Final Project Report

NWRT Project Number: 2-21-09

Project Title:

Use of trail cameras to estimate cow:calf ratios, calf mortality and predator abundance on the Bathurst caribou herd calving grounds

Project Leader:

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Summary:

Although barren-ground caribou (*Rangifer tarandus groenlandicus*) populations are thought to cycle over long periods of time, some herds have experienced widespread decline. The Bathurst herd has declined from an estimated 470,000 animals in the 1980s to an estimated 8,210 animals in 2018 (Adamczewski et al. 2019). The Committee on the Status of Endangered Wildlife in Canada has assessed barren-ground caribou as Threatened; similarly, the NWT Species at Risk Committee and the NWT Conference of Management Authorities have assessed barren-ground caribou as Threatened. The Bathurst herd is important to several communities in Nunavut and the Northwest Territories. One of the limiting factors for recovery of the herd may be early calf mortality from predation by bears, wolves and other predators. The main purpose of this study is to apply passive surveillance techniques to the challenges of estimating cow:calf ratios, calf mortality, and predator abundance within the calving grounds of the Bathurst caribou herd. We propose to use machine learning to identify and count animals classified by age, sex, and species. We then propose to use spatial mark-resight modelling to estimate the density of predators occupying the calving grounds. Results could inform policy and management for land-use planning, impact assessment and wildlife management at the territorial, regional or community levels, and make it possible to better assess the impact of harvesting on herd status or evaluate harvest management measures. We expect results to provide insight into predator effects on calf recruitment and provide managers with a better understanding of the way in which predators may affect population abundance.

Project Objectives:

The main purpose of the study is to apply passive surveillance techniques to estimate cow:calf ratios, calf mortality, and predator abundance within the calving grounds of the Bathurst caribou herd. In May, a surveillance array comprised of 96 motion sensitive cameras and 96 Autonomous Recording Units were deployed across a 1,600 km2 grid within high-use areas of the calving grounds.

Our research objectives are as follows: 1) apply already-established machine learning algorithms to identify and count wildlife; 2) develop a new machine-learning algorithm and classify caribou by age and sex to determine cow/calf pairs; 3) develop a new machine learning algorithm to identify individuals within a predator guild (grizzly bears, wolves, wolverine), and; 4) use spatial mark-resight modelling to estimate the density of predators occupying the calving grounds. Calf mortality would be assessed through changes in calf-cow ratios over time in June. A calving ground photo survey was conducted in June 2021, including a composition survey that will estimate the proportion of breeding females near the peak of calving. This will establish the maximum calf productivity on the calving grounds; calf-cow ratios over the succeeding weeks would provide a measure of early calf mortality.

Although not originally proposed, while transcribing the trail camera data, photos of collared caribou were observed. A mark-resight model will be attempted to determine whether a population estimate could be derived from the trail camera data.

Materials and Methods:

This project commenced in May 2021, when 96 Trail Cameras and Autonomous Recording Units (ARUs) were set up at 64 sites in the Bathurst calving grounds near Bathurst Inlet (see Figures 1 and 2). The locations were spaced across a 5 km x 5 km grid, where a trail camera and ARU were placed in the centre. In the northern half of the sites, a second unit was randomly placed within the grid square. The location of the grid was based on collaring data from 2016 to 2020. The blue polygon in Figure 1 represents the percentage of collared cows that calved in each area from 2016 to 2020. The units were set up by three members of the local Hunter and Trappers Organization, the Kugluktuk Angoniatit Association. The members took part in a classroom-based training session to familiarize them with the units, and then were given an in the field demonstration, before deploying the units.

In August 2021, the units were recovered. All 96 trail cameras were recovered, with 93 ARUs recovered. The remaining three ARUs were damaged by bears. The data from the units was downloaded and the units inventoried by four Inuit summer students.

Camera trap studies have become increasingly common among wildlife monitoring programs. However, users are faced with data processing bottlenecks due to the considerable number of images that require processing. This project alone has close to a hundred thousand photos. The photos are being transcribed by hand, but this is extremely time consuming. To address this problem, we shall leverage advances in deep learning and artificial intelligence using neural networks to automatically process images and the next stage of this project will involve the development of a recognizer.

Project Schedule:

The original project schedule that was proposed has slightly deviated. We proposed to have the transcription and data entry completed by November 30th, 2021. However, due to the volume of camera photos, transcription is not yet complete. We expect transcription will be completed early in the new year, but it has resulted in a delay.

Below is a breakdown of the completed activities and activities that remain to be done, as well as updated proposed completion dates.

Table 1- Breakdown of activities completed as part of the Bathurst caribou herd monitoring program

Task	Method	Detailed Activities	Status	Updated Status
Consult with affected communities	- Provide overview of the proposed project and work to affected communities	- Attended hunter and trappers' organization meetings and provided background on the project and an overview of the proposed work and the project objectives	Completed	Completed
Training of Kugluktuk community members	- Train members of the hunter and trapper organization to	- In office training session introducing the project, the data collected and how to activate the trail cameras and autonomous recording units	Completed	Completed

	conduct the field work component of the project	- In field training session going over the deployment methods, data sheets and methods to record habitat data		
Deploying of units	- Setting up recording stations and deploying trail cameras and autonomous recording units	- Establishing recording stations in a grid pattern spaced 5 km apart in areas with a clear view of the surrounding area - Activating and mounting trail cameras and autonomous recording units onto steel angle iron posts - Recording of site data and unit information	Completed	Completed
Collection of Data	- Deployed units passively survey the calving grounds	- Trail cameras are activated by motion and will take photos when activated - Daily time lapse photos taken at noon - Autonomous recording units will take a recording of ambient sounds for the first 10 minutes of every second hour	Completed	Completed
Recovery of units	- Deployed units will be retrieved by members from the HTO and by Inuit summer students	- Returning to recording stations and retrieving the mounted trail cameras and autonomous recording units from the angle iron steel posts, and removing the steel posts - Recording of site data and unit information and taking photos of the site	Completed	Completed
Download of data	- Downloading data from the SD cards in the trail cameras and autonomous recording units	- Removing SD cards from trail cameras and autonomous recording units - Managing of data sheets, scanning data, and entering data from data sheets - Organizing SD cards, downloading data, organizing data by site, and backing up data to two external hard drives	Completed	Completed
Inventorying of equipment	- Inventorying equipment and performing any necessary repairs	- Inventorying trail cameras and autonomous recording units - Evaluating the condition of units and replacing any missing parts and performing any necessary repairs	Completed	Completed
Data exploration	- Reviewing of data and data exploration	- Reviewing of data collected during field work - Preliminary synthesis of data	31-Oct-21	Completed

		- Exploratory analysis of data		
Development of neural network	- Developing a neural network to automatically process images that have been recorded by the trail cameras	- Building an existing convolutional neural network (CNN) architecture called YOLOv4 to classify the calving ground images (i.e., identify animals to species) - Re-train the CNN parameters and optimize model predictions for 10 classes of arctic wildlife, including caribou and grizzly bear - Validation of models on a test dataset, and re-train to address species identification errors - Repeated the training and validation process until we reached high accuracy (i.e., >90% accuracy)	15-Jan-22	First iteration completed and now will be trained, expected completion May 2022
Data processing	- Running the neural network to process the data collected by the trail cameras	- Using the neural network to process camera-trap image data by tallying species-specific detections in space and time	01-Feb-22	Completed with first iteration and will be conducted with trained version, expected completion May 2022
Testing of facial recognition	- Use of BearID to identify individual bears from trail camera photos	- Application of deep learning to grizzly bear facial recognition using object detection, landmark detection, a similarity comparison network, and machine-based classification to identify individuals - Employing the open-source application, BearID, to detect, rotate, extract, and embed the facial features of individuals detected	15-Feb-22	Currently in progress, expected completion May 2022
Analysis of results	- Statistical analysis to estimate predator abundance and calf mortality	- Using spatial mark-resight model to incorporate encounters of marked individuals as part of the estimation framework accommodating for encounters of individuals without marks - To estimate calf mortality, the number of cow-calves will be tallied, and a generalized linear model will be run comparing ratios over time	30-Mar-22	Expected completion September 2022

Reporting of results	- Writing of report and scientific publication	- Developing a report to be distributed to stakeholders - Preparing report summarizing the results of this work	15-Apr-22	Expected completion October 2022
Reporting results to communities	- Presenting the results to affected communities	- Giving presentations to the hunter and trapper organizations of the affected communities that provide an overview of the project, an explanation of the results and the implications of the results	30-May-22	Expected completed December 2022

Preliminary results/discussion:

We have successfully transcribed data by hand 81 of 96 sites. This amounts to the manual review and tagging of 211,339 photos of the 245,922 photos taken by the project.

We have processed the entire dataset using a first iteration of the neural network, a total of 245,922 images. This model had training data from the Qamanirjuaq calving grounds with very few images of some classes that are more prevalent in the Bathurst area (including bears, wolves, wolverine, fox). As such, we expected the first iteration of the model to perform poorly for those classes. However, the initial results showed good accuracies for all common classes (including caribou: 93%, bear: 85%, muskox: 76%, wolf: 60%, and fox: 60%).

The initial results of the model performed better than anticipated for some of the classes that received very little training. The model will be further improved and refined, as poorly performing classes are better represented in the Bathurst data when compared to the Qamanurjuaq data set. We expect the second version of the neural network to be significantly improved.

Following the second version of the neural network, spatial patterns of presence and abundance of caribou will be investigated as the accuracy is high (93%). At this point, we are starting to build the workflow for modeling spatial patterns, and then will feed the more accurate results into the workflow once generated.

We've completed a trial of the Bear Face ID methods and the results are promising. The model identifies individuals across a sequence of images. Through manual processing, it is possible to conclude that we're looking at a single bear across a sequence of photos because of the time differences and the fact that we can often track the bear's movement from image to image. That's not the case for neural networks; they must rely on their trained parameters and the structure of the bear's face to determine whether the bear is the same or not. Even though it seems obvious to humans, the model's ability to correctly identify bears in sequences of images is a good sign that the parameters are solid. There are several bear images, but many of them are extreme close-ups as the bear is playing with the equipment rather than a clear photo of the animal. We are exploring the possible use of genetic data that may be available for the area in the coming year to validate the model.

Inuit Participation

This project is a collaboration between the KAA, GNWT and the GN. Inuit were involved in the design, implementation, data collection, and transcription of photos. Three members of the KAA were hired to participate in this project, and four Inuit summer students were involved. In addition, two Inuit GN staff have been involved in the project. All received training on how to use wildlife sensor technology.

Reporting to communities/resource users:

Communities have been kept up to date on the progress of this project through regular email and telephone updates. Additionally, the project lead presented on the status of this work at EHTO and KAA board meetings, and at the Kitikmeot Regional Wildlife Board meeting, and at a Nunavut Inuit Wildlife Environment Advisory Committee meeting.

Community / HTO	Before research	During research	Completion of research

KAA	Date: 01/01/2021 Type: email/telephone	Date: On-going Type: in-community	Date: 31/03/2022 Type: email/telephone
OHTO	Date: 01/01/2021 Type: email/telephone	Date: On-going Type: email/telephone	Date: 31/03/2022 Type: email/telephone
BHTO	Date: 01/01/2021 Type: email/telephone	Date: On-going Type: email/telephone	Date: 31/03/2022 Type: email/telephone
EHTO	Date: 01/01/2021 Type: email/telephone	Date: On-going Type: remotely	Date: 31/03/2022 Type: email/telephone
KRWB	Date: 01/01/2021 Type: email/telephone	KRWB AGM Type: in-community	Date: 31/03/2022 Type: email/telephone

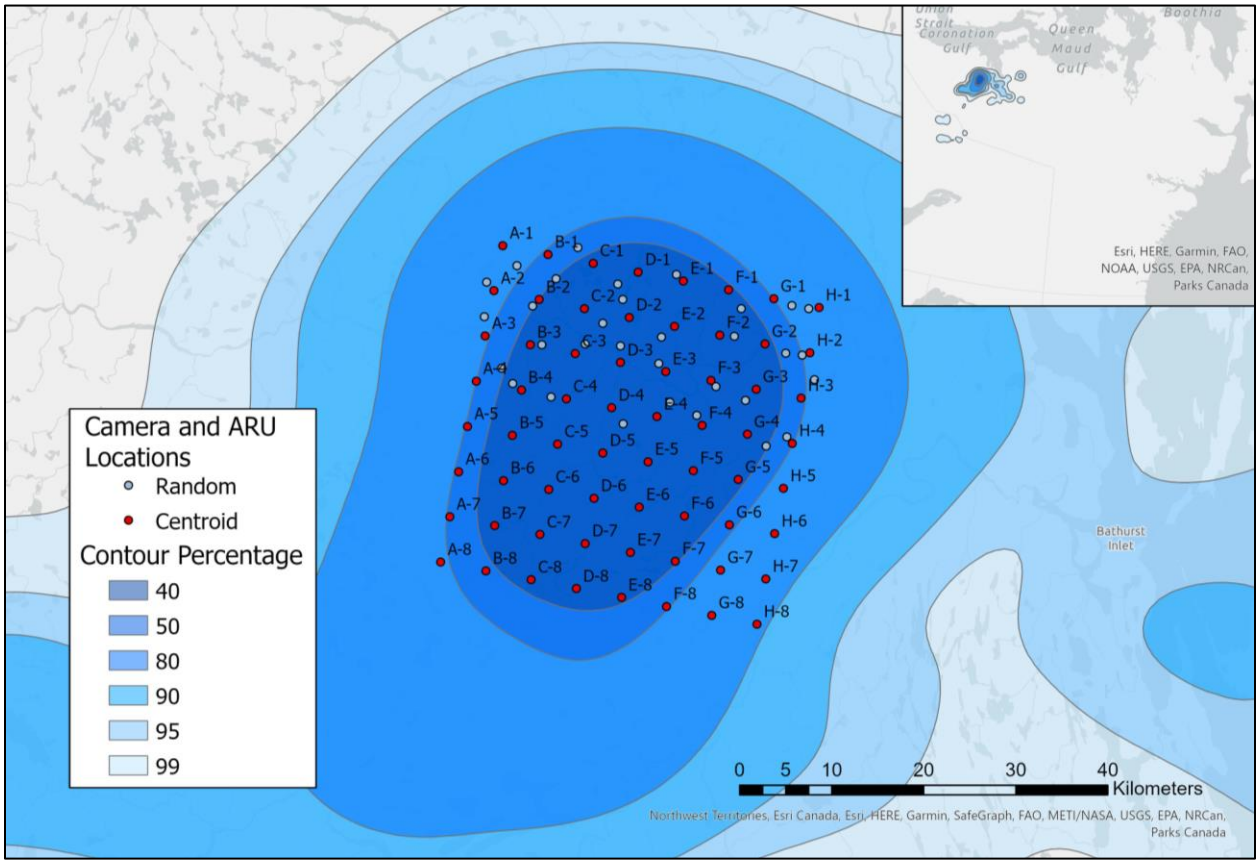

Figure 1- Location of sites where the environmental sensors (trail cameras and autonomous recording units) were deployed in the Bathurst caribou calving grounds. The dark blue kernel density indicates the calving ground locations from Bathurst caribou collars (2016-2020).

Figure 2- Photos from in the field training session and the deployment and retrieval of trail cameras and recording devices (ARUs) as part of the Bathurst monitoring program. These photos may be posted to social media.

Figure 3- Photos of a wolf, barren-ground caribou, and grizzly bear (left to right) captured by trail cameras as part of the Bathurst monitoring program.

Final Financial Report

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Project Leader:

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Original Project Budget:

Cash							
Item	**Unit**	**Unit Cost**	**GN**	**GNWT**	**NuWCRU**	**NWRT**	**Total**
Rotary Wing Charter Ferry Costs Spring (hrs)	3.7	$1,340				$4,958	$4,958
Rotary Wing Charter Ferry Costs Fall (hrs)	3.7	$1,340				$4,958	$4,958
Rotary Wing Charter Field Time Spring (hrs)	16	$1,340		$5,360		$16,080	$21,440
Rotary Wing Charter Field Time Fall (hrs)	16	$1,340		$5,360		$16,080	$21,440
Fuel drums and caching	6	$2,000				$12,000	$12,000
Community member fee (per day)	30	$350				$10,500	$10,500
Graduate student stipend (per year)	1	$25,197			$25,197		$25,197
Research services (machine learning, design, analysis, reporting)	30	$1,000	$15,000	$15,000			$30,000
Cameras	20	$600	$12,000				$12,000
Camera security enclosure	20	$70	$1,400				$1,400
Shipping	1	$1,000	$1,000				$1,000
Deployment equipment (e.g., posts, screws, wing nuts, auger)	100	$70		$5,000		$2,000	$7,000

Camera set up equipment (signs, felts, compasses, cameras)		$5,000				$5,000	$5,000
Perdiem pilot	10	$160	$1,600				$1,600
SD cards (128 GB)	100	$75				$7,500	$7,500
AA Lithium Batteries (12 per camera)	1200	$4				$4,800	$4,800
Multi-slot SD card readers	2	$200				$400	$400
Emergency kit (emergency provisions)	1	$800				$800	$800
Harddrive (14TB)	3	$400				$1,200	$1,200
Total Cash			$31,000	$30,720	$25,197	$86,276	$173,193

In Kind	**Unit**	**Unit Cost**	**GN**	**GNWT**	**NuWCRU**	**NWRT**	**Total**
Person days	10	$1,000	$10,000	$10,000	$10,000		
Cameras	80	$700		$56,000			
Equipment (Computers, GPS, etc)	-	-	$5,000				
Total Inkind			$15,000	$66,000	$10,000	$0	$91,000

Total			**GN**	**GNWT**	**NuWCRU**	**NWRT**	**Total**
			$46,000	**$96,720**	**$35,197**	**$86,276**	**$264,193**

Original Contributions:

Contributor	Funds ($K)	In-kind (PY or $K)
Government of Nunavut (Confirmed)	$29,058	$15,000
Government of Northwest Territories (Confirmed)	$20,320	$66,000
NuWCRU (Confirmed)	$25,197	$10,000
NWMB (Requested)	$86,276	-

TOTAL FUNDS	$173,193	$91,000

Explanation of changes:

Several major changes occurred in the original project budget and original contributions.

The Nunavut Cooperative Research Unit is no longer a contributor of the project; however, the World Wildlife Fund and the Aboriginal Fund for Species at Risk were added as contributors.

The overall cost of the project significantly changed as well, with additional rotary time and fuel being required by the project. Furthermore, the decision was made to use angle iron posts to deploy the units, rather than wooden posts. This was to mimic other deployment strategies used in Alaska, with the objective of safeguarding the integrity of the set of the environmental sensors and to facilitate the set up of the posts into permafrost. The change of material added an additional cost and required an air charter to deploy the posts due to the added weight which made transport by helicopter during deployment impossible.

Additionally, the project proposed to deploy 98 environmental sensor stations in a 7 by 7 grid, spaced 5 km apart. However, 96 monitoring sites were established in an 8 by 8 grid spaced 5 km apart. The resulting project monitored a larger area, but less intensively.

Financial Report:

Cash						
Item	**GN**	**GNWT**	**NWRT**	**AFSAR**	**WWF**	**Cost**
Rotary Spring			$ 47,820	$ 24,697		$ 72,517
Rotary Fall			$ 33,538	$ 32,221		$ 65,759
Replacement Fuel Cost	$ 3,585		$ 1,055	$ 4,560		$ 9,200
Caching posts		$ 11,250				$ 11,250
Fall fuel			$ 3,863	$ 10,000		$ 13,863
Community member fee (per day)	$ 10,695					$ 10,694
Research services (machine learning, design, analysis, reporting)	$ 5,000				$ 25,000	$ 30,000
Return Shipping for ARUs and Cameras to YK	$ 1,519					$ 1,519
Shipping ARUs and Trail Cameras to Kugluktuk		$ 2,285				$ 2,285
Shipping bolts, batteries and nuts		$ 493				$ 493
Dangerous Goods Transport (Discovery Mining)		$ 140				$ 140
Deployment equipment (e.g., posts, screws, wing nuts, auger)		$ 11,891				$ 11,891
SD cards (128 GB)		$ 7,330				$ 7,330
D Alkaline Batteries (4 per ARU)		$ 895				$ 895

D Alkaline Batteries (4 per ARU)	$ 150					$ 150
AA Lithium Batteries (12 per camera)		$ 9,050				$ 9,050
Multi-slot SD card readers	$ 100					$ 100
Total Cash	**$ 21,049**	**$ 43,333**	**$ 86,276**	**$ 71,478**	**$ 25,000**	**$ 247,136**

In Kind	**GN**	**GNWT**	**NWRT**	**AFSAR**	**WWF**	
Person days	$ 30,000	$ 10,000				
Cameras		$ 56,000				
Autonomous Recording Units (ARUs)		$ 100,000				
Equipment (Computers, GPS, harddrives, etc)	$ 25,000					
Total Inkind	**$ 55,000**	**$ 166,000**	**$ -**	**$ -**	**$ -**	

Total	**GN**	**GNWT**	**NWRT**	**AFSAR**	**WWF**	**Total**
	$ 76,049	**$ 209,333**	**$ 86,276**	**$ 71,478**	**$ 25,000**	**$ 478,136**

Explanation of variances:

The variance between the proposed project budget and actual budget was by applying more funding from NWRT to the rotary and to the fuel costs, with the GN covering the cost for the community member that participated in the project.

I certify that this is an accurate statement of the Trust project funds received and disbursed in accordance with the joint contribution agreement.

A. Roberto-Charron

Project leader

May 17, 2022

Finance department signature