



Data Quality Standards for Monitoring Caribou Populations in Wrangell- St. Elias National Park and Preserve, Central Alaska Network

Natural Resource Report NPS/CAKN/NRR—2018/1757



ON THE COVER

Photograph of a radiocollared cow from the Mentasta caribou herd.
Photograph courtesy of the National Park Service

Data Quality Standards for Monitoring Caribou Populations in Wrangell- St. Elias National Park and Preserve, Central Alaska Network

Natural Resource Report NPS/CAKN/NRR—2018/1757

Judy A. Putera

National Park Service
Wrangell-St. Elias National Park & Preserve
P.O. Box 439
Copper Center, AK 99573

September 2018

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the [Central Alaska Network website](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Putera, J. A. 2018. Data quality standards for monitoring caribou in Wrangell-St. Elias National Park and Preserve, Central Alaska Network. Natural Resource Report NPS/CAKN/NRR—2018/1757. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	iv
Tables.....	iv
Executive Summary	v
Acknowledgments.....	v
Introduction.....	1
Protocol Overview.....	1
Rationale for Caribou Monitoring.....	1
Measurable Objectives	3
Sampling Design.....	4
Rationale for Sampling Design Selection.....	4
Identifying the Survey Area	4
Capture and Radiocollaring of Caribou.....	5
Estimation of Herd Size.....	5
Mentasta Herd	6
Chisana Herd	6
Fall Sex and Age Composition.....	7
Radiotelemetry: Survival and Seasonal Distribution.....	7
Data Quality Objectives.....	9
Representativeness and Data Comparability	9
Completeness.....	9
Measurement Quality Objectives and Performance Standards	10
Literature Cited	11

Figures

	Page
Figure 1. Mentasta and Chisana caribou herd annual ranges.....	2

Tables

	Page
Table 1. Quality Objective table for caribou monitoring protocol.....	10

Executive Summary

The purpose of this report is to document the standards used by the National Park Service (NPS) Central Alaska (CAKN) Inventory and Monitoring Network for activities related to the collection, processing, analysis, and publication of caribou monitoring data as described in Protocol for Monitoring Caribou in Wrangell-St. Elias National Park and Preserve, Central Alaska Network (Putera and Miller *in review*). This plan also serves as a guide for all CAKN personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Acknowledgments

Funding for this project was provided through the National Park Service, Central Alaska Inventory and Monitoring Network.

Introduction

The purpose of this report is to document the standards used by the Central Alaska Network (CAKN) for activities related to the collection, processing, storage, analysis, and publication of monitoring data as described in in Protocol for Monitoring Caribou in Wrangell-St. Elias National Park and Preserve, Central Alaska Network (Putera and Miller *in review*). The policies and procedures documented in this quality-assurance plan for activities follow the quality-assurance plan for other monitoring activities conducted by the CAKN and supplement the National Inventory & Monitoring Division Quality Management Plan. The Standard Operating Procedures provide detailed protocol/program activities associated with caribou monitoring. This plan serves as a guide for all personnel who are involved in protocol/program activities and as a resource for identifying memoranda, publications, and other literature that describe associated techniques and requirements in more detail.

Protocol Overview

The Central Alaska Network (CAKN) has adopted a holistic view of network ecosystems and will track the major physical drivers of ecosystem change and responses of the two major components of the biota: plants and animals. Thus, the CAKN has identified *Fauna Distribution and Abundance* as one of its top three Vital Signs. In general, the CAKN wants to know where fauna are distributed across the landscape and to track changes in both their distribution and abundance. The *Fauna Distribution and Abundance* Vital Sign comprises monitoring efforts for a suite of vertebrate species spanning the significant elevation gradient found in CAKN parks, and includes species of specific interest within each park.

Rationale for Caribou Monitoring

Caribou occur in all 3 CAKN parks and are of interest from several perspectives. They are 1 of 6 keystone large mammal species in interior Alaska that are of great importance to the ecosystem and to people for both consumptive and non-consumptive uses. WRST is mandated by the Alaska National Interest Lands Conservation Act (ANILCA 1980) to protect habitat for and populations of caribou (Section 201 (9)), to provide the opportunity for continued subsistence uses (Section 804 (4)), and to conserve natural and healthy wildlife populations (Section 814(1)). General statewide hunting is allowed throughout all National Preserves in Alaska and subsistence harvest by federally qualified residents is allowed within 12 of 13 park units created by ANILCA, including the three CAKN units. This monitoring protocol focuses on 2 caribou herds, the Chisana and Mentasta that have primary spring, summer (calving), and fall ranges in WRST (Figure 1).

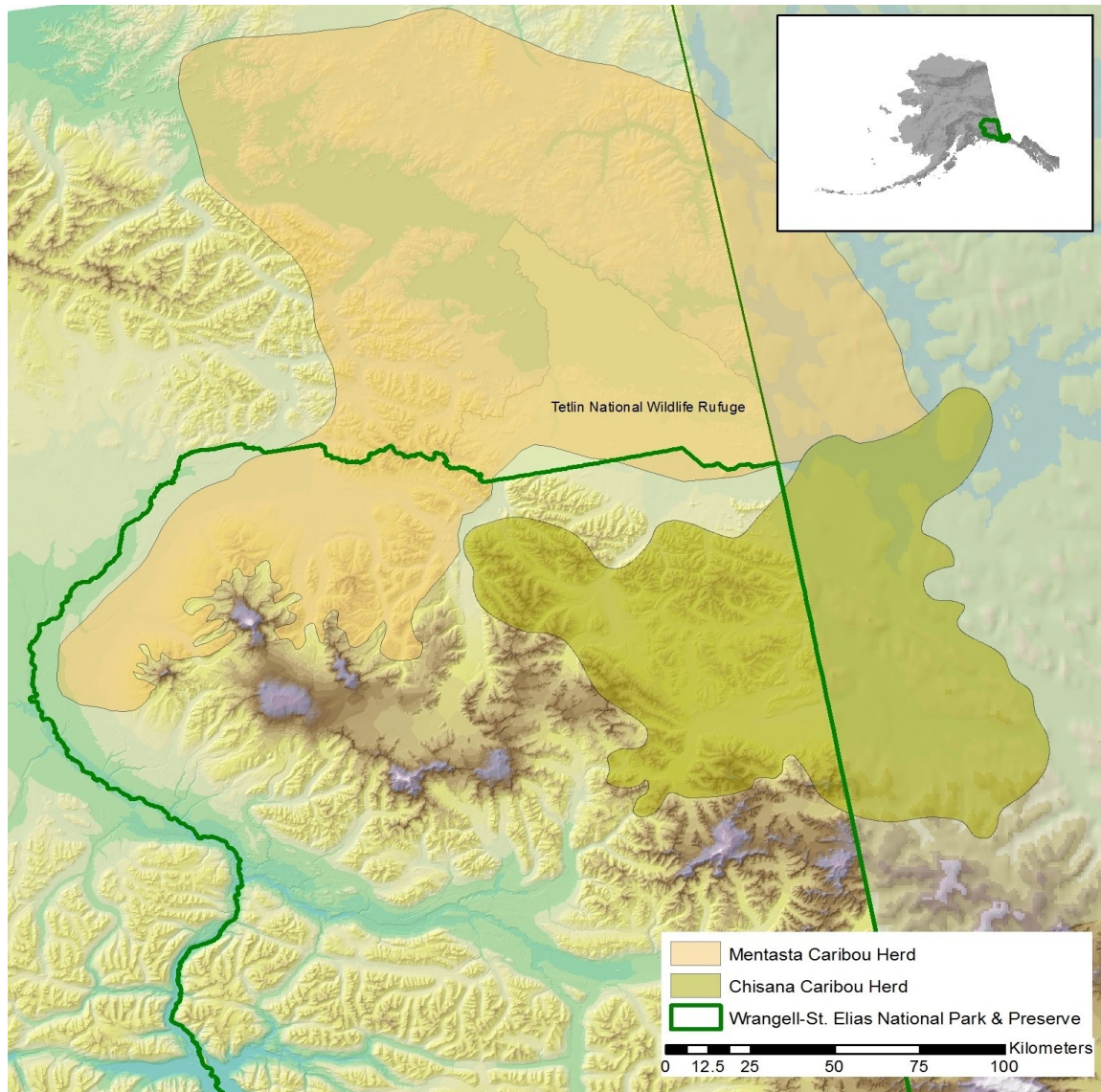


Figure 1. Mentasta and Chisana caribou herd annual ranges.

The Chisana caribou herd is a small international woodland caribou (*Rangifer tarandus caribou*) herd that ranges across the Alaska-Yukon border. The summer range is primarily within WRST, while the winter range has a larger proportion of the herd occurring in Yukon. Estimated at approximately 1800 animals in the late 1980's, the population rapidly declined in the 1990's, and in 2002 the herd was listed as a "Specially Protected" population under Yukon's Wildlife Act. The herd is also one of 36 herds comprising the Northern Mountain Caribou population designated a species of "Special Concern" in Canada under the federal Species at Risk Act (SARA). Human harvest from the herd was closed in 1994 and in 2003 a 4-year captive calf rearing program was initiated in Yukon that likely stabilized the herd at approximately 700 animals.

The Mentasta caribou herd, estimated at 3,200 caribou in 1987, also experienced dramatic population declines in the 1990's. The Mentasta herd was an important subsistence resource for local hunters

but the population decline led to closure of state regulated hunting in 1990 and federal subsistence harvest in 1992. In 1995, a cooperative management plan was developed by state and federal managers that established a framework for determining harvest quotas based on population size and calf recruitment (WRST 1995). The Mentasta herd has failed to reach these population goals and hunting within WRST remains closed. However, some Mentasta caribou winter in neighboring TNWR and are subject to incidental harvest during a subsistence winter season targeting the larger Nelchina caribou herd.

Estimates of population size, rate of change, sex and age composition, recruitment, and distribution are crucial to making informed management decisions for caribou populations. Information gained from monitoring caribou in WRST will be fully integrated with other vital signs monitored in CAKN. The vital sign of vegetation structure and composition will be determined by monitoring forage plants that caribou depend on. Weather data, predominately snow depths, can be used as an indicator of winter severity and any correlations with overall weather change can be compared to changes in the caribou population.

Measurable Objectives

The primary objectives for the monitoring described in this protocol are:

1. Determine population size and trend of the Mentasta and Chisana caribou herds.
2. Assess calf recruitment and adult sex ratios for these herds.
3. Estimate annual adult female survival.
4. Document seasonal distribution of caribou from these herds throughout the year.
5. Assess trends in mass and body size of adult females.

Sampling Design

Rationale for Sampling Design Selection

Caribou herd size estimates are generally derived from fixed-wing or helicopter aerial surveys, either by directly counting animals that are observed or by photographing post-calving aggregations (i.e. photocensus; Davis et al. 1979, Valkenburg et al. 1985). The photocensus approach is most effective for larger caribou herds that form dense aggregations during late-June and early-July. Generally, population estimates derived from either type of aerial survey are minimum counts, commonly inflated by a subjective estimate of the number of caribou that were missed during the survey.

For the Mentasta and Chisana herds, population estimates since the early 2000's have been primarily derived from aerial surveys using the sightability-model approach (Samuel et al. 1987, Bodie et al. 1995, Udevitz et al. 2006) to account for individuals missed during the surveys and to estimate the number of caribou outside the survey area based on detection and distribution of radio-collared animals during the surveys (Adams 2003; Adams and Roffler 2005, 2007). These approaches provide objective estimates of herd size with measures of precision, unlike the more common and subjective minimum counts. Radio-collared individuals also provide the basis for assessing survival and seasonal distribution, and greatly facilitate locating caribou for composition surveys.

For small caribou herds like the Mentasta and Chisana, calf recruitment is an important determinant of population trend (Adams et al. 1995a,b; Farnell and Gardner 2002; Jenkins and Barten 2005) and is commonly assessed annually by determining calf:cow ratios during fall composition surveys. These fall surveys also provide estimates of adult sex ratios, important for guiding harvest management decisions. Adult female survival is also an important vital rate contributing to herd trends and can be estimated by regular monitoring of radio-collared individuals. During captures to install radiocollars on caribou, immobilized individuals can be easily weighed, measured, and blood-sampled to provide information on trends in body size and disease exposure.

The basic caribou monitoring design for this protocol involves maintaining a sample of 40-50 radiocollared female caribou in each herd, locating those caribou periodically throughout the year to assess herd distribution and adult female survival, and conducting aerial surveys to estimate herd size and composition (adult sex ratio; calf:cow ratio). Radiocollared cows are used to determine sightability and adjust the herd size estimate. Caribou are captured via helicopter darting or netgunning; instrumented with radiocollars; weighed, measured, and blood-sampled, then released.

Identifying the Survey Area

The Mentasta herd range includes the north Wrangell Mountains from the Cheshnina River north and east to the Upper Copper River, and as far east as the Canadian border. Surveys to determine Mentasta caribou herd size estimates will be conducted on calving and summer range on the western and northern slopes of Mt. Drum and Mt. Sanford within WRST. Early fall composition counts and efforts to capture and radiocollar caribou will be conducted within the same survey area. Mentasta caribou may winter within WRST or outside as far east as the Canadian border and along the Taylor Highway (Figure 1). Seasonal radiotracking flights will occur throughout all seasonal ranges.

The Chisana herd ranges primarily within a 13,200 km² area throughout the Nutzotin and north Wrangell Mountains from the Nabesna River east into Yukon Territory, Canada (Figure 1). The herd's range is drained by the Donjek, Generc, White, Chisana, and Nabesna rivers. In May, the herd is dispersed in the Alaska uplands portion of their range for calving. During the post-calving period (June–July), they aggregate into larger groups, mostly in the Solo Flats area and Flat Creek drainage of Alaska. Caribou are usually found near summering–wintering areas during the fall breeding season. During winter much of the Chisana herd tends to move into lowland spruce forest in the Yukon portion of their range where about 70% of collared caribou are found there each winter. Unusual winter movements north to the Beaver Creek area have occurred when the much larger Nelchina herd was present in varying abundance between 1989 and 1995.

Herd size estimates, fall composition counts, radiocollaring, and radiotracking will occur within the primary range of both herds in WRST. These activities will also take place in the Yukon portion of the Chisana herd's range under direction of biologists from YDE. Late fall, winter, and early spring radiotracking of the Mentasta herd may occur outside of WRST boundaries.

Capture and Radiocollaring of Caribou

The caribou monitoring design requires maintaining a sample of 40-50 radiocollared female caribou in each herd. The number of annual mortalities will dictate the frequency of collaring efforts. In general, caribou are captured during September-March when air temperatures are cooler and to avoid late pregnancy. Captures in the Mentasta herd are limited to the first half of September because they are commonly mixed together with the much larger Nelchina herd during mid-September to early May. For the Chisana herd, captures can be conducted in early October along with the fall composition survey or herd size estimate, or during late March-early April. Captures of new caribou should be well-scattered throughout the range of the herd based on the distribution of existing radiocollared caribou or aerial surveys to assess the herd's distribution.

Estimation of Herd Size

Herd size will be estimated by applying the sightability-model approach (Samuel et al. 1987, Udevitz et al. 2006) to account for detection probabilities that vary with group size, given an adequate number of radio-collared caribou. In brief, the method requires that aerial surveys are conducted without the aid of radio-telemetry to locate groups and at sufficient intensity for sightability to be generally high. Marked groups (i.e. those containing ≥ 1 radio-collared caribou) missed during the regular survey are located and counted shortly after the survey is completed. Group sizes of marked groups and whether each group was observed or missed during the survey is used to determine the relationship between sightability and group size via logistic regression, to arrive at detection probabilities relative to group size. With that information, caribou missed in unmarked groups can be accounted for in a population estimate for the survey area. Further, a variance and confidence interval can be derived via jackknife (Manley 1991), bootstrap (Udevitz et al. 2006), or Monte Carlo methods. Software is now available, utilizing the R platform (R Development Core Team 2006) to apply the logistic regression sightability model to aerial survey data to derive population estimates, and associated standard errors and confidence intervals (Debevec and Udevitz 2008, Fieberg 2012).

Aerial surveys to estimate herd size should be conducted every one or two years for the Mentasta herd and every three years for the Chisana herd.

Mentasta Herd

Censuses are conducted in late June, at the traditional time for conducting post-calving counts for caribou. At this time of year, caribou tend to be grouped well and in open, high-elevation habitats, particularly on warm days with little wind. A day or 2 prior to the census, all caribou are radio-located to provide an assessment of their distribution. During the census, 3 tandem fixed-wing aircraft, with a biologist on board, are used to search the herd's summer range above 4,000 feet on the flanks of Mt. Sanford and Mt. Drum from the Cheshnina River on the south to the Upper Copper River/Copper Glacier on the north and east. Each aircraft crew searches for caribou, without the aid of telemetry, in a pre-assigned sector, expending 4-5 hours of survey time. Caribou groups that are observed are counted and classified as cows, calves, and obvious bulls (small bulls that are indistinguishable from cows fall in the "cow" class). Observers use radiotelemetry to determine whether a group is marked (includes ≥ 1 radioed caribou) and the identity of all radioed caribou in each marked group. Once the survey is completed, the aircraft crews compare their results to determine which radiocollared caribou were missed during the survey. Immediately following the survey, caribou that were unaccounted for during the survey are radio-located and their groups counted and classified. The group's location determines whether they were in the survey area and missed or outside the survey area and not available to be observed. Groups located outside the survey area are accounted for in the population estimate. The final fall herd size estimate is derived using the estimated number of cows during the June census and the number of calves and bulls per 100 cows observed during the fall composition count.

Chisana Herd

Censuses employing the sightability-model approach are conducted in October. During this time of the year, caribou are in rutting aggregations and predominantly inhabiting the open, upland habitats. Sightability is generally high, but can be adversely affected by incomplete snow cover. A further advantage is that fall population size can be directly estimated rather than extrapolated from early summer counts. During other seasons, Chisana caribou are either in small, scattered groups (summer) or commonly found in forested areas in loose aggregations (winter), both resulting in poor sightability.

To conduct censuses of the Chisana herd, the distribution of all radiocollared females in the herd is determined to delineate a survey area that encompasses the region inhabited by nearly all the radioed caribou with a reasonable buffer and bounded by obvious geographic features and treeline. During each census, a helicopter, with 1-2 observers in addition to the pilot, searches habitats within the survey area without the aid of radiotelemetry. The number of cows, calves, and small, medium, and large bulls is determined and recorded for each caribou group encountered. The occurrence of marked individuals within each group is determined via radiotelemetry immediately prior to conducting the classification count of the group. Simultaneously, a Supercub locates radiocollared caribou to determine their locations and group sizes. Following the survey, the crews determine which radiocollared animals were missed by the helicopter, and those groups are then located by the

helicopter and classified. With information on marked groups observed and missed by the helicopter crew, the relationship between sightability and group size (total caribou in each group) is determined via logistic regression. Corrections for unmarked groups missed during the survey will be used to arrive at an estimate of total caribou in the survey area.

In most years for both herds, a few radiocollared females (0-6%) may be widely scattered outside the survey area. The survey area cannot be expanded to include these individuals because the resulting survey area would be too large to adequately survey with the time and money available. To account for caribou outside the survey area, we assume that the proportion of radiocollared females in the survey area is similar to that of the population and divide the survey area estimate by the proportion of radiocollared females that were within the survey area.

Fall Sex and Age Composition

Fall composition surveys provide data to determine calf recruitment to fall (calf:cow ratio) and adult sex ratios (bull:cow ratio) used in estimating herd size and evaluating bull survival. Helicopter surveys to assess calf recruitment and adult sex ratios should be conducted annually. Required resources include a helicopter and 1-2 biologists to conduct the composition count and a fixed-wing aircraft and pilot to help locate caribou groups. If funding is available, radiocollared caribou can be located via fixed-wing aircraft a few days prior to the composition count to increase efficiency during the count. Starting at one end of the survey area, the fixed wing aircraft should fly ahead of the helicopter with the telemetry receiver on, scanning for radio-collared caribou. As caribou groups are located using telemetry, the fixed wing aircraft directs the helicopter to each group for classification. Large groups should be herded into smaller groups so that animals are easier to sex and age, and are not missed or double counted. All caribou encountered are classified as cows, bulls, or calves based on their appearance and external sex characteristics. Bulls are further classified as small (antlers and body size indistinguishable from cows), medium (antlers and body size larger than adult cows, but with smaller beam diameter, shorter length, and fewer points than fully-mature bulls), or large (large-bodied individuals with fully developed antlers (3+ feet) with thick beams, long antler length, and many points).

Radiotelemetry: Survival and Seasonal Distribution

All radiocollared caribou are relocated by aerial radio-tracking from fixed-wing aircraft at intervals throughout the year to evaluate survival patterns of adult females, provide an assessment of the herd's season distribution and to aid in conducting population surveys. Ideally, caribou should be radiotracked approximately every 2 months, however budgets probably cannot accommodate this intensity. The minimum annual radio tracking schedule is 1) mid June to determine postcalving distribution as part of the postcalving census (Mentasta herd), 2) late September to mid October to assess distribution for fall composition surveys, survival over the summer, and rutting distribution, 3) late January to document survival and midwinter distribution, and 4) mid March to determine late winter distribution and survival. As funding allows, additional radiotracking flights should be conducted in 1) mid May to determine productivity of radiocollared females by observation of calves at heel, retained hard antlers, or distended udders, 2) late July to determine survival and summer

distribution, and 3) late November to determine survival and early winter distribution. Additional radio tracking will be required to support population estimates and composition surveys.

Information collected for each caribou as it is located includes the date and time located, the mode of the signal (active or mortality), estimated group size, sex and age composition of animals if possible, and coordinates of the location or waypoint number from the onboard GPS. For mortalities it is useful to take a close look from the air to determine if a carcass or evidence of a kill can be seen and to determine whether the location of the mortality can be easily accessed by helicopter. In order to accurately determine the distribution and survival of caribou within a herd, it is very important to locate all the caribou during each radio-tracking effort if at all possible. On occasion, a few caribou will be difficult to locate and invariably some will be missed. Commonly, these animals either determine the extremes of the herd's distribution or are dead in areas where the radio-signal range is limited due to terrain. It is imperative that the number of missed animals is kept to a minimum and that they are noted and additional efforts are made to locate them in the subsequent radiotracking bout.

Data Quality Objectives

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate and transferable information.

Representativeness and Data Comparability

A sightability model approach will be used to estimate the herd size. A caribou group is the basic unit for analysis and the probability of observing a marked (containing at least one radiocollared animal) group is modeled as a function of covariates. The statistical methods are described for use with the statistical freeware R (version 3.4.2) and the R Sightability Model Package (version 1.3, Fieberg 2014). R is a combination of a statistics package and a programming language and can be downloaded for free from <http://www.r-project.org/>. Several books have been published that demonstrate how to download, install and use R (Zuur et.al. 2009, Crawley 2012).

The Sightability Model package implements a logistic regression sightability abundance estimator (Steinhorst and Samuel 1989) via the Sight.Est function. The package assumes that a set of sightability trials are performed using radiocollared animals and the resulting logistic regression model is applied to future operational surveys (herd size estimate) in which the same covariates, used to model detection probabilities from the trail data, are collected. Because radiocollared animals are maintained in the herd(s), the sightability trial data will be collected during the operational survey. The covariates are group size and survey crew. A model selection approach will be used, in which multiple models with different combinations of covariates are compared using AICc (small sample correction) values (Burnham and Anderson 2010). The four candidate sightability models are 1) the null model (intercept-only with no covariates); 2) Group size; 3) Survey crew; and 4) Group size * Survey crew. The model with the lowest AICc value will be chosen.

Completeness

If surveys are unable to be completed in a scheduled year due to funding or logistical issues, they will be attempted in the next year if possible to provide density and abundance information. Although completing surveys on all plots is desirable, it is not required. Due to the flexibility of the analytical framework, valid estimates can still be produced if some plots are not surveyed. That said, at some point, incomplete coverage becomes a problem. Consultation with a biometrician is considered necessary if >25% of plots remain uncompleted at the end of the survey period. The biometrician must use expert judgement to determine proper inference when surveys are incomplete.

Measurement Quality Objectives and Performance Standards

See Table 1 for quality objectives.

Table 1. Quality Objective table for caribou monitoring protocol.

Observation Type	Measure / Quality Indicator	Quality Objective
Field Observations	Location accuracy	+/- 1 m (horizontal), no standards for vertical accuracy
	Group size	Pilot and observer must agree
	Sex	Pilot and observer must agree
	Female body wt	+/- 1 kg
Derived Observations	Herd size	Sightability model (Steinhorst and Samuel 1989 (SOP #7))
	Female survival	Sightability model (Steinhorst and Samuel 1989 (SOP#7))

Literature Cited

- Adams, L.G. 2003. Chisana caribou census – 19-20 October 2003. US Geological Survey-Alaska Science Center, Anchorage, AK.
- Adams, L.G., and G.H. Roffler. 2005. Chisana caribou census – 15-16 October 2005. US Geological Survey-Alaska Science Center, Anchorage, AK.
- Adams, L.G., and G.H. Roffler. 2007. Chisana caribou census – 13-14 October 2007. US Geological Survey-Alaska Science Center, Anchorage, AK.
- Adams, L.G., B.W. Dale, and L.D. Mech. 1995a. Wolf predation on caribou calves in Denali National Park, Alaska. Pages 245-260 in L.N. Carbyn, S.H. Fritts, and D.R. Seip, eds. Ecology and conservation of wolves in a changing world: proceedings of the second North American symposium on wolves. Canadian Circumpolar Institute Occasional Paper 35, University of Alberta, Edmonton. 642pp.
- Adams, L.G., F.S. Singer, and B.W. Dale. 1995b. Caribou calf mortality in Denali National Park, Alaska. *Journal of Wildlife Management* 59:584-594.
- Barten, N.L., R.T. Bowyer, and K.J. Jenkins. 2001. Habitat use by female caribou: tradeoffs associated with parturition. *Journal of Wildlife Management* 65:77-92.
- Bodie, W.L., E.O. Garton, E.R. Taylor, and M. McCoy. 1995. A sightability model for bighorn caribou in canyon habitats. *Journal of Wildlife Management* 59:832-840.
- Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 4th edition. Springer, New York, New York.
- Chisana Caribou Herd Working Group. 2012. Management plan for the Chisana caribou herd: 2010-2015. Government of Yukon, Department of Environment, Whitehorse, YT 48pp.
- Davis, J.L., P. Valkenburg, and S.J. Harbo. 1979. Refinement of the aerial photo-direct count-extrapolation caribou census technique. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Final Report. Juneau, AK.
- Debevec, E., and M.S. Udevitz. 2008. SIGHTMOD. US Geological Survey, Anchorage, Alaska. (http://alaska.usgs.gov/science/biology/biometrics/aerial_survey.html)
- Ecological Metadata Language (EML) Specification. Ecological Metadata Language (EML) Specification. Knowledge Network for Biocomplexity, n.d. Web. 19 May 2016. <<https://knb.ecoinformatics.org/#external//emlparser/docs/eml-2.1.1/index.html>>.
- Farnell, R., and C.L. Gardner. 2002. Chisana Caribou Herd – 2002. Yukon Department of the Environment, Whitehorse, Yukon, Canada.

- Federal Geographic Data Committee. FGDC-STD-001-1998. Content standard for digital geospatial metadata (revised June 1998). Federal Geographic Data Committee. Washington, D.C.
- Fieberg, J. 2012. SightabilityModel:Wildlife Sightability Modeling. R. package version 1.0. (<http://CRAN.R-project.org/package=SightabilityModel>).
- Harper, P., editor. 2007. Caribou management report of survey-inventory activities, 1 July 2004 30 June 2006. Alaska Department of Fish and Game, Division of Wildlife Conservation. Juneau, Alaska.
- Jenkins, K.J. 1995. Population dynamics of the Mentasta caribou herd, Wrangell-St. Elias National Park & Preserve: Progress report and preliminary assessment. Research and Resource Management Report No. 95-1, 44pp. Wrangell-St. Elias National Park & Preserve.
- Jenkins, K.J., and N.L. Barten. 2005. Demography and decline of the Mentasta caribou herd in Alaska. Canadian Journal of Zoology 83:1174-1188.
- Lieb, J.W., W.B. Cella, and R.W. Tobey. 1994. Population dynamics of the Mentasta Caribou Herd. Research Final Report. ADF&G, Division of Wildlife Conservation, Anchorage, AK.
- Manley, B.F.J. 1991. Randomization and Monte Carlo methods in biology. Chapman and Hall, NY.
- Murie, A. 1944. The wolves of Mount McKinley. Fauna in the National Parks of the United States, Fauna Series No. 5. U.S. Government Printing Office, Washington, DC.
- Olson, S.T. 1958. Caribou management studies-movements, distribution and numbers. US Fish and Wildlife Service. Federal Aid in Wildlife Restoration Completion Report. Juneau, AK.
- R Development Core Team. 2006. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. (<http://www.R-project.org>)
- Roffler, G.H., L.G. Adams, S.L. Talbot, G.K. Sage, and B.W. Dale. 2012. Range overlap and individual movements during breeding season influence genetic relationships of caribou herd in southe-central Alaska. Journal of Mammalogy 93:1318-1330.
- Samuel, M.D., E.O. Garton, M.W. Schlegel, and R.G. Carson. 1987. Visibility bias during aerial surveys of elk in north-central Idaho. Journal of Wildlife Management 51:622-630.
- Siniff, D.B., and R.O. Skoog. 1964. Aerial censusing of caribou using stratified random sampling. Journal of Wildlife Management 28:391-401.
- Skoog, R.O. 1968. Ecology of the caribou in Alaska. Ph.D. dissertation. University of California, Berkeley, CA.
- Steinhorst, K.R., and M.D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.

Udevitz, M. S., B. S. Shults, L. G. Adams, and C. Kleckner. 2006. Evaluation of aerial survey methods for Dall's sheep. *Wildlife Society Bulletin* 34(3):732-740.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 190/148517, September 2018

National Park Service
U.S. Department of the Interior



[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525