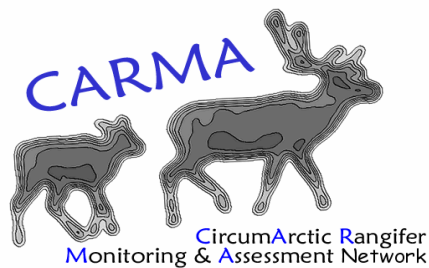


***Rangifer* Health & Body Condition Monitoring**

MANUAL



Circum Arctic *Rangifer* Monitoring and Assessment (CARMA) Network

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Table 1. Rangifer HEALTH and BODY CONDITION (Males and females) QUICK REFERENCE for INDICATOR MONITORING						
Indicator Monitored	Sample or measure	Visual Appraisal (Hands Off)	Sampling of Live Rangifer (Capture – Release)	Sampling of Harvested Rangifer		
				Level 1 Minimal Collection	Level 2 Field measurements & sample collections	Level 3 Extensive measurements & sample collections TAKE PHOTOGRAPH
AGE STRUCTURE						
Age	Age estimate	Maturity class	- Maturity class - Age class	- Maturity class (Cementum age)	- Maturity class - Age class - Cementum age	- Maturity class - Age class - Cementum age
LONG TERM NUTRITIONAL STATUS						
Morphometrics	Body mass		Body mass		- Body mass - rumen mass (optional)	- Body mass - Rumen contents mass - Shoulder weight
	Mandible		Abnormalities		- Jaw size - Abnormalities	- Jaw size - Tooth wear/ breakage - Abnormalities - Mandible marrow fat
	Metatarsus		Metatarsus length	- Metarsus length - Marrow color (Marrow fat)	- Metarsus length - Marrow fat - Marrow color	- Metarsus length - Marrow fat - Marrow color
SHORT TERM NUTRITIONAL STATUS						
Fat	Backfat		- Ultrasound - Palpation	- Depth	- Depth	- Depth - Ultrasound to validate
	Kidney and fat			- Kidney and fat	- Kidney and fat	- Kidney and fat
	General fatness		Palpation	- Body condition score	- Body condition score	- Body condition score
Condition (protein)	- Gastrocnemius - Peroneus					- Gastrocnemius - Peroneus
Diet	Plant cell fragments	Fecal sample	Fecal sample	Fecal sample	Fecal sample	- Fecal sample - Rumen contents
	Trace vitamins and minerals		Blood sample		Liver	- Blood sample - Liver

Table 1. *Rangifer* HEALTH and BODY CONDITION (Males and females) QUICK REFERENCE for INDICATOR MONITORING

Indicator Monitored	Sample or measure	Visual Appraisal (Hands Off)	Sampling of Live <i>Rangifer</i> (Capture – Release)	Sampling of Harvested <i>Rangifer</i>		
				Level 1 Minimal Collection	Level 2 Field measurements & sample collections	Level 3 Extensive measurements & sample collections TAKE PHOTOGRAPH
INDIVIDUAL HEALTH						
Parasites - Organ / tissue	Lungs, liver, metatarsus, other (see Appendix A)	Fecal sample		Hunter reports of lesions or presence of parasites	- Organ and tissue samples - Count of gross lesions or parasites	- Extensive organ and tissue samples - Count of gross lesions or parasites
Parasites - Gut	Abomasum, gut, feces (see Appendix A)	Fecal sample	Fecal sample		Fecal sample	- Fecal sample - Abomasum - Gastrointestinal tract
Parasites - Nasal / dermal	Warbles and nasal bots (see Appendix A)	Observation (spring count)	Categories of abundance	Categories of abundance	Categories of abundance	Categories of abundance
Parasites	Secondary host distribution					Abundance/density estimates of secondary hosts
Diseases	Blood and fecal samples (see Appendix A)	Fecal sample	- Serum and whole blood (or blood on filter paper) - Fecal samples	Fecal sample	- Serum and whole blood - Blood on filter paper Fecal sample	- Serum and whole blood - Blood on filter paper - Fecal sample
Stress	Fecal corticosteroids	Fecal sample			Fecal sample	Fecal sample
Immune response	Lymphocyte counts and serum haptoglobin		- Serum and whole blood - Fecal sample		- Serum and whole blood (or blood on filter paper) - Fecal sample	- Serum and whole blood (or blood on filter paper) - Fecal sample
Unhealthy animals				Hunter submitted samples	Hunter submitted samples	Hunter submitted samples
Contaminants & Metals	Liver sample Kidney sample					- 500g of liver - 500g of kidney (use kidney collected for fat index)
	Muscle sample					500g of muscle

Table 2. *Rangifer* HEALTH and BODY CONDITION (Adult females only) QUICK REFERENCE for INDICATOR MONITORING

Indicator monitored	Sample or measure	Visual Appraisal (Hands Off)	Sampling of Live <i>Rangifer</i> (Capture – Release)	Level 1 Visual appraisal	Level 2 Field form	Level 3 Field Collection
MATERNAL INVESTMENT						
Protein Balance	Isotopes in urea vs. body protein	- Snow urine sample - Fecal sample	Blood serum and blood clot		Blood on filter papers (need to validate)	- Bladder urine - Muscle tissue - Blood serum - Clot
	Fetal tissues					Fetal tissue sample
Protein Balance, diet	Fecal sample					Fecal sample
Fetal development	Fetal mass and length		Calf size and mass if captured			- Fetal mass - Fetal length - Muscle sample
Reproductive state, reproductive history, diseases	Blood serum or blood on filter paper		Blood sample		- Lactation and pregnancy status/state - Blood sample	- Lactation and pregnancy status/state - Blood sample - Uterus and ovaries
Reproductive state	Snow urine	Urinary progestogens				
	Milk production		Lactation recorded	Lactation recorded	Lactation recorded	- Lactation recorded - milk samples (June-December)

INTRODUCTION

Across the circumpolar north, people are voicing concerns and questions about caribou and reindeer health and abundance. Many answers to those questions can come from herd-wide monitoring (routine gathering of information to measure, analyze and report on change) using both traditional and scientific knowledge.

The CARMA Network recognizes that, at present, knowledge about how environmental change can affect the Arctic's *Rangifer* herds is fragmentary, and the relationship between *Rangifer* and the people's vulnerability to changes in caribou herd size and movement is largely undocumented.

The CARMA Network proposes to:

- 1) provide baseline information on representative *Rangifer* herds and the human communities dependent upon them, and
- 2) establish a network that will standardize on-going monitoring and assessment of these *Rangifer* systems.



Porcupine caribou herd, northern Yukon (D. Russell, CWS)

The CARMA Network¹ is acting as a forum for documenting and assembling indicators to monitor caribou and their environment. CARMA is taking the lead to describe monitoring indicators in a manual that also includes standardized protocols from previous studies on *Rangifer* and other cervids (Langvatn 1977, Huot and Picard 1988, Chan-McLeod *et al.* 1995) and newly developed protocols relevant to community and hunter evaluation (Kofinas *et al.* 2003, Lyver and Gunn 2004). The manual and protocols will ensure that we are collecting and managing data in a comparable way². The target audience for the manual is technical staff (biologists, wildlife technicians, fish and wildlife officers) and researchers that are affiliated with the CARMA Network. The standardized monitoring data will be used to report on the status and trends in barren-ground caribou (wild reindeer and caribou) in the circumpolar regions.

This manual mostly describes technical measurements, but we have also included community-based monitoring where we already have experience with harvesters' approaches and have calibrated those with science-based approaches (for example, Lyver and Gunn 2004). Other examples of community-based monitoring are available (Arctic Borderlands Ecological Knowledge Co-op³). We recognize the need for using both traditional knowledge and science-based knowledge concurrently (for example, Hawley *et al.* 2004).

Some of the concerns and questions expressed by people dependent on caribou and reindeer are⁴:

- *What do we know about the herd (the baseline information)?*
- *What role has or does global change play in the health of the herd?*
- *What are hunters observing with respect to changes, and how are these changes affecting the long-term health of the herd?*
- *What are the implications of those changes to people's relationship with the caribou?*
- *How have changes affected caribou movements and behavior?*
- *How can this information best be shared?*

Monitoring includes the system of observations that underlies the set of information and interpretation termed 'traditional knowledge'. People on the land, whether traveling or hunting, are continuously observing the land and its wildlife including caribou. In parallel, monitoring also includes the ecological information collected by agencies and individuals to address management questions through

¹ <http://www.rangifer.net/carma/about.cfm>

² We do not intend the manual to detail lab procedures (such as tooth sectioning or extraction of parasite cysts from tissues) nor does the manual specify the detail that a particular study should adopt. We intend that levels of detail can be mixed and matched depending on the questions being asked. We have not included a prescribed form for data entry or data sharing at this stage, but reviewers of this manual should indicate if it is desirable.

³ <http://www.taiga.net/coop/index.html>

⁴ <http://www.rangifer.net/carma/about.cfm>

modeling, time series measurements, indicators research, data collection and analysis, interpretation, and data reporting.

This manual includes two approaches to monitoring: 1) observing status and trends and 2) using model validation. Most monitoring procedures measure “snapshots” of status, and repeated measures are then used to determine trends. However, within the array of status measurements, other indicators may be inferred (e.g.; milk in the udder as a measure of winter lactation; stable isotopes for determining dependency on maternal versus dietary protein for fetal growth). Trend monitoring helps identify long-term changes in the herd, and can be used to evaluate likely drivers such as the human and natural factors causing those changes. The second approach to monitoring involves model development and validation in which a hierarchy or array of testable hypotheses or theories determined for one herd is tested to see if it can be applied to other herds. For example, some relationships (*i.e.* models), such as between autumn fat weight and probability of pregnancy, were developed for one herd. We now need to know if these relationships are valid for other reference herds.

Caribou are monitored at three scales: the individual, herd and region. This manual describes monitoring at the scale of the individual caribou and is focused on health and physical condition. Although information is collected at one scale, it can be integrated and interpreted at another scale. For example, hunters observe how fat individual caribou are, and the information from hunters in all communities is compiled to rate the body condition (based on fat) of the herd in that particular year. Because caribou and reindeer researchers have identified weaning and breeding strategies driven by environmental factors (e.g. habitat quality, snow conditions) and predation, noting the number or incidence of outlier individuals (*i.e.* those smaller or larger than the population mean) is another means to relate individuals to the herd scale. Subsequent to this manual on condition and health, the CARMA Network will produce additional manuals that will focus on monitoring at the scale of the herd (vital rates and rates of change in abundance and distribution) and on monitoring of the environment (climate and habitat).

At each of the three scales of monitoring, we draw on our collective experience to list suitable indicators. Body condition indicators are attributes that we can monitor, and relate to environmental indicators to assess the relative importance of change in the human–*Rangifer* system (e.g., Is change in forage availability or quality more important than exposure to parasites?). The indicators that are monitored have to be both scientifically credible and acceptable to people in the communities. The indicators have to be practical, which includes being cost effective, and they have to be relatively easy to explain in order to share the results. For *Rangifer*, we have experience with many indicators, and know that they are practical. However, we are open to testing new indicators. We have grouped the indicators according to what they are being used to monitor, for

example, morphometrics, fat levels, protein balance (Tables 1 and 2 at the beginning of this manual).

There are essentially three opportunities when condition indicators can be monitored; during visual appraisal of individuals (*i.e.* hands-off), during sampling of live individuals (capture and release studies), and during sampling of harvested caribou. An accurate visual appraisal of animals, which can be made at every opportunity, is dependent on the expertise and experience of the observer. Cost will vary depending on sampling effort, but in general, monitoring based on visual appraisal has low costs. During harvesting, there is a range of quantitative and qualitative information that can be gained and we have three levels of field protocols for monitoring indicators (see Tables 1 and 2):

Level 1 - visual appraisal with minimal field collections

Level 2 - field measurements & sample collections

Level 3 - extensive measurements & sample collections (and extensive analysis of samples collected in the field)

Level 1 protocols provide primarily qualitative or categorical data, while level 3 protocols provide primarily quantitative data. The levels of sampling intensity are determined by the objectives. However, we anticipate that 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). We also recognize that the most intensive monitoring will be applied to the herds selected as reference herds.



Bull caribou, Porcupine caribou herd, northern Yukon (W. Nixon, CWS)

Objectives

The essence of designing a monitoring study/protocol is to identify and agree upon objectives⁵ (the questions to be answered). Although each stakeholder group (aboriginal users, governments, industry and others) will have their own particular information requirements for their specific herds, the CARMA Network anticipates that as long as the standardized sampling protocols are followed, the data collected will be interchangeable within the CARMA Network. With health and body condition monitoring, we anticipate some objectives will be addressed with quantitative indicators and others with qualitative indicators.

Objectives or questions addressed with qualitative indicators may include:

- Are caribou in good shape for the time of year compared to other years?
- Do caribou have more warble fly larvae under the hide this year compared to other years?
- Are there calves and older animals that are abnormally small or large compared with most other caribou of their age?

Objectives or questions addressed with quantitative indicators may include:

- Is the functional response between autumn fat weight and probability of pregnancy the same for all reference herds?
- Is the functional response between nitrogen reserves/dietary sources of nitrogen and parturition rates the same for all reference herds?
- How do differences in the level of parasites and infectious diseases between herds account for differences in body reserves and conception rates?
- Do autumn body weight of calves and maternal fat reserves correlate to summer habitat quality, and how do these factors dictate weaning strategy?
- Is herd-specific autumn back fat depth correlated to long term winter habitat quality?
- Is depletion of femur marrow fat related to spring habitat quality?
- What is the relationship between climatic conditions, geography, population density, and the prevalence, intensity and diversity of parasites and infectious diseases in a herd?
- What is the relationship between population density, prevalence, intensity, and diversity of parasites and infectious diseases, and body condition, conception rates and early growth and survival of calves?

Objectives must be attainable. As obvious as this seems, in practice, it does not always happen. Sample sizes must be large enough to determine relationships between variables through rigorous statistical analyses. Simply collecting data rarely meets an objective. What stakeholders usually want is information to make a management decision, therefore, the data collected must address a specific objective or set of objectives. Analysis of the data is essential. However, statistical analyses require a large enough sample set to describe the variation

⁵ For example, Spellerberg (1991) described a generic environmental monitoring approach derived from various world-wide systems, and the first step was to define objectives.

(sampling precision) and detect changes or trends with reasonable statistical confidence (power). A sample size that is too small will not provide an accurate estimate of trends in the indicator that is being measured.

Appropriate levels of sampling should be estimated prior to the work beginning. This is a key point for the subsequent utility of estimating trends. For example, we can use data from captive animals to evaluate minimum sample sizes and statistical power (probability of not making a type II error). Statistical power analyses can estimate the level of confidence from a time series of sample collections and are essential in studies to determine trends over time. For example, Macdonald (2004) describes the use of power analysis in measuring trends in contaminants in biological samples. Power analyses can also estimate the probability of correctly rejecting the null hypothesis, *i.e.* the probability of detecting a change or trend if it is present. Several inputs are required in a power analysis: sample size, the magnitude of the possible change being measured, an estimate of sample variability, and the required level of significance. Power analyses offer an approach to ensure that sampling is based on the amount of variation encountered (although attention should be paid to statistical noise relative to biological information). For example, if an indicator being measured becomes more variable, a power analysis will reveal whether sample size has to be increased.

For example, required sample sizes are estimated for detecting pathogens occurring at various levels of prevalence in barren-ground caribou herds at a confidence level of 0.95 (S. Kutz pers. comm. 2006).

Prevalence of the pathogen (%)	Sample size necessary to detect the pathogen (0.95 confidence level)	
	Bluenose East (~33,300 male caribou)	Bluenose West (~10,400 male caribou)
50	5	5
40	6	6
30	9	9
20	14	14
15	19	19
10	29	29
5	59	59
2.5	119	118
1	297	294
0.5	591	581

Ideally, this manual will provide guidance in selecting the best protocols to use to achieve certain objectives. For example, when is the maturity age estimate sufficient for monitoring demographic trends? Does the added value from estimating age using age class or cementum age always justify sample collection from captured or harvested caribou? Although we cannot anticipate all specifics, we can offer the following guidance.

Firstly, we are aiming to develop a common minimum level of trend monitoring for representative circumpolar herds. We anticipate that level 1 and level 2

protocols for data collection will be widely used to attain the objectives set for this trend monitoring (e.g. qualitative measurements based on visual appraisal with some level 2 measurements from harvested *Rangifer*).

Secondly, the objectives for model validation monitoring will require more intensive and quantitative data collection – level 3 protocol. For example, research on a link between body condition and reproductive success determined for the Central Arctic caribou herd (Cameron *et al.* 1993) was applicable to the Porcupine caribou herd (Gerhart *et al.* 1997). However, to be able to monitor how additional factors, such as variation in climate or changes in habitat, may potentially affect body condition, and ultimately, reproductive success, the nature of this link needs to be established for other herds.

Additionally, the intensity of monitoring depends on the management or research questions being asked: frequently, herds that are declining or expecting industrial activity within their range are more intensively monitored. There is a trade-off, of course, as more intensive monitoring has a higher price tag with respect to coordination and logistics effort, and sample processing and analysis. There may also be challenges in obtaining sufficient sample sizes that are not biased by hunter preference. Sample bias may be less of an issue if the same criteria are used over time, as trends can still be tracked (Kofinas *et al.*, 2002, 2003; Lyver and Gunn 2004).

An important consideration in designing monitoring programs is to ensure that the protocol is respectful of the caribou and the people who harvest them. Collecting samples from harvested caribou and the capture and release of caribou would require approval of user communities and co-management boards.

Relationship with existing monitoring systems

Although it is relatively simple to apply protocols to new monitoring initiatives, we recognize that monitoring is already underway. Reconciliation of the various protocols raises potential challenges with using data from the existing monitoring systems (Cantor 1996). The CARMA Network will be developing a data management framework that includes protocols for data sharing/exchange and sets a common understanding of intellectual property. Data agreements, whether formal or informal, will enable the pooling of data/information for broad scale analyses. In developing this manual, we have attempted to minimize the challenge of integrating existing monitoring programs within the CARMA Network by working with the biologists involved, and adapting their protocols when possible.

Availability, sharing and housing data

An effective monitoring protocol will require sharing/exchanging of data and information in both the short term and long term. There is also a need for information protocols that will effectively address the release and use of

traditional knowledge. The protocols and policy relevant to CARMA cooperators are being developed (2008) and will be placed on the CARMA webpage.

Information management would also ensure that expanded or new monitoring activities would use standardized and repeatable methods. If new monitoring variables are introduced, they should fit within the context of the CARMA Network data management framework. Determining the relationship between new variables and those used in the past will require retrospective analyses before the new variables can be used to assess trends.

The approach

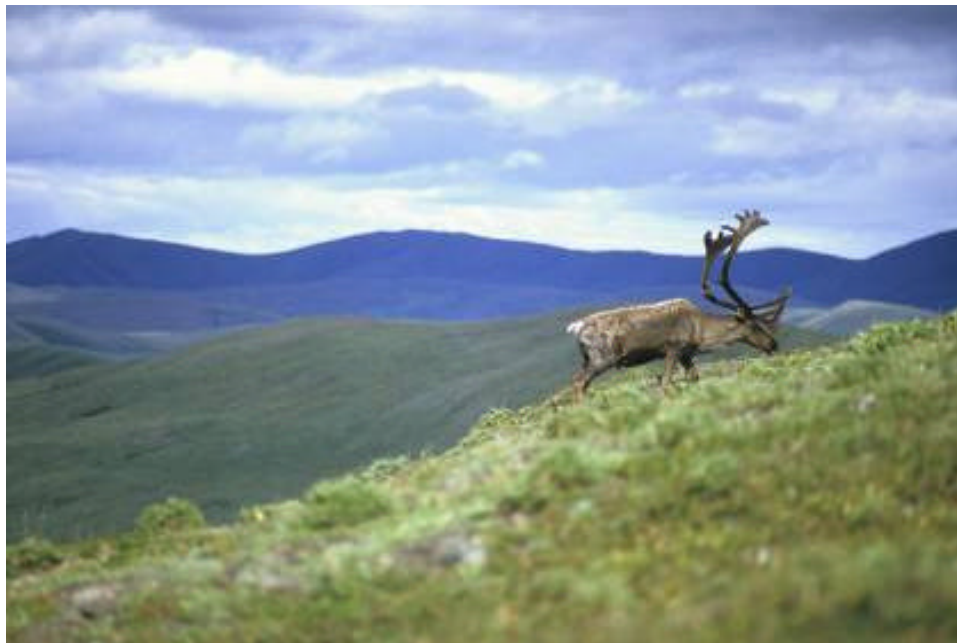
The following is a recommended approach to managing collection of data across the circumpolar north, using harvested jaws as an example:

- a. Identify regional partners/cooperators to administer the collections and take the basic measurements.
- b. Use regionally appropriate means to inform hunters and request contributions (some people may need convincing to extract jaws, as heads are a traditional desired part of the caribou).
- c. Depending on specific objectives, sample collections may be distributed over the whole range of the herd, over all seasons, and over all age and sex classes. Collect as many jaws as each collaborator can afford to process and measure. If collaborators need to prioritize, focus on adults in fall and spring to enable comparisons over time.
- d. To compare between herds, coordinate seasonal timing of collections and standardization of measurements (units of measurement and instruments used, *etc.*, for example, the diastema measured with calipers to the nearest mm).
- e. Enter data into compatible databases using standard variable names and standard detail regarding measurements.
- f. Conduct standard quality control after data have been entered, and archive the “clean” data set using appropriate backups. Use only copies of the original clean data set for any analyses, data summaries, *etc.*
- g. Review the terms of data exchange/data sharing agreements.
- h. Contribute data to the CARMA Network for synthesis.
- i. CARMA will report results back to collaborators as soon as possible and provide feedback on synthesis across herds within 1 year.
- j. Use jaw information from reference herds, for which detailed body condition information is also being collected, to give a baseline for extrapolation to non-reference herds.

INDICATORS FOR MONITORING BODY CONDITION AND HEALTH

Over the last 20 years, biologists and caribou users have collectively recognized that the welfare of caribou herds depends on working together and sharing our knowledge and experience. This is especially true for monitoring caribou health and condition. In February 2000, a workshop on “Monitoring Caribou Body Condition” was held to develop a community-based system for monitoring caribou that would track individual and herd well-being (body condition and disease/parasite status), detect changes in environmental conditions, and contribute to a co-management assessment of future impacts. Specific discussions focussed on: the state of knowledge regarding links between body condition and productivity; the role of communities in monitoring caribou body condition; assessing the techniques being used to determine body condition; and cost-effective, practical methods to monitor body condition, especially involving caribou user communities (Kofinas *et al.* 2002). Protocols in this manual draw on the previous workshop to help standardize monitoring of caribou condition and health. Tables 1 and 2 summarize the body condition and health indicators to be monitored, and the different options for intensity of monitoring.

Infectious diseases and parasites influence the health and population dynamics of caribou (Huot and Beaulieu 1985) as well as their resilience to environmental change. Thus, it is important to monitor the occurrence and diversity of infectious diseases and parasites in caribou populations in order to establish baseline values of health parameters for detecting future changes.



Bull caribou in the northern Richardson Mountains (S. Smith)

1. AGE

For any animal that is handled, an indication of its age should be recorded. There are three possible levels of detail at which to record age: maturity class, age class, or cementum age. The level chosen will depend on monitoring objectives.

Maturity class

There are three maturity classes – calf, sub-adult (juvenile and yearling) and adult – that are generally recognizable even when caribou are not being handled (*i.e.* during a visual appraisal).

Age class

It is possible to determine age classes from tooth wear, based on visual inspection (using photographs) of harvested or captured caribou in the field, but this must be determined for each herd. Age classes were calibrated during the Porcupine Caribou Herd Body Condition Monitoring by comparing tooth wear to cementum age. Calf and yearling caribou have deciduous incisors and are distinguished from each other by body size and shape.

Cementum age

This is a well-established technique for objectives that require year-class resolution (for a review with many photos, see Miller 1974). The first incisors are used for cementum aging, and can be collected in capture-release and harvest studies. From harvested caribou, where a collection program is in place, ideally the whole jaw will be collected (along with the vitals – sex of the animal, date, location, and hunter).

2. MORPHOLOGICAL MEASURES

2.1 Body mass

Hunters can categorize body mass as large, average or small (level 1). For level 2 and 3 protocols, body mass is measured by weighing the body. For level 3, indexing body mass from the mass of the front shoulder needs validating across a range of herds. Also for level 3, the mass of rumen contents can be used to estimate the mass of gut contents (Staaland *et al.* 1984) which when subtracted from body mass gives a measure of empty body weight. Empty body mass is the preferred standard for comparing total body mass and total body protein due to the seasonal variation in rumen mass and alimentary fill.

2.2 Mandible

Skeletal size reveals trends in body condition, because size depends on the animal's environment as well as genetics. Skull and jaw size have been found to be relatively plastic – changing size with environmental conditions during gestation and early life. Whole jaw collections allow us to track mandible size trends over time (for herds that are monitored long term), while mandible fat

measurements allow us to measure the animal's seasonal and annual condition. Information from jaws, combined with a consistent measure of body condition (e.g. back fat depth), provide a cost effective means of tracking short-term and long-term changes in health and nutritional status (forage quality/availability) relative to nutritional requirements.

2.3 Metatarsus

Metatarsus length can be measured both on live and harvested caribou. However, as an index to body mass, validation will be required for each herd.

3. FAT

Fat reserves are relatively easy to measure and are an efficient and effective measure of caribou condition. A key use for monitoring seasonal and annual changes in fat reserves is for a first approximation of trend in fecundity; the level of fat reserves (or status) in early winter relates to the probability of conception in adult females.

For live caribou either being observed or handled in the field, quantitative information on fat reserves can be scored by visual assessment or by palpation (Gerhart *et al.* 1996a). Hunters also have their categories for caribou fatness and these can also be applied to harvested caribou (Lyver and Gunn 2004). For animals that are handled and released, ultrasound can provide an index of fatness, which can be calibrated for each herd using harvested animals.

Overall assessment of fatness

Overall fatness/body condition can be assessed by hunters, caribou health monitors, or regional wildlife staff using a decision key based on one measurement of back fat and a visual appraisal of the absence or presence of fat around the kidneys and intestines and the appearance of the fat in the long-bone marrow. A key developed for the Porcupine Caribou Herd (Kofinas *et al.* 2002, 2003) links quantitative body fat estimates in fall-early winter to rates of pregnancy (Figure 1).

When quantitative information on body condition is required, the decision key can be modified to include measures of the fat reserves (Figure 2).

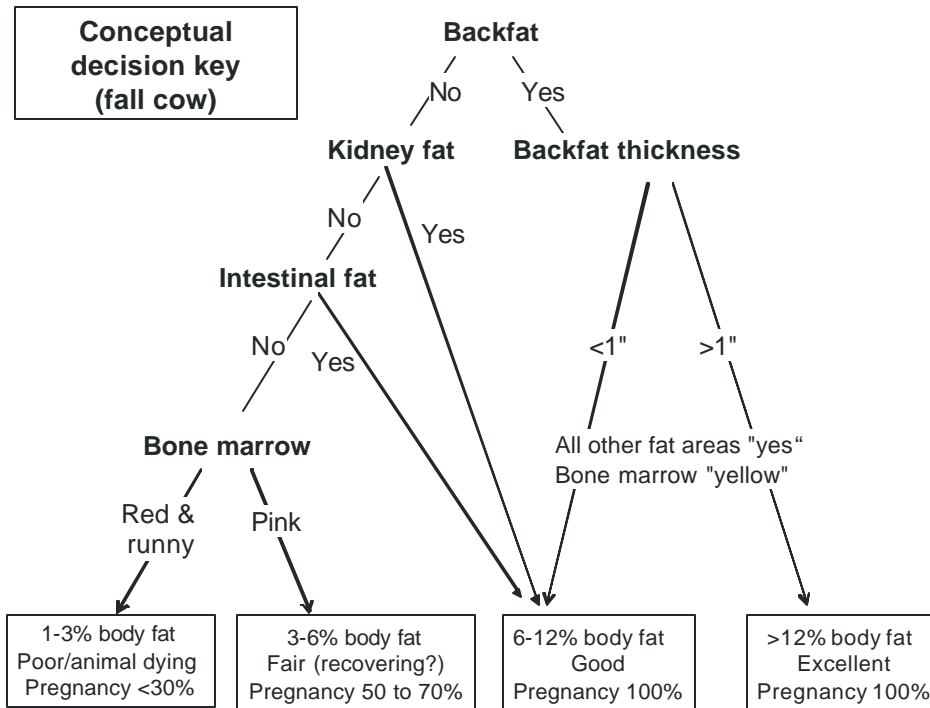


Figure 1. Decision key based on visual assessment to determine whether caribou are in relatively poor, fair, good, or excellent body condition (after Kofinas *et al.* 2002, 2003).

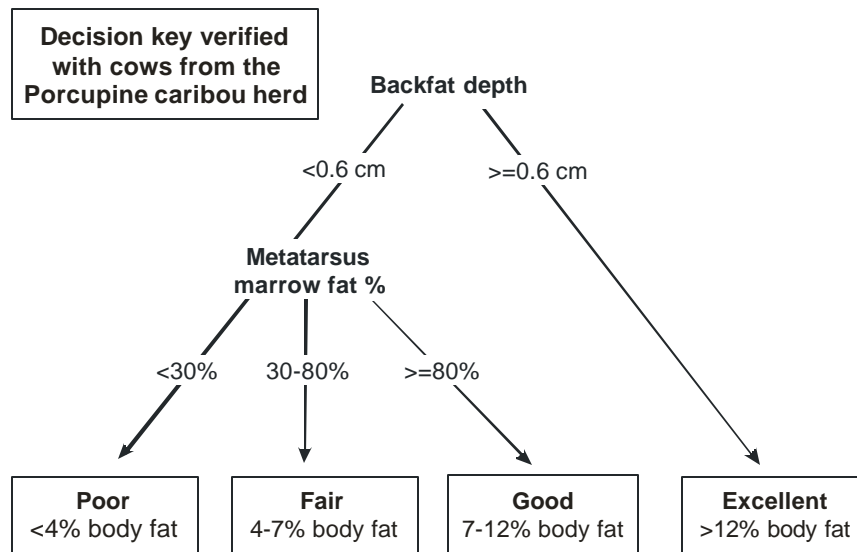


Figure 2. Proposed key to determine body condition based on quantitative measures of body fat indexes. The key has been verified for females of the Porcupine Caribou (from Cooley *et al.* in progress).

To determine the significance of overall energy reserves to survival and productivity of the individual, body condition measurements (back fat, kidney fat index, marrow fat %, mass of metatarsus marrow fat) can be converted to total body fat and energy stored as fat in adults (Reimers *et al.* 1982, Adamczewski *et al.* 1987, Chan-McLeod *et al.* 1995, Huot and Goudreault 1985, Gerhart *et al.* 1996b). Likewise indicator muscles and bones can be used to estimate the total protein and bone mass in an animal (Ringberg *et al.* 1981, Adamczewski *et al.* 1987, Chan-McLeod *et al.* 1995, Huot and Goudreault 1985). The relationships in the estimation of total body fat, protein and bone for an individual requires more documentation.

4. DIET

The rationale for using diet as an indicator is that it helps interpret condition and also relates condition to habitat and range considerations. Current techniques include measuring: the relative abundance of botanical components of rumen and fecal contents; the chemistry of wax ester indicators in feces (Dove and Mayes 2006); and isotopic ratios of nitrogen ($\delta^{15}\text{N}/^{14}\text{N}$) and carbon ($\delta^{13}\text{C}/^{12}\text{C}$) in newly synthesized tissues, such as hooves, hair, antlers, and blood proteins (Barnett 1994, Kielland and Finstad 2000, Kielland 2001, Barboza and Parker 2006). For all three techniques, reference plant samples will be needed to “fingerprint” or group plant species by fragment surface morphology, indicator wax ester alkane chemistry, or N and C isotope ratios.

Fecal and ruminal plant cell fragment composition used with digestibility correction factors can provide an estimate of diet composition.

Analysis of **fecal plant alkane and wax esters** can be combined with plant cell fragment analysis to give a quantitative estimate of intake.

To deal with individual variation, composite samples can be assembled using one fecal pellet from each of 20 fresh pellet groups. Pellets can also be collected from the rectum of handled or harvested caribou. Pellets can be frozen or salted to prevent decomposition.

For plant fragment analysis, samples are processed in a commercial or university lab, and may require some reference plants in some cases. Plant alkane-wax ester analysis requires processing in a specialized analytical laboratory.

Isotopic signatures of nitrogen and carbon in bone, antler and hoof can be used to infer a baseline of long-term (from bone) and short-term (from antler and hoof) diet composition. Samples can be air-dried or frozen and must be analyzed by mass spectrometry in a specialized laboratory.

5. INDIVIDUAL HEALTH

5.1 Disease and parasites

The prevalence and intensity of diseases and parasites are relatively unknown in most *Rangifer* herds. The relationship between body condition and disease or parasites is not well described; an increase in intensity of infection may be the consequence or cause of poor condition. However, for some parasites, such as gastro-intestinal nematodes or warble flies, the sub-clinical effects on pregnancy and body condition are known (Stein *et al.* 2002).

Objectives for monitoring diseases and parasites include the need to establish baselines for the prevalence and intensity of known or expected diseases and parasites (Appendix A). Those two objectives will be met by sampling as per the level 2 protocol; a combination of qualitative and quantitative sampling. The most intensive sampling (level 3 protocol) will be required to meet the objective for surveillance to detect diseases and pathogens when there are no visible lesions. Level 3 sampling will also be necessary to validate any proposed relationships between body condition and the intensity and prevalence of parasites and diseases.

Some parasites, such as warble flies and nose bot flies, and hydatid disease can be assessed as categorical data from visual inspection. Most diseases and parasites, however, require careful sample handling and laboratory analyses. Viral and bacterial pathogens and some parasites can be detected in blood or serum samples. Exposure to disease and parasites can also be monitored through the host's immune response, which can be determined from blood lymphocyte counts or levels of serum haptoglobin.

Some helminths, protozoa, viruses, and bacterial pathogens can be detected in feces, while others will require post mortem gross or microscopic examination in order to be detected. Once the range of prevalence has been described, follow-up sampling can be adapted to prevalence. For pathogens that are prevalent at low levels, a small sample of individual caribou may not detect the particular pathogen of interest. In contrast, if a pathogen is prevalent in half the population being sampled, a small sample (5 caribou) should be sufficient for detection.

6. MATERNAL STATUS

6.1 Weaning status

Cows may use different weaning strategies from year to year, depending on their health and energy reserves, range conditions and duration of the insect season. For the Porcupine caribou herd, the weaning strategy in one year had an important influence on cow productivity in the following year (Russell and White 2000, White *et al.* 2000). In early winter (November), lactation status can be

determined by presence of milk in the cow's udder combined with analysis of a milk sample. Milk samples can be obtained during capture-release or hunter harvest. Clear liquid (milk) obtained from the udder indicates that weaning has just occurred. Concentrated milk (> 25% dry matter) indicates that weaning is occurring and dilute milk (<25% dry matter) indicates extended winter lactation with weaning occurring in the spring (White *et al.* 2000). Females in the latter category are undergoing a one or two year breeding pause (Russell *et al.* 2000). The importance of documenting lactation status is because of the relationship between condition, lactation, and calf survival (Figure 3).

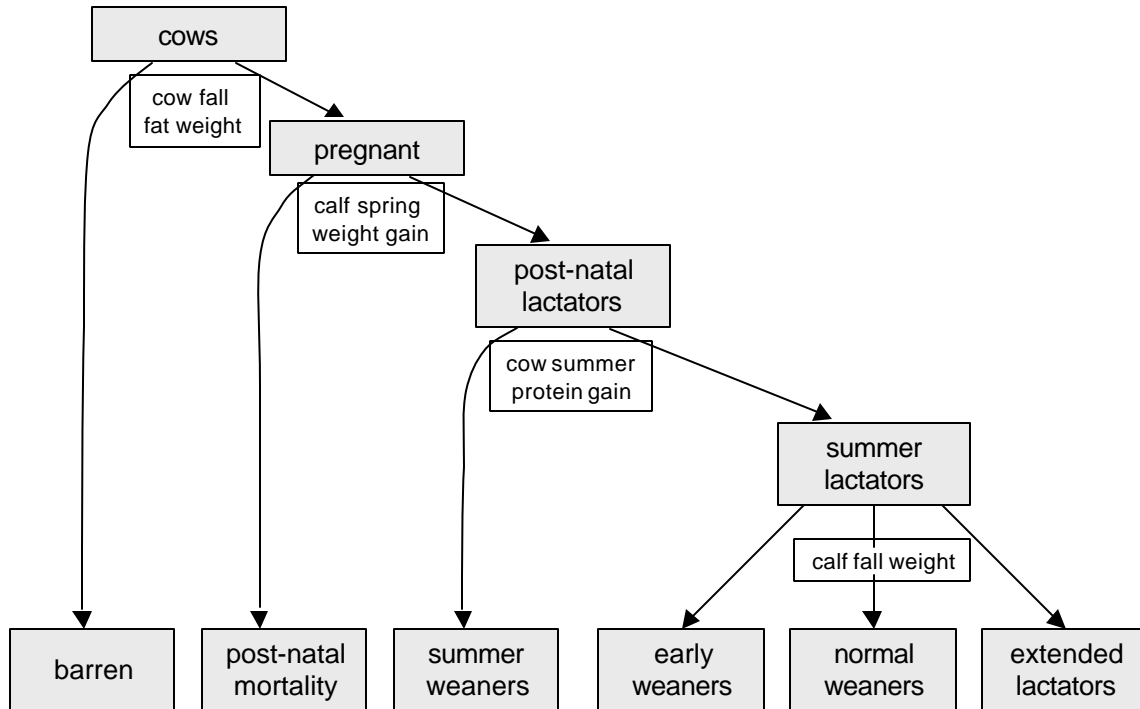


Figure 3. The relationships between cow condition, lactation and weaning time (Russell *et al.* 2005)

6.2 Pregnancy status

Blood samples can be collected during capture and release activities (e.g. radio collaring) in November to detect early pregnancy from progesterone levels (Gerhart *et al.* 1997, Russell *et al.* 1998), and at this time and later to determine, from a change in the level of pregnancy specific protein B (PSPB), whether intra-uterine embryonic resorption or mortality has occurred (Russell *et al.* 1998). In March, blood progesterone levels differ by an order of magnitude between pregnant and barren cows (D. Cooley, results for Porcupine caribou herd).



Porcupine caribou herd, northern Yukon (W. Nixon, CWS)

7. PROTEIN STATUS AND BALANCE

Individual muscles (such as the gastrocnemius and peroneus) can be weighed to estimate lean body mass (total body mass minus fat) (Ringberg *et al.* 1981, Adamczewski *et al.* 1987, Chan-McLeod *et al.* 1995) which gives an estimate of protein status and reserves. This makes a valuable addition to the determination of body condition based on fat (as detailed in section 3) and using calibrated indices of body fat from harvested animals (Reimers and Ringberg 1983, Huot and Goudreault 1985, Adamczewski *et al.* 1987; Chan-McLeod *et al.* 1995). In addition, both muscle mass (Ringberg *et al.* 1981) and protein mass (Reimers *et al.* 1982; Gerhart *et al.* 1996b) are related to body mass, but they are more highly related to fat-free, ingesta-free body mass. These relationships offer alternative and incrementally more accurate estimates of protein status where individual muscle mass is not measured, and where field measurements are confined to body mass alone or body mass plus body condition based on fat indices.

A new technique developed for *Rangifer* allows the determination of trends in protein (or N) balance of the individual, or protein/N balance of a caribou sub-population based on field samples of feces and urine on snow. The technique, based on stable isotope ratios of $^{15}\text{N}/^{14}\text{N}$ in blood or fecal/urine samples, can determine the likelihood that an animal is in positive, negative, or highly negative N balance at the time of sampling (Barboza and Parker 2006). Thus N balance can be compared with protein reserves and used to track the source of N (diet vs. body protein) used by the cow for fetal growth and development (Parker *et al.* 2005). Maternal protein reserves entering winter and the availability to cows of

dietary protein in winter is thought to strongly affect fetal development and birth weight in caribou (Allaye-Chan 1991, Gerhart *et al.* 1996b, Parker *et al.* 2005).

8. CONTAMINANTS

The Northern Contaminants Program (NCP) collects samples from selected herds, archives and processes them within a pre-determined time frame. The CARMA Network is working with the NCP to augment the existing program with samples from herds in northern Québec. For other herds, samples can be collected and archived until funds are available for analysis.

The objective of the NCP is to measure contaminant levels in caribou in the Canadian Arctic to determine if they are a potential problem for the animals or people who are eating them, and to see if the levels are changing over time. Monitoring caribou populations across the Arctic will also provide a better understanding of how contaminants get to the Arctic, and how they behave in different parts of the Arctic.

9. GENETIC TYPING (also refer to the population/demographics manual)

Although at one time, body condition (non-skeletal) was assumed to reflect environmental conditions, there is growing evidence for an inheritable component (for example, Merilä *et al.* 2001). In terms of monitoring, given this uncertainty in genetic versus environmental determinants of body condition, there is a strong argument for describing current levels of genetic variation using nuclear and mitochondrial DNA, and ensuring that the samples are archived. If new techniques develop, a baseline of samples from animals with known body condition will be available: for example, Côté *et al.* (2005) concluded that genetic neutral markers at microsatellite loci may have had too low a power to detect heterozygosity–fitness correlations, but they suggested that use of the candidate-gene approach might be more revealing.

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APPENDIX A. Known pathogens of North American caribou and samples required for diagnoses

From: The Sahtu Wildlife Health Monitor Program by A. Neimanis and S. Kutz **date** (references available in that report).

Pathogen	Subspecies affected	Sample(s) required for diagnosis	Reference
<i>Babesia</i> sp.	captive woodland caribou in Minnesota and Oklahoma	whole blood	(Holman, Petrini, Rhyan & Wagner 1994); (Petrini, Holman, Rhyan, Jenkins & Wagner 1995)
<i>Besnoitia tarandi</i>	woodland and barren-ground caribou; woodland caribou in SK	gross lesions, parasite	(Northwest Territories Resources Wildlife and Economic Development - NWT RWED 2002); (Wobeser 1976)
Bluetongue virus	Alaskan caribou	serum (or blood on filter paper)	(Zarnke 2000)
<i>Bovicola tarandi</i> (chewing lice)	northern caribou	gross lesions, parasite	(Durden 2001)
Bovine adenovirus 3	caribou in Québec	serum (or blood on filter paper)	(Elazhary, Frechette, Silim & Roy 1981d)
Bovine respiratory syncytial virus	northern Alaskan caribou	serum (or blood on filter paper)	(Zarnke 2000)
Bovine viral diarrhea virus (or a cross-reacting virus)	caribou in Québec, caribou in Alaska	serum (or blood on filter paper)	(Elazhary, Frechette, Silim & Roy 1981c); (Elazhary, Roy & Frechette 1979b); (Zarnke 1983)
<i>Brucella suis</i> biovar 4	woodland caribou in Nahanni National Park, barren-ground caribou in NWT	serum (or blood on filter paper), gross lesions	(NWT RWED 2002); (Tessaro & Forbes 1986)
Bunyamwera virus (species unspecified)	captive caribou, Wisconsin	serum (or blood on filter paper)	(Hoff, Spalatin, Trainer & Hanson 1970)
<i>Cephenemyia trompe</i> (nose bot)	barren-ground caribou	gross lesions, parasite	(NWT RWED 2002)
Contagious ecthyma	northern caribou, Alaskan caribou	gross lesions, serum (or blood on filter paper)	(NWT RWED 2002); (Zarnke, Dieterich, Nieland & Ranglack 1983); (Zarnke 1983)
Coronavirus	caribou in Québec	serum (or blood on filter paper)	(Elazhary, Frechette, Silim & Roy 1981b)
<i>Cryptosporidium</i> sp.	northern Alaskan caribou	feces	(Siefker, Rickard, Pharr, Simmons & O'Hara 2002)

Pathogen	Subspecies affected	Sample(s) required for diagnosis	Reference
<i>Dermacentor albipictus</i> (winter tick)	woodland caribou in Alberta (Welch)	gross lesions, parasite	(Welch, Samuel & Wilke 1990)
<i>Echinococcus granulosus</i> (Hydatid disease)	northern caribou	gross lesions, parasite	(NWT RWED 2002); (Rausch 2003)
<i>Elaphostrongylus rangiferi</i>	caribou in NFLD	feces (Baermann)	(Lankester & Fong 1998)
Epizootic hemorrhagic disease virus	Alaskan caribou	serum (or blood on filter paper)	(Zarnke 2000)
<i>Fascioloides magna</i> (Giant liver fluke)	wild woodland caribou in Québec	feces, parasite from liver	(Choquette, Gibson & Simard 1971)
<i>Fusobacterium necrophorum</i>	caribou in the USA	gross lesions	(Rausch 1953)
<i>Giardia</i> sp.	caribou	feces	B. Elkin pers. comm.
<i>Hypoderma tarandi</i> (warbles)	northern caribou	gross lesions, parasite	(NWT RWED 2002)
Infectious bovine rhinotracheitis virus (or a cross-reacting virus)	caribou in Québec, woodland caribou in SK, Alaskan caribou	serum (or blood on filter paper)	(Elazhary, Frechette, Silim & Roy 1981a); (Elazhary, Roy & Frechette 1979a); (Jordan, Rettie & Tessaro 2003); (Zarnke 1983)
<i>Leptospira interrogans</i>	woodland caribou in Yukon, Alaskan caribou	serum (or blood on filter paper)	B. Elkin pers. comm.; (Zarnke 1983)
Malignant catarrhal fever	Alaskan caribou	serum (or blood on filter paper)	(Zarnke, Li & Crawford 2002)
<i>Marshallagia marshalli</i>	caribou in NWT and Nunavut	feces	(Hoberg, Kocan & Rickard 2001)
<i>Nematodirella</i> spp. (<i>alcidis</i> , <i>longissimespiculata</i>)	caribou from Alaska and northern Canada	feces	(Hoberg <i>et al.</i> 2001)
<i>Nematodirus</i> spp. (<i>filicollis</i> , <i>odocoilei</i> , <i>skrjabini</i> , <i>tarandi</i>)	caribou from Alaska, NFLD, NWT, Québec and BC	feces	(Hoberg <i>et al.</i> 2001)
Northway virus (arbovirus)	Alaskan wild caribou	serum (or blood on filter paper)	(Zarnke, Calisher & Kerschner 1983); (Zarnke & Yuill 1981)
<i>Ostertagia</i> spp. (<i>gruehneri</i> , <i>arctica</i> , <i>mossi</i>)	caribou in Alaska and throughout Canada	feces	(Hoberg <i>et al.</i> 2001)
Papillomas and fibropapillomas	barren-ground caribou, NWT	gross lesion	(Broughton, Miller & Choquette 1972); (NWT RWED 2002)
Parainfluenza virus 3	captive and wild caribou	serum (or blood on filter paper)	(Van Campen & Early, 2001)

Pathogen	Subspecies affected	Sample(s) required for diagnosis	Reference
<i>Parelaphostrongylus andersoni</i>	woodland and barren-ground caribou in northern Canada and Alaska	feces (Baermann)	(Lankester 2001)
<i>Parelaphostrongylus odocoilei</i>	woodland caribou in AB	feces (Baermann)	(Gray & Samuel 1986)
<i>Parelaphostrongylus tenuis</i>	experimentally infected and introduced caribou	feces (but fatal, therefore should not be seen in healthy caribou)	(Lankester 2001)
Poxvirus	captive reindeer in the Toronto Zoo	gross lesions	(Robinson & Kerr 2001)
Rabies	northern caribou	serum (or blood on filter paper)	(NWT RWED 2002)
<i>Sarcocystis</i> sp.	barren-ground caribou	gross lesions (only if severe), muscle, parasite	(NWT RWED 2002)
<i>Setaria labiatopapillosa</i>	caribou in North America	whole blood, parasites from carcass	(Becklund & Walker 1969)
<i>Solenoptes tarandi</i> (sucking lice)	northern caribou	parasites	(Durden 2001)
<i>Taenia hydatigena</i> (cystocercosis)	northern caribou	gross lesions, parasite	(NWT RWED 2002)
<i>Taenia krabbei</i> (muscle cysts)	barren-ground and woodland caribou	gross lesions, parasite	(NWT RWED 2002)
<i>Teladorsagia</i> spp. (<i>boreoarcticus</i> , <i>circumcincta</i> , <i>trifurcata</i>)	caribou from Alaska and northern Canada	feces	(Hoberg <i>et al.</i> 2001)
<i>Toxoplasma gondii</i>	barren-ground caribou, NWT and Nunavut	serum (or blood on filter paper)	(Kutz, Elkin, Panayi & Dubey 2001)
<i>Trichostrongylus axei</i>	caribou from NFLD	feces	(Hoberg <i>et al.</i> 2001)
<i>Trypanosoma</i> sp.	wild woodland caribou, AB, barren-ground caribou in NWT	whole blood	(Lefebvre, Semalulu, Oatway & Nolan 1997); S. Kutz pers. comm.
West Nile virus	captive reindeer	serum (or blood on filter paper)	(Palmer, Stoffregen, Rogers, Hamir, Richt, Pedersen & Waters 2004)