Adaptive Co-Management Framework

Barren-ground Caribou Technical Working Group

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Background

In 2019, the Wek'èezhìı Renewable Resources Board (WRRB) recommended[1] that an adaptive management framework be collaboratively developed with the WRRB, Government of the Northwest Territories (GNWT) and Tłı̨chǫ Government (TG) for the Bluenose-East and Bathurst caribou herds (Appendix A) to guide how the Barren Ground Caribou Technical Working Group (BGCTWG[2]) considers monitoring information. The WRRB staff and technical adviser have led the collaboration by drafting the framework and seeking input from the BGCTWG. Between November 29, 2019 and present, the WRRB has been providing new sections of the framework for discussion at BGCTWG meetings.

The WRRB is suggesting that to avoid "re-inventing the wheel", the framework be built on what was already accepted in 2010 and 2019 (Appendix A). The key points in 2010 were to:

1) allow reconsideration of the implementation of management actions without lengthy delays by having three assessments of monitoring information including Tłı̨chǫ monitoring (Appendix B) each year; and
2) ways of measuring success so that adjustments can be made if results are not achieved or if conditions change such that a different approach is warranted.

This framework is for the BGCTWG to assess the monitoring data that becomes available throughout the year and use it to reassess the implementation success of management and monitoring activities. The framework will encourage collaborative understanding and discussions considering the different sets of indicators. The need to step co-management forward using both Indigenous and Scientific knowledge is being increasingly recognized.

Table A1 describes current technical monitoring of the Bathurst herd. A similar table was submitted as part of the 2019 Joint Management Proposal for Bluenose East. Previously, most scientific monitoring results were reported in the GNWT calving ground survey reports or in joint proposals for WRRB which were every 2 or 3 years. This Adaptive Management Framework aims to incorporate the technical monitoring indicators into assessment and adjustment of the implementation of management actions three times a year. For example, the adaptive management framework will not lead to changes in total allowable harvest, but instead how a total allowable harvest is implemented, and monitored. In the case of wolf management, the adaptive management framework could help identify where implementation could be adjusted to meet the objectives of the program.

The Advisory Committee for Cooperation on Wildlife Management (ACCWM) has developed the Taking Care of Caribou Management Plan for Bluenose-east, Bluenose-west, and Cape-Bathurst herds (ACCWM, 2014). The Bathurst Caribou Advisory Committee is in the process of finalizing the Bathurst Caribou Management Plan. The Adaptive Co-management Framework was designed to compliment the work of these Committees. The BGCTWG recognizes that different decision-making bodies and agencies exist for the Bluenose-East and Bathurst Caribou herds and wishes to support these systems with targeted and timely results of herd monitoring to support management decisions.

Adaptive Management Background

Adaptive management is not simply monitoring and occasionally changing management actions. An adaptive approach involves systematically proposing alternative ways (pathways) to meet management objectives and predicting the outcomes of those alternatives based on the current state of knowledge. After implementing one or more of these alternatives, monitoring is undertaken to learn about the impacts of

[1] Board's Recommendation #17-2019 (Kǫk'èetì Ekwǫ̀) and Recommendation #9-2019 (Sahtì Ekwǫ̀),

[2] The BGCTWG was established in 2011 to to develop and implement management and monitoring activities for barren-ground caribou and their habitat within Wek'èezhìı.

management actions, and results are then used to update knowledge and adjust management actions. Adaptive management focuses on learning and adapting, through shared knowledge to determine together how to create and maintain sustainable resource systems.

Adaptive management is often applied to reduce uncertainty and increase knowledge of a wildlife system. An initial step is to define the logical pathways to management actions; alternative pathways may also be defined. Following implementation of the management action(s), indicators are monitored to describe responses to the management actions which test validity of the pathway and assess effectiveness of the management action. This adaptive management cycle is often iterative over time. Implementing adaptive management is made robust by a more diverse inclusion of knowledge (Holling and Meffe 1996).

We define adaptive management as comparing monitoring results to our expectations about what proposed actions may achieve and consequently revising management actions based on what we learned. By collaborating on the detailed pathways, we aim to be clear and specific about the required monitoring and how it can be used to modify management actions and minimize surprises (unpredicted) events (Runge 2011).

In caribou management, we often must choose a management action despite limited understanding and high uncertainty. This can lead to disagreement among stakeholders who have different views on the implication of management actions. An adaptive approach states these viewpoints, incorporates them into the decision-making, and uses management itself to help identify the most appropriate action. In this way, we can better understand caribou through time and management can be improved. "*The rationale for AM is that it permits managers to take action in managing complex ecosystems without waiting for all the scientific uncertainties around such action to be resolved*" (Tyler, 2008, p.7)

Adaptive Co-Management Framework

We use the term Adaptive Co-Management to have a more formal meaning than simply learning from experience. We are in agreement with Williams (2011) who wrote, *"…a key difference between scientific investigation and adaptive decision-making is that the treatments in adaptive management are management interventions, chosen to achieve management objectives as well as learning".* We have called the collaborative work we are doing for Barren-ground caribou an "Adaptive Co-Management Framework" as it is based on more than one knowledge base and culture and is in a co-management context. This Framework builds on existing management approaches currently in place on the Bathurst and Bluenose-East herd and with the published literature (Tyler 2008, Berkes 2009). The framework outlines logical pathways linking problems such as a declining herd caused by low cow survival with proposed actions such as reducing predators or harvest levels to directly increase adult survival. However, we recognize that predator and harvest management actions are not robust tests of research hypotheses as we do not have research controls or reference populations, and there are potential confounding factors. Our focus away from hypothesis testing to collaborative decision-making (through adaptive co-management) may be more practical (Scarlett 2013) than formal adaptive management.

The concept of an adaptive co-management framework requires thresholds, decision points or benchmarks, and the last named is our preferred term (Addison et al. 2016, Cook et al. 2016, Peacock et al. 2020). Applying benchmarks emphasize the logic and transparency of how the monitoring data are providing feedback on the outcomes of management actions and if and how they should be modified. As the possible management actions are relatively few and are assessed through more than one indicator, we have developed a framework that integrates and maps how multiple monitoring indicators may be used for specific benchmarks in Appendix D (Foster et al. 2019). To help us understand the multiple factors influencing caribou populations and to assess whether management actions are making a difference, the monitoring results for the current year are compared to the previous year's benchmark (or the previous monitoring results for the indicators that are not sampled at annual intervals). For indicators that have been monitored relatively consistently, we will also assess trend(s) and patterns over longer periods (multiple years).

Adaptive Management Framework and Bathurst and Bluenose-East herd management planning

The adaptive management framework is in parallel with the wider scale of herd management planning. In essence, the framework provides a collaborative way of implementing adaptive management and will benefit herd management planning through the experience of developing indicators, benchmarks, applying them to management activities and monitoring the results. The adaptive management framework is directed at the annual implementation and evaluation of management actions; whereas herd management planning is applied over a longer-term and considers the herd's natural cycles in abundance. The framework seeks to incorporate an array of indicators to assess whether management actions are modifying caribou trends and recognizes complexity and interconnectedness of contribution factors affecting caribou demography. Figure 1 illustrates the caribou year and the approximate timing of monitoring actions. Figure 2 depicts the monitoring actions and the proposed annual review of monitoring results. This is expanded upon in table 2.

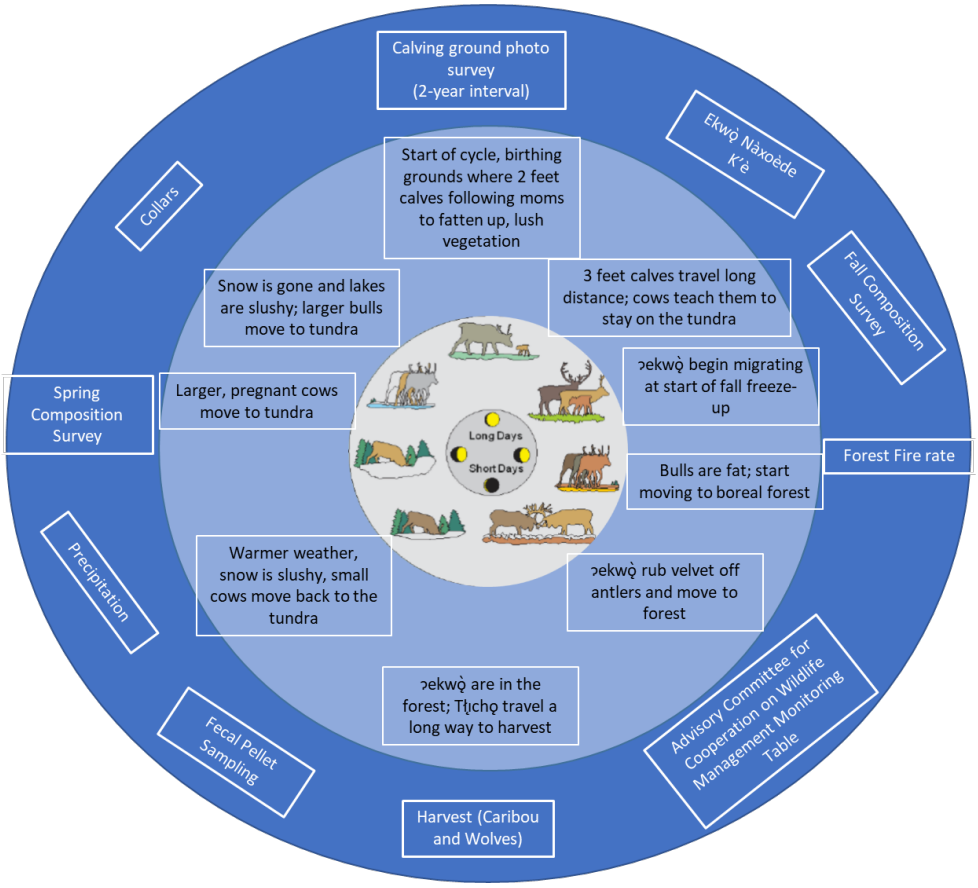

Figure 1. A description of the caribou year and the approximate timing of monitoring actions.

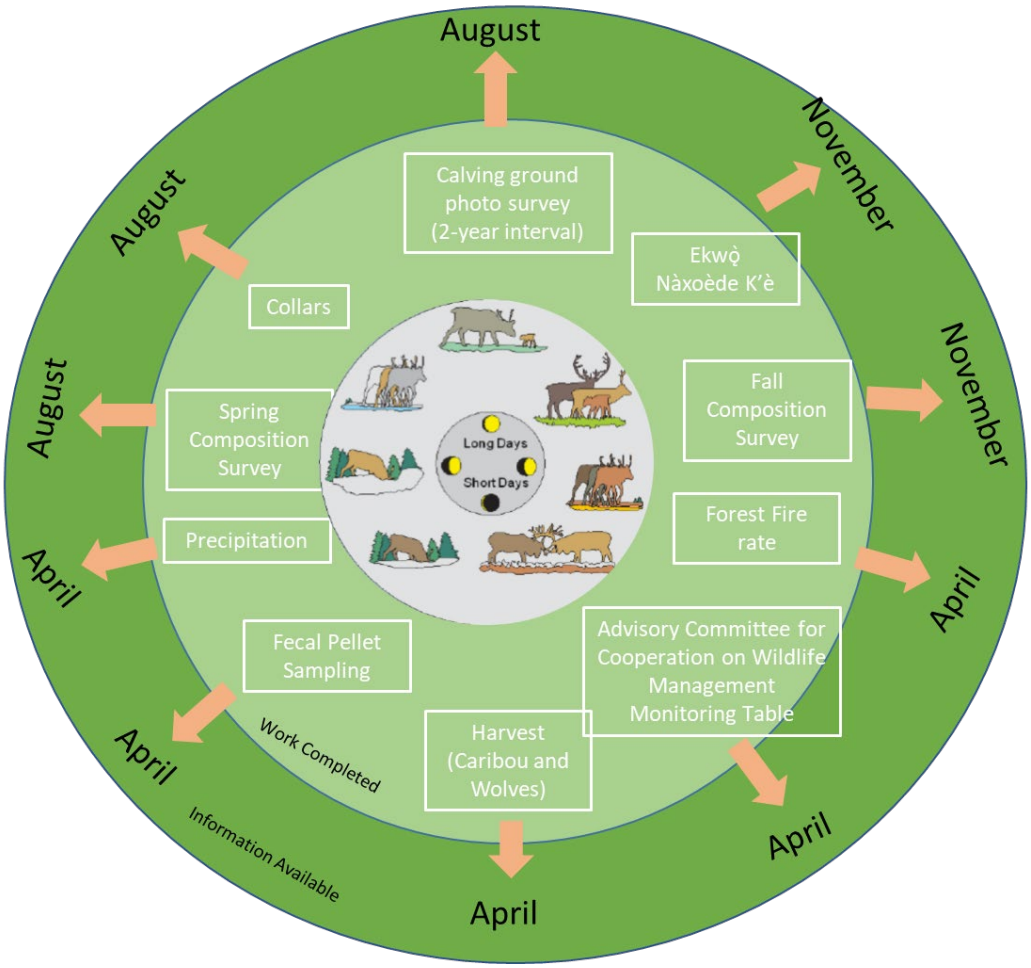

Figure 2. An Illustration of timing of indicator collection and assessment periods.

STEP 1 Selecting Indicators

The adaptive co-management framework identifies indicators relevant to management objectives (Tyler, 2008) and for which data exist (or can be easily gathered) and, critically, through different knowledge systems. We have relied on the Tłı̨chǫ selection of indicators (Table 1, Appendix B) which have similarities to hunter's experience and knowledge elsewhere that are used as indicators for the Porcupine Caribou Herd (ABEKS 2014, Gagnon et al 2020). The scientific indicators for caribou and their measurement are well-established for caribou (Gunn and Russell 2007, Gunn and Eamer 2008). The scientific indicators reflected in Figures 1 and 2 and Table 2 generally reflect the monitoring activities conducted by ENR but actual activities are subject to annual budget allocations and therefore may differ from year to year. The ACCWM has developed a set of community-based and scientific monitoring indicators for use in implementing the Taking Care of Caribou Management Plan (ACCWM, 2014; Appendix C). Though relevant to Bathurst and Bluenose East, information is collected annually by the ACCWM for the Bluenose-East and so references to the ACCWM indicators in Table 2 are for use in the Adaptive Management Framework for Bluenose-East only at this time.

We have recognized the different ways indictors are measured. The Tłı̨chǫ indicators are based on accumulated caribou knowledge and experience which can be expressed as the extent of change relative to what is normal or expected. Currently, the Tłı̨chǫ indicators are monitored during late summer/fall which is a key time to understand how caribou have fared earlier in the summer, their condition just before the rut and in

preparation for the winter. The ACCWM community-based monitoring information is collected through surveys with harvesters and land users on an annual basis. Thus, typically this information is collected the winter season when harvesters are on the land but collated at the end of the harvest season; prior to the meeting of the committee.

The scientific indicators are typically expressed as continuous measurements and as averages with a measure of precision (e.g. the coefficient of variation). In some instances, the level of an indicator is associated with the likelihood of an increase or decrease based on experience across herds. For example, adult caribou cow survival typically has to be at least 87% if the herd is not to decline and calf:cow ratios in late winter should be at least 30 calves to 100 cows. Indicators do not work in isolation of each other to assess trends in herd size. Adult survival, and calf survival are integrated with pregnancy rates to project herd size for example. The projected rate of change can be calculated based on adult female survival rates and late winter composition (example in Appendix E). In addition, the effect of weather has been correlated with changes in adult and calf survival (Boulanger and Adamczewski 2017).

Likely pathways between individual indicators and management actions are shown in Appendix D. The indicators do not describe underlying mechanisms but rather relationships – for example, calf survival is the consequence of pregnancy rates, predation rates, accidents or disease, parasites and weather that modifies forage quality and quantity.

Table 1. Tłı̨chǫ monitoring indicators (see Appendix B)

Category	Indicator	Threshold July/August	Threshold August/September
Weather	Daily weather pattern (precipitation, wind speed and direction, humidity, barometric pressure, temperature)	Wet/dry Cold/normal/warm	Wet/dry Cold/normal/warm
Weather/ insects	Caribou behaviour in response to weather/insects	Undisturbed/disturbed	Undisturbed/disturbed
Weather/ insects	Predator behaviour in response to weather/insects	Undisturbed/disturbed	Undisturbed/disturbed
Habitat	Dryness/growth of vegetation/caribou forage	Poor/normal/good	Poor/normal/good
Habitat	Environmental change	Changes/normal	Changes/normal
Insects	Severity of insect harassment	Minimal/normal/ extreme	Minimal/normal/ extreme
Health	Skinny; bony; fatigued	Skinny/Normal/Fat	Skinny/Normal/Fat
Health	No bones visible on rump and back		
Health	Layer of fat shows on the neck and back, and back to rump.		
Hide	Hide colour unhealthy: discolored, patchy. Healthy: even color, no patches, new coat.	unhealthy/healthy	unhealthy/healthy
Walking Posture	Unhealthy: walking with lagging head. Healthy: normal posture; head straight or slightly down when walking	unhealthy/healthy	unhealthy/healthy
Number injured			
Signs of disease			

Overall health			
Calves	Cow-to-calf ratio	High/normal/Low	High/ normal/Low
Calves	Number of cows without calves	High/ normal/Low	High/ normal/Low
Calves	Number of twins	High/ normal/Low	High/ normal/Low
Predators	Daily sighting rates for wolf, eagle, wolverine and grizzly bear	Rate/day	Rate/day
Predators	Signs: tracks, kill sites Rates per animal: wolf, eagle, wolverine and grizzly	Rate/day	Rate/day
Predators	Relationship between caribou and predators		
Industry	Caribou behavior and movement affected by visible presence, noise, scent from industrial infrastructure and activities		

The Tłı̨chǫ Habitat indicator for industrial disturbance is for the vicinity of Contwoyto Lake and Point Lake, while the Bathurst Caribou Range Plan is across the annual range of the Bathurst herd. The Range plan's indicators and proposed monitoring and actions are not included in the Adaptive management framework at this time. However, to summarizes its scope and indicators it is included in the flowchart for indicators and management actions (Appendix D).

STEP 2 Rating benchmarks for the indicators

We have applied Benchmark categories to the indicators based on a level of risk relative to the trend in herd size (increasing, stable or declining). Using a traffic-signal color coding (Table 2). The color-coding allows people to see the relative strength of the evidence from multiple indicators underlying an assessment of how management actions might be affecting herd status and trend. This traffic-signal ranking is already familiar in caribou co-management planning (Porcupine Caribou Management Board 2010; Advisory Committee for Cooperation on Wildlife Management 2014). Our approach is similar to that proposed for assessing muskox and caribou health specifically body condition in the Kitikmeot Region (Peacock et al. 2020), who acknowledged that they had not built an approach to assessing management activities.

Table 2. Indicators, annual monitoring actions, and their season relative to the timing of the BGCTWG and their benchmark categories (desired range) for Bathurst and Bluenose-East herds

Monitoring Actions	When collected	When Available[1]	Monitoring Indicator	Benchmark		
Herd Status and Trend						
Annual rate of collar loss (Females)	Continually	Aug	Adult Female Survival	>.89%	0.89 %	≤89.0%
Spring composition survey: calf:cow ratio & sex and age composition	Mar-Apr	Aug	Over winter calf survival	≤ 30:100 cows	~30:100 cows	≥ 30:100 cows
Calving ground survey	Jun	Aug	% breeding females (~ pregnancy rate)	>80%	80%	<80%

Calving ground survey	Jun	Aug	Calf:cow ratio: Initial calf survival	>10%	<10%	
Calving ground survey	Jun	Nov	Trend herd size[2]	Increase	Stable	Decline
Calving ground survey	Jun	Nov	Calving density[2]	Increase	Stable	Decrease
Tłı̨chǫ Ekwǫ̀ Nàxoède K'è	June-Sept	Nov	Calf:Cow	≥ average		
Fall Composition Survey	June-Sept	Nov	Summer calf survival	>40%	40%	<40%
Composition Survey: sex and age	Oct	Nov	Bulls:Cows	≥ 40:100 cows	~40:100	>40:100
ACCWM Community-based monitoring	Continually	April	Adult Composition	Normal	Bad	Very bad
Harvest (Caribou)	Oct - Mar	Apr	Annual Harvest	<30	30	>30
Fecal Pellet Sampling	Oct-Marc	Apr	Pregnancy Rate	80%	<80%	<<80%
Tłı̨chǫ Ekwǫ̀ Nàxoède K'è	June-Sept	Nov	Body Condition	Healthy	Unhealthy	Very unhealthy
ACCWM Community-based monitoring	Continually	April	Body Condition	Healthy	Unhealthy	Very unhealthy
Herd Range Use and Affiliation						
Collars; fidelity to calving ground	Jun	Aug	Emigration	<5%	5%	>5%
ACCWM Community-based monitoring	Continually	April	Range and Movement Patterns	Distribution as expected		
Predator Harvest and Abundance						
Composition Surveys	Apr l & Oct	Aug	Sighting rates	≤ average		
Harvest (Wolves)	Oct- Apr	Apr	Wolf harvest	≤ average		
Collar distribution	Nov-Mar	Apr	Winter range overlap	Not yet available		
Tłı̨chǫ Ekwǫ̀ Nàxoède K'è	June-Sept	Nov	Predators on Summer Range	≤ average		
ACCWM Community-based monitoring	Continually	April	Predator Populations	≤ average		
Cumulative Disturbance						
Land Use activities	Annual	Apr	total disturbance footprint	See Range Plan[1]		
Tłı̨chǫ Ekwǫ̀ Nàxoède K'è	June-Sept	Nov	Interactions with Industry	≤ average		
ACCWM Community-based monitoring	Continually	April	Human disturbance	≤ average		
Environmental Conditions						
Forest fire rate	May-Oct	Apr	Annual area burnt	≤ average		

Tłı̨chǫ Ekwǫ̀ Nàxoèdè K'è	June-Sept	Nov	Environmental Conditions	≥ average		
Tłı̨chǫ Ekwǫ̀ Nàxoèdè K'è	June-Sept	Nov	Mushrooms	≥ average	<average	<<average
Tłı̨chǫ Ekwǫ̀ Nàxoèdè K'è	June-Sept	Nov	Insects	≤ average	>average	>>average
Tłı̨chǫ Ekwǫ̀ Nàxoèdè K'è	June-Sept	Nov	Dryness/growth of vegetation/caribou forage	Normal-good	poor	Very Poor
ACCWM Community-based monitoring	Continually	April	Environment and Habitat	≥ average		
Precipitation	April	April	Snow survey monitoring	Average	>average	>>average
Precipitation	Continually	April	Precipitation information from mines on the range	Average	>average	>>average

[1]When available is when data are available for BGCTWG discussions in confidence not than a final report

[2] Numerical benchmarks can be included after discussions

STEP 3. Applying the monitoring indicators to assess monitoring and management actions

The third part of the adaptive management framework is how the BGCTWG assesses monitoring results to describe effects of the management actions relative to the indicator benchmarks. This assessment is the basis for recommendations as to whether implementation of management actions should be modified and whether frequency and type of monitoring needs to be changed. Consideration for the timing of monitoring and the management actions is needed as the indicators are monitored at different time intervals during the year or for the complete year. For example, adult and calf survival are measured over a year but the year differs: adult survival is measured from the collars from 20 June to 1 July while calf survival is measured at three intervals between June and April. Calf survival can be roughly tracked over those intervals, and projected estimates of λ can be developed using the most recent estimate of adult female survival. This would be consistent with a general expectation that adult female survival would be less variable. Still, other indicators are monitored once a year over a 6-8-week summer/fall period.

Additionally, there is a variable lapse of time when the fieldwork is undertaken, and the results become available (Table 2). The timing of the management actions and their effects varies through the year and the timing of when decisions are made to modify management actions, or their monitoring is tied to fiscal year considerations as well as caribou biology and co-management. As such, we have determined that April, August, and November are the best times for the BGCTWG to assess the results of management actions and monitoring. In the event that information isn't available for the assigned meeting date, the topic will be deferred to the next meeting.

By considering the monitoring results for a selection of indicators (Table 2) and having discussions in April, August, and November each year, the BGCTWG can balance using the most up-to-date monitoring results while respecting the time it takes to compile results. This understanding and discussion about measuring success of the management actions builds a collaborative approach and will increase the efficiency of formal management proposals and their reviews. The timing of the discussions will allow adjustments to be made if results are not achieved or if conditions change such that a different approach is warranted to either or monitoring and management actions.

The benchmarks for the indicators relevant to the management action will be compared to the monitoring results. In most cases, there will be more than one indicator and consensus through discussion will be sought as to whether the management action has brought about change and that it is the required change. Then the BGCTWG can then recommend whether management actions needs to be revised, or whether the monitoring needs to be increased or reduced in being able to detect changes.

STEP 4. Recommendations, Tracking, and Reporting

Following each assessment meeting the BGCTWG will write a summary of findings and discussion. When applicable, the BGCTWG will provide for recommendations as to whether management actions should be modified and whether frequency and type of monitoring needs to be changed. There are also instances where the BGCTWG can use the evaluation to guide their decision making, for example, as it relates to the implementation of the mobile zone. An annual summary of the advice provided to decision makers, and decisions made by the BGCTWG will be written for reporting purposes. This summary can then be provided to partner organizations, such as the ACCWM, for their use.

Updating the Adaptive Management Framework

This framework has been developed by the Barren-ground Caribou Technical Working Group to guide its consideration of monitoring information and is based on the management, monitoring, and research that is presently being undertaken. The BGCTWG acknowledges that that this landscape will eventually change, and the adaptive management framework will need to be updated to remain relevant and useful.

The BGCTWG also acknowledges that there is monitoring, and research information available that has not necessarily been incorporated into this version of the framework. To begin implementing the framework in a timely matter we have listed some of these items here for development later:

- Industry mitigation measures
- Climate variable monitoring data (CARMA's MERRA-based caribou range climate database)
- Vegetation monitoring data
- Harvester monitoring information from the Tibbitt the Contwoyto Winter Road
- Direct gathering of knowledge from elders and land-users to obtain information on monitoring indicators on the range of the Bathurst herd during the winter season

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APPENDIX A. WRRB Background on Adaptive Management and the Barren-ground Caribou Technical Working Group

The May 2010 Joint TG and GNWT proposal[3] introduced applying Adaptive Management as the capability to learn and adapt to changing circumstances and uncertain conditions (p.11). TG and GNWT proposed (Figure 5) an adaptive management cycle with three reviews of monitoring and management during each year to "allow reconsideration of management actions without lengthy delays." (p. 19). As well as commenting on the need to avoid delays, TG and GNWT had written that "Any approach to management must have ways of measuring success so that adjustments can be made if results are not achieved or if conditions change such that a different approach is warranted."

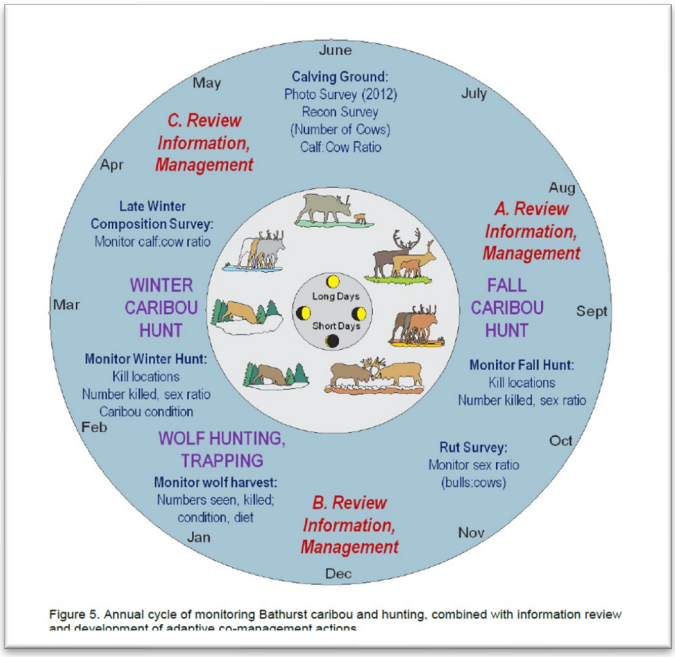

Figure 5. Annual cycle of monitoring Bathurst caribou and hunting, combined with information review and development of adaptive co-management actions

In the May 2010 Joint Management Proposal, TG and GNWT also proposed a technical working group to review monitoring information and to develop management options following the proposed adaptive management cycle. WRRB subsequently recommended an annual review of monitoring information and for measuring effectiveness of management actions (WRRB 2010; p. 37[4]). The WRRB had 11 recommendations (#29 to 40) that covered each monitoring indicator with recommendations for science and Tłı̨chǫ knowledge and specified that reporting on monitoring results to the WRRB and the general public was to be a minimum of April, September and December.

In 2010, the WRRB (Section 14) had three recommendations for the adaptive management framework. TG and GNWT varied[5] Recommendation #44 (WRRB's organizational chart for the Technical Working Group), accepted

[3] TG and GNWT. 2010. *Revised Joint Proposal on Caribou Management Actions in Wek'èezhìı, May 2010*.
[4] WRRB. 2010. Report on a Public Hearing Held by the Wek'èezhìı Renewable Resources Board 22-26 March 20105-6 August 2010 Behchokǫ̀, NT
[5] January 2011, TG and GNWT responses to WRRB. 2010. Report on a Public Hearing Held by the Wek'èezhìı Renewable Resources Board 22-26 March 20105-6 August 2010 Behchokǫ̀, NT

Recommendation #45 that that the WRRB staff participate in the Tłı̨chǫ– ENR Technical Working group and accepted Recommendation # 46. Recommendation #46 was for TG and GNWT to develop criteria to assess success or failure that would indicate when management actions are to be revised. Subsequently, a similar table (Table A1) for adaptive management to 2010 also was included in the joint TG and GNWT proposals for Bathurst and Bluenose East caribou herds for 2016[6] and 2019[7]. However, as noted by the WRRB during the 2016 and 2019 public hearings, the table did not include specific thresholds or criteria for assessing the effectiveness of management actions. While the monitoring indicators are listed as a table in 2010, 2016 and 2019, the table format does not clarify how the indicators contribute to decisions about management actions (except the trend in estimated caribou numbers on the calving grounds).

Table A1. Biological monitoring of Bathurst Herd as per the 2019 Joint Management Proposal

Indicator(s)	Rationale	Desired Trend	Adaptive Management Options	How Often	Notes
1. Estimate of breeding cows and extrapolated herd size from calving ground photo survey	Most reliable estimate for abundance of breeding cows and and total number of cows & can be extrapolated to herd size based on sex ratio.	Stable or increasing trend in numbers of breeding cows and herd size in 2023.	If trend in breeding cows increasing, continue as before; if trend stable-negative, re-consider management.	Every 2 years	Last survey 2018, next surveys in 2020 and 2022. Trend in breeding females is key indicator of herd trend.
2. Cow fecundity; composition survey on calving ground in spring (June)	Proportion of breeding females in June at peak of calving establishes initial fecundity or approximate pregnancy rate.	Proportion of breeding cows at least 80%.	Low ratio indicates poor fecundity and suggests poor nutrition in previous summer; survey data integrates fecundity & neonatal survival.	Annual	Essential component of calving ground photographic survey. Proposed increase to annual survey to monitor initial calf production and subsequent survival
3. Fall sex ratio and calf:cow ratio; composition survey (October)	Tracks bull:cow ratio and fall calf:cow ratio. Fall calf:cow ratio provides an index of calf survival from birth through initial 4.5 months.	Bull:cow ratio above 30:100; calf:cow ratio of more than 40:100.	If bull:cow ratio below target, consider reducing bull harvest. Low fall calf:cow ratios suggest poor calf survival.	Annual	Sex ratio needed for June calving ground extrapolation to herd size.
4. Calf:cow ratio in late winter (March-April); composition survey	Herd can only grow if enough calves are born and survive to one year, i.e., calf recruitment is greater than mortality.	At least 30-40 calves:100 cows on average.	Sustained ratios ≤ 30:100, herd likely declining; may re-assess management.	Annual	Calf productiion & survival vary widely year-to-year, affected by several variables, including weather.
5. Caribou pregnancy monitoring from late winter fecal sampling	Fecal pellet samples collected during late winter composition surveys (and caribou captures for collaring) may be used to estimate pregnancy rates. This would complement June composition surveys.	Pregnancy rates of at least 80%.	Low pregnancy rates indicate poor fecundity and low potential for calf production.	Annual	Preliminary sampling conducted to date. Sampling depends on minimal herd overlap on winter ranges, as reflected by collared cows
6. Cow survival rate estimated from OLS model and annual survival estimates from collared cows	OLS model-based cow survival estimate (2007-2014) was 78% (CI= 76-80%). Need survival rate of 85% (combined with ~35 calves:100 cows) for stable herd. Increased collar number to 50 cows should improve annual estimation.	At least 83-86% by 2022.	If cow survival continues <80%, herd likely to continue declining.	Annual	Population trend highly sensitive to cow survival rate; recovery will depend on increased cow survival.
7. Total harvest from this herd by all users groups (numbers & sex ratio)	To achieve a TAH of zero for Bathurst herd, accurate monitoring of all ekwǫ̀ harvest is essential and to determine whether management objectives are achieved, and actions are effective.	All harvest reported accurately and within agreed-on limits.	Re-assess recommended harvest annually; if herd continues to decline, re-assess harvest limit.	Annual	Multiple factors other than harvest may contribute to decline but harvest is one of the few factors humans control.
8. Maintain up to 70 satellite/GPS collars on herd (50 on cows, 20 on bulls)	Collar information is key to reliable surveys, evaluating fidelity to calving grounds, tracking seasonal movements, defining range/habitat use, monitoring survival and implementing harvest management in the Bathurst mobile conservation area (MCBCCA).	Additional collars added every March/April to maintain up to 70 collars on herd.		Annual additions to keep total of 70.	Information from collared caribou is essential to monitoring and management of all N. America caribou herds.
9. Wolf Harvest on Bathurst range	Several Indigenous governments and communities have expressed interest in increasing wolf harvest by hunters and trappers to increase caribou survival.	Increased harvest of wolves	If herd continues to decline, consider increased focus on wolf harvest to slow herd decline and increase likelihood of recovery.	Annual	Herd overlap in winter likely means mixing of wolves associated with those herds and may influence effectiveness of wolf removals.

In the 2010 joint TG GNWT management proposal, reporting on monitoring to the WRRB and general public was to be at least three times a year[8]. However, although the Barren-Ground Caribou Technical Working Group frequently met, how monitoring indicators were used to trigger management actions is unclear and to assess

[6] TG and GNWT. 2015. The *Joint Proposal on Caribou Management Actions for the Bathurst Herd: 2016-2019*

[7] TG and GNWT. 2019. The *Joint Proposal on Management Actions for the Bathurst Ekwǫ̀ (Barren-ground caribou) Herd: 2019 – 2021*

[8] TG and GNWT. 2011. Revised Joint Proposal on Caribou Management Actions In Wek'èezhìi Implementation Plan. Submitted to WRRB

progress to achieving the objectives. Instead, the reporting on how monitoring contributes to management actions has become a 3-year cycle based on the reporting of calving ground surveys with demographic indictors used to interpret trends and not used as assessment points. The monitoring did not include Tłı̨chǫ knowledge for the monitoring indicators.

In the 2016 Reasons for a Decision report[9], the WRRB expressed concern about adaptive management and the timely availability of monitoring information (p.19). “ENR argued that specific thresholds were premature and that it was more useful to diagnose causes of the decline, the WRRB agrees with TG that thresholds are needed to determine and evaluate management actions.” (p. 20). Consequently, the WRRB recommended that the “BGCTWG prioritize biological monitoring indicators in order of need for effective management and develop thresholds under which management actions can be taken and evaluated. Implementation of this recommendation should be completed by no later than the end of March 2017” (recommendation #8B). However, GNWT[10] varied the recommendation to the effect that GNWT was prepared to “explore linkages between monitoring indicators and management actions as proposed by the WRRB”.

[9] WRRB. 2016. Reasons for Decisions Related to a Joint Proposal for the Management of the Bathurst ekwò (Barren-ground caribou) Herd - PART B. Wek’èezhìı Renewable Resources Board, Yellowknife, NT.

[10] November 206, TG and GNWT responses to WRRB. 2016. Report on a Public Hearing Held by the Wek’èezhìı Renewable Resources Board Part B, Behchokǫ̀, NT

APPENDIX B. Complete list of indicators from Tłı̨chǫ Research and Training Institute (TRTI)

Ekwǫ̀ Nàxoède K'è: 2019 Results

Indicator 1: Habitat

- Daily weather pattern (temperature, wind direction, humidity, barometric pressure)
    - Ekwǫ̀ behaviour in response to weather
    - Daily insect activity in response to weather
- Ekwǫ̀ and predator behaviour in response to weather/ insect activity
- Conditions of vegetation and ekwǫ̀forage
- Effects of environmental changes on habitat and ekwǫ̀

Indicator 2: Ekwǫ̀

Ekwǫ̀ health

- Unhealthy: skinny; bony; fatigued
- Healthy: normal conditions. No bones visible on rump and back. Layer of fat shows on the neck and back, and back to rump. Look at tail: if it's short, then the animal is fat and healthy

Hide colour

- Unhealthy: discoloured; patchy
- Healthy: nice colour; no patches. In July: white-coloured hide (shed winter coat in June- July);
- August: darker color and shorter hair (new winter coat is coming)

Walking posture

- Unhealthy: limping, or walking with lagging head
- Healthy: prancing, or normal posture; head straight or slightly down when walking

Injured animals

- Number of caribou injured in the herd
- Types of injuries
- Signs of disease

Calves

- Calf-to-cow ratio
- Number of cows without calves
- Number of twins: sign of a healthy herd, as the cow is healthy enough to support two calves—
- demonstrates cows have not been under stress, and good habitat quality

Indicator 3: Predators

- Number, signs of and location of ekwǫ̀predators
- Relationship between ekwǫ̀and predators

Indicator 4: Industrial Development

- Ekwǫ̀ behaviour and movement affected by visible presence, noise, scent from industrial
- infrastructure and activities

APPENDIX C. ACCWM Monitoring Table

	Community-Based		Scientific[11]	
Information	**Measure**	**How often**	**Measure**	**How often**
Population size	High, medium, low, critical	Throughout the year	High (Green) Medium (Yellow/Orange) Low (Red)	Green: every 4-5 years Yellow: every 3-4 years Orange and Red: every 3 years
Population trend and rate of change[12]	Observations: increasing, stable, decreasing	Throughout the year	Increasing, stable, decreasing	Annually
Productivity and recruitment	Observations: many or few calves	In summer, fall, and winter	Number of calves per 100 cows	Every winter (except years population estimate is done)
Adult composition	Observations: many or few bulls (and bull health)	Throughout the year	Number of bulls per 100 cows	Following population estimates or every 3-5 years
Body condition and health	Observations: good, fair, poor, abnormal	Throughout the year, especially during harvest	Fat indices, pregnancy rate, parasite and disease level	Level 1 annually; more intensive Level 2/3 every 5 years
Harvest levels	Harvest reporting	Monthly	Calculate total harvest and sex ratio from community data	Annually
Predator populations[13]	Observations: high, medium, low	Throughout the year	Carcass collection (reproduction, health, etc.)	Green and Yellow: every 5 years Orange and Red: every year
Range and movement patterns	Locations of caribou absence/presence	Throughout the year	Range use, movement patterns	Annually (based on collar data and observations throughout year)
Environment and habitat	Observations of food quality and availability, extent of burns, weather, snow depth, etc.	Throughout the year	Seasonal range use, fire, changes in plant productivity, green-up, climate, etc.	Annually to establish baseline and then to be determined thereafter
Human disturbance	Observations: high, medium, low	Throughout the year	Track land uses and disturbance levels	Annually, and then to be determined thereafter

Figure 1. ACCWM Monitoring Table. Using information collected from both scientific and traditional/local knowledge, the ACCWM discusses herd status according to the ten factors. (ACCWM.com)

APPENDIX D. Details for scientific indicators can be used as assessment points for those indicators which are quantitatively measured

	Indicator(s)[11]		Current 2018	Target (Assessment Point)		Management actions (draft – more detail needed)
Key indicators						
1	Trend (Rate of change λ) in herd size	Trend estimated number breeding cows on calving ground [12; 13]	> 95% CI = 2,709 - 4,880 CV 14% Λ = 0.92 (CI=0.83-0.99) 2015-2018	Λ = ≤0.00 sig. decline	≤ 2709 breeding females	Increase wolf harvest/targeted removal
				stable Λ = 0.00	2709- 4880	Maintain wolf harvest/targeted removal
				Sig. increase Λ = ≥0.00	≤ 4880 breeding females	Maintain wolf harvest/targeted removal
		Adult survival+recruitment[14]	Λ = 0.00	See above		See above
2	Adult cow survival	Satellite collars	0.87 ±0.07 SE CV = 8%	≤0.67 0.% CL		Increase wolf harvest/targeted removal
				0.67 - 0.87		Maintain wolf harvest/targeted removal
				≥0.87		Maintain wolf harvest/targeted removal
		Population modeling		See above		
Supporting Interpretive vital rates indicators; apply to interpret/modify adult survival and or trend in numbers of breeding females						
3	Calf survival	Pregnancy rate (fecal)	[15]	95% Confidence Limit		Modify threshold for adult survival
		Birth rate (calving ground)	[5]	95% Confidence Limit		
		Fall calf:cow ratio	[5]	95% Confidence Limit		
		Late winter calf:cow	[5]	95% Confidence Limit		
	Productivity	fecundity x calf survival	[5]	> 0.30		
4	Emigration	Switching collared cows calving grounds	27%	≥ 5% calving ground switching		And removal (lethal or non-lethal) predators from calving grounds

[11] Methods to select and measure indicators are to be described in text and see also CARMA manual
[12] . Index is based on measuring Numbers (density) of 1+ year old caribou on calving ground from recon surveys
[13] Also required to estimated breeding females from estimated number 1+year old caribou on calving ground
[14] Spreadsheet or other population models for years when no calving ground surveys
[15] Data not available from Boulanger *et al.* al. 2019

APPENDIX E. The relationship between management actions and the indicators to measure their effects