Literature Review and Interviews: Indigenous Ways of Knowing Boreal Caribou Populations

Report prepared for the ʔehdzo Got'ı̨nę Gots'ę́ Nákedı (Sahtú Renewable Resources Board) and the Department of Environment and Natural Resources, Government of the Northwest Territories

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Executive Summary

This report was prepared for the Department of Environment and Natural Resources (ENR) of the Government of the Northwest Territories and the ʔehdzo Got'ı̨nę Gots'ę́ Nákedı (Sahtú Renewable Resources Board, SRRB) based on a literature review and interviews with experienced researchers and knowledge holders about indigenous ways of knowing and monitoring boreal caribou. Boreal caribou are listed as threatened in Canada and the Northwest Territories (NWT), and wildlife management organizations in the NWT are mandated to monitor the population abundance and trend in order to make management planning decisions.

Boreal caribou are an important animal for First Nations and Métis communities in almost all regions of the NWT. Hunters and Elders have comprehensive traditional knowledge about past and current caribou populations, movements, health, habitat, and other topics. In many indigenous societies, this type of information is traditionally used in an adaptive management processes. Therefore traditional, community, and indigenous knowledge can be of value for determining wildlife population abundance and trends, among many other topics, and a range of monitoring programs accommodate indigenous people or methods to some degree.

This report reviews approaches to understanding and developing indigenous knowledge and ways of knowing about wildlife populations that could have potential as monitoring methods for boreal caribou populations. It details theoretical and methodological considerations for ENR, who plan on initiating a monitoring program for boreal caribou with NWT communities, and includes a discussion of limitations and challenges. Several northern case studies are presented as examples of monitoring projects that are already underway, and a suite of eight potential monitoring measures or 'indicators' are introduced, including a consideration of their possible applicability for boreal caribou. While there is an emphasis on traditional knowledge systems of the north, literature and models for working with indigenous ways of knowing from other parts of the world are also included in this review and report where relevant.

Finally, this report builds on the existing literature by proposing methods to develop a monitoring program for boreal caribou population abundance and trends in the NWT. The authors recommend that ENR initiate a collaborative and iterative approach to develop regionally and culturally-appropriate monitoring approaches with interested communities across the NWT.

Acknowledgements

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Introduction

Boreal caribou (Woodland Caribou [Boreal population], *Rangifer tarandus caribou*) are listed as threatened in Canada and the Northwest Territories (NWT).[1] Wildlife management organizations in the NWT need to understand population abundance and trends in order to make effective planning decisions (for more information on the reasons why boreal caribou are monitored and other introductory topics, please see Demars, Boulanger et al. 2014). In addition, boreal caribou are an important species for Aboriginal communities in many regions of the NWT. A 2014 report commissioned by the Department of Environment and Natural Resources of the Government of the NWT (ENR) focussed on scientific methods for monitoring rare and elusive species and included recommendations for survey design for monitoring boreal caribou (Demars, Boulanger et al. 2014). During a review of this report, the ʔehdzo Got'ı̨nę Gots'ę́ Nákedı (Sahtú Renewable Resources Board, SRRB) identified that indigenous monitoring methodologies were a considerable gap in the report. Subsequently, ENR provided funding to SRRB for a literature review – supplemented by interviews – of indigenous methods to monitor boreal caribou, and this report is the result.

Existing literature indicates that harvesters and Elders have in-depth knowledge of these animals that is based on oral tradition, hunting experience, and careful observation (see for example McDonald 2010, Benson 2011, Dehcho First Nations 2011, Legat 2012a, Species at Risk Committee 2012, Legat 2013, Legat and McCreadie 2015). There is likely considerable Traditional Knowledge (TK) held by harvesters and Elders that has not yet been documented. Taken together, this information is of value for monitoring boreal caribou population abundance and trends.[2]

This report reviews approaches to understanding and developing indigenous knowledge and ways of knowing about wildlife populations that have potential as monitoring methods for boreal caribou. This report first explores community participation in scientific monitoring programs, and then introduces the literature on indigenous monitoring methods. The monitoring of wildlife populations, especially northern wildlife and caribou populations, is discussed more specifically. Finally, some next steps for ENR to start a collaborative monitoring endeavour are suggested. This report builds on previous work and discussions between TK researchers and experts, who have been working together in the NWT to build effective and collaborative monitoring and research projects for many years (SENES Consultants Ltd. 2007, McGregor, Bayha et al. 2010).

This report uses the words 'monitoring' and 'indicator,' which have useful and relevant meanings in both standard English and in scientific use. The authors also use 'indigenous monitoring' to refer to how Aboriginal communities understand, watch, take care of, and refer to the animals, plants, weather,

[1] NWT SARC Assessment: Threatened, Federal Species at Risk Act list: Threatened, COSEWIC Assessment: Threatened, NWT General Status Rank: Sensitive, NWT List of Species at Risk: Threatened. http://www.nwtspeciesatrisk.ca/en/content/nwt-woodland-caribou-boreal-population Accessed May 29, 2015

[2] TK monitoring is useful for many more topics than abundance and trends, however the scope of this work included only population trends.

human-animal relationships, and other parts of the ecosystems within which they live. In some cases, it is also used to refer to projects or programs that gather and use this knowledge within, for example, resource-management frameworks (a fuller discussion on how the term indicator may be used are provided later in this report – see **Indigenous methods for monitoring wildlife populations** section). However, the authors recognize that there are other terms and concepts, which vary regionally, that are used to describe how indigenous communities understand and steward boreal caribou populations, and which may be preferred by NWT communities. As suggested later in the document, it would be beneficial to further develop these terms and concepts in regional language workshops. Once more appropriate terms have been identified, they can be used, and can help guide, monitoring efforts.

Methods

Literature review

Literature reviewed for this report is primarily academic, with some grey literature as well. It was identified using academic search engines (Google Scholar) and from the authors' existing collections. Keywords searched were **indigenous**, **monitoring** and **traditional knowledge**.[3] Broader search terms (for example citizen science) returned too many results without strong ties to indigenous methodologies for understanding population abundance and trend. The related topics of citizen science/ volunteerism, traditional knowledge, *etc*., each have a large corpus of literature that was outside of the scope of this project.

Interviews with experienced researchers and knowledge holders

Five researchers and knowledge holders – including academics, consultants, and indigenous knowledge holders – were interviewed to supplement and guide the literature review. The questions and list of interviewees were developed in consultation with ENR and the Executive Director of the ʔehdzo Got'ı̨nę Gots'ę́ Nákedı (SRRB). Efforts were concentrated in regions where people tend to encounter and harvest boreal caribou relatively frequently (*i.e.*, Tłı̨chǫ, Sahtú and Dehcho – due to time constraints, interviewees from the Gwich'in and South Slave regions were not included). A short biography for each interviewee is included at the end of this report.

The overarching themes explored in the interviews were:

- What kind of monitoring programs are respectful, appropriate and successful? Do you know of any working examples that are based on indigenous ways of knowing?
- What ways of knowing (or kinds of indicators) do people use when they are keeping track of boreal caribou?
- Do you know of any suitable sources we should look at or other people we should contact for information on indigenous ways of monitoring rare and elusive species?

[3] The phrase "traditional knowledge" or TK will be used throughout the report, along with indigenous knowledge, indigenous monitoring, and traditional ecological knowledge. Literature exists about the use, suitability, definitions, and critiques of these and other phrases. This is considered outside the scope of this report.

The objectives of the interviews were to:

- Identify any additional materials to be reviewed
- Fill any information gaps from the published literature (e.g., specific regional and cultural information)
- Identify any appropriate monitoring programs already underway in the range of boreal caribou
- Identify possible methods or indicators for monitoring rare and elusive species populations that could be used in the regions of the NWT that rely on boreal caribou most heavily.

Interviews averaged approximately 1.5 hours in length and were conducted on a one-to-one basis, over the telephone, using a semi-structured interview format. One participant was interviewed over two, two-hour sessions. There was additional follow-up with interviewees through emails and phone calls. Questionnaires were tailored according to the specific expertise of each interviewee, but a generic format is included at the end of this report. Results were recorded through type-written notes during the interviews, and interviewees were asked to review their information as it was used in the report.

Information resulting from the literature review and the interviews has been integrated into the relevant themes developed in this report. Information from the interviews is cited as personal communications.

Community cooperation and participation in scientific monitoring

Indigenous, Aboriginal, or community participation in scientific monitoring is a relatively common-place occurrence, and complementary methodologies have been the subject of many projects and studies (for an example see Huntington, Gearheard et al. 2011, among many others). Danielsen, Burgess et al. (2009) have classified monitoring projects into five broad categories, depending on level of community participation in and ownership over the program (see Figure 1, below). The categories range from programs which are wholly the domain of 'outside' scientists on the one hand, to community-driven, governed, and led initiatives on the other. These are non-exclusive categories and hybrid projects exist.

Each category of monitoring program has varying costs to different stakeholder groups, varying requirements, varying accuracy/precision, and varying strengths. For example, category 1 projects are cheap for local stakeholders, expensive for outside stakeholders, and do not result in prompt local decision-making. Category 4 and 5 programs have differing expense profiles than category 1, but increase local stakeholder capacity and support prompt decision-making on a local level (Danielsen, Burgess et al. 2009, see also Danielsen, Burgess et al. 2010 for specific comments on turn-over time between monitoring and decision-making).

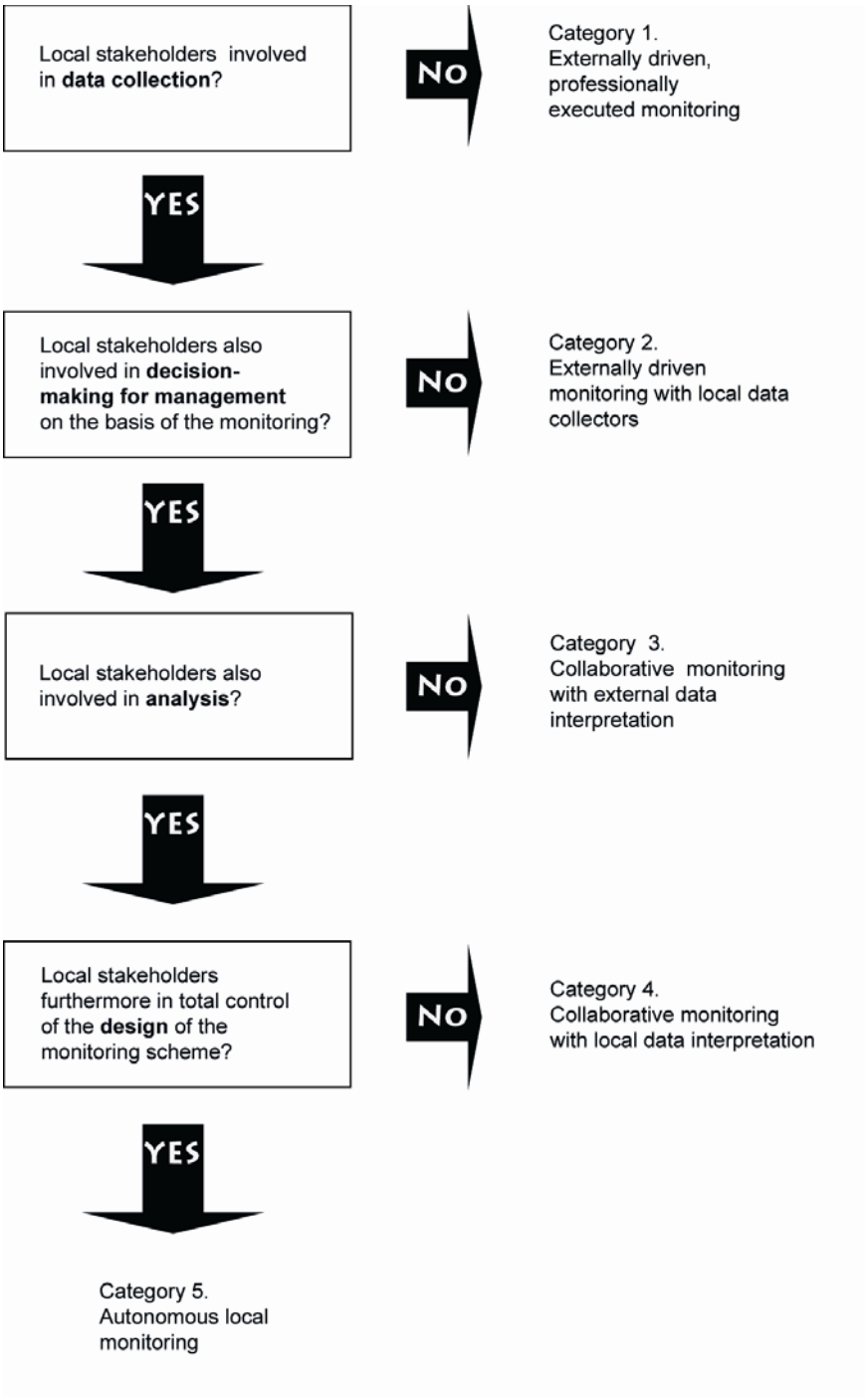

Figure 1. Categories of natural resource monitoring schemes (Figure S1 from Danielsen, Burgess et al. 2009, supplementary materials).

Indigenous participation in scientific monitoring, as noted above, can take many forms. There may be indigenous participation at any or many levels – project governance, project design, or project data-collection. For example, a community governance organization may decide that monitoring of a

particular animal or threat is needed for some purpose, and may work with technical personnel to conduct research and prepare reports that can be used to advance community interests; this has happened with boreal caribou fieldwork in some parts of the NWT (Redvers 2015). The scientist or technician may be directed by and consult with the community on all aspects of project design (Housty, Noson et al. 2014), or may use standard scientific techniques and deliver a standard report. Researchers who have a mandate to monitor changes to wildlife or other ecological change may also consult with community governance about project direction. They may work with knowledge-holders to identify habitat, appropriate survey transect locations, and troubleshoot field logistics, among other topics. Collaborative research projects like this have been happening within the range of boreal caribou in Canada since at least the 1990s (Courtois 2015). Finally, researchers often hire community members in a broad variety of roles, including project management, field staff, wildlife monitors, field safety guides, wildlife protection, or others (Aurora Research Institute 2013). These projects may have community participation or even oversight, but all share a methodological basis: that they are essentially scientific endeavours (for example, track counts, observational surveys, camera traps, molecular sampling, radio collaring, *etc*.), with indigenous participation. There is generally some level of co-production of knowledge in these programs, whether explicit and through indigenous participation in project design, or implicit and possibly even unacknowledged, such as the informal participation in logistics decisions by field staff (for a review of multiple community monitoring projects and their cross-validations with science projects, see Danielsen, Jensen et al. 2014a).

Many monitoring projects which explicitly include 'knowledge co-production' or joint/cooperative techniques focus on the complementarity or similarity of the different knowledge systems. Co-production of knowledge is of particular value when rapid environmental change necessitates rapid adaptive management, and flexible co-management processes (Armitage, Berkes et al. 2011).

In addition, the complex logistics and expense of purely scientific monitoring projects and the rapid pace of change in the arctic and sub-arctic can confound standard monitoring programs. Co-operative projects with multiple data streams, projects where land-users collect data, and indigenous monitoring projects all can be effective in addressing these issues (Bennett and Lantz 2014). As knowledge-generation systems, both science and TK are subject to critical examination, and credible in their own right (Geertsema 2008). The following sections describe types of scientific monitoring with varying levels of community participation.

Scientific Monitoring Programs

Biological and ecological monitoring programs often make use of local assistants, field workers or monitors. These individuals are engaged or employed to conduct in-the-field components of research projects, such as water sampling or track counts (Aurora Research Institute 2013). In the Northwest Territories, the inclusion of traditional knowledge is governed by a policy which dictates that government departments "will incorporate traditional knowledge into government decisions and actions where appropriate" (Government of the NWT 2003). As a result, ecological and biological research often includes a TK component. However, there is a varying degree of community participation in these projects.

There are often monitoring programs required by various government departments as a condition of Environmental Impact Assessment and/or Land Use or Water licensing processes. For example, this may include a water monitoring component for Fisheries and Oceans Canada, a wildlife abundance monitoring program, a dust monitoring component, and many others. To varying extents, these monitoring programs may include indigenous participation (see for example Herrmann, Sandström et al. 2014)

Harvest Surveys

Interviews and surveys of harvesters to gather harvest data is a common technique used in northern Canada (Winbourne 2013). These surveys provide information for managers about locations, numbers and trends in hunting. They traditionally rely on a census approach, attempting to record all harvests in an area. A fuller discussion of the census-style harvest study as used in the NWT and Nunavut is available in Winbourne (2013). Interviews with key harvesters can also be used to gather and extrapolate harvest data, a technique which also has received some validation (Jones, Andriamarovololona et al. 2008, and see more about Nunavut's Community-based Monitoring Network below). There has also been validation that "count statistics, garnered through harvesting practices, can be used as credible indices to determine estimates of species abundance" (Geertsema 2008: 76, see also Fragoso, Silvius et al. 2000).

Harvest study data are considered potentially rich and valuable sources of information about many more topics than solely harvest, such as wildlife range (Kowalchuk and Kuhn 2012), health and disease occurrence, and broader ecological observations. Harvest studies also regularly integrate demographic information, such as sex ratios and age structure of animals harvested (Fragoso, Silvius et al. 2000). There are limitations associated with the methods and data produced by northern harvest surveys and for these reasons, many communities and regions are exploring alternate ways of monitoring harvests today – some of which are based in more traditional, indigenous systems (Winbourne 2013). In addition, there has been a recent move towards pairing harvest data collection with community-based monitoring (**Knowledge Co-production: mixed projects/multiple data streams**, below).

Knowledge Co-production: mixed projects/multiple data streams

Community-based monitoring is reasonably well established in the Arctic (Gofman 2010). Many of these programs include components from traditional knowledge projects, harvest surveys, and more scientific endeavours like track counts and aquatic sampling.

Some projects have employed harvesters to make observations on the land through more traditionally scientific approaches. Bennett and Lantz (2014) used participatory photography to facilitate documentation of TK observations of environmental change, and paired the photography with semi-structured interviews to document and communicate local observations about the environment. Photographs were taken of various landscapes within the Inuvialuit Settlement Area, and were used in the interviews to elicit information about the content of the photographs. Observations and photographs were stored in a web-enabled spatial database available for community use (Bennett and Lantz 2014). Other monitoring programs also use web-mapping systems to share information. For example, sea-ice monitoring observations in Alaska and Russia are loaded into a web map to promote

The Arctic Borderlands Ecological Knowledge Society

The Arctic Borderlands Ecological Knowledge Society monitors and assesses changes in the range of the Porcupine Caribou Herd and adjacent Mackenzie Delta area in NWT, Yukon, and Alaska.

Our approach is to empower member communities to monitor, record, and share knowledge and stories about the ecological processes and wildlife status in the north. …[Community members and scientists] identified the three main issues that should be the focus of ecological monitoring: climate change, contaminants, and regional development. [We] also decided that an important part of the program should be to bring together science and local and traditional knowledge…

ABEKS has a list of approximately 75 indicators that participants are interested in monitoring to track ecosystem change. Potential indicators were initially identified at the first Annual Gathering, with new ones periodically identified at subsequent Gatherings, meetings, and as the need arose.

Developed data sets are in place for approximately 65 indicators. These are currently being updated to reflect the latest information available and several new ones are being developed and added.

Community researchers conduct interviews with local experts each year. Observations about fish, berries, caribou, unusual animal sightings, weather conditions, and other aspects of the environment and communities, are pulled together. Annual results, reports and interview questions are available (Arctic Borderlands Ecological Knowledge Co-op Society 2015).

adaptive management and bolster traditional information sharing techniques (Eicken, Kaufman et al. 2014). The Arctic Borderlands Ecological Knowledge Co-op is another example of a long-term monitoring project using multiple data streams.

Harvesters participating in scientific projects can engage in research and monitoring by collecting data, improving logistics, and in other ways, but also through self-reflection and ongoing education through the life of the program. For example, Kofinas, Lyver et al. (2003) used a questionnaire/form to gather information about caribou cow body condition in a monitoring project. The form was used to describe body condition, and hunters were paid an honoraria for each form. A form was filled out after each successful day of hunting. An improvement was noted over several years – hunters became more adept at filling out the forms, and paid closer attention to the indicators used in the project to more specifically recall information about each caribou.[4]

The ongoing Community-based Monitoring Network (CBMN) pilot study in Nunavut is a technology-supported effort to collect harvest study data without the standard reliance on census interviews. Harvesters record their observations of wildlife, harvest, and the environment through a hand-held computer unit. Data is collected from the units and compiled by trained community data clerks. The data is used in various wildlife management processes by the Nunavut Wildlife Management Board. The harvesters are hired as professionals and are compensated for their time and expertise (Nunavut Wildlife Management Board n.d. For information relevant to statistical validation of this type of data-gathering, see Luzar, Silvius et al. 2011). Hand-held computers with touchscreen capability are also in use in several Cree communities for monitoring of various wildlife including caribou. When caribou are encountered,

[4] Questionnaires delivered through interviews were also used by Herrmann, Royer et al. (2012), who supplemented the questionnaires with mapped data and scientific data.

information about the animals and even photographs are entered into the computer and automatically uploaded to a database. The database is supplemented and contextualized with in-depth interviews (Herrmann, Sandström et al. 2014).

The Inuvialuit Game Council has embarked on a similar broad-based initiative (Knopp, Pokiak et al. 2013). A community-based monitoring program for Beluga whales, including a traditional knowledge study, is also starting within the Inuvialuit Settlement Region (Gillman, Hynes et al. 2015).

Further south, Gunn (2004: iii) described a scientific modelling project where the "Deh Cho First Nations database of lifetime harvest kill sites and sightings from an aerial survey" were used alongside GIS landscape modelling, to compare harvest locations and computerized wildlife modelling. Other monitoring efforts which are underway in the NWT and include community participation or co-production of knowledge include insect sampling and monitoring, track counts, ungulate health and population monitoring, and numerous other programs supported through the Cumulative Impact Monitoring Project.

This type of collaborative work has a longer history in other parts of Canada. For example, Cree hunting organizations in James Bay obtained management rights over beaver harvesting in their territories in the mid-1970s. Senior hunters known as stewards or 'tallymen' traditionally made decisions about the beaver harvest, and the policy shift in the mid-1970s reinstituted a more traditional, community-directed management scheme. Knowledge co-production is used to assist the decision-making process: using air photo imagery to obtain counts of lodges, combined with the stewards' knowledge of beaver population in the lodges, sustainable harvest levels are set by the Cree organizations. Harvest levels are also monitored using these two sources of information, which are complementary (Moller, Berkes et al. 2004).

There are also several examples of positive collaborative research efforts between the Innu Nation and government agencies such as the Department of National Defense and Environment Canada that were initiated in the 1990s (Sable, Howell et al. 2007, Courtois 2015). Based on their experiences with these monitoring programs, the Innu Nation has gone on to form university partnerships to establish academic training modules that are grounded in Innu traditions (see text boxes below about both the Innu Guardians and the Ashkui Project).

In recent years, the Heiltsuk First Nation has catalyzed a perhaps uniquely diverse set of participatory collaborative relationships. The network includes representatives of academia, tribal government, provincial and federal governments, resource management, and conservationists, as well as local community leaders. The focus of these relationships is on co-creating research agendas which support actions to improve resource authority and stewardship across traditional Heiltsuk territory (Housty, Noson et al. 2014, see text box below).

Innu Environmental Guardians

The Innu Environmental Guardians project is a decade long monitoring endeavour operated as a joint project between the Innu Nation and Saint Mary's University. Over the years, the program has included 'modules' or courses based out of the university, which study and monitor different aspects of the landscape, selected through ongoing community consultation. Different module topics meant different methodologies were used to gather information – for example, sample plots were established for the climate modules. Over the years, up to 14 Guardians worked with Elders and other participants in the program, which included a focus on both Innu knowledge and science (Trant, Jacobs et al. 2012).

Grizzly bear monitoring by the Heiltsuk First Nation, BC

The Heiltsuk First Nation has worked collaboratively to undertake Grizzly bear monitoring through molecular analysis of hair samples. The methodology was created to be culturally appropriate, and the project in its entirety upheld Heiltsuk customary law. During the course of the project they developed a summary of 'exemplary principles' for conducting collaborative research and monitoring.

More broadly, research can empower and legitimize the unique, geographically rooted epistemologies that characterize many indigenous communities and, in so doing, enable an interweaving of the analytical power of science with concepts such as Gvi'ilas [customary laws and principles]. Legitimate union between high-quality science and First Nations perspectives on resource use represents a key advance in conservation practice, which serves the interests of all people (Housty, Noson et al. 2014: 12).

The Ashkui Project: Linking Western Science and Innu Environmental Knowledge

Since 1997, the federal department of Environment Canada has collaborated with the Innu Nation (First Nation) of Labrador and social scientists from the Gorsebrook Research Institute (GRI) at Saint Mary's University in Halifax, Nova Scotia to incorporate social sciences and community involvement into environmental research. The initial goal was to develop comprehensive baseline ecological data of the Labrador landscape from both Innu and Western scientific perspectives. To provide an initial focal point for research, consultations were held with members of the Innu community to identify an aspect of the landscape that was deemed culturally significant and distinct. The landscape feature the Innu chose is ashkui*, giving rise to what was referred to as the* Ashkui Project *in Labrador, Canada.*

Ashkui *have been defined by Innu elders (*tshishennuat*) as early openings in the water. The importance of* ashkui *comes in the springtime when an abundance of waterfowl, fish and animals are attracted to the newly opened water. Innu families set up camp near these sites and stay for weeks and months at a time to exploit and celebrate the rich and varied resources of the land and water. These sites are still of importance to Innu for their livelihood and psychological well-being. Conveniently,* ashkui *were also the home of the Harlequin duck, an endangered species that Environment Canada was mandated to study. Conducting research at these sites would allow for Environment Canada's continued focus on waterfowl inventories and hydrometric research. GRI social scientists, working closely with* tshishennuat *and Innu co-researchers/Guardians, have documented some of the complex knowledge of those Innu who grew up on the land, and whose lives were inextricably linked to the* ashkui *sites. Based on this research and the identification of a number of* ashkui *sites that were in current use or had been regularly used in the past by Innu families, Environment Canada scientists in the spring of 1999 set up a 325 km* ashkui *research network comprising fifteen stations. These sites were used to sample and analyse three freshwater systems – clear, coloured and brackish.*

[The project has expanded to include the Innu Environmental Guardians Program, an initiative to assist in training members of the Innu community in ecosystem management in preparation for self-government. The project has a commitment to incorporate Indigenous Ecological Knowledge (IEK) and to work with the Innu Nation in the overall project design and structure (Sable, Howell et al. 2007: 110).

Internationally, biodiversity monitoring has been a particularly active area for participatory research methodologies. International examples often include very comprehensive study methodologies, with multiple data streams and data validation processes. For example, in the Rio das Mortes Indigenous Reserve in Brazil, community members hired by the World Wildlife Fund monitored harvest under the direction of a biologist. The project attempted to construct baseline information about the wildlife populations monitored and estimate if the harvest was sustainable (Fragoso, Silvius et al. 2000). 'Hunter self-monitoring' has been demonstrated to be a valuable technique in Bolivia as well, especially for identifying long-term trends rather than short-term changes in wildlife, for which it is less accurate (Noss, Oetting et al. 2005). Like Fragoso, Silvius et al. (2000), Noss, Oetting et al. (2005) also tested several techniques to directly monitor wildlife populations. This included line transect surveys, drive counts, track counts, and use of trained dogs. Community monitors were used to undertake some of these activities – hunters first volunteered and then were hired part-time to do data collection, and 'para-biologists' were trained and hired full time within each community to support wildlife research and manage data collection and validation (Noss, Oetting et al. 2005).

Community-based monitoring projects are also well established in many other areas of the world – for example, numerous examples of Amazonian, African, and Australian monitoring projects are described in the literature (see for example Ferraz, Marinelli et al. 2008). Non-northern but relevant examples include:

- Abundance surveys using line transects in Paraguay (Hill, Padwe et al. 1997, Hill, McMillan et al. 2003)
- Whale shark monitoring using TK interviews, and community-supported standard monitoring techniques in Indonesia (Stacey, Karam et al. 2012)
- Multi-species track-based monitoring undertaken by both Aboriginal and non-Aboriginal participants, to understand "broad-scale population trends and status of remnant threatened species and the distribution and abundance of invasive species in arid Australia" (Southgate and Moseby 2008: i)
- TK interviews to complement and contextualize small-scale scientific monitoring studies to determine declines in abundance of numerous animals in Australia. The interview information was compared to other data streams and found to be strongly consistent (Ziembicki, Woinarski et al. 2013)
- Community monitoring workshops focussed on adaptive management, community buy-in, and data collection about marine protected areas in the Philippines (Uychiaoco, Arceo et al. 2005).
- Line transect data and TK focus groups to monitor biodiversity in Nicaragua (Danielsen, Jensen et al. 2014b)

Indigenous methods for monitoring wildlife populations

Indigenous or Aboriginal traditional knowledge systems tend to encompass both a body of knowledge as well as a cultural framework for understanding human relationships with non-human animals and the surrounding environment (Berkes, Berkes et al. 2007). Collecting and using TK is considered best practise for research in many disciplines, and TK has legal standing for environmental impact assessment

in socio-economic and biophysical disciplines, and other environmental policy development and re search.[5]

The body of literature pertaining to traditional knowledge as a field of study has grown enormously over the last two decades. Nonetheless, there are relatively few in-depth sources that explore indigenous monitoring methodologies; none were found during this literature review which focus on ways of monitoring what is considered by scientists a 'rare and elusive species' such as boreal caribou. As such, theory and methodology must be drawn from case studies of indigenous monitoring in general, and relevant ideas and methodologies drawn out.

Even in areas where there is very limited contact with a wildlife species, Idrobo and Berkes (2012) have reported that useful indigenous knowledge exists. They use a study case of the Greenland shark, a species with no traditional use and which has been only recently encountered by Pangnirtung Inuit during commercial fishing. For these species in particular, knowledge co-production through dialogue between indigenous harvesters and other stakeholders can be particularly productive, especially if research is oriented towards contextualizing knowledge about a rarely encountered species, as species-specific information "can be further interpreted in the light of extensive Inuit knowledge of other species and marine ecosystems" (Idrobo and Berkes 2012: 411).

> *Most traditional monitoring methods used by indigenous cultures are rapid, low-cost, and easily comprehensible assessments made by the harvesters themselves as they hunt. Hence, most of the known methods for monitoring populations are based on some aspect of the harvest or on observations related to harvests.*
>
> (Moller, Berkes et al. 2004: 2).

Unlike the Greenland shark, boreal caribou have traditionally held value as a food source in all regions where they occur, and are very important to some communities. In many parts of the NWT and Canada, a long-standing reliance of First Nations on boreal caribou has resulted in an extensive body of knowledge about the animal and targeted ways of increasing encounter rates (Bayha 2015, Legat 2015, Polfus 2015a). So while boreal caribou may not be equally abundant nor harvested similarly or consistently across the Northwest Territories (Species at Risk Committee 2012), indigenous knowledge about these animals does exist and its potential utility for monitoring programs is currently being explored in the Sahtú, Dehcho and Tłı̨chǫ regions (Legat 2015, Polfus 2015a, Redvers 2015).

On a larger scale, indigenous monitoring of ecosystem integrity or health is based on the ways Aboriginal people observe, learn, understand, generate knowledge, interpret, and make associations about ecosystem function, structure, and composition (Geertsema 2008). This is no different in the NWT, where traditional knowledge is based on the consistent nature of Aboriginal people's engagement with the land (Legat 2012b, Bayha 2015).

[5] For a more detailed background and theoretical treatment of traditional knowledge which is outside the scope of this report, see for example Berkes, Colding et al. (2000), Geertsema (2008), Berkes and Berkes (2009), Fienup-Riordan (2014), and Polfus, Heinemeyer et al. (2014) among many others.

Tłı̨chǫ people are trained since a very young age, so they see everything that's going on as they do any activity. They are constantly looking at whatever food the animal is eating, constantly processing all the information that they can use to survive... they can put a lot of variables together fast. That's why it's so important to be on the land all the time – because they see subtle things. Scientific monitoring is good, but very specific and very exclusive. The traditional knowledge way of doing things is more inclusive and tells you a lot more about what's going on (Legat 2015).

… TK monitoring is happening all the time. It's not formal, but people share what they see, touch, etc. and that's happening all the time – this extends to the youth – they're really interested in wildlife and the environment (Polfus 2015a).

This on-going interaction creates 'land-based experts' – a subset of TK holders who have engaged in regular and long-term land-based activities – and local communities with highly developed ecosystem knowledge and monitoring expertise (Geertsema 2008). Knowledgeable and active harvesters observe and share stories with each other; Elders help to contextualize the observations within a longer-term framework (Legat, Chocolate et al. 2008a, Legat 2012b). This interpretation of information is an equally critical part of these traditional knowledge systems (Redvers 2015). For many caribou-reliant communities across the north, information sharing and interpretation/contextualization has traditionally taken place at annual or seasonal gatherings, where families would come together to discuss things such as how their year's harvesting went, whether wildlife populations were healthy or not, and what they had been observing on the land over the course of the previous year (Winbourne 2013, Bayha 2015). It was at these gatherings that harvest decisions were usually made for the upcoming season or year – family leaders discussed where to harvest and what to harvest based on the information that was shared.

In the spring time, the people had a big gathering to renew, to get back in touch with family members. A lot of people from the lake would go to Tulít'a. They had these huge gatherings and they made it like stories but that's what they were doing – they brought in information, exchanged information, and made decisions about where to hunt in the fall and things like that. They had information from all the families and there were people all over the lake, so they had information from everywhere. You have to understand that when people shoot fat animals it makes them happy. They would talk about all the best animals they harvested and from that information they would decide how and where to hunt the following year. The information from all the other animals would come into it as well. Animals tend to go to the best [ecosystem], especially the geese – they go to the first open water and grass. There's a relationship with everything, so that connection starts to add to how they make a decision. You have to know the stories – stories about raven, what they mean, how they behave – throughout the year, every animal would have a story. So coming together and sharing stories in the spring gathering, people add to their basic knowledge of the land, water and wildlife. That's a whole different way of looking at things (Bayha 2015).

Indigenous monitoring tends to have a learning cycle at its core, which promotes sustainable use of the resources being monitored (Moller, Berkes et al. 2004), and builds resilience to various changing contingencies in the environment, including variations that occur over the medium- and long-term (Berkes, Colding et al. 2000). In modern times, a good example of how TK can promote sustainable use is through the very fast turn-around times between indigenous monitoring and decision-making, especially within an adaptive management framework. This can 'tighten' the adaptive management cycle, *i.e.* decrease the time it takes for information to filter into management protocols (Uychiaoco, Arceo et al. 2005). For example, in the above example of seasonal gatherings, self-governing local monitoring occurred in a way that resulted in virtually simultaneous monitoring and management of a wildlife resource (these projects tend to fall under 'Category 5 – autonomous local monitoring' as described in Figure 1). There are several recent northern initiatives that seek to re-establish this system for monitoring caribou populations in particular (Barnaby and Simmons 2013, Winbourne 2013).

> *In terms of utilizing knowledge, TK is a body of knowledge but also an approach to learning – an approach to the gathering and processing of information – and still people are out there using the land that have the ability to look at the land through traditional eyes, and so process that information individually as well as through a community or peer review process. But the fact is that aspects of Dene TK are incredibly scientific. They use similar techniques, including peer review. I mean, they better have accurate knowledge or they won't survive. An element of TK is that it can be extremely precise. It has its own indicators from which monitoring indicators can be developed that still allow portions of that information to be recorded and processed as data as well. This is very important in terms of interfacing with dominant/ scientific based forms of information.*
>
> *(Redvers 2015, interview)*

Other recent, related northern developments include 'observing networks' that have been initiated in several regions (see for example Fidel, Kliskey et al. 2014). An observing network is a broad-based information collection scheme that can bring community observations, often of larger ecological or climate change issues, together into a single project and single information storage system. An "understanding of the effects of climate change on Arctic communities and resulting adaptations can be enhanced through Community-Based Observing Networks (CBONs). CBONs allow for systematic data collection by locals to address community concerns" (Fidel, Kliskey et al. 2014: 49). Observing networks are built on the idea of recording, and formalizing to some extent, the countless observations made by individuals every day (Pulsifer, Huntington et al. 2014). In some cases, the data is used directly by community or regional co-management organizations (Fidel, Kliskey et al. 2014). The information gathered in community based monitoring or observing networks can be very broad – for example, one James Bay TK study gathered information on population trends, migration patterns, distribution, health, habitat, and more. The information gathered was then integrated into a community based monitoring information storage system (Herrmann, Royer et al. 2012 – more details on the inclusion of baseline TK data are provided in the **Baseline boreal caribou traditional knowledge** section, below).

As noted in the **Knowledge Co-production: mixed projects/multiple data streams** section above, monitoring programs are often undertaken within a framework having multiple components or data-gathering streams – a scientific component and a 'traditional' or indigenous monitoring component are completed at the same time. The scientific monitoring components may or may not include some level of community participation. In many cases, data from different sources used in a combined approach is found to be superior to relying on information from a single source (Fragoso, Silvius et al. 2000, Gunn 2004, Moller, Berkes et al. 2004, Gillman, Hynes et al. 2015, among others). A combined approach can bring more robust findings, and can also promote community buy-in. "Retaining traditional monitoring methods is potentially crucial because they provide one of the few channels through which customary users can scrutinize science" (Moller, Berkes et al. 2004: 9). Community support is not the only or even main reason for such an approach, as "collaborative comparisons provide an avenue towards a more complete understanding of ecosystems and can lead to more effective management decisions" (Polfus, Heinemeyer et al. 2014: 119). In collaborative projects, the TK component often addresses gaps which may have otherwise existed in a science-only program (Herrmann, Royer et al. 2012). In the NWT, collaborative approaches to boreal caribou research have already shown success in the Dehcho and Sahtú regions (Gunn 2004, Polfus 2015a, Redvers 2015).

Science and TK can be complementary when it comes to questions of time scales, averages *vs.* extremes, quantitative *vs.* qualitative, hypothesis production *vs.* testing mechanisms, and objectivity *vs.* subjectivity (Moller, Berkes et al. 2004). Despite their differences, it can be argued that some forms of TK and science share an empirical basis and are based on experience and observation (Davis and Ruddle 2010 in Polfus, Heinemeyer et al. 2014, Redvers 2015). Roots (1998) proposed a 'staircase of knowing' to describe and differentiate how knowledge is produced, including western science and TK (Figure 2, next page).

Traditional knowledge-based monitoring has a particular strength in identifying cumulative effects and general ecosystem health (Geertsema 2008). In one definition, cumulative effects are "the incremental and interacting impacts of anthropogenic [human-induced] land and resource use and development stressors upon ecological, social, cultural and economic systems" (Geertsema 2008: 19 – wildlife definitions might include natural stressors). The effectiveness of TK monitoring for cumulative effects highlights the strengths of TK in assessing changes over time. For example, to understand cumulative effects, these points must be taken into account:

- Similar and dissimilar development produce cumulative results
- Impacts of development accumulate temporally and spatially
- Accumulation takes place in both incremental and synergistic ways
- System altering effects may occur immediately or in a delayed fashion, and may be much more than a simple addition of incremental effects
- Some development is growth inducing and thus represents a significant impetus for future development (Tollefson and Wipond 1998 in Geertsema 2008: 20)

Staircase of knowing

Western science focusses on the first four steps of the staircase, although often seeks understanding as well. TK collapses the first three steps into the living experience and observation of the land, and focusses on the top three.

> *Most knowledge starts with* observations*, — sometimes, in western technical science, it starts with* measurement*. When the observations or measurements are related to some standard or common experience [i.e., through verification], they become data… And, of course, understanding, put into perspective with judgement according to respected human values, can lead to* wisdom*. Notice that as one proceeds up this staircase, the content and the idea become more subjective, and carry more human values. … there can be no knowledge that is completely objective and free from human value (Roots 1998: 43-44).*

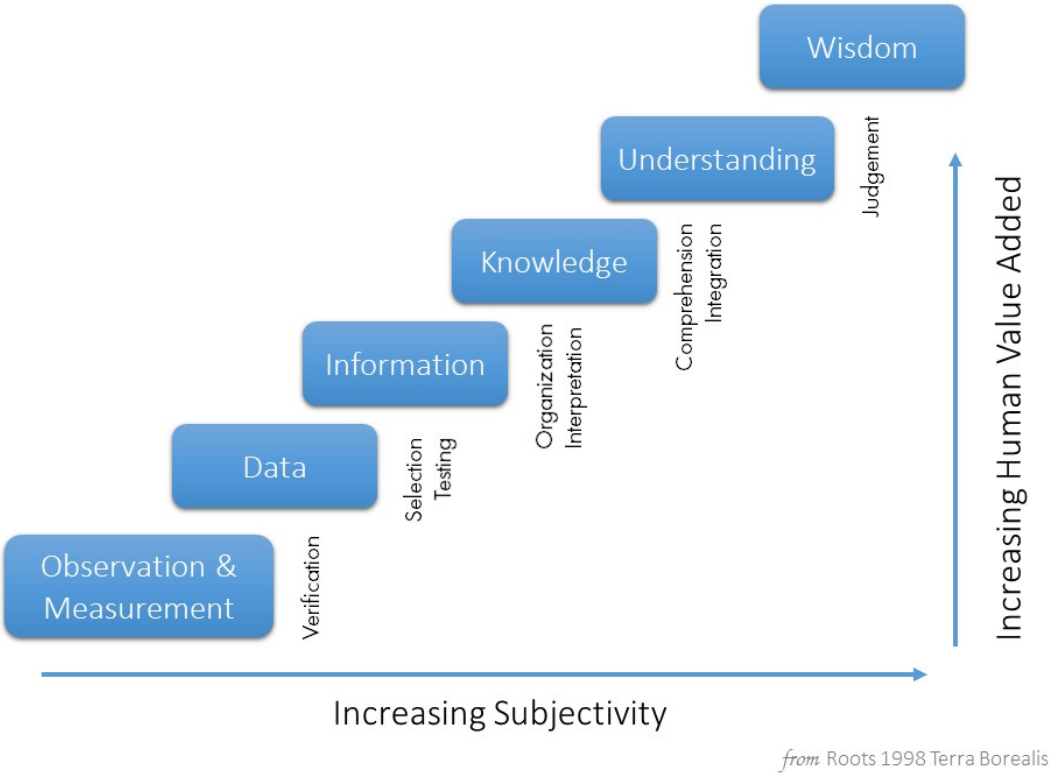

Figure 2. Staircase of knowing (Roots 1998: 42, redrawn by J. Polfus and used with permission).

Cumulative effects are thought to be of particular importance when monitoring caribou.

> *[C]ase studies from Sweden and Canada commonly show that diverse effects, such as hydroelectric development, forestry activities, roads, increasing predator numbers, climate change, exacerbate the impacts of mining on reindeer/caribou populations and habitat. Therefore, we argue that it is not the impact of the mine alone, but the cumulative and interactive impacts that need to be considered when assessing reindeer/caribou populations. Hence, it is important to highlight the importance of systematic community mapping of all possible interactions and cumulative impacts in order to understand the species' vulnerability in the context of multiple stressors, and identify areas that are "double exposed" such as migration routes or calving grounds (Herrmann, Sandström et al. 2014: 44).*

While there is evidence that caribou can habituate to industrial developments such as mines and pipelines, there is also concern amongst some indigenous communities that the current situation is leaving the caribou too few options to do otherwise, thereby forcing the caribou through a difficult set of choices and ultimately stressing the animals.

> *Everything that we do in that whole migration area of the Bathurst herd, I don't think they have much room to do anything else. And I don't think the herd can 'habituate' – no I don't think so. Maybe some things – they show that in the Porcupine caribou grazing near the pipeline, but you're talking years and years and years and some [developments] are pretty close to the calving area so the caribou don't have a choice – they have to go there – and it has to be a pretty big impact on the herd itself (Bayha 2015).*

Generally, Aboriginal harvesters and knowledge holders are very good at seeing the relationship between humans and caribou – this extends to their ability to assess direct and indirect effects of human activities (Legat 2015).

There are barriers to the way scientific data-gathering may realistically capture evidence of, for example, the synergistic ways in which multiple unrelated impacts to the land may interact (examples of these barriers include reduced or compacted observational timelines, differences in breadth of focus, *etc*.). However, these are topics which observation and experience of the land – in other words, TK – can potentially address more easily, comprehensively and sustainably. It is likely that an indigenous 'holistic' approach to knowing the land and knowing the caribou can better anticipate the overall effects of these multiple, diverse impacts. Improved monitoring and management may be a matter of re-discovering traditional ways or principles for knowing and caring for wildlife populations. This topic is explored more fully in the next section.

General principles for indigenous monitoring

General principles for indigenous monitoring have been suggested by several authors (Kofinas, Lyver et al. 2003, Geertsema 2008, among others, Housty, Noson et al. 2014). A list of almost 30 principles and best practises for TK/community monitoring in the NWT was developed by a group of TK Practitioners

for the Cumulative Impact Monitoring Program (now under ENR) in 2007 (SENES Consultants Ltd. 2007: iii-iv). The following principles apply most directly to the monitoring of boreal caribou.

1. [Monitoring projects should be based on a] long term partnership approach with indigenous communities and regional organisations, affirming indigenous values, guidelines, priorities and methods.
2. Indigenous language, concepts, and modes of knowledge production are the starting point for research.
3. TK engages in a dialogue of equals with science, rather than being subsumed within scientific methods and objectives.
4. …[I]indigenous knowledge production is holistic, cumulative and contextual. Thus community priorities and interests will necessarily shift, evolve, and exceed the boundaries of the "Valued Component" model. A fixed formula for monitoring along scientific lines is not realistic.
5. [TK is] The indigenous practice, communication and interpretation of human environment relationships across generations. …a dynamic, pluralistic, and evolving process that incorporates oral history, spirituality, experience, and scientific data in varying proportions.
6. The collective aspect of TK knowledge production incorporates verification procedures and cross-scale analysis.
7. A participatory methodology is recommended, ensuring that long term programs are community-owned and incorporate ongoing capacity-building and training aspects.
8. In keeping with the participatory methodology, specific monitoring procedures are defined by partnering institutions and are not imposed through a centralized model.
9. Knowledge produced in local and regional scales should be discussed and synthesized across regions.
10. Raw data is owned by participating communities and/or institutions and governed by locally established confidentiality guidelines.
11. Information sharing agreements should ensure that professional archiving norms are followed so as to ensure that information is not destroyed or lost…
12. Both documented and oral communication modes are equally as important in TK monitoring processes.
13. Regular evaluation should take place through both community and academic review procedures, using regionally established criteria.

Based on an assessment of how Cree hunters have kept track of, and continue to monitor their traditional territories and the development within them, Geertsema (2008) suggested that effective monitoring based on TK should have these characteristics (compare Heiltsuk First Nation example in Housty, Noson et al. 2014):

1. Incorporate appropriate, and numerous, indicators.
2. Use diagnostic measures (such as quantitative or quasi-quantitative measures like buckets of blueberries harvested, inches of sub-cutaneous fat, *etc*.).
3. Assess at an appropriate scale, preferentially local landscape scales.

4. Assess indicators numerous times per year, over both a short (5 year) and longer (up to 50 year) scale (Geertsema 2008).

Indigenous measurement of ecological change

Indigenous communities have, through interaction with their world, survived and thrived due to an ability to interpret and filter signals, or indicators, of fuzzy natural systems in both the short and long term. An indicator is "something that provides an indication, especially of trends"[6] and can work within monitoring endeavours by identifying and measuring changes from a known baseline (Geertsema 2008).

Many indigenous monitoring programs described in the existing literature rely on some sort of measure or 'indicator.'

> *Indicators are expressions about the state of some aspect of a system. If a reasonable baseline state can be established and if this state is measured constantly over time, it can provide people with a sense of whether a trend (for better or for worse) is emerging. An indicator tells us a little bit about a system, and hints at what might be going on with it. Because it is only a piece of information, without the context and relationship to the rest of the system, it can be open to misinterpretation (Tsetta, Gibson et al. 2005: 62).*

Indigenous indicators are a component of the "sophisticated knowledge systems of local land-based cultures and their capacity to learn and adapt to ecological change" (Parlee 2006: 84). They "provide clues to the complex classification system that local communities have evolved to deal with variability in any natural resource" (Gupta Anil and Jitendra 1996: 11).

The indicators used by indigenous communities to understand and communicate about important aspects of their environment and ecology have evolved to highlight the interconnectedness of the various components of living systems (Parlee 2006). Indicators (also known as heuristics, rules of thumb, and sometimes just called "categories" – see for example Eicken, Kaufman et al. 2014) cut across the ecological complexity of the systems being monitored, allow for holistic

Inuit knowledge of long-term trends and cycles of caribou populations

Over more than a decade in the 1980s and 1990s, information about caribou migration and population trends was recorded from Inuit Elders and harvesters on Baffin Island. The information was gathered through an accounting of each participants life story – each hunting trip was reviewed, mapped, and all caribou sightings and harvests were diligently recorded.

The Elders and harvesters' data was collated carefully by the research team, and a decade-by-decade description of caribou abundance and distribution was created and verified (Ferguson, Williamson et al. 1998).

[6] Indicator. (n.d.). Collins English Dictionary - Complete & Unabridged 10th Edition. Retrieved June 06, 2015, from Dictionary.com website: http://dictionary.reference.com/browse/indicator

approaches, and have the benefit of being easily enforceable through social rules (Berkes and Berkes 2009). Indicators used by indigenous communities measure both the incidence and scale of disturbances (Parlee 2006). Monitoring ecological change is an inherent aspect of traditional management (Berkes, Colding et al. 2000).

Although indicators are naturally used by people to assess and monitor their world, they are also used in more scientific endeavours (such as biology, ecology, medicine, community medicine, sociology, climate change science, forestry, environmental impact assessment including socio-economics, *etc*.). Indicators, however – especially ecological indicators – are not exclusively or even primarily tools of western science. Nor did they develop originally within western science. Indicators "have been used for centuries to guide environmental and livelihood planning and action, long before scientific knowledge attempted to understand the processes of environmental change and development" (Mwesigye 1996: 74 in Parlee 2006). Scientific endeavours may emphasize the reductionist aspects and focussed representativeness of indicators – and may focus on identifying cause and effect. However, focussing simply on cause and effect or correlations does not usually characterise indigenous monitoring processes (Berkes, Berkes et al. 2007). Indigenous communities rely on knowledge of natural systems gained through instruction and experience to develop indicators useful in assessing intricate systems and prompting dialogues about these systems. Indigenous indicators honour ecological complexity, and the ever-growing, changing, and adapting nature of TK makes this body of knowledge particularly suitable for monitoring within an adaptive management framework.

Indigenous monitoring systems using indicators can be seen as based on an iterative process of "watching, listening, and learning" (Parlee and Manseau 2005: 35). In addition, the indicators used by Indigenous communities tend to be intricately tied to the health of the resource, as that is linked with the health of the indigenous community itself – a concept known as socio-ecological health (Parlee 2006).

Indigenous monitoring systems tend to have a high degree of flexibility built into them, meaning that different indicators may become more or less significant at different times. Overall, a pre-ordained single or small number of consistent indicators may not provide high-quality data for assessing trends in abundance over time. Instead, a 'suite' of indicators is more appropriate and will provide comprehensive information about changes in the landscape and animals, and best identify stressors or threats for management purposes (Geertsema 2008). In one program, the "[v]ariability in the condition, abundance and distribution of [caribou and moose] and other species necessitated the tracking of many kinds of ecological indicators" (Parlee, Goddard et al. 2014: 47).

Different indicators are also monitored or observed by TK holders at different frequencies, "the lead time for different signals is considered crucially dependent on a homeostatic [internally consistent/regulating] ability of a system… different indicators have to be monitored at different frequencies to generate meaningful results" (Gupta Anil and Jitendra 1996: 21). Indicators may be spatially bound and seasonally specific – for example, thin female caribou may be expected during the fall migration at a certain location, but a similar appearance would be considered unusually 'skinny' at other times of year (Parlee 2006). Caribou overwintering in different locations are expected to produce

different body conditions, and body condition will change in a predictable way through the seasons (Lyver 2005).

Traditional knowledge research has been used to identify thresholds beyond which rapid ecological change may occur (Parlee, Geertsema et al. 2012). However, it is generally difficult to establish thresholds for various indicators in ecological research due to the constantly changing context within complex ecological systems (Polfus 2015a). A dialogic system with Elders, harvesters, youth, wildlife management stakeholders, and researchers may overcome the limitations of using thresholds, indicators, and TK monitoring in general. The following case studies are of northern monitoring projects that demonstrate various methodologies to share information and support harvester/decision-maker dialogues.

Case studies

Monitoring barren-ground caribou migration patterns with the Denésǫliné of Łutsël K'é

In 2000 and 2001, researchers Kendrick and Lyver worked with the Denésǫliné community of Łutsël K'é. Łutsël K'é harvesters and Elders shared information about barren-ground caribou migration patterns, including changes to the migration over time. The harvesters and Elders shared information about migration cycles, migration phenomena considered outside of the norm, and other topics. The researchers interviewed Elders and active hunters using semi-directed interviews. Questions focussed on topics identified by the community as important to understanding the changes in caribou migration patterns and health.

> *Only elders were interviewed about their cumulative knowledge of caribou movements, indicators of caribou body condition, and the possible effects of development on caribou movements and condition. All interviews employed local facilitators fluent in both English and Denésǫliné (Kendrick and Lyver 2005: 178-9).*

Łutsël K'é Dene First Nation Socio-ecological and Environmental Monitoring

One component of the West Kitikmeot Slave Study was a large monitoring project undertaken by the Łutsël K'é Dene First Nation (2003-2005). The monitoring project included both socio-economic change, and ecological change (Lutsel K'e Dene Community Members 2005). The harvesters and Elders shared information about the indicators they used to detect ecological change. Information about the indicators (both spatial and contextual) was shared in semi-directed interviews, using a questionnaire, "in a series of seasonal cycles corresponding to the rhythms of the land and Dene life (*i.e.* spring duck hunting season, fall caribou hunting season, *etc.*)" (Lutsel K'e Dene Community Members 2005: 12). An honoraria was offered for participation in the interviews. Occasionally, the main researcher travelled out on the land with harvesters, where they shared information in a participatory setting. The project built on a previous study between 1997 and 2001 which documented Łutsël K'é knowledge of caribou, especially the relationship between change and Tłı̨chǫ laws associated with caribou (Legat, Chocolate et al. 2008a).

[F]rom the Tłįchǫ perspective; without knowledge one does not know or understand the principles for living, nor does one know the rules and laws governing respectful behaviour towards other beings, including caribou beings. And, finally without knowledge one does not have the skill to take the action necessary to act in a respectful manner or act according to agreements that have been made – whether formal or informal, old or new (Legat, Chocolate et al. 2008b: 33-34).

The earlier project focussed on identifying laws governing respectful behaviour, storage of caribou meat, and other topics. Although an attempt was made to categorize and list the laws, "extracting the laws from the story and attempting to categorize them under themes took away from the importance of the oral narratives to understanding correct, meaningful and respectful behaviour" (Legat, Chocolate et al. 2008a). For the second component, environmental indicators were developed by Elders, land-users, and local governance in a multi-phased project. Community health indicators were identified through an academic project, and information gathered about them quantitatively through a census (Lutsel K'e Dene Community Members 2005).

The following indicators were used to share information about barren-ground caribou (Lutsel K'e Dene Community Members 2005: 23):

- Numbers of caribou harvested by local hunters in the traditional territory
- Locations of caribou harvesting activities
- Presence and numbers of caribou at traditional lake/river crossings during peak crossing seasons
- Amount of fat noticed while butchering caribou
- Color and consistency of marrow
- Visual aesthetic of caribou
- Behaviour of caribou
- Movement ability of caribou
- Presence of discolorations or parasites in muscle and/or internal organs
- Quality of hide

Information was organized into a spatial (computerized mapping) database with a software add-on for all the textual information. The project directors recognized that the socio-economic health of the community was intricately tied to the health of the environment, and ensured that the indicators used had a social dimension. The indictors were also regionally specific – for example, different lakes were assessed differently, for fish population change.

Responses to the questions about each indicator were collated and presented as graphs. In addition to ecological indicators, indicators of community health were gathered, such as 'how many times did you attend a drum dance over the last year?', 'how many nights did you spend on the land in the last year?', and 'how often did you take a youth out on the land?' These indicators were used to show changes over the two years of the study in participation in traditional activities and knowledge transmission (Lutsel K'e Dene Community Members 2005).

Twelve years after the first round of monitoring, this project was revisited for the purposes of tracking chronic wasting disease (Parlee, Goddard et al. 2014). Grouping observations into three themes – abundance, condition, and distribution, the original observations were compared to data shared by harvesters and Elders in interviews in 2010. For questions of abundance, interviewees were asked about trend and likely reasons for noted trends. The decade-long hiatus allowed for some of the predictions from the earlier study to be considered by the 2010 participants (Parlee, Goddard et al. 2014).

Monitoring of Natural Resources in Greenland

A multi-year program to monitor natural resources in Greenland was initiated in 2009, and was a co-operative project undertaken by an advisory group of natural resource committees in communities, Danish scientists, government staff, and other stakeholders. The methodology was selected through community consultation and the program was run through the community natural resource councils. Each committee proposed monitoring activities and targets, identified spatial limits to monitoring activities, provided adaptive management recommendations, and maintained census data of wildlife counts (Danielsen, Topp-Jørgensen et al. 2014). Knowledge was generated using co-production methodology: a census from patrol records, and community focus groups.

> *Once every three months, the NRC [natural resources committee] meets in the community. At this meeting, data and knowledge from the community's monitoring of natural resources are summarized by each member, and then discussed, and interpreted. Suggestions for management initiatives are also considered. The local interpretation is prompted by the filling-in of a summary form which, at the end of the meeting, is signed by the participants. Both data on dead and observations of live animals are accompanied by data on effort (Danielsen, Topp-Jørgensen et al. 2014: 76).*

Other case studies

Other relevant case studies that use a system of indigenous indicators in ecological monitoring include:

- The monitoring berry harvest and well-being with the Teetł'it Gwich'in of Fort McPherson (Parlee 2006). For example, in the category of "Signs and Signals that the Berries are Good," indicators included:
  - Number of plants flowering
  - Rate of maturation of berries
  - Survival/spoilage of berries relative to microclimate (Parlee 2006: 129)
- Monitoring barren-ground caribou body condition, through both interviews and field observations, using mainly various types/locations of fat as an indicator (Lyver 2005).
- Monitoring ('understanding' and 'communicating') ecological change with the Denésǫliné community of Łutsël K'é (Parlee 2006)
- Comparison of monitoring barren-ground caribou body condition by TK and western science in Alaska, Fort McPherson, and Łutsël K'é (Kofinas, Lyver et al. 2003). A key was developed to

assess fat on female caribou, used as a proxy of breeding success. A questionnaire accompanied by photographs was used to obtain information

- Breeding success of Canada Geese to estimate later hunting success, including assessments of nests and later of young geese per adult pair (Berkes 1982 in Moller, Berkes et al. 2004).
- Polar bear monitoring at the sub-population level by appropriate formally recognized 'community clusters' – groups of communities who share access to the same sub-population (Dowsley 2009)
- Boreal caribou TK research was conducted by the Tłı̨chǫ under a species at risk process in preparation for monitoring (Legat 2012a, Legat 2013). The overall research project included a TK and a science component, the results of which were presented side by side in a single overview report (Wek'èezhìi Renewable Resources Board 2013)

In some TK monitoring projects, specific indicators are not used. For example, in a Cree monitoring program, key species were selected as indicators of overall ecosystem health. For each animal selected, 'population size' and 'population trend' were considered parameters. Information about these topics was shared through general and directed questioning (Herrmann, Royer et al. 2012). TK studies focussing on biophysical knowledge, for example for species at risk purposes, also often include direct questions about population abundance and trends (for boreal woodland caribou examples, see Benson 2011, Dehcho First Nations 2011). However, generally there is an attempt to classify information into categories or indicators, which also prompts discussion about each topic.

> *What we decided to do was to map all the domains that people were interested to study, and then categorize them. Once we were able to reduce and sort the indicators, we felt the ideal methods would be more apparent. The questions we used to sort the indicators were:*
>
> *- What are the goals of the Yellowknives Dene? Which of the indicators tell us about these goals? For example, one major goal turned out to be equity or equal treatment of the Yellowknives Dene at the mines, and many categories of information spoke to that theme.*
>
> *- What are the means to the end? Which of the indicators or items tell us about the means to the ends? Many of the indicators turned out to be paths towards the ultimate goals, such as equity. For example, the number of miners hired and their job positions spoke to the goal of equity (Tsetta, Gibson et al. 2005: 68)*

Cree hunters in northern Alberta and BC tended to use the following indicators when asked about ecosystem health and cumulative impacts of development:

- Species abundance and trends
- Species population dynamics
- Species body condition
- Critical habitat abundance and condition, and
- Water quality and yield (Geertsema 2008: 98).

Cree communities in northern Alberta and BC also use systematic ecosystem monitoring elements such as 'cultural keystone species' as indicators of ecosystem health (Geertsema 2008). This is another example of the knowledgeable selection of components of a larger system which provide information about the whole system – "[r]eduction is necessary for making measurement possible" (Gupta Anil and Jitendra 1996: 19). Participatory approaches are also being used to identify and develop appropriate indicators for monitoring impacts on community health (for example, Lutsel K'e Dene Community Members 2005, Tsetta, Gibson et al. 2005)

Limitations and challenges

There are several important limitations and caveats to consider when assessing indigenous monitoring methodology and literature. Within indigenous communities, the use of indicators can be seen as a 'reductionist' approach to understanding a very complex system, and can create resistance to monitoring programs that rely on them.

> *All of it is about relationships – not just about the caribou, but about the relationship they have with the land. We're the ones who reduce it and have to learn to look at it a different way. Anthropologists should be doing more to help the biologists understand better… You can't separate humans from nature, or humans from animals. You can't separate culture from an understanding of nature. We do look at one thing all the time – that's our belief system (Legat 2015).*
>
> *Indicators simply cannot capture the complexity of this kind of change, which is why the Yellowknives created a research project that can capture indicators as well as stories about change (Tsetta, Gibson et al. 2005: 63).*
>
> *Oral narratives, then, should be considered in totality just as all scientific literature is reviewed and considered (Legat, Chocolate et al. 2008b: 8).*

This challenge can likely be minimized by good dialogue and collaborative development of monitoring programs that include Aboriginal concepts and terminology (Courtois 2015).

As mentioned previously, many of the indicators, and methods to identify indicators, described in the case studies and in other reviewed literature may not relate to boreal caribou – considered a rare and elusive species by scientists. Much of the northern literature relates to indigenous ways of knowing barren-ground caribou (which are neither rare nor elusive) and therefore may have limited applicability to monitoring boreal caribou in some parts of the NWT. The dearth of literature specifically focussed on indigenous monitoring of rare and elusive species suggests that particular attention must be paid to validating not only the information produced during a monitoring project, but also the methodology. Some of the indicators commonly used in indigenous monitoring programs (hunting effort, and body condition) also have methodological or data-validation issues, and these are noted below in the appropriate sections describing these indicators and explored more fully in Demars, Boulanger et al. (2014). Indigenous monitoring techniques in general may be most easily applied to qualitative

assessments and trends, rather than quantitative assessments (Burton 2012). In addition, there can be variations in accuracy depending on the species of concern (Burton 2012).

A larger potential complication when using indigenous monitoring techniques relates to the larger social and political contexts and potentially, struggles, of Aboriginal communities. As noted by Nielsen and Lund (2012: 2), monitoring data gathered at a community level about contested resources is "information that can potentially be used to revoke [a community's] management, use and taxation rights." Even when a community is participating on a fundamental level, including project governance, conservation agendas are politicised. The "conditions under which [monitoring] information is produced and communicated is important for understanding and interpreting it" (Nielsen and Lund 2012: 2).

> *… no matter where the information comes from, in order to make a decision you need the best information in front of you from all sources. So if you're doing the health of fish, TK might be better information on relationships between ecosystem processes, but Western science is better at testing for mercury. Any sensible manager wants the full breadth of that information. Having been trained in Western science and being indigenous I see the value in both. The difficulty is playing that bridge role between good information and the dominant methodology and conclusions. So it's about doing it for the right reasons as opposed to just for a certain methodological reason (Courtois 2015).*

Internal and external verification and validation – for example, dialogue and information sharing between knowledgeable Elders and hunters, biologists, and other stakeholders – may overcome identified issues with local monitoring. Clarity and transparency in participant selection and remuneration may also promote accuracy and sustainability in monitoring programs.

The greatest challenge perhaps lies in striking a balance between respecting the cultural context and meeting the structure and rigor required to make management decisions, a structure which is more well-defined in scientific endeavours.

> *If you want to use indigenous indicators in a more structured, scientific manner, I think you can design monitoring programs that incorporate those indicators, but have enough structure to produce data. … [Our] idea was to use multiple harvesters over long periods of time and to model what people did traditionally – that is, coming in to talk about what they saw on the land after they came back in. Where we ran into problems was in trying to develop a software program that would be relatively easy to use that could automatically tabulate or document that data in a text and map format so you could start to build a composite. If you're going to look at community-based monitoring, you're going to get a lot more data in terms of broader things like population, population trends, winter habitat use, etc. … But notions of community-based monitoring systems relying on harvesters, and a single software that could correlate the data over regions or the territory, could really be a wonderful tool to get a handle on what's happening out there (Redvers 2015).*

Although traditional on-the-land activities and information sharing can result in accurate assessments of relative population abundance and trends over time (Bayha 2015), these information systems are reliant on a sufficient level of participating in land-based activities over time.

> *Dene ways of knowing are fundamentally experiential in nature. They only operate effectively when people engage in traditional activities on the land – hunting, fishing, gathering, travelling and camping. Having people in close contact with the land ensures that new information about the land is continually being generated through observation and experience (Lutsel K'e Dene Community Members 2005: 13).*

In areas of the NWT where this may pose a limitation, several interviewees suggested that it could be at least partly overcome by offering financial incentives for people to spend time out on the land in areas where boreal caribou occur (Legat 2015, Polfus 2015a). "We need to get our people back on the land or at least get them to know about the wildlife, rebuild those relationships" (Bayha 2015).

Towards an indigenous approach for understanding and monitoring boreal caribou populations

> *Aboriginal people are the original caribou researchers. Knowledge about caribou has for generations been key to survival, so people have gained an intimate understanding of caribou social-ecological relationships, behaviour, movements, and health. Monitoring what they observe in the natural environment is a key aspect to their traditional management system. Sharing and exchanging what they see on the land while traveling or harvesting is a regular and expected responsibility of each member of the community. Observations relate to location of caribou (or other animals), the population and health of the herd, and the state of the habitat.*
>
> *Any indications of problems including population decline, size and weight, and discoloration or spots on meat are discussed thoroughly and common understandings develop as to the cause and what actions should be taken. Monitoring extends beyond the caribou, comprehending the status of caribou habitat at both local and landscape scales, interactions with other wildlife, and harvesting practices. Decisions about hunting caribou are made based on numerous factors. Decision-making is collective, with strong leadership from the most knowledgeable, to ensure that the well-being of the caribou is considered. It is believed that caribou are free beings that make their own decisions and have their own leaders – caribou are not to be managed like ranch stock. People must have a strong system of self-governance, including strong leaders, teachers, and learners who follow the traditional laws.*
>
> *Aboriginal people continue to have a strong interest in research and monitoring as a basis for wise management. Traditional knowledge perspectives continue to be a strong basis for learning*

about changes that may be occurring, since they bring together knowledge from the past with the current knowledge that comes through the maintenance of respectful harvesting practices.

Because of the many environmental and social changes that are taking place on the land, there is a need for the new research tools offered by scientific methods. Considered together in balance, traditional knowledge and science can provide a more complete understanding of caribou populations. Means need to be found for respectfully exchanging knowledge across cultures. This can create the basis for collaborative caribou stewardship (Barnaby and Simmons 2013: 12).

Information provided by both the literature review and the interviews indicates that there are numerous, diverse ways of monitoring wildlife populations that can be respectful and inclusive of traditional indigenous methods and ways of knowing. This section of the report explores how applicable these ideas may be for NWT communities and boreal caribou abundance and trends in particular. It is important to re-iterate that wide-ranging boreal caribou may be harvested in several cultural regions of the NWT and that suitable methodologies will be best co-developed with the interested communities in each region. It was repeatedly stressed in the interviews that different people, in different areas, have different ways of knowing boreal caribou, and that any monitoring programs that are developed will need to be tailored to regional knowledge, culture and experiences. That work was beyond the scope of the current project, but some suggested steps and recommendations are included below, along with consideration of several potential indicators.

Identification of potential measures

Some or all communities or regions may decide that data sharing or data gathering guided by categories or indicators, or other similar measures, is the most appropriate way to share knowledge about changes in boreal caribou populations. NWT communities can best describe qualitatively how they track boreal caribou through time – in other words, which types of information or ways of knowing ('indicators') about caribou are important. In some regions/communities, this work has already begun (Arctic Borderlands Ecological Knowledge Co-op Society 2015, Legat 2015, Redvers 2015). When categories of information which are valuable for understanding population ('caribou health' or 'distribution', for example) have been identified, these can be 'unpacked' to better understand how they indicate changes in caribou (Parlee 2006).

Potential indicators of boreal caribou population size and trend are introduced below and organized into eight main types or categories. These categories are not unique to boreal caribou nor northern cultures or landscapes, but are common to many indigenous monitoring systems or ways of knowing wildlife populations throughout the world. For each category below, the authors describe the indicator and briefly consider its applicability for boreal caribou.

'Watching, listening, and learning' – Knowledge, knowledge transmission, and rules for appropriate behaviour

Communication and cooperation between harvesters is a key factor in maintaining a cohesive understanding of current trends in wildlife (Parlee and Manseau 2005, among others, Bayha 2015, Redvers 2015). 'Being knowledgeable' about caribou is an important indicator of the health of the social-ecological relationship between people and caribou (Legat, Chocolate et al. 2008a).

In addition, monitoring any trend in knowledge transmission will shed light on the continuation of the ability of indigenous monitoring to include feedback in the form of discussion, education and verification – the "watching, listening, and learning" (Parlee and Manseau 2005: 35).

Rules governing the use of resources such as caribou are a cultural institution which has evolved to promote sustainability through regulating an ethic of sharing and conservation (Wray and Parlee 2013).

> *In gatherings, elders teach not just facts, they teach listeners how to learn. They share not only what they know but how they know it and why they believe it is important to remember (Fienup-Riordan 2014: 93).*

Knowledge about appropriate use of caribou is often conceptualized as a series of laws or rules. Although it is not necessarily appropriate or useful to separate laws governing behaviour from the oral traditions within which they exist (Legat, Chocolate et al. 2008b), they may be categorized into broad groups. The rules may include prohibitions on harvesting in certain places and/or at certain times, and also generally – and importantly – may include provisions about or requirements for ongoing monitoring (Berkes and Berkes 2009). In the Tłı̨chǫ region, the laws and rules are within a framework of 'being knowledgeable,' which includes the totality of respectful, appropriate, and sustainable behaviour towards caribou (Legat 2008). Many of the elements identified for Tłı̨chǫ systems are common to other regions of the NWT as well.

> *Without knowledge of caribou and the language to discuss caribou behaviour, caribou habitat, and indicators of caribou health, people are likely to abuse and waste rather than use, preserve and share.*
>
> (Legat, Chocolate et al. 2008b: 22).
>
> *[S]carcity of a resource may generate new economic opportunities which may dilute the institutional norms about the use of that resource within sustainable limits.*
>
> (Gupta Anil and Jitendra 1996: 20)

> *The Dene term for land management is about behaving towards the land in a way that allows it to continue to provide for us. So what's key when discussing a caribou decline is how are we behaving towards the animal such that they are not able to maintain their populations? Something we are doing as people is not working. If the animals aren't able to provide for us the way they used to, we have to look at our behaviour as people. Research tends to look at animals' behaviour. Elders feel that the animals always behave perfectly, the way they're supposed to. We need to look at our behaviour not theirs. Taking that into account, when you look at collaring and chasing them around with a helicopter, etc. we're interfering with the ability of the animals to live their lives and be true to their own spirits –*

that's the concern. So the way in which we gather information can have a negative impact (Redvers 2015).

Importantly, a system of monitoring and research using indicators such as those described here would be non-invasive, which will increase community buy-in, better suit traditional methodologies, and could speed up acceptance of any new monitoring endeavours (Redvers 2015).

Some general rules for behaviour include (Kendrick and Lyver 2005, Parlee, Manseau et al. 2005, Parlee and Berkes 2006, Legat, Chocolate et al. 2008b, Herrmann, Royer et al. 2012, Wray and Parlee 2013):

- Harvest appropriately – 'take only what you need,' 'don't be picky'
- Behave respectfully towards the animal – 'don't make fun' or 'don't be arrogant'
- Avoid chasing or otherwise pestering the animal
- Use as much of the caribou as possible, discard carefully, and do not waste
- Learn and teach the correct way to act in order to be respectful of caribou
- Avoid discussing caribou negatively, or focussing only on the negative

These and other rules may be region-specific and their integration into a monitoring program would be at the discretion of the participating harvesters and Elders.

Flexibility in laws and rules will relate to cycles and trends in abundance of resources, among other factors (Parlee and Berkes 2006, Wray and Parlee 2013). Understanding the need for flexibility through time should be integrated into any proposed methodology.

Changes in traditional use are seen as a result of cumulative changes in the surrounding social and ecological systems. As such, the nature of the changes to traditional use can be used to indicate socio-ecological changes (Geertsema 2008). In fact, all other indicators described in this report require a high level of human observation. Careful observation is a traditional rule itself – "[h]umans should observe relationships between caribou and other beings and in doing become knowledgeable of the signs animals give" (Legat, Chocolate et al. 2008b: 11). Active harvesters may also be aware of sustainable harvest levels and whether or not these are being maintained, although hunting by non-community members may impact their ability to assess this with accuracy (Dehcho First Nations 2011).

Expectedness

Themes of **expectedness**, **predictability**, and **variations beyond normal** are important when considering monitoring programs (see for example Kendrick and Lyver 2005, Parlee and Berkes 2006, Parlee 2006).

Hunters and fishers, who are in day-to-day intimate contact with the environment, are experts in reading signs and signals of changing seasons, animal movements and abundance patterns. They have a mental image of what is normal and expected, and are very adept in noting environmental conditions that fall outside of the norms (Berkes, Berkes et al. 2007: 158).

Information representing unnatural change is a high priority, potentially revealing impacts to nature that need to be addressed by community leadership (Lutsel K'e Dene Community Members 2005: 15).

One of the characteristics of traditional monitoring is that observers tend to note unusual rather than average patterns and occurrences (Moller, Berkes et al. 2004: 4).

The ability to predict snow and ice conditions, the weather, and the timing of wildlife migrations are crucially important. But all of these phenomena have become more unpredictable, and even the seasons have shifted. A hunter who cannot predict the weather ("is the storm breaking so I can get out?"), read the ice ("should I cross the river?"), or judge snow conditions ("could I get back to the community before nightfall?") is limited in mobility (Berkes, Berkes et al. 2007: 157)

Changes in harvesting levels, effort and style/methods

Hunting effort or encounter information can be used to monitor population abundance and trends for 'rare and elusive species' within formalized, scientific endeavours (see for example Kindberg, Ericsson et al. 2009, Keane, Jones et al. 2011). However, it is also a relative measure used by indigenous peoples – for example, as harvesters share information amongst themselves. A qualitative discussion of harvesting effort and style may be an appropriate indicator for changing populations and may be included as an indicator for some regions, particularly where boreal caribou are targeted as prey.

> *Here in Délı̨nę there were certain people that always had a history with harvesting boreal caribou. Charlie [Neyelle] told me there were Bedzikatı̨né – a group of Dene that live and follow boreal caribou and they would always follow boreal caribou. There are certain families that have*

spent a lot more time hunting boreal caribou than other families. So they would tend to be the families that were successful – Charlie is one of them. His father was hunting boreal caribou all his life and was always successful. So his family has that knowledge (Bayha 2015).

Most participants in the expert interviews mentioned that knowledge of boreal caribou on the landscape will be "patchy" – that is, certain families, in certain areas, tend to harvest the animals most intensively and therefore carry the most knowledge about them. The rich information held by these harvesters necessarily relies on their continuing ability to harvest and "be on the land". "One way you could do that in the Sahtú would be to have people living in their cabins on the land with support, and they could be the boreal caribou monitors. They just live their lives, but then they could report on what they're seeing, *etc*." (Polfus 2015a). Support for programs that encourage traditional harvesting activities is likely to assist in maintaining these knowledge bases for future monitoring efforts (Legat 2015, Polfus 2015a). "If we're going to have healthy herds in the future then we have to have good relationships and that goes to hunting as well. You have to respect the animals and harvest them all the same" (Bayha 2015).

Quantitative information gathered for some indicators – such as catch per unit effort (CPUE) data extrapolated from census-style harvest studies – has recognized limitations which can reduce accuracy (see discussion in Winbourne 2013). This includes factors such as the set amount of time it takes to butcher an animal, and prey saturation, when the harvester has all they need or can carry. Harvesting in only specific locations can also affect the assessment of abundance from CPUE numbers (Moller, Berkes et al. 2004).

Changes in body condition, health, and behaviour

Indicators of body condition in various types of caribou have been used as a proxy for abundance or to assess changes in caribou health. "Signs of wellness are read continuously and cumulatively, [thereby] establishing a norm" (Berkes, Berkes et al. 2007: 153). Assessing individual animals has certain strengths in a monitoring protocol – they provide better information for diagnostic purposes and "consequently they may serve well as early warning Indicators" (Geertsema 2008: 22). Body condition indicators commonly used include (Kofinas, Lyver et al. 2003, Parlee and Berkes 2006, Berkes, Berkes et al. 2007, Geertsema 2008, Legat, Chocolate et al. 2008b, Dehcho First Nations 2011, Herrmann, Sandström et al. 2014, Bayha 2015, Redvers 2015):

- General shape and size of the animal
- Fat – including various locations on the body. Fat is measured quantitatively
- Condition/appearance of the organs or tongue
- Appearance- colour and texture – of marrow and other fat
- Hair colour
- Parasitism in various organs and tissues, external parasites
- Visible disease
- Growths or other abnormalities
- Condition and size of antlers

- Meat flavour, appearance, and storage characteristics
- Condition and feel of skin, coat and hide condition

Barren-ground caribou body condition is "recognized by both aboriginal people and scientists as an important indicator of herd well-being" (Gerhart et al. 1996 and Kofinas et al. 2003 in Lyver 2005: 45). In particular, caribou fat is both an indicator used to assess caribou and herd health, and an important food source (Lyver 2005). As such, harvesters may very well pay particular attention to fat when observing caribou.

There are multiple locations within a caribou's carcass where fat can be observed. Organ fat may be of particular use. For example, moose kidney fat was specifically noted as changing in response to ecological change in northern Alberta (Parlee, Geertsema et al. 2012).

> *The majority (86%) of elder men stated that they used brisket fat as their main indicator of caribou body condition, whereas 80% of elder women used back fat as one of theirs. Elder men also based their assessment on the amount of fat on the back, the kidneys, and around the stomach. In addition to these fat deposition sites, women used the inside of the pelvic bone and around the ribs. Women also noticed that in some years there would be more fat on the hides of caribou (Lyver 2005: 47).*

Kofinas, Lyver et al. (2003) created and tested a key for assessing body condition in barren-ground caribou, to identify the probability of calving.

> *The key uses the presence or absence of back fat, intestinal fat, kidney fat and femur marrow fat in a hierarchical decision tree leading to each animal being classified into body-fat categories, with those categories corresponding to a relationship between fat levels and the animal's overall percentage of body fat (Kofinas, Lyver et al. 2003: 47).*

Changes to subcutaneous and organ fat is used by communities from northern Canada and Alaska, to the Maori of New Zealand as an indicator of ecological health (Parlee 2006). Body condition is a proxy of many environmental conditions, such as feed availability, weather stress, reproductive history, likelihood of breeding success, and others (Kofinas, Lyver et al. 2003). Other health indicators may include leg injuries and broken limbs. Injuries like this may be intertwined with changes in the landscape and development, which may cause caribou to change their normal behaviour (Kendrick and Lyver 2005).

Monitoring body condition has been such a key aspect of understanding traditional resources that a comprehensive vocabulary has developed to discuss it (Kofinas, Lyver et al. 2003). As discussed more fully below in the **Proposed methods for developing boreal caribou monitoring** section, Elders and harvesters may wish to rely on Aboriginal language descriptions and categories to monitor body condition. Additionally, Aboriginal languages are also important to capture nuances within other measures.

Body condition assessments (and breeding assessments) also suffer from non-random sampling (Moller, Berkes et al. 2004). As noted by Lyver (2005) and others, harvesters are adept at identifying caribou body condition differences even at a distance. Hunters select certain caribou to harvest, often those with the best body condition. Finally, body condition may not relate easily to abundance (Moller, Berkes et al. 2004).

Behaviour may be used by hunters to indicate an animal's age. For example, 'jittery' behaviour may indicate that a caribou is younger (Parlee 2006). Behaviour may also relate to health very directly – Łutsël K'é hunters specifically seek barren-ground caribou based on the way they walk, "the manner in which the animal moves (*i.e.* "walks with a swagger")" (Kofinas, Lyver et al. 2003: 45). Behaviour may also include larger-scale changes, like alterations to seasonal movements (Legat, Chocolate et al. 2008a).

Observations of long-term population trends

Direct questions about population abundance and trend are common and useful in monitoring endeavours – 'population density sensing' (Moller, Berkes et al. 2004). This includes information gathered via 'collective information gathering' (Moller, Berkes et al. 2004) – such as community hunts, or through other information sharing platforms such as social media.

> *I would put a lot of faith in the Délı̨nę harvest because it's the same every year. So if you have information for ten years, Dene will harvest a certain amount of woodland caribou every fall. We do have one spring hunt – even if it's only nine or ten caribou it's still an indication that we have a good population. Just west of Délı̨nę – it's a huge area where Délı̨nę has lots of stories, information and history about that herd – that's the only one that Délı̨nę harvests on a regular basis and has a healthy relationship with, aside from the odd harvesting in other parts of Great Bear Lake… unless you go into the mountains or Colville Lake or Fort Good Hope area. Again, say ten years of information, I think you can analyze that versus on a yearly basis (Bayha 2015).*

Harvesters may quantify certain wildlife species and keep a mental record of these numbers for many years, but often the question is "is there enough" rather than "how many are there." Further, "[o]nce survival needs are met, hunters continue to observe population trends and changing ecological conditions accurately, but without numerical quantification" (Ferguson, Williamson et al. 1998: 202). Legat, Chocolate et al. (2001: 69-75) successfully used a metric of enough *vs*. not enough in a barren-ground caribou monitoring project and charted years when there were not enough caribou. The Elders suggested complex socio-ecological and seasonal reasons for the differences over time.

> *And ["enough"] is assessed based on all the other ecological conditions at the same time. So "enough" is a changing dynamic amount and will vary by year/season, etc. In a bad year with lots of snow – it might be "enough" to have fewer caribou than a year that was exceptionally easy and lots of calves were born. I think this is important – and it was brought up also with regards to how Sami people manage the number of reindeer in their herds. A certain landscape doesn't have a set quota of animals. But it can support a healthy balance of animals (of a specific*

age structure and dynamic) that changes year to year due to growing season and other environmental factors (Polfus 2015a).

Harvesters observe changes in population dynamics, including the "sex, age, population size, natality, mortality, immigration and emigration, of one species temporally occupying a spatially explicit area." Abundance estimates may be made directly from observations, and changes in population dynamics are also used to indicate changes in the ecosystem in much broader terms (Geertsema 2008: 121). "If all of the Dél̨nę people lived like they did 100 years ago, harvesting every day, they would have a pretty good idea of the numbers and that would be the main thing they would talk about. Every day that information is passed onto somebody" (Bayha 2015).

Traditionally people were out on the land and definitely paid attention to [boreal caribou] tracks, bedding areas, feeding patterns, the number of animals in a group at different times of the year (by their tracks), animal sightings, harvest levels, amongst other things – these were all parts or components of overall monitoring. Traditionally – and this is not going back a long way for these patterns to have diminished a little bit – harvesters would talk to each other afterwards. Within a region, people would talk to each other about where they had been, what they were seeing, whether they had harvested, whether the tracks were of two, three or four animals – those kinds of things were definitely discussed during fall and winter. … People follow those patterns and can have an assessment of whether populations are stable, increasing or declining and they're aware of how many animals are being harvested by their own communities (Redvers 2015).

Changes in habitat (environment, climate, insects, *etc.*)

…to know caribou is to know the vegetation they depend on and therefore to know that habitat should be protected for caribou use (Legat, Chocolate et al. 2008b: 11).

Changes in the habitat may be inextricably intertwined with changes in an animal's health, population, and range (Parlee 2006). "Monitoring the status of the resource is a common practice among many groups of traditional users, and is often accompanied with the monitoring of change in ecosystems" (Berkes, Colding et al. 2000: 1254). Changes in other animals may also indicate changes to the environment, which can have predictable effects on caribou (Legat, Chocolate et al. 2008a). Ecosystem-level changes of particular note to harvesters may include linear disturbances, fragmentation, and loss of critical habitat or special sites, such as mineral licks (Geertsema 2008).

General information about habitat may be gleaned through questions about the land – cleanliness, smells, disturbance, and any notable changes. Questions about water and water quality will also yield information (Parlee 2006). Many Aboriginal communities use indicators of climate and weather conditions to understand complex changes to their ecosystems due to climate change (Parlee, Manseau et al. 2005).

There may, in particular in areas with the heaviest traditional use of boreal caribou, be sites or landscapes of particular importance to the caribou (Species at Risk Committee 2012, Courtois 2015). If these sites or landscapes can be identified, then they should be monitored specifically. This may include special ecological zones (for example, 'treeline') or natural or cultural sites (Parlee 2006).

Global climate change may be implicated in changes to caribou habitat, harvest, breeding cycles, and food supply (Parlee 2006). There may be a preference in any community to discuss climate change as a separate indicator, or to use indicators of things on the land that are changing due to climate change (which may include predation, forest fires, habitat, *etc*.).

Forest fire occurrence and size have been implicated as important for caribou, and information about forest fires is carefully noted by harvesters (Parlee and Manseau 2005, McDonald 2010, Benson 2011, Dehcho First Nations 2011). "When asked directly for comment on whether or not burn rates had changed during their lifetimes, almost all [Łutsël K'é] elders stated that the frequency and intensity of fires had increased in recent times" (Kendrick and Lyver 2005: 181). Other Elders commented on the annual cycles of the implications of differing levels of fire intensity.

> *Today we're beginning to realize that fires do burn very efficiently – there are heavy burns and they burn everything right to the mineral soil, the permafrost, so of course [the caribou] are not going to go back in there. But the light burns are part of the ecosystem and they have [a function]…. If you burn your grass very lightly, then you're going to have very green grass, lots of new grass, but it has to be a very light burn (Bayha 2015).*

Industrial development, including mining and petroleum development, may impact caribou directly or indirectly (McDonald 2010, Dehcho First Nations 2011). For example, dust from mines blows onto vegetation and into waterways, where the effects may cascade (Kendrick and Lyver 2005). Harvesters and Elders pay close attention to changes in caribou habitat, health, and behaviour as a result of development. Aside from contamination issues, caribou may also avoid certain types of development (Kendrick and Lyver 2005). Development may also affect water systems – water flows, water quality. Changes to these systems have much broader ecosystem-level effects (Geertsema 2008).

Another factor which may affect caribou is sensory disturbance (McDonald 2010, Dehcho First Nations 2011). "[B]oreal caribou are particularly sensitive to sensory disturbance and have been affected by sensory disturbance from oil and gas exploration in the past… The potential impact of pending and future development remains a major concern" (Dehcho First Nations 2011: 14).

Changes in distribution, location, and/or group size

Indigenous communities pay careful attention to changes in distribution of important resources across their landscapes, with a comprehensive understanding of ecological variability (Parlee 2006). While some recent publications including TK of boreal caribou have indicated that this topic may either be an information gap (Species at Risk Committee 2012) or of limited utility in assessing population abundance or trends (Demars, Boulanger et al. 2014), workshops in the communities may help to determine this more precisely.

Changes in predation

Changes in predation is considered a key factor in considering boreal caribou population (McDonald 2010, Benson 2011, Dehcho First Nations 2011).

When determining how to gather information on predation, the complex relationships between predation and prey health need to be teased out. Predators may or may not be associated with a healthy population. "The abundance of wolves and foxes is also a sign that the land is healthy" (Parlee 2006: 91).

Other quantitative or qualitative measures

Community or regional organizations, harvesters or Elders may have other measures that are useful in describing changes to boreal caribou abundance and trends. For example: some authors have suggested that monitoring threats is much more effective than broad-based monitoring of other indicators (Ferraz, Marinelli et al. 2008). Competition from other animals has also been suggested as a factor in population trends, for example within range overlaps with muskoxen (Benson 2011).

This may include attempts at directly monitoring 'expectedness' (see box, above). For example, Moller, Berkes et al. (2004: 8) have both "*Noting of unusual patterns - Detecting environmental change by noting extremes (strange distribution, breeding failure, etc.)*" and "*Observations of species mix - Presence or absence of desirable or undesirable species or assemblages*" as traditional monitoring methods.

Harvesters and Elders may also be able to comment on other indicators that are often addressed in scientific monitoring programs, such as breeding success, cow to calf ratios and calf survival.

> *If [Dene] are going to hunt in the spring time they are going to be hunting cows. Sometimes they have a fetus or two – they would make a big deal if they ever harvested a cow with two fetuses and they talk about it as the health of the herd. If there are two fetuses, that means they are healthy to the Dene; that's very important to them (Bayha 2015).*

Calf survival is considered an important factor affecting population abundance and trends, but has not typically been well-represented in TK, especially relating to woodland caribou (Dehcho First Nations 2011). Nonetheless, monitoring programs are currently being explored that could provide information on numbers of calf/cow pairs observed along lake and river shores (Tsetso 2015).

Proposed methods for developing boreal caribou monitoring programs

A boreal caribou TK monitoring project needs to be conceptualized with, and directed by, NWT communities or regional Aboriginal organizations, with the explicit approval and participation of knowledgeable harvesters and Elders. It is well established that community consultation can be used to determine the best research methods in any region (Tsetta, Gibson et al. 2005, Danielsen, Topp-Jørgensen et al. 2014). There are number of standard information gathering and information sharing plans, such as community and regional workshops, story cycles, focus groups, informal sharing, one-on-one or small group interviews, census forms or questionnaires, and participant observation – some of

these are discussed below. Importantly, as indigenous monitoring is intertwined with indigenous traditional stewardship methods, NWT communities may wish to forego a data-gathering and analysis model in preference for May Gathering-type regional meetings where information sharing and management decisions are made around the same table (see box next page for more information on the May Gatherings). In addition, each region, or possibly each community, will have logistical, political, and cultural frameworks within which any stage of information gathering or sharing must work – in keeping with indigenous world views and knowledge (see for example Hart 2010).

> *… it's not like a Dene person has data in his head and you can pick pieces out; they don't think that way. So what you have to do is say, 'Where did you hunt caribou?' You have to start with that. He has to tell you where he went, why he went there, everything. When I talked about the springtime gatherings and knowledge was shared and they would talk about how to hunt, a way to ask properly would be to ask about their stories (Bayha 2015).*

As the population of boreal caribou is widely dispersed, it would also be appropriate and important to have meetings that bring together knowledgeable Elders and harvesters, plus youth participants, from each region to contextualize, discuss, and review each region/community's information. This cross-regional meeting will ensure that variations in observations can be contextualized and assessed. It will also ensure, through dialogue between knowledgeable Elders, that any specific information is being understood within a complex social-ecological system. Other stakeholders should be present at the meeting and participate in the dialogue, including ENR biologists, researchers, and staff from co-management organizations. For example: the ABMI report indicated that boreal caribou are more dispersed in certain seasons than others. Elders and harvesters who access the land in some seasons but not others may have detailed observational data from only certain seasons. A dialogue between Elders/harvesters and research scientists would serve to increase the understanding of boreal caribou by both parties (Demars, Boulanger et al. 2014). An integrative approach is useful in terms of knowledge co-production, but also respectful of traditional approaches. "The integrated perspective offered by Cree elders and harvesters is a strength of this alternative knowledge system and is also arguably necessary for understanding the cumulative nature of environmental change" (Parlee, Geertsema et al. 2012: 20).

The May Gatherings, Northern Tutchone Region, YT

Heralded as a uniquely successful example of how harvest data collection and use can take place in the north, the 'May Gatherings' are a locally-developed platform for sharing information and management considerations for select species in parts of the Yukon Territory. The process arose out of a desire of the Selkirk First Nations to implement self-governance and develop their own wildlife act in a way that was rooted in their culture.

The annual gathering is a coming together of three First Nations each spring to discuss fish and wildlife issues. The process arose to revive a traditional gathering that took place at river camps in the spring, as that is typically a hard time of year to move on the land. There, families would visit, gaff jackfish, and talk about how their winter had gone. After four or five families had reported their observations and experiences, the headman would re-assign them to areas for the coming winter. As a result, everyone knew where each family would be, resource competition was lessened, and areas that were known to be low for wildlife could be rested. People would part ways but then get together again the following May. The Gathering is an annual custom that has been revived for the past 12 years as part of traditional governance.

Approximately 100-150 people take part in the Gathering each year. A typical meeting agenda consists of presentations on harvest results and wildlife population status from the regional biologist together with local First Nation staff. This is followed by observations from citizens and discussions about harvest responses where required. The focus is on big game species such as moose and caribou, but other species are also discussed. Aside from information on harvesting and population levels, observations on wildlife health and a range of other topics (e.g., industry, development) may also be discussed. Hunters and the biologist then talk about interpreting the information that has been presented – Is the harvest is too high? Is more information needed? Do harvesting areas need to be rotated? The process takes about three days and has evolved over the years to include a balance of more cultural activities as well, such as contests and dancing. Following the Gathering, a technical report is prepared that includes all the data and is only distributed to the First Nations. A document including some information on resolutions that came about as a result of the meeting is prepared for other audiences.

The information that results from the May Gatherings is useful to resource managers, First Nation communities, and Renewable Resource Councils. Now that the Gathering has been going on for years, children are also being introduced to the process at an early age – they are present in the room, amongst the elders, learning about resource stewardship.

Recently, similar gatherings were also organized in the southern NWT as a means of discussing caribou management issues (Barnaby and Simmons 2013, Winbourne 2013).

Each region or community may place different weight on different types of information. For example, Kofinas, Lyver et al. (2003) found that hunters weigh different sources differently when obtaining information about body condition, migration, and population trends. Information from scientists, other hunters, personal observation, or game wardens is gathered and weighed based on topic and source.

Dene and Métis harvesters have always cherished opportunities to gather and share stories about their hunts. This is how they can compare experiences, measure these against "baselines" from stories handed down to them by their parents and grandparents, develop an understanding of how the herd is doing, and make wise decisions about future harvesting. This is a traditional knowledge approach to monitoring and stewardship. Such monitoring must involve all three generations: elders and adult harvesters need to tell the ancient stories and stories from their own experiences, and youth need to hear the stories and experience them on the land (SENES Consultants Ltd. 2010: 6).

There are several current, working examples of monitoring systems in Canada that are rooted in indigenous traditions and could be applicable to boreal caribou in the NWT (*e.g.* Ungava Peninsula Caribou Round Table – see box, numerous First Nation-led Watchmen and Guardian programs). One common principle these programs share is that monitoring work is not divorced from management actions – indigenous participants are integrally involved not just in information gathering and sharing but in making management decisions based on that information (Bayha 2015, Courtois 2015).

ENR must approach and engage in a dialogue with each region and/or community to identify how best to undertake a monitoring program. Topics should include:

- What types of information are important?
- How often does the information need to be considered?
- How best to access, share, interpret, document and store information?
- How will intellectual property be assured?
- What methods are most appropriate?
- Who will participate?

UPCART - Ungava Peninsula Caribou Round Table

In April 2013 the Aboriginal governments and Nations of Québec and Labrador [formally] announced the creation of the Ungava Peninsula Caribou Aboriginal Round Table, a united and powerful voice that endeavors to preserve caribou and the deep relationship that aboriginal people have long held with it.

The Round Table has been created to respond to the decline of the migratory caribou and will strive to develop a conservation and management system in a way that respects all cultures and traditions. This gathering is a strong step towards aboriginal leadership and responsibility towards the preservation of the land and animals on which they depend.

A technical Committee has also been assigned to support the activities of the Round Table and initiate the development of a Conservation Plan for the Ungava Caribou Herds, including a process for recommending the sustainable sustenance and cultural allocation of caribou while respecting the sovereignty and independence of each member nation.

Caribou is an integral part of the Aboriginal cultural, physical and spiritual well-being, as well as the food security of the involved nations. All members of the Round Table share deep respect and responsibility towards the caribou, and agreed that actions must be taken to respond to this critical decline of the George River Caribou Herd and the uncertain future of the Leaf River and Torngat Caribou Herds (Grand Council of the Crees 2013).

- Other topics, as desired by ENR or community/regional organizations[7]

ENR's dialogue with regional and community organizations and leadership about the content and method of information gathering for management purposes will also best suit the bridging nature of a monitoring program (see for example McGregor, Bayha et al. 2010). Community consultation can ensure that a new monitoring program will fit with and benefit from existing casual or formal monitoring efforts (Danielsen, Topp-Jørgensen et al. 2014). Any program should explicitly support and cultivate the social mechanisms behind traditional/adaptive monitoring and management practices, including the "[g]eneration, accumulation, and transmission of local ecological knowledge" (Berkes, Colding et al. 2000: 1253).

Early on, regional workshops should be conducted to assess the state and location of knowledge and knowledge holders. This is likely to be an appropriate time to consider geographic boundaries for the work as well as scope or topic boundaries – that is, determine a suitable approach to monitoring, define what areas information is likely to address, learn about who is knowledgeable in those areas, and what ways they know about boreal caribou. It is possible that a second round of workshops would then be required to further develop an appropriate methodology and terminology for the work. Again the importance of conducting collaborative research into language and translation of concepts is critical to successful TK research (Polfus 2015a). If a monitoring program based on tracking some kind of indicators is preferred, indicators are also generally identified using participatory approaches (Legat, Chocolate et al. 2008b).

> *My use of the word indicator is short-hand; I rarely use the word. In Innu Nation kind of science, the concept of relationships is a very strong one and there's a way of getting at a western concept of indicators by describing relationships between different species, their value and what the implications are. I would translate it that way. In forestry they typically use indicators, so when we approached that with Innu elders, we asked them, 'Why is that plant where it is?' You deconstruct it. 'Who does it need to live with? What conditions does it need? What happens if you remove any of those things?' You need to be really descriptive about it (Courtois 2015).*
>
> *Why don't you use Dene terms? 'Monitoring' sounds like you're checking up on something and it doesn't seem natural. It should be more of a term like 'how are the caribou doing?' because they talk about it like people. So if you want to know how someone is doing in a nice way, that's how you'd say it – how is the land doing? How is the caribou doing? You will need to go back and forth with a translator to get it right (Bayha 2015).*

[7] Community consultation may also outline much more specific aspects of a program, for example, how program participants will be selected and reimbursed (Danielsen et al. 2014). Community and regional organizations can also identify appropriate individual participants. Individuals selected to participate in a monitoring project may have decades of experience harvesting woodland caribou, and may be able to provide a long-term historical view (Geertsema 2008). Participants may also have previous formal education (for example, from Aurora College through their Natural Resource Training Program or through Dechinta Bush University) in data-gathering.

For some measures, Aboriginal languages may provide the richest and most appropriate ways to record observations and categorize information (Kofinas, Lyver et al. 2003). Aboriginal languages are critical to how harvesters and Elders interpret and interact with their environment. Knowledge is encoded within languages, and furthermore, grammar can oblige speakers to include certain relevant pieces of information with others. By affecting how people interact with their world, language also affects memory, perception, and categorization (Polfus 2015b). Technical linguistic workshops may be required to identify and define, to the level appropriate, terms used to understand caribou. These terms may contain related and embedded meaning which relates to a caribou's environment, feeding, reproduction, and habitat (See for example ʔehdzo Got'ı̨ne Gots'ę́ Nákedı and Species at Risk Secretariat 2013).

> *One thing I think is really important with TK monitoring is the language. A lot of the information is encoded in the language and in the names for the land. Having the language be part of a monitoring process is really crucial – I think that's where you could have the most powerful kind of influence of the information. We're doing a lot of work to try and understand all the different words for caribou and what they mean and there are just beautiful examples of words for how you hunt caribou that are tied into the environment and knowledge of caribou behaviour (Polfus 2015a).*

> *We found that meeting with small groups of elder experts, accompanied by younger community members, for two- and three-day gatherings devoted to a specific set of questions was an effective and rewarding way of addressing topics. Unlike interviews, during which elders answer questions posed by those who often do not already hold the knowledge they seek, gatherings (like academic symposia) encourage elders to speak among their peers at the highest level.*
>
> (Fienup-Riordan 2014: 93)

It will likely be appropriate to have an iterative process for refining the methodology in each region as well (Danielsen, Topp-Jørgensen et al. 2014). This will allow the monitoring program to build on successes, adapt to logistical or other issues, and best meet community and management needs. It may be possible to have an adaptive methodology and collect information on indicators or other more basic methodological aspects during early, open-ended interviews with harvesters, which would be followed by a more structured interview process as information is collated actively and relevant regional indicators are identified (Idrobo and Berkes 2012).

Indicators, if selected by a region or community, can be carefully worded to ensure that the information gathering process is undertaken in such a way that it "promotes ongoing learning and communication with the elders and harvesters that hold and have ownership of this knowledge" (Parlee 2006: 89). It is important to also be explicit about the context in which a change (or lack of change) is observed or experienced. For example, when changes in harvesting effort or style may be the result of changes in temporal or spatial methods of harvesting (Geertsema 2008).

Information sharing must include appropriate wildlife management boards and other decision-makers, as "indicators in the absence of self-governing institutions fail to evoke appropriate social response" (Gupta Anil and Jitendra 1996: 25). Indigenous knowledge gathered through monitoring is interrelated with indigenous management (Parlee 2006). "So when we talk about monitoring, we don't use that language but talk about guarding. Also guardians never did monitoring for monitoring's sake. Every time it was done it had to be integrated into some form of a management process" (Courtois 2015). "Where indicators have meaning within a community, they can also be vehicles of cultural continuity" (Parlee 2006: 105). The practise of sharing information about caribou between hunters and Elders is inherently appropriate to the rules governing caribou use. "Elders emphasized how respectful behaviour is to know, use and share resources" (Legat, Chocolate et al. 2008b: 22).

Elders' understandings of how information gathered by harvesters in the form of such indicators as body condition and group composition function to provide direction to future harvest (Winbourne 2013, Bayha 2015). "Hunters would also observe many health-related indicators, including size and composition of the [barren-ground caribou] groups, rate and direction of movements, behaviour, and body condition, to decide which groups to follow to their winter range and which animals to harvest" (Parlee and Manseau 2005: 31). Lyver (2005) found that hunters who provided body condition information in interviews were consistent with their observations of caribou in the field, particularly those hunters with decades of experience. Observations from interviews were also considered a better representation of the body condition of caribou over a one-time field observation, although the "use of both field and interview evaluation methods in a monitoring program would be ideal" (Lyver 2005: 50). Interviews or information sharing gatherings also have the benefit of being less expensive than field observation and less obtrusive for the harvesters.

Elders can also filter shorter-term trends, cycles, and variations in all indicators to reach an understanding of longer-term trends. For example,

> *Łutsël K'é elders and hunters reported that [barren-ground] caribou body condition varied because of (1) forest fire frequency or severity (or both); (2) declines in the quality and availability of vegetation; (3) weather-related variables (deep snow and ice); (4) disturbance (mining development and hunting pressure); and (5) the distance caribou had to migrate, which was often estimated on the basis of reports from other communities and how far south the hunters had to travel to harvest animals (Lyver 2005: 48).*

Elders understand and can account for the biases in information gathered strictly from harvest and observation. For example, when using a 'key' of body condition to assess probability of calving, another potentially confounding aspect of the community-based monitoring system is hunters' bias for harvesting the best quality animals available (Kofinas, Lyver et al. 2003: 50, see also Demars, Boulanger et al. 2014). The assistance of Elders in interpreting any information will be a critical part of any monitoring program based on the traditional knowledge of caribou.

Traditional people observe, reflect on what they observe, test it, bring it back to their cohorts who are deemed to have equivalent knowledge – which is essentially a peer review process – so when they come to a conclusion you can be sure it's accurate. It's as valid and reliable as scientific data. Where it has some limitations is in that they are not using technological tools. Elders have ways of determining if water is clean and suitable to drink, but they are not doing monitoring or analysis that breaks down the chemical components to determine exactly what's in the water. I absolutely believe you can send harvesters or elders out on the land – they have in their minds what they determine to be the health of the land or wildlife populations. It may not be as easily quantified, but they are able to perceive when there is a diminishment in fat, or if an animal has thick enough hair for that time of year, etc. All of those things are very fact and evidence-based things that can be incorporated into a well-constructed database, but one can't lose the context. It is important to interpret the data within the context. Sometimes interpreting that data or information outside of its context is where you run into problems (Redvers 2015).

Monitoring measures selected for any region should be appropriate for the harvesting or land-use activities generally undertaken by the communities in that region. For example, if a particular indicator supposes direct observation of caribou at a time of year when it is unlikely that members of the community will observe the caribou, that indicator may not be appropriate (*e.g.*, direct observations at boreal caribou calving areas are unlikely to be experienced or shared by Dene harvesters). A focus on information which is both relevant to understanding trends and traditionally gathered is likely to be more fruitful and suitable (see for example Lyver 2005).

Although interviews or focus groups may be the standard for TK research, there are some who are finding those methods less effective today and are exploring alternate means of conducting research in northern communities (Legat 2015). Some of these more recent methods rely on strong collaboration with communities and receiving input and guidance from elders at all stages of a research project. There are also moves to better integrate research and management activities, as witnessed in the Northern Tutchone May Gatherings (Winbourne 2013) and the Ungava Peninsula Caribou Round Table (UPCART, see box, above) (Courtois 2015).

If information sharing and validation via the internet is proposed for a boreal caribou monitoring program, social media may be more effective due to extensive buy-in and ease of use. In any case, data storage for monitoring projects should be addressed very early in the process. In addition to projects with a dedicated web-mapping component (or web-based delivery of the project's data to community decision-makers), there are also web-based TK data warehouses. ELOKA (Exchange for Local Observations and Knowledge of the Arctic) is one example. ELOKA is a web-based storage system for cataloguing and delivering data gathered through various TK projects, originally conceived of to address challenges of TK data management:

A central challenge of LTK [local and traditional knowledge] research and CBM [community-based monitoring] is to develop effective and appropriate ways of recording, storing, managing, and ethically sharing data and information that enable creative use now and over the long term.

The data need to be available and useful to Arctic residents and researchers, as well as other interested groups such as teachers, students, scientists, and decision makers. Precious data and knowledge from Elders is in danger of being lost or misplaced. At the same time, inter-generational knowledge transfer in northern communities has and is being challenged as a result of recent shifts in culture (e.g. introduction of television, the Internet), and tragic social disruptions through time (e.g. relocations, the residential school system in the Canadian Arctic). These socio-cultural realities are strong drivers in the effort to preserve, maintain, and ultimately strengthen traditional knowledge construction. At a practical level, other important data remain hidden and at risk because of hardware and software obsolescence and a general lack of documentation and maintenance. Furthermore, investigators often lack awareness of previous studies causing repetition of research, research fatigue in communities, and wasted resources, as well as a reluctance or inability to initiate or maintain community-based research without an appropriate and available data management system (Pulsifer, Gearheard et al. 2012: 272).

ELOKA's web-based storage system for traditional knowledge and indigenous monitoring data, or another web-enabled system, may be of interest to some regions. At the very least, considerations of the sustainable storage of data and the inclusion of project metadata should be included in all discussions of methodology. Data storage and data sustainability is of the utmost importance for TK projects (Pulsifer, Gearheard et al. 2012, Pulsifer, Huntington et al. 2014). Web-based storage of data may be accompanied by hand-held computers for data-gathering. Already, many harvesters in the north are equipped with their own phones/cameras and are sharing harvesting observations through social media sites such as Facebook (Polfus 2015a) (see for example the *Inuit Hunting Stories of the Day* Facebook page at https://www.facebook.com/groups/inuithuntingstoriesoftheday/).

Standard TK research procedures that rely on interview and/or focus group methods usually also include some level of peer review or information verification/validation. After preliminary information sharing activities in each region or community, a local verification session may be the next step. Verification sessions may have multiple steps, and may integrate and include other local stakeholders. For example, the Łutsël K'é ecological and socio-economic monitoring program had a three-step process. Information collected through interviews was first reviewed by Elders and harvesters, who pondered and contextualized the information. Where appropriate, information was also provided to community and other organizations and government departments. Finally, an 'Integrative Interpretation Workshop' brought together the environmental and socio-economic components for the community's interest (Lutsel K'e Dene Community Members 2005).

Verification sessions may also serve as knowledge co-production, relying upon Elders' and harvesters' ability to use 'fuzzy logic.' Fuzzy logic, a term which comes from a computing, is a way of understanding knowledge production that allows for aggregating information to form partial understandings and with partial truths, rather than relying on a 'binary' yes-or-no/true-or-false. Fuzzy logic also helps in understanding how traditional knowledge systems work in regards to ecological knowledge production. Indeed, fuzzy logic facilitates understanding the process by which ecological knowledge acquires its holistic sense, providing insights about the organization of general components of nature, including

those for which there are neither experiential nor symbolic interactions (Idrobo and Berkes 2012: 412). It is possible that the quality of information gathered and shared will improve through time through this process, and as harvesters gain experience participating in the monitoring program and the decision-making processes which it influences.

In the UPCART and Northern Tutchone 'May Gatherings' models, some form of community verification is taking place during the information sharing phase of the work (Winbourne 2013, Courtois 2015).

Overall, the effectiveness of a community monitoring program relates to many factors. "[A]n effective community-based monitoring protocol is dependent on the trust of resource users who are involved in the process" (Kofinas, Lyver et al. 2003: 50). There may be individuals within a community who are particularly entrusted with management duties and therefore seen as a repository of TK/monitoring knowledge (Berkes, Colding et al. 2000). While undertaking a caribou body condition monitoring project, Kofinas, Lyver et al. (2003) identified the following determinants that any monitoring project would be effective.

- Desire of community/hunters to participate
- Compatibility with hunting
- Sensitivity to cultural values
- Use of hunters' existing methods and knowledge
- Cost (labor and material)
- Amount of special training required
- Extent to which continuity of individuals is needed
- Contributions to regional monitoring
- Capability of providing a physical assessment of harvested animals while providing annual trend information on the population as a whole
- Extent to which the system is predictive
- Compatibility with the existing local systems of community members and local biologists' methods
- Contributions/additions to assessing food quality for communities (*i.e.* human health implications relating to the consumption of meat) (Kofinas, Lyver et al. 2003: 48)

The methodology selected by any community or region must be both sustainable and suitable. It must be sustainable within logistical and financial limits, for a multi-year monitoring and management process. A monitoring endeavour is a program, rather than a stand-alone project. The final methodology must fit within the broader needs of boreal caribou recovery planning, the cultural and political framework of each region, and the land-use activities and knowledge of the participants (see Danielsen, Topp-Jørgensen et al. 2014 for a Greenland example).

Scale of projects

Community and regional organizations will be best-equipped to decide on the appropriate scale and scope of a monitoring program, and then undertake the program. Some communities may decide that a reasonable spatial scale is the 'local landscape' rather than a regional or multi-regional scale (Geertsema

2008). However, harvesters and Elders may not feel that a bounded area is appropriate (Legat, Chocolate et al. 2008a). A monitoring project may bring multiple communities either within or across a regional boundary together, if the caribou populations in question link them. For example, polar bear TK and community-based monitoring in Nunavut has followed this 'community cluster' approach, as polar bears have distinct sub-populations that span multiple communities. "Community cluster refers to a social unit made up of neighbouring communities that share a spatially-defined resource (e.g., a wildlife population)" (Dowsley 2009: 44). Finally, just as participatory indigenous monitoring programs are well-suited to understand long time frames, they may be well suited for very large regional scales as well – even 20-30 communities and tens of thousands of square kilometers (Luzar, Silvius et al. 2011).

Summary of Recommendations: Monitoring boreal caribou

The following is a summary of recommendations for ENR about using indigenous methodologies to monitor boreal caribou populations:

1. Initiate a conversation with community and regional governance to determine how to plan for monitoring in that area – note that different approaches will likely be desired in different communities and regions. This conversation should likely include which community/regional bodies will represent the community for the planning process, along with more specific topics as outlined in the **Proposed methods for developing boreal caribou monitoring programs** section above, including:
    - Which potential measures may be appropriate and feasible for use in a monitoring program
    - What methods could be appropriate (*e.g.*, whether or not to gather data or to hold information-sharing and decision-making meetings)
    - How/when/where and in what language to conduct research, if appropriate
    - What adjacent projects (recording baseline or historical information, language workshops, *etc*.) are also appropriate
    - Geographic boundaries and scale of regional monitoring
    - A framework for information sharing and use
    - Research team composition
    - Elder and youth participation

Note that initial conversations should include team members with an anthropological background and familiarity with relevant monitoring projects, and should have some sense of the overall NWT picture to assist with ENR envisioning linkages between the regional or community projects.

2. Develop locally-based monitoring programs based on information from #1 that will meet information needs for boreal caribou abundance and trends.
3. Develop mechanisms for documenting and housing data and sharing information within and between communities/regions.
4. Pilot monitoring programs with communities to determine feasibility, effectiveness, and suitability.
5. Modify programs based on lessons learned in #4.

Other Recommendations: Baseline boreal caribou traditional knowledge

For much of the Northwest Territories, baseline boreal caribou traditional knowledge has not yet been fully recorded for population abundance and trends, nor other related topics. Baseline research should include traditional caribou nomenclature, socio-ecological relationships, traditional harvest rules, and traditional knowledge transmission. Baseline data collection should also focus on caribou range, distribution, population, behaviour, adaptation, biology, health, threats, *etc*., and a full record of trends. The baseline should also include a discussion with Elders on how to appropriately gather the information needed to respectfully monitor caribou.

> *The communities aimed to develop their baseline studies when the mines first opened, Fred Sangris said, 'One question to gauge impact of the mines is: what was the situation before the mines opened up? Where do we start gauging it from? Last year? Or before they started? It is not just Diavik, but also BHP, and Snap Lake.' And Chief Beaulieu added: 'If you do a survey, we need a baseline.' Unfortunately, the communities will have to start with what they have now, data from 2005, as funds were not available for research until this time (Tsetta, Gibson et al. 2005: 63).*

Indigenous communities may be able to monitor animal populations back through time over hundreds or even thousands of years (Parlee 2006). This 'historical' baseline is extremely useful as it may be the only existing data from the time pre-dating development in the NWT. Legat, Chocolate et al. (2001) were able to record detailed observations in group interviews dating back 70 years. The observations shared include information about caribou range, population, and health. In addition, observations over multiple decades can identify any predictable, cyclical shifts in populations which may masquerade as effects from harvest or predation (Ferguson, Williamson et al. 1998). Knowledge of these shifts has obvious and important implications for management decisions. Modern observations can be compared to pre-development baselines to identify longer term trends (Legat, Chocolate et al. 2008b). As such, the knowledge of Elders can be considered both current and historical baseline information. Elders have years of experience on the land, and even if they no longer harvest, can still be very well informed of current trends by active harvesters (Lyver 2005). Elders could therefore provide comparisons of current information against their own baseline on the fly in verification meetings, or more formally through a TK study.

Baseline information may already be available from previous studies (see Species at Risk Committee 2012 for gaps assessment on existing boreal woodland caribou TK), many of which are not specifically focussed on monitoring but contain extremely relevant information.

Interviewee biographies

Walter Bayha was born in the Sahtú and currently resides in Délįnę, NT. Walter has extensive experience and an educational background in resource management. He has worked for 32 years with both governments in the territories and the last 15 years with First Nations. Walter chaired the Sahtú Renewable Resources Board for 12 years, and has been a member of the Sahtú Land and Water Board and Mackenzie Valley Land and Water Board for 15 years. He is presently Senior Caribou Adviser to the Déljne First Nations, working on plans to develop community and Sahtú caribou harvesting of the Bluenose-East caribou herd. Fluent in both English and North Slavey, he has an excellent understanding of resource management. Traditional Environment Knowledge has been a major interest the last 30 years in Walter's work. His Dene background is moving forward to help him make challenging caribou and resource management decisions for his community. Hunting and fishing have always been part of Walter. He is presently employed by the Déljne Land Corporation, the main organization implementing the Sahtú Dene and Metis Comprehensive Land Claims Agreement in the Déljne District of Sahtú. Walter directs all work in the Lands Management and Administration for the Community of Déljne soon to be self- Governing in April, 2016.

Valerie Courtois is a member of the Innu community of Mashteuiatsh, in Québec, and a specialist in Aboriginal issues in lands and resource management and forest ecology. She completed her undergraduate studies in Forestry Sciences at the University of Moncton in 2002, and regularly lectures at universities and conferences around the world, focusing on ecosystem planning and First Nations issues. As environmental planner for the Innu Nation in Labrador from 2003 to 2009, Valerie was responsible for land-use planning and management of environmental programs, including the Innu Nation Environmental Guardians Program. She has participated in various caribou planning and research initiatives in Labrador and beyond. Since her time at the Innu Nation, she has worked as a consultant in Aboriginal Forestry, including certification and spatial planning. Valerie has also acted as the Canadian Boreal Initiative's Senior Advisor, Aboriginal Affairs, since February 2010. In that role, she works with a number of Aboriginal communities and leaders in conservation across the Boreal region, with a focus on responsible development and sound management of relationships with the land. She is also the Director of the Indigenous Leadership Initiative of the International Boreal Conservation Campaign, Happy Valley, NL.

Allice Legat is a practicing anthropologist with an interest in what it means to become and be knowledgeable. Her current research focus is on how the past informs the present, especially in an environment of industrial development and climate change. Allice is a long time northerner who has worked extensively with Indigenous communities on both heritage and cultural matters. Much of her work focusses on relationships. Allice is committed to a research methodology that follows the knowledge system of the community she is working with. She has worked with communities on traditional governance, barren-ground and boreal caribou, place and space as well as health of land and health of people. Allice is currently working with the Sahtú Renewable Resources Board on an Environment Monitoring Framework and on a Traditional Knowledge Guidelines project, and Sahtú Dene Knowledge of Wolverine. She is also working with the Wek'eezhii Renewable Resource Board on Wıldfıres, Tǫdzı (Boreal Caribou) and Habitat Use, and with the K'atlodeeche First Nation on Climate

Change and Health. She is currently a Research Associate with the Arctic Institute of North America, University of Calgary, an Honorary Research Fellow with the Anthropology Department, University of Aberdeen and was the Roberta Bondar Fellow, Trent University, Peterborough, Ontario during 2012-2013.

Jean Polfus is a doctoral candidate in Natural Resources and Environmental Management at the University of Manitoba. Her research focuses on non-invasive population genetics and traditional knowledge of caribou populations in partnership with the ʔehdzo Got'ı̨nę Gots'ę́ Nákedı (SRRB) and five ʔehdzo Got'ı̨nę (RRCs) of the Sahtú Region of the Northwest Territories. Under the supervision of Dr. Micheline Manseau, Jean's research explores the genetic and cultural diversity of caribou and generates a permeable interface between science and society. Jean is committed to an approach to conservation that respects the lives and experiences of people that depend on natural resources for their livelihood. Her research supports the management initiatives of First Nation people by using an innovative combination of approaches that help to translate ideas and concepts between worldviews and cultures and promote a more thorough and mutually affirming understanding of wildlife conservation. Jean lives in Tulit'a, NT.

Peter Redvers is a long time northerner who has worked extensively with First Nation and Métis communities on a wide range of community planning, cultural research, and conservation planning initiatives. His formal training is in adult education and community development, but his love of the northern eco-cultural landscape propelled him to become actively involved in cultural and environmental issues. He has worked with communities to engage with and carry out traditional knowledge research geared toward environmental assessment and regulatory intervention, land and resource management programming, and engagement in the NWT Protected Areas Strategy. For the past decade, he has primarily worked in the Dehcho region on PAS initiatives and engagement in other land and resource management planning initiatives. He has a particular interest in boreal caribou protection and has coordinated some field-based research relating to boreal caribou over-wintering habitat. Peter currently works at the Director of Lands, Resource, and Negotiations for the Kátł'odeeche Fırst Natıon and divides his time between Hay River and Yellowknife, NT.

Interview questions

- What have you learned about indigenous or traditional ways of monitoring animal populations in the [Dehcho/Sahtú/Tłı̨chǫ] region?
- Do you know of any monitoring programs that are rooted in indigenous methods?
- How do [Dehcho/Sahtú/Tłı̨chǫ] harvesters tend to encounter and know boreal woodland caribou? Is this the same as it was in the past?
- How do you think Dene knowledge and traditional ways monitor population trends for an animal like boreal caribou?
- If one scientific method is to pay attention to certain cues or indicators to help monitor population trends, do you think this is an appropriate concept in an indigenous system? Is there a Dene term for a concept like 'monitoring'? Is there a traditional concept related to the idea of indicators? Or is it inappropriate in a traditional knowledge context and another tool is needed?
- In your view, where does science come in? What kind of research questions do you think can be answered by scientific research and what are better answered through traditional knowledge or indigenous ways of observing boreal woodland caribou?
- Do you think it would be possible to collaboratively develop a monitoring system built on indicators based in both scientific knowledge and indigenous knowledge? Do you feel that would be possible or appropriate?
- Some of the reports we've found about ways of respecting and monitoring caribou focus on barren-ground. Is there a difference in the principles, laws and cultural values between woodland caribou and barren-ground caribou?
- Because of the close traditional relationship between Dene people and the land, would it be useful or possible to monitor more cultural things, such as knowledge and skills and how and whether they are being passed on? If so, how would that type of thing be monitored?
- How do we get from the cultural aspects (knowledge as an indicator, stories, *etc*.) into concrete monitoring of population numbers while remaining culturally respectful? Is it possible to bridge that gap?
- Do you know of any suitable sources we should look at or people we should contact for this work? (from your region or other regions?)

Bibliography

Arctic Borderlands Ecological Knowledge Co-op Society. (2015). "Arctic Borderlands Ecological Knowledge Co-op." 2015, from http://www.arcticborderlands.org/.

Armitage, D., F. Berkes, A. Dale, E. Kocho-Schellenberg and E. Patton (2011). "Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic." Global Environmental Change **21**(3): 995-1004.

Aurora Research Institute (2013). Working Together towards relevant environmental monitoring and research in the NWT. Inuvik, NT, Aurora Research Institute**:** 16.

Barnaby, J. and D. Simmons (2013). Bathurst Caribou Harvesters' Gathering January 29-31, 2013. Northwest Territories, Tłı̨chǫ Government and Wek'èezhìi Renewable Resources Board**:** 32.

Bayha, W. (2015). Expert interview: Boreal Caribou Monitoring. Interview conducted by Janet Winbourne on June 19 and July 3 2015.

Bennett, T. D. and T. C. Lantz (2014). "Participatory photomapping: a method for documenting, contextualizing, and sharing indigenous observations of environmental conditions." Polar Geography **37**(1): 28-47.

Benson, K. (2011). Gwich'in Traditional Knowledge: Woodland Caribou, Boreal Population. Fort McPherson, NT, Gwich'in Social and Cultural Institute**:** 52.

Berkes, F. and M. K. Berkes (2009). "Ecological complexity, fuzzy logic, and holism in indigenous knowledge." Futures **41**(1): 6-12.

Berkes, F., M. K. Berkes and H. Fast (2007). "Collaborative Integrated Management in Canada's North: The Role of Local and Traditional Knowledge and Community-Based Monitoring." Coastal Management **35**(1): 143-162.

Berkes, F., J. Colding and C. Folke (2000). "Rediscovery of Traditional Ecological Knowledge as Adaptive Management." Ecological Applications **10**(5): 1251-1262.

Burton, A. C. (2012). "Critical evaluation of a long-term, locally-based wildlife monitoring program in West Africa." Biodiversity and Conservation **21**(12): 3079-3094.

Courtois, V. (2015). Expert interview: Boreal Caribou Monitoring. Interview conducted by Janet Winbourne on July 9 2015.

Danielsen, F., N. D. Burgess, A. Balmford, P. F. Donald, M. Funder, J. P. G. Jones, P. Alviola, D. S. Balete, T. O. M. Blomley, J. Brashares, B. Child, M. Enghoff, J. O. N. FjeldsÅ, S. Holt, H. HÜBertz, A. E. Jensen, P. M. Jensen, J. Massao, M. M. Mendoza, Y. Ngaga, M. K. Poulsen, R. Rueda, M. Sam, T. Skielboe, G. Stuart-Hill, E. Topp-JØRgensen and D. Yonten (2009). "Local Participation in Natural Resource Monitoring: a Characterization of Approaches Participación Local en el Monitoreo de Recursos Naturales: una Caracterización de Métodos." Conservation Biology **23**(1): 31-42.

Danielsen, F., N. D. Burgess, P. M. Jensen and K. Pirhofer-Walzl (2010). "Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement." Journal of Applied Ecology **47**(6): 1166-1168.

Danielsen, F., P. M. Jensen, N. D. Burgess, R. Altamirano, P. A. Alviola, H. Andrianandrasana, J. S. Brashares, A. C. Burton, N. Corpuz and M. Enghoff (2014a). "A multicountry assessment of tropical resource monitoring by local communities." BioScience: biu001.

Danielsen, F., P. M. Jensen, N. D. Burgess, I. Coronado, S. Holt, M. K. Poulsen, R. M. Rueda, T. Skielboe, M. Enghoff, L. H. Hemmingsen, M. Sørensen and K. Pirhofer-Walzl (2014b). "Testing Focus Groups as a Tool for Connecting Indigenous and Local Knowledge on Abundance of Natural resources with Science-Based Land Management Systems." Conservation Letters **7**(4): 380-389.

Danielsen, F., E. Topp-Jørgensen, N. Levermann, P. Løvstrøm, M. Schiøtz, M. Enghoff and P. Jakobsen (2014). "Counting what counts: using local knowledge to improve Arctic resource management." Polar Geography **37**(1): 69-91.

Dehcho First Nations (2011). Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region - Plain Language Summary. Fort Simpson, Northwest Territories, Dehcho First Nations**:** 15.

Demars, C., J. Boulanger and R. Serrouya (2014). A literature review for monitoring rare and elusive species, and recommendations on survey design for monitoring boreal caribou. Edmonton, Alberta, Alberta Biodiversity Monitoring Institute**:** 59.

Dowsley, M. (2009). "Community clusters in wildlife and environmental management: using TEK and community involvement to improve co-management in an era of rapid environmental change." Polar Research **28**(1): 43-59.

Eicken, H., M. Kaufman, I. Krupnik, P. Pulsifer, L. Apangalook, P. Apangalook, W. Weyapuk and J. Leavitt (2014). "A framework and database for community sea ice observations in a changing Arctic: an Alaskan prototype for multiple users." Polar Geography **37**(1): 5-27.

Ferguson, M. A., R. G. Williamson and F. Messier (1998). "Inuit knowledge of long-term changes in a population of Arctic tundra caribou." Arctic: 201-219.

Ferraz, G., C. E. Marinelli and T. E. Lovejoy (2008). "Biological Monitoring in the Amazon: Recent Progress and Future Needs." Biotropica **40**(1): 7-10.

Fidel, M., A. Kliskey, L. Alessa and O. P. Sutton (2014). "Walrus harvest locations reflect adaptation: a contribution from a community-based observation network in the Bering Sea." Polar Geography **37**(1): 48-68.

Fienup-Riordan, A. (2014). "Linking local and global: Yup'ik elders working together with one mind." Polar Geography **37**(1): 92-109.

Fragoso, J., K. Silvius and M. Villa-Lobos (2000). "Wildlife management at the Rio das Mortes, Xavante Reserve, MT, Brazil: integrating indigenous culture and scientific method for conservation." World Wildlife Fund-Brazil.

Geertsema, K. A. (2008). Contributions of Cree Knowledge: Nakatehtamasoyahk Ote Nekan Nitaskenan, University of Alberta.

Gillman, V., K. Hynes, L. Loseto and S. Ostertag. (2015, 2015-04-22). "Enhancing Community-Based Monitoring of Ecosystem Changes in the ISR Through the Inclusion of Local and Traditional Ecological Knowledge Indicators." Retrieved 19 June 2015, 2015, from http://www.science.gc.ca/default.asp?lang=En&n=F2F84BB1-1&offset=5&toc=show.

Gofman, V. (2010). Community-based monitoring handbook: lessons from the Arctic. CAFF CBMP Report. CAFF International Secretariat, Akureyri, Iceland.

Government of the NWT (2003). Northwest Territories Policy 53.03 Traditional Knowledge. 53.03. Government of the NWT. Yellowknife, NT, Government of the NWT**:** 6.

Grand Council of the Crees. (2013, 2013-04-26). "Aboriginal leaders of Québec and Labrador unite to protect the Ungava caribou." Retrieved July 21, 2015, 2015, from http://www.gcc.ca/newsarticle.php?id=305.

Gunn, A. (2004). Boreal caribou habitat and land use planning in the Deh Cho region, Northwest Territories, Department of Resources, Wildlife, and Economic Development, Government of the Northwest Territories.

Gupta Anil, K. and S. Jitendra (1996). "Indicators as Indigenous Ecological Knowledge:" Lamp Posts"," Crossroads" and" Turning Points"." IIMA Working Papers.

Hart, M. A. (2010). "Indigenous worldviews, knowledge, and research: The development of an indigenous research paradigm." Journal of Indigenous Voices in Social Work **1**(1): 16.

Herrmann, T. M., M.-J. S. Royer and R. Cuciurean (2012). "Understanding subarctic wildlife in Eastern James Bay under changing climatic and socio-environmental conditions: bringing together Cree hunters' ecological knowledge and scientific observations." Polar Geography **35**(3-4): 245-270.

Herrmann, T. M., P. Sandström, K. Granqvist, N. D'Astous, J. Vannar, H. Asselin, N. Saganash, J. Mameamskum, G. Guanish, J.-B. Loon and R. Cuciurean (2014). "Effects of mining on reindeer/caribou populations and indigenous livelihoods: community-based monitoring by Sami reindeer herders in Sweden and First Nations in Canada." The Polar Journal **4**(1): 28-51.

Hill, K., G. McMillan and R. Fariña (2003). "Hunting-Related Changes in Game Encounter Rates from 1994 to 2001 in the Mbaracayu Reserve, Paraguay Cambios Relacionados con la Cacería en las Tasas de Encuentro de Especies Cinegéticas de 1994 a 2001 en la Reserva Mbaracayu, Paraguay." Conservation Biology **17**(5): 1312-1323.

Hill, K., J. Padwe, C. Bejyvagi, A. Bepurangi, F. Jakugi, R. Tykuarangi and T. Tykuarangi (1997). "Impact of Hunting on Large Vertebrates in the Mbaracayu Reserve, Paraguay." Conservation Biology **11**(6): 1339-1353.

Housty, W. G., A. Noson, G. W. Scoville, J. Boulanger, R. M. Jeo, C. T. Darimont and C. E. Filardi (2014). "Grizzly bear monitoring by the Heiltsuk people as a crucible for First Nation conservation practice." Ecology and Society **19**(2).

Huntington, H. P., S. Gearheard, A. R. Mahoney and A. K. Salomon (2011). "Integrating traditional and scientific knowledge through collaborative natural science field research: Identifying elements for success." Arctic: 437-445.

Idrobo, C. and F. Berkes (2012). "Pangnirtung Inuit and the Greenland Shark: Co-producing Knowledge of a Little Discussed Species." Human Ecology **40**(3): 405-414.

Jones, J. P., M. M. Andriamarovololona, N. Hockley, J. M. Gibbons and E. Milner-Gulland (2008). "Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species." Journal of Applied Ecology **45**(4): 1205-1212.

Keane, A., J. P. G. Jones and E. J. Milner-Gulland (2011). "Encounter data in resource management and ecology: pitfalls and possibilities." Journal of Applied Ecology **48**(5): 1164-1173.

Kendrick, A. and P. O. B. Lyver (2005). "Denésoliné (Chipewyan) knowledge of barren-ground caribou (Rangifer tarandus groenlandicus) movements." Arctic: 175-191.

Kindberg, J., G. Ericsson and J. E. Swenson (2009). "Monitoring rare or elusive large mammals using effort-corrected voluntary observers." Biological Conservation **142**(1): 159-165.

Knopp, J., F. Pokiak, V. Gillman, L. Porta and V. Amos (2013). Inuvialuit Settlement Region Community-Based Monitoring Program (ISR-CBMP): Community-Driven Monitoring of Locally Important Natural Resources. Arctic Observing Summit 2013. Vancouver, Canada**:** 11.

Kofinas, G., P. Lyver, D. Russell, R. White, A. Nelson and N. Flanders (2003). "Towards a protocol for community monitoring of caribou body condition." Rangifer **23**(5): 43-52.

Kowalchuk, K. A. and R. G. Kuhn (2012). "Mammal Distribution in Nunavut: Inuit Harvest Data and COSEWIC's Species at Risk Assessment Process." Ecology and Society **17**(3).

Legat, A. (2008). "Walking stories; leaving footprints." Ways of Walking: Ethnography and Practice on Foot: 35-49.

Legat, A. (2012a). Boreal Caribou Habitat and Habitat Use in Wek'èezhìi: Tłıçhǫ Knowledge Component. Yellowknife, NT, Gagos Social Analysts, Inc.**:** 18.

Legat, A. (2012b). Walking the land, feeding the fire: knowledge and stewardship among the Tlicho Dene, University of Arizona Press.

Legat, A. (2013). Boreal Caribou Habitat and Disturbance in Wek'èezhìi: Tłıçhǫ Knowledge Component. Yellowknife, NT, Frost Centre for Canadian Studies and Indigenous Studies, Trent University and Gagos Social Analysists, Inc.**:** 29.

Legat, A. (2015). Expert interview: Boreal Caribou Monitoring. Interview conducted by Janet Winbourne on July 5 2015.

Legat, A., G. Chocolate and M. Chocolate (2008a). Monitoring the Relationship between People and Caribou (Modified Version of the Report Monitoring Caribou: Tłįchǫ Laws and Indicators of Change). Yellowknife, NT, Tłįchǫ Government**:** 65.

Legat, A., G. Chocolate, M. Chocolate and Tłįchǫ Government (2008b). Monitoring Caribou The Relationship between Tłįchǫ Laws and Indicators of Change. Yellowknife, NT, West Kitikmeot Slave Study Society**:** 35.

Legat, A., G. Chocolate, B. Gon, S. A. Zoe and M. Chocolate (2001). Caribou Migration and the State of their Habitat: Tłıçhǫ Knowledge and Perspectives on ʔekwǫ̀ (Barrenland Caribou). Yellowknife, NT, Whàehdǫǫ̀ Nàowo Kǫ̀, Dogrib Treaty 11 Council.

Legat, A. and M. McCreadie (2015). When Caribou Return: Impacts of Wildfire on Tǫdzı (Boreal Caribou). Yellowknife, NT, Gagos Social Analysts, Inc**:** 58.

Lutsel K'e Dene Community Members (2005). Ni hat'ni - Watching the Land: Results of 2003-2005 Monitoring Activities in the Traditional Territory of the Lutsel K'e Denesoline. Yellowknife, NT, West Kitikmeot Slave Study Society**:** 110.

Luzar, J. B., K. M. Silvius, H. Overman, S. T. Giery, J. M. Read and J. M. V. Fragoso (2011). "Large-scale Environmental Monitoring by Indigenous Peoples." BioScience **61**(10): 771-781.

Lyver, P. O. B. (2005). "Monitoring Barren-Ground Caribou Body Condition with Denésǫłıné Traditional Knowledge." Arctic: 44-54.

McDonald, R. (2010). Boreal Caribou Traditional Knowledge Collection Study. Tulita, NT, Sahtu Renewable Resources Board**:** 10.

McGregor, D., W. Bayha and D. Simmons (2010). "“Our Responsibility to Keep the Land Alive”: Voices of Northern Indigenous Researchers." Pimatisiwin **8**(1): 101.

Moller, H., F. Berkes, P. O. B. Lyver and M. Kislalioglu (2004). "Combining science and traditional ecological knowledge: monitoring populations for co-management." Ecology and Society **9**(3): 2.

Nielsen, M. and J. Lund (2012). "Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania." **10**(1): 1-14.

Noss, A. J., I. Oetting and R. Cuéllar (2005). "Hunter Self-monitoring by the Isoseño-Guaraní in the Bolivian Chaco." Biodiversity & Conservation **14**(11): 2679-2693.

Nunavut Wildlife Management Board (n.d.). The Nunavut Wildlife Management Board's Community – based Monitoring Network Pilot Study**:** 13.

Parlee, B. and F. Berkes (2006). "Indigenous Knowledge of Ecological Variability and Commons Management: A Case Study on Berry Harvesting from Northern Canada." Human Ecology **34**(4): 515-528.

Parlee, B. and M. Manseau (2005). "Using Traditional Knowledge to Adapt to Ecological Change: Denésǫłıné Monitoring of Caribou Movements." Arctic: 26-37.

Parlee, B., M. Manseau and Lutsel K'e Dene First Nation (2005). "Understanding & Communicating about Ecological Change." Breaking ice: Renewable resource and ocean management in the Canadian North **1**: 165.

Parlee, B. L. (2006). Dealing with ecological variability and change: perspectives from the Denesoline and Gwich'in of Northern Canada, University of Manitoba.

Parlee, B. L., K. Geertsema and A. Willier (2012). "Social-ecological thresholds in a changing boreal landscape: insights from Cree knowledge of the Lesser Slave Lake region of Alberta, Canada." Ecology and Society **17**(2): 20.

Parlee, B. L., E. Goddard, Ł. K. é. D. First Nation and M. Smith (2014). "Tracking Change: Traditional Knowledge and Monitoring of Wildlife Health in Northern Canada." Human Dimensions of Wildlife **19**(1): 47-61.

Polfus, J. (2015a). Expert interview: Boreal Caribou Monitoring. Interview conducted by Janet Winbourne on June 12 2015.

Polfus, J. L. (2015b). Section of draft manuscript: PhD Thesis (Language and interpretation). Winnipeg, MB, University of Manitoba**:** 3.

Polfus, J. L., K. Heinemeyer, M. Hebblewhite and N. Taku River Tlingit First (2014). "Comparing traditional ecological knowledge and western science woodland caribou habitat models." The Journal of Wildlife Management **78**(1): 112-121.

Pulsifer, P., S. Gearheard, H. P. Huntington, M. A. Parsons, C. McNeave and H. S. McCann (2012). "The role of data management in engaging communities in Arctic research: overview of the Exchange for Local Observations and Knowledge of the Arctic (ELOKA)." Polar Geography **35**(3-4): 271-290.

Pulsifer, P. L., H. P. Huntington and G. T. Pecl (2014). "Introduction: local and traditional knowledge and data management in the Arctic." Polar Geography **37**(1): 1-4.

Redvers, P. (2015). Expert interview: Boreal Caribou Monitoring. Interview conducted by Janet Winbourne on June 12 2015.

Roots, F. (1998). "Inclusion of different knowledge systems in research." Terra borealis **1**: 42-49.

Sable, T., G. Howell, D. Wilson and P. Penashue (2007). "The Ashkui project: linking Western science and Innu environmental knowledge in creating a sustainable environment." Local science vs global science: Approaches to indigenous knowledge in international development: 109-127.

SENES Consultants Ltd. (2007). Discussion Paper: Traditional Knowledge Framework. Yellowknife, NT, CIMP**:** 142.

SENES Consultants Ltd. (2010). ʔekwę Hé Naidé: Living With Caribou Traditional Knowledge Program 2005-2009 Preliminary Review of Management and Policy Implications. Yellowknife, NT, Sahtu Renewable Resources Board**:** 16.

Southgate, R. and K. Moseby (2008). "Track-based monitoring for the deserts and rangelands of Australia." Report for the Threatened Species Network at WWF-Australia.

Species at Risk Committee (2012). Species Status Report for Boreal Caribou (Rangifer tarandus caribou) in the Northwest Territories. Yellowknife, NT.

Stacey, N., J. Karam, M. G. Meekan, S. Pickering and J. Ninef (2012). "Prospects for Whale Shark Conservation in Eastern Indonesia through Bajo Traditional Ecological Knowledge and Community-based Monitoring." Conservation & Society **10**.

Trant, A. J., J. D. Jacobs and T. Sable (2012). "Teaching and learning about climate change with Innu Environmental Guardians." Polar Geography **35**(3-4): 229-244.

Tsetso, D. (2015). Personal communication: phone call (Resource Management Coordinator, Dehcho First Nations). J. Winbourne.

Tsetta, S., G. Gibson, L. McDevitt, S. Plotner and E. J. Charlo (2005). "Telling a story of change the Dene way: Indicators for monitoring in diamond impacted communities." Pimatisiwin: A Journal of Aboriginal and Indigenous Community Health **3**(1): 59-69.

Uychiaoco, A. J., H. O. Arceo, S. J. Green, M. T. D. L. Cruz, P. A. Gaite and P. M. Aliño (2005). "Monitoring and Evaluation of Reef Protected Areas by Local Fishers in the Philippines: Tightening the Adaptive Management Cycle." Biodiversity & Conservation **14**(11): 2775-2794.

Wek'èezhìi Renewable Resources Board (2013). Overview: Boreal caribou habitat and habitat use in Wek'èezhìi Yellowknife, NT, Wek'èezhìi Renewable Resources Board**:** 46.

Winbourne, J. (2013). Review and Assessment of the Sahtu Settlement Harvest Study, 1998-2005. Tulita, NT, ʔehdzo Got'ıŋ ę Gots'ę́ Nákedı (Sahtú Renewable Resources Board)**:** 100.

Wray, K. and B. Parlee (2013). "Ways We Respect Caribou: Teetł'it Gwich'in Rules." Arctic: 68-78.

Ziembicki, M. R., J. C. Z. Woinarski and B. Mackey (2013). "Evaluating the status of species using Indigenous knowledge: Novel evidence for major native mammal declines in northern Australia." Biological Conservation **157**(0): 78-92.

ʔehdzo Got'ıne Gots'ę́ Nákedı and Species at Risk Secretariat (2013). Report of the Sahtu Species at Risk Terminology Workshop**:** 28.