NBCKC Monitoring Practices for Boreal Caribou

TELEMETRY IN CANADA

National Boreal Caribou Knowledge Consortium

Front Cover Photo Credit: Agnes Pelletier

Telemetry in Canada

Contents

TELEMETRY

Introduction to Telemetry

Telemetry is a wildlife population monitoring tool for collecting location-based data. These data are collected from Global Positioning System (GPS) and/or Very High Frequency (VHF) signals emitted from a collar carried by an animal (Mech and Barber 2002). In a telemetry-based monitoring program, the Very High Frequency (VHF) radio transmitter and/or Global Position System (GPS) unit allow for remote detection of the collared animal. As such, these collars are well suited to monitoring movement, activity, and demographic information of individuals over a coarse-scale study area (e.g. range scale) (White and Garrott 1980, Murray 2006, Larter and Allaire 2018). For the purpose of this report, we assume a tracking collar has both VHF and GPS capabilities.

Camera collars are a wildlife population monitoring tool for collecting animal behavioural data (Thompson *et al.* 2012). These data are collected from the images and video files from a camera mounted on the collar carried by an animal. As such, camera collars are particularly well suited to fine-scale behavioural studies, such as those concerned with foraging behaviours of animals. These cameras may be used independently or may be mounted in tandem with the GPS/VHF units used for telemetry tracking.

Photo Credit: Richard Neville

To deploy telemetry collars requires direct handling of caribou. Protocols must be followed when caribou are handled and restrained (including the installation and possible retrieval of the collar) to minimize stress on the animal. Likewise, animals must be handled only by trained personnel (CCAC 2003, Sikes and Gannon 2011). Adult females are usually the priority for collaring to help with estimating survival and recruitment (e.g., Rettie and Messier 1998). In a handful of studies, adult males have been collared for the determination of rutting locations (e.g. Larter and Allaire 2018), though this remains uncommon due to current collar design limitations in accommodating for the swelling of the neck during the rut and subsequent shrinking afterward. Calves are rarely tracked, but they can be collared or marked with a transmitter tag soon after birth to assess calf survival. Inherent issues with collaring calves include the additional stress put on adult females during handling, the considerations that collars may be too heavy for use on calves (e.g. Rasiulis *et al.* 2014), and that current collar designs are inadequate in accommodating for calf growth.

In Canada, GPS/VHF telemetry-based surveys are a caribou monitoring method with a long history: most provinces and territories have relied heavily on telemetry data from adult female caribou for baseline population data, providing the foundation for most boreal caribou scientific datasets (NBCKC 2019). Furthermore, GPS/VHF telemetry-based datasets are often combined with aerial survey datasets. Both aerial surveys and telemetry monitoring are important sources of information to inform jurisdictional planning, including management and recovery measures for caribou populations and their habitat. Data collected through these monitoring methods include, for example, population size and growth rate (Environment Canada 2011, Hervieux *et al.* 2013, Johnson *et al.* 2020), and patterns of habitat use and connectivity (e.g. Arsenault 2003, Galpern and Manseau 2013).

In contrast to radio collars, camera collars are a more recent development in wildlife monitoring technology. Camera Collars have only recently begun to be integrated in monitoring programs in Canada (e.g. Thompson *et al.* 2012, 2015, Newmaster *et al.* 2013).

TELEMETRY

Indigenous Knowledge in monitoring programs

Through the production of Boreal Caribou Monitoring in Canada Part 1: Perspectives from the NBCKC Monitoring Working Group, a number of field methods were identified as commonly used in Canada for monitoring boreal caribou, yet these methods are often conducted without being grounded in Indigenous methodologies. Applying both Indigenous and non-Indigenous ways of knowing to caribou monitoring programs has numerous benefits (e.g. Raygorodetsky and Chetkiewicz, 2017). As such, opportunities for how Indigenous Peoples and their knowledge could benefit a monitoring program have been identified throughout the text of the toolkit. In addition, the Practical Aspects to Reconciling Indigenous and non-Indigenous Ways of Knowing toolkit (*in prep*) will highlight practical guidance for using multiple ways of knowing caribou and will help readers understand the characteristics of meaningful collaboration with Indigenous communities. For example, such characteristics include (but are not limited to): Indigenous people co-coordinating the program from the onset of planning; equitable sharing of decision-making as it pertains to the monitoring program; frequent communication throughout all phases of a program; dedication to relationship-building and mutual learning; agreement on ethical principles surrounding project design and implementation; transparency in collection, use, and storage of data (e.g. OCAP principles); adherence to protocols established by local governance and co-management boards, and making space (dedicating time, energy, and resources) to include both capacity building, and compensation for time, in the monitoring program.

Examples of collar vendors

- Ex-Eye LLC, 10224 Broadsword Drive Bristow VA. 20136 USA Ph: 703 319 0976, Fax: 703 330 0021, Email: Mehdi@Ex-eye.
- Lotek Wireless Inc., Newmarket ON, https://www.lotek.com/
- Vectronic Aerospace, Berlin Germany, https://vectronic-aerospace.com/

Photo Credit: Rachel Cook

4. Radio-collared female tracking

4.1 AT A GLANCE

Animal tracking collars are a technology where Very High Frequency (VHF) radio transmitters and/or Global Positioning System (GPS) units and their associated batteries are mounted onto collars. These collars are particularly useful for monitoring distribution and habitat use, especially at the range scale (White and Garrott 1980, Chubbs *et al.* 1993, Smith *et al.* 2000, Joly *et al.* 2003, Musiani *et al.* 2007, Polfus *et al.* 2018). The sensors in these collars can also be programmed to recognize different movement activity (running vs. resting), ambient temperature, and mortality (Mech and Barber 2002, Rasiulis *et al*. 2014, Raponi *et al*. 2018). Opportunistic sampling at the time of collar installation also allows for the collection of data related to an individual's health, disease, size, and body condition. Finally, it is a common practice in Canada to combine telemetry studies with aerial survey studies to determine population trend, size, density, and recruitment (e.g. BC RIC 2002, Courtois *et al*. 2003, ASRD 2010)

Most tracking collars have both a GPS unit and VHF transmitter, allowing for both remote data collection and field-based research to be conducted (e.g. Mech and Barber 2002, WildlifeACT 2014). The main differences between the two technologies are presented in Table 1 for relative comparison:

	Very High Frequency (VHF) transmitters	**Global Positioning System (GPS)**
Data acquisition	Animals do need to be relocated: the observer searches for the animal using the radio signal from the collar, then records an observed location on a handheld GPS or map. Alternatively, radio signals are triangulated from at least 3 locations without direct observation of the animal.	Animals do not* need to be relocated: modern collars send GPS locations to the monitoring team at a pre-programmed rate, allowing for remote data collection during night or day.
Mortality sensor	Radio emits a faster radio pulse if animal has not moved for more than a pre-programmed number of hours.	Collar sends an alert message that the collar has been stationary for more than a pre-programmed number of hours.
Battery lifespan	Longer (up to 20 years)	Shorter (up to 5 years)
Overall collar weight	Lighter	Heavier (increased weight of GPS system, data transmitter, and batteries)
Price	Relatively low cost of purchase (although aircraft monitoring can be expensive)	More expensive

Table 1: *A comparison between Very High Frequency (VHF) transmitter and Global Positioning System (GPS) tracking collars (Mech and Barber 2002, WildlifeACT 2014, Rasiulis et al. 2014). *older models of GPS collars stored the data until the collar was physically retrieved, which is still an option to reduce data acquisition costs.*

4. Radio-collared female tracking

4.2 SUITABILITY FOR MONITORING

4.2.1 CARIBOU POPULATION PARAMETERS THAT CAN BE MONITORED

From Suitability Table 1: Selecting a monitoring method that best suits your objectives

x	Method is not appropriate for estimating this parameter
✓	Method provides some information or can be combined with other methods for inference
✓✓	Method provides considerable information and is appropriate for estimation
✓✓✓	Method is most appropriate and/or intended specifically for estimation of this parameter

Note: table is meant to be used in combination with the other tools in the toolkit and may not reflect regional subtleties when used alone

		Distribution			Abundance				Demography			Health			
		Distribution/ Occupancy	Dispersal/ Movement	Habitat use	Population density	Population size	Effective population size	Minimum counts	Population growth trend	Survival/ Mortality	Recruitment/ Reproduction	Body condition	Disease	Other health indices	Foraging/ Nutrition
Telemetry	Radio-collared-female tracking/sampling	✓✓	✓✓✓	✓✓✓	✓	✓	x	✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓

***Note that the only parameters listed here are the primary population metrics that are explored in detail in Comparative Table 1 to allow for standardized comparison among monitoring approaches; all other information that can be obtained from this method is detailed in following "Additional parameters and information" section.*

4.2.2 ADDITIONAL PARAMETERS AND INFORMATION THAT CAN BE MONITORED (BEYOND THOSE LISTED IN TABLE 1)

Telemetry studies require that caribou be live-captured and handled during the deployment of collars. This provides a rare opportunity to observe the animal's body condition, morphometrics, and collect samples that would otherwise be unavailable (hair, feces from a known individual, blood, or skin samples). These pieces of information can help understand individual and population health (Carlsson et al. 2019 and Ewacha et al. 2017). While efficient, this practice is not a requirement for telemetry studies to be successful. As such, we categorize the collection of the following as "opportunistic".

- A body condition index can be estimated by scoring the fatness at multiple sites and multiplying it by the body mass (Gerhart *et al*. 1996).
- Exposure to different parasites and diseases can be tested by collecting blood samples (Turgeon *et al*. 2018, Carlsson *et al*. 2019)
- Health indices such as pregnancy, age, parturition, stress, and trace minerals can be evaluated (Rettie and Messier 1998, Schaefer *et al*. 1999, Ewacha 2017)

4. Radio-collared female tracking

- Fecal, blood or tissue samples can be collected by staff in the field. Training is required for these collections (as explained for migratory caribou in Brodeur *et al*. 2017).

4.2.3 IMPLEMENTATION

- Tracking collars provide location-based data that inform patterns of distribution and habitat occupancy (White and Garrott 1980).
- Tracking collars can provide survival data. If the collar is moving, the caribou is considered alive, whereas when no movement is detected after a pre-programmed period of time, the collar indicates a change in behaviour (WildlifeACT 2014, Rasiulis *et al*. 2014). For example, Thompson et al. (2012) defined the GPS mortality 'flag' in their study as a period of 16 hours of inactivity.

Photo Credit: Chuck Grandy

- Cause of mortality can be investigated. Once the collar sends out a mortality signal, the supposed mortality site is visited to collect site information and biological samples, which often allow for the determination of cause of death. Site information can include signs of predation, stress, or natural mortality. Samples can include bones, fur, or blood (Rasiulis *et al*. 2014, Mahoney *et al*. 2016, Larter and Allaire 2018).
- Parturition and calf survival can be inferred from GPS data, based on 'pre-calving movements' (e.g. Thompson *et al*. 2012, DeMars *et al*. 2013, Larter and Allaire 2018). In their study, Thompson *et al*. noted that reduced movement may have causes other than a birthing event, and that movement patterns can be verified either by camera collars (see section 5) or by an aerial recruitment study (see section 1).
- Although a common practice, there are challenges with using collar data for population range delineation of boreal caribou (NBCKC 2019). First, male boreal caribou individuals are often not considered as they are typically not the ones targeted for collaring. This can lead to “gaps” in distribution patterns, as exemplified by Brodeur *et. al* (2017) with migratory caribou. Second, if the collars do not send location data frequently enough, there is potential for misrepresenting home range size (Joly 2005). However, if the collars send location data too often, the battery will drain more quickly, increasing the need to re-capture the animal (e.g. Mech and Barber 2002, Joly 2005). Third, Indigenous communities can be opposed to invasive monitoring techniques such as collaring, and sufficient engagement should take place to determine if this method is appropriate. For example, NBCKC (2019) found that some Traditional Knowledge holders are opposed to the collaring of caribou for range delineations. Thus, rather than using radio collar data alone to inform range boundaries, radio collar data can be augmented by observations obtained by other methods (Dzus 2001, BC RIC 2002, ASRD 2010, MNRF 2014, DeMars *et al*. 2017, MFFP 2019).

4. Radio-collared female tracking

4.2.4 ADVANTAGES

- This approach to population monitoring has a long history in Canada, providing opportunities to detect changes over space and time (NBCKC 2019, Johnson *et al*. 2020)
- Telemetry radio collars can complement other ongoing projects. For example, collars can serve as a correction factor to account for detectability challenges in aerial-based survey studies. (See "Aerial Surveys" chapter introduction, and references therein.)
- Whereas aerial surveys only provide a winter "snapshot" of distribution and occupancy, telemetry-based studies reveal seasonal distribution and occupancy patterns. Note that this assumes the sample of collared animals is of sufficiently large size, and is representative of the population (Murray 2006, or as highlighted with migratory caribou in Brodeur *et al*. 2017).

4.2.5 DISADVANTAGES

- If male caribou have not been collared as part of the monitoring program, population size, density, and sex ratios may not reliably be determined from telemetry data alone.
- Telemetry-based monitoring programs often require long-term investment in funds for deploying collars, as well as paying for the collar data fees. Deployment of collars is expensive, requires a helicopter pilot

4.3 CONSIDERATIONS AND REQUIREMENTS

From Suitability Table 2: Comparing suitability and requirements of monitoring methods:

Spatial Scale

✓ Method provides some information at this spatial scale

✓✓ Method is appropriate for application at this spatial scale

✓✓✓ Method is most appropriate for application at this spatial scale

Co-application of Indigenous Knowledge:

P – Planning D – Data collection

A – Analysis R – Reporting

***Note:** Table is meant to be used in combination with the other tools in the toolkit and may not reflect regional subtleties when used alone*

		Spatial Scale		Data Needs **		Community Involvement		Resources			Ethical Considerations		
		Local/study area	Regional/range	Minimum sampling requirements	Ability to assess data confidence	Local opportunity	Co-application of IK	Equipment costs	Personnel costs	Skills required	Capture/ handling	Potential stress from monitoring	Carbon footprint
Telemetry	Radio-collared -female tracking/sampling	✓	✓✓✓	variable (see text)	High	Low/ Med	P	High	Med	High	Yes	Low/ Med	Med

** Two spatial scale scores for Aerial imagery represent Manned and Unmanned aircraft, respectively // ** These are general guidelines only; refer to text for details of sampling requirements*

4. Radio-collared female tracking

and staff with specific skill-sets, and is fossil-fuel intensive.

- Unless yearling caribou are targeted for collaring, the age of individuals is often unknown*, and demographic estimates (reproductive success, and survival) can be biased. This may be mitigated if the age or number of years an animal has been collared can be included in analyses (Schaefer *et al*. 1999, Prichard *et al*. 2012).

**in some jurisdictions, age of individuals is estimated at time of handling, informed by teeth wear.*

4.3.1 SPATIAL SCALE

- Telemetry-based studies are often conducted at the extent of the population range, as many caribou can be monitored throughout their entire distribution during the entire annual cycle, or as long as the battery lasts.

Photo Credit: Al Arsenault

- The size of geographic area covered by a given collar can be limited by "battery life, collar weight, storage/transmission capacity, and frequency of animal recapture" (Joly 2005); however, modern collars have long lifespans, are lightweight, and can transmit locations remotely - meaning the spatial scale they cover is more often limited by the length of time that the caribou is alive and the duration of the telemetry program (Rasiulis *et al*. 2012).
- Telemetry collars are known for their ability to collect an abundance of "fine-scale spatial and temporal animal location data" (Hebblewhite *et al*. 2007) at the individual level.

4.3.2 DATA NEEDS

- For reliable survival estimates, 35 collared individuals are needed from medium-to-large sized populations (i.e., >100 individuals) or 20-30 collared individuals from small populations (i.e., 25-50 individuals) (Art Rogers, *unpublished data*).
- The required number of collars, number of locations per collar, and number of years of observations are determined by the study design and research question. Consider for example, that the objective of the study governs the needed extent and frequency of relocations: to estimate survival demands as little as one coarse relocation per month, while documenting habitat selection demands many more locations at a fine resolution.

4.3.3 COMMUNITY INVOLVEMENT

Opportunity for Local community involvement

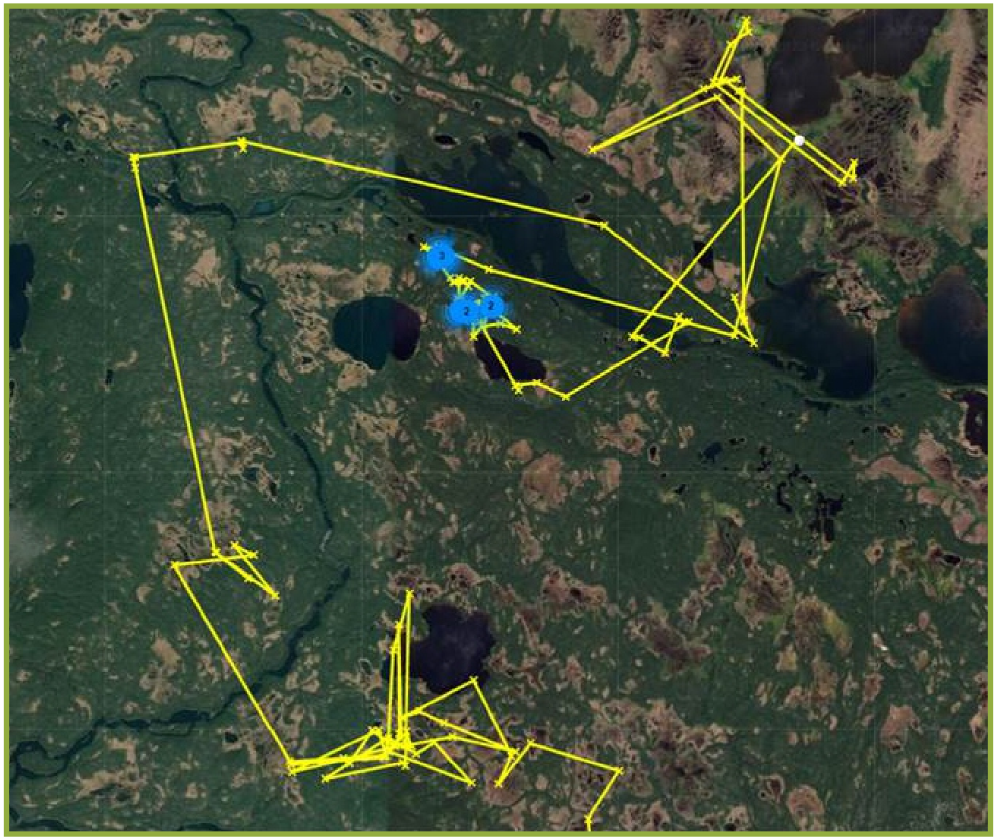
- Deploying and retrieving collars can benefit from local knowledge and the involvement of traditional knowledge holders – for instance, to assist in ensuring representative sampling across the population range and to help in live-capturing animals (following adequate training). However, the fieldwork is often brief and seasonally restricted. Once collars are deployed, the collection of radiotelemetry data is typically automated and done remotely.

4. Radio-collared female tracking

Potential for Co-application of Indigenous Knowledge

Note that any application of Indigenous Knowledge must be conducted in a manner which is agreed upon by all parties, is transparent, serves the local communities where the information originated from, and adheres to local Indigenous data governance and sovereignty.

- Planning
  - Indigenous Knowledge can be used in survey area delineation in the absence of other caribou distribution data, can be used to supplement overall caribou distribution knowledge in areas that are data deficient, and can be used to verify knowledge of caribou historical distribution.
- Data collection
  - The authors note that though no examples have been provided for this section to date, there is an opportunity to learn more about how Indigenous Knowledge can inform analysis of telemetry data. Should the reader know of information which may resolve this knowledge gap, kindly contact the NBCKC Secretariat.
- Analysis
  - The authors note that though no examples have been provided for this section to date, there is an opportunity to learn more about how Indigenous Knowledge can inform analysis of telemetry data. Should the reader know of information which may resolve this knowledge gap, kindly contact the NBCKC Secretariat.
- Reporting
  - The authors note that though no specific examples have been provided for this section to date, lessons learned through community-based monitoring programs highlight an opportunity for collaboration in reporting and knowledge-sharing of monitoring program results. For example, while scientists could lead in the development of academic papers or journal publications, local community members (notably youth) may collaborate in the interpretation of program results, and subsequently lead in knowledge sharing within their communities. As noted by Raygorodetsky and Chetkiewicz (2017) this practice has been applied when Community Based Monitoring programs are rooted in Multiple Evidence Based principles.



TELEMETRY

4. Radio-collared female tracking

Cost: $$$

Logistical Complexity: MODERATE-COMPLEX*

*Logistical complexity highly dependent on availability of qualified staff and on optimal capture conditions

4.3.4 RESOURCES

Equipment costs

- Expenses to consider in radio-collared monitoring will vary, based on: helicopter (or other aircraft) use, purchase of tracking collars, data fees associated with the collars (the cost of which varies by operating system, recording frequency and data transmission frequency), and live-capture equipment (3 or more sets of capture nets and associated buckets, a netting gun, and ankle hobbles).
- For aerial tracking and collar recovery, the helicopter (or airplane) must be configured with external antennae for telemetry relocation, as explained by Brodeur *et al.* (2017).

Personnel costs

- Trained staff are required for animal capture and collar installation, as well as for subsequent aerial tracking.
- Staff are required for monitoring incoming remote data: of particular importance is the early detection of mortality flags, to facilitate prompt visits to mortality sites.

Photo Credit: Joseph Townley

Skills required

- Field staff must be skilled in animal care and handling.
- Of particular importance to VHF-based studies, staff must be skilled in relocating collared wildlife via telemetry on the ground and from an aircraft. Staff must also be skilled in associated animal sexing, classification, and surveying.
- Live capture of caribou from a helicopter requires a pilot with a specific skill set and level of experience.
- If determining the cause of mortality for collared caribou, staff must be trained in field necropsy procedure.

Capture/Handling: YES

4.3.5 ETHICAL CONCERNS

Capture/handling

- Caribou are directly handled while GPS/VHF radio collars are being installed.
- Telemetry studies need to follow strict animal care protocols (Sikes and Gannon 2011), including limits on herding, chase, and handling times, on collar weight, and protocols to monitor the caribou's condition throughout the capture.

4. Radio-collared female tracking

- In the case of boreal caribou monitoring in Canada, specific guidelines for the weight, size, and shape for collars have not yet been established, but researchers should at least follow guidelines established by the Canadian Council on Animal Care (CCAC 2003). Modern designs that minimize collar weight are likely to minimize effects, such as impaired survival (Rasiulis *et al.* 2014). In addition, collars can be modified for juvenile caribou, to allow for tracking survival and causes of mortality (Mahoney *et al.* 2016).

Potential stress from monitoring

- Stress on the animal is low while the collared animal is being tracked (i.e. between collar mounting/removal), though the effects of wearing a collar for extended periods are subject to debate (e.g. Mech and Barber 2002 including references therein, Rasiulis *et al.* 2014, NBCKC 2019).
- A typical GPS collar for caribou, with a 4-year life expectancy, weighs about 700-900 g, which represents approximately 0.7-1.1% of the average female caribou's body weight, based on an average of 80-100 kg (Couturier *et al.* 2009).

Carbon/environmental footprint

- Medium: requires deployment to site by helicopter to fit the collars on the caribou, and if only VHF collars are being used (without GPS), then re-sighting is required. Due to the large spatial extent of caribou home ranges, this would be conducted by an aircraft as well.

4.4 EXAMPLES

LABRADOR The Newfoundland and Labrador Department of Fisheries, Forestry and Agriculture uses collared female tracking and sampling as the primary methodology for monitoring boreal caribou populations. The number of collars deployed on each sub-population is determined based from power analysis to ensure a sample size sufficient to precisely estimate annual survival rates. Adult female caribou are captured by net-gunning from a helicopter, immobilized with hobbles, and have their eyes covered with a hood. They are then fitted with a collar that logs the caribou's location every 12 hours and sends a notification to Departmental staff if the collar stops moving. These collars also emit a VHF signal, to aid in re-locating the caribou in the future. During capture, data and samples related to the caribou's health and body condition are collected. This process takes 20 minutes, after which the caribou is released and walks away. The location and activity data recorded by the collars get downloaded remotely, and provides the information needed to monitor movement rates, delineate seasonal ranges and important habitat use, and reduce sources of human disturbance to the caribou population and its range. The mortality sensors in the collars allow the estimation of annual survival rates using known-fate models. They also help establish the main causes of mortality by notifying staff when and where an animal has died so that it can be investigated. The combination of the GPS locations and VHF frequency allow improved efficiencies when conducting aerial counts or composition surveys because they inform survey stratification and help in locating animals quickly. The collars currently deployed on boreal caribou in the province have a lifespan of approximately 5 years. The data and samples collected during the collaring captures are used to study stress and reproductive hormones, estimate pregnancy rates, monitor for parasites and disease, and explore whether caribou are nutritionally challenged.

4. Radio-collared female tracking

4.4 EXAMPLES

ALBERTA The Government of Alberta uses radio-collared caribou cows to help determine the calf to cow ratio of a herd. This information gives insight on the reproductive fertility and an estimate of the net reproductive rate (R0) of a herd. This is done through aerial surveys of boreal caribou herds in the province where it is known that a caribou cow is outfitted with a VHF or satellite collar. The specific frequency of that collar is inputted into the radio receiver, and the collar is tracked until the individual is located. Individuals are confirmed through the visual identification of a collar, or even through a photograph using a telephoto lens. Once the individual is located, observers in the aircraft record the collar that has been tracked, count the total number of individuals within a group, and visually identify sex and age structure (calf/juvenile/adult) of individuals present. During boreal caribou cow-calf recruitment surveys, having one of the observers take pictures of the groups found has proven to be effective in verifying the classification of individuals once the survey is over. Finally, monitoring the same herd across multiple years allows staff to determine both the cow-calf recruitment rate and the likelihood that new individuals in the herd contribute genetically to the next generation. Low calf numbers may be used as indicative of herd stress or potentially high rates of predation on calves - further research (such as continued monitoring) is warranted in cases where this is suspected.

Photo Credit: Foothills Landscape Management Forum

5. Camera Collars

Photo Credit: Sabrina Plante

5.1 AT A GLANCE

Video camera collars are a new technology for caribou monitoring, where cameras and their associated batteries are mounted onto modified GPS collars (Thompson *et al.* 2012, Newmaster *et al.* 2013). Cameras record video for a pre-set duration at fixed intervals during the day, providing snapshots into the lives of individual animals. These cameras are especially useful in observing unusual or rarely-detected behaviours, and complement the conventional transmitters to locate and track the elusive individuals. The collars must be retrieved to collect video recordings, either by recapturing the animal or by using collars that self-detach.

The most common configuration for ungulates is to mount the camera at the base of the collar such that the lens is aimed forward, toward the back of the jaw. Lotek Wireless Inc. was the first collar company to offer these cameras as an add-on to their standard GPS collars, but more companies are now making them available (e.g. Vectronic Aerospace). In addition, cameras can be purchased directly from the camera developer (e.g. Ex-eye LLC) and subsequently mounted on existing collars. Camera-collar information can therefore be collected either independently or as a supplement to more conventional GPS collar monitoring programs.

TELEMETRY

5. Camera Collars

5.2 SUITABILITY FOR MONITORING

5.2.1 CARIBOU POPULATION PARAMETERS THAT CAN BE MONITORED

From Suitability Table 1: Selecting a monitoring method that suits your objectives

- x — Method is not appropriate for estimating this parameter
- ✓ — Method provides some information or can be combined with other methods for inference
- ✓✓ — Method provides considerable information and is appropriate for estimation
- ✓✓✓ — Method is most appropriate and/or intended specifically for estimation of this parameter

Note: table is meant to be used in combination with the other tools in the toolkit and may not reflect regional subtleties when used alone

		Distribution			Abundance				Demography			Health			
		Distribution/ Occupancy	Dispersal/ Movement	Habitat use	Population density	Population size	Effective population size	Minimum counts	Population growth trend	Survival/ Mortality	Recruitment/ Reproduction	Body condition	Disease	Other health indices	Foraging/ Nutrition
Telemetry	Camera collars	✓✓	✓	✓✓	x	x	x	x	x	✓	✓✓	✓	✓	✓	✓✓✓

***Note that the only parameters listed here are the primary population metrics that are explored in detail in Comparative Table 1 to allow for standardized comparison among monitoring approaches; all other information that can be obtained from this method is detailed in following "Additional parameters and information" section.*

Photo Credit: Agnes Pelletier

5. Camera Collars

5.2.2 ADDITIONAL PARAMETERS AND INFORMATION THAT CAN BE MONITORED (BEYOND THOSE LISTED IN TABLE 1)

- Opportunistic sampling at the time of camera collar fitting and recovery could include collection of hair, blood, fecal samples (Brockman *et al.* 2017), or body condition data if collected by trained individuals or experienced capture teams (Cook *et al.* 2010).
- Although more a function of the GPS collar than the video component per se, videos can provide some information on distribution and habitat use.
- Camera collars can provide information in addition to the categories listed above, including:
  - Weather, insect abundance/harassment, and local resource availability
  - Mortality from harvest or predation (as standard GPS collars do)
  - Social factors like group size and age/sex composition
  - Response to predators
  - Estimates of daily time budgets and energy expenditure. For example, in bears, camera collars have been used to track behaviours of stalking, sleeping, mating, grooming, and quantitative characteristics of individual predation events such as search time and handling time (Brockman *et al.* 2017)
  - Reproductive state and calving period (e.g. DeMars *et al.* 2013, Viejou *et al.* 2018, Walker *et al.* 2020)
  - Calf survival and health. Such attributes are otherwise difficult to measure since calves cannot be fitted with collars themselves. Pregnant females can be fitted with collars in winter and calf health and survival can be monitored through the mother's camera (Walker *et al.* 2020).

Photo Credit: Gerry Racey

5.2.3 IMPLEMENTATION

- Camera collars can obtain fine-scale observations of foraging behaviors. For example, videos from camera collars have been particularly helpful in the determination of summer diet selection by caribou because collection of fecal material in the summer is virtually impossible (Thompson *et al.* 2012, 2015, Cook *et al. research in progress*).
- Camera collars may be used to verify foraging habitat types, and corroborate habitat mapping data (Thompson *et al. draft ms not yet submitted*).
- The GPS function of the camera collar allows for determination of distribution and occupancy.
- Camera collars can provide valuable insight into reproductive behaviour, calf birth, calf survival, and parturition (e.g. Thompson *et al.* 2012, Gregoire 2017, Viejou *et al.* 2018, Walker *et al.* 2020).
- If camera collars are placed on caribou predators, these may be used to identify individual classes of predators responsible for the majority of mortality, which would enhance predator research and manager programs (Brockman *et al.* 2017).
- While camera collars provide information on composition of the diet and foraging behaviour, they do not allow for collection of two additional pieces of information necessary to assess nutritional value of habitats: bite mass to calculate intake (grams per unit of time) and nutrient content of the diets (energy, protein, secondary compounds).

5. Camera Collars

Currently, accurate bite mass data can be collected only through site-specific studies with tame animals. Nutrient content data can be obtained by tame animals and diet simulations and also may be assessed by analysis of stomach contents, although differential rate of digestion of different forages can bias these results (Shipley, Cook, and Hewitt, *in press*).

- Camera collars may be inappropriate when animal location is the primary concern, as this information could be obtained using a regular GPS collar without the additional weight of the camera.
- Camera collars may also be inappropriate where there is an abundance of human activity that could raise personal privacy concerns.

5.2.4 ADVANTAGES

- Camera collars can be useful to provide additional information beyond that available through regular GPS collars or camera traps.
- Camera collaring programs are often combined with existing GPS tracking programs, to cut down on costs and increase efficiency between the two monitoring methods.
- Camera collars provide insight into fine-scale details of caribou behaviour and habitat selection which were previously unknown. Such knowledge has the potential to overturn (or change) misconceptions on behaviour and habitat selection (McNeill *et al.* 2020, Thompson *et al. draft ms not yet submitted*). For example, Thompson *et al.* (2012) highlight an observation of caribou calving in a different habitat than inferred from other observation methods (not on an island as expected, but instead in lowland spruce habitat away from nearby lakes). Similarly, the Caribou Ungava research program in northern Québec observed females eating the placenta after calving and consuming many mushrooms during summer - behaviours not reported in other herds (S. Plante, personal communication)
- Cameras can be programmed to record videos at specific intervals during the day and of specified length, or to be activated by particular events (activity patterns, birth, mortality).

5.2.5 DISADVANTAGES

- Costly in terms of purchasing collars as well as deployment and retrieval (though less costly if combined with other collar-based telemetry monitoring programs).
- Similar to most other telemetry collars, the current size and weight of camera collars, as well as the lack of expandable collar material, prohibits their use on calves (Rasiulis *et al.* 2014).

Photo Credit: OMNRF

5. Camera Collars

- The field of view is limited and what is observable depends on camera placement (Cook *et al. research in progress*).
- Video quality depends on ambient condition. For instance, if deployed during rainy or snowy seasons, the video may be foggy or blurry; data cannot be collected at night; and bright sunny conditions reduce the quality of videos for analysis (Thompson *et al.* 2012, Cook *et al. research in progress*).
- Camera failure rates may be high, and battery life limits the amount of video that can be recorded before collection. Exeye camera collars have 104 hours of available recording time, but with battery loss of 10-15% per month, they may only be able to record about 24 hours of video over 36 weeks (Thompson *et al.* 2012, Cook *et al. research in progress*).
- Collars must be retrieved (either by re-capturing the animal or through drop-off methods) to obtain the video as there is currently no capability for satellite-based transfer.
- This technique for diet studies is in need of independent, rigorous evaluation of its reliability and accuracy, as there exists variation among animals, habitat conditions, video quality and video observers. At this stage, caution should be given regarding data interpretation until additional evaluation occurs (Cook *et al. research in progress*).
- Analysis is typically very time consuming, as studies can produce tens of thousands of clips (Thompson *et al.* 2015, Cook *et al. research in progress*).
- The accuracy of analysis can depend on the expertise of the viewer (e.g. their knowledge of local flora, caribou behaviour) (Cook *et al. research in progress*).

Photo Credit: Agnes Pelletier

5. Camera Collars

5.3 CONSIDERATIONS AND REQUIREMENTS

From Suitability Table 2: Comparing suitability and requirements of monitoring methods

Spatial Scale

- ✓ Method provides some information at this spatial scale
- ✓✓ Method is appropriate for application at this spatial scale
- ✓✓✓ Method is most appropriate for application at this spatial scale

Co-application of Indigenous Knowledge:
P – Planning D – Data collection
A – Analysis R – Reporting

Note: *Table is meant to be used in combination with the other tools in the toolkit and may not reflect regional subtleties when used alone*

		Spatial Scale		Data Needs **		Community Involvement		Resources			Ethical Considerations		
		Local/study area	Regional/range	Minimum sampling requirements	Ability to assess data confidence	Local opportunity	Co-application of IK	Equipment costs	Personnel costs	Skills required	Capture/ handling	Potential stress from monitoring	Carbon footprint
Telemetry	Camera collars	✓✓✓	✓	variable (see text)	Unkn.	Med	P, A	High	Med/ High	Med	Yes	Low/ Med	Med

** Two spatial scale scores for Aerial imagery represent Manned and Unmanned aircraft, respectively // ** These are general guidelines only; refer to text for details of sampling requirements*

5.3.1 SPATIAL SCALE

- Camera collars are best suited to fine-scale studies (e.g. a subset of a population's range) because of their limited battery life expectancy, however camera collars have also been used to record the summer and fall migrations of migratory caribou covering hundreds of kilometres.
- Data from multiple fine-scale studies may be scaled up to the range-scale depending on the level of accuracy of the data, sufficient sample size (i.e., number of collars deployed, and length of video collected), and maps of important habitat features.

5.3.2 DATA NEEDS AND CONFIDENCE

Minimum samples per year

- Sampling frequency is somewhat dependent on the camera collars themselves, as camera settings affect the battery life and thus how long the collars can be left on the animal. The earliest versions of camera collars provided approximately 24 hours of video recording over 36 weeks (Thompson *et al.* 2012), but more recent products can provide up to 70 hours of video. Thus, the duration and frequency of video clips determine the amount of time they are deployed before retrieval.

5. Camera Collars

- It is unknown how the duration and frequency of videos affects confidence in the data. Optimal sampling strategies need further consideration and evaluation as this method continues to be developed. For example, though 10-second videos on the hour during daylight hours may be enough to capture presence of calf or other life history features, it may not be enough for precise representation of diet composition or time budgets. More work is needed on this topic.

Photo Credit: Doug MacNearney

Minimum sampling years

- Objectives for using the camera collars will greatly influence the number of years of data collection needed.
- In general, at least two years of data help to account for year-to-year variation in weather and other factors.
- For demographic estimates, as with regular GPS collars, at least one year of data is required to determine survival; for calf survival specifically, at least one year of data is needed and females need to be fitted while pregnant.

Ability to assess data confidence

- This is currently the biggest “unknown” associated with this monitoring methodology. Cook *et al.* (*research in progress*) put video collars on tame caribou, elk, moose, white-tailed deer, and mule deer to compare diet composition estimated from video collars to the 'gold standard' of fine-scale foraging data: direct observations using tame animals. This study was designed to look at influences of habitat conditions (e.g., density of vegetation), how the animal forages (e.g., how fast they eat, how diverse their diets are, whether there is a bias depending on what they eat relative to head position), ambient conditions (e.g., weather, time of day), observer experience (e.g., students, plant taxonomist specialists, foraging ecology specialists), and whether these vary across ungulate species. This project is still in the analysis phase, but preliminary results suggest limitations with the technique for fine-scale foraging applications (Cook *et al., research in progress*)
- For calf survival, time of death can usually be determined to within one or two days, as the calf is usually seen on video recordings every day; Caribou Ungava research has shown that the date of calf death can often be determined with camera collars (e.g. Vuillaume PhD project 2015-present: see example section below).

5. Camera Collars

5.3.3 COMMUNITY INVOLVEMENT

Opportunity for Local community involvement

- Video observation of behaviours, feeding habitat, and movement can be validated with observations by community members
- Videos can also be shared with community members
- Local community members can be trained to analyze footage and provide interpretation of observed behaviours

Potential for Co-application of Indigenous Knowledge

Note that any application of Indigenous Knowledge must be conducted in a manner which is agreed upon by all parties, is transparent, serves the local communities where the information originated from, and adheres to local Indigenous data governance and sovereignty.

- Planning
    - o Indigenous Knowledge can be used to help delineate the survey area, can be used to supplement overall caribou distribution knowledge in areas that are data deficient, or can be used to verify knowledge of caribou historical distribution.
    - o Indigenous Knowledge can be used to inform areas where camera collars may be deployed to gain further insights into caribou behaviours.
- Data collection
    - o The authors note that though no examples have been provided for this section to date, there is an opportunity to learn more about how Indigenous Knowledge can inform analysis of telemetry data. Should the reader know of information which may resolve this knowledge gap, kindly contact the NBCKC Secretariat.
- Analysis
    - o The authors note that though no examples have been provided for this section to date, there is an opportunity to learn more about how Indigenous Knowledge can inform analysis of telemetry data. Should the reader know of information which may resolve this knowledge gap, kindly contact the NBCKC Secretariat.
- Reporting
    - o The authors note that though no specific examples have been provided for this section to date, lessons learned through community-based monitoring programs highlight an opportunity for collaboration in reporting and knowledge-sharing of monitoring program results. For example, while scientists could lead in the development of academic papers or journal publications, local community members (notably youth) may collaborate in the interpretation of program results, and subsequently lead in knowledge sharing within their communities. As noted by Raygorodetsky and Chetkiewicz (2017) this practice has been applied when Community Based Monitoring programs are rooted in Multiple Evidence Based principles.

Photo Credit: Lukas Mundy

5. Camera Collars

Cost: $$$

5.3.4 RESOURCES

Equipment costs

- High equipment costs – can cost upwards of CAN$4,000 per camera collar; however, they may be refurbished and purchased for approximately CAN$1,200.
- Collars with timed drop-offs may be more expensive. Drop-offs are ~CAD$400 if purchased separately, though are usually included in a "collar bundle" (Lotek, Newmarket, Ontario).
- High costs associated with deployment and retrieval, as this is often done using a helicopter, though can be reduced by combining camera studies with other collar-based monitoring efforts.

Personnel costs

- Moderate to high personnel costs. Very time-consuming to deploy and retrieve the collars – this can be made more cost-effective by adding to other ongoing deployment and capture efforts for other objectives.
- Significant training or expertise may be required, as footage review and analysis can be very time-consuming.

Photo Credit: Gerry Racey

Logistical Complexity: MODERATE-COMPLEX*

*Logistical complexity highly dependent on availability of qualified staff and on optimal capture conditions

Skills required

- Requires moderate skill level for the deployment and retrieval of collars – the methodology is not too complex but fitting collars should be done by experienced staff.
- A higher skill level may be required to analyze the videos – depending on the objectives, volunteers/students may be able to do this, but in other cases, contracting a plant taxonomist or other botanical expert may be required.

Capture/Handling: YES

5.3.5 ETHICAL CONCERNS

Capture/handling

- Capturing and handling the animal is required for the deployment of collars. Further capture and handling may be necessary to retrieve collars without a timed drop-off mechanism that release the collars for retrieval.
- If conducted by well-trained personnel, adding a video camera into ongoing telemetry collar projects adds no *additional* handling time or stress for the animal.

Potential Stress from monitoring

- Stress on the animal is low while the collared animal is being tracked (i.e. between collar mounting/removal), though the effects of wearing a collar for extended periods are subject to debate (e.g. Mech and Barber 2002 including references therein, Rasiulis *et al.* 2014, NBCKC 2019).

5. Camera Collars

- Larger batteries allow for longer videos, but also add more weight to the collar. The most recent camera collars weigh <500 g but may only be suitable for a single year of study due to a reduced battery supply.

Carbon/environmental footprint

- Because of the need for helicopter use in deployment of collars, the carbon footprint is moderate or high. However, the additional carbon footprint of the cameras is low.

5.4 EXAMPLES

NORTHERN ONTARIO In Canada, camera collars were developed to conduct nutritional studies in Northern Ontario (Thompson *et al.* 2012, 2015; Newmaster *et al.* 2013). Since then, videos from camera collars have been used to assess additional aspects of caribou life history and habitat selection patterns (McNeill *et al.* 2020, Thompson *et al. draft ms not yet submitted*). For instance, in a recent study, Walker *et al.* (2020) used video collars to evaluate a model (DeMars *et al.* 2013) that aimed to predict birth events (parturition) and mortality events within 4 weeks after birth. The initial identification of parturition and neonatal mortality events would not have been possible without the video-collar footage, because it allowed the researchers to evaluate the accuracy of the DeMars *et al.* (2013) modelling approach. Due to the model's high accuracy at predicting parturition (100%) and neonatal mortality (88%), the model was then tested using additional caribou with unknown reproductive status. The researchers then used the GPS location data associated with the video collars to a) determine habitat selection during the neonatal and post-partum time periods and b) evaluate the risk of neonatal mortality within 35 days postpartum in relation to linear features and land cover types.

NORTHERN QUÉBEC There are two ongoing projects in the Caribou Ungava research program that use camera collars. Vuillaume *et al.* (*in prep.*) are using camera collars to evaluate calf survival from birth (June) to September. Traditionally a classification is conducted in November to assess recruitment, but there was little known about the period between birth and fall classification. Through the use of camera collars, this work has permitted the matching of mothers and calves, and assessment of daily calf survival. Béland *et al.* (*in prep*) are using camera collars to assess fine-scale habitat selection at two scales of analysis: 1) selection of local habitat used for feeding, and 2) selection of food resources among those available. The researchers have developed an access sheet to record all relevant information, to streamline the very time-consuming process of extracting detailed information from videos (much of which has been conducted by employing undergraduate students). In addition to these targeted types of data, the videos have provided additional qualitative descriptions of insect abundance (absent, medium abundance, abundant), representing the first time that fine-scale insect abundance can be evaluated in relation to migratory caribou. For more information on this ongoing research, see the project website https://www.caribou-ungava.ulaval.ca/en/accueil/.

REFERENCES

Arsenault, A.A. (2003). Status and conservation management framework for woodland caribou (*Rangifer tarandus Caribou*) in Saskatchewan. Saskatchewan Environment Fish and Wildlife Technical Report 2003-03. 40 pp.

Alberta Sustainable Resource Development (ASRD). (2010). Aerial Ungulate Survey Protocol Manual.

British Columbia Resources Inventory Committee (BC RIC). (2002). Aerial-based Inventory Methods for Selected Ungulates: Bison, Mountain Goat, Mountain Sheep, Moose, Elk, Deer and Caribou. ISBN: 0-7726-4704-6

Brockman, C. J., Collins, W. B., Welker, J. M., Spalinger, D. E., & Dale, B. W. (2017). Determining kill rates of ungulate calves by brown bears using neck-mounted cameras. Wildlife Society Bulletin 41, 88–97

Brodeur, V., Rivard, S., Dussault, C., Harvey, L., & Taillon, J. (2017). The Use of Satellite Telemetry to Estimate the Abundance of a Migratory Caribou Population. Québec. Ministère des Forêts, de la Faune et des Parcs, 25 pages. Technical report.

Canadian Council on Animal Care. (CCAC) (2003). Guidelines on the care and use of wildlife. Canadian Council on AnimalCare, Ottawa, Ont.

Carlsson A. M., Curry, P., Elkin, B., Russell, D., Veitch, A., Branigan, M., *et al.* (2019) Multi-pathogen serological survey of migratory caribou herds: A snapshot in time. PLoS ONE 14, e0219838.

Chubbs, T. E., Keith, L. B., Mahoney, S. P., & McGrath, M. J. (1993). Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland. Canadian Journal of Zoology 71, 487-493.

Cook, R. C., Cook, J. G., Stephenson, T. R., Myers, W. L., McCorquodale, S. M., Vales, D. J., Irwin, L. L., Hall, P. B., Spencer, R. D., Murphie, S. L., Schoenecker, K. A., & Miller, P. J. (2010). Revisions of rump fat and body scoring indices for deer, elk, and moose. Journal of Wildlife Management 74, 880–896.

Cook, R. C., Berry, S. L., Crouse, J. A., Cook, J. G., Shipley, L. A., Denryter, K. A., Ulappa, A. *et al. Research in progress*. Evaluation of video collars for use in foraging ecology of large ungulates.

Courtois, R., Gingras A., Dussault, C., Breton, L., & Ouellet, J-P. (2003). An aerial survey technique for the forest-dwelling ecotype of Woodland Caribou, *Rangifer tarandus caribou*. Canadian Field-Naturalist 117, 546-554.

Couturier, S., S. D. Coté, J. Huot, and R. D. Otto. 2009. Body condition dynamics in a northern ungulate gaining fat in winter. Canadian Journal of Zoology 87:367-378.

DeMars, C. A., Auger-Méthé, M., Schlägel, U. E., & Boutin, S. (2013). Inferring parturition and neonate survival from movement patterns of female ungulates: a case study using woodland caribou. Ecology and Evolution 3, 4149–4160.

DeMars, C., Boulanger, J., & Serrouya, R. (2017). A literature review for monitoring rare and elusive species, and recommendations on survey design for monitoring boreal caribou. Technical report. Caribou Monitoring Unit, Alberta Biodiversity Monitoring Institute. https://cmu.abmi.ca/wp-content/uploads/2017/10/REPORT_DeMars_et_al_Lit-review-and-recommendations-report-MarchFINAL.pdf

Dzus, E. (2001). Status of the woodland caribou (*Rangifer tarandus caribou*) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association. Wildlife Status Report No. 30. Edmonton, AB. 47 pp.

Environment Canada. (2011). Scientific Assessment to Inform the Identification of Critical Habitat for Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada: 2011 Update. https://www.registrelep-sararegistry.gc.ca/virtual_sara/files/ri_boreal_caribou_science_0811_eng.pdf

Ewacha, M. V. A., Roth, J. D., Anderson, W. G., Brannen, D. C. & Dupont, D. L. J. (2017). Disturbance and chronic levels of cortisol in boreal woodland caribou. Journal of Wildlife Management 81, 1266-1275. doi:10.1002/jwmg.21288

Galpern, P. & Manseau, M. (2013). Modelling the influence of landscape connectivity on animal distribution: a functional grain approach. Ecography 36, 1004-1016. doi:10.1111/j.1600-0587.2012.00081.x

Gerhart, K. L., White, R.G., Cameron, R.D. & Russell, D.E. (1996). Estimating fat content of caribou from body condition scores. Journal of Wildlife Management 60, 713-718.

Gregoire, L. (2017). Caribou cams show calf birth, herd behaviour in Nunavik. Caribou Ungava project uses camera collars to track Leaf River herd. Nunatsiaq News. Accessed online from https://nunatsiaq.com/stories/article/65674caribou_cams_show_calf_birth_herd_behaviour_in_nunavik/ on February 02, 2020.

Hebblewhite, M., Percy, M., & Merrill, E. H. (2007). Are all global positioning system collars created equal? Correcting habitat-induced bias using three brands in the central Canadian rockies. Journal of Wildlife Management 71, 2026-2033

Hervieux, D., Hebblewhite, M., DeCesare, N. J., Russell, M., Smith, K., Robertson, S., and Boutin, S. (2013). Widespread declines in woodland caribou (*Rangifer*

REFERENCES

tarandus caribou) continue in Alberta. Canadian Journal of Zoology 882, 872–882.

Joly, K., Dale, B. W., Collins, W. B., & Adams, L. G. (2003). Winter habitat use by female caribou in relation to wildland fires in interior Alaska. Canadian Journal of Zoology 81, 1192-1201.

Joly, K. 2005. The effects of sampling regime on the analysis of movements of over-wintering female caribou in east-central Alaska. *Rangifer* 25, 67-74

Johnson, C. A., Sutherland, G. D., Neave, E., Leblond, M., Kirby, P., Superbie, C. & McLoughlin, P. D. (2020). Science to inform policy: Linking population dynamics to habitat for a threatened species in Canada. Journal of Applied Ecology (In press). doi:10.1111/1365-2664.13637

Larter, N. C., & Allaire, D. G. (2010). Dehcho boreal caribou study progress report, April 2010. Environment and Natural Resources, Fort Simpson. https://www.enr.gov.nt.ca/sites/enr/files/resources/progrep15_dehcho_boreal_caribou_study_final_ncl_2.pdf

Lavelle, M. J., Blass, C. R., Fischer, J. W., Hygnstrom, S. E., Hewitt, D. G., & VerCauteren, K. C. (2015). Food habits of adult male white-tailed deer determined by camera collars. Wildlife Society Bulletin 39, 651–657.

Mahoney, S. P., Lewis, K. P., Weir, J. N., Morrison, S. F., Glenn Luther, J., Schaefer, J. A., Pouliot, D. & Latifovic, R. (2016). Woodland caribou calf mortality in Newfoundland: insights into the role of climate, predation and population density over three decades of study. Population Ecology 58, 91-103. doi:10.1007/s10144-015-0525-y

McNeill, E. P., Thompson, I. D., Wiebe, P. A., Street, G. M., Shuter, J., Rodgers, A. R., & Fryxell, J. M. (2020). Multi-scale foraging decisions made by woodland caribou (*Rangifer tarandus caribou*) in summer. Canadian Journal of Zoology 98, 331-341. https://doi.org/10.1139/cjz-2019-0197.

Mech, L. & Barber, M. (2002). A Critique Of Wildlife Radio-tracking And Its Use In National Parks. U.S. National Park Service Report. 1-78.

Ministère des Forêts, de la Faune et des Parcs, Gouvernement du Québec (MFFP). (2019). Inventaire aérien du caribou forestier (*Rangifer tarandus caribou*) au cours de l'hiver 2019 dans le secteur de la Basse Côte-Nord. ISBN: 978-2-550-85343-5

Ministry of Natural Resources and Forestry, Government of Ontario (MNRF). (2014). Integrated Assessment Protocol for Woodland Caribou Ranges in Ontario. Species at Risk Branch, Thunder Bay Ontario, vii + 95pp.

Murray, D. L. (2006). On improving telemetry-based survival estimation. Journal of Wildlife Management 70, 1530–1543.

Musiani, M., Leonard, J.A., Cluff, H.D., Gates, C.C., Mariani, S., Paquet, P.C., Vilá, C. & Wayne, R.K. (2007). Differentiation of tundra/taiga and boreal coniferous forest wolves: genetics, coat colour and association with migratory caribou. Molecular Ecology 16, 4149-4170.

Newmaster, S. G., Thompson, I. D., Steeves, R. A. D, Rodgers, A. R., Fazekas, A. J., Maloles, J. R., McMullin, R. T., & Fryxell, J. M. (2013). Examination of two new technologies to assess the diet of woodland caribou: video recorders attached to collars and DNA barcoding. Canadian Journal of Forest Research 43, 897–900.

Polfus, J. L., Heinemeyer, K., Hebblewhite, M., & Taku River Tlingit First Nation. (2014). Comparing Traditional Ecological Knowledge and western science in woodland caribou habitat models. Journal of Wildlife Management 78, 112-121.

Prichard, A. K., Joly, K., & Dau, J. (2012). Quantifying telemetry collar bias when age is unknown: a simulation study with a long-lived ungulate. Journal of Wildlife Management 76, 1441–1449. DOI: 10.1002/jwmg.394

Raponi, M., Beresford, D. V., Schaefer, J. A., Thompson, I. D., Wiebe, P. A., Rodgers, A. R. & Fryxell, J. M. (2018). Biting flies and activity of caribou in the boreal forest. Journal of Wildlife Management 82, 833-839. doi:10.1002/jwmg.21427

Rettie, W. J. & Messier, F. (1998). Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. Canadian Journal of Zoology 76, 251-259.

Rasiulis, A. L. V., Schmelzer, I., & Wright, C. G. (2012) The effect of temporal sampling regime on the characterization of home range for female boreal woodland caribou (*Rangifer tarandus caribou*) in Labrador, Canada. Rangifer, 20, 227-239.

Rasiulis, A. L., Festa-Bianchet, M., Couturier, S., & Côté, S.D. (2014). The effect of radio-collar weight on survival of migratory caribou. Journal of Wildlife Management 78, 953–956; DOI:10.1002/jwmg.722

Schaefer, J., Veitch, A., Harrington, F., Brown, W., Theberge, J., & Luttich, S. (1999). Demography of Decline of the Red Wine Mountains Caribou Herd. Journal of Wildlife Management 63, 580-587. doi:10.2307/3802646

Shipley, L. A, R. C. Cook, and D. G. Hewitt. In press (2020). Techniques for Wildlife Nutritional Ecology. Pages 439-482 in N. J. Silvy, editor. Research and management techniques for wildlife and habitats. Eighth edition. The Wildlife Society, Bethesda, Maryland, USA.

Sikes, R. S., & Gannon, W. L. (2011). Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92, 235-253.

REFERENCES

Smith, K. G., Ficht, E. J., Hobson, D., Sorensen, T. C., & Hervieux, D. (2000). Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology 78, 1433-1440.

Thompson, I. D., Bakhtiari, M., Rodgers, A. R., Baker, J. A., Fryxell, J. M., & Iwachewski, E. (2012). Application of a high-resolution animal-borne remote video camera with global positioning for wildlife study: observations on the secret lives of woodland caribou. Wildlife Society Bulletin 36, 365–370; DOI: 10.1002/wsb.130.

Thompson, I. D, Wiebe, P. A., Mallon, E., Rodgers, A. R., Fryxell, J. M., Baker, J. A., & Reid, D. (2015). Factors nfluencing the seasonal diet selection by woodland caribou (*Rangifer tarandus tarandus*) in boreal forests in Ontario. Canadian Journal of Zoology 93, 87-98.

Turgeon, G., Kutz, S. J., Lejeune, M., St-Laurent, M.-H., & Pelletier, F. (2018). International Journal for Parasitology: Parasites and Wildlife 2, 90-94.

Vuillaume, B. (2015-ongoing). PhD project: Camera collars to study calf survival. Accessed on April 04, 2020, from: https://www.caribou-ungava.ulaval.ca/fileadmin/documents/Capsules/capsule__15_EN.pdf

Viejou, R., Avgar, T., Brown, G. S., Patterson, B. R., Reid, D. E. B., Rodgers, A. R., Shuter, J., Thompson, I. D., & Fryxell, J. M. (2018). Woodland caribou habitat selection patterns in relation to predation risk and forage abundance depend on reproductive state. Ecology and Evolution 8, 5863–5872. DOI: 10.1002/ece3.4124.

White, G. C., & R. A. Garrott. (1990). Analysis of wildlife radio-telemetry data. Academic Press, New York, New York, USA.

Walker, P., Rodgers, A. R., Shuter, J. L., Thompson, I. D., Fryxell, J. M., Cook, J. G., Cook, R. C., & E. H. Merrill. (2020). Comparison of woodland caribou calving areas determined by movement patterns in northern Ontario. Journal of Wildlife Management (*in press*). DOI:10.1002/jwmg.21961

WildlifeACT. (2014). GPS and VHF Tracking Collars used for Wildlife Monitoring. Accessed online from https://wildlifeact.com/blog/gps-and-vhf-tracking-collars-used-for-wildlife-monitoring/ on March 25, 2020.

Photo Credit: Walter Andreef

Back Cover Photo Credit: Gerry Racey