Final report: Review of monitoring indicators for Rangifer in preparation for Arctic caribou status and trends reporting

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INTRODUCTION

In this report we outline monitoring activities of the CircumArctic Rangifer Monitoring and Assessment (CARMA) Network that can contribute to the 2017 State of The Arctic Terrestrial Biodiversity (StArT) Report. Based on this overview, we:

(1) describe CARMA's approach to indicators developed since 2005.
(2) relate indicators to the large herbivore Focal Ecosystem Component (FEC) attributes identified in the Arctic Terrestrial Biodiversity Monitoring Plan; and
(3) recommend caribou indicators that could be developed for the StArT report.

In describing CARMA's monitoring, we have summarised the background context for CARMA relative to the Arctic Council and its constituent bodies responsible for terrestrial monitoring. The Conservation of Arctic Flora and Fauna Working Group of the Arctic Council (CAFF), is the biodiversity working group of the Arctic Council. In February 2000, CAFF met in Iceland to respond to an Arctic Council recommendation that a circumpolar monitoring network be established and then in 2001, CAFF published the first overview of circum-arctic biodiversity (*Arctic Flora and Fauna: Status and Conservation*). The overview noted the fragmentary nature of information available to describe trends and a similar theme of information gaps was emphasized when the 2005 Arctic Climate Impact Assessment (ACIA) recommended that arctic biodiversity monitoring be expanded. In response CAFF initiated the Circumpolar Biodiversity Monitoring Program (CBMP) charged with establishing species monitoring networks and CAFF proposed that that one of the species networks monitor *Rangifer* and their interactions with people.

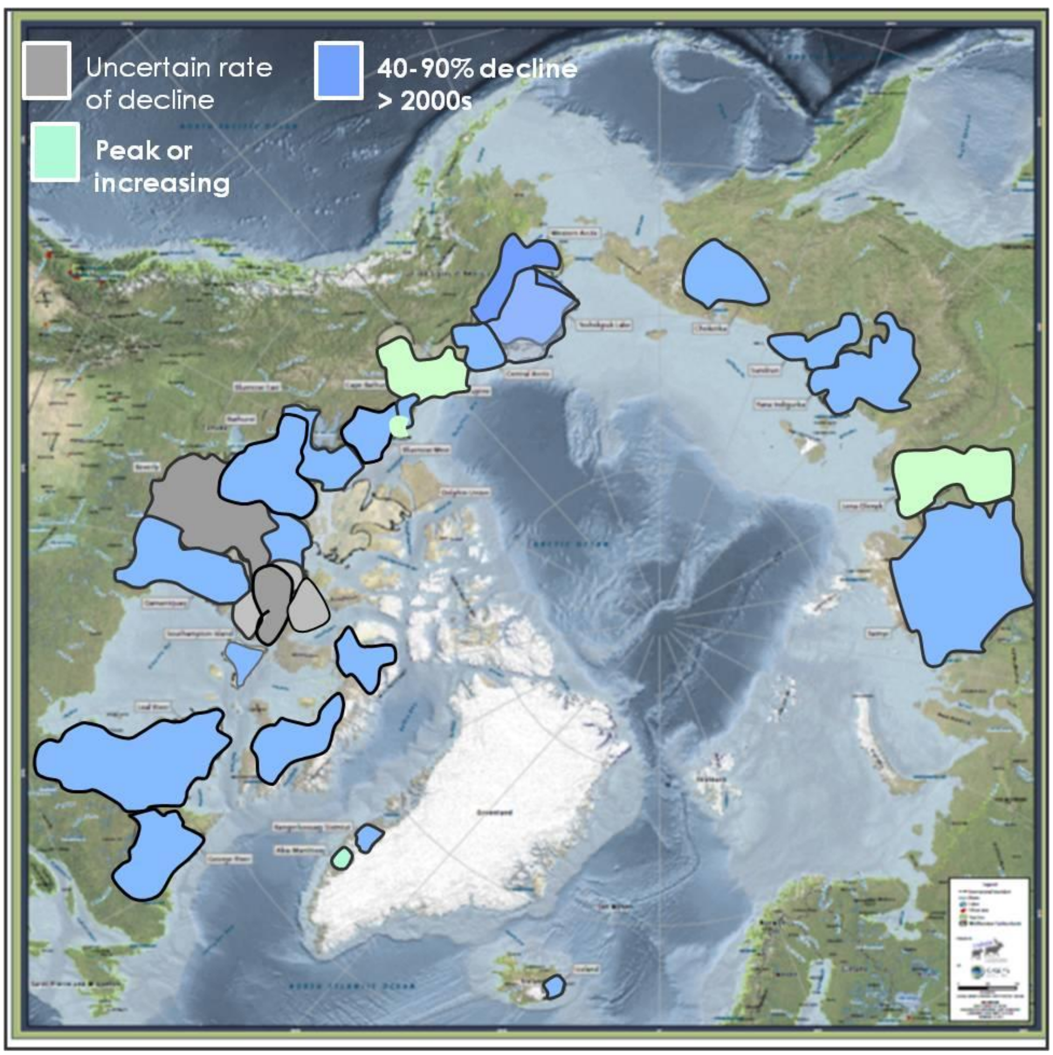
The *Rangifer* network was named the CARMA Network. It originated in 1999 (Russell et al 2000) in recognizing the value of collaborating throughout circum-arctic regions in light of potential impacts on *Rangifer* from climate change and industrial development. CARMA was officially launched at an international meeting in November 2004 (CAFF 2006). CAFF (2006) describes CARMA and its emphasis on being a flexible and open network for historical and current information on *Rangifer* using information from community, industry, university and government agency partners. The network has reported circum-arctic summaries of indicators for the human-Rangifer system for CAFF biodiversity reports and the annual Arctic Report Cards as well as updating the herd descriptions on the CARMA website.

CARMA contributed to CAFF's preliminary assessment of status and trends in Arctic biodiversity as the overview report, *Arctic Biodiversity Trends 2010: Selected Indicators of Change*. CBMP had developed the list of 22 species used as indicators for the overview report which included the status of wild reindeer and caribou based on CARMA's compiled data on trends in herd size. The report noted the need for long-term observations. Following the publication of the 2010 report, CAFF undertook a more detailed assessment which was published in 2013 as the *Arctic Biodiversity Assessment – Status and trends*. This report also included CARMA's updated compiled information on trends in abundance for wild reindeer and caribou.

CARMA has focused on migratory tundra caribou and wild reindeer that calve and summer on the tundra and some, but not all, migrate below the tree-line to winter in the northern boreal forest. In Russia, the sub-species are *R. tarandus phylarchus* (Kamchatka/Okhotsk reindeer) and *R. tarandus sibiricus* (Siberian Tundra Reindeer). The Alaskan sub-species is *R.t. granti* and in northern Canada it is *R.t. groenlandicus* which also occurs on the larger islands in Hudson Bay, Baffin Island and Greenland (Syroechkovski, 2000; Grubb et al. 2005). Although CARMA has emphasized the continental herds of migratory tundra caribou, it is in the process of including the caribou on Arctic Islands. In Russia, *R. tarandus pearsoni* occurs on the arctic island of Novaya Zemlya. Peary caribou (*R.t. pearyi)* occupy the Canadian High Arctic Islands and *R. t. platyrhynchusis are* found on Svalbard Islands. On the large Canadian Arctic Island of Victoria, a larger-bodied type of Peary caribou calve and summer on the island but migrate to the mainland for the winter. They are termed Dolphin and Union population and their taxonomic status is uncertain.

Migratory tundra caribou are typical of keystone species which require large areas of suitable habitat for persistence and in turn supports a diversity of parasites, predators and scavengers. While impacting nutrient cycling a (Gunn et al. 2011a). Across the circum-arctic ranges, topography, climate and vegetation are regionally different leading to variability in caribou ecology. Despite the variability, decadal climate fluctuations at a continental scale provide a degree of synchrony to fluctuations in abundance. Uncertainty of the under-lying mechanisms and the extent of fluctuations remain despite the importance of changing abundance to people who depend on them and, ultimately, to the tundra biodiversity.

Figure 1. Most recent status and location of migratory tundra caribou



(1) CARMA's approach to indicators

Rangifer seasonal migrations are over large, sparsely-settled areas in the Arctic which influences the frequency of monitoring and the selection of indicators. Typically most monitoring requires expensive aircraft support which limits frequency of monitoring. However, aboriginal hunters are also monitoring through their activities (Lyver and Gunn 2004; Brook et al. 2009; Russell et al 2013a; Arctic Borderlands Ecological Knowledge Co-op http://www.taiga.net/coop/index.html). People on the land, when traveling or hunting are continuously observing the land and caribou. In parallel, agencies collect ecological information to address management questions through modeling, time series measurements, indicators research, data collection and analysis, interpretation, and data reporting.

Most monitoring is to measure "snapshots" of status, and when repeated, the measures are then used to determine trends. Trend monitoring identifies long-term changes in the herds, and is used to evaluate likely drivers - human and natural factors causing change. In recent years, interest in standardized approaches to monitoring has grown: for example, Oakley et al. (2003) and Gibb et al. (1999) emphasize having realistic and measurable objectives for monitoring which, in turn, dictates sampling design. Designing effective caribou monitoring programs requires statistical power (the ability to detect change), precision, and accuracy. Statistical power is the probability of rejecting a null hypothesis that is false. It is the outcome of sample size, sample variance and effect size (Steidl et al. 1997, Gerrodette 1987). Power analyses can be used to determine whether sample size (for example, number of transects) will be sufficient to detect the desired effect, such as the difference between two estimates of population size.

CARMA through its annual meetings in 2007 and 2008 collaboratively developed a suite of indicators for Rangifer and compiled manuals detailing the methodology for demography and body condition/health indicators. A third manual, covering habitat/environmental monitoring was not completed. CARMA (2008) proposed 10 indicators for monitoring the health and condition of individual caribou and 10 indicators for populations (Tables 2 and 3). CARMA's two manuals are advisory and describe standardized approaches with supporting literature. The manuals are available on the CARMA web site (http://carma.caff.is/index.php/resources/field-protocols) along with supporting literature.

Indicators for monitoring migratory tundra caribou are at the individual, herd and regional scale. For individual, population and regional monitoring, CARMA identified indicators which as well as being scientifically credible are acceptable to communities. The indicators have to be practical, which includes cost effectiveness and being relatively easy to explain to share the results. Generally for monitoring, indicators are selected because they meet the following criteria (i) early warning of natural responses to environmental impacts; (ii) directly indicate the cause of change rather than simply the existence of change (iii) provide continuous assessment over a wide range and intensity of stresses, (iv) are cost-effective to measure and (v) can be accurately estimated (references in Carignan and Villard 2002).

Monitoring is primarily focused at the scale of sub-populations (herds), and the frequency and methods differ between herds, which limits the integration or comparison of herd-specific data sets. CARMA, through workshops and the demographic manual encourage the standardization of reporting and data collection to support the investigation of relationships between a changing environment and the different caribou herds. During the 2010 CARMA 7 meeting participants contributed to a monitoring questionnaire that catalogued the types and frequency of indicators were being collected for herd-specific monitoring (Figure 2).

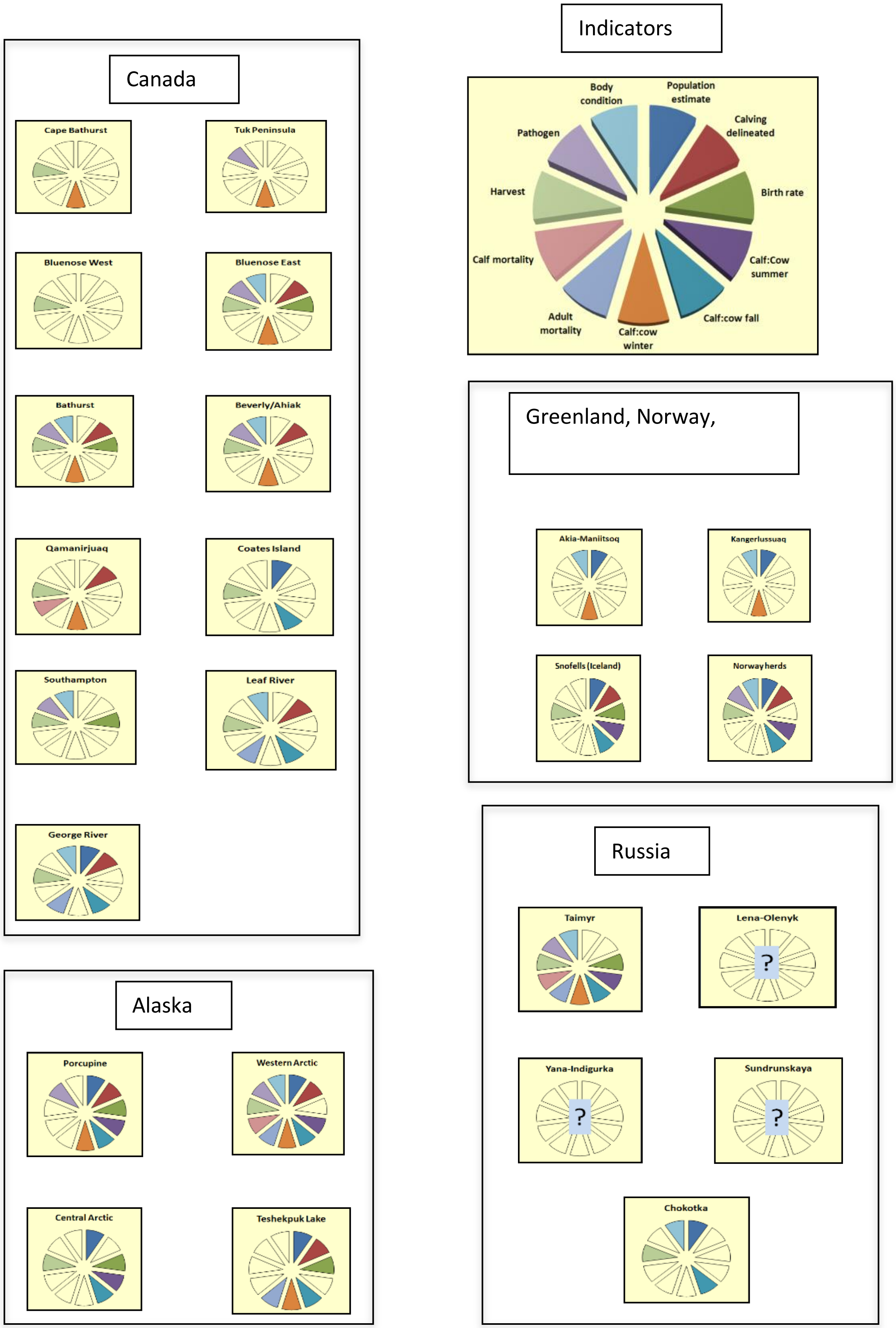


Figure 2. Summary of indicators monitored by region in 2010 (CARMA 2010)

The CARMA list of 20 individual and population indicators are almost all indicators that reveal underlying mechanisms and causes for trends in abundance. However, knowing the rate of increase (or decrease) is the most useful attribute of *Rangifer* populations for circumpolar monitoring. Monitoring involves estimating abundance with sufficient precision that moderate changes can be detected. A rule of thumb is that a survey estimate with a coefficient of variation of 10% or less is acceptable for management decisions, although a 10% level of precision can only detect a 30% difference or greater between two estimates. The power of detecting changes in populations usually increases with the sample size of the parameter being measured. Trend can be determined by measuring changes in abundance or by using expert opinion (usually aboriginal hunters). The 2nd level of monitoring includes mechanisms for the observed rate of increase or decrease based on monitoring more indicators. The 3rd level of trend monitoring has only been applied for a few herds and for relatively limited periods, as it is intensive.

Table 1. The three sampling levels and their indicators for demographic monitoring of *Rangifer*.

Indicator	Level 1	Level 2	Level 3
Abundance (direct)	Trend in herd size	Trend in herd size	Trend herd size
Abundance (indirect)	Trend in herd size		Long-term trend and climate patterns (hoof scars)
Vital rates		Birth rate Annual calf survival Mortality – adult Recruitment Sex ratio Harvest rates	Age specific fecundity Seasonal calf survival Mortality – age specific Recruitment Sex ratio Harvest rates Predation rates
Dispersal		Natal and breeding dispersal	Natal and breeding dispersal

Abundance status and trends

a) Population size at the time scale of annual to decades:

In the Alaska Department of Fish and Game mostly estimates total minimum population size, based on an aerial photo direct count extrapolation (photocensus) technique. Radio tracking is used to locate post-calving aggregations so that they can be photographed, and using both radio telemetry and aerial visual searches to find caribou outside the large aggregations. For some herds in Canada, biologists use photography of post-calving aggregations; for other herds, sampled counts (either visual or photographic) are done over seasonal ranges and extrapolated to a population total. Reconnaissance surveys are used to determine survey areas by mapping the extent of caribou distribution (with the additional advantage that it can lead to allocating survey effort relative to caribou density to increase precision). Frequently, the locations of radio-collared caribou are used to define the survey area with the assumption that the collars are representative of the herd's seasonal distribution.

An alternative approach to the direct count for a minimum population estimate is a sample count to estimate abundance. For example, caribou counted from an aircraft flying along a transect and the resulting extrapolation to an estimate of density is assumed to reflect the actual density of the entire herd. In caribou monitoring, the most common sample unit is a transect which may be bounded (strip) or unbounded (line) transect. Much of the design details are included in individual survey reports and summarized in the CARMA manual.

b) Population size at the time scale of decades to centuries:
This indicator is the frequency of caribou hoof scars left on exposed spruce across trails in the treeline transition where caribou return during late summer and early fall. The scar are aged through dendrochronology (Payette et al. 2004; Zalatan et al. 2006).The duration of sampled period depends on longevity of the black spruce roots and is up to 200 years based on tree-ring chronologies. The indicator has only been applied to the Bathurst, western Beverly, George and Leaf River herds. The pattern of changing abundance from the frequency of the hoof scars shows similarities with recollections of aboriginal elders. The elders use different indicators for past abundance including whether enough caribou were harvested at fall camps (Dogrib Treaty 11 Council. 2001).

The advantage of this indicator (long term frequency of hoof scars) is that it long-term enough and with sufficient resolution to detect through the tree ring chronologies and hoof scars low-frequency environmental signals with relatively small changes in magnitude such as decadal patterns driven by teleconnections.

Individuals – health and condition

Individual level indicators are described in detail in the CARMA manual. The indicators at the scale of the individual health and physical condition are usually integrated and interpreted at the population scale which can raise questions of sample representation (biased toward one area or sex age class; for example pregnancy rates in the Beverly herd varied across the different areas of the winter range and by age class (Thomas and Barry 1990). Indicators can be integrated to monitor evolutionary strategies: fat indicators can be used to monitor pregnancy rates (Figure 3) and protein indicators are used to monitor weaning strategies (Russell and White 2000).

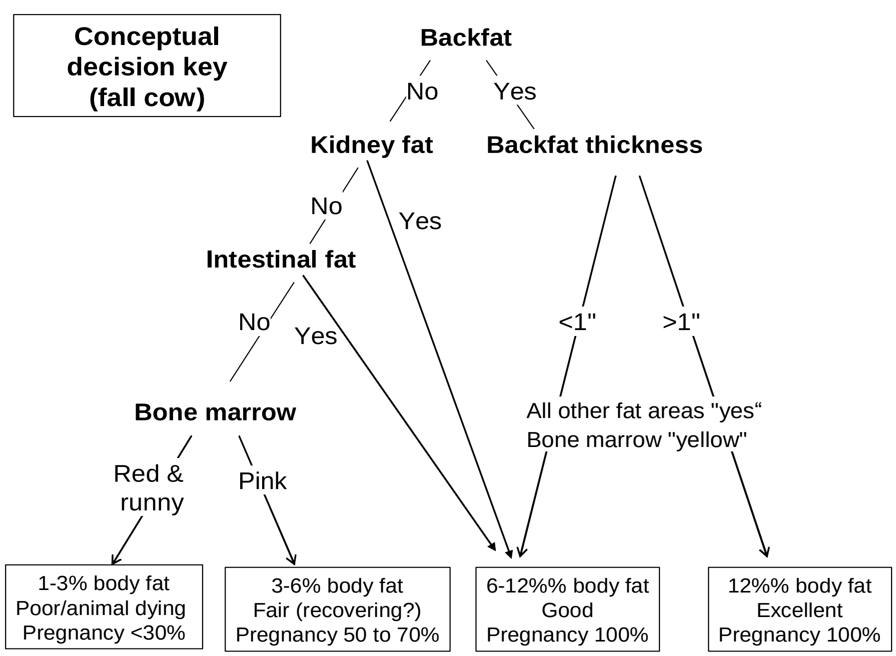


Figure 3. Decision key based on visual assessment to determine whether caribou are in relatively poor, fair, good, or excellent body condition (after Kofinas et al. 2003).

Table 3 lists the most frequently used indicators although the monitoring is determined by the type of sampling opportunity: indicators can be monitored during visual appraisal of individuals (*i.e*. hands-off) such as during capture and release of caribou for collaring), and during sampling of harvested caribou. The levels of sampling intensity are determined by the objectives but the most intensive monitoring (level 3) will be associated with specific research projects (*e.g*. validating a functional relationship established for one herd in order to determine if it is applicable to other herds).

The current monitoring for health and condition indicators is uncertain as harvests for at least Canadian herds is restricted which reduces opportunities for sampling. Previously, much of the monitoring for individual health and condition was during research projects and in their absence, reliance for monitoring is from hunters. More information is needed on the extent of community-based monitoring.

Table 2. List of 10 indicators to monitor health and condition at the individual level (CARMA 2008)

Indicator Monitored	Sample or measure
AGE STRUCTURE	
Age	Age estimate
LONG TERM NUTRITIONAL STATUS	
Morphometrics	Body mass , mandible, metatarsus
SHORT TERM NUTRITIONAL STATUS	
Fat	Backfat, kidney, narrow
Protein status	-leg muscle (Gastrocnemius/-Peroneus)
Diet	Plant cell fragments
HEALTH	
Parasites	
Disease	
Stress	Fecal corticosteroids
Contaminants & Metals	Liver sample Kidney sample
Contaminants & Metals	Muscle sample

Range use – Habitat

The second priority for implementing the Terrestrial Biodiversity Monitoring Plan is to describe which human and environmental factors influence *Rangifer* and which are the most important regions (including calving grounds, migratory corridors, major hunting/ foraging areas, etc.) and how are they changing. While a considerable amount of information has been routinely collected on seasonal ranges through aerial surveys and telemetry (for example Campbell et al. 2012), less progress has been made in either analyzing distribution or movement data. Recent work on delineating and assessing conservation concerns for calving grounds (Gunn et al 2012) has led to listing locations and trends for some calving grounds (Table 7).

Remote sensing has largely unrealized potential to monitor the status and trends in caribou habitat and landscapes. For a few herds such as the Canadian Bathurst herd, the status and trends of vegetation have been analyzed (Chen et al. 2012) and the human footprint on the landscape is mapped through cumulative effects analyses undertaken for industrial development (Gunn et al. 2011b). An exception to the lack of use of remote sensing is for climate. Climate is a principle driver of caribou ecology and so CARMA has downloaded the MERRA retrospective remote sensing database of climate variable for the seasonal ranges or regions for migratory tundra herds (Russell et al. 2013b).

Table 3. Calving grounds listed by abundance phase, and shifts (from Gunn et al 2012).

	Period years	Abundance phase	Predictability location	Annual shifts	Individual annual shift rate
Western Arctic	>20	4 phases	cumulative overlap mapped	Non-directional	<5%
Teshepuk	>20	Increase	cumulative overlap mapped	Non-directional	>5%
Central Arctic	>20	Increase	cumulative overlap mapped	Non-directional	>5%
Porcupine	>20	All 4 phases	cumulative overlap mapped	Directional and non-directional	<5%
Cape Bathurst	>20	decrease, low numbers	cumulative overlap mapped	Non-directional	<5%
Bluenose West	>20	decrease, low numbers	cumulative overlap mapped	Non-directional	<5%
Bluenose East	>20	decrease, increase	cumulative overlap mapped	Directional and non-directional	<5%
Bathurst	>20	4 phases	Annual overlap analysis (centroids)	Directional and non-directional	<5%
Ahiak	>20	increase	cumulative overlap mapped	Non-directional	<5%
Beverly	>20	4 phases	cumulative overlap mapped	Non-directional	>5%
Qamanirjuaq	>20	4 phases	Annual overlap analysis (centroids)	Non-directional	<5%
Wager Bay	>20	uncertain	cumulative overlap mapped		<5%
Lorrilard	>20	uncertain	cumulative overlap mapped		<5%
Leaf River	>20	Increase, decline	Annual overlap analysis (centroids)	Directional and non-directional	<5%
George River	>20	4 phases	Annual overlap analysis (centroids)	Directional and non-directional	>5%
Taimyr	>20	Increase, decline	Annual overlap analysis (centroids)	Non-directional	unknown

(2) How CARMA's indicators relate to the large herbivore Focal Ecosystem Component attributes from the Arctic Terrestrial Biodiversity Monitoring Plan

As a follow up on the Arctic Biodiversity Assessment which had noted on the fragmentary information available for the assessment, CAFF is undertaking a State of the Arctic Terrestrial Biodiversity to be a baseline for future assessments every 5 years and retrospective trends in arctic biodiversity using peer-reviewed data. The future assessment reports will use CBMP's networks and monitoring plans. CBMP has held workshops (Svoboda et al. 2012) to develop an Arctic Terrestrial Biodiversity Monitoring Plan (Christensen et al., 2013). CAFF then established an international CBMP Terrestrial Steering Group (CBMP-TSG) to manage a 3-year implementation guide to implement the CBMP-Terrestrial Plan's integrated monitoring. The Arctic Terrestrial Biodiversity Monitoring Plan has an ecosystem approach with Focal Ecosystem Components (FECs) identified through their ecological and human relevance during workshops (Christensen et al., 2013). The FECs selected were similar to those that CBMP had previously identified which included *Rangifer* (such as caribou/wild reindeer) are described by attributes (such as abundance) and then the attributes are measured by parameters (number of wild reindeer for example).

The Arctic Terrestrial Biodiversity Monitoring Plan's goal for the mammal monitoring (including caribou and wild reindeer) is to track and report observed changes in abundance, productivity, and distribution, and to monitor the likely biotic and abiotic drivers of change (Table 4). CARMA already has listed monitoring protocols for the attributes: abundance, demographics, health and body condition but not specifically for genetic variation or phenology (Table 1) which the Terrestrial Monitoring Plan lists as recommended and essential, retrospectively.

Table 4. Attributes and their parameters for large mammals Focal Ecosystem Components (from Christensen et al. 2013).

Attribute	Priority	Parameter	Scale	Method/ reference	Protocol/ Complexity	Temporal recurrence	CARMA Comments for migratory tundra caribou/wild reindeer
Abundance	Essential	Number, density	Local/ regional	*Aerial/land-based surveys*,	Basic	3 years	<u>Available for 11/20 herds</u>
Demographics	Essential	Age structure, mortality, fecundity	Local/ regional	*Aerial/land-based surveys*, telemetry	Basic	3 years	<u>Available for some herds</u>
Spatial structure	Essential	Distribution of migratory herds	Local/ regional	*Telemetry; aerial/ landbased surveys*, harvest records, tissue samples	Basic/ advanced	3 to 5 years	<u>Mostly unanalyzed & unavailable</u>
Health	Essential	Pathogen prevalence & intensity, body condition, contaminants	Local/ regional	*Harvest records, tissue samples*, fecal analysis; bone length; animal collections	Basic/ advanced	Annually	<u>Unavailable for herds at annual scale; available for a some herds for a few years</u>

Diversity: genetic	Recommended	Heterozygosity, population genetics and connectivity, breeding	Local	*DNA analysis*	Advanced	3 to 5 years	Available for most herds as one-time sampling; variable technique and number of locii
Phenology	Essential	Parturition; breeding	Local/ regional	*Telemetry; surveys*	Basic	Annually	Available all herds from MERRA data as plant growth degree days

However while CARMA does include similar attributes, the parameters differ between CARMA and the Arctic Terrestrial Biodiversity Monitoring Plan. CARMA's list of indicators and methods is more detailed although it is worth noting that at the moment, CARMA lacks the people and funding to compile and report on indicators other than abundance. CARMA also lists more detailed and different methodology and more variable timescale.

Table 5. Attributes and their parameters for large mammals (from Christensen et al. 2013) relative to CARMA's monitoring indicators for 20 migratory tundra caribou herds in 2010 (excludes some historic data but reveals current practices).

Attribute	ATBMP Parameter	CARMA indicator	CARMA Temporal recurrence	CARMA Comments for migratory tundra caribou/wild reindeer
Abundance	Number (of individuals)	Number	Variable	Number is available for 11 herds
	Density	Not used	--	CARMA does not use density as an indicator Density is mostly unavailable or available only for calving grounds
Demographics	Age structure,	Age structure	3 years	Available for 7 herds
	Mortality,	Mortality – adult		Available for 5 herds
		Harvest		Available for 15 herds
	Fecundity	Birth rate	Annual	Available for 8 herds
	Productivity	Calf survival (1 month)	Annual	Available for 6 herds
	Calf survival	Calf survival (6 month)	Annual	Available for 10 herds
		Calf survival (10 month)	Annual	Available for 12 herds
	Adult sex ratio	Sex ratio	3+ years	Available for 10 herds
		Immigration/ emigration		Available for 12 herds based on satellite telemetry or genetics
Spatial structure	Distribution of migratory herds	Annual and seasonal herd ranges	3 to 5 years	CARMA compiles overall seasonal ranges for all herds and calving grounds for 7 herds: trends are unanalyzed but potentially available

				especially for herds with telemetry
Health	Pathogen prevalence & intensity,	Prevalence	Annually	Unavailable for herds at annual scale; available for a 11 herds for a few years
	Body condition,		Annually	Available for 8 herds with trends available
	Contaminants		3 to 5 years	Available for 7 herds
Diversity: genetic	Heterozygosity, population genetics and connectivity, breeding	Advanced	3 to 5 years	Available for 20 herds as one-time sampling; variable technique and number of locii
Phenology	Parturition; breeding	Basic	Annually	Available 20 herds from MERRA data as plant growth degree days

The most frequently used attribute (indicator) is measuring the status and trends of *Rangifer* is a priority part of implementing Circumpolar Biodiversity Monitoring Program's Arctic Terrestrial Biodiversity Monitoring Plan (Christensen et al., 2013). To date, while frequency of monitoring the circum-arctic Rangifer populations varies, monitoring the indicator for population size is partially effective as the population trend for 75% of the 47 Rangifer populations is measured (populations with >2 estimates or within the last 10 years). The following Tables 3-6 provide an update and report on sub-population trends as to whether they are increasing or declining or stable at high or low numbers.

Table 6. Frequency of population estimates and trends in estimated abundance for migratory tundra caribou in Alaska, Greenland, Iceland and Russia (from CARMA).

Subpopulation/geographic area		No. estimates	Recent Trend
Alaska			
Western Arctic	1976-2013	14	Declining
Teshepuk	1978-2013	10	Declining
Central Arctic	1978-2013		Declining
Greenland			
Akia- Maniitsoq	2001-2010	3	Declining
Kangerluusuaq- Sisimiut	2000-2010	3	Stable
Iceland	-2013	?	Increasing
Russia			
Taimyr	1972-2009	16	Declining
Lena-Olenyk	1975-2009	9	Increasing
Yana Indigurka	1975-2002	10	Declining
Sundrun	1975-2012	9	Stable
Chokotia	1974-2002	3	Declined

Table 7. Frequency of population estimates and trends in estimated abundance for migratory tundra caribou in Canada (from CARMA). Populations with no estimates for 10 years are rated as unknown.

Subpopulation/geographic area		No. estimates	Recent Trend
Porcupine	1972-2013	13	Increasing
Tuktoyaktuk Pen.	2005-2012	4	Declining
Cape Bathurst	1986-2009	7	Stable at low no.
Bluenose West	1986-2009	7	Stable at low no.
Bluenose East	2000-2013	5	Declining
Bathurst	1970-2014	15	Declining
Beverly/Ahiak	1971-2011	11	Declining
Boothia Pen.	1985-2006	3	Unknown
Northeast mainland	1983-2005	2	Unknown
Lorillard	1983-2004	4	Unknown
Wager Bay	1983-2004	4	Unknown
Qamanirjuaq	1974-2014	9	Declining
Southampton	1978-2011	9	Declining
Coats Island	1980-1991	2	Unknown
Baffin Island (S, N, NE)	1991-2-13	3	All declining
Leaf River	1973-2011	10	Declining
George River	1975-2011	6	Declining

Russian arctic islands

Novaya Zemlya is an archipelago with two large islands, Severny (northern) and Yuzhny (southern) extending about 1,000 km with several smaller islands (90 600 km^2). Reindeer occur on the islands and have increased to more than 5000 wild reindeer.
http://www.barentsobserver.com/index.php?id=430415&xxforceredir=1&noredir=1
http://www.arctic-info.com/news/09-09-2014/russian-arctic-scientists-saw-novaya-zemlya-deer-for-the-first-time

"Since the founding of the National Park, study of Novaya Zemlya reindeer only found bones, excrement and tracks. Scientists began to doubt the existence of the subspecies on the island. Hope was only provided by a photo of a dead deer in 1996. Since then, nobody had seen deer. . . . . The Novaya Zemlya subspecies of reindeer is listed in the Red Book of Russia (category 5 protection) and in the Red Book of Archangel Region (category 4 of protection). It is endemic to the archipelago of Novaya Zemlya, with a concentration of population on Yuzhnaya Island."

Severnaya Zemlya is parted glaciated and in the 1990s, had less than 100 reindeer (De Korte et al. 1995). Franz Josef Land is the most northly archipelago (191 islands totaling about 16 000km^2) at 80-81^{o}N. Currently wild reindeer do not occur on there but when climate was warmer, based on radio-carbon dated antlers. New Siberian (Novosibirskie)(3 larger and 9 smaller islands totaling 36 300 km^2). The main islands are not glaciated and low-lying. The southern most island is about 50 km from the mainland across ice-covered waters most of the year. Baskin (2005) reports no surveys since 1981 for the reindeer that migrate to the mainland for the winter when numbers are high. Bely Island at northern end of

Yamal has a small isolated population of tundra wild reindeer (Syroechkovskii 1995) which needs special monitoring and protection.

New Siberian (Novosibirskie) island group is 3 larger and 9 smaller islands (36 300 km^2). The main islands are not glaciated and low-lying. The reindeer calve on the southern most island is about 50 km from the mainland across seasonally ice-covered sea. Baskin (2005) reports no surveys since 1981 when the estimate of 17,000 was reported for the reindeer that migrate to the mainland for the winter when numbers are high. Bely Island at northern end of Yamal has a small isolated population of tundra wild reindeer (Syroechkovskii 1995) which needs special monitoring and protection.

Svalbard reindeer
Svalbard reindeer are restricted to a few peninsulas with limited exchange. Long-term monitoring suggests an increase in the number of Svalbard reindeer during recent decades. Annual monitoring of the reindeer population is through direct ground counts
(Table 4). Frequency of estimates and trends in estimated abundance for Svalbard reindeer in Norway (from Aanes et al. 2003, Reimers 2012).

Table 8. Overview of population estimate timing and techniques for Svalbard reindeer and recent trends

Island grouping	Survey frequency (years)	Time period	Recent trend	2013/14
Adventdalen[1]	Annual direct count	1979-2014	Increasing	1200
Edgeøya	Irregular	1976 - 2006	Stable to decreasing	
Reindalen**,**	Annual direct count	1979-1999+	Increasing	800
Brøggerhalvøya (introd. 1978	Annual direct count	1979-1999+	Increasing	120

[1]http://www.manchester.ac.uk/discover/news/article/?id=12502

“In 1978 fifteen animals were reintroduced to Brøggerhalvøya This population grew exponentially to 360 individuals by 1993 and subsequently declined to below 100 individuals during the winter of 1993/94 because of extreme winter conditions that lead to thick ground ice.

Management status and monitoring

The Svalbard reindeer was harvested heavily in Svalbard from 1860 to 1925, and the population was dramatically reduced. The harvest was banned, except for scientific sampling, between 1925 and 1983. This period of protection resulted in recovery of the reindeer and the reindeer spread and re-colonized their former ranges. There has been no recent effort to census the whole archipelago yet, so the total current population size is not known. However, data from many parts of the archipelago and long-term monitoring data from a few specific locations, suggest an increase in the number of Svalbard reindeer during recent decades. Annual monitoring of the reindeer population in Adventdalen (1979–2013) has shown that the population size varies between 400 to 1200 individuals. Similar numbers and population dynamics has also been documented in the adjacent valley of Reindalen. In Nordenskiöld Land a quota-based harvest conducted by residents takes place each year (15 August 15 – 20 September) in six designated areas. This harvest is believed to have only minor impacts on the reindeer populations in the area and is managed to be sustainable in the long term."

http://www.npolar.no/en/species/svalbard-reindeer.html

Canadian High Arctic Islands - Peary caribou
Gunn and Poole (2013 unpubl.) summarized the survey design and methods for 61 aerial surveys leading to 55 estimates of abundance on Canada's High Arctic Islands for Peary caribou. In four aerial surveys, numbers of Peary caribou were too few to generate a credible estimate (Northwest Victoria and Prince of Wales-Somerset) and for two surveys, the estimate is not available (Banks 1979-80 and Boothia Peninsula 2006). The frequency of estimated abundance varies from about 2 years to 7 years with three large groups of islands with no estimates of trend for the nine geographic survey areas (Table 5).

Table 9. Frequency of estimates and trends in estimated abundance for Peary caribou and Dolphin And Union caribou on Canada arctic islands (from Gunn and Poole unpubl. 2013).

Island grouping	Mean ± SE survey frequency (years)	Number of estimates	Recent trend
Banks	1970 - 2010	16	Increasing
NW Victoria Island (excludes 1987, 1988)	1980 - 2010	7	Stable low numbers
Prince of Wales-Somerset (and Russell)	1974 - 2004	3	Unknown if recovery
Boothia Peninsula	1974 - 2006	4	Declined
Melville-Prince Patrick (Eglinton and Byam Martin)	1961 - 2012	11	Increasing
Prime Minister Islands	1961 - 1997	2	Unknown
Bathurst +satellite islands	1961 - 2013	11	Increasing
Eastern Queen Elizabeth Islands (Devon, Ellesmere, Axel Heiberg)	1961 - 2006	2	Unknown
Ringnes Island Group	1961 - 2007	2	Unknown
Dolphin & Union Central, southern, SW and NE Victoria Island	1997 -2007	2	Unknown

Data availability: CARMA during its 2007 and 2008 meetings discussed monitoring data availability and established data sharing protocols and a manual for how to add metadata http://carma.caff.is/index.php/resources/data-repository/access-to-metadata. The data and metadata are entered to the on-line Polar Data Catalogue https://www.polardata.ca/pdcinput/login.ccin.

However, most Rangifer monitoring data and metadata are not entered into the Polar Data Catalogue. Instead herd monitoring data is usually available from individual biologists or government agencies. Alaska reports every 2 years on the annual monitoring of demographic parameters from its annual inventory program. Reports for 2001 to 2011 are available at http://www.adfg.alaska.gov/index.cfm?adfg=librarypublications.wildlifemanagement.

In Canada, there is no single data repository but Government of Northwest Territories does maintain a database with access to NT data on request (www.enr.gov.nt.ca/sites/default/files/wmis). For other herds and regions contacting government wildlife agencies and co-management boards (CARMA lists the co-management boards - http://carma.caff.is/index.php/library/linklist). Likewise for Greenland and Russia, access to data or metadata is through contacting individual biologists and government agencies.

We note that there is a considerable amount of monitoring information from hunters that is not readily available as, for example, along the lines of the Arctic Borderlands Ecological Knowledge Co-op. We highlight the advantages of community-based monitoring as it has been applied for the Porcupine herd.

(3) Recommended indicators for Arctic caribou/wild reindeer status and trends and available sources of data.

Our recommendations for the State of the Arctic Terrestrial Biodiversity (StArT) are based on CARMA's experience with existing monitoring of wild reindeer and caribou. We have summarised the existing indicators and their availability. The most widespread indicator is for trends in sub-population abundance. While distribution for all sub-populations (herds) is potentially available, compiling the data from the data holders is handicapped as methods are more variable and data are less available. The mechanisms for changes in abundance are revealed through demographic indicators, regional habitat trends; climate (including an indicator for plant phenology) and health and condition. Those indicators are only available for a sub-set of herds (reference herds) because some herds are not monitored with sufficient frequency or enough indicators.
We would recommend:

1. Abundance, trends and phenology (climate) for all herds including arctic islands currently available through CARMA as spreadsheets.
2. Demographics for key reference herds*
3. Spatial structure (seasonal and annual ranges) for all herds currently available up to 2010 (see Appendix A for details
4. Health for key reference herds*
5. Phenology – link CARMA's existing environmental variables to life cycle periods (e.g. link Growing Degree Days to peak of calving) for all herds,

* proposed reference herds - Western Arctic herd, Teshekpuk, Porcupine, Bluenose West, Bathurst, Qamanirjuaq, Southampton, George River, Greenland, Iceland, Hardangavidda Taimyr).

CARMA currently has the information available updated to 2010 for all herds. Compiling and updating information 2010 to 2015 and getting feedback on the indicators and methodology could be undertaken at the proposed CARMA 9 meeting in December 2015.

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APPENDIX A. Methodology and sources for preparing seasonal shape files for caribou herds for CARMA

Seasonal ranges

- For each herd, developed shp files of the following seasons:
    - Calving (extent of calving)
    - Summer
    - Fall (combined rut and migration)
    - Winter
    - Spring
- Seasonal ranges were supplied by some agencies for some herds; otherwise I built seasonal ranges based on agreed-upon criteria.
- These were cumulative season shp files (not annual), using all available data combined among years.
- A separate shp file was built for each season for each herd; annual ranges were built by merging and dissolving seasonal ranges. (For the Bathurst herd, I built annual ranges to be able to build 2 winter ranges. The shift in the winter range has caused a contraction in the southern boundary as the herd has declined. The size of the overall winter range is so great that it encompasses areas with very different local climates due to the proximity of the Great Bear and Great Slave lakes). Note that the combined polygons from the 4-5 seasons will not likely perfectly match an annual range based on all the data (or one based on the sum of each year produced on its own).
- Data handling for each herd varied based on available data, labelling, etc. (Table 1).
- Fixed kernel polygons were produced (all 90%), using standard settings (href, volume density, 120 raster resolution) from the Rodgers and Carr Home Range extension for ArcView 3.2a.
- If we had chosen different range methods (MCP, adaptive kernel, etc.) the results would differ. The 90% (or 95%) fixed kernel is pretty standard, and seemed the best for what was needed
- Note that fixed kernels are affected by sample size of locations, and the distribution and concentration of locations. A concentration in one area with a thin scatter elsewhere can produce polygons that overestimate boundaries compared to the data; altering the href value can assist. For example, for Bathurst data, the full "fall" has roughly 5,500 locations, while the "fall migration" has only about 1,500 and the "rut" has about 4,000. These different sample sizes affect the kernel shapes, so you would not expect kernels from 2 sets of locations to equal a kernel from the combined data.
- In most cases I did not balance location numbers or sample size among individuals, although data were provided in this manner in a few cases.
- Initial labelling of seasonal ranges was consistent, with the 3 letter herd code (as supplied by Anne) and the seasons 'spring', 'calving', 'summer', 'fall', and 'winter'.

Table 1. Summary of herd ranges (as of 29 Dec 2010)

	Herd	Source of ranges	Timeframe	Sent to Jing
1	Bathurst	Collar data	1996-2009	Yes
2	Ahiak	Collar data	2001-2010	Yes
3	Beverly	Dated survey maps, BQCMB	~1957-1995	Yes
4	Qamanirjuaq	Dated survey maps, BQCMB	~1957-1995	Yes
5	Cape Bathurst	Collar data	1996-2010	Yes
6	Bluenose West	Collar data	1996-2010	Yes
7	Bluenose East	Collar data	1996-2010	Yes
8	Dolphin and Union	Collar data	1996-2006	Yes
9	George River	Polygons	2006-2009	Yes
10	Leaf River	Polygons	2006-2009	Yes
11	Teshekpuk	Polygons	1990-2009	Yes
12	Western Arctic	Collar data	1987-2010	Yes
13	Central Arctic	Collar data	1986-2006	Yes
14	Porcupine	Collar data	1985-2010	Yes
15	Kangerlussuaq-Sisimiut	Collar data	1998-1999	Yes
16	Akia-Maniitsoq	Collar data	1997-1999	Yes
17	Iceland	Polygon from CARMA site	Recent?	Yes
18	Taimyr	Mapped ranges from figures	Unknown	Yes
19	Yana-Indigurka	Mapped ranges from figures	1980-1990	Yes
20	Sundrunskaya	Mapped ranges from figures	Unknown	Yes
21	Lena-Olenyk	Mapped ranges from figures	Unknown	Yes
22	Chokotka	Mapped ranges from Don	Unknown	Yes

- Projections were stated, and in most cases ranges were supplied in geographic/lat-long projection (essentially unprojected).
- Tundra and Taiga polygons were created by Jing, with Canadian treeline supplied from own sources, and world treeline supplied by Martha Raynolds from the Circumpolar Arctic Vegetation Map from http://www.arcticatlas.org/, with mapping originally developed by the Alaska Geobotany Center (http://www.geobotany.uaf.edu/). Treeline coverage was converted to Geographic projection by Dave Taylor.
- Area (km^2) of each range (Table 2 – Appendix)was calculated by establishing a View in ArcView 3.2a in Sinusoidal (equal-area) projection, pulling in the geographic (unprojected) shape files and converting them to projected polygons in that View, and then by using the AWR9 extension (D. Pritchard, Saskatoon, SK, unpubl. data) to add area (ha) to each polygon. Because of resolution differences in the background used to clip the tundra and taiga polygons from annual ranges and the background used to build the seasonal ranges (which clipped to remove ocean and combined into annual ranges), the sum of tundra and taiga ranges did not exactly equal the annual range in 10 herds. In 8 of the herds the difference was <0.7%, with the annual range always larger than the combined tundra and taiga ranges. For the Iceland herd the difference

was 1.6%, likely related to the relative amount of coastline involved. The difference for the Teshekpuk herd was 3.2% because of the blocky fixed kernel polygons supplied (I have altered this with a clipped version).

Bathurst herd (BAH) herd

- Collar data from Jan Adamczewski, ENR, GNWT; seasonal ranges by Kim Poole, AWR (kpoole@aurorawildlife.com).
- All collar data from Apr 1996 to Dec 2009 (*n* = ~80 adult cows). Mainly satellite collar data (ranging from daily to every 5-7 days fix rate; which I generally get as a single Best per Day location), and since Nov 2008 GPS data (up to 8 locs/day). Obvious non-Bathurst animals pulled out (based on calving locations).
- Provided in UTM zone 12 projection.
- Produced 90% fixed kernel polygons.
- Seasons based on previous work.
- Peak calving grounds (the area used by parturient cows during the 7-day period centred on the peak of calving) and the extent of calving (the outer perimeter of all known annual calving grounds (Russell et al. 2002)) are also available.
- Dates used for the Bathurst herd were:
    - Calving: ~4-8 Jun – 30 Jun.
    - Summer: 1 Jul to 22 Aug.
    - Fall (combining fall migration and rut/late fall): 23 Aug to 5 Dec.
    - Winter: 6 Dec to 14 Apr.
    - Spring: 15 Apr to calving (~4 June (1996-1998) or 8 June (≥1999)).
- Shp files for cumulative peak calving grounds and extent of calving also provided (from previous work, covering 1996 to 2007, but will include the areas for 2008 and 2009; Gunn, A., K.G. Poole, and J. Wierzchowski. 2008. A geostatistical analysis for the patterns of caribou occupancy on the Bathurst calving grounds 1966–2007. Unpublished report prepared for Indian and Northern Affairs Canada, Yellowknife, NWT.)
- Also built annual winter ranges; 13 from 1996-97 to 2008-09. All but 3 of the 13 ranges were fairly distinct to one side of the GSL-East Arm-Artillery Lake line. I merged the polygons, and clipped them to this line for analysis.

Ahiak herd (AHI) herd

- Collar data from Jan Adamczewski, ENR, GNWT; seasonal ranges by Kim Poole, AWR.
- All collar data from Apr 2001 to Mar 2010 (*n* = 62 adult cows, ~48,700 locations). Mainly satellite collar data (ranging from daily to every 5 days fix rate), and since Nov 2008 GPS data (generally 2-6 locs/day, which I reduced to 1-2/day).
- Seven Beverly-calving caribou removed from initial data.
- Produced 90% fixed kernel polygons, in geographic projection.
- Seasons are the same as for the Bathurst herd, except start of calving.

  - Calving: 10 Jun – 30 Jun, based on analysis of movement data and calving ground distribution surveys, which showed median dates of calving of collars and peak of calving to be roughly 10-13 Jun (Nishi et al., unpubl. data).
- Clipped Ahiak summer, spring and calving ranges to remove ocean (spring mainly the issue).

Beverly (BEV) and Qamanirjuaq (QAM) herds

- Older data (pre-1995) obtained with permission from GNWT-ENR (GN-DoE did not give permission to use more recent Nunavut data).
- Basis was work done in the mid-1990s by Leslie Wakelyn (BQCMB; wakelyn@theedge.ca), who pulled together countless surveys, maps and collar data. Leslie produced overall seasonal ranges that were a general amalgamation of the data for 10-25 years over time periods that generally began in the late 1950s and extended to the early 1980s to mid-1990s. Dave Taylor (cstndt@ssimicro.com) facilitated obtaining and deciphering the data.
- Shp files of 7 existing seasonal ranges were amalgamated into the 5 seasons we are using as follows (with original polygon names):
  - Calving: Calving (26 May – 25 Jun): Bcall; Qcall
  - Summer: Post-calving (26 Jun – 31 Jul) and Late summer (1 Aug – 15 Sep): Bpall and Blall; Qpall and Blall
  - Fall: Fall migration and rut (16 Sep – 31 Oct) Bfall; Qfall
  - Winter: Early winter (1 Nov – 31 Dec) and Late winter (1 Jan – 15 Mar) Ew and Lwhi merged and split in 2.
  - Spring: Spring migration (16 Mar – 25 May): Bsmall and Qsall
- Qam fall polygons were small and scattered; redrawn by Anne to a more realistic fall range and digitized.
- Projection in Geographic.
- Data incorporates primarily survey data, and thus represents both sexes.

Cape Bathurst (CBH), Bluenose West (BNW) and Bluenose East (BNE) herds

- Collar data obtained from Bonnie Fournier, ENR, Yellowknife (Bonnie_Fournier@gov.nt.ca) from the WMIS system. Data from Inuvik (primarily CBH and BNW) and Sahtu (BNE).
- Data separated by SAT and GPS collars.
  - SAT collar duty cycle was often 1, 5, or 7 days, depending upon time period and season.
  - GPS collars varied from 3-6 locations/day, and were roughly rarefied to 1 location/day.
  - All Tuk Pen and 3 Bathurst herd caribou removed.
  - All animals assigned as "Unknown" herd removed.
  - All males (n = ~42) removed.
- Sample size of females: CBH n = 59, ~25,400 locations; BNW n = 98, ~29,000 locations; BNE n = 70, ~19,400 locations. All 1996-2010.
- Assumed the herd identifiers in the database were correct; a fair bit of cross exchange observed with some animals.
- Seasons are the same as for the Bathurst herd.

    - Calving (extent of calving) to cover 21 days from 10-30 Jun (based on estimated peak of calving from 2007 and 2008 calving ground distribution surveys [Poole et al. 2010. An operations guide to barren-ground caribou calving ground density, dispersion and distribution surveys, based on an assessment of the June 2007 and 2008 surveys, Northwest Territories and Nunavut. Draft Manuscript Report, ENR, GNWT]). Spring and summer abut each end.
- 90% fixed kernels, in geographic projection. A few ranges had the odd outlier polygon; these could be ignored if needed.
- All Cape Bathurst herd seasonal ranges clipped to remove ocean.
- A number of caribou travelled far from their "traditional" ranges. The 90% FK will correct for most of these animals.

Dolphin and Union (DUH) herd

- Collar data from Poole et al. (2010. Sea ice and migration of the Dolphin and Union caribou herd in the Canadian Arctic: an uncertain future. Arctic 63:414-428), where we assigned locations for each individual into seasons by examining movement rates, directionality, and spatial locations of individuals, rather than using predetermined calendar dates.
- Originally had 4 datasets. Removed data from 1 dataset (VIC8789) from the late 1980s because of shift to wintering on the mainland (as had occurred earlier in the 1900s at higher numbers). Therefore, satellite collar locations (range from daily to every 7 days) from 29 adult females, ~8,300 locations from 3 datasets from 1996 to 2006.
- Seasons are as follows:
    - Calving: covers movements within the extent of calving (~10 Jun to ~1 Jul). Parturition location and date were determined from a rapid reduction in movement rates and loss of directionality. Only parturient cows considered for the calving period.
    - Summer: ~early Jul to the start of fall.
    - Fall: Sep through Oct-Nov). May or may not be interrupted by staging; however, it generally continues after a period of staging, with a final leg that includes crossing on newly formed sea ice to the adjacent mainland.
    - Winter: ~mid-Nov–mid-Dec to ~Apr to early May.
    - Spring: ~21 Apr to ~9 Jun.
- Seasonal ranges in 90% fixed kernels, in geographic projection.
- Seasonal ranges quite broad in relation to caribou collar locations, because of the relatively smaller sample sizes, the wider spread to the locations (especially SHAL9698 and NVI0306), and the jump over the ocean for wintering.
- Calving, summer and winter seasons clipped to remove ocean; fall and spring seasons are when DU caribou do use the ocean.

George River (GRH) and Leaf River (LRH) herds

- From Mael Le Corre (lecorremael@hotmail.com), PhD student of Steeve Côté, Universite Laval.
- Seasonal ranges with combined data from winter 2006 to winter 2010; data used for calving, summer and fall are from 2006 to 2009.

- Data from adult females, 76 for the George River and 86 for the Leaf River herds; all satellite collars.
- Kernels built with LSCV and Href method. LSCV is far too fine and blocky; will use Href.
- Original projection NAD 1983 Quebec Lambert (prj file attached). Converted to Geographic projection for ocean clipping.
- Seasons as follows (peak of calving is the second week of June):
    - Calving: Jun 8 – Jun 30; data are from 2006 up to 2009
    - Summer: Jul 1 – Aug 14; data are from 2006 up to 2009
    - Fall: Aug 15 – Nov 30; data are from 2006 up to 2009
    - Winter: Dec 1 – Mar 31; data are from 2006 (Dec 2005) up to 2010
    - Spring: Apr 1 – Jun 7; data are from 2006 up to 2010 (April)
- Clipped ocean from spring, summer, and fall ranges to remove ocean for the LRH, and from spring and summer for the GRH.

Teshekpuk herd (TLH)

- From Lincoln Parrett, Alaska Dept. of Fish and Game, Fairbanks (lincoln.parrett@alaska.gov).
- Lincoln provided fixed kernel polygons produced using Kernel HR (Seaman et a. 1998). 5 km grid and LSCV (therefore very blocky with numerous lone polygons), weighted by animal within each year and by annual range. Projections WGS84 UTM Zone 5 for all except migrations, which were done in GCS_North_American_1983.
- Seasonal ranges calculated in various ways, and the date ranges are not continuous:
    - Calving: was combined “Calving” calculated (1-12 Jun 1994-2009) from observation of calving sites, all cows, and “Late June” (7-30 Jun 1994-2009) from satellite collars. Subsampled locations, both females and males (8F:2M ratio). As Lincoln noted “there are some peripheral dingle-berries associated with the “late June” distribution because it includes non-parturient cows and a few bulls”. I combined these 2 polygons to build Extent of calving. Polygons overlap nicely, with more scatter of outer smaller polygons during “late June”. These scatters could be removed or retained.
    - Summer (1 Jul-31 Aug) from satellite collars. Subsampled locations. Doesn’t specify, but assume both females and males (mostly females).
    - Winter (1 Dec-30 Apr 1990-2009) from satellite collars. Subsampled locations; pooled by period. Doesn’t specify, but assume both females and males (mostly females). Huge scatter, with many smaller polygons at great distances from the calving area (partly a result of LSCV method). Three main polygons/clusters, which were combined on Lincoln’s suggestion (“*If you were to ask me for more of an "expert opinion" generated winter range, I would just draw lines around those three main areas you can see in the map, one between Atqasuk and Wainwright, one just west of Nuiqsut, and the last a section of the central Brooks range, including the foothills on both sides*”).
    - Spring migration (16 Apr-31 May 1990-2008). Generated from continuous path from each collared animal (*n* = 146 paths from 74 caribou) within 15 km^2 cells to include

magnitude of use, and 90% volume contours built from that. Therefore, not a kernel-based analysis. Note projection is GCS_North_American_1983.

- Fall migration (16 Sep-30 Nov 1990-2009). Same rationale, methods, attributes and projection as spring migration (*n* = 198 paths from 106 caribou). Not a kernel-based analysis. Projection is GCS_North_American_1983.

Western Arctic herd (WAH)

- Collar data from Jim Dau, Alaska Dept. of Fish and Game [jim.dau@alaska.gov].
- Data from cows only standardized to provide 1 location every 6 days year round, 1987-2010; 161 caribou, ~11,750 locations.
- PTT data; first highest quality location used each day; low quality locations excluded (i.e. ARGOS 00, A0 and B0 location quality).
- All WAH collars have been deployed during September dating back to the mid 1980s; however, this data set excludes data until 1 June of the following year to ensure that collars are randomly distributed throughout the herd.
- Seasons (determined by Jim Dau by looking at speed and direction of travel using PTT data for the years 1987-2010 combined):
    - Calving: combined “calving” and “post-calving” 3-30 Jun
    - Summer: “insect” 1 Jul-2 Aug
    - Fall: 3 Aug-6 Dec
    - Winter: 7 Dec-13 Apr
    - Spring: 14 Apr-2 Jun
- Seasonal ranges built in geographic projection.
- Clipped all seasonal ranges to remove ocean.

Central Arctic herd (CAH)

- Collar data from Steve Arthur, Alaska Dept. of Fish and Game.
- All females, satellite collars, best per day, 1986-2006, daily locations. 75 caribou, ~24,300 locations.
- Quite a bit of overlap with the Tesh herd to the west. A few stragglers off to the west that created a couple of isolated polygons in 2 seasons; did not cull these animals out.
- Seasons as per Russell et al. (1993) for the Porcupine herd:
    - Calving: 1-21 Jun
    - Summer 22 Jul-15 Aug
    - Fall: 16 Aug-30 Nov
    - Winter: 1 Dec-31 Mar
    - Spring: 1 Apr-31 May
- Seasonal ranges built in geographic projection.
- Clipped all seasonal ranges to remove ocean.

Porcupine herd (PCH)

- Collar data from Dorothy Cooley, Yukon Environment [Dorothy.Cooley@gov.yk.ca].
- All females, satellite collars, best per day, 1985-2010, ~95 caribou, ~25,900 locs.
- Seasons lumped as per Russell et al. (1993):
    - Calving: 1-21 Jun
    - Summer 22 Jul-15 Aug (combined “migration” (22-30 Jun) into summer)
    - Fall: 16 Aug-30 Nov
    - Winter: 1 Dec-31 Mar
    - Spring: 1 Apr-31 May
- Seasonal ranges built in geographic projection.
- All seasons except winter clipped to remove ocean (minor bands along the shore).

Akia-Maniitsoq (AKH) (southern) and Kangerlussuaq-Sisimiut (KQH) (northern)

- Data from Christine Cuyler [chris.cuyler@natur.gl].
- Data from 1997-99; more recent data (2008-10) might have created problems with data sharing and permission to use.
- Sample size for AKH is 8 caribou, ~1,670 locations, Apr 1997 to Mar 1999.
- Sample size for KQH is 7 caribou, ~816 locations, Mar 1998 to Mar 1999.
- All females.
- Christine thought the same season ranges as for Bathurst herd would be appropriate:
    - Calving: 8 Jun – 30 Jun.
    - Summer: 1 Jul to 22 Aug.
    - Fall (combining fall migration and rut/late fall): 23 Aug to 5 Dec.
    - Winter: 6 Dec to 14 Apr.
    - Spring: 15 Apr to 7 Jun
- Seasonal ranges built in geographic projection.
- Needed to use Href 0.6 or 0.8 for AKH calving, summer and spring ranges because of wide dispersion of locations, to tighten in seasonal ranges.

Iceland herd (ICE)

- Single season range digitized from CARMA website. Approximately 6,000 feral reindeer, descended from transplant from Norway.
- Digitized into Google Earth, exported to OziExplorer and then translated into Arc shp file in decimal degrees (the latter care of Dave Taylor, Yellowknife).
- Annual range likely fairly accurate and recent given the degree information available on herd numbers.
- Annual range built in geographic projection.

Taimyr herd (TAI)

- Seasonal ranges written on background map of the area by Leonid Kolpashikov (Russian Academy of Sciences, Norilsk (kolpak46@norcom.ru).

- Digitized from water and contour background from 1:1,000,000 DCW (Digital Charts of the World) into Clarke 1866 Lambert Conformal Conic, and converted into geographic projection (courtesy of J. Shaw, Caslys Consulting).
- Season dates unknown, but fairly clear for calving, summer and winter range. Fall and spring migration provided in the same map with broad arrows; these were digitized using best judgement.
- Date range unknown.

Lena-Olenyk herd (LEN)

- Seasonal ranges written on background map of the area by Valery Safronov (Institute of Cryolite Zone Biological Problems of Siberian Branch of Russian Academy of Sciences, Yakutsk - vmsafronov@ibpc.ysn.ru).
- Digitized from water and contour background from 1:1,000,000 DCW (Digital Charts of the World) into Clarke 1866 Lambert Conformal Conic, and converted into geographic projection (courtesy of J. Shaw, Caslys Consulting).
- Season dates unknown, but fairly clear for calving, summer and winter range. Fall and spring migration provided in the same map with broad arrows; these were digitized using best judgement.
- Date range covered unknown.

Yana-Indigurka herd (YAN)

- Seasonal ranges written on background map of the area by Valery Safronov (Institute of Cryolite Zone Biological Problems of Siberian Branch of Russian Academy of Sciences, Yakutsk - vmsafronov@ibpc.ysn.ru).
- Digitized from water and contour background from 1:1,000,000 DCW (Digital Charts of the World) into Clarke 1866 Lambert Conformal Conic, and converted into geographic projection (courtesy of J. Shaw, Caslys Consulting).
- Season dates unknown, but fairly clear for calving, summer and winter range. Fall and spring migration provided in the same map with broad arrows; these were digitized using best judgement with pre-calving combined with spring migration.
- Range covers 1980-90.

Sundrunskaya herd (SUN)

- Seasonal ranges written on background map of the area by Valery Safronov (Institute of Cryolite Zone Biological Problems of Siberian Branch of Russian Academy of Sciences, Yakutsk - vmsafronov@ibpc.ysn.ru).
- Digitized from water and contour background from 1:1,000,000 DCW (Digital Charts of the World) into Clarke 1866 Lambert Conformal Conic, and converted into geographic projection (courtesy of J. Shaw, Caslys Consulting).

- Season dates unknown, but fairly clear for calving, summer and winter range. Fall and spring migration provided in the same polygon without arrows, thus “SUNfall” represents both spring and fall migration between summer and winter ranges.
- Date range covered unknown.

Chokotka herd (CHO)

- Five seasonal ranges digitized from slide from Don Russell with Google Earth background.
- No information on background on caribou herds, years, etc.
- Digitized into Google Earth, exported to OziExplorer and then translated into Arc shp file in decimal degrees (the latter care of Dave Taylor, Yellowknife).
- Merged ranges to annual range (filled in a couple of small holes in the middle of the 5 ranges when building the annual); also split to tundra and taiga portions of the annul range.
- All range built in geographic projection.

Table 2. Size (km^2) of seasonal ranges for 22 caribou herds.

Herd	Calving	Summer	Fall	Winter	Spring	Taiga	Tundra	Annual
Bathurst	37,454	68,927	148,631	159,443	222,665	180,654	95,313	275,967
Ahiak	31,011	194,273	278,385	177,853	268,908	155,971	251,390	407,361
Beverly	38,195	257,220	232,709	239,036	360,012	363,778	149,975	513,753
Qamanirjuaq	28,384	175,268	133,857	202,019	275,175	286,376	96,157	382,534
Cape Bathurst	3,575	6,353	21,557	13,661	21,285	714	26,559	27,273
Bluenose West	17,258	31,915	73,380	42,345	68,212	20,652	81,269	101,922
Bluenose East	21,614	96,932	114,350	78,173	76,238	122,839	70,249	193,087
Dolphin and Union	107,890	158,298	105,043	44,102	111,823	0	250,435	250,435
George River	9,972	95,929	120,237	112,657	129,702	203,275	13,170	216,445
Leaf River	86,672	161,033	347,096	211,093	363,943	378,126	179,905	558,031
Teshekpuk *[@]	13,676	26,630	126,487	40,606	178,410	14,589	203,913	218,045
Western Arctic *	57,470	87,840	277,598	232,521	219,258	92,315	233,111	326,138
Central Arctic *	13,067	34,389	49,643	62,650	49,768	10,935	63,224	74,430
Porcupine *	22,653	71,893	180,696	175,321	135,956	145,240	81,846	227,436
Kangerlussuaq-Sisimiut *	992	952	1,086	839	620	0	1,580	1,590
Akia-Maniitsoq *	3,753	2,482	1,856	1,484	3,772	0	4,807	4,839
Iceland						15,303	130	15,685
Taimyr *	90,331	185,297	393,395	309,812	279,875	423,258	321,677	748,417
Yana-Indigurka	15,668	93,770	175,604	102,117	114,247	204,813	75,573	280,390
Sundrunskaya *[#]	8,272	63,244	39,922	32,109	39,922	52,637	62,109	114,775
Lena-Olenyk *	9,503	88,745	131,299	118,523	92,329	219,463	66,472	286,323
Chokotka	10,198	51,534	28,120	31,314	22,738	35,436	56,854	92,290

*Small differences in areas related to land-ocean outline used to clip for tundra and taiga backgrounds.

[@]Clipped ocean from TLH annual range.

[#]Fall and spring ranges are the same.