying the top model for each sex x season
-For four seasons, added models with interaction terms including mosquito index values and oestrid index values.
-Following addition of insect models, competing models were then re-run with train data and compared with AIC, identifying the top model for each sex x season combination
-The top model covariates for each season were moved forward base landcover model for integrated Step Selection Analyses (iSSA)

Step 3 iSSA

Section 2.8.8.3, 3.9.2

-top SSA model covariates for each sex x season used as base landcover for other candidate models.
-Candidate models created with distance-to-feature covariates
-Competing conditional logistic regression models were run with train data then compared with BIC, identifying the top model for each sex x season
Top model selected as the iSSF for the sex by season

Candidate model evaluation tables in Appendix G
iSSF (top model) covariates and coefficients in Appendix H