APPENDIX G.23

Caribou Monitoring Triggers and Recommendations Report

MARY RIVER PROJECT
Caribou Monitoring | Triggers and Recommendations

Prepared For
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ENVIRONMENTAL DYNAMICS INC.
Down to Earth Biology

EXECUTIVE SUMMARY

Background — The Mary River Project (the Project) is within the North Baffin Island caribou range. These caribou have shown cyclical fluctuations in their abundance (i.e., the total number of individuals within the subpopulation) and are currently at a period of low abundance. As per Project permitting requirements, monitoring is conducted to evaluate the Project's potential impacts on caribou. Recently, representatives for governments and community harvesters — comprising the members of the Project's Terrestrial Environment Working Group (TEWG) who provide oversight/review, commentary, and guidance related to Project effects mitigation and monitoring activities — expressed concern about the Project's approach to caribou monitoring and its ability to identify potential Project-related effects. Central to this concern is (1) whether Project infrastructure (e.g., roads) represent a barrier to caribou movement and (2) to what extent Project features/activities may result in indirect habitat loss (i.e., due to access or avoidance).

Approach — In response to the TEWG's input, EDI Environmental Dynamics Inc. (EDI) was retained to develop a study design to address these questions and concerns. Collar data from 2008–2011 were used to assess the feasibility and requisite subpopulation size (or density) of caribou required for a future collaring program with statistically robust data to inform the key questions. The Government of Nunavut provided GPS collar data (2008–2011) for the North Baffin Island caribou subpopulation. Those data were collected when caribou were actively harvested along the Tote Road (built in the late 1960s) and during road improvements and bulk sampling for the Mary River Project. The data do not apply to the current Project, which includes the mining and transport of up to 6 million tonnes of iron ore.

Key Findings — The 2008-2011 collaring data analysis demonstrated that individual movement patterns were variable, and migratory movements were not predictable. Until North Baffin Island caribou reinitiate migratory behaviour (expected to occur once caribou numbers increase), statistically meaningful telemetry-based monitoring of the Project's potential impact on caribou movement between seasonal ranges is not achievable. Still, the spatial and temporal nature of the data provided an opportunity to assess indirect habitat loss in low use (northern) versus 'control' (unconstructed, southern) transportation corridors. Seasonal 'base' habitat models were created and extended to test for zones of influence (ZOI). A ZOI was detected for the northern transportation corridor, but its magnitude and extent depended on the scale of the analysis. The result highlights the need to analyze location data only from individual caribou interacting with a development footprint. Without considering this potential interaction, unlikely ZOIs could be statistically detected that are not biologically relevant to caribou interactions and, thus, misinform mitigation efforts.

Conclusions — Results of this assessment show that a sample of 35 collared caribou per year is most likely required for a study informing potential Project impacts on caribou. The collaring program and analyses require at least 350 caribou, or 35 groups, to be present within the study area(s). The assessment also confirms that resources are best directed towards ongoing surveillance monitoring until caribou density increases in the study area(s).

Note: This report is presented in two sections: the report's main body summarizes key investigative themes and findings with limited technical details; the second part, presented in Appendix A, supports the report's main body (methods, results and discussion) with further technical detail.

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1 INTRODUCTION

The Mary River Project (the Project) is an iron ore mine located on North Baffin Island, Nunavut, owned/operated by Baffinland Iron Mines Corporation (Baffinland). The Project refers to the construction, operation, closure and reclamation of a 22.2 million tonne per annum (mtpa) open-pit mine having an expected 21 years life-of-mine. Construction of the Project and associated facilities started in 2013, and mining began in September 2014. As part of Project approval, the Nunavut Impact Review Board (NIRB) Project Certificate No. 005 outlines numerous conditions requiring Baffinland to monitor terrestrial environment effects. Monitoring of the terrestrial environment is guided by the Terrestrial Environment Mitigation and Monitoring Plan (TEMMP; Baffinland Iron Mines Corporation 2016); oversight is provided by the Terrestrial Environment Working Group (TEWG) comprising discipline experts, government representatives, and rights holders. Terrestrial environment monitoring began in 2012, and adaptive modifications to monitoring activities at the Project have been applied to the TEMMP since this time.

Barren-ground caribou (*Rangifer tarandus groenlandicus*) have been identified as a key species of interest to the local/regional Inuit Community and, therefore, are a focus for terrestrial environment monitoring. That said, caribou are currently at a historical low in their population cycle (Savikataaq 2020); consequently, population densities are too low to evaluate Project-related effects effectively. Since operations began, few-to-no caribou have been observed near the Project. As caribou numbers are currently too low for impact monitoring, a numerical 'trigger' has yet to be established to identify caribou densities required for an effective study. In the interim, caribou observations collected via Baffinland's surveillance monitoring program presently inform caribou distribution in proximity to the Project. Baffinland has implemented height-of-land and road surveys to collect data on the local distribution of caribou relative to the Project. This information is then supplemented by motion-triggered camera monitoring initiated in the late-summer of 2021 to broaden data capture.

Recently, representatives for governments and community harvesters (comprising the members of the TEWG) expressed concern about the Project's approach to caribou monitoring and its ability to identify potential Project-related effects. Central to this concern is (1) whether Project infrastructure (e.g., roads) represent a barrier to caribou movement and (2) to what extent Project features/activities may result in indirect habitat loss (i.e., due to access or avoidance). Building from ongoing monitoring activities at the Project (described above), the objectives of this report are to develop a study design that addresses these questions and concerns and establish a numerical 'trigger' to identify caribou densities required for an effective study.

Note: This report is presented in two sections: the report's main body summarizes key investigative themes and findings with limited technical details; the second part, presented in Appendix A, supports the report's main body (methods, results, and discussion) with further technical detail. Study objectives and preliminary results were first presented to the TEWG (June 24 and December 10, 2020). A draft of this report was provided to the TEWG on October 6, 2021. Written comments were received from the Qikiqtani Inuit Association (QIA) and the Government of Nunavut (GN) on December 3, 2021. This report incorporates feedback received during those meetings and a response to the written comments, where relevant. Detailed responses to comments on the draft report are provided in Appendix B.

2 BACKGROUND, STUDY APPROACH AND RATIONALE

2.1 NORTH BAFFIN ISLAND CARIBOU

Understanding of North Baffin Island caribou subpopulation ecology is currently incomplete. Nevertheless, efforts have taken place to estimate the subpopulation size (Ferguson and Gauthier 1992, Campbell et al. 2015), composition (Pretzlaw 2016, Ringrose 2018), spatial distribution (Jenkins and Goorts 2011), and habitat selection (EDI Environmental Dynamics Inc. 2012). Other studies have focused primarily on the Baffin Island caribou population as a whole or the other more southerly subpopulations (Kelsall 1949, Tener and Solman 1960, Macpherson 1963, Kraft 1984, Ferguson 1989).

The distribution of the northern subpopulation and habitat use is informed by telemetry datasets (from 1987–1994 and 2008–2011) provided by the GN. It is evident from these data that the subpopulation's density dictates the spatial distribution of caribou on North Baffin Island. These caribou are currently different in their behaviour and ecology from most barren-ground herds. The subpopulation does not presently exhibit clear patterns of directed migration, has no distinct seasonal ranges, and moves little overall (i.e., median rate = 1.1 km/day). Their movement is so limited that some caribou have contracted ranges that they occupy during all seasons (Campbell et al. 2015). The pattern of changing range use as a function of caribou density is evident when comparing caribou location densities (95% seasonal utilization distributions) of earlier telemetry data (from 1987–1994), when caribou were more abundant, to the more recent telemetry data (from 2008–2011).

The North Baffin Island subpopulation of caribou was relatively large in the past, and estimated to be 50,000–160,000 caribou in 1991 (Ferguson and Gauthier 1992). Although this population estimate was speculative and lacked robust statistical methods, a steep decline in size and density has been evident since then. The most recent estimates of density and population size for caribou in the Mary River area (39,357 km^2) were 5.7 caribou/1,000 km^2 or 224 caribou in total (95% confidence interval [CI] = 96–521), respectively, based on a 2014 aerial survey (Campbell et al. 2015). Such low densities resulted in a moratorium on caribou harvest for the northern subpopulation (Government of Nunavut, Department of Environment 2014). Most of the caribou observed during the 2014 survey were recorded either south of the deposit or further southeast towards the central Baffin Island subpopulation. Recently, the GN identified the caribou population cycle (occurring at periods of 50–90 years) as present across all of Baffin Island and assessed the current status of the population as in a 'Red Phase,' which is described by abundances <10% of the expected peak (Government of Nunavut 2019). The previous Red Phase was estimated to span approximately 30 years, from 1935 to 1965.

Caribou densities tend to be proportional to the land's net primary productivity (COSEWIC 2016). The densities of North Baffin Island caribou are much lower than those of Central and South Baffin Island caribou (i.e., 2.18 caribou/1,000 km^2 compared to 19.5 caribou/1,000 km^2; Campbell et al. 2015) is likely due to lower productivity and less vegetation cover on north Baffin Island. The two other subpopulations exhibit different movement types and broader spatial coverage consistent with their relatively higher densities and available forage (Campbell et al. 2015). The greatest density estimate of Baffin Island caribou was on Prince Charles Island (i.e., 169.30 caribou/1,000 km²), with a caribou density approximately 100 times greater than found in the Mary River area.

The densities of other barren-ground caribou subpopulations are provided in Table 1 for comparison to put the density of North Baffin Island caribou into perspective. Evidence suggests that population density and migration are linked. For example, the Dolphin and Union subpopulation migration across the Coronation Gulf seems associated with changes in population density. Dolphin and Union caribou stopped migrating to mainland Nunavut during a previous population low, then resumed migrating when the population started to recover and increase in density (COSEWIC 2018).

Table 1. Densities of barren-ground caribou subpopulations in Canada.[1]

Subpopulation	Location	Density (# caribou/1,000 km²)	Source
Bathurst	NWT	7,000–203,000	Gunn et al. 2012
Beverly	NU	3,500	Campbell et al. 2012
Ahiak	NU	1,200	Campbell et al. 2012
Dolphin and Union	NWT/NU	542	Dumond et al. 2013
Prince Charles Island	Baffin Island, NU	169	Campbell et al. 2015
South Baffin[2]	Baffin Island, NU	12	Campbell et al. 2015
North Baffin	Baffin Island, NU	2	Campbell et al. 2015

[1] This table is not meant to serve as an exhaustive account of all barren-ground subpopulations; examples are provided for relative comparisons.
[2] Density estimate excludes Prince Charles Island caribou density (combined = 19 caribou/1,000 km²).

2.2 EFFECTS MONITORING AND MITIGATION

Many factors can impact caribou habitat availability and movement, including human presence, harvest, climate, forage and predator abundance, and industrial development (e.g., mining). Potential impacts of industrial development activities can be quantified by assessing the area surrounding a project's footprint where caribou behaviour, specifically, habitat avoidance, is expected to be altered. A standard approach is to quantify this zone of influence (ZOI) and determine the total 'indirect habitat loss' from avoidance behaviour. However, there is considerable variability in the size and magnitude of ZOIs due to differing methods of data collection and analysis (e.g., Boulanger et al. 2012, Johnson and Russell 2014, Baltensperger and Joly 2019, Johnson et al. 2020). There are also potential technical and conceptual flaws in how ZOIs are addressed. Bajina et al. (2021) discussed these topics at the 18th North American Caribou Workshop and demonstrated through a literature review (28 articles) that most investigations of ZOIs lack an understanding of mechanisms and do not explicitly consider the effect of different spatiotemporal scales on the estimates derived. For example, investigating different spatial extents using the same telemetry data can result in vastly different ZOI distances and magnitudes of avoidance (Bajina et al. 2021). More importantly, it is unclear how one may infer population-level effects from individual-level behavioural responses without identifying and measuring ecologically relevant mechanisms.

Caribou movement has also become one of the focuses for northern mining projects because these projects interact with subpopulations that conduct long-distance, directional migrations between calving and wintering grounds. For example, the Ekati and Diavik diamond mines put considerable resources towards monitoring and mitigating effects on caribou because the projects are located directly within the migratory path of the Bathurst subpopulation. The Beverly and Ahiak subpopulations also interact with those mines in some years. Recently, an all-weather access road linking the Meadowbank Mine to Baker Lake, and the newer Whale Tail haul road linking the Whale Tail deposit to the Meadowbank Mine, has served as a case study for expanding methods of analyses and monitoring (Boulanger et al. 2020). Movement analyses have included quantifying delays and deflections/failures in road crossings for caribou. Studying the changes in caribou habitat use and movement related to human developments provides information that can be used to reduce human impacts on caribou.

Monitoring and Mitigation at the Mary River Project

Baffinland developed a TEMMP as part of the initial project submission to NIRB in 2012. The TEMMP is a document that is updated regularly as new information becomes available. The plan guides actions to reduce the Project's potential risk on the terrestrial environment, including caribou. The plan also prescribes the work Baffinland does to monitor the Project's possible effects. A monitoring framework provides the basis and structure for all monitoring work completed by Baffinland. The framework (Figure 1) includes three interrelated study categories:

1. Baseline Research — referring to studies that address information gaps and inform surveillance or monitoring programs.
2. Surveillance Programs — intended to acquire information on the occurrence of key indicators interacting with the Project.
3. Effects Monitoring Programs — designed to address and quantify the causal relationships between the Project and key indicators.

Baffinland has focused efforts on caribou-related surveillance programs and habitat monitoring. Surveillance programs include the annual height-of-land (HOL) and snow tracking surveys to document caribou occurrence near the current Project footprint. Incidental observations of caribou on or near the Project footprint are also included under the surveillance program. Habitat monitoring includes studying dust deposition and metals uptake on caribou forage and investigating the Baffin Island caribou population cycles through Inuit Qaujimajatuqangit (IQ) interviews. The work completed under the TEMMP monitoring framework is reported annually to the NIRB.

A monitoring program (as defined in Figure 1) to study the Project's potential effect(s) on caribou has not yet been initiated. TEWG members have asked Baffinland when monitoring Project effects on caribou movement, and indirect habitat loss will begin. This question is addressed through the analyses, discussion, and study design recommendations presented in this report.

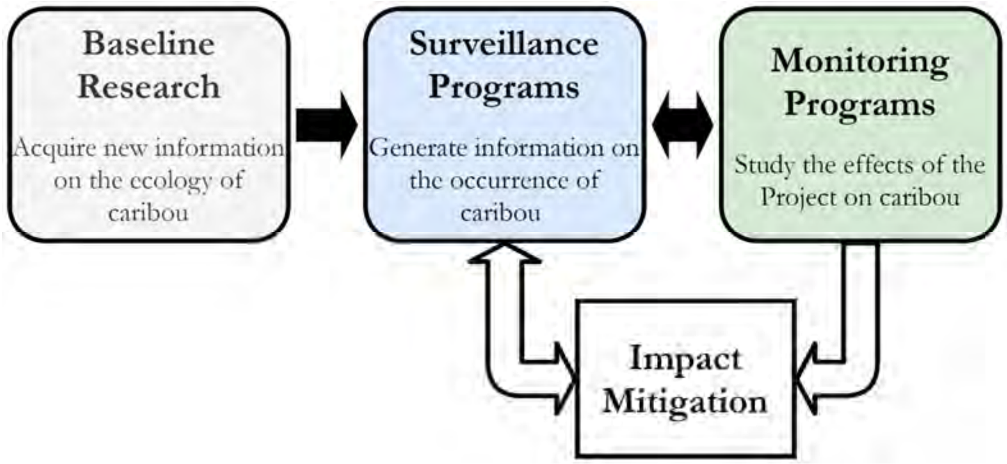


Figure 1. Effects monitoring categories (as described in the TEMMP).

2.3 APPROACH AND RATIONALE

This report focuses on developing a study design for a future impact monitoring program that would address two essential questions:

1. Does Project infrastructure (e.g., roads) represent a barrier to caribou movement?
2. Do Project features/activities result in indirect habitat loss (i.e., due to access or avoidance)? If so, to what extent?.

A critical review of studies that addressed movement and indirect habitat loss for caribou in similar settings provided the basis for the assumptions in this report (see Defining Potential Impacts, below; also, see Appendix A). The assessment considers the context of North Baffin Island caribou subpopulation's ecology when providing recommendations for a monitoring study. Key assumptions derived from a review of the literature included (a) that barriers to movement are only ecologically relevant during migration, (b) that avoidance behaviour corresponds with indirect habitat loss, and (c) the potential for caribou to interact with the Project is dependent on subpopulation size and density.

A collaring program for caribou using Global Positioning System (GPS) technology, or similar data that provides frequent fixes and good location accuracy, was deemed to provide an appropriate data capture to meet monitoring objectives. Hence, historical caribou collar data (from 2008–2011) on North Baffin Island was used to gain insight into local caribou movement, range use, and habitat selection, thereby informing the study design of a future monitoring program. These data were used to investigate: (1) the appropriate sample size for a monitoring program (defined as the number of collared caribou per year); (2) the spatial bounds of the study area and the sampling protocol; and (3) the procedures to statistically assess a response and, ultimately, quantify an ecologically relevant impact across spatial scales pertinent to management decisions.

The spatial and temporal nature of the data provided an opportunity to assess movement barriers and indirect habitat loss in low use (northern) versus 'control' (unconstructed, southern) transportation corridors. The

2008–2011 collar data were collected while harvester and exploration-related activity occurred along the Tote Road. There had been frequent and intermittent use of the Tote Road (built in the late 1960s) by harvesters during the snow-free season and frequent harvester access along the northern and southern transportation corridors during the winter. Upgrades to the Tote Road started in August 2007 through November 2008. Mining of the 113,000-tonne bulk sample started in late 2007, which was trucked up the Tote Road using a fleet of conventional highway tri-axle trucks with pup trailers, was completed by October 2008. During the collar period, other disturbances in the region included that associated with the collaring activity in April 2008 and 2009 (Jenkins and Goorts 2011).

The current approach was thorough in its analyses and critical literature examination. Following the assessment, a study design is presented that will yield useful and meaningful data to Baffinland and reviewing parties. To date, his level of thoroughness has been lacking in the development and implementation of impact monitoring at other existing projects. Though several other projects have included detailed triggers for increased monitoring or mitigation (e.g., Agnico Eagle Mines Ltd. 2019), little focus has been placed on how monitoring triggers or study design requirements were derived to quantify ecologically relevant and statistically detectable effects (e.g., Golder Associates Ltd. 2014, 2017, TMAC Resources Inc. 2017, ERM 2018, Sabina Gold and Silver Corp. 2019). A potential reason for this may be the presence of larger (sub)population sizes and greater caribou densities near these projects, which would eliminate sample size issues. However, the spatial extent of a study area is also a crucial consideration that is not often evaluated explicitly based on regional context (e.g., Golder Associates Ltd. 2014) and may rely on other studies (e.g., 11 km to 14 km; Boulanger et al. 2012).

Additionally, in certain cases, the goals of monitoring programs are not tied to ecologically relevant effects mechanisms. For example, a study at the Meliadine Mine in NWT recorded behavioural observations of caribou to identify disturbance responses (e.g., alert, trotting or running) at different distances from a road (ERM 2021). Still, it is unclear how such behaviours translate to population-level effects, let alone individual fitness (see Section 3.3 in Appendix A for discussion). In contrast, the current work seeks to develop impact monitoring recommendations that provide ecologically relevant information to support useful mitigation.

Defining Potential Impacts

Project-related impacts are typically defined and delineated at local versus regional scales. Local effects refer to potential consequences of direct interaction with the Project footprint; in the present context, this includes harm or injury of individual caribou. Generally, site personnel monitor these interactions through surveillance monitoring such as incidental observations and height-of-land and snow track surveys. They may also be informed by external sources such as hunter observations and aerial surveys. Mitigation is responsive and localized. Regional effects refer to consequences extending beyond the Project footprint; this includes vital rates and demographic trajectory in the present context. Proximate causes of these regional effects (both measurable responses) include avoidance behaviour and (migratory) movement barriers. Both responses can affect caribou access to important life-history requisites, such as food, shelter, refuge from predators, and traditional calving grounds.

Barriers to caribou movement have been a concern of human developments occurring within the ranges of migratory caribou subpopulations for decades (e.g., Klein 1971). The early documented effects of development projects on caribou movement were local in scale and quickly mitigated through design. As technological advancements in telemetry collars allowed the collection of more frequent collar locations, studies documented reduced numbers of caribou crossing than expected (e.g., Dyer et al. 2002), creating new questions about the effects of development on caribou migrations. More methods are now available to analyze increasingly large movement data sets with repeated observations. These analyses are generally conducted for individual caribou movement trajectories (i.e., paths), and few population-level methods exist for analyzing movements (Gurarie et al. 2019). A common measure to identify potential barriers to caribou migration is the delay in crossing development infrastructure. Delays in caribou movement across features have been documented up to 30 days during the fall migration (Wilson et al. 2016) and seven days during spring migration (Boulanger et al. 2020). However, in both these examples, a large number of caribou showed no delay in crossing. The smaller documented delay during spring migration makes biological sense as caribou are moving to calving grounds before they birth calves, making the effect potentially more biologically relevant. Ultimately, it is important to consider ecological context, such as access to forage based on distribution and movements, and the propensity for dispersal in small (sub)populations (Beckmann 2011), when assessing potential barriers in movement to caribou.

Abundant evidence exists for quantifying the indirect loss of caribou habitat due to human developments. The area of reduced habitat quality is commonly referred to as the ZOI, which reflects an area of disturbance beyond the development's footprint (i.e., the regional scale). Quantified effects include a loss of habitat beyond the actual development footprint. For example, a commonly used ZOI for predicting the effects of new or active mines is 14 km (Government of the Northwest Territories 2019), based on an analysis of the Bathurst caribou subpopulation distribution near the Ekati Mine (see Boulanger et al. 2012). More recent analyses of the indirect loss of Bathurst caribou habitat due to the Ekati Mine have shown that the mine's effect is much less clear than a simple distance from the development footprint. Annual variation in biotic and abiotic factors affects the ZOI size, and the ZOI may be undetectable in some years (Boulanger et al. 2021). The mechanisms causing the documented indirect habitat loss are not entirely understood. Still, they are assumed to be from sensory disturbance (see Appendix A for detailed discussion). The ultimate consequences of indirect habitat loss are not fully understood for barren-ground caribou (i.e., population-level changes). There is variation in both natural abundance cycles and the extent of project interactions among subpopulations. The most persuasive evidence of the effect of indirect habitat loss on caribou comes from a study of boreal woodland caribou that applies a buffer to human developments to quantify total disturbance within a caribou range, which is then correlated with the probability of caribou population persistence (Environment Canada 2011). Indirect habitat loss is a well-documented effect of human development on caribou, but the links to mechanisms, consequences and, ultimately, impacts have yet to be determined.

3 METHODS (BRIEF)

This section provides a summary of the methods used in the study. Refer to Appendix A for a comprehensive description of methods, rationale, and assumptions.

Several stages of data preparation and analyses were required to address the key aspects of study design. Initially, an examination of the most recent caribou collar data (from 2008–2011) was conducted to identify seasonal spatial distributions and caribou movement patterns.

Caribou movement at the individual-level was analyzed to explore how caribou move within their range and concerning the low use (northern) and 'control' (unconstructed, southern) transportation corridors. Movement paths (i.e., trajectories) for each of the 30 collared caribou were estimated by year for analysis and visualization. Caribou movement types (Spitz et al. 2017) were classified to describe North Baffin Island caribou movement variation.

Seasonal data were used to develop 'base' habitat models with resource selection functions, which tested resource selection probability based on several environmental covariates (e.g., vegetation cover, elevation, slope, aspect). Base habitat models were then extended to include the partial effects of the low use (northern) and 'control' (unconstructed, southern) transportation corridors — hereafter referred to as ZOI models.

Finally, the initial collar dataset was used in precision-sensitivity (analyses) simulations to identify the sample size of caribou that would yield the greatest precision for identifying effects. The precision-sensitivity analysis was necessary to inform sample size selection for an impact monitoring study design.

All statistical analyses and computer simulations were conducted in R version 3.6.2 (R Development Core Team 2020) and all spatial analyses in a geographic information system, QGIS version 3.10.2 (QGIS Development Team 2020).

4 RESULTS AND DISCUSSION

4.1 MOVEMENT

As described in Section 3 (Methods), collared caribou were classified into four groups. Resident caribou are classified as those that spend their entire year moving within a small area with no clear seasonal patterns in their movement. Migrant caribou are those that complete directional, long-distance movements to occupy different ranges during each season but show fidelity to those seasonal ranges. Mixed-migrants include caribou that move across the landscape without a distinct pattern or unpredictable ways. Caribou that had incomplete movement trajectories (i.e., lacking for an entire year) remained unclassified.

Movement strategies varied substantially among individuals in the North Baffin Island caribou subpopulation. Such variation was also evident for the same caribou among years, i.e., caribou changed their behaviour. The most common type of movement exhibited by caribou reflected resident type behaviour within their individual ranges, but all movement types were observed, including migrant and mixed-migrant behaviour (Table 2). The distribution of the different movement types within the subpopulation range indicates that caribou west of the Project during 2008–2011 were more likely to be migrants and are less likely to switch movement types (Map 1). All caribou west of the Project (that included multiple years of data) remained migrants each year. Caribou east of the Project during 2008–2011 exhibited the greatest variation in movement types among caribou and years. Individual caribou unexpectedly switched between movement types during the three years of study, demonstrating plasticity in movement behaviour.

Compared to other barren-ground caribou subpopulations across northern Canada, the North Baffin Island caribou subpopulation does not exhibit traditional and predictable migratory movements. Some individual caribou show seasonal migratory movements within this subpopulation, while others switch movement strategies among years. Such variation in movement types within individual caribou and among years limits the applicability of standard movement analyses used to study Project-related effects on caribou movement (e.g., biased correlated random walk, which is a method applied to identify changes in expected movement by caribou migrating across mine roads; see Appendix A). While some individuals may interact with the Project and demonstrate movement that permits such analyses, those caribou were only a small proportion of the collared sample. Assuming the 2008–2011 sample of collar data is still reflective of caribou near the Project area, the current low density of caribou and their varied behaviour prohibits collecting an adequate sample size needed to make definitive conclusions about Project effects on seasonal migration movements.

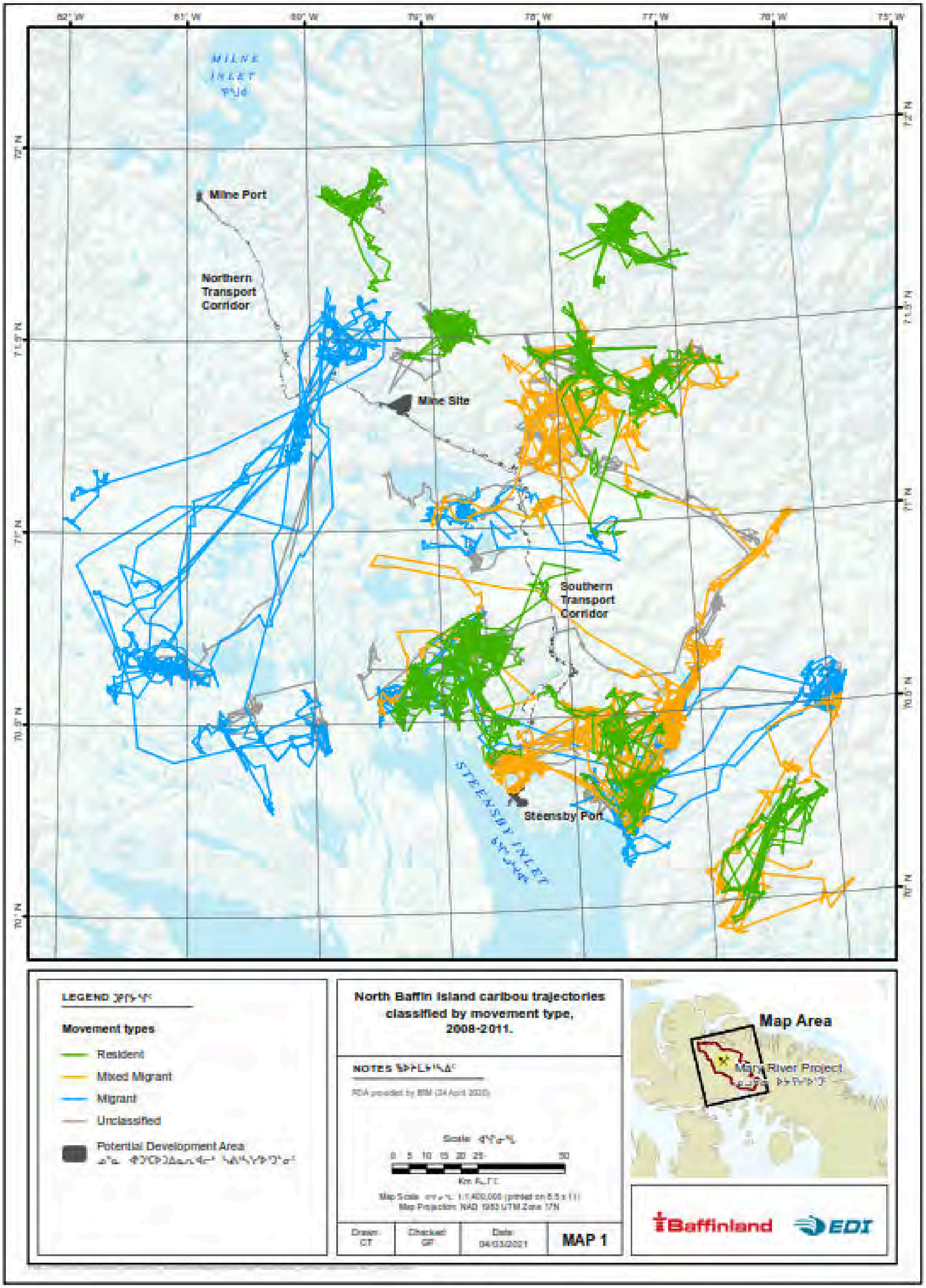
Population size and density affect female fecundity (Pachkowski et al. 2013) and calf-survival (Mahoney et al. 2016) because of competition for food resources (Bowyer et al. 2014). Ultimately, such competition shapes caribou demography and distribution, including range expansion and contraction (Messier et al. 1988, Bergerud 1996, Ferguson et al. 2001, Mahoney and Schaefer 2002, Hinkes et al. 2005, Ricca et al. 2012). Thus, the extent of space-use provides a useful indicator for numerical changes in caribou populations (Schaefer and Mahoney 2013). Because fluctuations (or cycles) in caribou population size and distribution are common (see Hinkes et al. 2005 for examples), there is a reasonable expectation that caribou densities will increase on

North Baffin Island — in accordance with IQ, and with the abundance cycles suggested by the GN (Government of Nunavut 2019). If and when this occurs, caribou ranges are expected to expand until they occupy North Baffin Island's northwestern extent in greater numbers. The analyses above demonstrate that caribou may show directed seasonal migrations once densities increase, given their retained migratory potential.

Table 2. Count of each North Baffin Island caribou movement type by year estimated from locations of 30 collared caribou.

Movement Category	2008	2009	2010	2011	Total
Migrant	1	7	2	–	**10**
Mixed migrant	1	12	2	–	**15**
Resident	–	8	11	–	**19**
Unclassified[1]	–	3	8	13	**24**
Total	**2**	**30**	**23**	**13**	**68**

[1] Unclassified = caribou that died or collars that failed to make the time-series complete.



MILNE INLET
Milne Port
Northern Transport Corridor
Mine Site
Southern Transport Corridor
Steensby Port
STEENSBY INLET
LEGEND
Movement types
Resident
Mixed Migrant
Migrant
Unclassified
Potential Development Area
North Baffin Island caribou trajectories classified by movement type, 2008-2011.
NOTES
PDA provided by BIM (24 April 2020)
Scale
0 5 10 15 20 25 50
Km
Map Scale 1:1,400,000 (printed on 8.5 x 11)
Map Projection: NAD 1983 UTM Zone 17N
Drawn: CT
Checked: GP
Date: 04/03/2021
MAP 1
Map Area
Mary River Project
Baffinland
EDI

4.2 INDIRECT HABITAT LOSS

Resource selection differed between the growing and winter seasons. The Normalized Difference Vegetation Index (i.e., greenness, NDVI) was the most important variable driving resource selection in the growing season. NDVI is an indicator of available forage and is expected to be important during the growing season. In contrast, much of the available forage is covered by snow in winter, so selecting these resources (NDVI) tends to be weaker. Distance to water was the most important variable for winter resource selection; it had the greatest mean effect on the probability of caribou occurrence. Caribou were more likely to occur near waterbodies such as lakes and rivers. This affinity for waterbodies also likely corresponds with a decreased likelihood of occurrence at higher elevations during winter. In winter, snow conditions in some regions can limit caribou use of higher elevations as hardness and depth usually increase. Caribou tend to avoid deep snow because it hinders movement across the landscape and restricts cratering access to ground lichen. Another proxy that may capture the effect of snow is aspect; southern slopes are windswept and snow sparse, while northern slopes tend to accumulate snow. The probability of selection in winter was much higher for southern aspects than northern, and caribou occupied low-to-moderate slopes (i.e., 10–20°) along southern aspects. Because snow is not a contributing factor to resource selection outside of winter, these effects are not seen in the growing season's base habitat model. For example, caribou tended to select mid-to-high elevations (i.e., 400–600 m), at low-to-moderate slopes (i.e., 5–15°), with no apparent aspect preference during the growing season.

When extending base habitat models to develop ZOI models, there was evidence of ZOIs for the low use Northern Transportation Corridor. See Map 1 in Appendix A for an example of how suitable habitat is distributed during the growing season relative to the Northern Transportation Corridor. When considering all known collar locations up to approximately 180 km from the Tote Road (i.e., the full dataset), two peaks in the log-likelihood surface for the growing season were identified: 5 km and 71 km (Figure 2). The greatest statistical support (i.e., the highest log-likelihood) was for the 71 km ZOI around the Northern Transportation Corridor. The odds of caribou being present outside of that boundary were 2.03 times greater than the odds of caribou being present on the road. During the winter season, the greatest statistical support was for a 28 km ZOI around the Northern Transportation Corridor (Figure 3). The odds of caribou being present outside of that boundary were 204.38 times greater than the odds of caribou being present on the road. These results are attributed to very distant, 'resident' caribou with very low movement rates within distinct home ranges.

The importance of scale in the analysis of ZOIs is made clear when considering large-scale gradients in habitat selection (see Appendix A). The marginal effect of distance to the Northern Transportation Corridor was relatively weak within approximately 50 km of the Tote Road's footprint (see Figure 5 in Appendix A). As a result, the data were re-analyzed by including locations only within 50 km of the corridor, and the ZOI was re-estimated. Following this sub-setting of the data, the ZOI estimate decreased to 4 km from the Northern Transportation Corridor (Figure 4). Therefore, the initial peak in the log-likelihood surface at 71 km (Figure 2) resulted from the large-scale spatial segregation of caribou across the landscape. Once the effect of large-scale habitat selection was removed by excluding caribou beyond 50 km, the ZOI distance was estimated to be much closer to the Northern Transportation Corridor. The reduced scale (i.e., within 50 km) for analysis is also supported by the expected movement distances by collared caribou. The average maximum step length for a caribou in the subpopulation was 25 km. Thus, caribou found at extremely far distances (i.e., distances >70 km) from the Northern Transportation Corridor are consistently outside the range needed to receive Project-related cues (or stimuli) of sensory disturbance that can affect habitat use.

The ZOI estimate for winter did not decrease by excluding caribou observations distant (e.g., ≤50 km) from the Northern Transportation Corridor. The ZOI estimate remained at 28 km (see Figure 6 in Appendix A). Thus, the ZOI estimate for winter was 24 km larger than the ZOI estimate for the growing season (i.e., Growing = 4 km and Winter = 28 km). However, under low use of the transportation corridor during the bulk sampling program, there is no reasonable mechanism that would cause such a drastic increase in avoidance of the Northern Transportation Corridor from growing to winter seasons. Potential explanations for the difference in detected ZOIs between seasons may be (1) insufficient sample size within the vicinity of the footprint, (2) insufficient annual collar data, or (3) external factors not considered in the base habitat model that shape habitat selection and subpopulation range at broader scales (e.g., mechanisms that yield different seasonal range use by caribou). For a description and map of the distribution of suitable winter habitat relative to the Northern Transportation Corridor, refer to the FEIS baseline materials (EDI Environmental Dynamics Inc. 2012).

For the unconstructed, 'control' Southern Transportation Corridor (Map 1), ZOIs could not be detected in either season, even with larger sample sizes relative to the analysis of the Northern Transportation Corridor (Growing — North = 3,493 obs., South = 5,564 obs.; Winter — North = 7,102 obs., South = 9,785 obs). During the growing season, caribou would be expected to avoid areas beyond 18 km from the proposed Steensby Rail alignment (Figure 5). Models tested with thresholds beyond this distance consistently had weak support, indicating that caribou were more likely to be in proximity to the corridor than farther from it. The result was expected and thus corroborated the classification of the Steensby Rail alignment as a 'control' for the current investigation because (1) there is no construction or development and limited activity along the Southern Transportation Corridor and (2) the caribou subpopulation range completely overlaps the area.

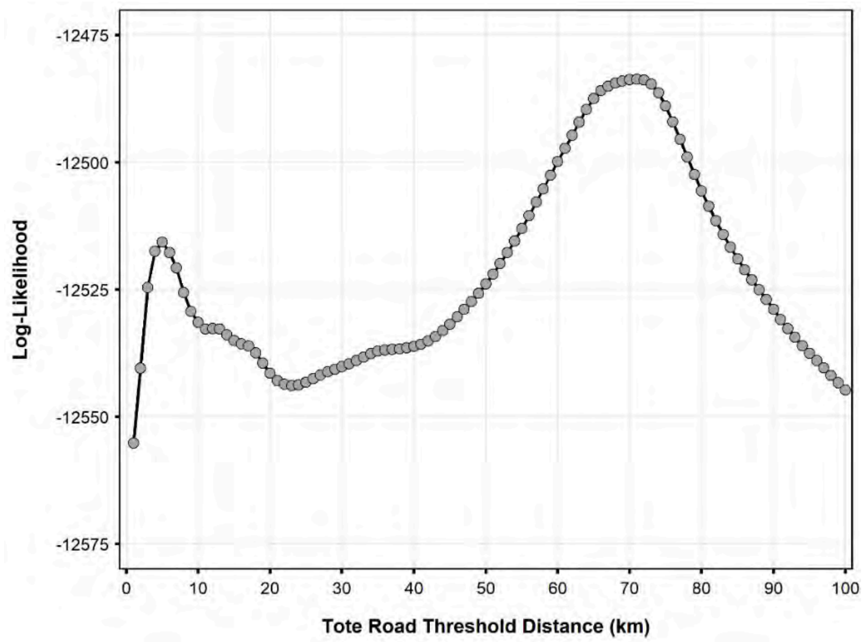


Figure 2. **A segmented regression approach estimates a zone of influence (ZOI) relative to the Northern Transportation Corridor using all collar data during the growing season (i.e., May 26–September 15), 2008 to 2011.**
The threshold distance with the highest log-likelihood value corresponds with the most likely ZOI (i.e., 71 km).

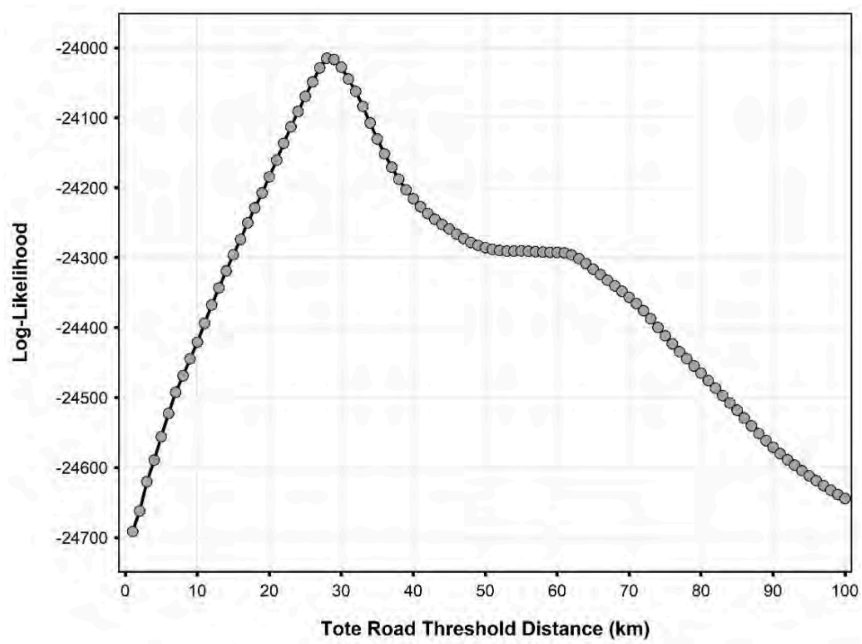


Figure 3. **A segmented regression approach estimates a zone of influence (ZOI) relative to the Northern Transportation Corridor using all collar data during the winter season (i.e., September 16–May 25), 2008 to 2011.**
The threshold distance with the highest log-likelihood value corresponds with the most likely ZOI (i.e., 28 km).

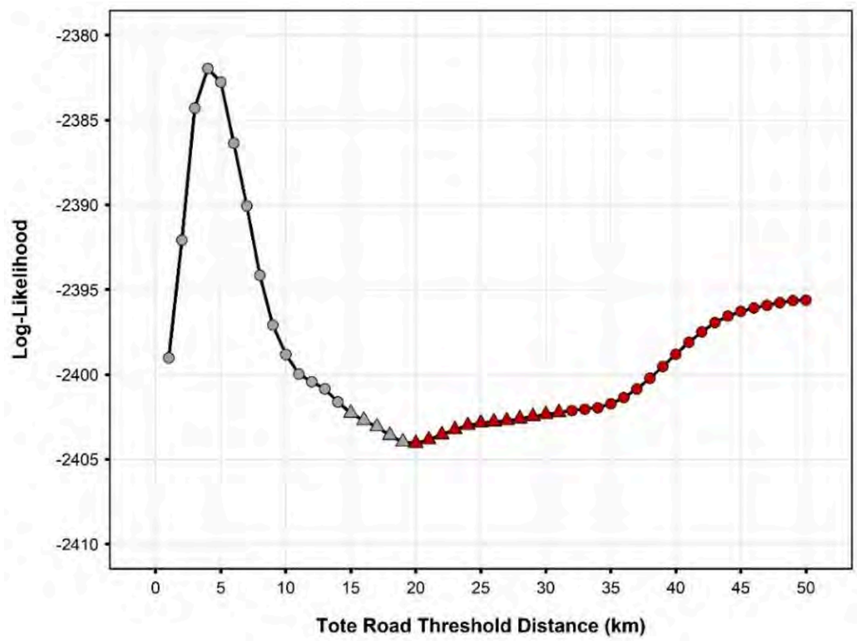


Figure 4. A segmented regression approach estimates a zone of influence (ZOI) relative to the Northern Transportation Corridor using collar data within 50 km of the footprint during the growing season (i.e., May 26–September 15), 2008 to 2011.

The threshold distance with the highest log-likelihood value corresponds with the most likely ZOI (i.e., 4 km). Circles and triangles indicate statistically significant and non-significant ZOI distances, respectively. Grey and red fills indicate positive and negative coefficients, respectively.

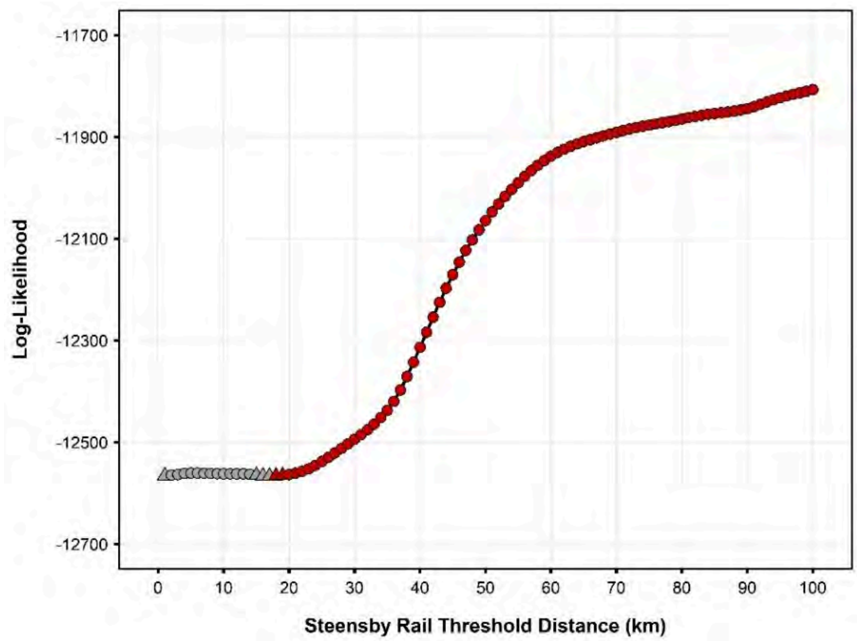


Figure 5. A segmented regression approach estimates a zone of influence (ZOI) relative to the proposed Southern Transportation Corridor using all collar data during the growing season (i.e., May 26–September 15), 2008 to 2011.

Circles and triangles indicate statistically significant and non-significant ZOI distances, respectively. Grey and red fills indicate positive and negative coefficients, respectively. No threshold distance is associated with a ZOI because the probability of selection decreases beyond 18 km, and log-likelihood values increase.

4.3 ESTIMATED SAMPLE SIZE FOR MONITORING

The distribution of ZOI distances and coefficient values produced by 1,000 simulations were assessed for the range of simulated sample sizes of caribou. We used local polynomial regression (LOESS) models to visualize the relationship between the CI widths and the number of collared caribou. The expectation was that CI widths would decrease in size as the sample size increased. The range of caribou numbers corresponding with a relatively 'flat' portion of the curve was then used to determine the appropriate sample size for an impact monitoring study.

Given that resampling relied on the collar data's inherent variation, the final distribution of ZOI distances produced by simulations yielded bimodal shapes for each sample size. The bimodal shape is simply an artifact of the large-scale spatial gradients observed in caribou distribution. The implications of sampling at such broad scales and how it affects the ability to detect indirect habitat loss are discussed in Section 5, Proposed Study Design and Considerations. Regardless, the intent was to determine a reasonable sample size at which the variation in distance estimates would be minimal. Initially, confidence interval widths decreased sharply with greater sample size, but the slope reduced in magnitude at sample sizes greater than 25 collared caribou (Figure 6). In contrast, estimates produced for the ZOI coefficients reduced sufficiently to level-off at a CI width less than one (Figure 7). The LOESS regression predicted this asymptote to occur just beyond 30 collared caribou.

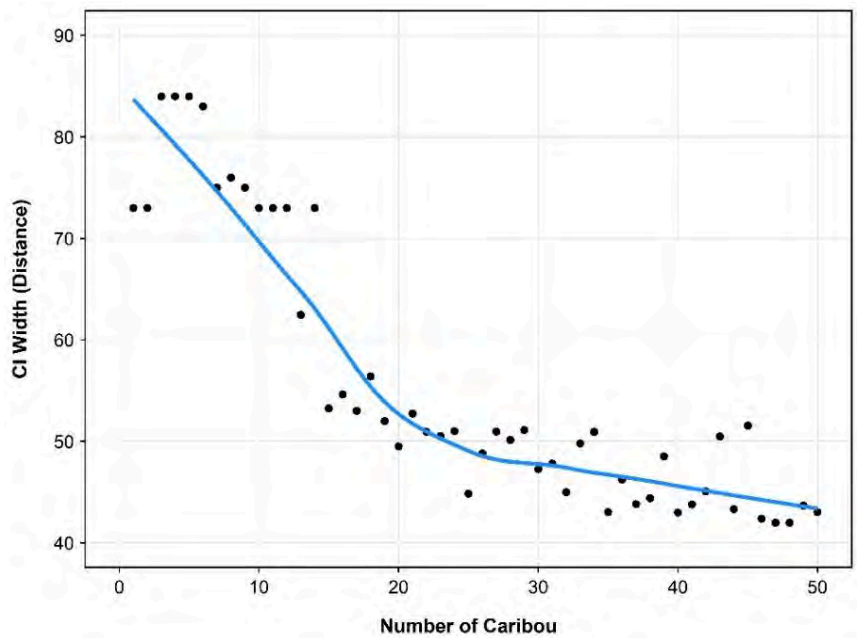


Figure 6. Confidence interval (CI) widths based on distributions of the zone of influence (ZOI) distances selected from 1,000 hierarchical bootstrapping simulations at different sample sizes of collared caribou.
Resampling of collar data for the winter season (i.e., September 16–May 25), 2008 to 2011. The blue line corresponds with the local polynomial regression (LOESS) fit to the data.

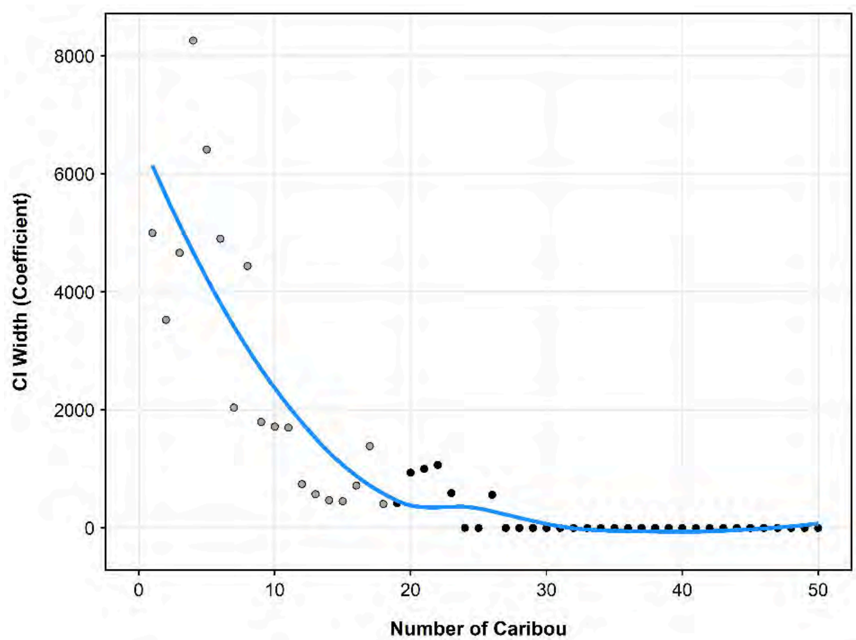


Figure 7. Confidence interval (CI) widths based on distributions of the zone of influence (ZOI) coefficients selected from 1,000 hierarchical bootstrapping simulations at different sample sizes of collared caribou.
Resampling of collar data for the winter season (i.e., September 16–May 25), 2008 to 2011. The blue line corresponds with the local polynomial regression (LOESS) fit to the data. Simulations produced different coefficient signs (+, –) among iterations; the colour of data points corresponds with simulations having at least one negative sign (grey) or all positive signs (black).

5 PROPOSED STUDY DESIGN AND CONSIDERATIONS

The analysis results were used to develop requisite aspects of a study design to inform impact monitoring studies. As mentioned, this study is intended to address (1) whether Project infrastructure (e.g., roads) represent a barrier to caribou movement and (2) to what extent Project features/activities may result in indirect habitat loss (i.e., due to access or avoidance). A key objective is then to establish a numerical 'trigger' to identify caribou densities required for an effective study. Here, a study design is proposed that identifies (a) the appropriate sample size of collared caribou, (b) the spatial bounds of the study area, (c) the distribution of sampling and the procedures to assess a response statistically, and (c) the analytical tools to quantify an ecologically relevant impact across spatial scales pertinent to the Project. Recommendations are provided and supporting discussion/rationale for understanding the Project's impacts on caribou.

5.1 DATA REQUIREMENTS AND TRIGGERS

The precision-sensitivity analysis results provide a range of sample sizes that would facilitate relatively precise estimates of indirect habitat loss. The lower limit to this range was 25 collared caribou for estimates of ZOI distances and 30 collared caribou for estimates of ZOI coefficients. The higher sample size (30 caribou) was used as a conservative starting point for collar sample size selection. In addition to statistical considerations, practicalities were considered to choose a sample size.

Recurring challenges in collaring programs include collar malfunctions, caribou mortality, or long-distance dispersal by caribou outside of the intended study area. With these considerations in mind, 35 collared caribou were identified as the necessary sample size to be deployed and maintained annually to facilitate accurate and precise estimates of ZOI distances and coefficients. The 35 collars are required annually and are not a total quantity for the impact monitoring study duration. A sample size of 35 collared caribou that interact with the Project is near the upper limit of sample sizes reported in other studies of caribou movement across human infrastructure.

For the sample to represent the North Baffin Island caribou subpopulation, there should be at least an order of magnitude difference between the number of caribou in the total population and the number of caribou collared. Therefore, since the sample size is 35 collared caribou, a subpopulation of 350 within a study area would be appropriate.

When presenting the proposed trigger of 350 caribou to the TEWG at the December 10, 2020 meeting, a group member suggested that the number of caribou groups observed may be a more appropriate and flexible indicator. Another group member mentioned that local hunters usually observe groups of ten caribou. Aerial surveys on North Baffin Island documented an average group size of seven caribou (Campbell et al. 2015). Based on the Government of Nunavut's collaring protocol, it is assumed that only one animal per group would be permitted to be collared. Therefore, observing 35 groups of caribou, each consisting of 7–10 animals (as has been observed in this subpopulation to date based on IQ and survey observations), provides an alternative trigger for impact monitoring.

Project-related impacts must be investigated without the negative bias that has plagued previous caribou studies (see Flydal et al. 2018 for discussion). Setterington (2018) discussed the prevalence of negative confirmation bias at the 17th North American Caribou Workshop. Key issues included (1) how behavioural observations are being interpreted as negative impacts without clear, measurable pathways to individual fitness or population-level effects, and (2) the spatial scale of project footprints and predicted effects relative to herd ranges and available habitat across the broader landscape (Setterington 2018). Choice of spatiotemporal scales and their influence on effects assessments (Plante et al. 2020, Bajina et al. 2021 [see Section 2.2]) must also be justified, made transparent, and discussed.

For investigations to be objective, a systematic collection of mine-related variables must be a requirement of a monitoring program, as suggested by Boulanger et al. (2020b). This would preclude speculative claims of Project-related impacts on caribou and, thus, prevent unfounded conclusions that are possibly a result of artificial correlations. Key measures needed to inform on potential Project effects include (1) timing, distance, and quantity of dustfall from the mine site and transport corridors; and (2) timing and relative intensity of activity at the mine site and traffic along transport corridors. These variables can be quantified and assessed in relation to caribou distribution and movement. Specifically, these measures will allow linking changes in sensory disturbance to changes in habitat selection by caribou and the crossing of infrastructure by caribou. Therefore, when impact monitoring studies commence, it will be important to incorporate into analyses several types of data that Baffinland collects annually, such as data on dust dispersion, traffic volume, helicopter overflights, and noise propagation. Investigating these mechanisms will be the only way to identify the cause (i.e., Project-related activity) and effect (i.e., caribou distribution and movement).

To distinguish potentially confounding effects, additional detailed measurements should be collected on non-Project-related variables, such as other human uses (e.g., hunting) and commonly used indices of spatiotemporally varying climatic (e.g., snowfall, drought) and biotic (e.g., caribou density, caribou forage, insect harassment) processes. Hunting may be addressed using data on caribou harvest effort from QIA's Culture Resource and Land Use study; these data can help determine the effect of hunting on caribou distribution. Most climatic data and relevant caribou-related indices can be estimated using NASA's Modern Era Retrospective Analysis for Research and Applications (MERRA) dataset (see Russell et al. 2013 for details). Baffinland's collection of data on caribou forage would also be useful to understanding the spatial distribution of caribou relative to the Project.

To successfully quantify Project-related delays in caribou movement to seasonal parts of their range, caribou must (1) move between discrete seasonal ranges and (2) attempt to cross Project infrastructure and linear features. Without such migrations, infrastructure and linear features pose no ecologically relevant barriers. The analysis of collar data found variation in the types of caribou movement that will limit the usefulness of a movement study at this time. An effective movement study requires migrating caribou and considering the appropriate location and time to deploy collars. Migrants in the 2008–2011 dataset occurred predominantly south and west of the Project, suggesting these are ideal locations to target caribou. As caribou density increases, there is some expectation that caribou may start to exhibit more migratory behaviour (see Section 5.2, Spatial Scale and Study Area). Surveillance monitoring that documents more caribou crossing the Northern Transportation Corridor will increase the potential for successfully studying the Project's impacts on caribou movement. Until caribou are predictably approaching or crossing the Project infrastructure and migrating between seasonal ranges, studying the Project's effect on caribou movement will remain exploratory and secondary to the study of indirect habitat loss.

One caveat to the trigger proposed is that, though current evidence suggests it to be accurate, there cannot be complete certainty as to whether the subpopulation size and density of caribou on North Baffin Island (as a whole) will increase. Thus, if an increase does not occur, but caribou more frequently interact with the Project, or if more recent data becomes available for caribou in proximity to the Project, different options for monitoring Project impacts should be explored.

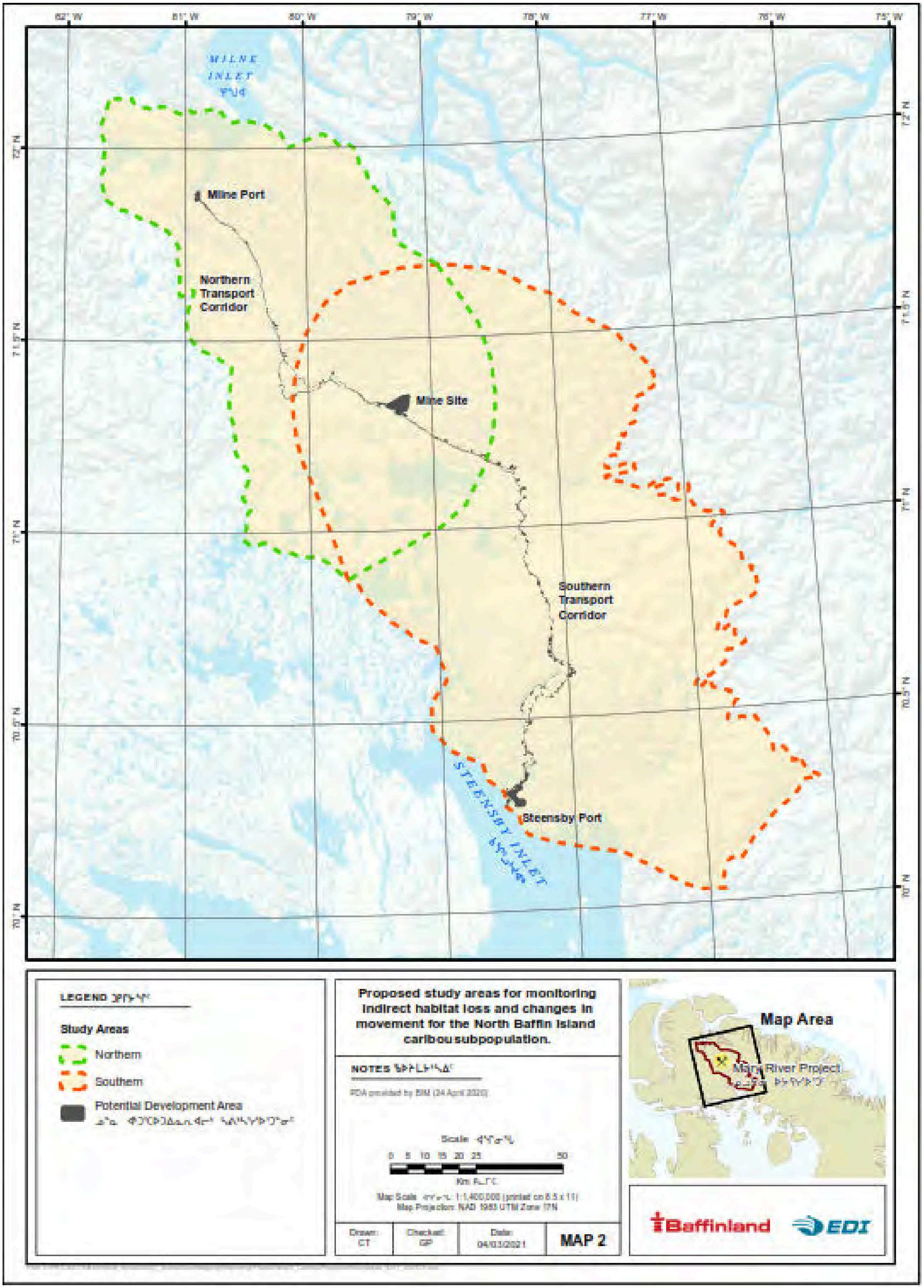
5.2 SPATIAL SCALE AND STUDY AREA

A key question that follows the selection of the caribou subpopulation's numerical trigger is… '*where should these 350 caribou be located and at what proximity from the Project?*', shifting the focus from a general requirement of abundance to one of density in a pre-defined study area.

The analysis of historical collar data (from 2008–2011) demonstrates the need for an appropriate spatial scale for sampling and analysis consistent with recent work applying the segmented regression approach to ZOI estimation (Boulanger et al. 2020, 2021). Large-scale habitat selection gradients at the edge of the North Baffin Island caribou subpopulation range were identified in the Project's area. To ensure that these gradients are not misinterpreted as Project-related effects, ZOIs need to be tested within a realistic distance from mine infrastructure (e.g., within 30–50 km from facilities or roads; Boulanger et al. 2020b) to link specific mine-related variables to caribou presence. Given the large extent of the current footprint (i.e., Northern Transportation Corridor, Milne Inlet, and Mine Site) and planned development (i.e., Southern Transportation Corridor and Steensby Port), it will be necessary to establish distinct study areas for each.

Overlapping study areas for the Northern and Southern transportation corridors are recommended for impact monitoring (Map 2). These study areas are bounded by the Regional Study Area, as defined and used in the Project baseline studies (EDI Environmental Dynamics Inc. 2012). They are overlayed and merged with an approximate 25 km buffer of the Mine Site to create separate Northern and Southern extents. Note that the approximate density of 350 caribou, or the 35 caribou groups in one study area, is not dependent on the other study area. For example, the trigger is likely to be reached in one study area before the other; consequently, an impact monitoring study would commence only in the study area where the trigger is met. The study area that does not meet the trigger could continue to be monitored using surveillance methods.

This report shows that at the current low densities of caribou within a 50 km buffer of the Project, it is impossible to implement a rigorous impact monitoring study to detect Project effects. Population density within the Northern and Southern study areas needs to be four to seven times greater than the 2014 Mary River stratum density of 5.7 caribou/1,000 km² (Campbell et al. 2015).


MILNE INLET
Milne Port
Northern Transport Corridor
Mine Site
Southern Transport Corridor
Steensby Port
STEENSBY INLET
82° W
81° W
80° W
79° W
78° W
77° W
76° W
75° W
72° N
71.5° N
71° N
70.5° N
70° N
LEGEND
Study Areas
Northern
Southern
Potential Development Area
Proposed study areas for monitoring indirect habitat loss and changes in movement for the North Baffin Island caribou subpopulation.
NOTES
Scale
0 5 10 15 20 25 50
Km
Map Projection: NAD 1983 UTM Zone 17N
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Date: 04/03/2021
MAP 2
Map Area
Mary River Project
Baffinland
EDI

5.3 CARIBOU MONITORING EFFORT TRIGGERS

A pathway should be implemented to use caribou density as a trigger for impact monitoring, beginning with current surveillance monitoring and ending with monitoring impacts of Project-related effects (Figure 8). Surveillance monitoring focuses on efforts by Baffinland (e.g., HOL surveys, snow tracking surveys, incidental observations) and includes information collected from external sources (e.g., hunter observations, GN composition surveys). When it is evident that caribou densities are increasing, it is recommended Baffinland initiate aerial surveys to collect data and estimate subpopulation size within the impact monitoring study area(s). A reasonable trigger for commencing surveys is to observe multiple groups of caribou over multiple surveys and sources. This provides a qualitative indication of increasing caribou density. Aerial surveys will then help determine how many caribou occur within the impact monitoring study area(s) and whether the number of caribou (or groups) observed is at, or close to, the target (i.e., approximately 350 caribou or 35 groups of caribou). When the subpopulation target is met, it will trigger the impact monitoring program, which will require the deployment of GPS collars (or equivalent technology at the time) to 35 caribou per year throughout the study.

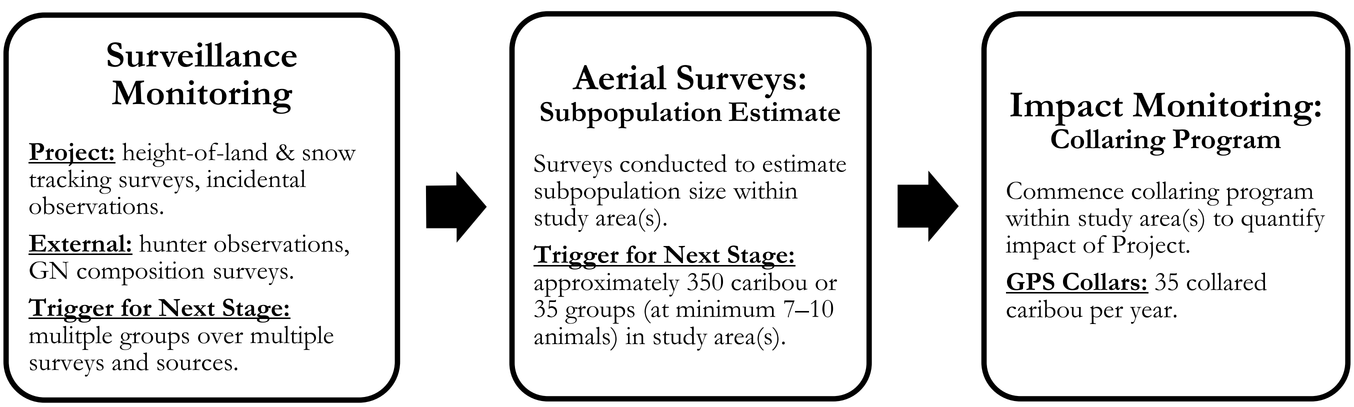

Figure 8. The caribou monitoring effort triggers connecting current surveillance monitoring to monitoring potential Project-related effects on the North Baffin Island caribou subpopulation.

6 SUMMARY

This work aimed to identify triggers for Project-related impact monitoring of caribou on North Baffin Island. Approximately 350 caribou or 35 caribou groups within the Study Area were identified as the trigger to initiate a collaring program, which would be the primary means of regional-level impact monitoring. This study also revealed that a minimum of 35 collars/year in a spatially limited area (for both the North and South footprints, respectively) is necessary to provide adequate sample sizes for evaluating (1) potential barriers to movement and (2) indirect habitat loss due to the Project.

Although this assessment provides clear recommendations based on known caribou ecology, critical review of the literature, and statistical modelling, it is expected that input from the TEWG and Inuit will refine the triggers for modifications to Baffinland's caribou monitoring programs moving forward.

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APPENDIX A DETAILED METHODS AND RESULTS — MARY RIVER PROJECT, CARIBOU MONITORING TRIGGERS AND RECOMMENDATIONS

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1 INTRODUCTION

The Mary River Project (the Project) is an iron ore mine operated by Baffinland Iron Mines Corporation (Baffinland) and located on North Baffin Island, Nunavut. This appendix provides detailed methods and results that support the statements made in the main body of the report regarding triggers and recommendations for barren-ground caribou (*Rangifer tarandus groenlandicus*) monitoring associated with the Project.

2 METHODS

2.1 DATA SOURCES AND PREPARATION

2.1.1 SPATIAL DATA ACQUISITION AND PREPARATION

2.1.1.1 Caribou Telemetry Locations

The Government of Nunavut provided the North Baffin Island caribou collar data. The data set included caribou locations acquired from very high frequency (VHF, from 1987–1994) and global positioning system (GPS, from 2008–2011) collars. These data provided collar and animal IDs, subpopulation designation (i.e., North or South Baffin Island), geographic coordinates, and fix date and times. We screened these data for duplicates and errors. For analyses relevant to quantifying Project effects, we used locations only from GPS collared caribou on North Baffin Island. In total, the data consisted of 31 unique animal IDs with a median fix rate of 22 hours.

2.1.1.2 Project Footprints

Baffinland provided spatial layers corresponding with the Northern Transportion Corridor, permitted Southern Transportion Corridor, Milne Inlet Port, permitted Steensby Port, and Mine Site. We estimated each caribou location's minimum distance from Project footprints for linear features (e.g., Northern Transportation Corridor) and facilities (e.g., mine area) using the 'NNJoin' tool in QGIS.

2.1.1.3 Environmental Covariates

We acquired spatial data from various sources to produce environmental covariates relevant to the analysis of resource selection by North Baffin Island caribou: vegetation cover, elevation, terrain ruggedness, slope, aspect, and distance to water. We reprojected spatial data to North American Albers Equal Area Conic (ESRI:102008) for analyses. We retrieved spatial covariate layers for elevation (m), slope (angle°), and aspect (bearing°) from Natural Resources Canada (NRCan) at a 20 m x 20 m resolution. To create continuous landcover layers covering the entire analysis area, we merged several raster layers for certain landcover covariates and assigned mean values to overlapping pixels. We used CanVec 250k Waterbody and Watercourse vector data to estimate distances to water bodies; the vector data were first rasterized and then distances from waterbodies (m) calculated. This lower resolution (250k) was used to identify major wiaterbodies and rivers in the regions, and avoid smaller ponds and streams.

We estimated terrain ruggedness using a vector ruggedness measure (VRM, an index from 0 to 1) based on methods described by Sappington et al. (2007). We estimated greenness by calculating the Normalized Difference Vegetation Index (NDVI, an index from -1 to 1) using Landsat 8 OLI/TIRS C1 Level-2 images (Band 4 and Band 5) downloaded from the USGS at a 30 m x 30 m resolution. Layers were chosen that minimized cloud cover (<10%) to improve accuracy. The NDVI spatial layer consisted of six different merged images, with mean values assigned to overlapping pixels. To extract appropriate covariate values for each caribou location, we resampled the finer resolution raster layers (20 m x 20 m) using bilinear interpolation to match the coarser resolution (30 m x 30 m) NDVI raster layer. The final step was to align all raster spatial layers.

2.1.1.4 Movement

To describe the movement of North Baffin Island caribou, we created caribou movement trajectories (i.e., paths) by connecting consecutive geospatial caribou locations in the time series dataset for each caribou ID by year. We restricted the start and end of each trajectory using the calendar year because caribou were assumed to be in their winter range by the end of each year. Each step (i.e., line) between consecutive locations is a modelled representation of an individual caribou's movement, and the attributes of each step allow estimation of caribou movement between fixes. We estimated the movement metrics for each step of the trajectory using the package adehabitatLT in R (Calenge 2006). Movement metrics included time, direction, distance travelled, speed, and net squared displacement. Net squared displacement is different compared to other movement metrics because it quantifies the cumulative change in distance from a given location to the first location in the trajectory (Calenge 2006). It is a useful metric for classifying different types of animal movement (Singh et al. 2016, Bastille-Rousseau et al. 2016).

2.1.1.5 Resource Selection and Indirect Habitat Loss

To quantify indirect habitat loss, we restricted our analysis to include only the GPS collar data because of their relatively frequent fix rates and greater sample size. We split telemetry data into winter (Sept. 16–May 25) and growing (May 26–Sept. 15) seasons by calendar dates but not by year because there were no discernable patterns in range use during other seasons relevant to caribou ecology (e.g., calving, post-calving, and migration), and because we were not interested in effects by year. We removed observations meeting certain conditions: fixes >99 hours from the previous fix (nine observations), outlier locations to the far west (>70 km distant from the nearest group of locations; 36 observations), and any collar IDs within a season that had very few locations recorded (i.e., two IDs in the growing season with <3 locations). In total, GPS collar data for 28 caribou were used to assess indirect habitat loss, which consisted of 5,637 locations in the growing season and 10,432 locations in the winter season. Based on the number of 'used' (or confirmed) locations within each season, we contrived 'available' locations by randomly sampling five times the number of used locations, i.e., we assigned 28,185 available locations to the growing season and 52,160 available locations to the winter season. Initially, we used these data to assess resource selection at two scales: population-level ('global availability'), with habitat being globally available within a regionally defined area; and individual-level ('matched-case'), with habitat availability being contingent on the used locations of each individual.

We selected random available locations to compare with known caribou locations for the two scales at which we analyzed resource selection. In the global availability analyses, we sampled available locations from an area defined by the minimum convex polygon delineating all caribou locations plus a 25 km buffer. We chose a 25 km buffer as an appropriate distance because it conformed with the geometric mean from the maximum step length distribution. The sampling area excluded the ocean shoreline and large waterbodies (identified from CanVec 5M vector data). Within this entire area, we randomly sampled available locations in QGIS using the 'Random Points in Layer Bounds' tool with a minimum distance of 50 m between locations.

In the matched-case analyses, we sampled available locations within a 95% radius of a caribou's mean step length. Assuming a uniform distribution, we obtained five random distances ($0 < d \leq$ 95% mean step length) and five random bearings ($0° < b \leq 360°$) for associated x- and y-coordinates. Distances and bearings were paired to calculate the change in x- and y-coordinates relative to an initially used location. Changes in coordinates and the location of new, available coordinates were calculated as follows:

$$\Delta\, x_i = d_i\, sin(rad[b_i]), \text{ followed by } x_i^{avail} = x_i^{used} + \Delta\, x_i$$

and,

$$\Delta\, y_i = d_i \cos(rad[b_i]), \text{ followed by } y_i^{avail} = y_i^{used} + \Delta\, y_i$$

where d is the distance, b is the bearing, and x and y are the easting and northing, respectively, for each *i*-th set of coordinates.

2.2 DATA ANALYSIS

2.2.1 MOVEMENT

A common approach to quantifying the effects of human infrastructure on migrating caribou is the biased correlated random walk method. The method has been applied to identify changes in expected movement by caribou migrating across a mine road in western Alaska (see Wilson et al. 2016) and mainland Nunavut (see Boulanger et al. 2020). The method provides a useful estimate of potential delays in crossing infrastructure. The method assumes that caribou are moving between seasonal ranges that are biologically necessary, e.g., caribou travelling between winter and calving ranges. Exploring the applicability of the biased correlated random walk method to North Baffin caribou requires that the available collar data (1) cross the Project and (2) caribou migrate between seasonal ranges. Also, the orientation of infrastructure is an important consideration. Infrastructure that is parallel in direction to a migration route has little potential to disrupt caribou trajectory and would not pose an ecologically relevant barrier — it is necessary to consider the functional responses to linear features when assessing barrier effects.

Early exploration of the GPS collar locations indicated that North Baffin caribou had varied movement strategies among individuals (Jenkins and Goorts 2011). Consequently, the first step of our analysis was to describe North Baffin Island caribou movements. We visualized annual (calendar year) movement trajectories for each caribou in a GIS and classified them according to the conceptual movement model described by Spitz et al. (2017). The movement categories included migrant, resident, and mixed migrant. The mixed migrant category combined the mixed migrant, disperser, and nomad movement types described by Spitz et al. (2017) to create an intermediate movement category. The disperser and nomadic movements are not likely caribou movement types. We excluded caribou from the analysis and summary if their annual trajectory did not include the entire non-winter season (i.e., spring migration to fall) because the movement could not be classified if the time series did not include the potential to departure and return to seasonal ranges. After excluding caribou trajectories with small samples of locations, 68 caribou movement trajectories remained from 2008–2011. The 68 trajectories represent the annual movements of 30 collared caribou (i.e., excluding a single caribou from the original dataset).

2.2.2 INDIRECT HABITAT LOSS

We addressed questions of indirect habitat loss by developing resource selection (probability) functions (RS[P]Fs), extending those base models to quantify avoidance behaviour (i.e., a zone of influence; ZOI), and then further extending those analyses to test the precision of estimates when varying sample size. We used results of the precision-sensitivity analysis to inform sample size selection for an impact monitoring study.

2.2.2.1 Resource Selection

We quantified probabilities of resource selection by caribou relative to several environmental covariates using logistic regression. Following information theoretic procedures, we then selected the most parsimonious model to describe resource selection in growing and winter seasons, i.e., the base habitat models. Initially, we developed RSPFs to estimate absolute probabilities of occurrence, a technique grounded in weighted distribution theory (Lele and Keim 2006, Lele et al. 2019). Absolute probabilities are often more desirable and useful for management decisions. Due to computational feasibility, and especially given the intent of running simulations (see Section 2.2.3, Estimate Sample Size for Monitoring), we also developed RSFs to estimate relative probabilities of occurrence. We evaluated both global availability and matched-case RSF models: the former with a standard generalized linear model (GLM) and the latter with a generalized linear mixed model (GLMM), which specifies caribou collar ID as a random effect and accounts for correlations between observations of a given ID.

The general formula for logistic regression is as follows:

$$logit(P) = \beta_0 + \beta_1 x_1 \ldots \beta_n x_n$$

where the predicted value P is dependent on the linear predictor ($\beta_0 + \beta_1 x_1 \dots \beta_n x_n$) through a logit-link function, and x is the *i*-th environmental covariate and β is its associated coefficient. In the matched-case scenario, an additional term S_j was added to account for the random effect (intercept) of each *j*-th collar ID. The linear predictors can then be used to calculate the probability of selection P:

$$P = \frac{e^{\beta_0 + \beta_1 x_1 \dots \beta_n x_n}}{1 + e^{\beta_0 + \beta_1 x_1 \dots \beta_n x_n}}$$

where e is the natural exponential function and P is bounded by $0 < P < 1$.

Prior to analyses, we converted the covariate, aspect, from continuous (degrees) to categorical (cardinal directions) based on 90° intervals — a common implementation (e.g., Gustine et al. 2006, Johnson et al. 2020). This choice was to prevent fitting a linear or polynomial relationship since we expect aspects to be relevant to solar radiation and snow cover, which are generally favoured to the south and east or west depending on prevailing winds.

We standardized all remaining (continuous) covariates to have a mean of zero and a standard deviation of one, the purpose being to rank the relative importance of each covariate. We also used non-standardized variables and their coefficients to interpret results because standardization has no meaningful effect on test statistics and significance values. To prevent biased estimates of coefficients and inflated errors, we assessed the covariates for multicollinearity using a correlation matrix (dropping variables with Pearson's product moment correlation $r > 0.7$), followed by variance inflation factor scores (dropping variables with VIF scores > 3). We dropped the VRM index due to its high correlation with Slope.

With all remaining covariates, we developed a global statistical model (not to be confused with 'global availability') and assessed the residuals against fitted values. We used a backward selection procedure on terms in the global model. We assessed the reduced models relative to the global model using corrected Akaike Information Criterion (AICc) scores (AICcmodavg package, Mazerolle 2019). An AICc score is the amount of information a candidate model loses when compared to the 'true' unknown (and unattainable) model, which perfectly describes a natural phenomenon (Burnham and Anderson 2002). In this case, the model with the lowest AICc score (and statistics) yields the best approximation of caribou resource selection, given the data. Once we chose the best model, we assessed the statistical significance (at $\alpha = 0.05$) of each covariate using the asymptotic chi-square (χ^2) distribution of the log-likelihood ratio test statistic.

2.2.2.2 Zone of Influence

We considered ZOIs for several footprint types (e.g., road versus facility) in the Project's northern and southern extents. To achieve the objectives of the current study, we deemed it sufficient to restrict our analyses to two features: (1) the Northern Transportation Corridor because it experienced low-to-moderate use at the time of data collection and was (at least partially) within the home range of sampled caribou; and (2) the planned Southern Transportation Corridor because it is not constructed and is entirely within the home range of sampled caribou, thus acting as a control.

We conducted ZOI analyses according to the methods of Boulanger et al. (2012). We used base habitat models to iteratively estimate a ZOI around Project footprints using a piecewise regression procedure with distance from footprints as an additional covariate. To identify the effects of scale on ZOI estimation, we conducted these tests both with and without accounting for broader scale habitat selection because the Project occurred at the periphery of the North Baffin Island subpopulation range. We identified gradients in large-scale habitat selection using generalized additive modelling that incorporated cubic spline terms for the base habitat covariates and included exact distances from the existing and proposed Project footprints. We determined whether broader scale selection affected caribou distances from infrastructure based on the regression's slope starting at the ordinate's intercept. We identified the distance up to which the slope was relatively invariant as the iteration zone, and then used this limit to test for selection gradients closest to Project infrastructure (see Boulanger et al. 2020).

We tested several distance thresholds: once using rarified datasets with only locations inside the identified iteration zone, and then using all caribou locations and testing thresholds up to 100 km. The assumptions were that caribou presence would be reduced, and resource selection altered, within the threshold; and that caribou presence would be increased, and resource selection unaltered, beyond the threshold. We assigned all distances at or beyond the defined threshold the same distance value. For example, if we tested a ZOI distance of 5 km, then all distances up to 5 km retained their values (i.e., numbers ranging from 0 km to 4.99 km), but all distances at or greater than the ZOI were assigned a value of 5 km (e.g., 6 km or 30 km were assigned values of 5 km). In total, 100 models (100 unique thresholds) were fit with the full dataset. The number of models corresponding with the rarified dataset, which accounted for large-scale habitat selection gradients, was the number equivalent to the outer boundary of the iteration zone. In other words, if the iteration zone was deemed between 0–20 km, then we tested only 20 models — one for each kilometre interval. We selected the best models, thus the most likely ZOIs, by evaluating the log-likelihoods of all models as a function of the distance thresholds. The highest log-likelihood corresponded with the model with the most statistical support.

2.2.3 ESTIMATE SAMPLE SIZE FOR MONITORING

Determination of the necessary sample size for future monitoring was the ultimate objective of this work, i.e., how many caribou would need to be collared to detect the Project's potential effects? We used the full collar dataset, which was also used to develop the ZOI habitat models, to conduct precision-sensitivity analyses through simulation. These analyses applied the underlying variation in caribou resource selection to quantify the influence of sampling on effects assessment, i.e., estimates of ZOI distance and magnitude of avoidance behaviour. In particular, the intent was to identify how spatially biased sampling and sample size affect the variation in these estimates of interest.

We conducted precision-sensitivity simulations specifically using the winter season dataset because of the season length, potential sample size requirement, and the shape of the log-likelihood surface used in ZOI estimation for the winter season (see Section 3.2.2, Zone of Influence). The method followed a hierarchical bootstrapping procedure. The first step was to resample with replacement, *N*-number of caribou collar IDs randomly. For each of these chosen IDs, we resampled the mean number of known ('used') caribou locations

(347 in winter) and five times as many unknown ('available') locations, both with replacement. This procedure occurred 1,000 times for each sample size N to produce 1,000 datasets. We conducted ZOI analyses (see Section 2.2.2.2, Zone of Influence for methods) using these 1,000 bootstrapped datasets and identified the most likely ZOI distance and associated ZOI coefficient. We assessed the distributions produced by these 1,000 point estimates and calculated bias-corrected and accelerated (BCa) 95% confidence intervals for each sample size. Figure 1 demonstrates the workflow for these precision-sensitivity analysis simulations.

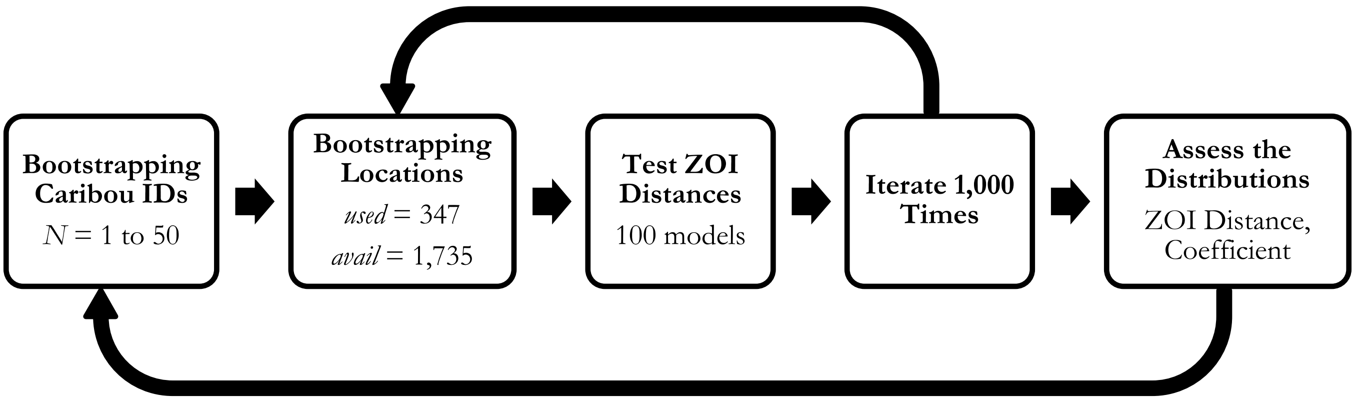


Figure 1. Workflow for precision-sensitivity analysis simulations to assess the effect of sample size on the zone of influence estimates.

3 RESULTS AND DISCUSSION

3.1 MOVEMENT

We estimated a total of 68 caribou movement trajectories for the dataset (Table 1). Twenty-four of these trajectories were discarded because the caribou either (1) died too early in the year to categorize the type of movement they were exhibiting, or (2) the collar reached the programmed end of life. The collars seemed to be programmed to drop because the time series of multiple collared caribou ended on July 31, 2011. After screening the caribou trajectories, 44 trajectories remained for 2008 to 2010 that spanned the entire range of seasons (i.e., winter to winter).

North Baffin caribou showed variation in the types of movement exhibited among individuals and for individuals across years. We classified caribou as migrants, mixed-migrants, or residents based on the net squared displacement plots for each trajectory described by Spitz et al. (2017). Trajectories that we did not classify were binned into the 'unclassified' category to summarize counts of caribou that interact with the Project and for mapping purposes. Movement types were easily classified for North Baffin Island caribou (Figure 2). The North Baffin caribou's most common movement reflects resident behaviour within individual ranges (Table 1). Residents are defined as caribou that spend their entire year moving within a small area with no evident seasonal patterns in their movement. Mixed-migrants were the next most common type of movement shown by the collared caribou. Mixed movements include caribou that were moving across the landscape but not in predictable ways. Mixed-migrants were most common in 2009, as that year included 80% of the mixed migrants classified. Migrants were the least common movement types observed in the data set but still represented in about 25% of classified trajectories. The reduction in the number of mixed migrants from 2009 to 2010 is not because these caribou had higher mortality rates than the resident caribou, but due to five of the mixed migrants changing to resident type movements. The reduction in migrants from seven to two caribou is due to five migrant caribou dying in 2010, potentially suggesting lower survival of caribou showing migratory behaviour. Individual caribou switched between movement types during the three years of study, showing behavioural plasticity, which was unexpected.

Caribou trajectories intersected disproportionately with the Project's proposed Southern Transportation Corridor compared to the Northern Transportation Corridor. The larger number of trajectories along the Southern Transportation Corridor is due mainly to the distribution of the collared caribou, and that the Northern Transportation Corridor only interacts with three migrant caribou that are moving from the southern portion of the range to the north and east of the Project footprint — likely to calve in more rugged terrain.

The distribution of the different movement types within the range indicates that caribou west of the Project are or were more likely to be migrants and are less likely to switch movement types, as all caribou west of the Project that included multiple years of data remained migrants each year. Caribou occupying the eastern portion of the range exhibited the greatest variation in movement types among caribou and years.

Compared to other barren-ground caribou herds across northern Canada, the North Baffin Island caribou subpopulation does not exhibit traditional and predictable migratory movements. Individual caribou within this subpopulation show seasonal movements that are migratory in nature and others that switch movement strategies among years. Biologists presumably expected that caribou were migrating between seasonal ranges on North Baffin when the most recent collaring program was conducted. The lack of movement shown by some 'resident' caribou is unexpected, given the documented history of caribou migration on Baffin Island, as is the variation in movement types among caribou and the plasticity of movement shown by individuals. Variation in movement types has been documented within populations of other species (e.g., moose; Singh et al. 2016). However, the plasticity observed in the movements of an individual caribou on north Baffin Island is surprising.

The lack of and variation in movement may be a density-dependent response to the current low density of caribou on north Baffin Island and the abundance of available habitat. The change in migration seen in the Dolphin and Union caribou herd, which stopped migrating between Victoria Island and mainland Nunavut during a population low then restarted the migration when the density of caribou increased (COSEWIC 2018), provides evidence of density-dependent migratory behaviour. Consequently, when caribou density increases on North Baffin Island as predicted, we should expect to start seeing caribou migrating between seasonal ranges. The migratory behaviour remains within the subpopulation, but the variation in the behaviour among years suggests that the migration may not currently be an ecological requirement or advantage for North Baffin Island caribou.

In the absence of migration, caribou movement analysis in relation to the Project, such as speed, turning angles, and tortuosity, is fraught with uncertainty and would lack ecological relevance. For example, individual caribou that are residents in an area near the Project may show slow movements and frequent turning, while a caribou migrating across the same area may show fast movement and few turns. Consequently, the type of movement behaviour exhibited by the caribou (i.e., resident versus migrator) has a greater effect on how the caribou move in relation to the Project than the effect of the Project itself. Mechanisms driving the changes in caribou movement related to the road, not including migratory behaviour, are related to avoidance, encompassed in the analysis of indirect habitat loss and the mechanisms associated with that effect.

Table 1. Count of each North Baffin caribou movement type by year. The unclassified movement type includes incomplete movement trajectories.

Movement Category	2008	2009	2010	2011	Total
Migrant	1	7	2		10
Mixed migrant	1	12	2		15
Resident		8	11		19
Unclassified		3	8	13	24
Total	2	30	23	13	68

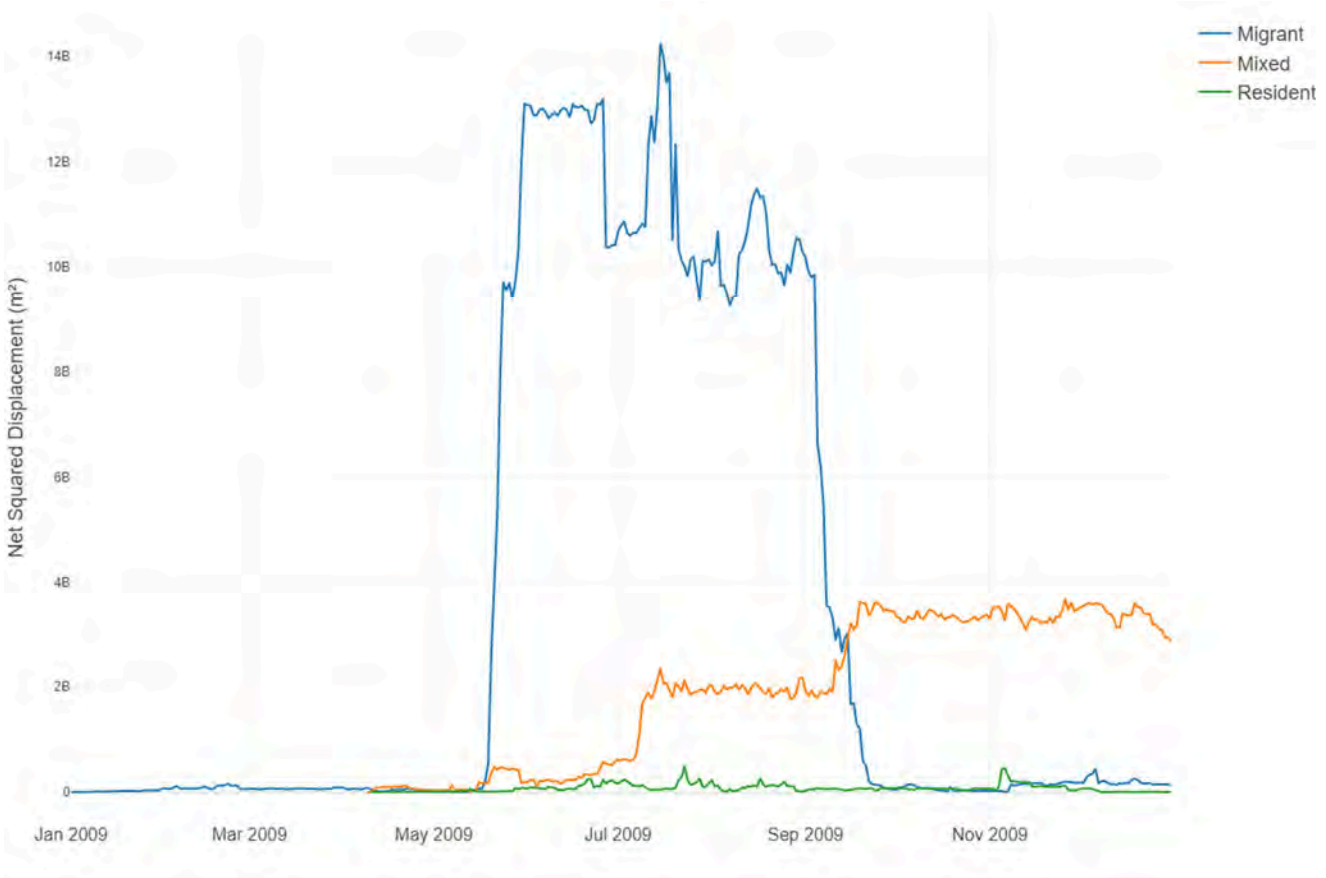


Figure 2. Example of the three North Baffin caribou net squared displacement movement metric exhibiting the three categories of movement types during 2009.

3.2 INDIRECT HABITAT LOSS

3.2.1 RESOURCE SELECTION

Two considerations were necessary to establish the appropriate model for resource selection by North Baffin Island caribou. (1) Was a matched-case ('mixed-model') design addressing the appropriate resource selection scale, and was it necessary to account for spatial autocorrelation? (2) Were absolute probabilities required over relative probabilities? We contemplated both of these in the context of developing a model of resource selection to, among other steps, aid and inform the design of a study for future monitoring of caribou. The growing season dataset was used to answers these two questions.

Resource selection by North Baffin Island caribou was relatively similar when comparing habitat availability among spatial scales, i.e., 'global availability' (GLM) versus 'matched-case' (GLMM). Growing season models at global (Table 2) and local (Table 3) spatial scales were qualitatively similar in their rank importance of variables but differed in their coefficients. Key differences included a probability of selection more influenced by elevation than slope in the GLM, whereas the reverse was true of the GLMM. But the most apparent difference between the models was the relative magnitude of the coefficients, both standardized (Table 2 and Table 3) and unstandardized (e.g., $NDVI_{GLM}$ = 4.65 versus $NDVI_{GLMM}$ = 2.23). The GLM ('global availability') captured differences in the ecological gradient at a broader spatial scale, resulting in higher selection coefficient values than the GLMM ('matched-case'). The advantage of the GLMM was that it accounted for potential spatial autocorrelation among locations of the same collar ID (i.e., the same individual). However, because of the similarity in the rank importance of variables between global and local models, modelling resource selection with a GLM was deemed sufficient. More importantly, 'global availability' is a better scale of analysis because (1) it considers resource selection at the population-level and may better explain the key drivers of the spatial distribution of caribou on North Baffin Island, and (2) it is consistent with the regional scale needed to quantify and interpret Project effects.

Table 2. Base habitat model of 'global availability' resource selection (RSF, relative probabilities) by North Baffin Island caribou during the growing season (May 26–Sept. 15), 2008 to 2011.

Environmental Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-0.68	0.12	101.64	< 0.00001
NDVI (greenness)	1.59	0.05	1425.75	< 0.00001
Distance to Water (km)	-0.58	0.03	389.83	< 0.00001
Slope (degrees)	0.83	0.03	863.86	< 0.00001
Slope² (degrees)	-0.26	0.01	693.00	< 0.00001
Elevation (m)	1.00	0.03	1452.32	< 0.00001
Elevation² (m)	-0.60	0.02	773.92	< 0.00001
Aspect (categorical)	—	—	101.64	< 0.00001
North	-1.19	0.13	—	—
South	-0.84	0.12	—	—
East	-0.89	0.12	—	—
West	-0.98	0.12	—	—

Table 3. Base habitat model of 'matched-case' resource selection (RSF, relative probabilities) by North Baffin Island caribou during the growing season (May 26–Sept. 15), 2008 to 2011.

Environmental Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-1.16	0.12	91.42	< 0.00001
NDVI (greenness)	0.64	0.03	351.15	< 0.00001
Distance to Water (km)	-0.08	0.02	23.22	< 0.00001
Slope (degrees)	0.24	0.02	99.00	< 0.00001
Slope² (degrees)	-0.10	0.01	73.74	< 0.00001
Elevation (m)	0.05	0.02	3.84	0.05
Elevation² (m)	-0.04	0.02	5.85	< 0.02
Aspect (categorical)	—	—	79.30	< 0.00001
North	-0.65	0.13	—	—
South	-0.35	0.12	—	—
East	-0.33	0.12	—	—
West	-0.55	0.12	—	—

The next consideration was whether absolute probabilities (RSPF) were essential, rather than relative probabilities (RSF), for this study's objectives. We developed both types of models for the growing season to compare differences in the relative contribution of environmental covariates and to compare the overall prediction on the probability of selection. Not only were the rank importance of covariates between RSF (Table 2) and RSPF (Table 4) models identical, but the magnitude of their associated coefficients deviated by only a tenth of a decimal point. The key difference was in the intercept, which ultimately affects the calculation of probability values. Overall, the absolute probabilities of the RSPF were much smaller than the relative probabilities of the RSF. However, these probabilities had a near-perfect (Kendall's tau) rank correlation ($z = 267.06$, $\tau = 0.97$, $p < 0.00001$). Given their similarities and the heavy computational requirements of RSPF models, we deemed RSFs appropriate for this study.

Table 4. Base habitat model of 'global availability' resource selection (RSPF, absolute probabilities) by North Baffin Island caribou during the growing season (May 26–Sept. 15), 2008 to 2011.

Environmental Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-3.70	0.97	14.61	0.0001
NDVI (greenness)	1.78	0.10	333.23	< 0.00001
Distance to Water (km)	-0.61	0.03	472.60	< 0.00001
Slope (degrees)	0.88	0.03	907.55	< 0.00001
Slope² (degrees)	-0.29	0.01	423.61	< 0.00001
Elevation (m)	1.12	0.04	621.51	< 0.00001
Elevation² (m)	-0.62	0.03	552.43	< 0.00001
Aspect (categorical)	—	—	30.93	< 0.00001
North	-0.91	0.16	—	—
South	-0.44	0.15	—	—
East	-0.51	0.15	—	—
West	-0.65	0.15	—	—

Following the decision made for the growing season, resource selection in winter was also modelled with 'global availability' to produce relative probabilities of selection (RSF). Resource selection differed between the two seasons. NDVI was the primary driver of resource selection in the growing season and had a regression coefficient twice the magnitude of that in winter (Table 4 versus Table 5). Distance to water was the most important variable for winter resource selection; it had the greatest mean effect on the probability of caribou occurrence. Caribou were more likely to occur in proximity to waterbodies such as lakes and rivers. This affinity for waterbodies also likely corresponds with a decreased probability of occurrence at higher elevations during winter. In winter, snow conditions in some regions can limit caribou use of higher elevations as hardness and depth usually increase with elevation. Caribou tend to avoid deep snow because it hinders movement across the landscape and restricts cratering access to ground lichen. Another proxy that may capture the effect of snow is aspect; southern slopes are windswept and snow sparse, while northern slopes tend to accumulate snow. The probability of selection in winter was much higher for southern aspects than northern, and caribou occupied low-to-moderate slopes (i.e., 10–20°) along southern aspects. Because snow is not a contributing factor to resource selection outside of winter, these effects are not seen in the growing season's base habitat model. For example, caribou tended to select mid-to-high elevations (i.e., 400–600 m), at low-to-moderate slopes (i.e., 5–15°), with no real preference of aspect during the growing season.

Table 5. Base habitat model of 'global availability' resource selection (RSF, relative probabilities) by North Baffin Island caribou during the winter season (Sept. 16–May 25), 2008 to 2011.

Environmental Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-1.31	0.07	340.42	< 0.00001
NDVI (greenness)	0.75	0.02	1555.87	< 0.00001
Distance to Water (km)	-1.07	0.03	1918.50	< 0.00001
Slope (degrees)	0.78	0.02	1610.61	< 0.00001
$Slope^2$ (degrees)	-0.20	0.01	944.96	< 0.00001
Elevation (m)	-0.16	0.02	106.24	< 0.00001
Aspect (categorical)	—	—	340.42	< 0.00001
North	-0.97	0.08	—	—
South	-0.34	0.07	—	—
East	-0.54	0.07	—	—
West	-0.66	0.07	—	—

3.2.2 ZONE OF INFLUENCE

Analyses did provide evidence of ZOIs for the Northern Transportation Corridor, including differences between growing and winter seasons. When considering all known collar locations up to ~180 km from the road (full dataset), we identified two peaks in the log-likelihood surface for the growing season: 5 km and 71 km (Figure 3). The greatest statistical support (highest log-likelihood) was for the 71 km perimeter around the Northern Transportation Corridor, where the odds of caribou being present outside of that boundary was 2.03 times greater than the odds of caribou being present on the road (odds ratio = $e^{0.01 \times 71km}$ = 2.03; Table 6). During the winter season, the greatest statistical support was for a 28 km perimeter ZOI around the Northern Transportation Corridor (Figure 4), where the odds of caribou being present outside of that boundary was 204.38 times greater than the odds of caribou being present on the road (odds ratio = $e^{0.19 \times 28km}$ = 204.4; Table 7). These results are attributed to very distant, 'resident' caribou that move little across the landscape and have fairly distinct (individual) home ranges.

The importance of scale in the analysis of ZOIs is made clear when considering large-scale gradients in habitat selection. During the growing season, the marginal effect of distance to the Northern Transportation Corridor was relatively weak within the first ~50 km, as demonstrated by the shallow curvature at low odds of selection (Figure 5). Beyond this distance, a steep gradient in selection is evident. Therefore, we rarified the original dataset to include locations only within 50 km of the Northern Transportation Corridor, and then re-estimated the ZOI. Consequently, the peak, and thus the estimated ZOI, was clearly at 4 km from the Northern Transportation Corridor (odds ratio = $e^{1.37 \times 4km}$ = 239.85, Table 8; Figure 7; Map 1). At this more appropriate scale, testing for a ZOI at thresholds >20 km revealed a reduced probability of caribou occurrences at those greater distances (red-filled points; Figure 7), driven by large-scale spatial segregation of caribou across the landscape. This reduced scale for analysis is also supported by the expected movement distances by collared caribou. We identified 25 km as the (geometric) mean step length, so caribou found at extreme distances (>70 km) from the Northern Transportation Corridor are consistently outside the range needed to receive cues (or stimuli) of sensory disturbance produced by activity (see discussion in Section 3.3). Thus, their habitat selection and spatial distribution would not be dependent on the road.

The ZOI estimate for winter did not decrease by excluding caribou observations distant (e.g., ≤50 km) from the Northern Transportation Corridor. The ZOI estimate remained at 28 km. The odds of selection rise sharply from the footprint (0 km) up to 28 km, levels off, rises once again until ~75 km, then gradually and precipitously declines at greater distances (Figure 6). Large-scale patterns in habitat use coincide with a greater occurrence of caribou at 28 km and ~75 km, and caribou tended not to be present within 28 km of the Northern Transportation Corridor. Therefore, the odds of observing a caribou at the Northern Transportation Corridor were two orders of magnitude less during the winter than during the growing season. This is explained by the number of unique collar IDs in the road's vicinity and the associated number of confirmed locations. For example, in the growing season dataset, three caribou are consistently within 10 km of the Northern Transportation Corridor (ranging from 47 to 72 confirmed locations). In contrast, in the winter season, only a single caribou with substantially fewer locations (16 confirmed) was within 10 km of the road. This produces a statistically apparent gradient of avoidance. However, there is no reasonable Project-related mechanism that would cause such a drastic increase in avoidance of the Northern Transportation Corridor from growing to winter seasons. Potential explanations for the difference in detected ZOIs between seasons may be (1) insufficient sample size within the vicinity of the footprint, (2) insufficient annual collar data, or (3) external factors not considered in the base habitat model that shape habitat selection and subpopulation range at broader scales (e.g., mechanisms that yield different seasonal range use by caribou).

Table 6. Disturbance (71 km ZOI) model of 'global availability' resource selection (RSF, relative probabilities) by North Baffin Island caribou during the growing season (May 26–Sept. 15), 2008 to 2011 at the Northern Transportation Corridor. Model constructed using full dataset.

Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-0.59	0.12	110.11	< 0.00001
NDVI (greenness)	1.69	0.05	1529.26	< 0.00001
Distance to Water (km)	-0.62	0.03	433.77	< 0.00001
Slope (degrees)	0.80	0.03	793.73	< 0.00001
Slope² (degrees)	-0.26	0.01	664.84	< 0.00001
Elevation (m)	1.05	0.03	1557.32	< 0.00001
Elevation² (m)	-0.62	0.02	831.42	< 0.00001
Aspect (categorical)	—	—	110.11	< 0.00001
North	-1.30	0.13	—	—
South	-0.96	0.12	—	—
East	-1.02	0.12	—	—
West	-1.09	0.12	—	—
ZOI (km)	0.21 (0.01)[1]	0.02	165.91	< 0.00001

[1] Brackets identify the non-standardized coefficients for calculations of odds ratios on the appropriate scale (km).

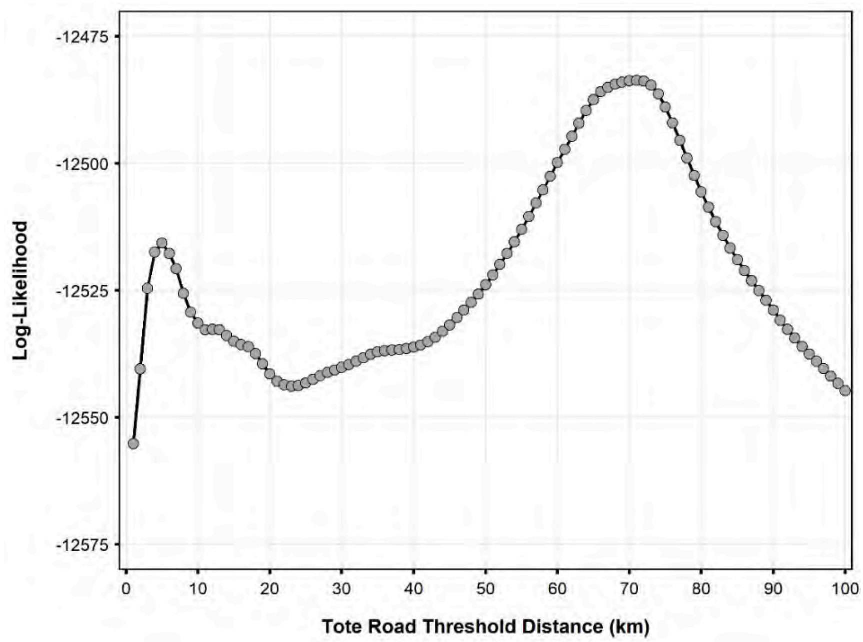


Figure 3. A segmented regression approach to estimate a zone of influence relative to the Northern Transportation Corridor using all collar data during the growing season (May 26–Sept. 15), 2008 to 2011.
The threshold distance with the highest log-likelihood value corresponds with the most likely ZOI (71 km).

Table 7. Disturbance (28 km ZOI) model of 'global availability' resource selection (RSF, relative probabilities) by North Baffin Island caribou during the winter season (Sept. 16–May 25), 2008 to 2011 at the Northern Transportation Corridor. Model constructed using full dataset.

Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-6.41	0.26	357.60	< 0.00001
NDVI (greenness)	0.78	0.02	1667.05	< 0.00001
Distance to Water (km)	-1.10	0.03	2036.52	< 0.00001
Slope (degrees)	0.79	0.02	1606.70	< 0.00001
Slope^2 (degrees)	-0.21	0.01	972.92	< 0.00001
Elevation (m)	-0.12	0.02	62.70	< 0.00001
Aspect (categorical)	—	—	357.60	< 0.00001
North	-1.12	0.08	—	—
South	-0.49	0.07	—	—
East	-0.69	0.07	—	—
West	-0.80	0.07	—	—
ZOI (km)	0.88 (0.19)[1]	0.04 (0.01)	1407.77	< 0.00001

[1] Brackets identify the non-standardized coefficients for calculations of odds ratios on the appropriate scale (km).

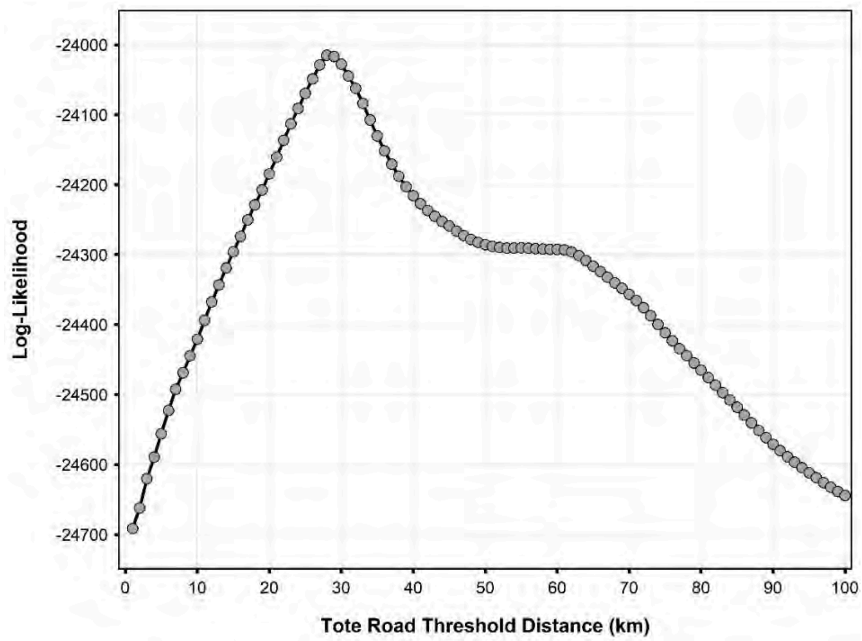


Figure 4. A segmented regression approach to estimate a zone of influence relative to the Northern Transportation Corridor using all collar data during the winter season (Sept. 16–May 25), 2008 to 2011.
The threshold distance with the highest log-likelihood value corresponds with the most likely ZOI (28 km).

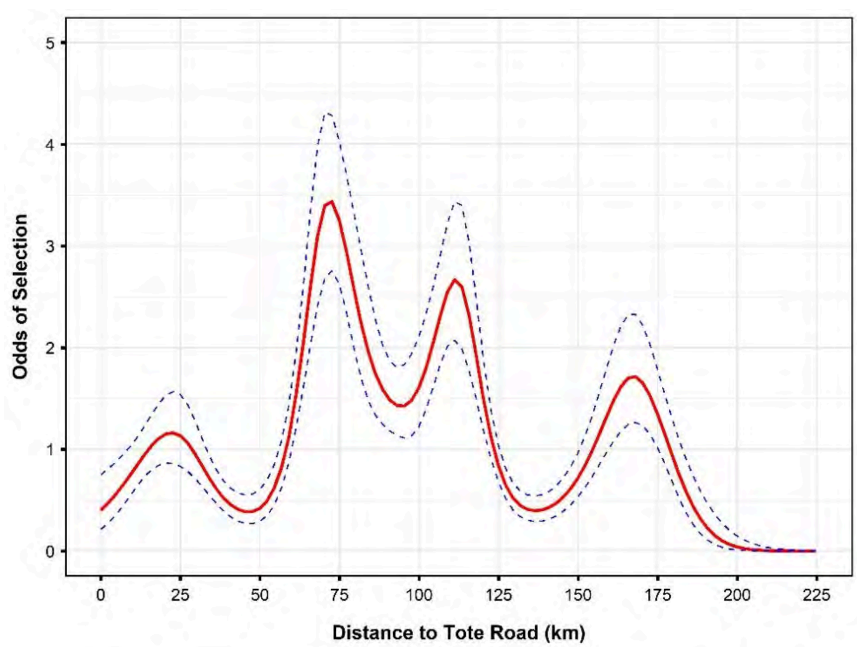


Figure 5. Marginal effects of distance to the Northern Transportation Corridor (km), growing season (May 26–Sept. 15), on selection gradients (odds of selection) based on a generalized additive model with cubic regression splines.
Solid red and dashed blue lines are the fitted mean and confidence intervals, respectively. The gradient is relatively weak in its absolute magnitude and rate of change for the first 45-50 km from the Northern Transportation Corridor.

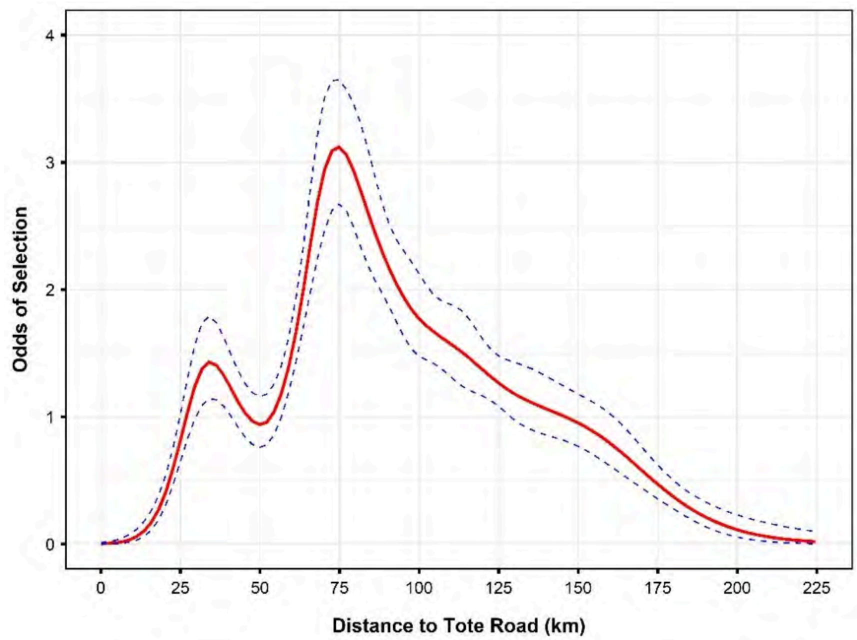


Figure 6. Marginal effects of distance to the Northern Transportation Corridor (km), the winter season (Sept. 16–May 25), on selection gradients (odds of selection) based on a generalized additive model with cubic regression splines.

Solid red and dashed blue lines are the fitted mean and confidence intervals, respectively. There is a steep gradient up to the ZOI (28 km), which was identified using the full dataset.

Table 8. Disturbance (4 km ZOI) model of 'global availability' resource selection (RSF, relative probabilities) by North Baffin Island caribou during the growing season (May 26–Sept. 15), 2008 to 2011 at the Northern Transportation Corridor. Model constructed using rarified dataset of locations within 50 km of the Northern Transportation Corridor.

Covariate	Coefficient Estimate	Standard Error	χ^2	*P*
Intercept (no aspect)	-1.18	0.21	36.31	< 0.00001
NDVI (greenness)	2.37	0.13	494.97	< 0.00001
Distance to Water (km)	-0.64	0.08	68.77	< 0.00001
Slope (degrees)	0.48	0.07	48.55	< 0.00001
$Slope^2$ (degrees)	-0.21	0.03	59.66	< 0.00001
Elevation (m)	1.98	0.08	702.94	< 0.00001
$Elevation^2$ (m)	-1.22	0.08	280.10	< 0.00001
Aspect (categorical)	—	—	36.31	< 0.00001
North	-0.94	0.22	—	—
South	-1.00	0.21	—	—
East	-1.27	0.21	—	—
West	-0.95	0.21	—	—
ZOI (km)	0.69 (1.37)[1]	0.17 (0.34)	44.19	< 0.00001

[1] Brackets identify the non-standardized coefficients for calculations of odds ratios on the appropriate scale (km).

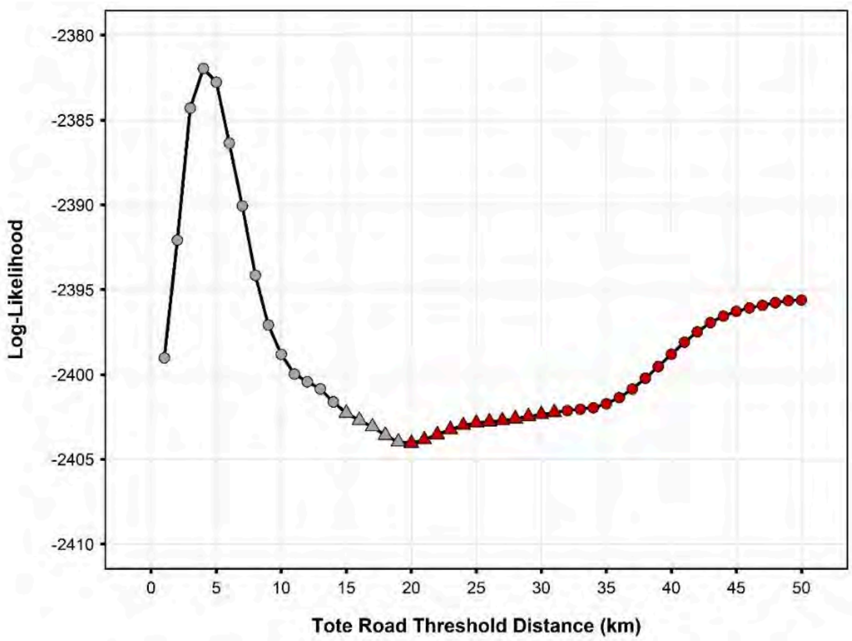


Figure 7. A segmented regression approach to estimate a zone of influence relative to the Northern Transportation Corridor using collar data within 40 km of the footprint during the growing season (May 26–Sept. 15), 2008 to 2011.

The threshold distance with the highest Log-likelihood value corresponds with the most likely ZOI (5 km). Circles and triangles indicate statistically significant and non-significant ZOI distances, respectively. Grey and red fills indicate positive and negative coefficients, respectively.

For the Southern Transportation Corridor, we did not identify ZOIs in either season, even with larger sample sizes relative to the analysis of the Northern Transportation Corridor (Growing — North = 3,493 obs., South = 5,564 obs.; Winter — North = 7,102 obs., South = 9,785 obs). For example, during the growing season, caribou exhibited negative selection beyond 18 km from the Southern Transportation Corridor (Figure 8). This pattern was as expected and corroborated our classification as a 'control' since no development occurs along the southern route, and because caribou behaviour was relatively consistent between northern and southern areas (i.e., resident and migrant caribou were identified both to the north and to the south of the mine). Models tested with thresholds beyond this distance consistently had greater support, indicating that caribou were frequently within proximity to the proposed railway. The lack of avoidance behaviour was expected because no footprint exists and, most importantly, the caribou subpopulation range completely overlaps the area. As a control, it also demonstrates that large-scale gradients in habitat selection do not necessarily conform with avoidance of a footprint. Though there is no positive or negative selection of the footprint itself (0 km), there is a strong, positive gradient beyond the footprint (up to ~30 km), followed by a strong, negative gradient (Figure 9). This gradient's shape is similar but more pronounced than the one identified for the Northern Transportation Corridor in the growing season. However, there were differences in the gradients and intensity of selection because the Southern Transportation Corridor does not occur at the periphery of the subpopulation's range, unlike the Northern Transportation Corridor.

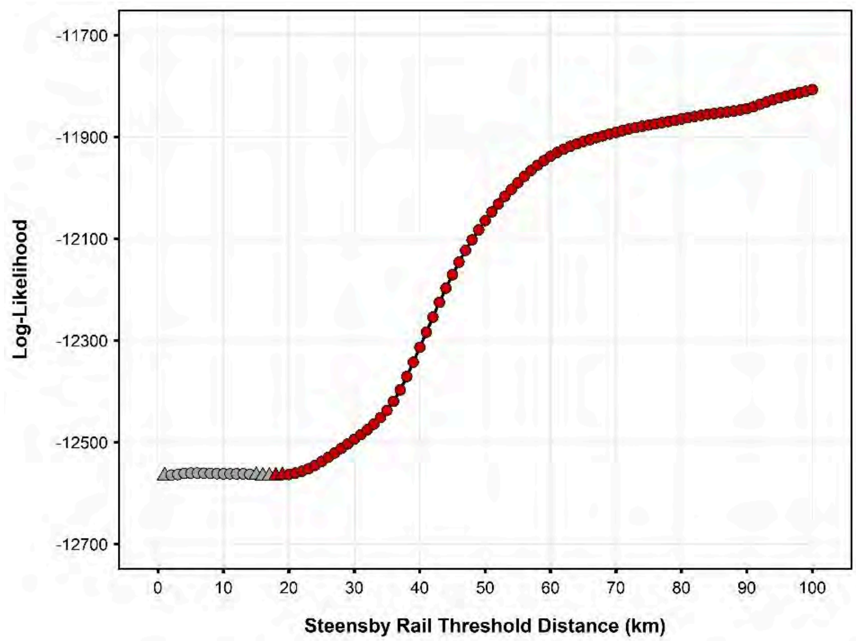


Figure 8. A segmented regression approach to estimate a zone of influence relative to the Southern Transportation Corridor using all collar data during the growing season (May 26–Sept. 15), 2008 to 2011.
Circles and triangles indicate statistically significant and non-significant ZOI distances, respectively. Grey and red fills indicate positive and negative coefficients, respectively. There is no threshold distance associated with a ZOI because the probability of selection decreases beyond 18 km, and log-likelihood values increase.

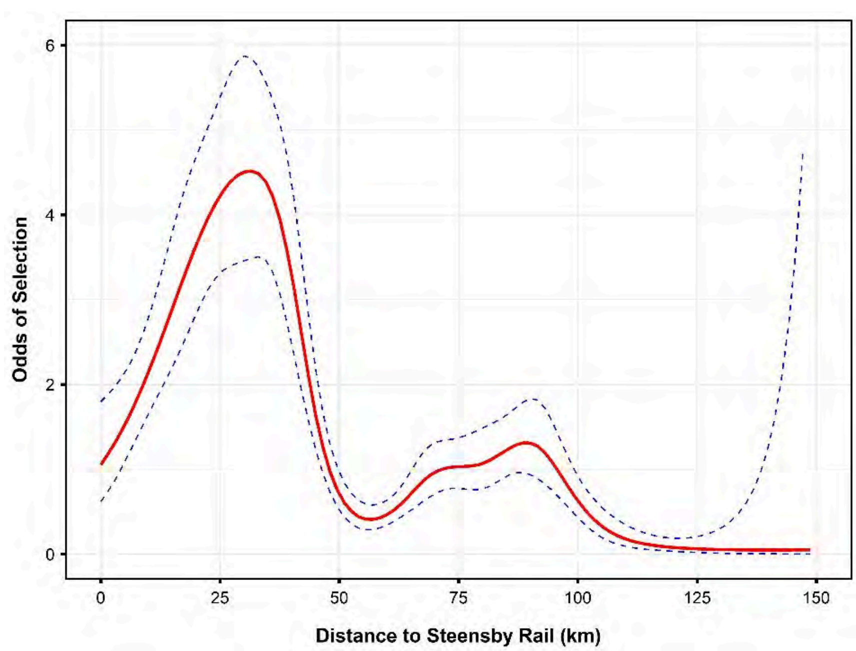
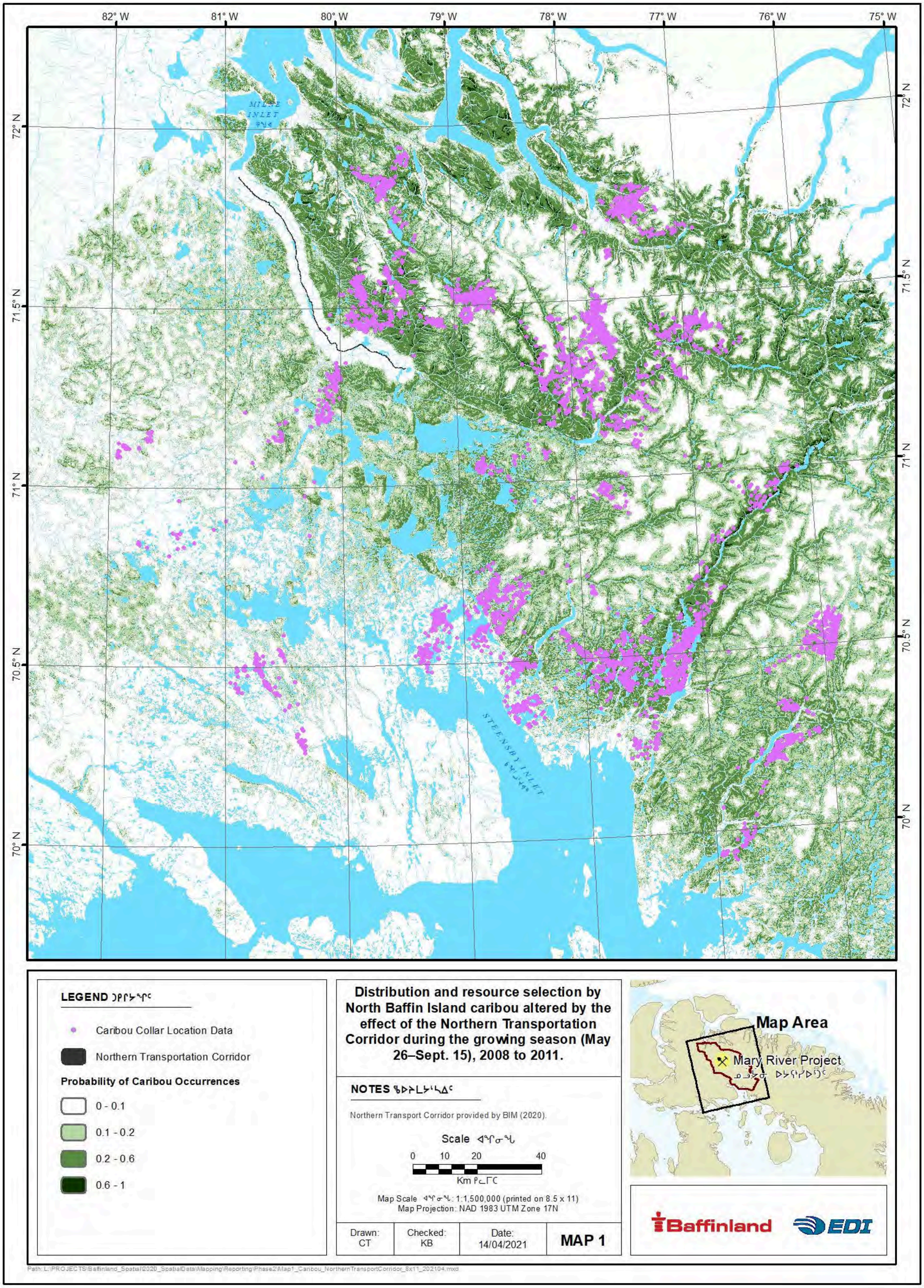


Figure 9. Marginal effects of distance to Southern Transportation Corridor (km), growing season (May 26–Sept. 15), on selection gradients based on a generalized additive model with cubic regression splines.
Solid red and dashed blue lines are the fitted mean and confidence intervals, respectively. Steep gradients occur at close, intermediate, and far distances from the footprint.


82° W
81° W
80° W
79° W
78° W
77° W
76° W
75° W
72° N
71.5° N
71° N
70.5° N
70° N
MILNE INLET
STEENSBY INLET
LEGEND
Caribou Collar Location Data
Northern Transportation Corridor
Probability of Caribou Occurrences
0 - 0.1
0.1 - 0.2
0.2 - 0.6
0.6 - 1
Distribution and resource selection by North Baffin Island caribou altered by the effect of the Northern Transportation Corridor during the growing season (May 26–Sept. 15), 2008 to 2011.
NOTES
Northern Transport Corridor provided by BIM (2020).
Scale
0
10
20
40
Km
Map Scale: 1:1,500,000 (printed on 8.5 x 11)
Map Projection: NAD 1983 UTM Zone 17N
Drawn: CT
Checked: KB
Date: 14/04/2021
MAP 1
Map Area
Mary River Project
Baffinland
EDI
Path: L:\PROJECTS\Baffinland_Spatial\2020_SpatialData\Mapping\Reporting\Phase2\Map1_Caribou_NorthernTransportCorridor_8x11_202104.mxd

3.2.3 ESTIMATE SAMPLE SIZE FOR MONITORING

We assessed the distributions of ZOI distance and coefficient values produced by the 1,000 simulations for the range of simulated sample sizes of caribou. We fit local polynomial regression (LOESS) models to visualize the relationship between the confidence interval (CI) widths and the number of collared caribou. We expected that CI widths would decrease in size as the sample size increased. We would then use the range of caribou numbers corresponding with a relatively flat curve to determine an appropriate sample size for an impact monitoring study.

Given that resampling relied on the collar data's inherent variation, the final distribution of ZOI distances produced by simulations yielded bimodal shapes for each sample size. This is simply an artifact of the large-scale spatial gradients observed in caribou distribution (see Section 3.2.2, Zone of Influence). We discuss the implications of sampling at such broad scales and how it affects our ability to detect indirect habitat loss in Section 3.3, Anthropogenic Mechanisms Affecting Caribou Distribution. Regardless, the intent was to determine a reasonable sample size at which the variation in distance estimates would be minimal. Confidence interval widths decreased sharply with greater sample size, but the slope reduced in magnitude at sample sizes greater than 25 caribou (Figure 10). In contrast, estimates produced for the ZOI coefficients reduced sufficiently to level-off at a CI width less than one (Figure 11). Our LOESS regression predicted this asymptote to occur just beyond 30 caribou.

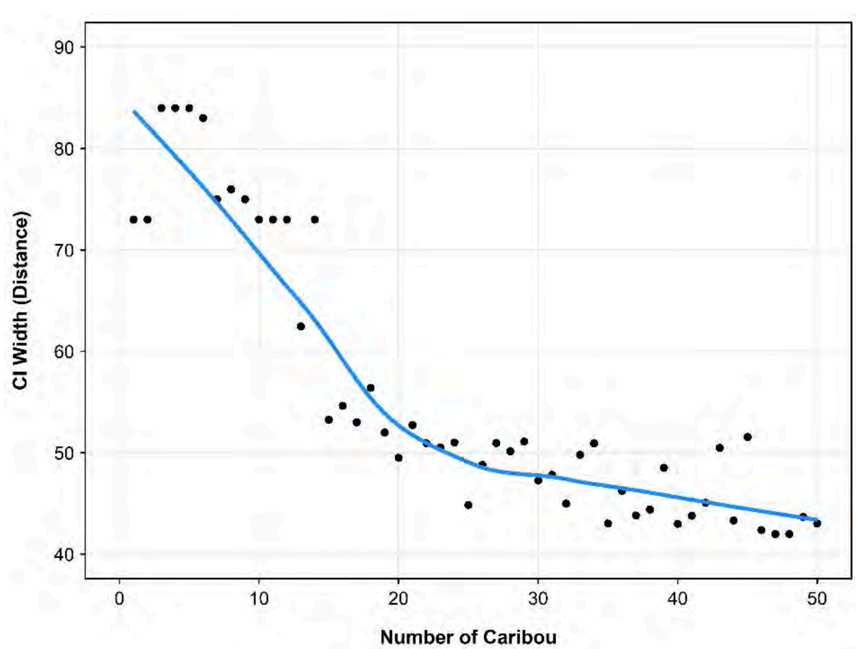


Figure 10. Confidence interval (CI) widths based on distributions of zone of influence (ZOI) distances selected from 1,000 hierarchical bootstrapping simulations at different sample sizes of collared caribou.
Resampling of collar data for the winter season (Sept. 16–May 25), 2008 to 2011. The blue line corresponds with the local polynomial regression (LOESS) fit to the data.

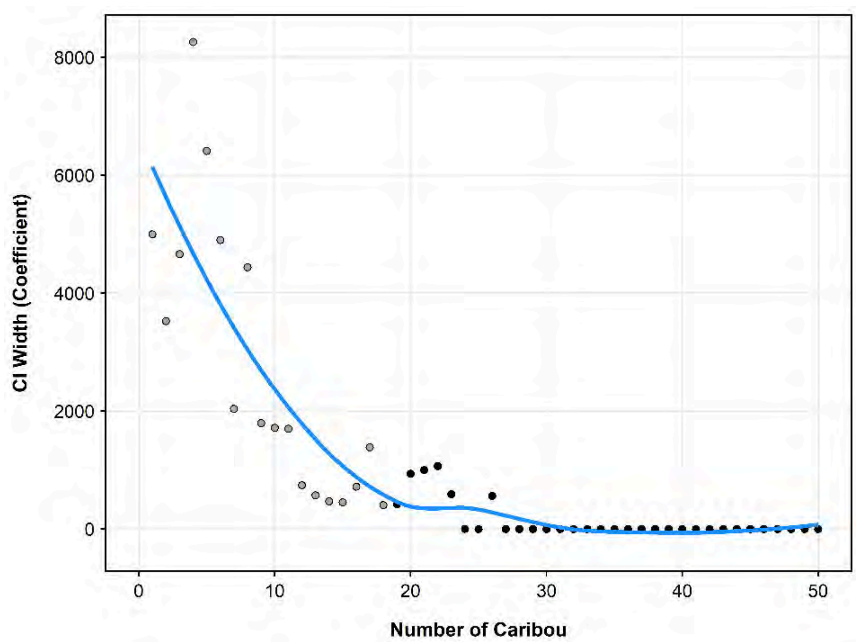


Figure 11. Confidence interval (CI) widths based on distributions of zone of influence (ZOI) coefficients selected from 1,000 hierarchical bootstrapping simulations at different sample sizes of collared caribou. *Resampling of collar data for the winter season (Sept. 16–May 25), 2008 to 2011. Blue line corresponds with the local polynomial regression (LOESS) fit to the data. Simulations produced different coefficient signs (+, –) among iterations; the colour of data points correspond with simulations having at least one negative sign (grey) or all positive signs (black).*

3.2.4 UPDATING DISTURBANCE COEFFICIENTS AND HABITAT LOSS ESTIMATES

In conducting this work, the methods selected to evaluate indirect habitat loss can easily be extended to a practical measures that will inform mitigation and management. These measures include disturbance coefficients and effective habitat loss. Disturbance coefficients are values that explain the total avoidance effect produced by Project-related disturbances within the ZOI. Disturbance coefficients are equivalent to the quotient between (1) numerator — the probability of caribou occurrence relative to the Project footprint when applying the ZOI estimate, and (2) denominator — the 'base' probability of caribou occurrence. These disturbance coefficients increase in value from the footprint (0 km) up to the ZOI boundary and identify the gradient of avoidance by caribou.

Another useful measure for mitigation and management is the amount of effective habitat loss. Effective caribou habitat is defined as the combination of dynamic abiotic (e.g., topography, microclimate) and biotic (e.g., lichen cover, conspecific density) conditions that support the life history requirements of caribou. Effective habitat can be estimated with the aid of RS(P)Fs — a key assumption being that the selection probability by caribou is directly proportional to habitat quality. The product of the selection probability and a unit of area equals the amount of effective habitat. Loss of effective habitat is determined by accounting for external (anthropogenic) forces that may degrade actual or perceived habitat quality when compared to baseline conditions. It is calculated as the difference in total effective habitat pre- and post-disturbance:

$$EH_{loss} = \frac{EH_{ZOI} - EH_{Base}}{EH_{Base}} \times 100\%$$

where EH_{ZOI} and EH_{Base} are the pre- and post-disturbance models, respectively, and are calculated as:

$$EH = \sum_{i=1}^{n} Area_i \times P_i$$

where the $Area$ (e.g., in hectares) and probability of occurrence P correspond for each i-th unit of area. Probability values are calculated for each i-th unit by interpolation, using the probability of the occurrence equation of the RS(P)F model. The EH value is dependent on the scale (e.g., localized area, study area, subpopulation range) and grain of analysis (i.e., size of the unit of area). It can be evaluated at different scales to provide targeted mitigation and make predictions about population demography. For example, if minimal loss to effective habitat occurs at a broad spatial scale (subpopulation range), it is unlikely to have consequences for the subpopulation. Alternatively, if there is substantial loss at a fine spatial scale (e.g., few kilometres from the footprint), then we can identify where the loss is greatest and focus mitigation actions at those locations by determining which habitat variables are most affected.

3.3 ANTHROPOGENIC MECHANISMS AFFECTING CARIBOU DISTRIBUTION

To study the impacts of anthropogenic disturbance on caribou distribution requires us to better understand and account for possible confounding factors that also shape spatial population dynamics. Objective and accurate investigation of impacts must consider the interaction of several potential mechanisms. We discuss why these mechanisms are important to measure and how they influence our assumptions for assessing barriers to movement and indirect habitat loss.

Our interpretations of potential barriers to movement and indirect habitat loss rely on two key assumptions: (1) barriers to movement are only relevant during directional migration, and (2) avoidance behaviour is commensurate with indirect habitat loss. These assumptions are crucial for quantified responses by caribou to be ecologically meaningful. Furthermore, we can redefine these 'responses' as true 'Project effects' only if we account for potentially confounding variables, whether spatial (e.g., subpopulation range expansion or contraction, migration routes) or temporal (e.g., population abundance cycle, variability in biotic and abiotic conditions), and provide evidence of a mechanistic link between Project activities and measurable effects.

Barriers to animal migrations are a relatively simple concept and are widely documented (Tucker et al. 2018). The most definitive example of barriers to terrestrial animal movements are highways that are uncrossable because of fencing or high traffic volumes (Seidler et al. 2018). The mechanism, in this case, is clearly associated with the design of the feature, sometimes intentional (i.e., wildlife fencing), and the effect is clear. Alternatively, and more commonly, animal movement barriers are better described as a filtering effect where an animal may choose not to cross or may delay crossing (Wilson et al. 2016). In this case, the mechanisms are less clear. But barriers are likely associated with infrastructure design that makes movement difficult or necessitates encounters with humans and human-related activity, which can slow the approach to the feature. Mechanisms that affect the migratory movement of North Baffin Island caribou potentially exist within the Study Area. Baffinland has partly mitigated potential effects through infrastructure design, but the lack of caribou interaction with the Project means the effects pathways are not understood in this setting. However, the current work identified that most caribou remain in small, local home-ranges for a substantial portion of the year and that distinct seasonal ranges are not evident for most caribou. Additionally, historical calving grounds are known to be north of the mine site and the Tote Road — these were not accessed seasonally by caribou based on our assessment of the available data. More productive habitat and watersheds are currently located east and south of the mine site and Tote Road where caribou are more abundant. Note: this is also consistent with caribou observations made by Baffinland's exploration teams (Baffinland Iron Mine Corporation 2019). At the current, low (sub)population size, North Baffin caribou are unlikely to be limited by access to forage based on their distribution and movements.

Avoidance behaviour is an effect that may be the result of either direct or indirect mechanisms of sensory disturbance. Direct mechanisms result from activities that produce stimuli that, when directly perceived by the animal, elicit a response. For example, high levels of dustfall, which can reduce lichen cover and its palatability (e.g., 1 km buffer of affected vegetation; Chen et al. 2017), or noise and activity, either as an auditory cue from blasting and drilling (e.g., up to 1 km avoidance during high activity; Eftestøl et al. 2019) or as vehicular traffic (e.g., proximity to road did not change with increased road traffic; Burson et al. 2000), can be investigated to determine their effect on caribou distribution relative to anthropogenic footprints. These mechanisms have been explored qualitatively (e.g., avoidance of low [1 km] versus high [2 km] use roads; Polfus et al. 2011), but quantitative measures are more appropriate where both the causes and effects have clear measures that are plausibly linked.

Indirect mechanisms are less clear but have been proposed as learned behaviours or group-level responses via public information (Boulanger et al. 2021). Though these factors may negatively affect caribou, either causing large-scale avoidance (Johnson et al. 2005) or substantial delays in road crossings (Boulanger et al. 2020), they may equally be potential drivers of habituation (Stankowich 2008, Johnson and Russell 2014). The issue with these so-called indirect mechanisms is the absence of a link to definitive measures of stimuli, unlike direct mechanisms. Conclusions of an effect are made based on correlations alone. In this sense, one is no longer taking a mechanistic approach and, instead, a correlative one to quantify Project effects. This is especially true because the species distribution modelling (i.e., RS[P]Fs) conducted here and elsewhere consider only components of the fundamental niche (i.e., Soberón and Peterson 2005) that drive the spatial distribution of caribou. Therefore, interpretation of a negative effect at this scale is speculative because a suite of potentially confounding factors are not considered (e.g., biotic drivers of large-scale habitat selection) that may lead to caribou not occupying the Project area. When such effects have been concluded, their mechanisms are rarely made explicit. Often, neither are the influences of scale (i.e., of sampling and analysis) on the estimates derived (e.g., 100+ km ZOIs; Johnson et al. 2005, Baltensperger and Joly 2019). In contrast, evidence favouring habituation, especially from data collected over several years, would be convincing because regardless of those confounding effects, the caribou would either still occur in proximity to the Project or cross one of its linear features without delay.

It has also been suggested that either abiotic or biotic factors, which cause caribou to reduce their avoidance of mine footprints, may lead to an ecological trap (Boulanger et al. 2021). Proposed examples include a reduced ZOI during intense drought years for the Bathurst herd (7.2 km mean ZOI; Boulanger et al. 2020b) and reduced ZOI for the Central Arctic herd during periods of high mosquito activity (1 km ZOI; Johnson et al. 2020). But for these to be ecological traps assumes that caribou are trading off high-quality habitat far away for perceived, yet supposedly dangerous, safe-havens close to anthropogenic footprints. At mine sites, the reduced habitat quality is likely restricted to within a few kilometres from the footprint. For example, noise monitoring results provided in Baffinland's annual reports demonstrate that Project-related noise was below 40dBA at 1.5 km from all Project areas, which meets operational thresholds (EDI Environmental Dynamics Inc. 2021). Additionally, the highest dustfall is mainly restricted to 1,000 m of the PDA (EDI Environmental Dynamics Inc. 2021), which is consistent with other studies (~1 km dustfall ZOI; Chen et al. 2017).

More importantly, ecological traps would only be present if a direct mechanism (e.g., dustfall) were at play that reduced actual habitat quality (e.g., lichen forage), thus yielding negative fitness consequences (Robertson and Hutto 2006, Hale and Swearer 2016), rather than perceived habitat quality. It would also assume that fitness consequences for settling near the footprint are more severe than remaining distant. Returning to the example of insect harassment, anthropogenic footprints may indeed be a refuge from insect harassment because of the sparse biotic environment. A potential counter-argument may be that increased cortisol levels from sensory disturbance and flight responses is of utmost concern. However, this argument disregards the fact that such responses can vary considerably due to context and types of stimuli (Noel et al. 2004, Stankowich 2008, Hansen and Aanes 2015, Plante et al. 2017, Eftestøl et al. 2019), and that insect harassment is known to affect (maternal) body condition due to increased movements and reduced rest and food intake (Russell et al. 1993, Gurarie et al. 2019). The consequence of remaining in a habitat swarmed by mosquitoes or oestrid flies is likely grave. It is not uncommon for caribou to seek out such refugia (e.g., Skarin et al. 2004, and discussion in Prichard et al. 2020). Therefore, choosing to occupy those footprints can be adaptive rather than maladaptive. Clearly, there is a fitness trade-off that is not well understood. Furthermore, increased glucocorticoid levels in animals do not necessarily correspond with distress or chronic stress — a common misconception (Romero and Beattie 2022). Under the right context, increased glucocorticoid levels can indeed be adaptive (Bonier et al. 2009, Sheriff and Love 2013). This example demonstrates why, when interpreting the results of these kinds of analyses, it is important to prevent preconceptions and negative biases from driving our conclusions (see Flydal et al. 2018).

Hunting pressure, a potential mechanism for larger-scale avoidance of road infrastructure by caribou and has the greatest potential to produce an ecological trap when caribou densities increase. Hunter access to haul roads with vehicles to increase their hunting efficiency, thereby posing a greater risk to caribou nearby (Plante et al. 2017). With the greater risk of predation, it is known that caribou demonstrate behavioural adaptations and vigilance (Bøving and Post 1997) that entail energetic costs (Frid and Dill 2002); generally, evidence suggests that hunted populations of ungulates show greater flight responses than non-hunted populations (Stankowich 2008). These responses to hunting may explain the difference in spatial distribution of caribou between growing and winter seasons relative to the Northern Transportion Corridor on North Baffin Island. In winter, hunters can access the area using the road and then more efficiently traverse the landscape beyond the Northern Transportation Corridor with snowmobiles. Therefore, a greater 'zone of hunting' may yield a greater 'zone of influence'. Detailed data collection would be required to investigate the potential impacts of hunting on caribou distribution relative to roads.

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APPENDIX B TEWG COMMENTS AND RESPONSES TO THE SEPTEMBER DRAFT REPORT

Response to TEWG Comments on the September 2021 Draft Report

EDI Environmental Dynamics Inc. (EDI) was retained by Baffinland Iron Mine Corp. (Baffinland) to provide recommendations and rationale for study design elements that are likely to yield robust monitoring and assessment of project effects at the Mary River Mine Project. The report — presented at two Terrestrial Environment Working Group (TEWG) meetings and submitted to the TEWG on October 6, 2021 — summarized a caribou collar program with proposed sample size, study areas, duration, and rigour deemed appropriate to inform Baffinland and interveners about measurable impacts to caribou due to the Project.

Project Commitment 54c requires that Baffinland provide a "*Description and justification of statistical design […] to support the conclusions drawn from monitoring impacts of the mine and related infrastructure on wildlife* (PC 54c). Relevant information about many of the comments are addressed under **Section 2.5.2: Holistic and Robust Data Analysis** of the *Terrestrial Environment Mitigation and Monitoring Plan* (TEMMP). This plan is the central Project resource that identifies how the monitoring programs will collect data and conduct meaningful, informative, robust, and useful analyses for decision-making and adaptive management practices.

The Government of Nunavut (GN) and the Qikiqtani Inuit Association (QIA) provided comments on December 3, 2021. Environment and Climate Change Canada (ECCC) and the Mittimatalik Hunters and Trappers Organization (MHTO) did not return any technical comments.

This Appendix responds to the GN and QIA comments; detailed clarifications and justifications are itemized systematically for each of the GN's (9) and QIA's (34) commentaries.

Response to GN Report Comments — A common theme of the GN's commentary appears to surround their perception of an inadequate sample design and the desire to apply an excessively cautious approach, regardless of study design. We consider that the GN may have misinterpreted the underlying rationale and undervalued the rigour of various inputs in the TEMMP and, specifically, the study design presented in this report. We are concerned with comments suggesting that a precautionary approach should be applied unilaterally and that ongoing implementation of the TEMMP is inadequate — especially when the comments are provided without any meaningful alternatives or solutions. The following detailed responses provide clarification and justification of the approach taken. Three of the nine comments resulted in minor revisions to the report.

Response to QIA Report Comments — A common theme of the QIA comments were addressed by directing the reviewers to areas in the document where the issue was discussed. Some responses provided the QIA with explanations of the technical aspects of some of the supporting literature. Some commentary highlighted areas requiring clarification or additional supporting evidence that will add value to the final report. Other comments (e.g., QIA-34) stretched a potential effect pathway beyond reason and seemingly questioned the professional ethics of the authors. Clarifications and justifications have been provided in the following detailed responses. Fifteen of the comments resulted in either minor revisions to the report or expansion on the discussion to clarify arguments and provide more supporting evidence as requested by the QIA.

Name: Bradley Pirie

Agency / Organization: Government of Nunavut

Date of Comment Submission: December 3, 2021

Document Reviewed: Mary River Project, Caribou Monitoring: Triggers and Recommendations, September 2021

#	Section Reference	Comment	Baffinland Response
1	General	The report is well written, informative and provides useful background to support implementation of caribou monitoring programs for the Mary River Project. However, several of the report's conclusion may warrant revision based on some of the following comments.	Thank you for the review. **Changes to Draft Report:** • Not applicable
2	Pg. 2, Section 1.1	<u>This section states:</u> "… caribou are currently at an all-time low in their population cycle, with densities being too low to make current efforts at monitoring informative for determining Project-related effects (Savikataaq 2020). Since operations began, few to no caribou have been observed near the Project. As caribou numbers are currently too low for impact monitoring, a numerical 'trigger' needs to be developed to identify caribou densities required for an effective study. In the interim, caribou observations collected via Baffinland's surveillance monitoring program continue to provide information on caribou distribution relative to the Project." <u>Comment:</u> The section in bold above was paraphrased from a letter to the Mayor of the Municipality of Pond Inlet from Premier Savikataaq, dated December 9, 2020. For clarity and transparency, the entire paragraph the boldened statement was derived from is included here: "*With respect to the Baffin Island caribou herd, Baffinland's Final*	Effective monitoring relies on sample size. This is entirely consistent with the GN's original statement "*Because of the low population level around the Project, it is difficult to collect meaningful data.*" Baffinland prepared this report to further inform the TEWG and NIRB about sample size and methodology for effective impact monitoring. Our paraphrasing of the GN's letter did not misconstrue its original meaning. Our report makes no claims about the utility of regional caribou monitoring. Instead, the report's purpose focuses on the utility of robust impact/effect monitoring. Impact monitoring requires measurable and detectable impacts (i.e., 'statistically significant'), and sample size directly affects such detectability. This issue of

#	Section Reference	Comment	Baffinland Response
		Environmental Impact Statement (FEIS) Addendum (the Proposal), the subject of this NIRB assessment, identifies that its current independent monitoring efforts are not yielding meaningful data in terms of caribou population levels near the Project. This is expected considering the population level of the Baffin Island caribou herd is at its lowest level in its recorded history. Because of the low population level around the Project, it is difficult to collect meaningful data. To address this information gap, the GN and Baffinland are working towards a Research Contribution Agreement intended to be signed prior to the Final Public Hearing. To be clear, the GN's regional caribou monitoring and research obligations do not hinge on this Contribution Agreement. Instead, this Research Contribution Agreement represents a collaborative approach to understanding project-induced impacts to caribou." It is the GN's assertion that the intent of the above paragraph was misconstrued by the Proponent in its summary as presented in Section 1.1 of the report. The GN does not believe that the statement "*caribou numbers are currently too low for impact monitoring"* is correct. The GN believes that the current surveillance methods employed by Baffinland are inadequate and do not detect Project-related effects on caribou. For these reasons (and to meet GN responsibilities) the GN has been carrying out regional monitoring in North Baffin and seeks to enter into a Contribution Agreement with the Proponent to support this important research. Nowhere in the Premier's letter does the GN state that it believes regional caribou monitoring is not necessary at this time, in fact it is quite the opposite. The GN strongly believes that project- related effects monitoring, in the form of regional and local scale monitoring, is required now.	detectability directly relates to our use of the word 'informative' in that: *"…densities being too low to make current efforts at monitoring informative for determining Project-related effects"*. In no way did the report suggest that monitoring is not required. We make a distinction between 'impact monitoring' (i.e., programs to address and quantify cause and effect linkages between Project activities and components of the receiving environment) and 'surveillance monitoring' (i.e., programs to produce information about the pattern of occurrence of key indicators), which are described in the Terrestrial Environment Mitigation and Monitoring Plan (Baffinland Iron Mines Corporation 2019) and outlined in the Caribou Monitoring Triggers Study report (EDI Environmental Dynamics Inc. 2021). Impact monitoring requires substantial resources on top of existing surveillance monitoring. We provided recommendations to allocate resources where they would bring the most value to the Project. For example, one aspect of surveillance monitoring that is part of ongoing initiatives (as noted in the TEMMP) is an aerial survey of the Regional Study Area (see the response to comment GN-8). This survey may identify if the recommended trigger is met to initiate impact monitoring. The GN may have recently conducted an aerial survey of much of the Regional Study Area (RSA) in support of

#	Section Reference	Comment	Baffinland Response
			their recent collar program and could have information of value to an assessment of caribou density in the RSA. If the GN maintains more recent data from their regional monitoring that would aid in assessing caribou abundance and distribution, or Project-related impacts, we would welcome those data to explore their implications for appropriate mitigation. It is unclear what the GN means by *"current surveillance methods employed by Baffinland are inadequate and **do not detect** Project related effects on caribou."* Baffinland has acknowledged this comment repeatedly in TEWG meetings and other correspondence from the GN. Baffinland is unaware of any method, be it a scientific survey or through Inuit Qauijimajatuqangit, that will robustly detect Project-related impacts at the extremely low density of caribou currently in the RSA. Additionally, Baffinland has not yet received any appropriate suggestions or direction on what alternative methods (if any) would meaningfully enhance the detection of project-related effects on caribou. Likewise, no meaningful solutions have been advanced by the GN or other TEWG members on how these perceived inadequacies should be addressed. It is also important to reiterate that surveillance monitoring and impact monitoring serve different purposes.

#	Section Reference	Comment	Baffinland Response
			Changes to Draft Report: • None identified.
3	Pg. 3, Section 1.3	<u>This section states</u>: "… there is considerable disagreement over the size and magnitude of the ZOI due to differing data collection and analyses methods (e.g., Polfus et al. 2011, Boulanger et al. 2012, Johnson and Russell 2014, Baltensperger and Joly 2019, Johnson et al. 2020)." <u>Comment</u>: The observed variation in estimated zone-of-influence (ZOI) size amongst published studies should not be classified as a "disagreement". The variation is likely the result of numerous factors including data collection, analytical methods, sub-species (or ecotype), habitat, season, population status, type, and intensity of human disturbances, etc. The literature cited to support this statement includes studies of woodland and barren- ground caribou conducted in a wide variety of human disturbance landscapes. Differences in estimates of ZOI amongst these studies as such does not represent disagreement. Importantly, the observed variation in ZOI estimates in the literature emphasizes that caution should be exercised when using ZOI estimates obtained in one study in assessing effects in a different setting. A precautionary approach to assessment, mitigation and monitoring of the Mary River Project's effects should be taken until Project- specific ZOI estimates are available. This precautionary approach should include initiation of regional caribou studies early in the life of the Project even if the recommended sample size cannot be immediately attained. As demonstrated in the analyses presented in the Baffinland report, and discussed in GN comments, lower sample sizes may still be capable of detecting Project-related effects. The inability to obtain recommended sample sizes should not delay initiation of caribou studies when one is	The statement will be revised as "[…] there is considerable variability in the size and magnitude of ZOIs…" When taken in context, this assertion points to the fact that most (if not all) available studies on ZOIs do not consider potential mechanisms and do not control for basic spatial patterns. This latter point refers to the simple geometric principle that, with increasing distance from a project footprint (or some focal point), the area associated with caribou habitat is also likely to increase unless such habitat is limited on the landscape; thus, it is expected that caribou presence or abundance increases at distances farther from the footprint (Golder Associates Ltd. 2020). If one does not control for such spatial pattern, one cannot help but find more caribou the farther away one looks from a project. Indeed, we agree that investigative setting (i.e., ecotype, habitat, season, population status, type, and intensity of disturbance) is important. We did not intend to imply that ZOI estimates need be universal. Rather, the purpose of this discussion thread is to provide more fulsome context and balanced evaluation regarding 'what are ZOIs', 'how they are currently measured' and 'what are their limitations' in relation to our understanding of project-related

#	Section Reference	Comment	Baffinland Response
		employing a precautionary approach to environmental management.	impacts. The precautionary approach suggests that appropriate mitigation and management actions should be applied if/where available scientific evidence is incomplete or inconclusive. That said, there must also be a sound and credible case that a risk of serious or irreversible harm exists (Privy Council Office 2003) — which does not appear to apply in the present context. Note: Refer to response to GN-8 regarding alternate/parallel monitoring approaches at the Project intended to bridge gaps about ZOI and surveillance monitoring. **Changes to Draft Report:** • The statement "… there is considerable disagreement over the size and magnitude of the ZOI…" was revised to "… there is considerable variability in the size and magnitude of ZOIs…" • The Polfus et al. (2011) reference will be removed as it was the only reference to (northern mountain) woodland caribou.
4	Pg. 5, Section 1.4	This section states: *"Key assumptions grounded in a review of the literature included (1) that barriers to movement are only ecologically relevant during migration, (2) that avoidance behaviour corresponds with indirect habitat loss, and (3) the potential for caribou to interact with the Project is dependent on subpopulation size and density."*	i) The sentence before the one quoted by the GN states: "*The assessment also considers the context of North Baffin Island caribou subpopulation's ecology when providing recommendations for a monitoring.*" This statement leads

#	Section Reference	Comment	Baffinland Response
		Comments / Questions: i) What literature was used to support the statement that barriers to movement are only ecologically relevant during migration? Are barriers to movement such as roads or cut-lines only ecologically relevant to migratory species? ii) The report should consider that barriers to movement of north Baffin caribou could affect Inuit access to caribou, regardless of whether caribou exhibit migratory behavior. This would constitute a Project effect and should be discussed.	directly to our key assumptions based on the literature review and the GPS collar data exploration. Therefore, the comments/questions provided by GN are not relevant to the scope of the discussion because we do not claim that barriers to movement are only applicable to migratory species. The GN should carefully review the evidence associated with caribou movement/avoidance of roads and especially cut-lines. The context in which the preponderance of evidence suggests that linear features affect caribou is regarding habitat-mediated apparent competition and facilitated predation in (southern) boreal ecosystems (Dickie et al. 2017, 2020, Serrouya et al. 2017, DeMars and Boutin 2018, Keim et al. 2019, Pigeon et al. 2020, Nagy-Reis et al. 2021). It is crucial to note that this habitat context is not evident for barren-ground caribou, such as the North Baffin subpopulation. Demographic patterns of barren-ground caribou are mainly driven by forage and weather events, not predation (Hayes and Russell 2000). Based on barren-ground caribou ecology and assessment of the data, our supposition is that movement barriers are only ecologically relevant to North Baffin

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			Island caribou when they seek access to different seasonal ranges. We know that restricting migration will likely lead to population-level effects (see Wilson et al. 2016 and references therein). Our assumptions are not meant to be broad and sweeping. In the right context, we agree that barriers to movement can be ecologically relevant if they impact foraging success, habitat selection, and energetics even in the absence of migration. Our analysis of GPS collar data demonstrated that most caribou remain in small, local home-ranges for a substantial portion of the year and that distinct seasonal ranges are not evident for most caribou. Additionally, historical calving grounds are known to be north of the mine site and the Tote Road — these were not accessed seasonally by caribou based on our assessment of the available data. More productive habitat and watersheds are currently located east and south of the mine site and Tote Road where caribou are more abundant. Note: this is also consistent with caribou observations made by Baffinland's exploration teams (Baffinland Iron Mine Corporation 2019). At the current, low subpopulation size, North Baffin caribou are unlikely to be

#	Section Reference	Comment	Baffinland Response
			limited by access to forage based on their distribution and movements (EDI Environmental Dynamics Inc. 2021). When assessing how linear features may prevent habitat connectivity and access, one must consider the propensity for dispersal, especially for small (sub)populations (Beckmann 2011). Overall, our assumption for movement is based on what is known about migration ecology and its affect on population dynamics, as well as habitat distribution and the configuration of the sole linear feature on the landscape. Of course, a caveat to these assumptions is that once population abundance increase, competition for space and forage, and the potential to interact with the Project, will also increase. When this occurs, the effect of the Tote Road as a potential barrier will certainly need to be investigated. Until then, mitigation measures to ensure crossing should continue to be implemented (e.g., maintenance of snow berms during winter). ii) Changes in Inuit access to caribou are not addressed in this study. **Changes to Draft Report:** • None identified.

#	Section Reference	Comment	Baffinland Response
5	Pg. 5, Section 1.4.1	This section states: *"Regional effects refer to consequences beyond the Project footprint, but due to its presence in the region, on vital rates and demographic trajectory."* Comment: Effects on the movement and distribution of caribou that affect human access to caribou should also be considered as a regional effect.	Acknowledged that human access to caribou is considered a regional potential effect. However, as noted in response to GN-4, human access to caribou is not a component of this study. **Changes to Draft Report:** • None identified
6	Pg. 15, Section 3.3	Comment: While the precision-sensitivity analysis is a useful one, the bootstrapping exercise is limited by the dataset. The report assumes that the source data are representative of caribou behavior under conditions existing when the Project is in its production phase. However, the 2008-2011 data used in the analysis do not satisfy this assumption. The analysis relies on collar data collected during a period of very low Project activity. For example, as indicated in Table 2, only 2 of the 68 collar-years in the dataset used in the analyses covered a period when the Tote Road was being used for ore hauling. Even during this short period of hauling (in 2008) Project activity levels were well below those currently in effect and those expected for Phase 2. Additionally, as indicated on Page A-6 of the report, the precision-sensitivity simulations were performed using the winter season dataset only. The power to detect Project effects such as ZOIs depends in part on the magnitude of the effect on caribou. Therefore, the estimated sample size requirements obtained from the analysis represent those needed to detect effects of low-moderate magnitude during periods of low activity. Samples sizes needed during periods of higher activity, will therefore be lower. This should be reflected in the conclusions of the report and consideration should be given to adopting lower trigger thresholds for initiation of a collaring study of Project effects.	Of course, analytical results are influenced by and dependent on the availability of quality data. It should be recognized that the GN provided the data in question. If more fulsome or up-to-date information is available, we are keenly interested in evaluating movement and indirect habitat loss during production years. Precision-sensitivity simulations were conducted only for the winter season dataset because (1) these data had the most caribou locations and (2) the effect size detected (28 km ZOI), whether artificial or real, was larger than for the growing season. Therefore, data from the winter season were the best available to conduct such analyses. The GN comment states: *"The power to detect Project effects such as ZOIs depends in part on the magnitude of the effect on caribou. Therefore, estimated sample size requirements obtained from the analysis represent those needed to detect effects of low-moderate magnitude during periods of low activity."* We generally agree with this statement. That being

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			said, using common techniques implemented in most analyses of ZOIs (see report for all references, especially Boulanger et al. 2012, 2021), we identified a ZOI of 28 km during a period of low activity. We consider that this effect size is quite large (see Table 7 in Appendix A), regardless of whether it is or isn't a statistical artifact of current methods used to test for ZOIs (see discussion in report). Therefore, the sample size recommendations provided are, in fact, conservative; the power to detect ZOIs smaller than 28 km is expected to be lower under the 35 caribou/year recommendation (i.e., a larger sample size would be required to detect smaller effects than those observed for the winter season). **Changes to Draft Report:** None identified
7	Pg. 17, Section 4.1 AND Pg. 8	This section states: *"With these considerations in mind, 35 collared caribou were identified as the necessary sample size to be deployed and maintained annually to facilitate accurate and precise estimates of ZOI distances and coefficients. The 35 collars are required annually and are not a total quantity for the impact monitoring study duration."* AND *"Finally, the initial collar dataset was used in precision sensitivity (analyses) simulations to identify the sample size of caribou that would yield the greatest precision for identifying effects."* Comments:	Maintaining 35 collared caribou/year facilitates an adequate sample size to detect a temporal change in a ZOI estimates. The goal would be to implement this recommendation during periods for which ZOI estimates are required, i.e., as per the GN's statement, periodically during changes in type or intensity of Project related activities or at different phases of the north Baffin caribou cycle. It would be beneficial to collect data over several years during each period of interest to incorporate a temporal component to analyses. For example, annual assessments (2009 to 2017) of ZOIs at

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		i) What is the rationale for needing to maintain 35 collars annually? Is there a need to have 35 collared caribou throughout the life of the Project? Estimation of ZOI need only be done periodically throughout mine life, for example when there are changes in type or intensity of Project-related activities or at different phases of the north Baffin caribou cycle. Please clarify, how long this level of collaring would be needed? ii) As noted in GN comments 2(i) and 5(i), lower sample sizes could still yield valuable results. Therefore, 35 should be an objective but not a requirement for initiation of a collaring study. Thirty-five collared caribou represents the number needed for greatest precision in identifying effects under low Project activity conditions. However, as demonstrated by the sensitivity analysis, lower sample sizes could still identify effects with reasonable precision. If effects are of greater magnitude than those present in the dataset used in this report the effective sample size will be lower. These considerations should be discussed in the report and considered in its final recommendations on triggers and the triggers adopted by the TEWG.	the Diavik-Ekati mine complex were needed to demonstrate the frequent variation in ZOI estimates (five out of nine showing either no ZOI or attraction to the mine areas) over a 9-year period (Boulanger et al. 2021) RE: Lower sample sizes… Please refer to the response to GN-6 and the effect size we assessed to develop sample size recommendations. Indeed, 35 collared caribou represents the number needed for greatest precision, but it also accounts for issues such as collar malfunctions, caribou mortality, and long-distance dispersal by caribou outside of the intended study area. As for the last point on caribou dispersal, we reassert that spatial scale is an important, non-trivial consideration for ZOI estimation. **Changes to Draft Report:** • Edits were made to elaborate on the likely interannual variation in caribou response to mining activities from other studies and discuss the implications in the Baffinland collar study design and requirement for continuous collar data collection.
8	Pg. I AND Pg. 17, Section 4.1	<u>These sections state</u>: *"The assessment also confirms that resources are best directed towards ongoing surveillance monitoring until caribou density increases in the study area(s)."* AND	As shown in Figure 8 of the report, regional monitoring programs (specifically within the RSA) are designated as impact monitoring, which we distinguish from surveillance monitoring.

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		"Surveillance monitoring that documents more caribou crossing the Northern Transportation Corridor will increase the potential for successfully studying the Project's impacts on caribou movement. Until caribou are predictably approaching or crossing the Project infrastructure and migrating between seasonal ranges, studying the effect of the Project on caribou movement will remain exploratory and secondary to the study of indirect habitat loss." <u>Comment</u>: i) Surveillance monitoring is needed at present given low caribou densities. However, GN disagrees that Baffinland's current local scale monitoring activities (i.e. height-of-land surveys and road surveys) provide sufficient surveillance to serve as a trigger for caribou effects studies. As noted by the GN during review of the Project annual reports, these monitoring methods lack effective range and intensity to adequately monitoring caribou. Surveillance activities must include methods corresponding to the spatial scale of the effects otherwise impacts may be occurring whilst local monitoring fails to trigger effects studies. The current local monitoring is of very low frequency and is incapable of effectively detecting caribou at distances equal to and beyond potential ZOIs for the Project. Regional monitoring in the form of a collaring program is needed to track changes in caribou density and distribution. The report, including Figure 8, should add a regional collaring program to the list of required surveillance tools.	We disagree that a collaring program would help track changes in caribou density, which falls outside of its intended purpose. We recommend that aerial surveys take place to estimate population size and density in the Project area before implementation of a collaring program. Aerial surveys, especially those conducted by the GN, would provide us with useful information about abundance and distribution to 'trigger' and supplement impact monitoring. Baffinland is committed to supporting regional-level surveys as per PC 51, as identified (first) in section 2.5.2 of the TEMMP, and recognized in Baffinland's Agreement in Principle with the GN. AS noted in response to GN-2, Baffinland has not yet received any appropriate suggestions or direction on what alternative methods (if any) would meaningfully enhance the detection of project-related effects on caribou. Likewise, no meaningful solutions have been advanced by the GN or other TEWG members on how these perceived inadequacies should be addressed. It is also important to reiterate that surveillance monitoring and impact monitoring serve different purposes. **Changes to Draft Report:** • None Identified

#	Section Reference	Comment	Baffinland Response
9	Map 2	Comment: i) It is unclear how the boundaries of these study areas were derived. The distance from Project infrastructure to the edge of the study areas varies substantially. Please provide greater detail on how boundaries were determined.	Boundaries of the study areas in Map 2 conform with those developed for the Project's *Terrestrial Wildlife Baseline Report – Final Environmental Impact Statement*, as mentioned pg.19 of the triggers report (cf. EDI Environmental Dynamics Inc. 2012 for more details). The baseline study area was split into Northern and Southern extents to assess the impacts of infrastructure at each respective extent independently. **Changes to Draft Report:** • Included a citation in the final report to the FEIS materials where the RSA boundaries were defined.

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Names: Jeff Higdon, Susan Leech

Agency / Organization: QIA

Date of Comment Submission: December 3, 2021

Document Reviewed: Mary River Project, Caribou Monitoring: Triggers and Recommendations, September 2021

#	Section Reference	Comment	Baffinland Response
1	Executive summary	*"Until North Baffin Island caribou reinitiate migratory behaviour, which is expected when caribou numbers increase, statistically meaningful telemetry-based monitoring of the Project's potential impact on caribou movement between seasonal ranges is not achievable."* How does Baffinland know caribou haven't started to reinitiate migratory behaviour? What does IQ say? How has it been considered here?	Current recommendations regarding the monitoring schedule are based on the best available data; Baffinland/EDI are committed to updating these recommendations based on new information. As the primary body on the TEWG representing Inuit, we invite QIA to summarize any additional information Inuit have shared with QIA related to caribou migration based on hunter observations and IQ. **Changes to Draft Report:** • None identified
2	Executive Summary	*"A zone of influence was detected for the northern transportation corridor, but its magnitude and extent depended on the scale of the analysis."* Can the authors consider developing an approach that would allow zone of influence to be determined using a mixed model (i.e., habitat models with social science methods based on IQ)?	Determining a ZOI is a quantitative exercise and requires specific measures of distance. That said, we are open to exploring and learning more about studies that QIA may be aware of that could integrate quantitative habitat models with IQ or provide other independent validation of results. **Changes to Draft Report:** • None identified
3	Executive summary	*"Results of this assessment show that a sample of 35 collared…The assessment also confirms that resources are best directed towards ongoing surveillance*	This comment falls outside of the scope and intent of this report. The QIA's interpretation of "*an appropriate application*

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		monitoring until caribou density increases in the study area." Given the risk of avoidance occurring at low densities that goes undetected, an appropriate application of the precautionary principle would be to ensure that all mitigation measures are taken now (i.e., avoiding disturbance during calving and post-calving periods in particular), with surveillance monitoring ongoing as caribou density increases.	*of the precautionary principle*" is addressed elsewhere in Project review and annual report commentary. **Changes to Draft Report:** • Not applicable
4	1.1	"*In the interim, caribou observations collected via Baffinland's surveillance monitoring program continue to provide information on caribou distribution relative to the Project*." Which program(s) is/are providing data on caribou distribution?	Currently, Baffinland is implementing height of land and road surveys to collect data on the local distribution of caribou relative to the Project. Motion-triggered camera monitoring was also implemented in late summer of 2021; 12 cameras were deployed at six paired sites to take photos every hour (24 hours/day) and photos triggered via motion sensors. More details about this program will be provided in the 2021 annual report. Plans for aerial surveys are also underway (see below in comment QIA-5 and QIA-18). **Changes to Draft Report:** • The discussion expanded in the final report.
5	1.2	Baffinland uses a population size of 224 caribou (95% CI = 96–521) in the Mary River area, based on the GN's 2014 aerial survey. There has been 6 years of potential population growth since then; are more recent estimates available from the GN? The upper 95% CI of the 2014 estimate also included sufficient numbers based on the EDI analysis. Population growth between 2014 and now could be modeled, and fit to newer estimates if they are	It is inappropriate to use the upper CI when estimating population levels, and making decisions about the allocation of resources for impact monitoring. These confidence intervals are extremely wide; the deviation of the upper CI from the estimate is greater than the estimate itself (i.e., 224 + 297 = 521). The GN's population estimate was for the entire North Baffin Island Herd range. Our sample size is required within the RSA. Estimates of abundance (224 caribou) and density (5.7 caribou/1,000 km²) are based on a total area of 39,357 km² for

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		available, as with continued growth since 2014, the population is likely at 350+ animals now. Caribou herds can grow rapidly under optimum conditions (which might not exist on Baffin Island at the present time). In 1967, 48 Coats Island caribou were introduced onto Southampton Island, which grew to 1,200 +/- 340 caribou in 1978, to 5,400 +/- 1,130 in 1987, 9,000 +/- 3,200 in 1990, 13,700 +/- 1,600 in 1991, 18,275 +/- 1,390 in 1995, and 30,381 +/- 3,982 in 1997, before declining to 17,981 +/- 2,127 in June 2003 (Campbell 2006 and references therein). These results indicate a population growth rate of ca. 27%/year between introduction in 1967 and 1997, before the population started to decline rapidly (40% decline between 1997 and 2003). A lack of predators and ideal habitat conditions undoubtedly played a role in the rapid increase post-introduction, but significant numbers of animals were also harvested both commercially and domestically during the six years that the herd declined (Campbell 2006). Reference: *Campbell, M. 2006. Monitoring condition, feeding habits and demographic parameters of island bound barren-ground caribou (Rangifer tarandus groenlandicus), Southampton Island, Nunavut. Government of Nunavut, Department of Environment, Final status report 3. Iqaluit, NU. 18 pp.* While it is likely that northern Baffin Island caribou numbers have not grown at this rate (due to habitat degradation, etc.), some positive population growth since the last survey can be expected. Harvesting has	the Mary River stratum (Campbell et al. 2015). This area is approximately two times larger than the RSA (21,053 km^2, EDI Environmental Dynamics Inc. 2012). For this study design, the RSA was split into 'northern' and 'southern' study areas. Therefore, the number of caribou within the Project area is roughly half what was estimated for the entire Mary River stratum. We are unaware of any recent estimates that are available from the GN or from IQ. We do not believe that extrapolating population size data without basis or using estimates from a spatially restricted subpopulation with different ecological (such as those noted by the QIA for the Coats Island caribou introduced caribou) contexts are useful exercises in this circumstance. **Changes to Draft Report:** • None identified.

#	Section Reference	Comment	Baffinland Response
		been limited, and wolves are at low abundance on Baffin Island so predation rates are expected to be low. Assuming 10% annual growth, the herd would have grown from an estimated 224 in 2014 to 440 caribou in 2021, which is well above the minimum herd size Baffinland/EDI say are needed for monitoring. A conservative estimate of 5% annual growth would result in a current (2021) population of ca. 320 animals from the 2014 estimate of 224. **What data are available to indicate that the herd has NOT yet reached the purported required minimum?**	
6	1.3	*"Currently, investigations of ZOIs also lack an understanding of mechanisms and do not explicitly consider the effect of different spatiotemporal scales on the estimates derived (Bajina et al. 2021)."* Bajina et al. (2021) is a non peer-reviewed conference presentation, far more information is needed here.	This conference presentation was compiled with professional rigor and senior technical oversight; arguments therein are supported by a review of methods/results of peer-reviewed articles and analyses. EDI can expand on the topics of this presentation (literature review, analyses/simulations, and conclusions) in the report. **Changes to Draft Report:** • EDI will summarize the topics of the Bajina et al (2021) presentation in the body of the report.
7	1.3.1	*"Incidental observations of caribou on or near the Project footprint are also included under the surveillance program."* The TEWG has suggested, multiple times, that more could be done with these data, e.g. haul truck observations with associated effort data. Baffinland should provide this analysis for all years since Project trucking started.	Too few observations of caribou prevent any type of quantitative analyses with these data. There were six caribou observed in 2013, and one caribou in 2020 observed interacting with the road. These numbers of observations are too low to conduct any type of project-related effects analysis on caribou behaviour. **Changes to Draft Report:** • None identified.

#	Section Reference	Comment	Baffinland Response
8	1.4	*"Key assumptions grounded in a review of the literature included (1) that barriers to movement are only ecologically relevant during migration, (2) that avoidance behaviour corresponds with indirect habitat loss, and (3) the potential for caribou to interact with the Project is dependent on subpopulation size and density."* Re: assumption 1, what evidence is available to support this? Barriers to movement could be ecologically relevant at other times of the year if they impact foraging success, habitat selection, energetics, etc. Re: assumption 3, how is interaction potential dependent on population size? Furthermore, why does a literature review require any assumptions at all? Do you mean to say "based on your literature review"? If yes, it seems to have missed some important evidence.	The cited paragraph mentions that our assumptions are based on a literature review. <u>Assumption 1:</u> Based on barren-ground caribou ecology and assessment of the data, our supposition is that movement barriers are only ecologically relevant to North Baffin Island caribou when they seek access to different seasonal ranges. We know that restricting migration will likely lead to population-level effects (see Wilson et al. 2016 and references therein). Our assumptions are not meant to be broad and sweeping. In the right context, we agree that barriers to movement can be ecologically relevant if they impact foraging success, habitat selection, and energetics even in the absence of migration. Our analysis of GPS collar data demonstrated that most caribou remain in small, local home-ranges for a substantial portion of the year and that distinct seasonal ranges are not evident for most caribou. Additionally, historical calving grounds are known to be north of the mine site and the Tote Road — these were not accessed seasonally by caribou based on our assessment of the available data. More productive habitat and watersheds are currently located east and south of the mine site and Tote Road where caribou are more abundant. Note: this is also consistent with caribou observations made by Baffinland's exploration teams (Baffinland Iron Mine Corporation 2019). At the current, low subpopulation size, North Baffin caribou are unlikely to be limited by access to forage based on their distribution and movements (EDI Environmental Dynamics Inc. 2021a). When assessing how linear features may prevent habitat connectivity and access, one must consider the propensity for dispersal, especially for small (sub)populations (Beckmann 2011).

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#	Section Reference	Comment	Baffinland Response
			Overall, our assumption for movement is based on what is known about migration ecology and its effect on population dynamics, as well as habitat distribution and the configuration of the sole linear feature on the landscape. Of course, a caveat to these assumptions is that once population abundance increase, competition for space and forage, and the potential to interact with the Project, will also increase. When this occurs, the effect of the Tote Road as a potential barrier will certainly need to be investigated. Until then, mitigation measures to ensure crossing should continue to be implemented (e.g., maintenance of snow berms during winter). Assumption 3: Potential interaction, or more generally overlap, of North Baffin Island caribou with the Project area is dependent on population size due to density-dependent habitat selection and range expansion, for which there is a plethora of evidence. Currently, the available data (GPS collars and aerial surveys) suggests that caribou are most abundant south and east of the Project. The expectation is that dispersal will occur following population growth. Further support from Section 3.1 of the report: *"Population size and density affect female fecundity (Pachkowski et al. 2013) and calf-survival (Mahoney et al.2016) because of competition for food resources (Bowyer et al. 2014). Ultimately, such competition shapes caribou demography and distribution, including range expansion and contraction (Messier et al. 1988, Bergerud 1996, Ferguson et al. 2001, Mahoney and Schaefer 2002, Hinkes et al. 2005, Ricca et al. 2012). Thus, the extent of space-use provides a useful indicator for numerical changes in caribou populations (Schaefer and Mahoney 2013)."*

#	Section Reference	Comment	Baffinland Response
			The reviewer suggests that the report "*…missed some important evidence*" but failed to identify what evidence was missing. **Changes to Draft Report:** • None identified.
9	1.4.	*"This level of thoroughness has been lacking in impact monitoring conducted at other existing projects to date."* No evidence is provided for this statement; it would be good to compare monitoring conducted at other projects in the north to ensure common standards of thoroughness are being achieved.	There are no other known impact monitoring studies that have considered a collar study design as was done in this report. We are unable to cite non-existent study designs. This is a technical report written for technical input from the TEWG. We presume that the QIA reviewers are familiar with terrestrial monitoring and monitoring literature from other northern sites. If the QIA can direct us to where a thorough study design such as this was developed, we will incorporate as a change to future versions of the report. **Changes to Draft Report:** • Included a review of impact monitoring study designs from other northern and Arctic projects in the final report.
10	1.4.1	*"In assessing potential Project-related impacts, a distinction is made between effects that occur at local versus regional scales. Local effects refer to potential consequences of direct interaction with the Project footprint, which includes harm or injury of individual caribou. Generally, site personnel monitor these interactions through surveillance monitoring such as incidental observations, height-of-land and snow track surveys."* The existing programs aren't doing much to monitor local effects, or if they are, all the available data are not being reported (see previous comment re: haul truck observations).	Current surveillance monitoring activities are designed to monitor local effects. The result of these monitoring activities will depend on caribou interaction with the Project. A local effect cannot be identified if caribou do not interact with the Project. Baffinland has provided all data to the TEWG for their review. This includes the incidental sightings that would be collected by haul truck observations. Baffinland has been transparent in evaluating and analyzing all collected data, and these results were provided in annual reports. **Changes to Draft Report:** • None identified

#	Section Reference	Comment	Baffinland Response
11	2	As noted in the overarching comments, splitting the methods and results into the main document and the appendix makes the document more difficult to review than it needs to be.	Reporting in this format is meant to facilitate greater accessibility to a broader audience. We assumed this effort would be appreciated by the QIA as it may allow for a greater number of their constituents to access this material. Our intent was not to make review difficult; rather, we summarized general findings sooner in the report for those reviewers preferring to evaluate key results and conclusions at a glance. Comprehensive technical/supporting information and rationale are then presented in the main document. **Changes to Draft Report:** • None identified
12	2.1.2.1	"*To quantify indirect habitat loss, we restricted our analysis to include only the GPS collar data because of their relatively frequent fix rates and greater sample size.*" Quantify differences, what is "relatively frequent"? See also comments below on caribou telemetry locations. "*We split telemetry data into winter (Sept. 16–May 25) and growing (May 26–Sept. 15) seasons by calendar dates but not by year because there were no discernable patterns in range use during other seasons relevant to caribou ecology (e.g., calving, post-calving, and migration), and because we were not interested in effects by year*." This fails to consider annual variation in green-up timing, etc., and could obscure some important environmental relationships. What is justification for date selection?	As mentioned in the report, both VHF and GPS data were provided by GN. Only GPS collar data were used in analyses because fix rates are relatively more frequent than those from VHF collars. Differences between GPS and VHF telemetry data are well-known/established. To clarify, we were not interested in year effects because patterns of habitat selection were consistent across years. Additionally, we did not explicitly include green-up timing but rather total vegetation cover during the peak period of the growing season (~July). Strong, consistent patterns in habitat selection were identified (see Tables 2 and Table 5 in Appendix A) and their ecological relevance was discussed in the report. Date selection was based on visual assessment of caribou locations and expectations of freeze and thaw that would affect caribou habitat selection. As mentioned in the quote provided in the comment: *"there were no discernable patterns in range use during other seasons relevant to caribou ecology (e.g., calving, post-calving, and migration)."* Therefore, broad seasons were

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			chosen to maximize the number of caribou locations when conducting analyses. **Changes to Draft Report:** • None identified
13	2.2.1	*"We excluded caribou from the analysis and summary if their annual trajectory did not include the entire non-winter season (i.e., spring migration to fall) because the movement could not be classified if the time series did not include the potential to departure and return to seasonal ranges. After excluding caribou trajectories with small samples of locations, 68 caribou movement trajectories remained from 2008–2011. The 68 trajectories represent the annual movements of 30 collared caribou."* 30 of how many total collared? How much data were excluded?	Thirty (30) of 31 unique animal IDs were used in the analysis. There were 31 unique animal IDs in North Baffin Island based on the GPS collar dataset provided by GN. The filtering of North Baffin Island caribou was based on an attribute ('Herd') provided in the dataset. **Changes to Draft Report:** • Add the above response within the text of the final report.
14	2.2.2.1	*"Prior to analyses, we converted the covariate, aspect, from continuous (degrees) to categorical (cardinal directions) based on 90° intervals."* Why?	There is no reason to assume a linear (or polynomial) relationship for aspect on a continuous scale. We expect aspects to be relevant to solar radiation and snow cover, which are generally favoured to the south and east or west, depending on prevailing winds. Overall, using aspect as a categorical variable is very common when developing resource selection functions. See Gustine et al. (2006) and Johnson et al. (2020) for two examples of this implementation. **Changes to Draft Report:** • Add the above explanation to the final report.
15	2.2.2.2	*"We tested several distance thresholds: once using rarified datasets with only locations inside the identified iteration zone, and then using all caribou locations and*	Distances thresholds were tested up to 100 km from the Tote Road, which is four times as large as the geometric mean of all maximum step lengths (~25 km) from collared caribou. Even the

#	Section Reference	Comment	Baffinland Response
		testing thresholds up to 100 km. The assumptions were that caribou presence would be reduced, and resource selection altered, within the threshold; and that caribou presence would be increased, and resource selection unaltered, beyond the threshold. We assigned all distances at or beyond the defined threshold the same distance value." Shouldn't the caribou movement data be used to define the thresholds?	reduced iteration zone, 50 km from the Tote Road, was twice as large as the geometric mean of all maximum step lengths. These iteration zones were chosen to explicitly account for observed caribou movement. This information is already included in the results (Appendix A of the report). **Changes to Draft Report:** • None identified.
16	2.2.3	*"We conducted precision-sensitivity simulations specifically using the winter season dataset because of the season length, potential sample size requirement, and the shape of the log-likelihood surface used in ZOI estimation for the winter season (see Section 3.2.2 Zone of Influence)."* But the season length was *a priori* and arbitrarily defined by the analysts	This comment is incorrect; its intention is not clear. The selection of season was neither *a priori* nor arbitrary. As mentioned in the report, the selection was based on evaluation of the collar data: *"We split telemetry data into winter (September 16–May 25) and growing (May 26–September 15) seasons by calendar dates but not by year because there were no discernable patterns in range use during other seasons relevant to caribou ecology (e.g., calving, post-calving, and migration) …"* **Changes to Draft Report:** • None identified.
17	3.2	*"Potential explanations for the difference in detected ZOIs between seasons may be (1) insufficient sample size within the vicinity of the footprint, (2) insufficient annual collar data, or (3) external factors not considered in the base habitat model that shape habitat selection and subpopulation range at broader scales (e.g., mechanisms that yield different seasonal range use by caribou)."*	Suitable winter habitat distribution was described and mapped in the FEIS baseline materials (EDI Environmental Dynamics Inc. 2012). Seasonal habitat mapping was secondary to this report. **Changes to Draft Report:** • Add to discussion reasoning for including a map of the growing season RSPF

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		How is suitable winter habitat distributed on the landscape?	
18	4.1`	*"Therefore, observing 35 groups of caribou, each consisting of 7–10 animals (as has been observed in this subpopulation to date based on IQ and survey observations), provides an alternative trigger for impact monitoring."* The analyses indicates a range of 245 to 350 caribou is required, which could be present now based on reasonable (and possibly conservative) population growth projections of the 2014 abundance estimate (see comment 5 above). When will Baffinland conduct surveys, and when does Baffinland expect to start collaring? What exactly does "observing 35 groups of caribou" mean? What sorts of observations (e.g., ground-based, aerial)? How will unique groups be distinguished? What role will IQ and hunter observations play?	As mentioned in the response to QIA-5, estimates of abundance (224 caribou) and density (5.7 caribou/1,000 km²) are based on a total area of 39,357 km² for the Mary River stratum (Campbell et al. 2015). This area is approximately two times larger than the Regional Study Area (21,053 km²) identified in Baffinland's FEIS (EDI Environmental Dynamics Inc. 2012). The RSA was split into 'northern' and 'southern' study areas in the triggers report. Therefore, the number of caribou within the Project area is roughly half what was estimated for the entire Mary River stratum. Further, *"EDI applied for a research permit to conduct aerial surveys, but ultimately the application was pulled as the GN created additional delays in the permitting process when they initiated engagement with the TEWG prior to reviewing the application. This resulted in an untimely delay in planning for the surveys, meaning that ultimately the window for fall surveys when caribou would be most detectable and in groups was missed. These surveys would have been useful to estimate both abundance and distribution relative to the Project. Baffinland and EDI are currently evaluating submitting another research permit application for 2022 surveys, however further discussion with GN on their 2022 regional research plans is required first. Updates will be provided to the TEWG when available.* Please refer to Figure 8 in Section 4.3 of the report. Thirty-five (35) groups were provided as an alternative, more flexible indicator based on a mean group size of 7–10 caribou. This option was previously discussed during a TEWG meeting on December 10, 2020. During the meeting, this group size was deemed appropriate based on the results of previous aerial

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<table>
<tr><th>#</th><th>Section Reference</th><th>Comment</th><th>Baffinland Response</th></tr>
<tr><td></td><td></td><td></td><td>surveys and IQ. Figure 8 explicitly states that these 35 groups would be identified by aerial surveys.

Changes to Draft Report:

• None identified.</td></tr>
<tr><td>19</td><td>4.1</td><td>“Project-related impacts must be investigated without the negative bias that has plagued previous caribou studies (Setterington 2018; see Flydal et al. 2018 for discussion), and appropriate spatiotemporal scales must be considered (Plante et al. 2020, Bajina et al. 2021).”

Setterington (2018) and Bajina et al. (2021) are non-peer reviewed conference presentations; more details are needed.

Flydal et al. (2018) note (Abstract) that “[o]ur case study illustrates how yearly variation may lead to false conclusions about the effects of infrastructure”. The analyses conducted here made arbitrary decisions on season definitions based on calendar dates and did not consider annual variation. This EDI report states that “we were not interested in effects by year”, which may be a significant deficiency in the analysis and subsequent results. More justification is needed.</td><td>It is unclear what is meant by “significant deficiency in the analysis and subsequent results”. The study objectives dictated the selection of methods. The purpose of the RSF and ZOI analyses were not to measure annual variation in habitat selection and Project-related effects. Instead, the purpose was to use caribou location data to develop a study design for impact monitoring. Collar locations were pooled across years because the number of unique collars per year was limited and because habitat selection patterns across years were consistent (see the response to comment QIA-12).

The primary objective was met because (1) clear patterns of habitat selection were identified, (2) a large effect size was detected, and (3) these patterns of habitat selection and statistical ZOI were used to inform requisite sample size for future monitoring.

These conference presentations were compiled with professional rigor and senior technical oversight; arguments therein are supported by reviewing methods/results of peer-reviewed articles and analyses. EDI can expand on the topics of this presentation (literature review, analyses/simulations, and conclusions) in the report.

Changes to Draft Report:

• The discussion expanded in the final report to include elements of the response above.</td></tr>
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#	Section Reference	Comment	Baffinland Response
20	4.1	*"One caveat to the trigger proposed is that, though current evidence suggests it to be true, there cannot be complete certainty as to whether the subpopulation size and density of caribou on North Baffin Island (as a whole) will increase. Thus, if an increase does not occur but caribou more frequently interact with the Project, or if more recent data becomes available for caribou in proximity to the Project, different options for monitoring Project impacts should be explored."* What date are available on population growth rates since the 2014 aerial survey? What other monitoring options are available, and how will IQ be considered?	We are not aware of any recent estimates that are available from the GN. In the absence of relevant data, we consider that it would be more useful to immediately undertake aerial surveys in the Project area to determine the abundance/density and distribution of caribou (see responses to comments QIA-5 and QIA-18). We would welcome any additional information from the QIA (including supplementary data and/or IQ) that could contribute to establishing timelines for impact monitoring. Current recommendations are based on available data; these recommendations can be updated as new information is received. **Changes to Draft Report:** • None identified.
21	4.2	*"This report shows that at the current low densities of caribou within a 50 km buffer of the Project, it is not possible to implement a rigorous impact monitoring study to detect Project effects. Population density within the Northern and Southern study areas needs to be four to seven times greater than the 2014 Mary River stratum density of 5.7 caribou/1,000 km² (Campbell et al. 2015)."* These are not "current" data on density since there has been 6 years of potential population growth.	We welcome any additional information from the QIA (including supplementary data and/or IQ) that could contribute to establishing timelines for impact monitoring. Current recommendations are based on available data; these recommendations can be updated as new information is received. If QIA has information that suggests population growth has occurred, we welcome such data. In the absence of relevant data, it would be more useful to immediately undertake aerial surveys in the Project area to determine the abundance/density and distribution of caribou. **Changes to Draft Report:** • None identified.

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22	4.3	*"Surveillance monitoring focuses on efforts by Baffinland (e.g., HOL surveys, snow tracking surveys, incidental observations) and includes information collected from external sources (e.g., hunter observations, GN composition surveys)."* These data (e.g., effort-based analyses of incidental observations) need to be presented.	These data are provided in annual reports provided by Baffinland and reviewed by the QIA's consultants. **Changes to Draft Report:** • Not applicable.
23	4.3	*"When it is evident that caribou densities are increasing, it is recommended Baffinland initiate aerial surveys to collect data and estimate subpopulation size within the impact monitoring study area(s)."* Section 4.1 states that "current evidence suggests it to be true" with respect to increasing subpopulation size and density. What current evidence? What do hunter observations indicate with respect to caribou density changes in recent years? Improved methods of collecting evidence of increasing caribou population densities are needed and should be addressed in this report.	Please refer to Government of Nunavut (2019). Based on expected population cycles, the assumption is that following a critical low period (Red Phase), the herd will once again increase in numbers. However, these population cycles are not thoroughly studied, which is why we provide a disclaimer that we cannot be certain about this increase. We believe that our statements were clear and transparent. Please refer to Figure 8 in Section 4.3 of the report. We state explicitly that aerial surveys are required to assess population size and density of caribou in the Project area prior to impact monitoring. As the primary body on the TEWG representing Inuit, we invite QIA to summarize any additional information Inuit have shared with QIA related to caribou population densities based on hunter observations. **Changes to Draft Report:** • None identified.
24		*"Aerial surveys will then help determine how many caribou occur within the impact monitoring study area(s) and whether the number of caribou (or groups)*	We agree that surveys are required in the RSA to determine the abundance/density and distribution of caribou. Please see our response to comment QIA-5 and QIA-18.

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		observed is at, or close to, the target (i.e., approximately 350 caribou or 35 groups of caribou)." Caribou on north Baffin may already be at the target abundance and surveys are therefore needed now. What GN data (e.g., number of groups detected during composition surveys) are available? Availability of IQ to inform caribou density?	The latest GN composition survey in spring of 2018 identified 100 total caribou on North Baffin Island, down from a total of 254 in the spring of 2017 (Ringrose 2018). However, we do not think these should be used as an indicator of decline because composition surveys are not meant to assess population size. The report does not mention group sizes identified. Surveys are periodically required to assess the population size and density of caribou in the RSA. As the primary body on the TEWG representing Inuit, we invite QIA to summarize any additional information Inuit have shared with QIA related to caribou population densities based on hunter observations. **Changes to Draft Report:** • None identified.
25	2.1.1.1	**Caribou telemetry locations** Unclear how many GPS collars and how many VHF collars in total (could use a table to illustrate); also how many by study area (i.e., northern transportation corridor vs. southern). Clarify – all collars were North Baffin caribou but split into two study areas? How many individuals per study area? Unclear how often fixes on collar locations were obtained for each collar type.	There were 31 GPS collars (2008–2011) and 4 VHF collars (1987–1994). VHF collars were only investigated for data exploration purposes and were not used in any analyses, as mentioned in the Executive Summary and throughout the report. We did not divide caribou by study area for our analyses. The study areas were recommended based on the results of our analysis and the testing of iteration zones to estimate a ZOI. Our rationale is provided in Section 4.2 of the report. The median fix rate of GPS collar data was a fix every 22 hours. **Changes to Draft Report:** • Relevant clarification as noted in the response above is provided in the final report.
26	2.1.1.3	**Spatial data**	To our knowledge, the NRCAN dataset have not been 'ground-truthed' on North Baffin.

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		No citation for NRCAN dataset; has it been ground-truthed on North Baffin? Why such low resolution for waterbodies? This is important because it comes up as important factor explaining winter distribution. How does the resampling method used (resampling the finer resolution raster layers from NRCAN using bilinear interpolation to match coarser resolution (30x30 m) NDVI raster layer) potentially impact results? Information on how land cover layers were merged isn't clear. Why use 250K vector data (and not higher resolution water body boundaries using 50K vector data)? NDVI calculations can be sensitive to topography (e.g., shadow effects); was this considered? Every spectral index has limitations (NDVI for example is sensitive to the effects of soil type), so it's recommended to apply additional indexes for more accurate analysis of vegetation.	The purpose of using lower resolution for waterbodies was to identify major waterbodies and rivers in the region, not smaller ponds and streams. Resampling methods are often applied when spatial data layers are of different resolutions. Resampling from finer resolution to coarser resolution yields less information loss and more accuracy than resampling from coarser resolution to finer resolution. There would be a concern if the resource selection coefficients' results were counterintuitive or deviated from expectations, but this was not the case (see Table 2 and Table 5 in Appendix A). We agree that there are always limitations to the spatial data used in developing resource selection functions. There are several ways the analysis could have been conducted different, and these were contemplated during model development (e.g., using other indices or extracting mean values from a large radii around locations). When acquiring Landsat data to derive NDVI, we only considered Band 4 and Band 5 layers with <10% cloud cover to improve accuracy. Overall, the relationship between NDVI and caribou locations was strong and met expectations (largest standardized, positive coefficient during the growing season; see Table 2 in Appendix A). **Changes to Draft Report:** • Relevant clarification as noted in the response above is provided in the final report.
27	2.1.2	**Movement** Re: restricting the start and end of each trajectory using the calendar year because caribou are assumed to be in their winter range by the end of the year. Does this	Yes, one caribou can have multiple trajectories, which is why there were a total of 68 trajectories from 30 caribou (see Section 2.2.1 in Appendix A).

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		mean that one caribou can have multiple movement trajectories in the dataset? Number of caribou movement trajectories from different caribou may be very low. How many different individual caribou are represented in the dataset? The movement analysis needs more explanation. What is net squared displacement? How is movement between fixes modelled? What does this look like in reality? Are the modelling locations used in the RSPF (confirm not?)? Is this better than just assuming a straight line between fixes? Would need to look at adehabitatLT package (Calenge 2006) and read on applicability to caribou that are non-migratory to know if this analysis approach is appropriate. Also how does the efficacy of the approach differ between GPS collars and UHF collars? Efficacy based on the space between relocations – but we don't know the relocation frequency for the dataset.	As stated in the report (Section 2.1 of Appendix A), net-squared displacement quantifies the cumulative change in location from the first location in the trajectory. This displacement is calculated in squared-metres (m^2), which helps to better visualize the displacement, relative to a starting location in mid-winter. This was used to classify different types of caribou movements into categories (i.e., migrant, mixed migrant, resident, and unclassified). There is no model, *per se;* the straight line between fixes are used to calculate displacement. As per the purpose of the analysis, this approach is appropriate to determine the presence and magnitude of migration behaviour (refer to Spitz et al. (2017) for further details). The median fix rate of GPS collar data was a fix every 22 hours. Only GPS collar data were used in analyses. VFH data were only used during data exploration and were not used in any analyses pertaining to the triggers report. **Changes to Draft Report:** • Relevant clarification as noted above is provided in the final report.
28	2.1.2.1	**RSPF and Indirect Habitat Loss** Only GPS collar (no sample size provided) Telemetry data was split into winter and growing seasons – no rationale provided. Another option could be to use the Inuit seasons for the analysis. How would that have changed the analysis? Removed observations based on certain conditions but don't explain why – 9 observations that had fixed greater than 99 hrs apart (why?); outlier locations to the	In total, 28 out of 31 GPS collars were used in developing RS(P)Fs and assessing indirect habitat loss. Choice of seasons were based on evaluation of the collar data, as mentioned explicitly in the report: "*We split telemetry data into winter (September 16–May 25) and growing (May 26–September 15) seasons by calendar dates but not by year because there were no discernable patterns in range use during other seasons relevant to caribou ecology (e.g., calving, post-calving, and migration) …*" Given that there was little difference in behaviour and range use among other ecologically relevant seasons, it is unlikely that conclusions made from the analysis

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		far west (why?); collar IDs that had very few locations recorded (why?) – this needs more explanation. Might be a better way to look at habitat selection – e.g., by dividing into habitat types and looking at the habitat types that are most often selected – particularly by telemetry relocations that are close together (spatially) – subsequent telemetry relocations that are close together would be indicative of selection. Winter season had double the locations to the growing season – what are the implications for the accuracy of the ZOI calculation?	would have changed by applying different seasons. In fact, we would have been more restricted in our sample size. Observations with >99 hours apart were removed because they correspond to collar fix errors (median fix rate = 22 hours). Outlier locations were removed because they were beyond the relevant spatial scale of the Project area. Note that all these outliers would have been excluded during assessment of indirect habitat loss based on the iteration zones we tested (up to a maximum of 100 km). Collar ID with very few locations were removed because they may induce potential bias in resource selection estimates and subsequent precision sensitivity analyses. Refer to Figure 1 of Appendix A to see that locations for each individual caribou ID were bootstrapped. The alternative method recommended in the comment is similar to a technique using selection ratios. However, this is not at statistically robust as the methods used in the report. If the QIA are aware of landcover data that would be helpful in future evaluations of habitat selection and Project-related effects, we would appreciate that information. During winter, more collar data provided more accurate inference of resource selection and indirect habitat loss. Therefore, the winter data were used for precision sensitivity analyses. **Changes to Draft Report:** • Relevant clarification as noted above is provided in the final report.
29	2.2.1	**Movement** Correlated random walk method – method assumes that caribou are moving between seasonal ranges that	We agree with this statement about correlated random walks; we state that this method does not apply to North Baffin caribou (see Section 3.1, page 9). After classifying movement

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		are biologically necessary. Since that's not likely the case at low population levels on North Baffin, is this method appropriate? The statement: Infrastructure that is parallel in direction to a migration route has little potential to disrupt caribou trajectory and would not pose an ecologically relevant barrier – this may be true if the road or linear structure eventually ends, making it possible for split groups of caribou to rejoin – but what are the implications if there's a barrier down the entire length of the migratory route? Also no evidence provided to support that this is the case re: parallel nature of infrastructure and migratory pathway in this case. Why were caribou trajectories with small sample locations excluded? How many samples were needed to include in the analysis? 68 trajectories for 30 collared caribou – how many in north and south study area?	behaviour with net-squared displacement, we also came to this conclusion. Please refer to Map 1 on page 11 for an example of multiple crossings of the Tote Road by a caribou. Additionally, the comment *"…no evidence provided to support that this is the case re: parallel nature of infrastructure and migratory pathway in this case"* is unclear. How does a feature pose a barrier to migration if it does not run in a direction opposing a migratory path? One must consider the functional responses to linear features when assessing barrier effects. Caribou trajectories with small sample sizes (i.e., # of locations) were excluded because net-squared displacement could not be calculated for trajectories that spanned less than a year. There seems to be a fundamental misunderstanding in QIAs comment about north and south study areas. The 68 trajectories for 30 collared caribou were not split into north and south study areas for analyses. North and south study areas were recommended based on the results of our analysis and the testing of iteration zones to estimate a ZOI (i.e., appropriate spatial scales to assess Project-related effects). Our rationale is provided in Section 4.2 of the report. These study areas were not used explicitly in analyses, which is why they only appear in our recommendations. **Changes to Draft Report:** • Relevant clarification as noted above is provided in the final report.

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30	2.2.2.2 and 3.1	**Zone of Influence** *"…the planned Southern Transportation Corridor because it is not constructed and is entirely within the home range of sampled caribou, thus acting as a control."* Is the southern part of North Baffin really a good control comparison for the northern part of South Baffin? Caribou behaviours are notably different. Re: changes in behaviour, see also work on Newfoundland caribou from Eric Vanderwal's lab at Memorial *"…that the Northern Transportation Corridor only intersects with three migrant caribou that are moving from the southern portion of the range to the north and east of the Project footprint…"* This statement calls into question the validity of looking at changes in movement patterns using the random walk method. This appears to be noted in this section.	The Southern Transportation Corridor is used as a relative control against the Northern Transportation Corridor because of the absence of a footprint. It is not clear to us what evidence suggests "caribou behaviours are notably different [between North and South areas]", but we welcome any additional information QIA has on the matter. We did not identify a difference in movement type between caribou to the north versus the south. For example, we identified resident and migrant caribou both to the north and to the south of the mine (Map 1, page 11). Thank you for pointing us to research on behavioural changes and will review relevant studies by Eric Vanderwal's lab. We agree with this statement about correlated random walks; we state that this method does not apply to North Baffin caribou (see Section 3.1, page 9). After classifying movement behaviour with net-squared displacement, we also came to this conclusion. **Changes to Draft Report:** • Relevant clarification as noted above is provided in the final report.
31	3.2.2	**Zone of influence** It is likely that for both winter and summer, we do not currently have enough data from individual caribou to understand the current scale of avoidance. However, there do appear to be some patterns of avoidance in the north that are not seen in the Southern Transportation Corridor. Further discussion needed to determine whether the lack of detectable ZOI in the south, and the apparent occurrence of seasonal ZOIs in	We did not assess ZOI for other seasons "because there were no discernable patterns in range use during other seasons relevant to caribou ecology (e.g., calving, post-calving, and migration) …" The lack of detectable ZOI in the south is expected given that this footprint does not exist (i.e., it was the <u>planned</u> footprint for Steensby Rail). We did not identify a difference in movement type between caribou to the north versus the south. For example, we identified resident and migrant caribou both to the north and to the south (Map 1, page 11).

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		the north, could be attributed to other differences – e.g., locations of collared caribou that exhibit migratory vs. non-migratory behaviour patterns; relative sample sizes; differences in behaviour of caribou in north and south of north Baffin Island. Did Baffinland look at these data relative to other seasonal breakdowns (e.g., calving, post-calving, rutting periods)?	It is not likely that relative sample size would have played a role, because most caribou observations were to the south and east of the Project. Thus, more caribou observations were present available for a ZOI analysis of the Southern Transportation Corridor than for the Northern Transportation Corridor (Growing: North = 3,493 obs., South = 5,564 obs.; Winter: North = 7,102 obs., South = 9,785 obs.). **Changes to Draft Report:** • Relevant clarification as noted above is provided in the final report.
32	3.3	*"Baffinland has partly mitigated potential effects through infrastructure design…"* How? It is unclear whether any design mitigations have been implemented to mitigate impacts to caribou movement and indirect habitat loss from the Project.	Materials submitted for Phase 2 list many additional mitigations planned should that Project phase be approved. **Changes to Draft Report:** • Not applicable.
33	3.3	"At mine sites, the reduced habitat quality is likely restricted to within a few kms from the footprint" – this statement requires additional back-up.	Noise monitoring results provided in annual reports demonstrate that Project-related noise was below 40dBA at 1.5 km from all Project areas, which meets operational thresholds (EDI Environmental Dynamics Inc. 2021b). The highest dustfall is mainly restricted to 1,000 m of the PDA (EDI Environmental Dynamics Inc. 2021b), consistent with other studies (~1 km dustfall ZOI; Chen et al. 2017). **Changes to Draft Report:** • The additional "back-up" as noted above is provided in the final report.
34	3.3	*"This example demonstrates why, when interpreting the results of these kinds of analyses, it is important to*	The comment states that cortisol levels from sensory disturbance and flight responses, which can vary due to context and types of stimuli (Noel et al. 2004, Stankowich 2008, Hansen and Aanes 2015, Plante et al. 2017, Eftestøl et al. 2019), have a

#	Section Reference	Comment	Baffinland Response
		prevent preconceptions and negative biases from driving our conclusions (see Flydal et al. 2018)”. To run through this example further, if climate change increases insects, driving caribou to use non-vegetated industrial sites as refuge, which leads to increased cortisol due to startling / sensory disturbance – there is a pathway to reduced calving success. This is an excellent example of cumulative effects and suggests a need for a precautionary approach to development, particularly in the face of climate change. The authors seem to be running the risk of the opposite problem: not being sufficiently precautionary in the face of widescale caribou declines throughout Canada’s north. This warrants additional, and more thoughtful, consideration in the discussion section.	greater negative effect than exposure to insect harassment, which is known to affect (maternal) body condition due to reductions in food intake and rest and increased movements (Russell et al. 1993, Gurarie et al. 2019). It is not uncommon for caribou to seek out such refugia (e.g., Skarin et al. 2004, and discussion in Prichard et al. 2020). Clearly, there is a fitness trade-off that is not well understood; under the right context, increased glucocorticoid levels can indeed be adaptive (Bonier et al. 2009, Sheriff and Love 2013). Furthermore, increased glucocorticoid levels in animals do not necessarily correspond with distress or chronic stress — a common misconception (Romero and Beattie 2022). There is no evidence for the statement *“this is an excellent example of cumulative effects,”* and an opposing case could be made that such refugia reduce the impacts of insect harassment. To clarify the intention of Section 3.3 (and our responses above), the purpose was not to definitively state one effect is worse than another. There is no clear evidence for either claim. The purpose was to point out that (1) such assertions should not be made without clear evidence and (2) that potential trade-offs should be discussed and used to drive future research questions. The use of a precautionary approach does not preclude the need for objective investigation, which is crucial to better our understanding of impacts to, and coexistence with caribou and other wildlife species. That is why *“it is important to prevent preconceptions and negative biases from driving our conclusions.”* We agree that the widescale caribou declines mentioned are a cause for investigation, and appropriate measures must be taken to understand and deal with those declines. Our recommendations do not disregard this fact. Rather, they

#	Section Reference	Comment	Baffinland Response
			consider (1) what is known about mechanisms that drive caribou population declines and (2) the regional context with regards to North Baffin caribou and the Project setting. Please also refer to our response to QIA comment #8. **Changes to Draft Report:** • None identified.

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