Annotated bibliography of barren-ground caribou response to disturbance: Preliminary assessment to support initial scoping exercise.

Prepared by: J. Gonet and F. Schmiegelow, for Government of the Northwest Territories, November 2017.

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Project Description:

This work comprises initial scoping of a literature review to summarize state of knowledge of population level effects of industrial disturbance on barren-ground caribou, intended to inform development of a barren-ground caribou research agenda, and to guide Government of Northwest Territories recommendations on habitat management and disturbance mitigation. The scoping was not exhaustive with respect to grey literature (i.e. government and consultant reports, environmental assessments, etc.), nor should it be considered a synthetic review; rather, it represents the first step in an assessment of whether such a review is warranted. This report was not intended for broad circulation. Distribution is at the discretion of the Wildlife Division, Department of Environment & Natural Resources, Government of the Northwest Territories (see contact below). All errors and omissions are those of the authors.

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1.0 Introduction

This work comprises initial scoping of a literature review to summarize state of knowledge of population level effects of industrial disturbance on barren-ground caribou, in order to inform development of a barren-ground caribou research agenda, and guide Government of Northwest Territories recommendations on habitat management and disturbance mitigation. The results of this effort are summarized in an annotated bibliography (Section 2.0), a searchable database with key attributes, and in archived copies of accessed publications. The scoping was not exhaustive with respect to grey literature (i.e. government and consultant reports, environmental assessments, etc.), nor should it be considered a synthetic review; rather, it represents the first step in an assessment of whether such a review is warranted. Sections 3.0 and 4.0 of this report provide an assessment of the available literature, and conclusions regarding this initial scoping exercise and potential next steps.

2.0 Annotated Bibliography

The annotated bibliography provides a scan of available literature on barren-ground caribou response to disturbances. The bibliography is divided into the broad topics of: recreation, fire, general infrastructure, infrastructure – mining, infrastructure – oil and gas, infrastructure – roads, transportation vehicles, and reviews of previous literature/misc. Rough synopses of each study are presented, outlining objectives, methods, and major findings.

A brief introduction to the topic is given at the start of each section, with a summary of potential gaps (if evident) and major conclusions from the literature reviewed. The final section (Section 2.8) omits the introduction in lieu of an assessment of existing reviews of barren-ground caribou response to anthropogenic disturbances, presented in Section 3.0.

2.1 Recreation

These studies examine the response of caribou to approaches by snowmobiles, skiers, and people on foot. With the exception of one study in Greenland, all others were conducted in Scandinavia. No studies from North America examining effects on barren-ground caribou from recreational activity were identified.

The studies largely find that increasing group size leads to decreased vigilance behaviour in caribou (Reimers et al. 2006), although the Greenlandic study had opposing conclusions (Aastrup 2000). Reimers et al. (2003) also hypothesized based on previous literature on caribou energetics, and their study on caribou encounter effects with humans, that no more than 3 daily caribou encounters with humans could be accommodated without negative energetic and potential demographic effects. Another major finding is that insect harassment may confound avoidance effects of tourist trails (Skarin et al. 2004), as well as other anthropogenic features, including industrial infrastructure (Reimers and Colman 2006; Section 2.8).

1) Aastrup 2000. Responses of West Greenland caribou to the approach of humans on foot.

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Citation: Aastrup P. 2000. Responses of West Greenland caribou to the approach of humans on foot. Polar Research 19(1): 83-90.
Location: Greenland
Herd: Akia, Isortoq
Disturbance Type: human contact, recreation
Summary: Three thresholds of caribou response to human approach were measured with a laser finder: "fright threshold distance", which was caribou's first sign of fright; "flight threshold distance", when the caribou first began to move away; and "run distance", which was the distance the caribou ran when provoked. Means and standard deviations were compiled for the three variables of interest. Variables were also evaluated in a generalized linear model to see if they were affected by the following parameters: season, locality, group type, group size, wind direction, insect harassment, vegetation type, topography, and interactions. Results show that groups of caribou had longer fright thresholds, flight thresholds, and run distances, indicating more vigilance than individuals. Groups with calves were more vigilant than female or male groups; vigilance was similar in male and female groups. Akia caribou were most vigilant during calving while the Isortoq herd was most vigilant after hunting. Flight threshold distances averaged 95m and mean run distances were between 95m and 145m.

2) Reimers et al. 2003. Behavior responses of wild reindeer to direct provocation by a snowmobile or skier.

Citation: Reimers E, Eftestol S, and Colman JE. 2003. Behavior responses of wild reindeer to direct provocation by a snowmobile or skier. Journal of Wildlife Management 67: 747-754.
Location: Norway
Herd: NA
Disturbance Type: skiers, snowmobiles
Summary: The study compared reindeer responses to direct provocation by skiers and snowmobilers. Herds were approached until the person was at the original location of the herd. Measurements were taken of 7 response distances, escape routes, and energy loss. Results suggest that reindeer provoked by snowmobiles discovered observers at longer distances than when provoked by skiers. However, total distance moved was shorter for snowmobiles than for skiers. Escape distances were longer when reindeer were lying rather than grazing. Estimated energy expenditure due to flight was between 0.2 to 2.9% of estimated total daily energy expenditure. The authors suggest a maximum of 3 daily encounters could be compensated for with no demographic consequences.

3) Reimers et al. 2011. Vigilance and fright behaviour in the insular Svalbard reindeer (Rangifer tarandus platyrhynchus).

Citation: Reimers E, Lund S, and Ergona T. 2011. Vigilance and fright behaviour in the insular Svalbard reindeer (Rangifer tarandus platyrhynchus). Canadian Journal of Zoology 89(8): 753-764.
Location: Svalbard
Herd: NA
Disturbance Type: fright behavior
Summary: The objective of this study was to measure vigilance, fright, and flight behaviour of reindeer. A single person approached reindeer on foot to measure response. Results show males are less vigilant than lactating and barren females, and vigilance decreased with decreasing group size. Vigilance behaviour was more relaxed than reindeer in southern Norway, possibly due to lack of natural predators. Some evidence of habituation to humans was found.

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4) Reimers et al. 2006. Flight by feral reindeer Rangifer tarandus tarandus in response to a directly approaching human on foot or on skis.

Citation: Reimers E, Miller FL, Eftestol S, Colman JE, and Dahle B. 2006. Flight by feral reindeer Rangifer tarandus tarandus in response to a directly approaching human on foot or on skis. Wildlife Biology 12: 403-413.
Location: Norway
Herd: NA
Disturbance Type: Skier
Summary: The objective of this study was to examine the behaviour of reindeer to approach by humans on skis and on foot. Wildlife response distance terminology and methodology recommended by Taylor & Knight (2003) was adopted and modified for this study. Results demonstrated that the farther away a person was when first sighted, the farther the reindeer group fled. Flight distance was greatest in July and least in September-October. In September, rutting behaviour affected reindeer more than being approached by a human. With increasing group size, both flight and distance moved decreased.

5) Skarin et al. 2004. Insect avoidance may override human disturbances in reindeer habitat selection.

Citation: Skarin A, Danell O, Bergtorm R, and Moen J. 2004. Insect avoidance may override human disturbances in reindeer habitat selection. Rangifer 24(2): 95-103.
Location: Sweden
Herd: NA
Disturbance Type: Recreation, Tourist trails
Summary: This study investigated the habitat selection of semi-domesticated reindeer. Fecal pellet group counts in 1473 vegetation plots were used to build caribou RSF models. Pellet groups were most abundant in high-altitude habitats and some heath type vegetation; pellet-group densities were also higher near tourist trails, which followed higher altitudes in the terrain. Reindeer moved towards higher altitudes when wind speed was low and temperature was high, and lower altitudes when temperatures were low and wind was strong. Authors suggest reindeer use high altitudes to escape insect harassment and warm weather even if disturbance is high from tourism.

6) Tyler. 1991. Short-term behavioral responses of Svalbard reindeer *Rangifer tarandus platyrhynchus* to direct provocation by a snowmobile.

Citation: Tyler NJC. 1991. Short-term behavioral responses of Svalbard reindeer *Rangifer tarandus platyrhynchus* to direct provocation by a snowmobile. Biological Conservation 56: 179-194.
Location: Svalbard
Herd: NA
Disturbance Type: snowmobile
Summary: The objective was to study the behavioural response of reindeer to snowmobile disturbance. Direct approaches of caribou groups by a snowmobile were employed. Reaction distance (when presence was first noticed), disturbance distance (when alarm behaviour was first observed), and distance of flight were recorded. Results show flight was a coordinated group response; response distances and times are provided. A median flight distance was found to increase daily energy expenditure by 0.4%, and decrease daily grazing time by 0.4%.

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2.2 Fire

Barren-ground caribou response to fire is an important component of disturbance effects on barren-ground caribou. Negative responses may results in potential cumulative effects with anthropogenic disturbances, as Barren-ground caribou often winter in the boreal forest, which is subject to high rates of disturbance by fire. The identified literature discusses how barren-ground caribou are affected by forest fire; however, it does not address how fire may interact with increasing human activity in the North. Anderson and Johnson (2014) also believe that, in association with examining patterns of occurrence, the "...integration of empirical mechanistic-based studies on the individual components of caribou biology with long-term monitoring of body condition and population trends and models that link animal nutrition, habitat supply, and reproduction" are needed.

The literature largely agrees that caribou begin using areas 40-60 years after fire (Scotter 1964; Joly et al. 2007; Collins et al. 2011; Anderson and Johnson 2014), although they prefer habitat with peak biomass that accumulates 80-120 years post-fire (Scotter 1964; Collins et al. 2011; Barrier and Johnson 2012). Models also predict that, as the climate changes, the increased occurrence of fires will lead to increased apparent competitor habitat, and decreased high quality habitat for caribou (Joly et al. 2012).

1) Anderson and Johnson. 2014. Distribution of barren-ground caribou during winter in response to fire.

Citation: Anderson TA, and Johnson CJ. 2014. Distribution of barren-ground caribou during winter in response to fire. Ecosphere 5(10):140. http://dx.doi.org/10.1890/ES14-00010.1
Location: NWT, Canada
Herd: Bathurst
Disturbance Type: fire
Summary: The objective of this study was to investigate influence of past fires on large-scale distribution of barren-ground caribou. Resource selection functions were used to examine relationships between caribou, vegetation type, fire history, and risk of predation. Caribou generally selected >40 year old habitat types, post-fire areas adjacent to burn boundaries, and mature forest with high percentages of lichen ground cover and herbaceous forage. Findings did not support the hypothesis that caribou altered distribution in relation to predation risk. Authors suggest barren-ground caribou may be less averse to burned areas than previously thought.

2) Barrier and Johnson. 2012. The influence of fire history on selection of foraging sites by barren-ground caribou.

Citation: Barrier TA, and Johnson CJ. 2012. The influence of fire history on selection of foraging sites by barren-ground caribou. Ecoscience 19(2): 177-178. doi:10.2980/19-2-3508
Location: NWT, Canada
Herd: Bathurst
Disturbance Type: fire
Summary: The objective of this study was to determine effects of forest stand attributes and wildfire on winter habitat use by barren-ground caribou. Field data describing forest stand and understory attributes were used to develop multinomial regression models. A combination of ground cover type and tree volume best described selection of feeding sites; increases in percent rock cover and basal area of conifer trees had negative influences on caribou feeding site selection. The most parsimonious

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regression model predicted site use with 87% accuracy. Biomass of fruticose lichens in the Bathurst range was higher than in Alaska or Yukon caribou ranges. Field evidence suggested that caribou used less than 1% of the burned sites investigated, while feeding sites were in areas 143 +/- 35 years old. Authors note that increases in number and severity of fires will lead to decreased winter habitat quality.

3) Collins et al. 2011. Fire, grazing history, lichen abundance, and winter distribution of caribou in Alaska's taiga.

Citation: Collins WB, Dale BW, Adams LG, McElwain DE, Joly K. 2011. Fire, grazing history, lichen abundance, and winter distribution of caribou in Alaska's taiga. J Wildl Manage (2):369.
Location: Alaska, USA
Herd: Nelchina Caribou Herd
Disturbance Type: fire
Summary: The objective of this study was to evaluate the impacts of fire and grazing history on lichen abundance and Nelchina Caribou Herd distribution. Vegetation characteristics and lichen abundance were determined at random points and caribou locations in current and historic winter ranges. A Kolmogorov-Smirnov goodness-of-fit test was used to compare stand age distributions and lichen cover at locations selected randomly and at locations used by caribou. Historic ranges had significantly less lichen biomass than current ranges due to caribou overgrazing. Caribou in current range selected for stands with <20% lichen cover, 1,250 kg/ha lichen biomass, and older than 80 yrs post-fire. Lichen in this region required >60 years after fire to reach levels to attract grazing by caribou, but did not reach maximum abundance until 180 years after fire. The authors conclude that recovery from overgrazing can occur very quickly (~20 years), and that the distribution of the Nelchina Caribou Herd highlights the importance of mid and late-successional habitat for winter forage. They suggest management in Alaska requires consideration of availability of productive winter caribou habitat with lead times >60 years.

4) Joly et al. 2007. Response of overwintering caribou to burned habitat in Northwest Alaska.

Citation: Joly K, Bente P, Dau J. 2007. Response of overwintering caribou to burned habitat in Northwest Alaska. Arctic 60 (4): 401-410.
Location: Alaska, USA
Herd: Western Arctic Caribou Herd
Disturbance Type: Fire
Summary: The objective of this study was to evaluate caribou distribution in relation to habitat type, age of burns and possible edge effects during winter. GPS satellite collars were deployed on adult females, and Landsat imagery was used to assess habitat. Recent burns (<55 years) were selected against range-wide; particularly, 26-55 year-old burns, and interior (core) portions of all burns. Caribou were more likely to select burned areas in late fall and early spring than midwinter. Authors believe allowing small fires to burn may create a mosaic of different-aged habitats that benefit a wide array of species, including caribou.

5) Joly et al. 2012. Simulating the effects of climate change on fire regimes in Arctic biomes: implications for caribou and moose habitat.

Citation: Joly K, Duffy PA, Rupp TS. 2012. Simulating the effects of climate change on fire regimes in Arctic biomes: implications for caribou and moose habitat. Ecosphere 3(5) Article 36.
Location: Alaska, USA

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Herd: Western Arctic Caribou Herd
Disturbance Type: climate change, fire
Summary: This study assessed the effect of climate change on fire regimes in NW Alaska. Alaska Frame-Based Ecosystem Code was used to explore interactions and feedbacks between fire, climate, vegetation, and caribou and moose habitat in northwest Alaska. Results suggest that, between 2008-2053, there will be an increase of 0-30% in forest area burned compared to 1950-2007, whereas the amount of burned tundra habitat will increase 0-61%. High quality habitat in caribou core winter range may decline up to 30%. Moose habitat was projected to increase 19-64% in their core winter habitat. Authors believe climate change could lead to decreased nutritional performance and apparent competition in northwest Alaska. Increasing fire regimes may warrant need for more fire suppression to actively manage for conservation of caribou habitat.

6) Rickbeil et al. 2017. Barren-ground caribou (Rangifer tarandus groenlandicus) behaviour after recent fire events; integrating caribou telemetry data with Landsat fire detection techniques.

Citation: Rickbeil GM, Hermosilla T, Coops NC, White JC, and Wulder MA. 2017. Barren-ground caribou (Rangifer tarandus groenlandicus) behaviour after recent fire events; integrating caribou telemetry data with Landsat fire detection techniques. Global Change Biology, 23(3): 1036-1048. doi:10.1111/gcb.13456
Location: NWT, Canada
Herd: Cape Bathurst, Bluenose West, Bluenost East, Bathurst, Ahiak/Beverly
Disturbance Type: fire, fire severity
Summary: This study aimed to determine how size and severity of fires are changing across five barren-ground caribou ranges and "…demonstrate how time since fire, fire severity, and season result in complex changes in caribou behavioural metrics estimated using telemetry data. Annual area burned and burn severity were assessed through time for each herd and related to two behavioural metrics: velocity and relative turning angle." Results show that "[t]ime since fire and burn severity both significantly affected velocity and relative turning angles. During fall, winter, and spring, fire virtually eliminated foraging-focused behaviour for all 26 years of analysis (1985-2011), while more severe fires resulted in a marked increase in movement-focused behaviour compared to unburnt patches. Between seasons, caribou used burned areas as early as 1-year post-fire." Authors believe changes in caribou behaviour immediately post-fire are primarily driven by changes in forest structure rather than changes in terricholous lichen availability.

7) Scotter 1964. Effects of forest fires on the winter range of barren-ground caribou in the Northern Saskatchewan

Citation: Scotter GW. 1964. Effects of forest fires on the winter range of barren-ground caribou in Northern Saskatchewan. Canadian Wildlife Service, Wildlife Management Bulletin series 1, no.18.
Location: Northern Saskatchewan, Canada.
Herd: NA
Disturbance Type: fire, vegetation change
Summary: This study addressed the following questions: what portion of the winter range in the study area has been burned? What effect has fire had on terrestrial forage and arboreal lichen production? What is the successional pattern of vegetation following forest fire? What is the effect of fire on forest soils? What effect does fire have on barren-ground caribou and other wildlife? The study also examined: forage utilization and terrestrial forage production, aboreal lichen production, plant succession following

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forest fires, effects of forest fires on soil properties, and effects of fire on wildlife. Caribou were found to prefer forest age classes greater than 51 years old, as evaluated by caribou pellet groups per acre. In forest ages 1-10 years of age ,a pellet group count of 41/per acre was found; in 11-30, 28/acre; in 31-50, 199/acre; in 51-75, 510/acre; in 76-120, 331/acre, and in 120+, 586/acre. Aerial surveys that looked at feeding patterns agreed with the pellet-group counts.

2.3 General Infrastructure

This literature covers general infrastructure, such as population centers, trails, cabins, resorts, and powerlines. Of 12 studies in this section, 11 are from Norway and 1 is from Manitoba, leading to significant regional-bias in results. Avoidance effects were found by at at least one study for all types of structures and human disturbances, including: population centers and ski trails (Vistnes et al. 2001; Antonnen et al. 2011), powerlines (Vistnes et al. 2001; Nellemann et al. 2001), resorts (Nellemann et al. 2010), and tourist cabins (Vistnes et al. 2001; Panzacchi 2013). Several studies report no effects, including: no barrier effects of infrastructure on caribou (Colman et al. 2012); no disturbance effects of powerlines (Reimers et al. 2007, Flydal et al. 2009).

1) Anttonen et al. 2011. Range selection by semi-domesticated reindeer (Rangifer tarandus tarandus) in relation to infrastructure and human activity in the boreal forest environment, northern Finland.

Citation: Anttonen M, Kumpula J, Colpaert A. 2011. Range selection by semi-domesticated reindeer (Rangifer tarandus tarandus) in relation to infrastructure and human activity in the boreal forest environment, northern Finland. Arctic 64(1):1-14.
Location: Finland
Herd: NA
Disturbance Type: infrastructure, buildings, roads, trails, mining
Summary: This study sought to determine how human disturbances affect caribou home range selection at broad and fine scales within early winter, late winter, and summer-autumn periods. GPS collar data from female adult caribou was used to determine home ranges of caribou, and evaluate home-range and within-home-range selection. At a broad scale, in late winter, caribou avoided most human disturbance by 1.5 km, whereas population centres were avoided by 2.5km, and 'forest roads' were not avoided at all; there was also no avoidance of forest roads, skiing trails, and gold digging areas in early winter. The least avoidance of human disturbance occurred within ranges during summer-autumn: population centres were still avoided by 2.5km, buildings by 400m, and main roads by 100m. Authors suggest considering broad scale needs when developing land use plans.

2) Colman et al. 2012. Is a wind-power plant acting as a barrier for reindeer Rangifer tarandus movement?

Citation: Colman JE, Eftestøl S, Tsegaye D, Flydal K, Mysterud A. 2012. Is a wind-power plant acting as a barrier for reindeer Rangifer tarandus movement? Wildl Biol 18:439-445.
Location: Scandinavia
Herd: NA
Disturbance Type: infrastructure, wind power

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Summary: This study sought to determine the effects of wind-power plants on movement and habitat usage of reindeer. Direct binocular observations were performed monthly from June to October at two study locations: one on a peninsula with no wind power plants and one on a peninsula with wind power plants. Expected numbers of reindeer west and east of wind power plants and the proportion of reindeer crossings were compared, focused on evaluating behavioural barriers rather than avoidance effects. Overall, the study found no barrier effects of wind power plants, and no cumulative effects of a road built next to new wind power plants. Authors believe wind power plants may not present a significant barrier to reindeer.

3) Flydal et al. 2009. Effects of power lines on area use and behaviour of semi-domestic reindeer in enclosures.

Citation: Flydal K, Korslund L, Reimers E, Johnson F, and Colman JE. 2009. Effects of power lines on area use and behaviour of semi-domestic reindeer in enclosures. Int J Ecol: 2009.
Location: Norway
Herd: NA
Disturbance Type: infrastructure, powerlines
Summary: The effect of two parallel powerlines on area use, behaviour, and activity of semi-domestic reindeer in enclosures was evaluated. Two treatment enclosures underneath powerlines and two control enclosures, all measuring 50x400m, were used. A mixed logistic regression model to compare proportion of restless behaviour, a mixed log-linear model of number of activity changes/minute, and a comparison of observations of activity vs predicted proportion of restless behaviour were used. Results suggest that individual locations within enclosures were not affected by the powerlines, and slightly more restless behaviour took place in treatment enclosures for domestic tame reindeer, while domestic wild were stable. Activity changes were more common for animals in treatment enclosures, with no indication of habituation. Domestic wild had more than three times the amount of restless behaviour than domestic tame reindeer. Authors believe power lines may be a minor disturbing factor.

4) Flydal et al. 2003. Reindeer (Rangifer tarandus tarandus) perception of noise from powerlines.

Citation: Flydal K, Rogstad I, Per E, Reimers E. 2003. Reindeer (Rangifer tarandus tarandus) perception of noise from powerlines. Rangifer 23: 21-24.
Location: Norway
Herd: NA
Disturbance Type: infrastructure, powerlines
Summary: This study examined reindeer perception of noise from powerlines. The noise coming from powerlines was measured through the use of microphones to record range of sound emitted from powerlines. The design was based on Flydal et al. 2001 study that examined at what ranges reindeer can perceive sound. Study concludes reindeer cannot hear noise from power-lines as well as humans, only detecting sound from powerlines that is above 250Hz.

5) Nellemann et al. 2001. Winter distribution of wild reindeer in relation to power lines, roads and resorts.

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Citation: Nellemann C, Vistnes I, Jordhøy P, and Strand O. 2001. Winter distribution of wild reindeer in relation to power lines, roads and resorts. Biological Conservation 101(3): 351-360. doi:10.1016/S0006-3207(01)00082-9
Location: Norway
Herd: Nordfjella
Disturbance Type: Infrastructure, human activity, power lines, resorts, roads
Summary: This study investigated the effects of infrastructure and human activity on distribution of wild reindeer. "Densities of reindeer for different distance zones from the power lines (0.0–2.5 km, 2.5–5.0 and >5.0 km) were compared using Kruskal–Wallis tests and multiple pairwise comparisons with Dunn's test. Use versus availability of distance zones in individual years were assessed using chi-square tests." Results show that in 6 of 8 years, areas within 2.5 km of power lines were used less than expected based on availability, and areas greater than 2.5 km were used more than expected. "Density of reindeer was 79% lower within 2.5m of power lines compared to background areas, increasing with distance from infrastructure for comparable habitat. Areas within 5 km of resorts or with roads and powerlines together were avoided in all years."

6) Nellemann et al. 2010. Effects of Recreational Cabins, Trails and Their Removal for Restoration of Reindeer Winter Ranges.

Citation: Nellemann C, Vistnes I, Jordhøy, Støen O, Kaltenborn BP, Hanssen F, Helgesen R. 2010. Effects of Recreational Cabins, Trails and Their Removal for Restoration of Reindeer Winter Ranges. Restoration Ecology 18(6): 873-881.
Location: Norway
Herd: Snøhetta, Rondane
Disturbance Type: resorts, ski trails, cabins
Summary: This study examined the effect of cabins, trails and their removal and restoration on caribou habitat selection. Surveys of caribou were completed using snowmobiles. The distribution of reindeer was analyzed in relation to 10 alpine resorts, and prior to and following relocation of ski trails and cabins in Norway to help restore former habitat. Reindeer used areas less than expected within 15 km of resorts. Reindeer abundance declined and mean distance between reindeer groups and resorts increased with increasing resort size. Over 20 years, there was no apparent habituation to resorts. When ski trails and tourist cabins were removed to restore historic range access, reindeer moved back into areas. Authors believe regulation of human traffic, relocation of trails, and removal of infrastructure and cabins can be effective in restoring access to and use of historic ranges and migration routes.

7) Panzacchi et al. 2013. Learning from the past to predict the future: Using archaeological findings and GPS data to quantify reindeer sensitivity to anthropogenic disturbance in Norway.

Citation: Panzacchi M, Van Moorter B, Jordhoy P, Strand O. 2013. Learning from the past to predict the future: Using archaeological findings and GPS data to quantify reindeer sensitivity to anthropogenic disturbance in Norway. Landscape Ecol (5):847.
Location: Norway
Herd: NA
Disturbance Type: infrastructure, cabins, roads, power lines, hiking trails, hydroelectric dams
Summary: Change in reindeer movements using archaeological findings in relation to anthropogenic disturbances were evaluated using data from GPS collars on adult females as well as the locations of

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archeological pitfall traps and hunting blinds. Path analysis was used to quantify direct, indirect and total effects of different infrastructures in 1, 5, and 10km-radius buffers, on probability of use of ancient movement corridors. First, areas currently used by reindeer were identified, then each pitfall or hunting trap location was classified as located or not located in current area used by reindeer. Multi-scale buffers around each pitfall trap/hunting blind were constructed and quantification of infrastructure within each buffer. Finally, the probability of use between the presence of infrastructure was determined. Results show that tourist cabins and roads had strongest long-term consequences: a single tourist cabin within 1 km would lead to complete area abandonment within 1km, and 1 km of road within 1 km would lead to 46% decrease in probability of use. Power lines and private cabins had indirect effects through their effect on roads, whereas hiking trails and hydroelectric dams had variable effects not significant on a national scale.

8) Reimers et al. 2007. Effects of a power line on migration and range use of wild reindeer.

Citation: Reimers E, Dahle B, Eftestøl S, Colman JE, and Gaare E. 2007. Effects of a power line on migration and range use of wild reindeer. Biological Conservation, 134: 484-494. doi:10.1016/j.biocon.2006.08.034
Location: Norway
Herd: NA
Disturbance Type: powerlines
Summary: Barrier and aversion effects of a 66 kV powerline were examined using. Aerial surveys and lichen surveys were used to determine caribou presence. The data were analyzed using a combination of GIS and information theoretic approaches. In 14 out of 22 years, reindeer crossed underneath and grazed under the powerline. Lichen measurements also indicated a higher use of lichen pastures along ridges close to and under the powerline compared to those up to 3 km from the powerline. Authors believe this winter grazing pattern reflects channeling of reindeer to ridges along an 8 km wide topographical corridor encompassing the power line, and is not attributed to the power line itself.

9) Vistnes and Nellemann. 2001. Avoidance of cabins, roads, and power lines by reindeer during calving.

Citation: Vistnes I, and Nellemann C. 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. The Journal of Wildlife Management 65(4): 915-925.
Location: Norway
Herd: NA
Disturbance Type: cabins, roads, powerlines
Summary: Avoidance behaviour of reindeer to human infrastructure was evaluated through mapping of reindeer distribution, sex, and general age composition during calving season. Spearman's rank correlation was used to evaluate relationship between reindeer density and distance to nearest development. Results show that mean reindeer density was 78% lower within <4 km of tourist resorts compared to >4 km from resorts (1.47 vs 6.68 reindeer/km^2, respectively). For powerlines, reindeer density was 73% lower within 4 km compared to >4 km from powerlines. Areas within 4 km of human structures were avoided despite low levels of traffic and high proportion of preferred habitat.

10) Vistnes et al. 2001. Wild reindeer: impacts of progressive infrastructure development on distribution and range use.

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Citation: Vistnes I, Nellemann C, Jordhøy P, and Strand O. 2001. Wild reindeer: impacts of progressive infrastructure development on distribution and range use. Polar Biology, 24(7): 531-537.
Location: Norway
Disturbance Type: powerlines, roads, ski trails, infrastructure
Summary:
This study looked at the distribution of reindeer in relation to density of powerlines, roads and ski trails. Aerial surveys were used, and the area was divided into 622 quadrats of 4 km^2 each, sorted into 19 categories of linear construction density. Results show that densities of reindeer were significantly lower in developed quadrats compared to undeveloped quadrats, and decreased with increasing density of development. In areas exceeding 1.3 km/km^2 of linear structures, no reindeer were observed. In areas exceeding 0.8 km/km^2 of linear structures, 1.1% of reindeer were observed. Results suggest reindeer have a critical threshold of development where they abandon an area.

11) Vistnes et al. 2008. Summer distribution of wild reindeer in relation to human activity and insect stress.

Citation: Vistnes I, Nellemann C, Jordhøy P, and Støen O. 2008. Summer distribution of wild reindeer in relation to human activity and insect stress. Polar Biology 31(11): 1307-1317. doi:10.1007/s00300-008-0468-2
Location: Norway
Herd: Hardangervidda, Nordfjella
Disturbance Type: resorts, roads, hiking trails.
Summary: Reindeer summer distribution in relation to human activity was examined using aerial surveys in 4 km transects. Densities of reindeer for different types of disturbance sources and distance zones were compared to a control group. Reindeer used areas <5km from tourist resorts and <2.5km from major roads and hiking trails less than expected from availability. 65% of reindeer were found in high-altitude areas without human development, which was only 21% of the area.

12) Wildlife Resource Consulting Services MB Inc. 2016 (June). Keeyask generation project terrestrial effects monitoring plan report #TEMP-2016-08, Caribou sensory disturbance monitoring report.

Citation: Wildlife Resource Consulting Services MB Inc. 2016 (June). Keeyask generation project terrestrial effects monitoring plan report #TEMP-2016-08, Caribou sensory disturbance monitoring report. Wildlife Resources Consulting Services MB Inc, Winnipeg, MB.
Location: Manitoba, Canada
Herd: Qamanirjuaq
Disturbance Type: infrastructure, roads, buildings
Summary: This monitoring project examined the effects of disturbance on caribou distribution and relative abundance near hydro projects during construction and operation. Ground transects and trail cameras were used to determine caribou presence or absence. Project-affected islands (islands within 2 km of infrastructure/borrow sources or within 4 km of the proposed powerhouse) appeared to support fewer caribou and caribou calves, compared to islands further away from the project construction areas. Similar results were found for moose, moose calves, and black bear. Gray wolf were present on a greater proportion of Project-affected islands, but the number of islands occupied was relatively small. Caribou were the second most common species observed in peatland complexes, and were detected in a relatively high number of these areas; however, caribou calves were detected in relatively few

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complexes. On transects along the access roads, caribou were also relatively common, and were present on the majority of access road transects during the second and third visits. Caribou calves were present on a relatively low number of transects. Adult caribou and adult moose sign density was greater within 2 km of the north or south access roads compared to densities greater than 2 km away. No difference was apparent in caribou calf or moose calf sign density.

2.4 Infrastructure – Mining

All studies in this category touch on mining in the Northwest Territories (NWT). Of seven studies, five directly study mining in NWT, while the remaining two have it as a component of the study (Herrmann et al. 2014; Johnson et al. 2014). The main gap in the literature, which is partially addressed in Chen et al. (2017), is the 'why' of caribou avoidance of mining infrastructure. Reimers et al. (2006) touch on this in their review of the caribou literature, and how the direct and indirect mechanisms of avoidance of human disturbance should be distinguished, although this may be impossible to quantify, as caribou associate human disturbance with predation risk (Silversten et al. 2012).

Zones of influence established around mines (the area that barren-ground use less than expected) were as follows: 11-14 km (Boulanger et al. 2012), 15-40 km (Golder Associates 2011), 11-38 km (Johnson et al. 2014). Johnson et al. (2005) also found that high quality habitat would be lost in a mining area encompassing portions of the NWT and Nunavut, with 2.5-5.2% lost in spring/autumn migrations and calving, and up to 37% lost during the post-calving period.

1) Boulanger et al. 2012. Estimating the zone of influence of industrial developments on wildlife: A migratory caribou rangifer tarandus groenlandicus and diamond mine case study.

Citation: Boulanger J, Poole KG, Gunn A, Wierzchowski J. 2012. Estimating the zone of influence of industrial developments on wildlife: A migratory caribou rangifer tarandus groenlandicus and diamond mine case study. Wildl Biol 18(2):164-79.
Location: NWT, Canada
Herd: Bathurst
Disturbance Type: Mining
Summary: This study evaluated the response of Bathurst Caribou herd to operation of two open-pit mines. Caribou habitat was first defined, habitat covariates selected, and zones of influence of the mine on caribou habitat selection estimated. When mines were operational, aerial surveys detected a 14km zone of influence. Date from satellite collars found a smaller, 11km zone of influence. Caribou were four times more likely to select habitat at distances greater than the zone of influence compared to the two-mine complex. It is hypothesized that fine dust deposit had an influence on the greater distances caribou were found to respond to industrial development than in other studies. Some evidence to support this hypothesis is presented.

2) Chen et al. 2017 (in prep.). How far can mining disturbances reach inside the Bathhurst caribou range?

Citation: Chen W, Leblanc SG, White HP, Prevost C, Milakovic B, Rock C, Sharam G, O'Keefe H, Corey L, Croft B, Gunn A, van der Wielen S, Football A, Tracz B, Pellissey JS, and Boulanger J. 2017 (in prep.) How far can mining disturbances reach inside the Bathhurst caribou range? Natural Resources Canada, Ottawa.

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Location: NWT, Canada
Herd: Bathurst
Disturbance Type: mining
Summary: This study aimed to quantify the distance various mine disturbances can reach (dust, noise, sight of operations). Field surveys and laboratory analysis were completed in the summers of 2015 and 2016. The sight of mining activities, noise level, dust on leaves, soil pH, and percent vegetation cover were measured along transects extending from the Ekati Diamond Mine. Preliminary results suggest extent of coarse particulate dust is 1 km from mine roads, and that visibility of mine related activities ranges from 1.6 – 4.9 km.

3) Golder Associates Ltd. 2011. Appendix III: Analysis of environmental effects from the Diavik Diamond Mine on wildlife in the Lac De Gras region.

Citation: Golder Associates Ltd. 2011. Appendix III: Analysis of environmental effects from the Diavik Diamond Mine on wildlife in the Lac De Gras region. Submitted to Mackenzie Valley Environmental Impact Review Board, March 2011.
Location: NWT, Canada
Herd: Bathurst, Ahiak
Disturbance Type: mining
Summary: This is an analysis of data on effects of the Diavik mine on caribou. Logistic regression and piecewise regression were used to calculate potential ZOIs of the Diavik mine on caribou. Scanning observations were used to determine changes in caribou behaviour. Nursery group zone of influences (ZOI) were at 40-km for 2005 and 2009 or 15-km for 2006 and 2008; 'all caribou groups' had similar ZOIs. There was no evidence that ZOI changed with changing activity levels at the mine. Caribou groups with calves within 5 km of the mine spent 10% less time feeding/resting and 7% more time alert/moving than groups greater than 5 km from the mine.

4) Golder Associates Ltd. 2014. Analysis of environmental effects from the Diavik Diamond Mine on wildlife in the Lac de Gras region.

Citation: Golder Associates Ltd. 2014. Analysis of environmental effects from the Diavik Diamond Mine on wildlife in the Lac de Gras region. Submitted to Mackenzie Valley Environmental Impact Review Board, September 2014. 159 pp.
Location: NWT, Canada
Herd: Bathurst and Ahiak Caribou Herd
Disturbance Type: mining
Summary: An updated analysis of data on effects of the Diavik mine on caribou. GPS collar data were used to generate resource selection functions that evaluated the influence of variables related to lakes, mines, and insects. Throughout the monitoring period, the mean caribou distance to the nearest Diavik-Ekati mine complex footprint was 98.3 km (SD = 44.9 km); 2.0% of movement paths were within 14 km of the nearest mine feature. Collared cows may be avoiding the mine complex and have shifted their distribution northwards from the mine.

5) Herrmann et al. 2014. Effects of mining on reindeer/caribou populations and indigenous livelihoods: community-based monitoring by Sami reindeer herders in Sweden and First Nations in Canada.

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Citation: Herrmann TM, Sandström P, Granqvist K, D'Astous N, Vannar J, Asselin H, and Cuciurean R. 2014. Effects of mining on reindeer/caribou populations and indigenous livelihoods: community-based monitoring by Sami reindeer herders in Sweden and First Nations in Canada. Polar Journal, 4(1): 28.
Location: Circumpolar
Herd: NA
Disturbance Type: mining
Summary: This study examines three case studies from Cree, Naskapi, and Sami communities to understand the effects of mining on caribou. All three case studies found negative effects of mining on caribou: roads created linear barriers in the Sami study; Cree saw roads as disrupting caribou habitat, and Naskapi observed avoidance behaviour of caribou around mining infrastructure, with associated population fragmentation. Some comparing and contrasting of the case studies is undertaken.

6) Johnson et al. 2005. Cumulative Effects of Human Developments on Arctic Wildlife.

Citation: Johnson CJ, Boyce MS, Case RL, Cluff HD. Gau RJ, Gunn A, and Mulders R. 2005. Cumulative Effects of Human Developments on Arctic Wildlife. Wildlife Monographs 160: 1-36.
Location: NWT, Canada
Herd: NA
Disturbance Type: Mines, infrastructure, human activity
Summary: This study investigated the impacts of human activities and associated infrastructure on distribution of Arctic wildlife. Covariates for vegetation, interspecific interactions, and human disturbance features were used to develop seasonal resource-selection models. For caribou, the post-calving model suggested a 37% decrease in high quality habitat and 84% increase in use of low quality habitat is association with human developments. In spring migration/calving and autumn migration, the model predicted reduction in use of high quality habitat by 2.5 and 5.2% respectively.

7) Johnson et al. 2014. Long-term distribution response of a migratory caribou herd to human disturbance

Citation: Johnson CJ, Russell DE. 2014. Long-term distribution response of a migratory caribou herd to human disturbance. Biological Conservation 177:52-63.
Location: Alaska, USA, and Yukon, Canada
Herd: Porcupine Caribou Herd
Disturbance Type: Infrastructure, roads, wells, trails, seismic lines
Summary: The objective of this study was to quantify avoidance responses and zone of influence associated with human settlements, main roads and minor disturbance features, including wells, trails, and seismic lines, and to evaluate habituation of caribou to human disturbance. Resource selection functions were used to quantify selection and disturbance responses of the Porcupine Caribou Herd. Zones of influence for settlements varied from 38 km in early periods of the study (1985-1999), to 34.5 km in later periods (1999-2012). Main road avoidance was estimated at 30k m in early periods and 18.5 km in late periods. Low use area avoidance was estimated at 11 km in early periods and 6 km in later periods. Authors suggest cautious interpretation of results, as animal behaviour varied across range of development types, and small effect sizes suggest uncertainty in results.

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2.5 Infrastructure – Oil and Gas

This literature covers the effects of oil and gas related development on barren-ground caribou populations, and comes exclusively from studies of the Central Arctic Herd in Alaska, in the Prudhoe Bay Oil Field, with the exception of one study. Griffiths et al. (2002) focused on potential effects of petroleum development on the Porcupine Caribou Herd, although they relied on extrapolation of effects from studies of the Central Arctic Herd. As well, Gunn and Russell (2017) recently completed a review of potential disturbance effects on the Porcupine caribou herd, focused on assessing caribou vulnerability to oil and gas exploration and development in Eagle Plains, Yukon. However, it is not yet publically available.

The literature generally agrees that caribou are negatively affected by oil and gas development. Arthur and Vecchio (2009) found that calves had lower weight in highly developed areas, which correlates with lowered calf survival. Cameron et al. (1995) found that areas of high development led to decreased caribou presence. Nellemann and Cameron (1996) found caribou avoided oil and gas infrastructure and lost preferred habitat. Smith et al. (1994) found sightings from roads decreased over the course of development. Whitten and Cameron (1983) found that heavily developed areas led to significant barrier effects. In 1983, Curatolo and Murphy also found that increased insect activity contributed to greater willingness to interact with oil and gas development. Cronin et al. (1998) and Fancy (1983) report no effects of oil and gas development on caribou distribution.

1) Arthur and Vecchio PA. 2009. Effects of oil field development on calf production and survival in the Central Arctic herd. Final Research Technical Report.

Citation: Arthur SM, and Del Vecchio PA. 2009. Effects of oil field development on calf production and survival in the Central Arctic herd. Final Research Technical Report. Alaska Department of Fish and Game, Federal Aid in Wildlife Resoration.Grants W-27-5 AND W-33-1 through W-33-4, Juneau, Alaska, USA.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Infrastructure, Oil and gas
Summary: This study examined survival rates, body mass changes, and skeletal growth of caribou calves in the Central Arctic Herd to determine any potential anthropogenic disturbance effects. Caribou calf summer distributions were modeled with 95% fixed kernel utilization distributions. Results show that calves that were heavier in September were more likely to survive the following winter, and body mass of calves born in a calving area with less anthropogenic disturbance was significantly greater than those born in areas with more anthropogenic disturbance. Growth rate as measured by metatarsus length was greater in low disturbance calves in June and September but not different in March. Authors believe similarities in distributions of caribou calves from the 2 calving areas (excluding the calving area) indicate differences in size of calves at birth and in September can be largely attributed to habitat quality on calving grounds. Calves in high anthropogenic disturbance areas may be displaced from preferred calving habitat areas.

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2) Cameron et al. 1995. Abundance and movements of caribou in the oilfield complex near Prudhoe Bay, Alaska.

Citation: Cameron RD, Lenart EA, Reed DJ, Whitten KR, and Smith WT. 1995. Abundance and movements of caribou in the oilfield complex near Prudhoe Bay, Alaska. Rangifer 15(1): 3-7.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Infrastructure, Oil and gas
Summary: This studied examined the distribution and movements of Central Arctic Herd caribou from 1980-1993. The number of caribou locations in 5 quadrants was totaled for insect inactivity/activity; numbers of east/west crossings on quadrant mid-lines were determined by sequential observations. Results show that quadrats within intensively-developed areas in the Prudhoe Bay oilfield complex supported significantly lower abundance and lateral movements. A functional loss of habitat was detected due to oil-field development. The authors believe there are limits to what caribou may adapt to in disturbed landscapes, recognizing 'inaccessible habitat is habitat lost.'

3) Cronin et al. 1998. Caribou Distribution during the Post-Calving Period in Relation to Infrastructure in the Prudhoe Bay Oil Field, Alaska.

Citation: Cronin M, Amstrup S, Durner G, Noel L, McDonald T, Ballard W. 1998. Caribou Distribution during the Post-Calving Period in Relation to Infrastructure in the Prudhoe Bay Oil Field, Alaska. Arctic 51(2): 85-93.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: infrastructure, oil and gas
Summary: The objective of this study was to quantify the relationship between caribou distribution and oil field development in the post-calving period, from 1990 to 1995. Ten, 1 km wide concentric intervals were constructed around infrastructure. Expected and observed number of caribou were compared using habitat utilization-availability analysis methods of Neu et al. 1974. Distribution of caribou was analyzed using log-linear regression models. Results indicated that caribou distribution was mostly unrelated to distance from infrastructure, and that caribou used habitat in Prudhoe Bay Oil Field; often occurring close to infrastructure, and thus do not appear to avoid oil field infrastructure.

4) Curatolo and Murphy.1983. Caribou responses to the pipeline/road complex in the Kuparuk oil field, Alaska, 1982.

Citation: Curatolo JA and Murphy SM. 1983. Caribou responses to the pipeline/road complex in the Kuparuk oil field, Alaska, 1982. Alaska Biological Research, Fairbanks, Alaska, 81pp.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: oil and gas, pipelines, insect harassment
Summary: This study examined the effects of pipelines and roads on caribou. Two study area sites and two study area controls were compared; each site was simultaneously monitored from observation towers. One site was a pipeline, one a pipe-road site, and the two controls were sites that had no roads or pipelines, but resembled the area with pipes. A significant reduction in pipeline crossings at pipeline road sites was detected compared to other study areas during mosquito season (29 June to 23 July); from July 24-August 1, in the Oestrid fly season, there was no significant difference in crossings. When

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insects were absent, caribou selected for higher pipe heights, and strongly selected to cross at places where pipe was buried.

5) Curatolo and Murphy. 1986. The effects of pipelines, roads, and traffic on the movements of caribou, Rangifer tarandus

Citation: Curatolo JA, and Murphy SM. 1986. The effects of pipelines, roads, and traffic on the movements of caribou, Rangifer tarandus. Canadian Field Naturalist 100: 218-224.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: infrastructure, roads, pipelines
Summary: This is the published version of Curatolo and Murphy (1983). Several study areas were selected and had observation towers established that were used to study the number of crossings of caribou over roads and pipelines. The study concludes that road traffic and elevated pipelines work synergistically, making caribou hesitant to cross roads.

6) Fancy. 1983. Movements and activity budgets of caribou near oil drilling sites in the Sagavanirktok River floodplain, Alaska.

Citation: Fancy SG. 1983. Movements and activity budgets of caribou near oil drilling sites in the Sagavanirktok River floodplain, Alaska. Arctic 38(2): 193-197.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: oil and gas, insect harassment, roads, pipelines, buildings
Summary: This study examined movement and activity patterns of caribou in relation to active drilling sites. Direct observations from towers were used. Observations of behaviour and insect harassment were measured. Of 99 groups that approached infrastructure, 70.7% crossed directly, 19.2% detoured the drill site, and 10.1% reversed direction. Authors believe no evidence was found that cows and calves avoided the area because of drilling operations.

7) Griffiths et al. 2002. The Porcupine Caribou Herd

Citation: Griffiths B, Douglas DS, Walsh NE, Young DD, McCabe TR, Russell DE, White RG, Cameron RD, and Whitten KR . 2002. The Porcupine Caribou Herd, Pages 8-37 in Arctic Plains Terrestrial Wildlife Research Summaries, Biological Science Report USGS 2002-0001.
Location: Alaska, USA
Herd: Porcupine Caribou Herd
Disturbance Type: oil and gas
Summary: This study documented the natural range in variation from 1983-2001 in ecological, life history, and physiological characteristics of Porcupine caribou as a basis for predicting potential effects of industrial development in the calving grounds on the herd. Known relationships between industrial activities and these characteristics in the Central Arctic Herd were used as a basis for extrapolation. The study concludes that petroleum development would result in restriction in calving sites and calving grounds, with associated effects of reduced calf survival, reduced weight and condition of parturient females and calves, and, potentially, recued weight and probability of conception for females in the fall.

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8) Hanson. 1981. Caribou (Rangifer tarandus) encounters with pipelines in northern Alaska

Citation: Hanson WC. 1981. Caribou (Rangifer tarandus) encounters with pipelines in northern Alaska. Canadian Field-Naturalist, 95(1): 57-62.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Infrastructure, pipeline, oil and gas
Summary: Behavior of caribou (Rangifer tarandus) upon encountering an experimental gas pipeline berm in northern Alaska was studied. Results suggested that a visual barrier effect greater than 1.2 m above ground level had a pronounced effect of deflecting the movements of caribou. Animals readily traversed lower berms but avoided high berms and thermokarst areas.

9) Murphy and Curatolo. 1987. Activity budgets and movement rates of caribou encountering pipelines, roads, and traffic in northern Alaska.

Citation: Murphy SM, and Curatolo JA. 1987. Activity budgets and movement rates of caribou encountering pipelines, roads, and traffic in northern Alaska. Canadian Journal of Zoology, 65: 2483-2490.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: oil and gas, insect harassment
Summary: Behavioural responses of caribou to roads, pipelines, and traffic were examined, using observations of caribou from 3m high towers. Authors report that, when insects were absent, activity budgets were significantly different for caribou within 600 m of a pipeline with traffic, and 300 m of a pipeline and road without traffic, compared to undisturbed caribou. Cow-calf dominated groups and groups larger than 10 animals reacted to lower levels of disturbance, and all groups reacted similarly to high levels of disturbance.

10) National Research Council. 2003. Chapter 8 pages 106-117 in: Cumulative environmental effects of oil and gas activities on Iaska's NorthSlope.

Citation: National Research Council. 2003. Chapter 8 pages 106-117 in: Cumulative environmental effects of oil and gas activities on Iaska's NorthSlope. The National Academies, Washington D.C., USA.
Location: Alaska, USA
Herd: NA
Disturbance Type: infrastructure, roads, pipelines, buildings
Summary: This study summarizes the science of disturbance effects of development on caribou, and contains some unpublished data. It was found that "[r]adio-collared female caribou west of the Sagavanirktok River shifted their calving concentration area from developed areas nearer the coast to undeveloped areas inland. No such shift has occurred for caribou calving east of the Sagavanirktok River where there is no development."…"From 1988 to 1994, parturition rates of radio-collared females in regular contact with oil-field infrastructure west of the Sagavanirktok River were lower than those of undisturbed females to the east. Reduction in parturition rates— the variable part of net calf production—for those caribou was exacerbated by intense insect harassment during the period. Thus, it appears that the effects of oil-field development accumulate with effects of insect harassment by impairing movements between coastal and inland habitats." "As a result of conflicts with industrial activity during calving and an interaction of disturbance with the stress of summer insect harassment,

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reproductive success of Central Arctic Herd female caribou in contact with oil development from 1988 through 2001 was lower than for undisturbed females, contributing to an overall reduction in herd productivity. The decrease in herd size between 1992 and 1995 may reflect the additive effects of surface development and relatively high insect activity, in contrast to an increase in the herd's size from 1995 to 2000, when insect activity was generally low."

11) Nellemann and Cameron. 1996. Effects of Petroleum Development on Terrain Preferences of Calving Caribou.

Citation: Nellemann C, and Cameron RD. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic 49(1): 23-28.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Oil and gas, roads, infrastructure
Summary: Habitat preferences of caribou were investigated in an oilfield region near Prudhoe Bay, Alaska. Methods used were mean % of caribou in quadrats, block style analysis of variance to identify clustering of caribou and rugged terrain types, spearman's rank correlation to evaluate relationships between caribou density and terrain ruggedness, Krukska-Wallis tests to compare caribou densities for different terrain types and distance zone, and Bonferronni tests to assess use vs availability of terrain types. Results show that where no oilfield development took place terrain ruggedness was correlated with calving caribou. In areas of oilfield development, caribou avoided infrastructure within 4 km of their location, and reduced use of rugged terrain by 52%, which led to a 43% increase in rugged terrain use 4-10 km of oilfield infrastructure. Terrain ruggedness is positively correlated with forage quality and biomass availability.

12) Smith et al. 1994. Distribution and movements of caribou in relation to roads and pipelines, Kuparuk development area, 1978-90.

Citation: Smith WT, Cameron RD, and Reed DJ. 1994. Distribution and movements of caribou in relation to roads and pipelines, Kuparuk development area, 1978-90. Alaska Department of Fish and Game Wildlife Technical Bulletin No. 12, 54pp.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Oil and gas, roads, pipelines
Summary: Summarize results of 1978-1990 monitoring of how caribou respond to oil field development. Calf percentage, sighting rate and mean group size were used to determine if changes in caribou behaviour were taking place due to human development. Observations were divided into preconstruction, initial construction, and advanced construction phases. Observations were made by surveys along roads, in conjunction with aerial surveys of the region. Results show that the numbers of caribou observed from the road were found to decrease over the course of the study. Study recommended that expansion of pipeline networks and facilities should be discouraged in calving areas.

2.6 Infrastructure - Roads

These studies look at the specific effects of roads on caribou habitat use. Most studies are related to the Central Arctic Herd and oil field development, except Wilson et al. (2014), which looks at modelled

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effects of road development on the Western Arctic Herd. Although many other studies include road effects in different regions, these studies focus specifically on road effects alone.

The majority of the literature found negative effects of roads on caribou habitat selection. Two studies found that, as road density increased, caribou progressively abandon the habitat near it (Cameron et al. 1992; Nellemann and Cameron 1996). Dau and Cameron (1986) found that as road density increased, so did the density of maternal caribou near them. Noel et al. (2004) found no effects of roads on caribou distribution, which Joly et al. (2006) challenge. The last study of specific note was conducted by Wilson et al. (2014), which examines the potential habitat loss for the Western Arctic Herd due to construction of an industrial road, finding potential high quality habitat loss between 1.5-8.5%.

1) Cameron et al. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska.

Citation: Cameron RD, Reed DJ, Dau JR, Smith WT. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska. Arctic 45: 338-342.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: oil and gas
Summary: This study examines changes in calving caribou distribution with increasing oil-field development in Prudhoe Bay. Results are based on aerial surveys. A zone within 6 km of Milne Point Road system was compared between pre- and post-construction periods. Results show that construction of a road through caribou calving grounds led to a decrease in caribou from 1.41 to 0.31 caribou/km^2 within 1 km of the road, and an increase from 1.41 to 4.53 caribou/km^2 within 5-6 km of the road. Relative caribou use of the area also declined.

2) Dau and Cameron. 1986. Effects of a road system on caribou distribution during calving.

Citation: Dau JR, and Cameron RD. 1986. Effects of a road system on caribou distribution during calving. Rangifer Special Issue No 1: 95-101.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: infrastructure, roads
Summary: This study aimed to determine the before-after effects of road development on calving caribou use. Forty quadrats were developed; analysis of quadrats with road system involved calving caribou presence or absence after construction of a road. Linear regression analysis was used to analyze differences in distribution of caribou within 6k m of a road system. The density of maternal females was positively correlated with distance from road post-construction, a correlation not present before road construction. Density of nonmaternal adults was unrelated to distance in both periods.

3) Noel et al. 2004. Caribou Distribution near an Oilfield Road on Alaska's North Slope, 1978-2001.

Citation: Noel LE, Parker KR, and Cronin MA. 2004. Caribou Distribution near an Oilfield Road on Alaska's North Slope, 1978-2001. Wildlife Society Bulletin 32(3): 757-771.
Location: Alaska, USA
Herd: Central Arctic Herd

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Disturbance Type: Infrastructure, roads, construction activity
Summary: Cow and calf density were examined in relation to oil-field infrastructure. Survey data were divided into 3 periods: pre-road construction (1978-1981), early post-road construction (1982-1987), and recent post-road construction (1991-2001). Numbers and densities of caribou in 6, 1-km intervals from Milne Point Road were tallied. Densities of calves was not significantly lower within 1 km of roads in comparison to pre-road periods. Calf density was higher within 1 km of road than within 1-6 km of the road during recent post-road construction period. Overall, the authors found the total number of calving caribou in the study area has declined, but caribou who are still using the area do not avoid areas near roads.

4) Joly et al. 2006. A Reevaluation of Caribou Distribution near an Oilfield Road on Alaska's North Slope.

Citation: Joly K, Nellemann C, and Vistnes I. 2006. A Reevaluation of Caribou Distribution near an Oilfield Road on Alaska's North Slope. Wildlife Society Bulletin 34(3): 866-869.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Comment on Noel et al. 2004
Summary: A series of comments on Noel et al. 2004 are summarized in this abstract: "Noel et al. (2004) claimed that oil development on Alaska's North Slope has not adversely affected caribou (Rangifer tarandus) distribution. Their argument was based on the lack of statistical difference between caribou densities at different distances from the Milne Point road, Prudhoe Bay, Alaska, USA,10–20 years after its construction. Our primary criticisms of that article are that the authors failed to include the effects of expanding oilfield infrastructure in their analysis, to incorporate 6 of 13 surveys, and to discuss data that revealed caribou largely abandoned their study area following this development. After the construction of the road, calving caribou were displaced from a previously used zone 0–4 km from the road, which subsequently increased use 4–6 km away from the road in the years spanning 1982–1987. With additional development of roads and pads in the calving grounds after 1987, affecting 92% of the study area, the remaining undisturbed fragments were too small for continued use of the area for concentrated calving. Our analysis of the Noel et al. data shows an overall gradual abandonment of the oilfield during calving and a drop in abundance of calving caribou by at least 72% within the oilfield, in spite of the fact that the total herd size had increased 4- to 5-fold during that time period. The major concentration of calving shifted to south of the oilfield, whereas such shifts in calving did not occur in the eastern portion of the Central Arctic Herd that was less affected by development."

5) Noel et al. 2006. Response to Joly et al. 2006. A Reevaluation of Caribou Distribution near an Oilfield Road on Alaska's North Slope

Citation: Noel LE, Parker KR, and Cronin MA. 2006. Response to Joly et al. 2006. A Reevaluation of Caribou Distribution near an Oilfield Road on Alaska's North Slope. Wildlife Society Bulletin 34(3): 870-873.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Response to comment on 2004 paper.
Summary: This paper responds to Joly et al. 2006's comments on their original Noel et al. 2004 paper, as summarized in the abstract: "Joly et al. (2006) critically reviewed our paper (Noel et al. 2004) describing caribou (Rangifer tarandus) distribution data in relation to an oilfield road in Alaska, USA.

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Their review focused on 4 primary points: 1) we concluded there were no adverse impacts to caribou distribution, 2) we failed to discuss data that revealed caribou abandoned the study area following additional development of gravel roads and pads, 3) we failed to consider expanding infrastructure and some surveys, and 4) our conclusions contradict others' findings. We did not draw conclusions, but rather presented our data and analyses and discussed possible explanations for our observations. We presented all of the original data showing a decline in caribou use of the area during calving and discussed potential influential factors. We discussed our method and rationale for the focus of our analysis on displacement from the Milne Point Road in order to replicate methods used in an earlier study. The fourth point reflects that we simply had different results from those of other studies."

6) Nellemann and Cameron. 1998. Cumulative impacts of an evolving oil-field complex on the distribution of calving caribou.

Citation: Nellemann C, Cameron R. 1998. Cumulative impacts of an evolving oil-field complex on the distribution of calving caribou. Canadian Journal Of Zoology 76(8):1425-1430.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: Infrastructure, oil and gas, roads
Summary: The objective of this study was to determine the change in calving caribou distribution and terrain use with increasing density of roads in oil-field development areas. Caribou density declined by 63% at road densities of >0.0-0.3 km/km^2 (low) and 86% at >0.6-0.9 km/km^2 (high). At high road densities, cow-calf pairs were virtually excluded. Effects of avoidance were most apparent in rugged terrain. Authors believe study shows that: females and calves are more sensitive to development than adult males and yearlings, the extent of avoidance greatly exceeds physical footprint of the oil-field, and greatest impacts are due to initial construction of infrastructure.

7) Wilson et al. 2014. Evaluating Potential Effects of an Industrial Road on Winter Habitat of Caribou in North-Central Alaska.

Citation: Wilson RR, Gustine DD, Joly K. 2014. Evaluating Potential Effects of an Industrial Road on Winter Habitat of Caribou in North-Central Alaska. Arctic 67(4): 472-482.
Location: Alaska, USA
Herd: Western Arctic Herd
Disturbance Type: Roads
Summary: The objective of this study was to understand how winter habitat use may be affected by construction of a road. The analysis was restricted to winter due to this being the season when caribou were most likely to encounter roads. Habitat variables used in analysis included presence/absence lichen, years since fire, and topography. A predictive map was developed of relative habitat value based on final averaged model. The potential road effects were assessed at 1 km, 2.5 km and 5 km. Results show that at all elevations caribou tended to select for more rugged areas with steeper slopes, though the effect was stronger at higher elevations. Caribou also selected for areas that had earlier snow-free dates in spring, though caribou at higher elevations selected areas with slightly later snow-free dates. Across the landscape, caribou selected for areas with relatively less dense vegetation, more lichen, and longer periods since fire, though the strength of these effects decreased with elevation. Overall, the construction of the proposed road would lead to 1.5 to 8.5% loss in high quality winter habitat. The authors believe the use of an objective set of methods to estimate potential impacts to wildlife habitat from proposed development could help resource managers work with developers.

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8) Whitten and Cameron. 1983. Movements of collared caribou, Rangifer tarandus, in relation to petroleum development on the arctic slope of Alaska.

Citation: Whitten KR, and Cameron RD. 1983. Movements of collared caribou, Rangifer tarandus, in relation to petroleum development on the arctic slope of Alaska. Canadian Field-Naturalist, 97(2): 143-146.
Location: Alasak, USA
Herd: Central Arctic Herd
Disturbance Type: Oil and gas, roads
Summary: This study examined the general distribution of caribou in the Central Arctic Slope area in Alaska. Results show that bulls crossed through road segments more often than cows or cows/calves. In off-road areas, bull and cow re-sighting patterns were not significantly different. The heavily developed Prudhoe Oilfield was an effective barrier to both bulls and cows.

2.7 Transportation Vehicles

These three studies examine the behavioural responses of caribou to vehicles. Calef et al. (1976) look at the disturbance effects of aircraft, recommending they should fly at altitudes greater than or equal to 300 m. Gunn et al. (1983) found disturbance effects of helicopters 950 +/- 650 m when landing near caribou groups. Lastly, Horejsi (1981) looks at the disturbance effects a ¾ ton truck has on caribou behaviour, finding 48% of caribou ran from the approaching truck, while 38% trotted. While this literature is dated with respect to publication (most recent study published nearly 35 years ago), there is no reason to believe results would differ, unless habituation has occurred. Newer types of vehicles may be in use and should be examined.

1) Calef et al. 1976. Reaction of barren-ground caribou to aircraft.

Citation: Calef GW, DeBock EA, and Lortie GM. 1976. Reaction of barren-ground caribou to aircraft. Arctic 29: 201-212.
Location: Alaska, USA and Yukon, Canada
Herd: Porcupine Caribou Herd
Disturbance Type: aircraft
Summary: This study examined the response of caribou to fixed-wing aircraft and helicopters. The effects of aircraft altitude, type of aircraft, season and terrain, together with activity and group size of caribou were determined. When aircraft flew at altitudes of less than 60m, panic or strong escape reactions were observed. A minimum altitude of 150m during spring and fall migrations, and 300m during all other periods, is recommended to avoid behaviour that would injury caribou. Authors recommend that aircraft should fly 300m (1000 feet) above caribou to avoid the possibility of injury during flight responses.

2) Gunn et al. 1983. Caribou behaviour, range use patterns and short term responses to helicopter landings on the Beverly calving ground, N.W.T., 1982.

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Citation: Gunn A, Glaholt R, Miller FL, and Jingfors K. 1983. Caribou behaviour, range use patterns and short term responses to helicopter landings on the beverly calving ground, N.W.T., 1982. NWT Wildlife Service, File Report No. 30.
Location: NWT, Canada
Herd: Beverly Herd
Disturbance Type: transportation vehicles, helicopters
Summary: This study's objective was to determine how caribou react to helicopter landings. Behaviour and activity budgets of cow-calf pairs in reaction to 16 helicopter landings were recorded. Landings took place 950 +/- 650 m from caribou, and the helicopter was shut off 20 minutes before flying away. Results show that most cow-calf pairs walked or trotted or galloped during post-disturbance opposed to pre-disturbance. The frequency and duration of nursing also decreased during landing, compared to before or after landings. Measurement of short-term consequences to populations exposed to human activities was deemed outside the scope of this project.

3) Horejsi. 1981. Behavioral response of barren ground caribou to a moving vehicle.

Citation: Horejsi BL. 1981. Behavioral response of barren ground caribou to a moving vehicle. Arctic 34(2): 180-185.
Location: Yukon, Canada
Herd: Porcupine Caribou Herd
Disturbance Type: vehicles
Summary: The objective of this study was to determine behavioural responses of caribou to a 3/4-ton pickup truck. Results show that 48% of caribou ran from vehicle while 38% trotted away; 29% of individual caribou either reversed direction and/or split from a group. Mean flight duration of females was 73 +/- 11 seconds, males was 38 =/- 6 seconds. In forested habitat, male caribou allowed much closer approaches of vehicles than females.

2.8 Reviews of Previous Literature and Misc.

1) Bergerud et al. 1984. The buffalo of the North: caribou and human developments.

Citation: Bergerud AT, Jakimchuk RD, and Carruthers DR. 1984. The buffalo of the North: caribou and human developments. Arctic 37(1): 7-22.
Location: Northern Canada
Herd: Kaminuriak, Nelchina, Central Arctic, FortyMile, Porcupine, BC, Newfoundland, Snohetta
Disturbance Type: Review
Summary: This review looks at the demographic, movement, and behaviour patterns of eight caribou populations. Authors believe there is no evidence that human activities had affected caribou productivity, but transportation corridors had allowed for greater hunting access. Authors believe caribou's ability to space themselves from their natural predators will allow them to adapt and this must not be inhibited.

2) Cameron et al. 2005. Central Arctic Caribou and petroleum development: distributional, nutritional, and reproductive implications.

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Citation: Cameron RD, Smith WT, White RG, and Griffith B. 2005. Central Arctic Caribou and petroleum development: distributional, nutritional, and reproductive implications. Arctic 58(1): 1-9.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: oil and gas
Summary: This review synthesizes findings of research on how oil and gas development affects caribou of the Central Arctic Herd. The review found that the abundance of calving caribou was less than expected within 4 km of roads, declining exponentially with road density. As infrastructure increased, the calving areas shifted to lower forage biomass areas. Authors believe poor body condition and lower parturition rate of caribou closer to development was due to development.

3) Cronin et al. 2000. Northern Alaska oil fields and caribou.

Citation: Cronin MA, Whitlaw HA, and Ballard WB. 2000. Northern Alaska oil fields and caribou. Wildlife Society Bulletin 28(4): 919-922.
Location: Alaska, USA
Herd: Central Arctic Herd
Disturbance Type: review, oil and gas
Summary: This study interprets increases in Central Arctic Herd with compatibility of caribou health and oil field development. Authors believe managers and regulators should acknowledge coexistence of caribou with oil and gas development.

4) COSEWIC 2016. COSEWIC assessment and status report on the Caribou Rangifer tarandus, Barren-ground population, in Canada.

Citation: COSEWIC. 2016. *in press*. COSEWIC assessment and status report on the Caribou Rangifer tarandus, Barren-ground population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 122 pp.
Location: Canada (Yukon, Northwest Territories, Nunavut, Alberta, Saskatchewan, Manitoba)
Herd: All barren-ground
Disturbance Type: review
Summary: This is the most recent status assessment for barren-ground caribou in Canada. It recommends a status of threatened, but has not yet been publicly released. It presents a review of threats, which include anthropogenic impacts. * need to expand and include in following section

5) Golder Associates Ltd. 2010. Gahcho Kué Project Environmental Impact Statement. Section 7: Key Line of Inquiry Caribou.

Citation: Golder Associates Ltd. 2010. Gahcho Kué Project Environmental Impact Statement. Section 7: Key Line of Inquiry Caribou. Prepared De Beers Canada Inc. Submitted to Mackenzie Valley Environmental Impact Review Board, December 2010.
Location: NWT, Canada
Herd: Bathurst, Ahiak, Beverly
Disturbance Type: review, mining
Summary: This environmental impact statement examines the potential effects the Gahcho Kue Diamond mine, based on best available knowledge to develop models and predictions of how the diamond mine will affect caribou. Throughout the assessment of mine effects on caribou: a 5 km ZOI

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applied to all active exploration permits, any direct habitat disturbance had a 500 m footprint radius, and a 15 km ZOI was applied to all active mine sites. Authors did not believe caribou become accustomed to encounters with disturbance. Similar ZOI's and disturbance coefficients to Golder Associates Ltd. 2014 were applied. Percent of estimated habitat lost for Bathhurst Herd was: 1.71% high quality spring/calving habitat, 1.67% high quality post-calving/summer habitat, 0.45% high quality autumn/rut habitat. Percent of estimated habitat lost for Ahirak was: 0% high quality spring/calving habitat, 0.22% high quality post-calving/summer habitat, 1.81% high quality autumn/rut habitat.

6) Golder Associates Ltd. 2014. Final Environmental Impact Statement (FEIS)—Meliadine Gold Project, Nunavut: Volume 6.0 Terrestrial Environment and Impact Assessment.

Citation: Golder Associates Ltd. 2014. Final Environmental Impact Statement (FEIS)—Meliadine Gold Project, Nunavut: Volume 6.0 Terrestrial Environment and Impact Assessment. Prepared for Agnico Eagle Mines. Submitted to Nunavut Impact Review Board.
Location: NWT, Canada
Herd: Qamanirjuaq, Lorillard
Disturbance Type: review, mining
Summary: This environmental impact statement examines the potential effects of the Meliadine Gold Project. Caribou collar data were used from the Government of NWT to inform potential ZOI's around the mine. Hypothetical and not modeled ZOIs were applied to mine footprints. ZOI's were determined based on Johnson et al. 2005, Weir et al. 2007, and Boulanger et al. 2012.

7) Golder Associates Ltd. 2014. Jay Project – Developer's Assessment Report (DAR). Section 12. Barren-Ground Caribou.

Citation: Golder Associates Ltd. 2014. Jay Project – Developer's Assessment Report (DAR). Section 12. Barren-Ground Caribou. Prepared for Dominion Diamond Ekati Corporation. Submitted to Mackenzie Valley Environmental Impact Review Board, November 2014. 159 pp.
Location: NWT, Canada
Herd: Bathurst
Disturbance Type: review, mining
Summary: An environmental impact statement that examined the potential effects of the Jay Project. Study summarizes best available knowledge to develop models and predictions of how the diamond mine will affect caribou. Similar ZOI's and disturbance coefficients to Golder Associates Ltd. 2010.

8) Government of Northwest Territories. 2017. Bathhurst caribou range plan - DRAFT. Government of Northwest Territories.

Citation: Government of Northwest Territories. 2017. Bathhurst caribou range plan - DRAFT. Government of Northwest Territories.
Location: NWT, Canada
Herd: Bathurst
Disturbance Type: review, mining
Summary: A range planning process took place to address cumulative effects on Bathurst caribou. A listing of average zone of influences from different sources is compiled in Appendix D. Averages for zones of influence of disturbances on barren-ground caribou were derived from the literature. Where no literature was available, an educated estimated was used. Traditional knowledge sources are

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reviewed, as well as the natural and human factors that affect Bathurst caribou. Appendix D lists ZOIs including: all season access road – 5 km, major electrical transmission corridor 4 km, public all-season paved highway 5 km, all season mainline access (haul) road – 5 km, winter road – 1 km, winter road only – 4 km, airstrip 5 km, camp 5 km, communication tower – 1 km, general industrial – 1 km, mineral exploration – 5 km, mine site (active) – 14 km, mine site (closed) - 5 km, misc. – 1 km, marine port – 5 km, power generation – 5 km, quarry – 5 km.

9) Government of Nunavut. 2011. Anthropogenic disturbance on ungulates: guidelines and mitigation of impacts.

Citation: Government of Nunavut. 2011. Anthropogenic disturbance on ungulates: guidelines and mitigation of impacts. EBA Engineering Consultants Ltd.
Location: Northern Canada
Herd: n/a
Disturbance Type: review
Summary: Anthropogenic impacts on muskox and caribou were reviewed, with an emphasis on facilities and human activities, linear features, and transportation. The review included primary and grey literature, and consultation with experts. Knowledge gaps were identified, and level of confidence in identified impacts was assessed. A lack of baseline information for Nunavut, and inability to distinguish natural population fluctuations from anthropogenic impacts, were cited as limitations. However, confidence in proposed setback distances (considered to be conservative) was high. A review of existing, and proposed new, mitigation measures formed a substantive component of this report.

10) Gunn et al. 2011. Chapter 8: Addressing cumulative effects in the Canadian Central Arctic -- understanding the impacts of human activities on barren-ground caribou.

Citation: Gunn A, Johnson CJ, Nishi JS, Daniel CJ, Carlson M, Russell DE, and Adamczewski JZ. 2011. Chapter 8: Addressing cumulative effects in the Canadian Central Arctic -- understanding the impacts of human activities on barren-ground caribou. Pages 113-133 in P.R. Krausman and L.K. Harris (Eds.). Cumulative effects on wildlife management: impact mitigation. CRC Press, Boca Raton, Florida.
Location: NWT, Canada
Herd: Bathurst
Disturbance Type: Review
Summary: The objective of this book chapter was to develop a cumulative effects model for barren-ground caribou, in order to better understand human impacts. The paper establishes the policy and management context for the issues in the NWT, reviews state of knowledge, then develops a conceptual framework for illustrating pathways linking landscape and environmental changes to caribou energetic and demographic responses. The authors emphasize resilience as an appropriate lens through which to evaluate the sustainability of human activities.

11) Integrated Ecological Research. 2015. Caribou zone of influence technical task group, draft guidance for monitoring the zone of influence (ZOI) of anthropogenic disturbance on barren-ground caribou

Citation: Integrated Ecological Research. 2015. Caribou zone of influence technical task group, draft guidance for monitoring the zone of influence (ZOI) of anthropogenic disturbance on barren-ground caribou, March 10, 2015, retrieved on March 2, 2017 at:

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http://www.reviewboard.ca/upload/project_document/EA1314-01_ZOI_Draft_Guidance_Document_10Mar15.PDF
Location: NWT
Herd: NA
Disturbance Type: Zone of Influence Guidance
Summary: This document aims to provide guidance regarding approaches to monitoring ZOI that will maximize the quality of monitoring data, when such monitoring is appropriate. A secondary objective for this document is to provide guidance on when ZOI monitoring is operationally and technically appropriate.

12) McCourt et al. 1974. Disturbance studies of caribou and other mammals in the Yukon and Alaska, 1972

Citation: McCourt KH, Feist JD, Doll D, and Russell JJ. 1974. Disturbance studies of caribou and other mammals in the Yukon and Alaska, 1972. Canadian Arctic Gas Study Limited, Biological Report Series 5, pp. 246.
Location: Yukon/Alaska
Herd: NA
Disturbance Type: Noise disturbance, cutline usage
Summary:
This study looks at how caribou and Dall sheep react to the simulated sound of a compressor station. Study found a 1/8 mile to 1/2 mile avoidance rate depending on the season. The study also looked at the % use of cutlines by caribou in the winter and spring, and the reaction to flights over caribou at different altitudes. **Note:** Only available in hardcopy.

13) Plante S, Dussault C, and Cote SD. 2017. Landscape attributes explain migratory caribou vulnerability to sport hunting. The Journal of Wildlife Management, 81(2): 238-247.

Citation: Plante S, Dussault C, and Cote SD. 2017. Landscape attributes explain migratory caribou vulnerability to sport hunting. The Journal of Wildlife Management, 81(2): 238-247.
Location: Quebec, Canada
Herd: Riviere-aux-Feuilles
Disturbance Type: hunting
Summary: This study evaluates the 'relative importance of caribou and hunter habitat selection and landscape characteristics on caribou vulnerability to sport hunting.' Resource selection functions of hunters and caribou were developed. Caribou harvest sites were then measured against probability of occurrence with hunter only, caribou only, co-occurrence of both, or landscape characteristics (distance to human infrastructures, elevation, land cover types). Landscape characteristics better explained caribou harvest sites than habitat selection by caribou or hunters. Caribou were more vulnerable near roads and outfitter camps, and strongly avoided roads. Caribou were also vulnerable on frozen lakes, though they avoided lakes. Overall, caribou were more vulnerable in areas of easy accessibility (roads) or where they could be more easily detected (smoother terrain and lakes).

14) Reimers and Colman. 2006. Reindeer and caribou (Rangifer tarandus) response towards human activities.

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Citation: Reimers E and Colman JE. 2006. Reindeer and caribou (Rangifer tarandus) response towards human activities. Rangifer 26(2): 55-71.
Location: Circumpolar
Herd: NA
Disturbance Type: Review
Summary: This study surveys the literature on behavioural response studies of reindeer to human activities. It found that the farther away a person was when first sighted, the farther the reindeer group fled. Distance fled was greatest in July and least in September-October. In September, rutting behaviour affected reindeer more than being approached by a human. With increasing group size, the distance when group responded by flight, and distance they moved, decreased.

15) Reimers et al. 2000. High voltage power lines and their effect on reindeer: a research programme in progress.

Citation: Reimers E, Flydal K, and Stenseth R. 2000. High voltage power lines and their effect on reindeer: a research programme in progress. Polar Res: 75-82.
Location: Norway
Herd: NA
Disturbance Type: Review
Summary: This is a review of literature on powerlines and their effects on caribou. The authors recommended a study on reindeer hearing capability be conducted (implemented in Flydal et al. 2003), and noted that knowledge of how reindeer respond to powerlines was lacking.

16) Rescan Environmental Services Ltd. (Rescan). 2013. The Back River Project Draft Environmental Impact Statement: Volume 5 Terrestrial Environment.

Citation: Rescan Environmental Services Ltd. (Rescan). 2013. The Back River Project Draft Environmental Impact Statement: Volume 5 Terrestrial Environment. Prepared for Sabina Silver and Gold. Submitted to Nunavut Impact Review Board.
Location: Nunavut, Canada
Herds: Dolphin and Union, Bathurst, Beverly
Disturbance Type: Environmental assessment
Summary: This component of an extensive report was prepared to support an environmental assessment of the potential effects of the Black River gold mining project on caribou. The report summarizes previous literature and applies it to evaluate potential effects on caribou in the region. Caribou location data were also analyzed for the four herds that could be impacted by the activities.,

17) Silversten. 2012. The influence of natural and anthropogenic factors on Rangifer movements and habitat use.

Citation: Siversten TR. 2012. The influence of natural and anthropogenic factors on Rangifer movements and habitat use. Department of Animal Nutrition and Management Uppsala, Swedish University of Agricultural Sciences, 30 pp.
Location: Scandinavia / Circumpolar
Herd: NA
Disturbance Type: Review

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Summary: This paper presents an overview of the existing knowledge of Rangifer foraging and antipredator behaviour, and impact of human disturbance on Rangifer habitat use. The main theories of foraging and antipredator behaviour in ecology are summarized, current and future challenges and knowledge gaps related to management of reindeer herding areas in Fennoscandia discussed.

18) Species at Risk Committee. 2017. Species Status Report for Porcupine Caribou and Barren-ground Caribou.

Citation: Species at Risk Committee. 2017. Species Status Report for Porcupine Caribou and Barren-ground Caribou (Tuktoyaktuk Peninsula, Cape Bathurst, Bluenose-West, Bluenose-East, Bathurst, Beverly, Ahiak, and Qamanirjuaq herds) (Rangifer tarandus groenlandicus) in the Northwest Territories. Species at Risk Committee, Yellowknife, NT.
Location: NWT
Herd: Tuktoyaktuk Peninsula, Cape Bathurst, Bluenose-West, Bluenose-East, Bathurst, Beverly, Ahiak, and Qamanirjuaq
Disturbance Type: Review
Summary: This is a status report for barren-ground caribou herds in NWT that includes a summary of anthropogenic effects. *need to expand and include in next section

19) Stankowitch. 2008. Ungulate flight responses to human disturbances: a review and meta-analysis.

Citation: Stankowitch T. 2008. Ungulate flight responses to human disturbances: a review and meta-analysis. Biological Conservation 141: 2159-2173.
Location: Circumpolar
Herd: NA
Disturbance Type: Review
Summary: The objective of this review was to 'comprehensively review studies measuring Artiodactyl escape responses. The author "…found evidence across studies that ungulates pay attention to approacher behavior, have greater perceptions of risk when disturbed in open habitats, and females or groups with young offspring show greater flight responses than adult groups. Increased group size and the presence of hunting showed weak but positive heterogeneous effects on flight behavior both between and within species. Humans on foot were more evocative than other stimuli (vehicles, noises). Populations in areas with higher levels of human traffic showed reduced wariness but a lack of alternative sites to move to may explain some of this effect. Hunted populations showed significantly greater flight responses than non-hunted populations." The conclusion was to "…suggest five factors to consider when forming predictive models of ungulate flight behavior: (1) how seasonal variation in reproductive status and body condition effects wariness, (2) the relative impacts of lethal and non-lethal human contact, and (3) unique natural history traits that may cause differences in flight behavior between populations, (4) the availability of alternative sites, and (5) shorter distances between feeding sites and refugia can reduce the impact of other factors on flight responses."

20) Trailmark Systems Inc. 2015. Review of post-2010 literature on human effects on barren ground caribou: focus on traditional knowledge, western science…

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Citation: Trailmark Systems Inc. 2015. Review of post-2010 literature on human effects on barren-ground caribou: focus on traditional knowledge, western science and caribou protection methods. Trailmark Systems Inc., Victoria, BC.
Location: Circumpolar, but mainly Canada focused
Herd: NA
Disturbance Type: Review
Summary: This is a review of post-2010 literature on barren-ground caribou response to disturbances. The review found more evidence for detrimental effects by linear features than neutral effects. Resource development was determined by indigenous community members to be the main source of impacts on barren-ground caribou. The authors also report some negative impacts of resource development infrastructure on caribou habitat based on scientific literature. Both traditional knowledge holders and scientific literature were strongly in agreement of the negative effects of aircraft and vehicles on caribou. The study also summarized local, regional, and cumulative effects of disturbances on caribou.

21) Vistnes and Nellemann. 2008. The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity.

Citation: Vistnes I, and Nellemann C. 2008. The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity. Polar Biology 31(4): 399-407.
Location: Circumpolar
Herd: NA
Disturbance Type: review
Summary: This is a review of reindeer and caribou responses to human activities. The authors found that, prior to the 1980's, most research was comprised of behavioural studies at local scales, that reported few and short-term impacts within 0-2 km of human activities. After the mid-1980s, regional scale studies began to report reduced use of areas by caribou within 5 km of infrastructure and human activity, with increased use of habitat beyond these disturbances. Of 85 studies reviewed, 83% of regional studies concluded impacts of human activities were significant, while only 13% of local studies report significance. The authors contest that accurate assessment of impacts of human activity on reindeer requires regional-scale studies, while long-term studies will help improve understanding of both temporal and spatial patterns.

22) Wolfe et al. 2000. Response of reindeer and caribou to human activities.

Citation: Wolfe S, Griffith B, and Wolfe C. 2000. Response of reindeer and caribou to human activities. Polar Research 19(1): 63-73.
Location: Circumpolar
Herd: NA
Disturbance Type: review
Summary: A survey of literature on the response of reindeer and caribou to human activities was conducted, with emphasis on the primary literature. The authors found that: “Individuals and groups of reindeer/caribou: 1) move away from point sources of disturbance; 2) increase activity and energy expenditure near disturbance; 3) delay crossing or fail to cross linear structures; 4) shift away from areas of extensive and intensive development; and 5) are killed by collisions with vehicles and by hunting along roads. Cows and calves during the calving season are the most easily disturbed group. Bulls in general and all reindeer/caribou during insect harassment are least likely to avoid development areas.”

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Mitigation measures are also reviewed. The authors conclude that cumulative effects studies at multiple scales are necessary; particularly, ones that clearly distinguish effects of human disturbance from natural variation in habitat conditions and demography. They lament the absence of comprehensive studies on natural populations.

3.0 Assessment of Review Literature

Reviews of barren-ground caribou responses to anthropogenic disturbances may be partitioned into several groups. The most comprehensive reviews are synthetic, report on state of knowledge, link the findings to ecological theory, and identify knowledge gaps (Wolfe et al. 2000; Reimers and Colman 2006; Vistnes and Nellemann 2008). General reviews examine the literature and summarize patterns in barren-ground caribou response to disturbances (Bergerud et al. 1984; Trailmark Systems Inc. 2015), with little connection to ecological theory or suggestions on what is missing from the literature. Specific reviews look at a central topic related to barren-ground caribou response to disturbances, such as to powerlines (Reimers. 2000) or human encounters (Stankowitch. 2008). The last category of reviews aims to apply the knowledge, either through environmental assessments (Golder Associates Ltd. 2010, 2014) or through range planning (Government of Northwest Territories. 2017). Each approach has strengths and weaknesses.

3.1 Synthetic Reviews

To date, the most comprehensive review of how caribou respond to disturbances was conducted by Vistnes and Nellemann (2008). This study partitions the caribou literature into studies before 1985 and those after 1985. The authors argue that studies before 1985 were mostly on a local and individual scale, and behaviorally focused, while studies after 1985 placed greater emphasis on regional and population scales. This is an important distinction. Of 85 studies reviewed, 83% of regional-scale studies concluded impacts of human disturbance on caribou were significant, whereas only 13% of local-scale studies report significant effects. The authors assert that accurate assessments of how caribou respond to anthropogenic disturbances require long-term, regional studies. Local behavioral studies of individual animals may lead to false conclusions, as they may include tolerant animals, which do not represent the whole herd. While they recognize that local and regional scale studies may be complementary, conducting only local scale studies can significantly underestimate impacts. Overall, Vistnes and Nellemann (2008) establish a strong framework for reviewing caribou disturbance literature.

An earlier review by Wolfe et al. (2000) was comprehensive with respect to treatment of different disturbance types, and provides implicit links to some ecological theory, although not as well developed as Vistes and Nellemann (2008). Consideration of spatial and temporal scales is not explicit as a framework for evaluations. However, the authors similarly highlight the need for regional/population-level studies, particularly focused on cumulative effects, and with an ability to clearly distinguish effects of human activities from those resulting from natural drivers of variation in habitat and population conditions, and how these may alter response.

Reimers and Colman (2006) separate the literature on caribou disturbance response between those studies that take direct measurements of caribou avoidance of human infrastructure and those that take indirect measurements. The authors consider direct measurements as those that rely on animal behavioral responses, while indirect measurements look at caribou distribution and range use through either range properties or animal location data. They note that indirect measurements of caribou

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response to anthropogenic disturbances may not take into account important confounding variables, which direct measurements of caribou response to disturbance can more easily discover. In the development of any new studies, the authors recommend that both indirect and direct measurements be used. Similar to Wolfe et al. (2000), they also highlight the importance of considering potentially confounding variables, such as natural variation in range use, and altitude effects on lichen growth, to better explain caribou response to human infrastructure and activities. Reimers and Colman (2006) do not consider issues of either temporal or spatial scales in moderating response.

Silversten (2012) focuses mainly on the predation aspect of how caribou respond to disturbances, and how they may perceive disturbances as predation risks. The review is not comprehensive, but rather places emphasis on disturbance factors that are important in Fennoscandia, which include predation, windmill, and tourist development. It lastly discusses the research necessary to more adequately explain the effects of human disturbance on reindeer populations in Fennoscandia.

Finally, Gunn et al. 2011 make a significant contribution to the literature in this area by synthesizing the state of knowledge (expert knowledge and empirical research) into a conceptual model that integrates the effects of resource development and land use, climatic variability, and hunting and predation for barren-ground caribou. The catalyst for this is to address cumulative effects, and the intent is to parameterize various components of the model. While the associated literature review is not exhaustive, it provides an excellent summary, and the theoretical links are used to generate hypotheses that structure the conceptual model.

3.2 General Reviews

Bergerud et al. (1984), completed the first examination of the demographic, movement, and behaviour patterns of eight caribou populations relative to human activities. At that time, they found no evidence that human activities had affected caribou productivity, yet found that transportation corridors had allowed for greater hunting access. The authors assert that caribou's ability to space themselves from their natural predators allows them to adapt to human activities, and this ability must not be inhibited. Overall, the conclusions of this paper are dated, but are usefully viewed through the lens of Vistnes and Nellemann (2008).

Cameron et al. (2005) synthesized findings of research on oil and gas development effects on caribou of the Central Arctic Herd, which is one of the longest and most studied barren-ground populations. The review found that the abundance of calving caribou was less than expected within 4k m of roads, declining exponentially with road density. As infrastructure increased, the calving areas shifted to lower forage biomass areas. The authors believe poor body condition and lower parturition rate of caribou closer to development was due to development. Overall, the paper draws from decades of data on the Central Arctic Herd and shows potential negative effects of anthropogenic disturbance that may interact with environmental variables such as insect harassment and forage availability.

Trailmark Systems Inc. (2015) completed a review of barren-ground caribou responses to human disturbance from both traditional knowledge and western science perspectives. Each study reviewed has its main findings listed, and the traditional knowledge section is full of quotes from Elders. The main conclusion drawn is that, to date, there is no unified message on how caribou respond to disturbances from either a traditional knowledge or scientific perspective, but that it is extremely unlikely that human

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disturbances will have a positive effect on caribou demographics, with effects either being neutral or negative.

3.3 Reviews of Specific Barren-ground Responses to Disturbance

Reimers et al. (2000) synthesize the literature on how caribou respond to powerlines, and suggests what is required to strengthen this knowledge. Stankowitch (2008) look broadly at ungulate flight responses to disturbances, with an extensive global perspective. These reviews are useful in determining caribou responses to specific disturbances, and the steps needed to further knowledge on the subjects they cover.

3.4 Environmental Assessments and Application of Disturbance Knowledge

The last category of reviews of barren-ground caribou disturbance literature focuses on the application of disturbance knowledge to mitigation of risks to barren-ground caribou. The largest body of relevant work concerns environmental assessments for various mines in the NWT. Other applications are the development of a range plan for the Bathurst Caribou herd, and guidelines for measuring zones of influence for caribou. Zones of influence (ZOI's) are defined as areas used less by caribou, or avoided completely, around anthropogenic disturbances (Integrated Ecological Research. 2015).
Golder Associates Ltd. (2010) developed an environmental impact statement of the potential effects of the Gahcho Kue Diamond mine. The study summarizes the best available knowledge to develop models and predictions of how the diamond mine might affect caribou. Golder Associates Ltd. (2014) followed similar methodology to examine the hypothetical impacts on the Bathurst herd that an expansion of the Daivik Diamond Mine (entitled the Jay Project) could have. Overall, the environmental assessments present a reasonable synthesis of available literature applied to real-world problems. Potential impacts are quantified using ZOIs that range from 0 to 15 km.

The Government of Northwest Territories Draft Bathurst Range Plan (2017) was developed to address cumulative effects on the Bathurst caribou herd. The plan is necessarily broad and considers ecological, cultural, and socio-economic variables when examining how Bathurst caribou may be affected by development. Three levels of disturbance are established to manage risk, including: critical, cautionary, and desirable. Appendix D of the Bathurst Range plan presents the most comprehensive overview of zones of influence used in different studies and other reviews of the literature. There is circularity in citations (as is true in other assessments), in that sources other than the original are included, resulting in potential misrepresentation of level of support for particular ZOI's (i.e. citing environmental assessments for zones of influence that use the same original references as the Bathurst Range Plan to establish their zones of influence).

4.0 Conclusions

It is now generally accepted that anthropogenic disturbances have both potential and realized effects on caribou populations. The prevalent method of quantification of these effects on barren-ground caribou has been to consider 'zones of influence' around human disturbances. These range from 0 to 15 km in management contexts or applications (Golder Associates Ltd. 2014; Government of Northwest Territories 2017), and up to 38 km in the scientific literature (Johnson et al. 2014). Energetic approaches have also been pursued. Generally, the different types of studies on how barren-ground caribou

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respond to disturbances are divided up regionally: the majority of recreational and general infrastructure studies are from Scandinavia; the majority of mining studies are from the NWT; and the majority of oil and gas studies and road studies are from Alaska.

While a number of recent reports briefly summarize state of knowledge, the last synthetic review in the primary literature was by Vistnes and Nellemann (2008). These authors highlighted critical considerations with respect to the spatial and temporal scale of studies, and framed the issues relative to underlying ecological theory. A subsequent evaluation by Gunn et al. (2011) further developed a conceptual model for understanding the potential cumulative effects of different population drivers, including industrial and natural disturbances, climate change, and harvest (hunting and predation). The model is hypothesis driven, based on state of knowledge at that time, and was intended to be parameterized with empirical data.

A common observation from many studies is the challenge of linking individual and behavioral responses to population level outcomes, mirroring concerns regarding the spatial extent of empirical studies, and scaling local responses to regional impacts. This is addressed by Gunn et al. (2011). The common mitigation approach of establishing zones of influence, and associated constraints on industrial activity, does not address cumulative effects at the population/range scale.

Given new studies in the primary literature, a rich brain trust of expert knowledge, evolving conceptual framing of the issues, rapid changes across caribou ranges, and identified management needs, there appears to be scope for a comprehensive review to make significant contributions to the development of a research agenda, as well as provide near-term guidance on habitat management and disturbance mitigation. Further, it could serve to reconcile responses of different subspecies of caribou; in particular, barren-ground and woodland (boreal ecotype), which are sometimes treated interchangeably with respect to management guidelines. Such confoundment was also evident in literature reviews.

A comparative review of disturbance effects on barren-ground and boreal caribou would be highly complementary. These subspecies have greatest overlap in distribution in the NWT (and adjacent areas of SK), and this is likely to increase with climate change. Understanding commonalities and differences in response, and the mechanisms driving these, would be a substantial contribution to the existing knowledge base, the application of this knowledge to management, and to the primary literature.

The literature is moving fast in areas related to this review, and additional articles have been published since this initial scan was completed. A more comprehensive review of the grey literature is also warranted. This is a prime area in which to engage experts. For example, Gunn and Russell recently completed a review of potential disturbance effects on the Porcupine caribou herd, focused on assessing caribou vulnerability to oil and gas exploration and development in Eagle Plains, Yukon. However, it is not yet publically available.

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