Ekati Diamond Mine

2013 WEMP Addendum — Wildlife Camera Monitoring Summary Report

DOMINION DIAMOND

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Executive Summary

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Caribou Monitoring is a priority at the Ekati Diamond Mine, and is a significant component of the Wildlife Effects Monitoring Program (WEMP). In order to examine how the presence and use of project roads may be affecting caribou movement, Dominion Diamond Ekati Corporation (DDEC) has undertaken a comprehensive monitoring program using motion triggered cameras to assess caribou behaviour along project roads.

Cameras have been used effectively to monitor crossing structures along roads as well as pipelines and other linear developments. Remote photography has replaced traditional methods of visual surveys, drive counts, radio telemetry, and track counts for examining the interactions between many wildlife species and industrial developments. This program is the largest of its kind in the sub-Arctic.

Camera based monitoring of caribou at the Ekati Diamond Mine began in 2011 with the deployment of 49 cameras along project roads, and continued in 2012 and 2013 with the implementation of 90 cameras each year. Caribou numbers, movements, and behaviours were assessed using the cameras and analysed to determine what, if any, effects the project roads have on caribou behaviour.

The primary objectives and results of the 2011-2013 camera monitoring program were to:

1. Determine temporal and seasonal trends in caribou abundance/encounter rates around the Ekati Diamond Mine site:
    - Caribou abundance recorded on cameras was consistent with data from GPS collaring studies and Traditional Knowledge, with a maximum abundance during late summer (August) and fall.
    - The largest encounter rate was at the north end of Main camp, at the Sable/Pigeon Road and Access Roads for total counts. The normalized data (corrected for effort) also indicate increased numbers of caribou at the Sable/Pigeon Road and Access Road area.
2. Determine how the frequencies of behaviours exhibited by caribou groups varied near and away from the road (on-road vs. off-road cameras):
    - Caribou behaviour did not vary between regions in a way that would suggest caribou have consistently different (more stressed versus less stressed) behaviours at different regions.
3. Explore spatial and temporal patterns in road crossing behaviours:
    - The most common behaviours at the group level at roads were foraging (135 observations), crossing or crossed the road running (15 observations), walking across/along roads (169 observations), and alert (88 observations).
    - Statistical evidence was found for an effect of on-road and off-road locations on the frequencies of six behaviours at the group level; investigating camera, walking, standing, foraging, bedded, and calm behaviours.
    - Deflections occurred infrequently at the Sable and Pigeon Road and Access Roads (near the main camp) and along the Misery Road.
    - No effect of group size on susceptibility to heavy or light vehicle was detected (i.e., both large and small groups behaved similar to potential vehicles disturbances).

4. Determine the extent that roads may deter caribou from crossing, and identify those factors that contribute to the permeability of site roads:
    - Observations of deterred road crossing were rare, representing less than 1% of observations of caribou groups, and individuals. In most cases, the deterrence could not be linked to a specific trigger such as a passing vehicle.
5. Quantify traffic levels on Misery Road as a potential deterrent to caribou movement:
    - Traffic on Misery Road was relatively consistent between 2011 and 2012, but increased substantially during 2013. The camera effort adjusted number of caribou road crossings did not change with changes in yearly traffic volumes.
    - Daily differences in traffic were substantial, but differences in traffic between days was not correlated with the number of caribou observations or the behaviour of caribou, suggesting that the road itself with vehicle traffic deters caribou from crossing the road at a very low rate (less than 1%).

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1. Introduction

The Ekati Diamond Mine, operated by Dominion Diamond Ekati Corporation (DDEC), is located in the Southern Arctic Ecozone of the Northwest Territories, approximately 300 km northeast of Yellowknife between Yamba Lake and Lac de Gras (Figure 1-1). Construction of the Ekati Diamond Mine began in 1997 and the mine officially opened in October, 1998. In 2011, the Ekati Diamond Mine had one open pit operation throughout the year (Fox Pit), and two underground mines (Koala Underground, and Koala North Underground), and in 2012 and 2013, had two open pit operations (Fox and Misery pits), and two operational underground mines (Koala Underground and Koala North Underground; Figure 1-2).

The Wildlife Effect Monitoring Program (WEMP) is a requirement of the original Environmental Agreement (Articles V and VII) and the Wildlife Effects Monitoring Plan. The WEMP was developed through extensive consultation with stakeholders, including regulators, scientists, and Aboriginal peoples, and this monitoring program has been conducted since 1997. The WEMP focuses on wildlife species and habitats that were identified during the Environmental Assessment Review Process (EARP; the regulatory regime that preceded *The MacKenzie Valley Resource Management Act* of 1998) as being of social or economic importance, or of particular ecological or conservation concern (i.e., Valued Ecosystem Components [VECs]). The WEMP uses scientific methodology and traditional knowledge as a source of information regarding wildlife species and their local ecological requirements. Several monitoring programs have been implemented as part of the Ekati Diamond Mine's WEMP to address concerns about road impacts, including road side surveys and snow track surveys, with varying degrees of success.

The monitoring of roads (and other mine infrastructure) is a significant component of the WEMP because roads are generally considered the primary mechanisms for potential direct impacts to wildlife via vehicle collisions and as barriers to movement. Roads may act as potential deterrents or attractants for wildlife (Trombulak and Frissell 2000). Wildlife behaviour relative to roads varies between species and within species such that certain populations, age/sex groups, or individuals react either positively, negatively, or have a neutral reaction to roads (Stuart-Smith and James 2000).

There is a growing body of evidence of the impacts of roads on wildlife (Trombulak and Frissell 2000; Underwood and Angold 2000; Carr et al. 2002; Roedenbeck et al. 2007). The primary effects of roads include:

1. *Habitat Loss* — Construction of roads results in loss of habitat, which results in disturbance and barrier effects that contribute to overall habitat fragmentation. Habitat loss associated with construction of the Ekati Diamond Mine was considered in the 1995 Environmental Impact Statement. Some habitat loss will be reversed during planned closure and reclamation activities.
2. *Disturbance* — Roads can disturb and pollute the physical, chemical, and biological environment and consequently alter habitat suitability for wildlife beyond the width of the road itself. Through its various Environmental Monitoring programs (e.g., WEMP, Aquatic Effects Monitoring Program, Air Quality Monitoring Program), the Ekati Diamond Mine continuously monitors and adaptively mitigates indirect effects of project infrastructure on the environment.
3. *Corridor* — Road verges and roadsides can provide refuges, new habitats, or serve as movement corridors for wildlife. Wildlife are regularly observed walking along Misery Road, but only for relatively short distances before returning to the tundra. Additionally, the road may provide some measure of insect relief for caribou.

Figure 1-1
Location of the Ekati Diamond Mine, Northwest Territories

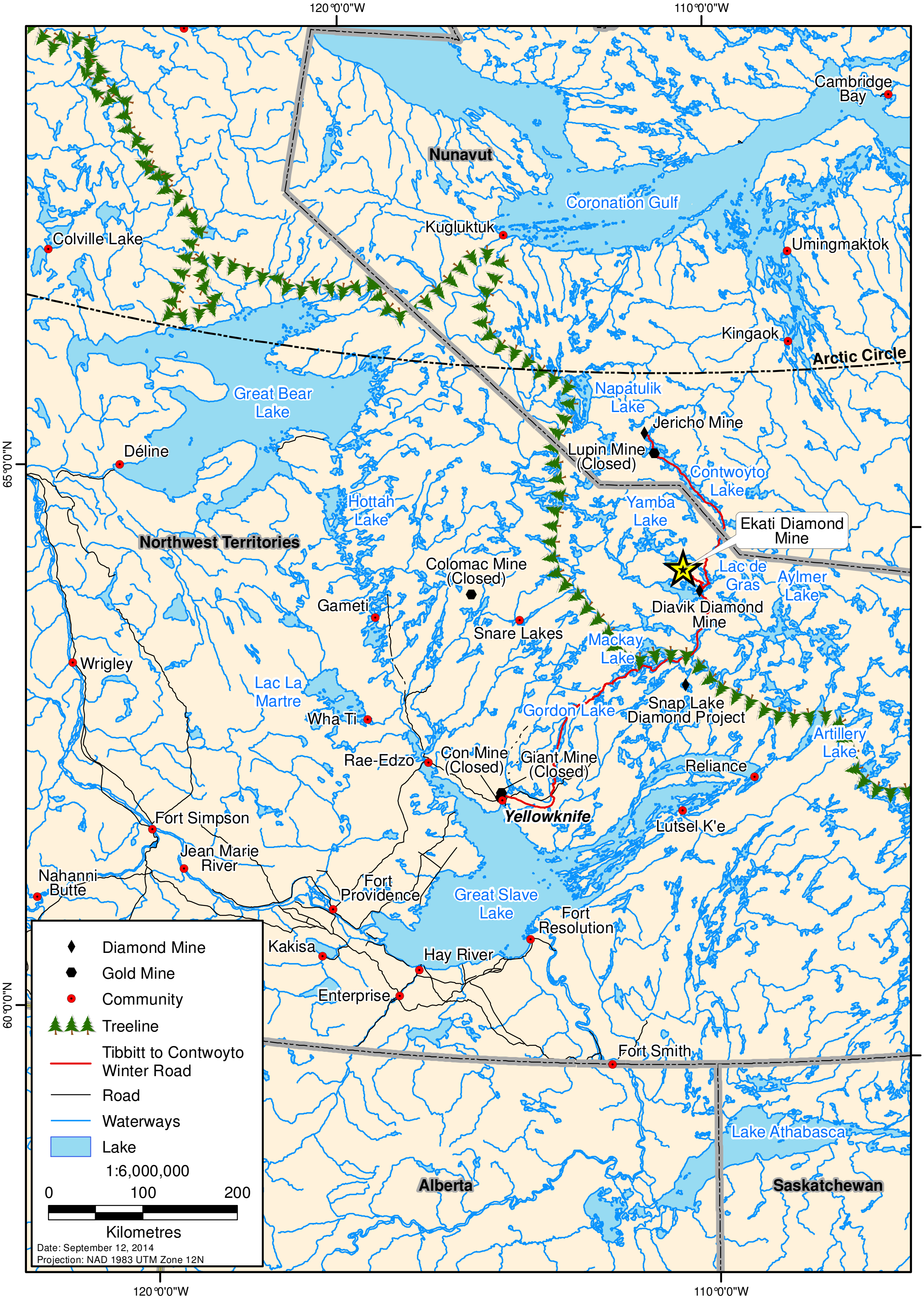
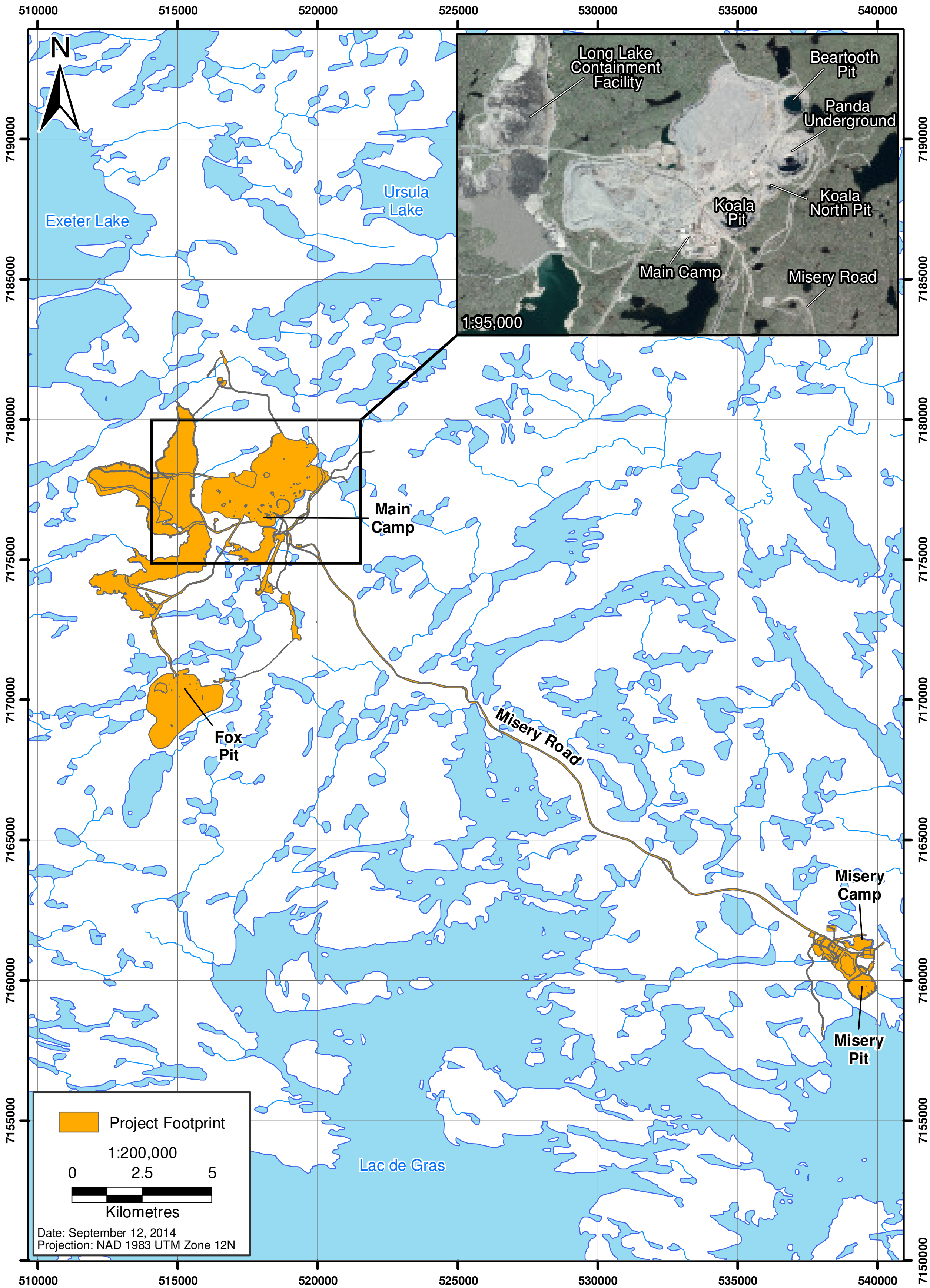


Figure 1-2
The Ekati Diamond Mine Site Map



4. *Mortality* — Traffic poses a risk of mortality for wildlife that utilizes verge habitats or try to cross the road. Collisions are also a traffic safety issue. At the Ekati Diamond Mine, wildlife have the right of way on all roads, and road closures are implemented when wildlife are in the vicinity to minimize any chance of collisions. With the exception of one wolf, no VEC wildlife have been killed due to vehicle collisions on Misery Road.
5. *Barrier* – For most non-flying terrestrial animals, roads can serve as movement barriers that alter movement patterns and can have energetic costs at local scales or make habitats inaccessible and isolate populations at larger scales. This is the least understood component of the overall effects of mine infrastructure on wildlife, and the focus of this study.

The barrier effect on wildlife results from a combination of disturbance and avoidance effects, physical obstacles, and traffic mortality that all reduce the permeability of the road. Disturbances due to traffic noise, vehicle movement, pollution, and human activity may result in wildlife avoiding the area. The road surface and embankments may impose physical barriers that animals cannot pass. Traffic mortality may further reduce the number of individuals that successfully cross the road barrier. Most infrastructure barriers do not completely block animal movements, but reduce the number of crossings quantitatively (Merriam et al. 1989).

The barrier effect is a non-linear function of traffic density, road width, roadside characteristics, the animals' behaviour and its sensitivity to disturbances. Traffic intensity and vehicle speed appear to have the strongest influence on the barrier effect of roads on those mammals that do not experience any physical barrier or repellent habitat effect in road corridors. With increasing traffic and higher vehicle speed, mortality rates usually increase until the deterrent effect of the traffic prevents more animals from getting killed. Muller and Berthoud (1994) suggested five categories of infrastructure/ traffic intensity with respect to their barrier impact on wildlife:

1. Local access and service roads with very light traffic can serve as partial filters on wildlife movements. They may have limited barrier impact on invertebrates and eventually repel small mammals from crossing the open space. Larger wildlife may use these roads as corridors, if they do not avoid habitat close to roads.
2. Minor roads with traffic below 1,000 vehicles per day may cause incidental traffic mortality and exert a stronger barrier/avoidance effect on small species, but crossing movements will still frequently occur.
3. Intermediate link roads with up to 5,000 vehicles per day may comprise a serious barrier to certain species. Traffic noise and vehicle movement are likely to have a major deterrent effect on small mammals and some larger mammals. Due to this repellence, the increase in overall barrier impact is not proportional to the increase in traffic volume.
4. Arterial roads with heavy traffic between 5,000 and 10,000 vehicles per day cause a significant barrier to many terrestrial species, but due to strong repellence by the traffic, the number of road kills may level out. Road kills and safety issues are the most important issues in this category.
5. Motorways and highways with traffic above 10,000 vehicles per day impose an impermeable barrier to almost any wildlife species, as the dense traffic repels most species approaching the road and kills those that attempt to cross.

Several roads have been constructed at the Ekati Diamond Mine, the longest of which is Misery Road, connecting Main Camp to Misery Camp approximately 26 km to the southeast. Misery Road is an all-season haul road constructed of clean granite with berms of varying heights that were constructed along the road to meet the safety standards set by the *Mines Act*. Upgrades to Misery Camp were completed in 2012 in preparation for renewed development of Misery Pit, and traffic along Misery Road is expected to increase substantially during the operation of Misery Pit while kimberlite is hauled to Main Camp for processing.

The use of remote motion-triggered cameras has a long history in wildlife research (Cutler and Swann 1999), but over the past two decades, camera traps have become more readily available and affordable. The result has been a rapid and diverse growth in their application (Rowcliffe and Carbone 2008). Increasingly, wildlife cameras are being used to monitor wildlife activity around roads and other human infrastructure (Olsson, Widén, and Larkin 2008; Braden et al. 2008; Dunne and Quinne 2009; Noel et al. 2006). Remote photography has replaced traditional methods of visual surveys, drive counts, radiotelemetry, and track counts (Silveira, Jácomo, and Diniz-Filho 2003). In contrast to the limitations of snow-track methods (Bull, Holthausen, and Bright 1992), such as those used previously at the Ekati Diamond Mine, remote photography can be used year-round. Cameras can remove observer and sample timing bias by providing data coverage 24 hours per day. Combined with 1-year battery life and memory storage for approximately 30,000 photos, data collection opportunities increase significantly over traditional techniques with minimal human involvement or invasiveness to wildlife.

Northern communities are particularly concerned about potential impacts to caribou in light of the significant population declines observed in recent decades. The WEMP includes several monitoring programs specific to the Bathurst caribou herd as it moves through the Ekati Diamond Mine and surrounding areas to measure the potential effects of the mine on caribou. The Ekati Diamond Mine is committed to the on-going evaluation of its wildlife programs to ensure those programs utilize the best information and techniques available to monitor and mitigate impacts to wildlife. Of particular interest to the Ekati Diamond Mine has been monitoring the degree to which roadways and other infrastructure may be acting as barriers to wildlife movement. Mitigation measures, such as caribou crossing ramps along Misery Road, are intended to enable wildlife to cross these linear features, minimizing habitat fragmentation. The risk of wildlife-vehicle collisions is reduced by giving wildlife the right of way, deploying signage along the road during periods of high wildlife activity, speed enforcement, and temporary road closures.

In addition to ongoing caribou monitoring activities, the Ekati Diamond Mine implemented the use of motion-triggered cameras to monitor caribou activity along Misery Road and Sable, Pigeon, and nearby Access Roads in 2011. The monitoring program also deployed some cameras near mine infrastructure, including Fox Pit, the Long Lake Containment Facility (LLCF), and the Waste Rock Storage Facility, all of which could potentially influence caribou movement. This report summarizes the results of the monitoring program from 2011-2013, and provides recommendations on how the camera monitoring program can continue to provide valuable information to monitor potential effects on wildlife movements and behaviour, which contributes to the ongoing evaluation and implementation of effective mitigation measures.

1.1 OBJECTIVES

The objectives of the 2011-2013 camera monitoring program were to:

1. determine temporal and seasonal trends in caribou abundance/encounter rates around the Ekati Diamond Mine site;
2. determine how the frequencies of behaviours exhibited by caribou groups varied near and away from the road (on-road vs. off road cameras);

3. explore spatial and temporal patterns in road crossing behaviours;
4. determine the extent that roads may deter caribou from crossing, and identify those factors that contribute to the permeability of site roads; and
5. quantify traffic levels on Misery Road as a potential deterrent to caribou movement.

2. Methods

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2.1 CAMERAS

2.1.1 Deployment

A maximum of 90 infrared motion-triggered cameras (PC800 Hyperfire Professional Semi-Covert IR; Reconyx™ LLP, Holman, WI) were deployed at 229 locations at the Ekati Diamond Mine from 2011 to 2013 (Figure 2.1-1). Cameras were retrieved and redeployed to new locations each year. For analyses, cameras were assigned to one of six geographical regions: Misery Road, Sable/Pigeon and related Access Roads, Long Lake Containment Facility (LLCF), Fox Pit, Waste Rock Storage Facility, and reference locations on the tundra (> 500 m from infrastructure). The number of cameras deployed within each region varied by year and by season (Table 2.1-1).

Table 2.1-1. Number of Cameras Deployed around the Ekati Diamond Mine by Year and Region

Year	Misery Road	Sable/Pigeon and Access Roads	LLCF	Fox Pit	Waste Rock Storage Facility	Reference sites	Total
2011	28	8	2			11	49
2012	55	21	11	1	2		90
2013	45(2)	24	7(4)	9(9)	5(5)	(20)*	90

** Numbers in brackets refer to the number of cameras relocated during the grizzly bear DNA program between June and August, 2013. Data from these cameras not incorporated into this report.*

In 2011, the majority (28 cameras) were placed along Misery Road at approximately 500 m intervals between Km 10 and Km 25 on alternating sides of the road (Figure 2.1-1; Table 2.1-1).

In 2012, the distribution of cameras along Misery Road was determined by habitat, focusing on areas where caribou activity was expected to be high. For example, primarily boulder fields are found adjacent to the road between Km 1 and Km 10, and cameras were placed approximately 500 m to 1 km apart in this section in areas where gaps in the boulder fields provided the likeliest road access. Between Km 11 and Km 25, the adjacent habitat is primarily heath tundra, and cameras were placed approximately 300 m apart to maximize opportunities to document caribou activity along the road.

In 2013, the majority of cameras were originally set up along Misery Road (45 cameras) and Sable/ Pigeon and related Access Roads (24 cameras) in patterns of deployment similar to those in 2012. However, a total of 20 cameras were redeployed from June to August, 2013 to monitor grizzly bear hair collection stations as part of a grizzly bear DNA mark-recapture study (ERM Rescan 2014a). Data from these cameras was therefore not included in the current report.

2.1.2 Set-up and Operation

The cameras record both motion-triggered photographs and timed photographs. A series of motion-triggered photos were automatically recorded whenever the camera's infrared signal-monitoring system detected movement in the camera's field of view. The triggering range is approximately 25 to 30 m depending on the size of the animal moving through the camera's field of view. Cameras were set to the highest sensitivity (i.e., lowest threshold) for motion detection and triggering. In 2011, cameras were programmed to record five images at a rate of 1/sec when triggered, with a 20-sec delay between triggers. To account for the possibility that information could be missed during an extensive trigger delay, in 2012 and 2013 cameras were programmed to record eight images at a rate of 1/s when triggered, with no delay before the next possible trigger to provide continuous behavioural data if animals remained in the field of view.

In all years, a timed photo was taken every 10 min throughout the day (144 images recorded per camera day) during the northern (April/May) and southern (September/October) migration periods. The dates and times of the digital images were recorded for each image.

Each camera was checked several times during the survey period to check battery levels, determine the available memory on the SD memory card, and ensure that the camera was still operating properly and had not been disturbed by wildlife or weather. Memory cards and batteries were exchanged when necessary to prevent data loss due to the memory cards reaching capacity or the batteries dying before the next visit.

2.1.3 Camera Effort

To account for variation in the amount of time that cameras were deployed among sites, all count data was adjusted by camera effort. Not all cameras were operational for the entire period, thus camera effort cannot be inferred based on start and stop dates alone. To account for gaps in coverage, days were removed when the cameras were not recording data due to camera malfunction, filled memory cards, and/or dead batteries. The standard unit of camera effort was one uninterrupted day during which a camera continuously recorded images without any technical problems. All data reported are scaled to one camera-day of effort; therefore, reported averages represent the number of individuals in all groups, the count of unique groups, or the subset of unique groups engaged in a particular composite behaviour during an average 24-hr period by month and region. The resulting scaled values are expressed as rates (e.g., groups per camera per day).

Photographs from all 49 cameras deployed in 2011 were available for analysis. Of the 90 cameras deployed each year in 2012 and 2013, photographic data was available from 89 and 62 cameras, respectively (Figure 2.1-1). Camera survey periods were from February 20 to November 13 in 2011, from March 23 to December 8 in 2012, and from March 28 to December 6 in 2013. As a result of few cameras deployed during winter and spring, analyses focused on the summer and fall periods. Total per-region camera effort was 20 – 120 camera-days in 2011, 1 – 240 camera-days in 2012, and 2 - 252 camera-days in 2013.

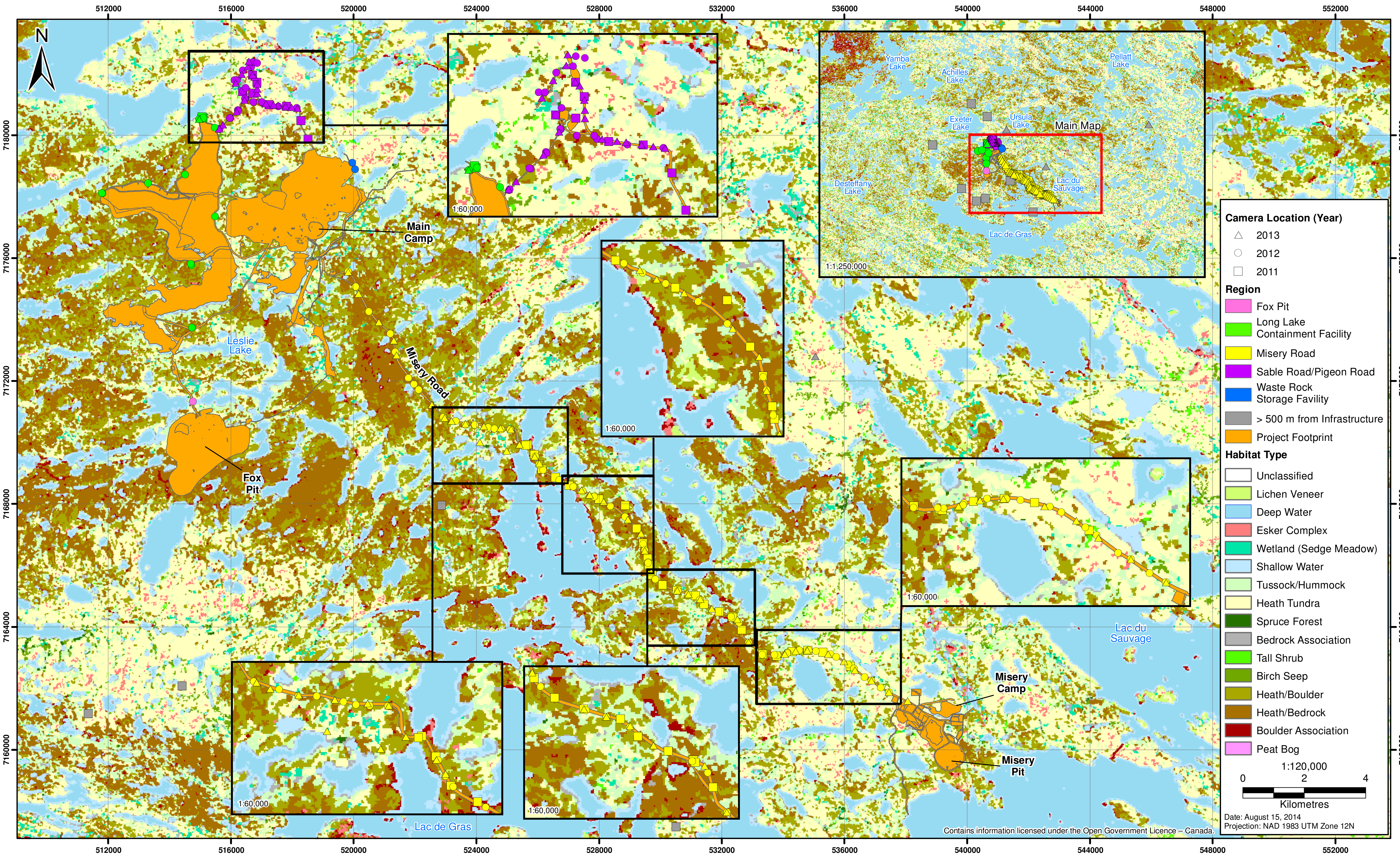
2.2 DATA COLLECTION

2.2.1 Caribou Groups, Composition, and Behaviour

Caribou may not act independently when they are part of a group (Body et al. 2014). As a result, the group was regarded as the most appropriate statistical unit for these analyses. For overall abundance by region, motion-triggered and timed photographs were pooled to increase seasonal coverage and increase the likelihood of detecting unique caribou groups that could be distinguished on the basis of group size and composition. Given that the Bathurst herd exhibits mass movement past the Ekati Diamond Mine during the northern and southern migration periods, a group was assumed to be unique when separated by a time gap of at least 30 minutes.

Variation in the effective field of view among camera locations potentially lead to some bias in the detectability of caribou in timed photos (e.g., boulder fields vs. open tundra; Plate 2.2-1), depending on the observer and time spent analysing each photo.

Figure 2.1-1
Camera Locations at the Ekati Diamond Mine, 2011 - 2013



Three caribou individuals (unknown age/sex) engaged in unknown behaviours (September 3, 2011)

A caribou (unknown age/sex) crossing the road (September 10, 2011)

Plate 2.2-1. Example of cameras at Misery Road with a large (left) vs. limited views of tundra (right).

Given the limitations to quantifying animal behaviour from timed photographs, behavioural analyses were restricted to motion-triggered photos (and those timed photos that were within the same field of view as the motion-triggered photos) to remove any potential bias in caribou detections. In addition, the cameras' limited field of view likely meant that portions of some groups were never photographed. Thus, remote camera monitoring yields conservative estimates of group size.

For each identified group, all visible caribou in each photograph was counted. Group size was defined by the maximum number of individuals observed in a series of photographs. When possible, individuals were classified by age (adult or juvenile) and sex (male, female, unknown). The dominant behaviour of each caribou group was determined (Table 2.2-1; Plate 2.2-2). Categorizing road usage and road avoidance was prioritized. Additionally, each individual that was exhibiting alert behaviour was noted (e.g., body oriented towards a potential stressor, ears erect and pointed in a particular direction in timed photos, or remaining motionless in an alarm posture throughout several consecutive motion-triggered photos). Potential stressors, such as vehicles traveling along the road, were also recorded whenever evident in the photos. As a conservative estimate of behaviour frequency, calm behaviours had the lowest priority in terms of scoring the dominant group behaviour.

Table 2.2-1. Caribou Coding Information Used for 2011-2013 Camera Data

Caribou Behavioural Codes	Description
CC	Crossed road walking
D	Deflected or deterred from path of motion
CW	Walked on or along road
ROR	Crossed road running
IC	Investigated camera
WR	Walking near road
S	Stop and stand
FR	Foraging near road
RER	Bedded near road
U	Unknown

(continued)

Table 2.2-1. Caribou Coding Information Used for 2011-2013 Camera Data (completed)

Alert Behaviour	Description
Y	Saw evidence of startle or stress (tail flick, head went up, quick run or change of direction)
N	No stress response obvious
U	Difficult to tell with visibility
Vehicle Present	**Description**
Y	Seen in frame, or seconds before or after
N	Absence of detection of vehicle (not the same as absence, as some frames did not allow you to see much of the road/traffic)

Note:
The Codes FR, RER, and WR are also used for data entry at "off-road" sites > 50 metres from roads. For these sites, these terms simply mean foraging, bedded, or walking. In analyses, these are identified separately by segregating between on-road and off-road cameras.

Crossing/crossed road
(Misery Road camera # 23, September 7, 2011)

Investigating camera while light vehicle passes by
(Misery Road camera #5, October 26, 2011)

Running on or across road
(Sable Road camera # 52; August 17, 2012)

Foraging near road
(Sable Road camera # 53; August 17, 2013)

Plate 2.2-2. Examples of behaviours: crossing, investigating, running, and foraging.

To illustrate the scoring protocol, groups containing at least some individuals that crossed a road were always scored as crossing/crossed the road (CC), unless any animal was deflected or deterred from crossing the road, in which case the group's predominant behaviour was scored as CC and deflected or deterred (D) (see Table 2.2-1). When these two activities (CC and/or D) were not assigned to a group, running (ROR) and/or walling (CW) along or on the road were the next behavioural categories to be considered. Only when none of the aforementioned behaviours were assigned to a group were other behaviour categories considered, in the following order of decreasing priority: IC, WR, S, FR, and RER (Table 2.2-1). Given that a group's composite behaviour was unknown (U) for many groups and small counts were recorded for the other behaviour categories, all group level behavioural events where at least one individual encountered a road were summed as 'road events' (e.g., 'road events' = CC + CW + ROR). 'Road events' include only those activities that involve direct interaction of caribou with a road.

2.2.2 Road Features

In order to assess which habitat features present on the landscape might attract or deter caribou (i.e. during foraging events), or facilitate movement across the Ekati Diamond Mine study area, each camera was assign to an individual habitat classification based on the dominant habitat type within 50 metres of the camera according to pre-existing habitat mapping. Structural features of Misery Road were measured because certain roadway features may potentially inhibit the ability of caribou and other wildlife to disperse across roadways (Wolfe et al. 2000; Bissonette and Cramer 2008). These features include differences in elevation between the road surface and the surrounding tundra, or between the adjacent berm and the toe (located at the beginning of the road's shoulder), presence/absence of berms within 50 metres of the camera, and presence of caribou ramps (man-made ramps with gradual incline that were created to facilitate caribou crossings at road, in areas where historical information from Community Members and presence of caribou tracks and trails suggest high use by caribou during annual migrations). These road features were quantified at all camera positions along Misery Road using a three-dimensional CAD survey data file produced by DDEC in 2013. However, the road height and berm presence data were not applicable to cameras positioned along Misery Road in 2011 or 2012 because the CAD survey was specific to Misery Road improvements in 2013.

At each 2013 camera position along Misery Road, road height (distance in metres from the tundra to the height of the road, including the berm) was estimated for each side of the road by subtracting the elevation at toe from either the elevation near the centre line of the road or berm elevation, whichever was greater. Caribou deflection events at the road were expected to be proportional to maximum road heights relative to both sides of the road. Though the road height adjacent to a wildlife camera may differ from the road height where caribou were located in an image, road heights at the camera location provide a reasonable approximation of berm characteristics that could influence caribou road crossing behaviour.

2.2.3 Vehicular Traffic Volume

Traffic volume at the Ekati Diamond Mine could potentially affect caribou presence and behaviour. In 2012 and 2013, a camera was installed at Km 1 on Misery Road (close to Main Camp) for the purpose of counting passing vehicles. This camera was programmed to record one photo per motion trigger.

Traffic was categorized into light vehicles (e.g., pickup trucks), medium vehicles (e.g., buses for transporting mine staff and water trucks), and heavy vehicles (e.g., Haulmax off-highway dump trucks for transporting mined rock from Misery Pit to the processing facility at the Main Camp). The total per-day count of passing vehicles also included those in unknown weight classes (e.g., headlights at night, partially photographed vehicles, and dust clouds). For each class, traffic volume was quantified as the per-day count of vehicles traveling in either direction along the road. Thus, the traffic data reported here are numbers of round trip excursions along Misery Road (or half the number of one-way trips).

Due to technical problems with the dedicated traffic camera in 2013 there were many gaps in the traffic data. These gaps were filled to some extent by data from other cameras along Misery road that were triggered by passing vehicles. There was no dedicated traffic camera in 2011 as measuring traffic volume was not an objective that year. Traffic volume along Misery Road in 2011 was estimated by averaging daily vehicle counts among all road-side cameras that were triggered by passing vehicles traveling in either direction along the road.

2.3 STATISTICAL ANALYSES

Camera data were used to examine spatial variation, seasonal trends, and year-to-year variation in caribou presence, group composition, and behaviour. Categorical comparisons were made among six geographical areas: Fox Pit; Long Lake Containment Facility (LLCF); Misery Road; Sable, Pigeon, and Related Access Roads; Waste Rock Storage Facility; and a reference category representing all camera locations at least 500 m from mine infrastructure. Additional categorical comparisons were made between ‘on-road’ cameras (< 50 m from a road) and ‘off-road’ cameras (> 50 m from a road; Figure 2.3-1).

2.3.1 Categorical Approach to Testing Broad Patterns of Spatiotemporal Variation

Statistical tests were conducted in R, version 2.14.0 (R Core Development Team 2011). The R function ‘glmer’ was used to construct generalized linear mixed models to examine the dependence of behavioural counts (adjusted by camera effort) on two main (fixed) factors: region and month. The class of generalized linear models is an extension of traditional linear models that allows the average of a population to depend on a linear predictor through a nonlinear link function, and allows the response probability distribution to be any member of an exponential family of distributions (Neter and Wasserman 1974). These models included sampling month as a random effect and incorporated a log link function.

The response variable was set to follow a Poisson distribution, which is appropriate for count and rate data (Whitlock and Schluter 2009), making the models a type of linear Mixed Model Poisson regression. Significance of the fixed factors was tested using Wald’s type 2 test. Linear Mixed Model Poisson regression with a log link function was used to model group encounter rate adjusted by camera effort (response variable) as a function of location (explanatory variable). The model included an offset term to adjust for season.

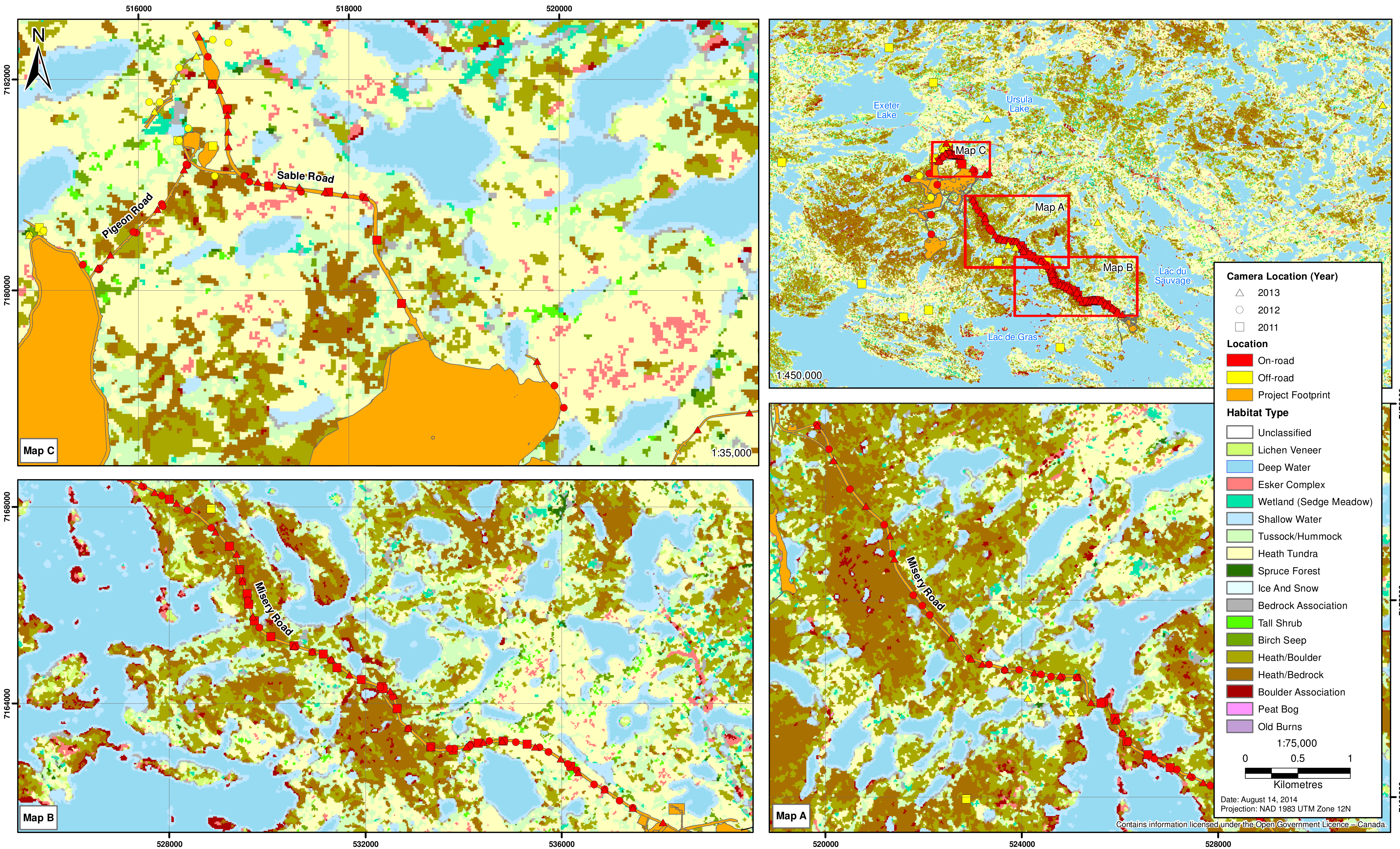
2.3.2 Approaches Used for Finer-scale Data Visualization

Pooling observations by region and year/month provides enough group observations for statistical comparison but potentially misses finer-scale spatial and temporal variation in the data. Accordingly, spatial and temporal variation (including year-to-year, month, and day-to-day variation) in the presence and activity patterns of caribou groups was assessed qualitatively in three ways.

The first approach emphasized spatial variation in caribou encounter rates to identify hot spots around the mine site where group encounter rates or total caribou numbers are consistently high. Hot spots were assessed by plotting camera positions on a map of the study area.

The second approach explored fine-scale spatial variation in behaviour patterns across the Ekati Diamond Mine across years. The per-camera total count for each behaviour was plotted as an open red circle, the diameter of which was proportional to the total yearly count of behaviours conducted by groups captured in motion-triggered photographs.

Figure 2.3-1
On-road and Off-road Cameras at the Ekati Diamond Mine, 2011 - 2013



The third approach overlooked some spatial information to examine fine-scale temporal variation (i.e., day-to-day fluctuations) in total counts of caribou groups, and all individuals summed across groups (all counts adjusted by camera effort) in the ‘on-road’ subregions.

2.3.3 Effect of Road Structure on Caribou Propensity for Road Crossing

In order to test the static effects of road features on caribou group crossing behaviour, the effort adjusted camera data to a standard linear, mixed-effects model using the R-function (*lmer* from the R package *lme4*) was performed to examine the presence (i.e., statistical significance) of a correlation between the number of groups, number of individuals, and frequency of caribou road crossing events (while walking and running) at on-road camera sites between 2011 and 2013. Off-road cameras were excluded from the models containing berm.presence and/or max.road.height. All models included year as a random effect. All other variables were modelled as fixed effects (e.g., berm.presence (factor), max.road.height (continuous variable), dom.habitat (factor), and on.off.road (factor). For the habitat analysis, there were three cameras for which the dominant habitat type was unclassified (due to gaps in the habitat classification mapping). These cameras were excluded from the habitat analysis. The encounter rates of the following behaviours at on-road camera sites were too infrequent to allow for statistical analysis: alert and running.

The expected outcomes for this test, under the hypothesis that steep terrain consisting of boulder and rubble fields acts as a barrier to caribou dispersal and migration, were (1) a negative correlation between maximum ‘at camera’ road height along Misery Road and rate of caribou road-crossing events and (2) a positive correlation between maximum ‘at camera’ road height rate of caribou deflections by the road.

2.3.4 Traffic rate and Road Events Analysis

Finally, a dynamic analysis of the potential effects of Misery Road traffic patterns on caribou presence and behaviour along the road was performed using a Linear Mixed Model Poisson regression approach that was very similar to that used above for the categorical model framework. Here, the generalized linear mixed models examined the dependence of total camera effort adjusted counts of groups along the side of Misery Road, or of normalized abundance or behavioural counts, on the two main factors (treated as fixed): daily traffic volume of a given vehicle class (a continuous rather than categorical variable) and month (treated again as a categorical factor).

3. Results

3. Results

3.1 CARIBOU POPULATION ANALYSIS

The caribou population analysis summarized and compared trends in caribou distribution by region, month, and year. The statistical analyses dealt with caribou groups as single units in months when caribou numbers were sufficiently large to enable statistical comparisons. Caribou were assigned to the same group if they occurred in the same photograph or series of photographs. These analyses focused on the number of groups moving through particular locations at particular times (e.g., during migration). It was important to analyse data using group as the sample unit (rather than individuals) because caribou do not move independently when part of a group. Group data were adjusted for camera effort and separated by period and location to examine encounter rates (i.e., groups per day).

3.1.1 Encounter Rates among Years

Across all years, a total of 587 caribou groups and 2,379 individual caribou were observed in motion triggered photos over 22,096 camera-days (Table 3.1-1; Figure 3.1-1 and Figure 3.1-2). Adjusting for camera effort per year resulted in a significant difference in both the number of caribou groups ($X^2 = 15.36$, df = 2, $P < 0.01$) and the number of caribou individuals observed per year ($X^2 = 390.6$, df = 2, $P < 0.01$). The lowest average number of caribou groups per camera-day was in 2013 (0.021) compared to 0.031 in 2011 and 0.030 in 2012. The average number of individuals observed per camera-day was highest in 2012 (0.163) compared to 2011 (0.075) and 2013 (0.072). This suggests annual variation in the size and number of caribou groups with the Ekati Diamond Mine study area consistent with longer term datasets (e.g., annual WEMP reports).

Table 3.1-1. Average Encounter Rates (Groups and Individuals per Camera-day), Reported by Year, 2011 to 2013

Year	Total Number of Groups Observed*	Total Number of Individuals Observed†	Total Camera-Days of Effort	Average Number of Groups/Camera/Day	Average Number of Individuals/Camera/Day
2011	137	336	4495	0.031	0.075
2012	256	1389	8542	0.030	0.163
2013	194	654	9059	0.021	0.072

**Yearly total counts of caribou groups deviate from expectations under hypothesis of no year-to-year variation in abundance.*
†Yearly counts of the total number of individuals deviate from expectations under hypothesis of no year-to-year variation.

3.1.2 Encounter Rates among Regions

Across all years, average caribou encounter rates were highly variable by month and by region. Daily caribou group encounter rates (Table 3.1-2) and total individuals in all groups (Table 3.1-3) are presented only for those months that were most intensively studied across all three years (July through October). Generally, encounter rates of caribou groups and individuals were highest in August, followed by October (Table 3.1-2 and Table 3.1-3).

The number of caribou groups recorded around the Ekati Diamond Mine varied significantly by region (Table 3.1-4). Similarly, there was a significant difference between the number of caribou individuals observed by region and by month (Table 3.1-4). Across all three years and after adjusted by camera effort, counts of caribou groups (Figure 3.1-1) and counts of caribou individuals (Figure 3.1-2) were consistently lowest at Misery Road, and highest in the northern areas (i.e., Sable, Pigeon, and Access Roads, and Waste Rock Storage Facility).

Table 3.1-2. Average Encounter Rates (Groups Counts per Camera-day), Reported by Region, July to October of 2011-2013

	2011				2012				2013			
Region	**Jul**	**Aug**	**Sep**	**Oct**	**Jul**	**Aug**	**Sep**	**Oct**	**Jul**	**Aug**	**Sep**	**Oct**
Fox Pit	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.00 (0.00)	n/a	n/a	n/a	n/a
LLCF	0.00 (0.00)	1.78 (1.64)	1.00 (0.00)	0.00 (0.00)	n/a	n/a	0.00 (0.00)	0.00 (0.00)	1.33 (0.58)	2.50 (2.12)	0.00 (0.00)	0.00 (0.00)
Waste Rock Storage Facility	n/a	n/a	n/a	n/a	0.00 (0.00)	1.62 (0.77)	0.00 (0.00)	3.00 (1.41)	n/a	n/a	n/a	n/a
Misery Road	0.00 (0.00)	1.00 (0.00)	1.36 (0.68)	0.00 (0.00)	1.00 (0.00)	1.17 (0.58)	1.00 (0.00)	1.00 (0.00)	1.20 (0.56)	1.08 (0.28)	0.00 (0.00)	1.00 (0.00)
Sable, Pigeon, and Access Roads	1.00 (0.00)	1.49 (0.74)	0.00 (0.00)	1.00 (0.00)	0.00 (0.00)	2.98 (4.01)	0.00 (0.00)	2.00 (1.51)	1.23 (0.43)	1.93 (1.16)	1.00 (0.00)	0.00 (0.00)
Reference Sites	1.00 (0.00)	1.87 (1.41)	1.00 (0.00)	0.00 (0.00)	n/a	n/a	n/a	n/a	n/a	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Note: Values are average reflect groups per day and values in brackets reflect standard deviation of the average.
n/a indicates that data is unavailable.

Table 3.1-3. Average Encounter Rates (Total Counts of Individuals in All Groups per Camera-day), Reported by Region and Month, July to October of 2011-2013

	2011				2012				2013			
Region	**Jul**	**Aug**	**Sep**	**Oct**	**Jul**	**Aug**	**Sep**	**Oct**	**Jul**	**Aug**	**Sep**	**Oct**
Fox Pit	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.00 (0.00)	n/a	n/a	n/a	n/a
LLCF	0.00 (0.00)	3.56 (3.68)	1.00 (0.00)	0.00 (0.00)	n/a	n/a	0.00 (0.00)	0.00 (0.00)	3.33 (4.04)	4.00 (4.24)	0.00 (0.00)	0.00 (0.00)
Waste Rock Storage Facility	n/a	n/a	n/a	n/a	0.00 (0.00)	2.31 (1.18)	0.00 (0.00)	378.50 (299.11)	n/a	n/a	n/a	n/a
Misery Road	0.00 (0.00)	1.00 (0.00)	3.25 (4.73)	0.00 (0.00)	1.00 (0.00)	1.50 (1.17)	1.00 (0.00)	1.00 (0.00)	1.27 (0.59)	1.15 (0.38)	0.00 (0.00)	1.00 (0.00)
Sable, Pigeon, and Access Roads	1.00 (0.00)	4.23 (3.30)	3.00 (2.00)	0.00 (0.00)	0.00 (0.00)	5.41 (8.58)	0.00 (0.00)	19.88 (34.14)	1.81 (1.76)	9.23 (15.40)	6.00 (1.41)	0.00 (0.00)
Reference Sites	1.00 (0.00)	2.90 (2.77)	2.83 (1.17)	0.00 (0.00)	n/a	n/a	n/a	n/a	n/a	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Note: Values are average reflect groups per day and values in brackets reflect standard deviation of the average.
n/a indicates that data is unavailable.

Table 3.1-4. Linear Mixed-effects Poisson Regression to Test Whether Caribou Abundance Varied by Region

Dependent Abundance Variable	LMM Statistic for Effect of Region	LMM Statistic for Effect of Month
Number of Caribou Groups Observed	*X^2 = 354.8, df = 5, P < 0.01	*X^2 = 352.6, df = 10, P < 0.01
Number of Individuals across Groups	*X^2 = 6130.7, df = 4, P < 0.01	*X^2 = 2007.8, df = 6, P < 0.01

** Indicates a statistically significant result.*

Figure 3.1-1
Number of Caribou Groups at the Ekati Diamond Mine, 2011 - 2013, Adjusted by Camera Effort

ERM

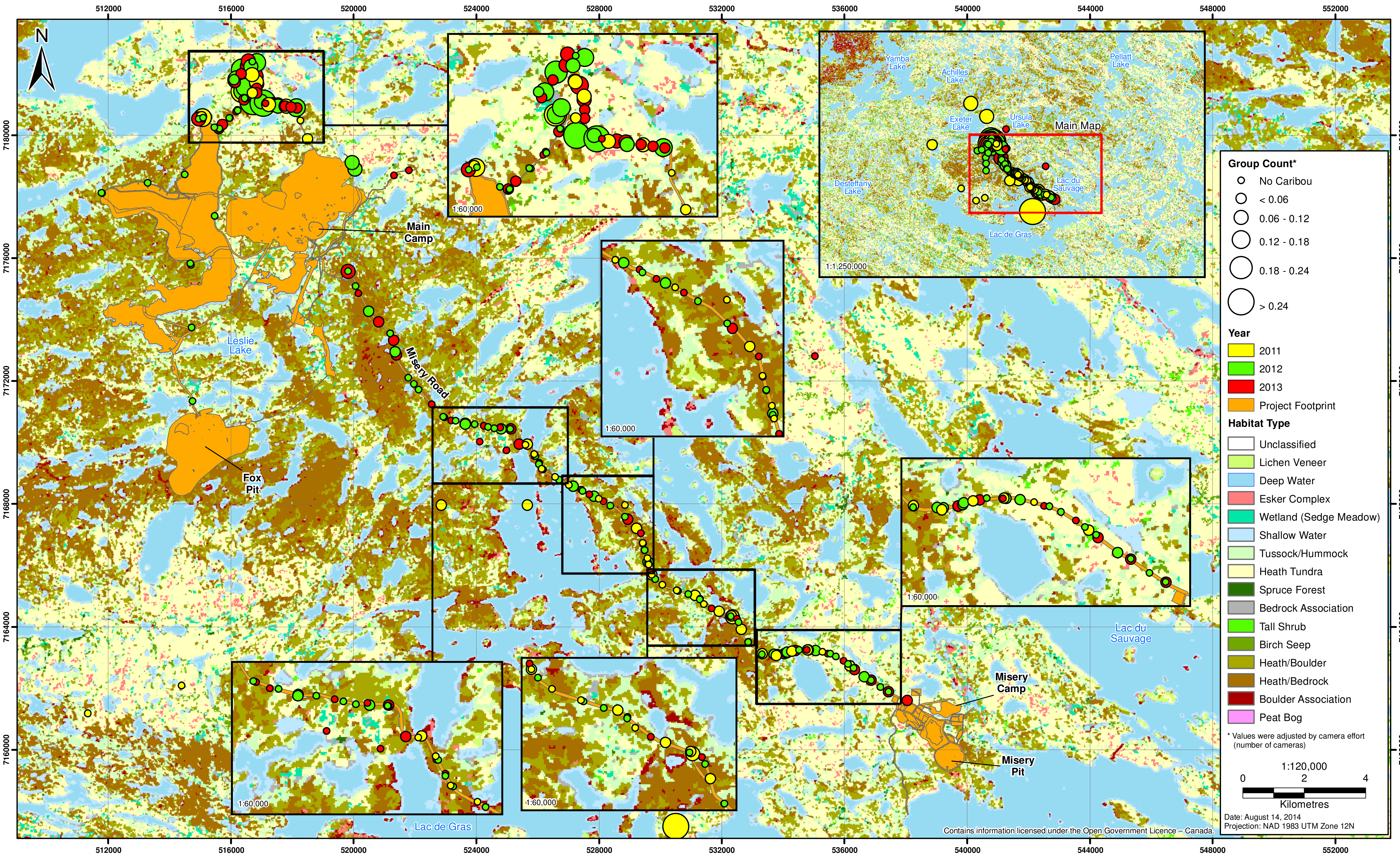
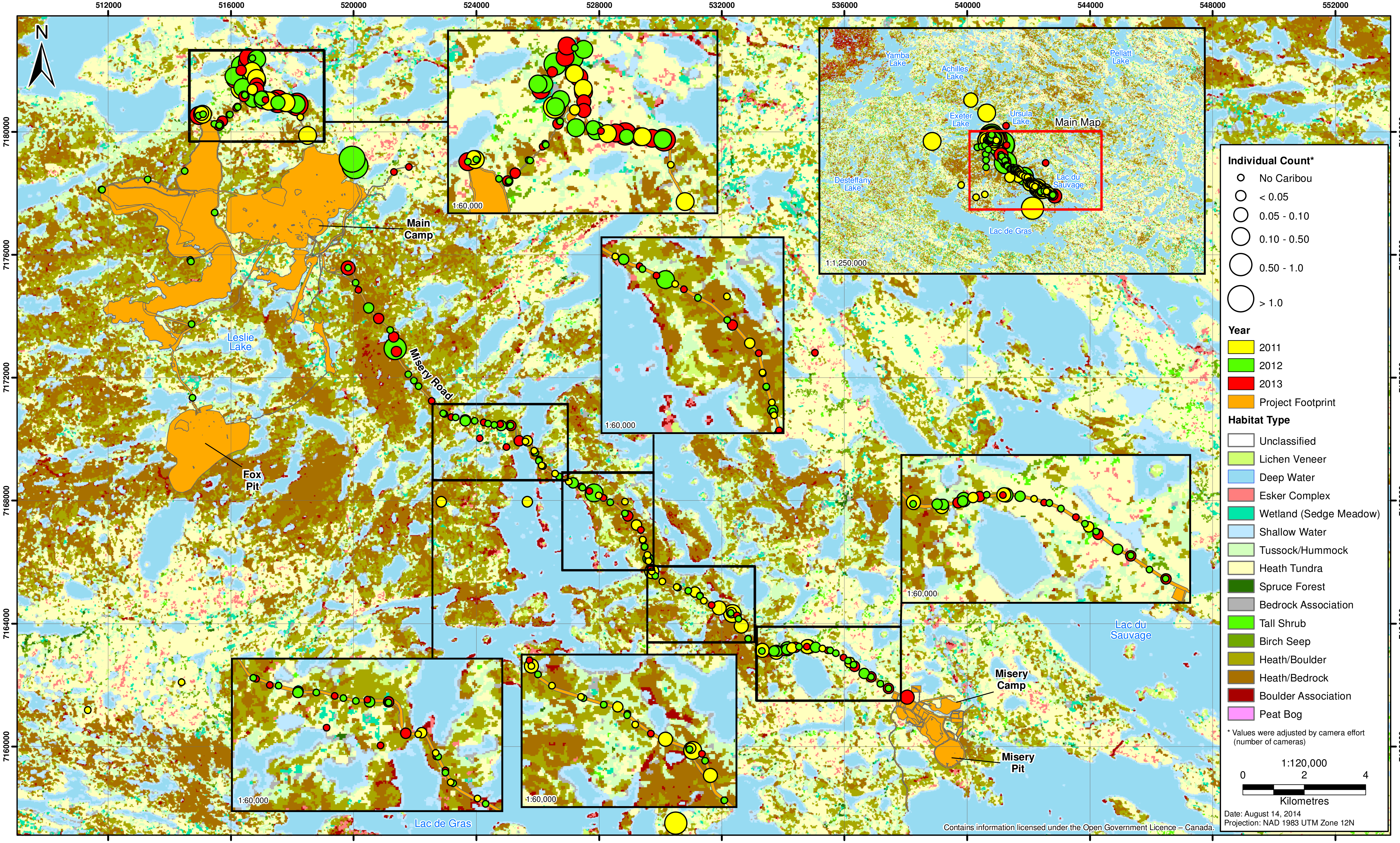


Figure 3.1-2

Number of Caribou Individuals per Group at the Ekati Diamond Mine, 2011 - 2013, Adjusted by Camera Effort



3.2 CARIBOU BEHAVIOURAL ANALYSES

3.2.1 Caribou Behaviour at Roads

Across all years, the dominant behaviours from 587 groups and 2,379 individual caribou were recorded during 331 days of camera effort (Table 3.2-1). Because the objective was to compare behaviours when caribou were actually observed, camera effort in this case only included those days when caribou were photographed (i.e., zeroes were omitted). The number of caribou groups recorded were higher at on-road cameras (66% of groups) than off-road cameras (44% of groups), although there were 2.4 times the number of camera days when caribou were photographed at on-road cameras relative to off-road locations. After adjusting for camera effort, there were approximately the same numbers of caribou groups at on-road cameras relative to off-road cameras.

Table 3.2-1. Summary of the Total Number of Caribou Groups Recorded by On-road and Off-road Monitoring Cameras, 2011, 2012, and 2013

Region	Number of Camera-days	Total Number of Groups Observed	Total Number of Individuals Observed	Number of Groups per Camera-day
On-road (< 50 m from road)	234	385	1929	1.65
Off-road (> 50 m from road)	97	202	450	2.08

The behaviours of caribou groups were summarized as the total number of caribou engaged in particular behaviours at on-road and off-road monitoring cameras, after being adjusted for camera effort (Table 3.2-2). The most common behaviours at the group level were foraging (1.02 groups per camera day), walking (1.48 groups per camera day), and grouped calm behaviours (1.16 groups per camera day; Table 3.2-2). When sample size was sufficient, the rates of all group level behaviours were statistically compared at on-road and off-road monitoring cameras. The models account for month and year.

Results indicated statistical evidence for an effect of on-road and off-road locations on the frequencies of six behaviours at the group level; investigating camera, walking, standing, foraging, bedded, and calm behaviours (Table 3.2-3). Examination of the data on a finer scale also indicated that calm behaviour, bedded, foraging, investigating camera, standing, and walking were observed more frequently at off-road cameras (Figure 3.2-1). Running was rare across all years and regions, and no spatial or temporal patterns were evident (Figure 3.2-1). Caribou deflections at on-road camera sites and alert behaviour (Plate 3.2-1) were relatively rare, occurring in less than 1% and 13% of caribou group observations, respectively.

3.2.2 Road Features and Caribou Crossings at Misery Road

Caribou abundance (number of groups and number of individuals) was first assessed in relation to the dominant habitat type surrounding each camera for on-road and off-road cameras at the Ekati Diamond Mine. When all caribou data was pooled (2011-2013), results suggested a significant effect of habitat on caribou abundance (Table 3.2-4). Caribou groups were more often associated with Boulder Associations, Esker Complexes, and Wetland (sedge meadow) habitats, and less often with Bedrock Associations, Heath Bedrock, Lichen Veneer, and Tall Shrubs, although the cameras were not evenly distributed among habitat types (Table 3.2-5).

Table 3.2-2. Summary of the Effort Adjusted Average Number of Caribou Groups Observed Engaging in Various Behaviours, Recorded by On-road and Off-road Monitoring Cameras, 2011 to 2013

Region	Bedded	Crossed Road Running	Crossed Road Walking	Deflected	Foraging	Investigated Camera	Running	Standing	Walking	Stressed Behaviour	Calm Behaviour
On-Road	0.00 (0.07)	0.05 (0.24)	0.64 (0.87)	0.01 (0.09)	0.26 (0.51)	0.05 (0.24)	0.00 (0.00)	0.02 (0.13)	0.58 (1.07)	0.06 (0.27)	0.32 (0.55)
Off-Road	0.02 (0.20)	0.03 (0.17)	0.20 (0.57)	0.00 (0.00)	0.76 (1.31)	0.06 (0.24)	0.02 (0.14)	0.07 (0.26)	0.91 (2.22)	0.51 (0.22)	0.85 (1.34)

Notes:
'Unknown' behaviours are not included. Numbers in brackets reflect Standard Error.
Stressed behaviours include the following grouped behaviours (alert, deflected, and all types of running, i.e., running and crossed road running).
Calm behaviours include the following grouped behaviours (bedded, foraging, and investigated camera).
On-road cameras were deployed within 50 m of an active road. Off-road cameras were deployed more than 50 m from the nearest road.
**Indicates a statistically significant result.*

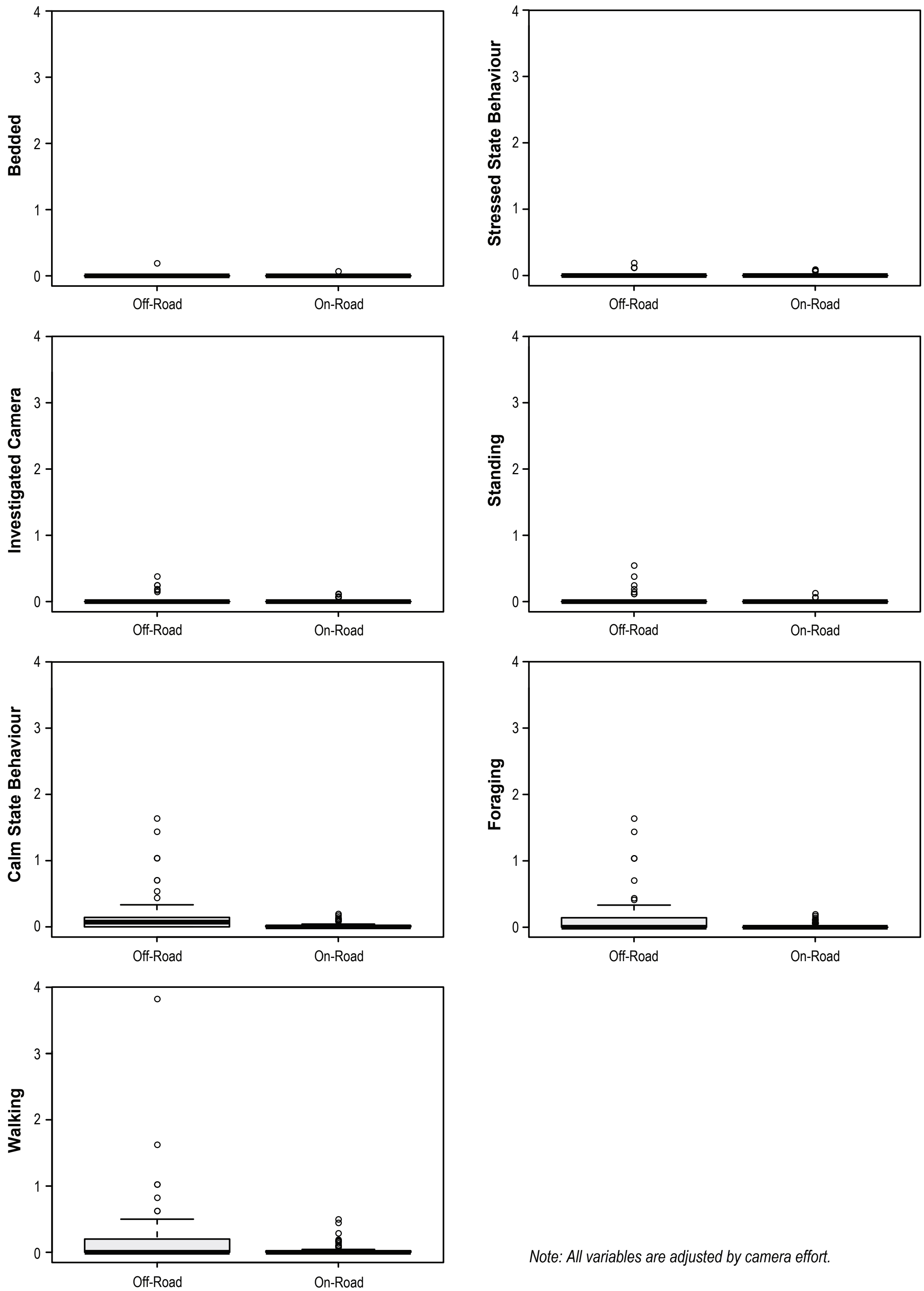
Table 3.2-3. Linear Mixed-effects Poisson Regression to Test Whether Caribou Behaviours Vary between On-road and Off-road Sites

Dependent Behaviour Variable	LMM Statistic for Effect of Proximity to a Road (on-Road† vs. off-Road‡)
Crossed Road Walking	$X^2 = 3.20$, df = 1, P = 0.07
Crossed Road Running	$X^2 = 2.69$, df = 1, P = 0.10
Deflected by Road	$X^2 < 0.001$, df = 1, P = 0.99
Alertness	$X^2 < 0.001$, df = 1, P = 0.99
Investigated Camera	*$X^2 = 12.45$, df = 1, P < 0.01
Running	$X^2 < 0.001$, df = 1, P = 0.99
Walking	*$X^2 = 247.20$, df = 1, P < 0.01
Standing	*$X^2 = 20.91$, df = 1, P < 0.01
Foraging	*$X^2 = 167.90$, df = 1, P < 0.01
Bedded	*$X^2 = 6.00$, df = 1, P = 0.01
Grouped Stressed Behaviours	*$X^2 = 6.61$, df = 1, P = 0.01
Grouped Calm Behaviours	*$X^2 = 187.60$, df = 1, P < 0.01

Notes:
X^2 = chi squared statistic
On-road cameras were deployed within 50 m of an active road. Off-road cameras were deployed more than 50 m from the nearest road.
** Indicates a statistically significant result.*

Figure 3.2-1

Caribou Group Behaviours at On-road and Off-road Cameras at the Ekati Diamond Mine, 2011 to 2013



Note: All variables are adjusted by camera effort.

Plate 3.2-1. Example in the Sable/Pigeon and Access Road Region of a caribou approaching Sable Road and then deflecting. Note the alert behaviour as the animal turns to run with its tail up (August 7, 2012).

Table 3.2-4. Results of Linear Mixed-effects Models Testing the Road Features and Month on Daily Counts of Caribou Groups and Individuals along Misery Road, 2011, 2012, and 2013

Dependent Abundance Variable	LMM Statistic for Effect of Habitat	LMM Statistic for Effect of Region
Total Daily Count of Caribou Groups along Misery Road	*X^2 = 20.10, df = 10, P = 0.03	*X^2 = 68.94, df = 5, P < 0.01
Total Daily Count of All Individuals along Misery Road	*X^2 = 401.74, df = 5, P < 0.01	*X^2 = 401.74, df = 5, P < 0.01

* *Indicates a statistically significant result.*

To examine the effect of road characteristics on caribou crossing events, a subset of the data was analysed from on-road cameras placed along Misery Road in 2011-2013. Misery Road is the longest and most heavily used road at the Ekati Diamond Mine, and provides an index of how roads may affect caribou at the Ekati Diamond Mine. The presence of caribou ramps was associated with a significant increase in the frequency of walking (X^2 = 1.98, df = 9, P < 0.01) or running (X^2 = 12.56, df = 9, P < 0.01) across Misery Road. There was no effect of the presence of caribou ramps on caribou deflection behaviour at Misery Road (X^2 = 0.16, df = 1, P = 0.69).

Table 3.2-5. Habitat Classification among On-road and Off-road Cameras along Misery Road, 2011 to 2013

Habitat Classification	Number of Cameras	
	On-road	Off-road
Heath Tundra	57	16
Heath/Boulder	40	2
Heath/Bedrock	29	5
Tussock/Hummock	27	5
Wetland (Sedge Meadow)	2	3
Esker Complex	4	0
Bedrock Association	2	0
Boulder Association	1	1
Spruce Forest	0	2
Lichen Veneer	1	0
Tall Shrub	1	0
Unclassified	0	3

Where data was available, maximum road height and the presence/absence of berms along Misery Road following 2013 road improvements were examined with respect to their potential effects on caribou crossing events. Results of the standard linear mixed-effects models indicated that there was a significant effect of the presence of berms on the frequency of caribou road crossing events while running, but not while walking (Table 3.2-6). Caribou were more likely to run across the road at areas where berms were not present. There was no significant effect of maximum road height on road crossing behaviour. Other individual behaviours indicative of stress (e.g., deflection, alertness, and running) were too rare for models to be fit to the data. When pooled together, potential stressed state behaviours were significantly correlated with berm presence (Table 3.2-6), such that berms tended to be associated with an increase in the rate of stressed state behaviours (or corresponding decrease in calm state behaviours).

Table 3.2-6. Results of Linear Mixed-Effects Models Testing the Effects of Maximum Road Height and Berm Presence/Absence Road Features on Caribou Behaviour along Misery Road

Dependent Behaviour Variable	LMM Statistic for Effect for Maximum Road Height	LMM Statistic for Berm Presence/Absence	LMM Statistic for Caribou Ramp Presence/Absence
Crossed Road Walking	X^2 = 0.34, df = 1, P = 0.56	X^2 = 0.11, df = 1, P = 0.75	*X^2 = 7.99, df = 1, P = 0.01
Crossed Road Running	X^2 = 1.03, df = 1, P = 0.31	*X^2 = 8.15, df = 1, P < 0.01	X^2 = 2.83, df = 1, P = 0.09
Deflected by Road	Insufficient data	Insufficient data	Insufficient data
Alert	Insufficient data	Insufficient data	Insufficient data
Investigated Camera	X^2 = 0.07, df = 1, P = 0.79	X^2 = 3.10, df = 1, P = 0.08	X^2 = 1.15, df = 1, P = 0.28
Running	Insufficient data	Insufficient data	Insufficient data
Walking	X^2 = 3.08, df = 1, P = 0.08	X^2 = 0.36, df = 1, P = 0.55	X^2= 0.01, df = 1, P = 0.92
Standing	Insufficient data	Insufficient data	Insufficient data
Foraging	X^2 = 2.82, df = 1, P = 0.09	X^2 = 3.16, df = 1, P = 0.08	X^2 = 0.91, df = 1, P = 0.34
Bedded	Insufficient data	Insufficient data	Insufficient data
Pooled Stressed Behaviours	X^2 = 1.03, df = 1, P = 0.31	*X^2 = 8.15, df = 1, P < 0.01	X^2 = 2.83, df = 1, P = 0.09
Pooled Calm Behaviours	X^2 = 1.90, df = 1, P = 0.17	*X^2 = 5.16, df = 1, P = 0.02	X^2 = 1.66, df = 1, P = 0.19

** Indicates a statistically significant result.*

3.3 TRAFFIC VOLUME

Among the three vehicle classes, heavy vehicles are of particular interest for monitoring effects on caribou because the pushback of Misery Pit (begun in 2011) has led to an increase in haul truck traffic on Misery Road. A dedicated traffic camera was deployed at Km 1 to quantify the daily and annual fluctuations in heavy vehicle traffic as well as the traffic volume of other vehicle classes using Misery Road (light and medium vehicles). All types of traffic were lowest in 2011, and increased in 2012 and 2013 (Figure 3.3-1 and Figure 3.3-2). Heavy vehicles accounted for the greatest increase in traffic in 2012 - 2013 (Figure 3.3-2).

A significant feature in the traffic volume data is the daily traffic fluctuations that could influence caribou movements. Dynamic responses of caribou to traffic along Misery Road were tested with a Generalized Linear Model (GLM) that included total traffic volume and month as the potential driving factors. The effect of month was significant for models: daily counts of caribou groups and daily count of all individuals along Misery Road (Table 3.3-1). Where data was available to assess caribou behaviours in relation to total traffic volume, results suggested a significant effect of traffic volume on walking, but no other behaviours (Table 3.3-2). The frequency of caribou road crossing events was not significantly affected by traffic volume. Sample sizes were too low to analyse the effect of traffic volume on deflection events and alertness, and there was no significant effect of total traffic volume on pooled stressed behaviours (e.g., deflected, running, alertness; Table 3.3-2).

Table 3.3-1. Results of Linear Mixed-effects Models Testing the Effects of Daily Total Traffic Volume and Month on Daily Counts of Caribou Groups and Individuals along Misery Road

Dependent Abundance Variable	LMM Statistic for Effect of Daily Total Traffic Volume	LMM Statistic for Effect of Month
Total Daily Count of Caribou Groups along Misery Road	$X^2 = 3.30$, df = 1, P = 0.07	*$X^2 = 15.03$, df = 6, P = 0.02
Total Daily Count of All Individuals along Misery Road	$X^2 = 0.18$, df = 1, P = 0.67	*$X^2 = 21.43$, df = 6, P < 0.01

** Indicates a statistically significant result.*

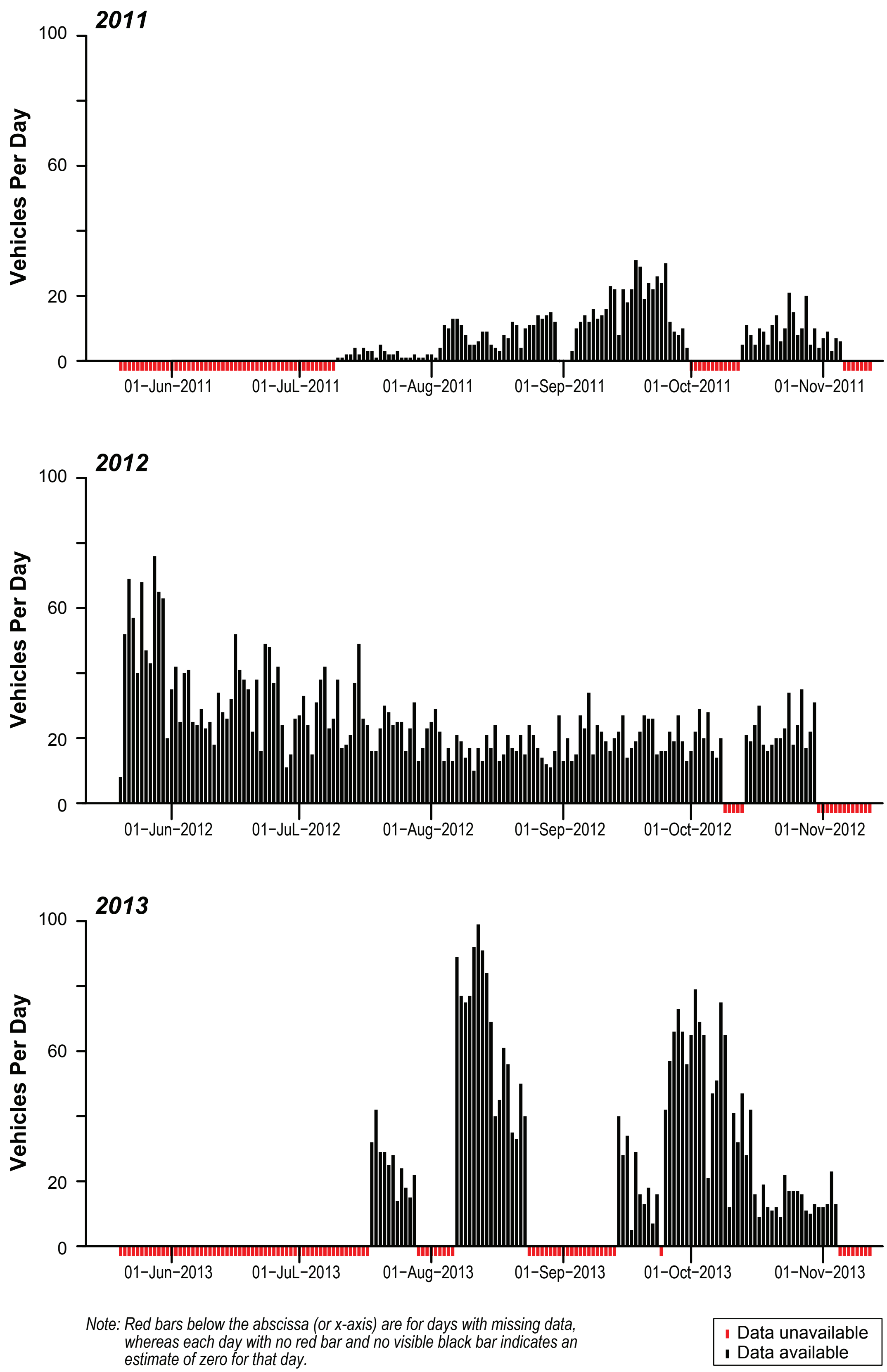
Table 3.3-2. Results of Linear Mixed-effects Models Testing the Effects of Daily Total Traffic Volume and Month on Caribou Behaviour along Misery Road

Dependent Behaviour Variable	LMM Statistic for Effect of Daily Total Traffic Volume	LMM Statistic for Effect of Month
Crossed Road Walking	$X^2 = 0.088$, df = 1, P = 0.77	*$X^2 = 16.25$, df = 6, P = 0.01
Crossed Road Running	$X^2 = 3.403$, df = 1, P = 0.07	$X^2 = 5.771$, df = 6, P = 0.44
Deflected by Road	Insufficient data	Insufficient data
Alert	Insufficient data	Insufficient data
Investigated Camera	Insufficient data	Insufficient data
Running	Insufficient data	Insufficient data
Walking	*$X^2 = 4.37$, df = 1, P = 0.04	$X^2 = 11.82$, df = 6, P = 0.07
Standing	$X^2 = 0.65$, df = 1, P = 0.42	$X^2 = 3.76$, df = 6, P = 0.71
Foraging	$X^2 = 0.002$, df = 1, P = 0.96	$X^2 = 8.11$, df = 6, P = 0.23
Bedded	$X^2 < 0.001$, df = 1, P = 0.99	$X^2 < 0.001$, df = 6, P = 0.99
Pooled Stressed Behaviours	$X^2 = 2.84$, df = 1, P = 0.09	$X^2 = 8.92$, df = 6, P = 0.18
Pooled Calm Behaviours	$X^2 = 1.37$, df = 1, P = 0.24	$X^2 = 7.24$, df = 6, P = 0.30

** Indicates a significant result.*

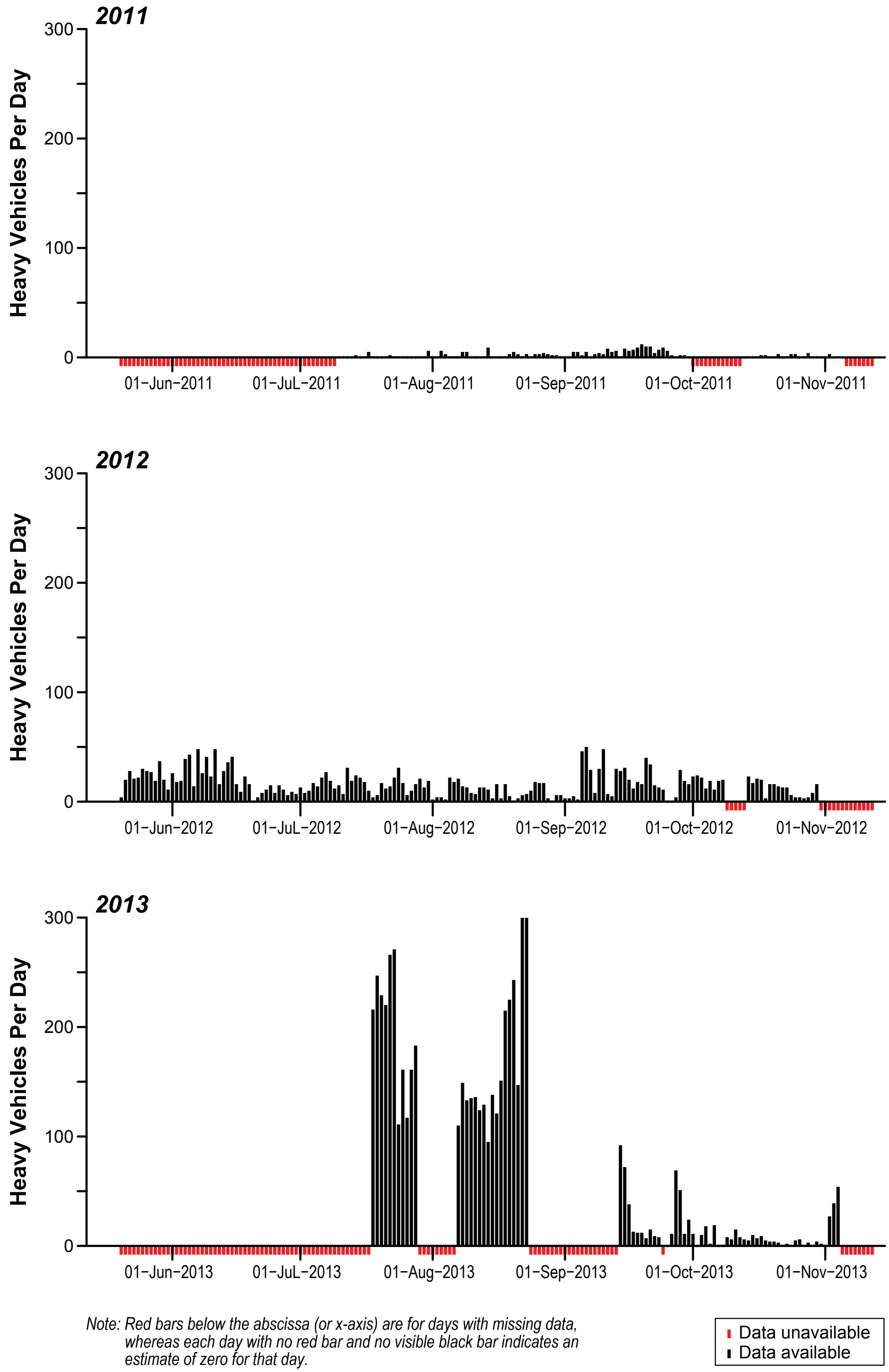
Figure 3.3-1

Light and Medium Traffic Volume per Day on Misery Road, 2011 to 2013



Note: Red bars below the abscissa (or x-axis) are for days with missing data, whereas each day with no red bar and no visible black bar indicates an estimate of zero for that day.

Heavy Vehicle Traffic Volume per Day on Misery Road, 2011 to 2013



Note: Red bars below the abscissa (or x-axis) are for days with missing data, whereas each day with no red bar and no visible black bar indicates an estimate of zero for that day.

To assess the extent that caribou walking behaviour was heavily influenced by the volume of heavy vehicles, light and medium vehicles were removed from the dataset. Heavy vehicular traffic volume had a significant effect by month, but no significant effect on daily fluctuations in caribou encounter rates, either by groups or individuals (Table 3.3-3). Caribou walking behaviour increased significantly as an effect of high volume heavy vehicular traffic, among caribou groups and individuals near Misery Road (Table 3.3-4).

Table 3.3-3. Results of Linear Mixed-effects Models Testing the Effects of Heavy Vehicle Traffic Volume and Month on Caribou Behaviour along Misery Road

Dependent Abundance Variable	LMM Statistic for Effect of Daily Heavy Vehicle Traffic	LMM Statistic for Effect of Month
Total Daily Count of Caribou Groups along Misery Road	X^2 = 3.28, df = 1, P = 0.07	*X^2 = 15.76, df = 6, P = 0.02
Total Daily Count of All Individuals along Misery Road	X^2 = 0.17, df = 1, P = 0.68	*X^2 = 21.67, df = 6, P < 0.01

** Indicates a statistically significant result.*

Table 3.3-4. Results of Linear Mixed-Effects Models Testing the Effects of Heavy Vehicle Traffic and Month on Caribou Behaviour along Misery Road

Dependent Behaviour Variable	LMM Statistic for Effect of Daily Heavy Vehicle Traffic	LMM Statistic for Effect of Month
Crossed Road Walking	X^2 = 0.20, df = 1, P = 0.65	*X^2 = 16.39, df = 6, P = 0.01
Crossed Road Running	X^2 = 3.42, df = 1, P = 0.06	X^2 = 5.76, df = 6, P = 0.45
Deflected by Road	Insufficient data	Insufficient data
Alert	Insufficient data	Insufficient data
Investigated Camera	Insufficient data	Insufficient data
Running	Insufficient data	Insufficient data
Walking	*X^2 = 4.53, df = 1, P = 0.03	*X^2 = 12.57, df = 6, P = 0.05
Standing	X^2 = 0.66, df = 1, P = 0.42	X^2 = 3.80, df = 6, P = 0.70
Foraging	X^2 = 0.03, df = 1, P = 0.87	X^2 = 8.08, df = 6, P = 0.23
Bedded	X^2 < 0.001, df = 1, P = 0.99	X^2 < 0.001, df = 6, P = 0.99
Pooled Stressed Behaviours	X^2 = 2.80, df = 1, P = 0.09	X^2 = 8.97, df = 6, P = 0.17
Pooled Calm Behaviours	X^2 = 1.82, df = 1, P = 0.18	X^2 = 7.01, df = 6, P = 0.32

** Indicates a significant result.*

4. Discussion

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Caribou cluster together at several different spatial and temporal scales, ranging from small clusters of just a few individuals that behave interdependently to large groups of many thousands of animals that consistently use the same breeding grounds, overwintering areas, and migration routes (Geist and Walther 1974; Helle 1981; Tyler 1991; Toupin, Huot, and Manseau 1996; Boulanger et al. 2004; Rescan 2013b; Body et al. 2014). This study examined the distribution of Bathurst caribou and their associated behaviours relative to infrastructure around the Ekati Diamond Mine between 2011 and 2013 through the use of motion-triggered cameras. Communities and regulators have expressed the need for a better understanding of how caribou respond to encountering roads. Of particular interest was assessing the overall permeability of Misery Road to caribou movements, and how lessons learned could be applied to the development of future roads to support the potential expansion of mining operations of the Ekati Diamond Mine (e.g., Lynx, Cardinal, Pigeon, and Jay Pits).

The largest encounter rate was at the north end of Main camp, at the Sable/Pigeon Road and Access Roads for total counts. The normalized data (adjusted for camera effort) also indicated increased numbers of caribou at the Sable/Pigeon Road and Access Road area. The Sable/Pigeon Road area was in a large area of good quality habitat (high greenness) that stretched to the north of the Ekati Site, including the Exeter Lake area.

Traditional knowledge (TK) was an important component in establishing the objectives for this study and determining where cameras should be deployed. Elders and other land users have indicated that areas to the north of the Ekati Diamond Mine are important to caribou as they migrate from their post-calving and summer range around Contwoyto Lake to their wintering grounds below treeline to the west and south of the Ekati Diamond Mine. Those moving west around the mine site utilize the Faye Bay area as an important movement corridor. Those moving south tend to avoid the boulder fields around the Ekati Diamond Mine and typically encounter Misery Road further to the south. Camera data are consistent with these patterns identified by TK, with encounter rates (relative to camera effort) highest in the Sable Road and Pigeon Pit areas compared to the other five regions. Along Misery Road, encounter rates were highest between Km 10-25 where the adjacent habitat was heath tundra or vegetated areas with some boulder associations.

When caribou encounter Misery Road, results indicate that the road is not an impermeable barrier to caribou movement through the Ekati Diamond Mine area, either due to the physical construction of the road or due to current traffic volumes. Cameras along Misery Road were located in areas where caribou were most expected to encounter the road, that is, in areas where adjacent habitat was identified by TK as suitable for foraging and/or movement. Overall, less than 1% of road encounters resulted in a deflection event, and some of these animals may have crossed the road elsewhere. In general, these deflection events were associated with steeper embankments composed of larger boulders. In addition, the frequency of crossing events and how caribou crossed Misery Road were related to the presence of a berm but not the maximum road height or traffic volume, suggesting that the verge interface between the adjacent habitat and the road is a determining factor in whether caribou will attempt to cross. It appears that ease of access and escape are more important to caribou than road height. For example, caribou are regularly observed crossing the ramps adjacent to the Sable Road culvert, despite the road being elevated several metres in that section of the road. It is possible that some deflection events were missed by cameras; however, the highest and steepest berms, and more inhospitable embankments and verges are generally located between Km 1-10. This section of Misery Road passes through extensive boulder fields where the likelihood of encountering caribou is inherently lower.

Traffic volume was not a significant factor associated with crossing events. Traffic volume along Misery Road at the Ekati Diamond Mine is approximately 3.5 times less than the 1,000 vehicles per day suggested by Muller and Berthoud (1994) that would cause some mortality in smaller species but not prevent movements of larger species. The maximum number of vehicles (all types) that were encountered in any one day between 2011 and 2013 was 299. Mortality along the road is regularly monitored and reported in the annual WEMP report. Mortality risk is mitigated by the enforcement of speed limits and ensuring that wildlife have the right of way at all times. Additionally, road signs and site wide email and radio notices are used to inform personnel of wildlife activity around the road. Road closures are regularly implemented to enable caribou movements through the area (Rescan 2014).

To facilitate the crossing of Misery Road by caribou, several caribou crossing ramps have been installed along the road to mitigate the potential barrier effect. The locations of these ramps were suggested by elders and other land users during a Caribou and Roads study that was undertaken in the mid-2000's, and during various site visits hosted by the Ekati Diamond Mine between 2009 and 2013. Results indicate a positive association between crossing events and the presence of these ramps, suggesting that caribou will preferentially use these ramps when they are available. Given the alignment changes to Misery Road and various upgrades throughout the entire length of the road, the Ekati Diamond Mine will consider additional ramps where verges may create an abrupt transition from road to adjacent high quality tundra areas.

While roads around the Ekati Diamond Mine may not pose a significant barrier to caribou movements, there is some evidence that caribou behaviour may shift relative to Project infrastructure as pooled calm state behaviours tended to be higher further from infrastructure. However, some stressed behaviour was also higher further from infrastructure. The reason for this discrepancy is unclear. It may partly be due to the difficultly of classifying behaviour from imagery, pairing alert behaviour with other behaviours (e.g., bedded + alert), and identifying reference cameras post-hoc. The camera deployment between 2011 and 2013 was intended to characterize the general distribution of caribou and their road interactions, rather than behaviour. A paired camera deployment along Misery Road (i.e., one camera along the road and the other 250-500 m from the road) and distinctive behavioural categories in 2014 should enable some behavioural comparisons, and corroborate findings from focal and scan behavioural surveys that are more reliable and robust techniques to classify behaviour of caribou relative to mine infrastructure.

5. Recommendations

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To further assess the use of caribou ramps as caribou crossings, road features and habitat interactions related to caribou crossing, and caribou use in future development areas, the following allocation of camera effort was deployed in 2014:

- Focus on periods during high caribou activity (~July to October);
- 2 cameras in LLCF (cell B);
- 15 cameras in the Pigeon/Sable area (Spur Road, Grizzly Road, PSD Road);
- 5 cameras between 500 m – 3 km from Sable Road ;
- 30 cameras along Misery Road (~every 1-2 km) at high caribou activity areas (see comments on attached figure) with good quality habitat (i.e., few boulder fields):
  - focus primarily between Km 10-25,
  - pair these cameras at 10 locations along the road; i.e., one adjacent to the road, the other 200-500 m out from the road, depending on habitat,
  - as cameras are being placed along the road, record details about the berm, including:
    - Berm height,
    - Slope,
    - Composition (average boulder size),
    - Adjacent habitat,
    - Also record dominant (> 50%) habitat in 30 m radius around the paired tundra camera;
- 1 camera along proposed Lynx Road;
- 1 road traffic camera (in previous location);
- 14 remaining cameras:
  - caribou crossing ramps,
  - high berm areas along the new road alignment adjacent to good habitat,
  - along proposed route to Jay,
  - Faye Bay,
  - Contwoyto Lake area as habitat modeling indicates this area is particularly important during post-calving and summer.

To reduce photo processing without compromising data quality, the following settings are recommended:

- 1 timed photo per 30 minutes;
- 4 photos per motion trigger at 1 photo per second;
- no delay between triggers; and
- for the road traffic camera, 1 photo per trigger, with a 5 second delay between triggers.

6. Literature Cited

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Adamczewski, J., Boulanger, J., Croft, B., Cluff, H. D., Elkin, B., Nishi, J., Kelly, A., D'Hont, A., and Nicolson, C. 2009. *Decline in the Bathurst caribou herd 2006–9: a technical evaluation of field data and modeling*. Environment and Renewable Resources, Government of Northwest Territories, Yellowknife, NWT, Canada. http://www.wrrb.ca/node/208 (accessed April 2013).

Armstrup, S.C., Noel, L, E., Durner, G.M., Cronin, M.A., McDonald, T., and Ballard, W.B. 1998. Caribou distribution during the post-calving period in relation to infrastructure in the Prudhoe Bay oil field, Alaska. *Arctic* 51: 85-93.

Bergerud, A. T., Jakimchuk, R. D., and Carruthers, D. R. 1984. The Buffalo of the North : Caribou (*Rangifer tarandus*) and Human Developments. *Arctic* 37(1), 7–22.

BHP Billiton. 1995. *NWT Diamonds Project, Environmental Impact Statement*. Prepared for BHP Billiton Diamonds, Inc. by Rescan Environmental Services Ltd.

Bissonette, J. A. and Cramer, P. C. 2008. *Effectiveness of Wildlife Crossings*. Transportation Research Board, Washington, D.C., National Cooperative Highway Research Program Report No. 615.

Body, G., Weladji, R. B., Holand, Ø., and Nieminen, M. (2014). Highly competitive reindeer males control female behavior during the rut. *PLoS ONE* 9(4), e95618.

Boulanger, J., Poole, K., Fournier, B., Wierzchowski, J., Gaines, T., and Gunn, A. 2004. *Assessment of Bathurst Caribou movements and distribution in the Slave Geological Province*. Department of Resources, Wildlife, and Economic Development, Government of the Northwest Territories. Yellowknife, NT. Manuscript Report No. 158.

Boulanger, J., K. G. Poole, A. Gunn, and J. Wierzchowski. 2012. Estimating the zone of influence of industrial developments on wildlife: a migratory caribou *Rangifer tarandus groenlandicus* and diamond mine case study. *Wildlife Biology*, 18: 164-79.

Braden, A. W., Lopez, R. R., Roberts, C. W., Silvy, N. J., Owen, C. B., and Frank, P. A. 2008. Florida Key deer Odocoileus virginianus clavium underpass use and movements along a highway corridor. *Wildlife Biology* 14,155–163.

Bull, E. L., Holthausen, R. S., and Bright, L. R. 1992. Comparison of three techniques to monitor marten. *Wildlife Society Bulletin* 20(4), 406-410.

Cameron, R. D., Reed, D. J., Dau, J. R., and Smith, W. T. 1992. Redistribution of Calving Caribou in Response to Oil Field Development on the Arctic Slope of Alaska. *Arctic* 45(4), 338–342.

Christiansen, F., Rasmussen, M. H., and Lusseau, D. 2013. Inferring activity budgets in wild animals to estimate the consequences of disturbances. *Behavioral Ecology* 24, 1415-1425.

Cutler, T. L. and Swann, D. E. 1999. Using remote photography in wildlife ecology: A review. *Wildlife Society Bulletin* 27(3), 571-581.

Dunne, B. M. and Quinne, M. S. 2009. Effectiveness of above-ground pipeline mitigation for moose (*Alces alces*) and other large mammals. *Biological Conservation* 142(2), 332-343.

Dyer, S. J., Neill, J. P. O., Wasel, S. M., and Boutin, S. 2002. Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta. *Canadian Journal of Zoology* 80, 839–845.

ERM Rescan. 2014a. *The Ekati Diamond Mine and Diavik Diamond Mine 2013 Interim Lac de Gras Regional Grizzly Bear DNA Report*. Prepared for Dominion Diamond Ekati Corporation by ERM Rescan: Yellowknife, NWT.

ERM Rescan. 2014b. *Ekati Diamond Mine: 2013 Wildlife Effects Monitoring Program*. Prepared for Dominion Diamond Ekati Corporation by ERM Rescan: Yellowknife, NWT.

ENR. (2006). *Caribou Forever – Our Heritage, Our Responsibility: A Barren-ground caribou management strategy for the Northwest Territories 2006-2010*. Environment and Natural Resources. Yellowknife, NWT.

Forman, R. T. and Alexander, L. E. (1998). Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29, 207-231.

Geist, V. and F. Walther, F., Eds. (1974). *The Behaviour of Ungulates and its Relation to Management*. IUCN Publications New Series No. 24, Morges, Switzerland.

GNWT ENR. 2013a. *Our Wildlife: Bathurst Caribou Herd*. Government of the Northwest Territories Department of Environment and Natural Resources. http://www.enr.gov.nt.ca/_live/pages/wpPages/Bathurst_Caribou_Herd.aspx (accessed November 2013).

GNWT ENR. 2013b. *Our Wildlife: Beverly - Ahiak Caribou Herd*. Government of the Northwest Territories Department of Environment and Natural Resources. http://www.enr.gov.nt.ca/_live/pages/wpPages/Beverly-Ahiak.aspx (accessed November 2013).

Helle, T. (1981*). Observations of home ranges and grouping patterns of the free-ranging semi-domestic reindeer (*Rangifer tarandus tarandus L.*) in Kuusamo*. Research Institute of Northern Finland A2, 33–53.

Horejsi, B. L. (1981). Behavioral response of barren ground caribou to a moving vehicle. *Arctic* 34(2), 180–185.

Klein, D. R. (1991). Caribou in the changing north. *Applied Animal Behaviour Science* 29(1), 279-291.

Miller. F. L. (2003). Caribou. In: *Wild mammals of North America: Biology, Management and Conservation* (eds Feldhamer GA, Thompson BC, Chapman JA), pp. 965–997. The John Hopkins University Press, Baltimore.

Neter, J. and Wasserman, W. (1974). *Applied Linear Statistical Models: Regression, Analysis of Variance, and Experimental Designs*. Homewood, IL, USA, Irwin Professional Publishing.

Noel, L. E., Butcher, M. K., Cronin, M. A., and Streever, B. (2006). Assessment of effects of an oil pipeline on caribou, *Rangifer tarandus granti*, use of riparian habitats in Arctic Alsaska, 2001-2003. *The Canadian Field-Naturalist* 120(3), 323-330.

Olsson, M. P. O., Widén, P., and Larkin, J. L. (2008). Effectiveness of a highway overpass to promote landscape connectivity and movement of moose and roe deer in Sweden. *Landscape and Urban Planning* 85, 133-139.

R Core Development Team (2011). *R: A Language and Environment for Statistical Computing*. Vienna, Austria, available from: http://www.R-project.org/, The R Foundation for Statistical Computing.

Reconyx. (2012). *HyperFire High Performance Cameras Instruction Manual*. Reconyx. http://images.reconyx.com/file/HyperFireManual.pdf (accessed June 2014).

Reimers, E., Eftestøl, S., and Colman J. E. (2003). Behavior responses of wild reindeer to direct provocation by a snowmobile or skier. *Journal of Wildlife Management* 67, 747-754.

Rescan. 2012a. *EKATI Diamond Mine: 2011 WEMP Addendum: Wildlife Camera Monitoring Summary Report*. Prepared for BHP Billiton Canada Inc. by Rescan Environmental Services Ltd.: Yellowknife, NWT.

Rescan. 2012b. *EKATI Diamond Mine: 2011 Wildlife Effects Monitoring Program*. Prepared for BHP Billiton Canada Inc. by Rescan Environmental Services Ltd.: Yellowknife, NWT.

Rescan. 2013a. *EKATI Diamond Mine: 2012 WEMP Addendum: Wildlife Camera Monitoring Summary Report*. Prepared for BHP Billiton Canada Inc. by Rescan Environmental Services Ltd.: Yellowknife, NWT.

Rescan. 2013b. *EKATI Diamond Mine: 2012 Wildlife Effects Monitoring Program*. Prepared for BHP Billiton Canada Inc. by Rescan Environmental Services Ltd.: Yellowknife, NWT.

Rowcliffe, J. M. and Carbone, C. (2008). Surveys using camera traps: are we looking to a brighter future? *Animal Conservation* 11(3), 185-186.

Silveira, L., Jácomo, A.T.A., Diniz-Filho, J.A.F. (2003). Camera trap, line transect census and track surveys: a comparative evaluation. *Biological Conservation 114*, 351-355.

Smith, W.T. and Cameron, R.D. (1983). Responses of caribou to industrial development on Alaska's arctic slope. *Acta Zool. Fenn* 175, 45-45.

Stuart-Smith, K. and James, R. C. (2000). Distribution of caribou and wolves in relation to linear corridors. *Journal of Wildlife Management* 64(1), 154–159.

Toupin, B., Huot, B., and Manseau, M. (1996). Effect of insect harassment on the behaviour of the Rivière George caribou. *Arctic* 49, 375-382.

Trombulak, S. C. and Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14(1), 18-30. DOI: 10.1046/j.1523-1739.2000.99084.x

Tyler, N. J. C. (1991). Short-term behavioural responses of Svalbard reindeer *Rangifer tarandus platyrhynchus* to direct provocation by a snowmobile. *Biological Conservation* 56, 179-194.

Whitlock, M. C. and Schluter, D. (2009). *The Analysis of Biological Data*. Greenwood Village, CO, USA, Roberts and Company Publishers.

Wolfe, S. A., Griffith, B., Gray Wolfe, C. A. (2000). Response of reindeer and caribou to human activities. *Polar Research* 19, 63-73.