



Monitoring Protocol for the Denali Caribou Herd, Denali National Park and Preserve, Alaska

Central Alaska Network Inventory and Monitoring Program

Natural Resource Report NPS/CAKN/NRR—2018/1754



ON THE COVER

Caribou meandering along gravel bar or a stream in Denali National Park and Preserve (NPS)

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Executive Summary

Caribou research methods developed over the last 25 years at DENA serve as the basis for this monitoring protocol. Our approach involves monitoring a large sample (> 50 individuals) of radiocollared adult females that is representative of the herd's age structure to assess their productivity and survival, and to facilitate conducting annual censuses and age/sex composition surveys. Caribou are captured via helicopter darting; instrumented with radiocollars; weighed, measured, and blood-sampled; and then released. We have standardized methods for estimating herd size each year based on an estimate of cow numbers in early June, obtained via helicopter surveys and corrected for sighting bias relative to group size, and extrapolation of that estimate to a fall herd size using summer survival rates of radiocollared females and fall age/sex composition ratios. All radioed females ≥ 2 years old are located by helicopter in mid-May to determine their reproductive status via observation of a calf at heel, retained hard antlers, or a distended udder (Whitten 1995), in order to assess annual herd productivity and age-specific productivity. Standardized helicopter surveys in late September provide information on calf recruitment to fall and adult sex ratios. Caribou are radiolocated approximately 8 times a year to determine survivorship and seasonal distribution patterns, and to facilitate other surveys.

Introduction

Rationale for monitoring caribou in Central Alaska Network Parklands

The Central Alaska Network (CAKN) is composed of 3 units of the U. S. National Park system: Denali National Park and Preserve (DENA); Yukon-Charley Rivers National Preserve (YUCH); and Wrangell-St. Elias National Park and Preserve (WRST). Given the overall goal of tracking major physical drivers of ecosystem changes and the resulting responses of the flora and fauna, CAKN has identified *Fauna Distribution and Abundance* as 1 of 3 primary vital signs for monitoring. In general, CAKN is interested in tracking the changes in the distribution and abundance of animals across the landscape. The *Fauna Distribution and Abundance* vital sign includes monitoring efforts for species of particular interest within each park, as well as a suite of species spanning the significant elevation gradient found in CAKN parklands.

Caribou (*Rangifer tarandus*) occur in all 3 management units within the network, and are 1 of the 6 large mammal species in interior Alaska that are of great importance to these ecosystems and to people for both consumptive and non-consumptive uses. The objectives defined for monitoring caribou in CAKN are to determine changes in abundance, distribution, and demographics, with a focus on estimating calf survival and recruitment (MacCluskie and Oakley 2005). Because of their wide-ranging movements, caribou herd ranges are seldom encompassed by discrete land management units and the CAKN parklands are no exception. The following 7 caribou herds utilize CAKN units:

- Chisana Herd: This international herd primarily inhabits the White River and Chisana drainages of WRST and adjacent lands in the Yukon Territory of Canada;
- Delta Herd: The Delta Herd ranges through the central Alaska Range east of DENA, but a small proportion of the herd winters along the Parks Highway from about the park entrance to Cantwell and are known to utilize areas in the eastern margins of DENA to about the Savage River;
- Denali Herd: The current herd range is largely encompassed by DENA, but Denali caribou regularly use adjacent lands, particularly in the Stampede Road townships to the northeast and the mountains of the Ohio Creek-West Fork of Chulitna River region to the south;
- Fortymile Herd: A large, migratory population of the eastern interior, the Fortymile Herd utilizes seasonal ranges in YUCH;
- Mentasta Herd: Herd ranges include northwestern WRST from the Cheshnina River north and east to the Upper Copper River, but Mentasta caribou have commonly wintered outside parklands east to the Canadian border and along the Taylor Highway;
- Nelchina Herd: The Nelchina Herd is a large, migratory herd and its annual range extends from summer ranges in the upper Chulitna drainages along the southeastern margins of DENA to migratory routes and winter ranges in northern WRST and east to the Canadian border; and
- Tonzona Herd: Much of the Tonzona Herd range occurs west of DENA, but this herd regularly utilizes ranges from the western boundary of DENA to about the Herron River.

Monitoring efforts supported by NPS have focused on 3 of these herds (Denali, Mentasta, and Chisana) because: (1) much of their year-round ranges occur within NPS-managed units, (2) all 3 herds have experienced significant declines since the late 1980s; (3) harvests on all 3 herds has been largely curtailed due to conservation concerns, and (4) previous research and monitoring of these caribou, particularly at DENA, provide understanding of the dynamics of such small, montane caribou populations against which future changes can be compared (Adams 1996, 2003, 2005; Adams and Dale 1998a,b; Adams et al. 1995a,b, 2005; Barten et al. 2001; Farnell and Gardner 2002; Jenkins and Barten 2005; Mech et al. 1998, Roffler et al. 2012).

Intensive research and monitoring of the Denali Caribou Herd, supported primarily by NPS, has been ongoing continuously since 1984 and is currently conducted through collaboration with the U. S. Geological Survey-Alaska Science Center (USGS). For the Mentasta Herd, the Alaska Department of Fish and Game (ADF&G) conducted the monitoring of Mentasta caribou through the 1980s with collaboration from WRST staff following establishment of that conservation unit. Beginning in late 1989, NPS funded a major research project to evaluate poor calf survival in that herd (Jenkins and Barten 2005) and WRST essentially assumed monitoring responsibilities for the Mentasta Herd at that time. As the calf mortality research was completed in 1997, USGS initiated new studies of survival and movements of Mentasta bull caribou and genetic relationships of caribou in the region (Roffler et al. 2012), and continued to collaborate with herd monitoring efforts through early 2004. Since then, WRST staff has worked with ADF&G personnel to monitor the Mentasta Caribou Herd. Little monitoring effort was expended on the Chisana Caribou Herd before the mid-1980s. During 1987-2003, herd monitoring was conducted collaboratively with ADF&G and the Yukon Department of Environment (YDE) sharing lead responsibilities (Farnell and Gardner 2002) and NPS contributing money and personnel to the effort. From October 2003 – May 2008, NPS supported a major research effort led by USGS to assess the herd's population dynamics, in association with a captive-rearing effort organized by YDE. Since 2008, monitoring of the Chisana Herd has again been conducted primarily by ADF&G and YDE with assistance by WRST staff.

The remaining caribou herds that utilize CAKN units (Delta, Fortymile, Nelchina, and Tonzona herds) have annual ranges that are predominantly outside of NPS-managed lands. Monitoring responsibilities for these herds are held by ADF&G; NPS has generally played little or no role in the assessment of their status and trends.

Caribou research and monitoring at Denali National Park and Preserve

Denali National Park has been the site of continuous, intensive research on the population dynamics of the Denali Caribou Herd since 1984 with systematic efforts to monitor this population stretching back over 70 years. The 1980 expansion of DENA to include 18,800 km² managed as National Park provides an unparalleled opportunity to investigate caribou population dynamics where ungulate populations (caribou, moose, and Dall's sheep) and the large carnivores that prey on them (wolves, grizzly bears, and American black bears) are largely unaffected by human harvest. Management of large carnivores and ungulates in Alaska, as well as throughout North America, engenders contentious debate about the influences of predation on the dynamics of ungulate populations. Research on Denali's large carnivore/ungulate system serves as an important benchmark for

comparison to manipulated large mammal systems. Further, the caribou research and monitoring effort provides objective information on the status and long-term trends of the Denali Caribou Herd and understanding of the causes of observed population changes.

Beginning with Adolph Murie's systematic attempt to enumerate the herd in 1941, as part of the landmark wolf studies he conducted (Murie 1944), the Denali Caribou Herd (referred to as the McKinley Herd prior to 1980) has been the subject of arguably the longest monitoring effort on any caribou population in North America. Murie continued to monitor herd size in most years through the mid-1960s until he left the park (Singer 1986). Following Murie, caribou numbers were estimated through the early 1970s by NPS staff, including Richard Prasil and Steve Buskirk, as well as Ph. D. student Gordon Haber (Haber 1977). With documented declines in the Denali Herd, as well as several other herds in Alaska, Will Troyer, an NPS wildlife biologist, initiated the first radiotelemetry-based research on Denali caribou in 1976 to estimate population size, age/sex composition, and calf recruitment, and to document seasonal movements and range use patterns (Troyer 1977, 1978, 1979, 1981); Troyer's efforts continued through 1980. During 1983-1985, Francis Singer focused his attention on the Denali Herd to monitor the population, reevaluate the available historic information on the herd (Singer 1986, 1987), and investigate calf mortality patterns (Singer 1986, Singer and Dalle-Molle 1985). With Singer's departure from Alaska in 1985, Layne Adams took over the caribou research and monitoring at Denali and continues to oversee this work to date (Adams 1996, 2003, 2005; Adams and Dale 1998a,b; Adams et al. 1995a,b, 2005).

The Denali Caribou Herd likely exceeded 20,000 caribou in the early 1900s (Murie 1935, Skoog 1968, Singer 1986). The first concerted effort to estimate the size of the herd was conducted in 1941 when Adolph Murie counted 21,585 caribou, including 6,900 calves, as they migrated through the park road corridor during 28 June to 2 July, and estimated that the herd numbered between 20,000 and 30,000 (Murie 1944). Given that most bulls were likely not in these post-calving groups, it is likely the herd numbered over 26,000 at the time (Singer 1986). During 1943-1955, minimum counts of the caribou in the Denali Herd ranged from 5,000 to 10,000 based on counts by Murie, other NPS staff, and local residents (Singer 1986), however the actual trajectory of the decline in caribou numbers during 1941 to 1955 cannot be determined (Adams et al. 1989). During 1955-1962, Murie estimated the herd at about 9,000 animals based on road counts of 6,000-8,400 (Singer 1986). Murie's road counts declined from 6,500 in 1963 to 3,850 by 1967, with mention of few calves in 1963 or 1964 and a late spring in 1966 (Singer 1986). However, Haber (1977) continued to estimate the herd at 7,500-8,500 animals in summer 1966-67. Following Murie's departure from the park, Haber (1977) reported that the herd declined from 8,000 to 1,500 caribou during 1968-72. Herd estimates were in the range of 1,000 caribou through the mid-1970s. Calf recruitment was very low during this period. In June 1972, following 2 severe winters in central Alaska (Gasaway et al. 1983, Van Ballenberghe 1985), Trent (1974) observed 630 Denali Herd adults and yearlings accompanied by only 13 calves on the south side of the Alaska Range. Harvest was not considered a factor in the herd's decline with an annual reported harvest of < 2% of the herd during the late 1960s-early 1970s (Adams et al. 1989).

In February 1976, NPS convened a review of management and research needs for the Denali Caribou Herd with ADF&G and University of Alaska-Fairbanks (UAF) personnel. As a result, Will Troyer, an NPS biologist, conducted a radiotelemetry study during 1976-1980 to determine population size, composition, and movements of caribou in Denali (Troyer 1977, 1978, 1979, 1981). Also, Rod Boertje, a UAF graduate student advised by Dave Klein of the Alaska Cooperative Fish and Wildlife Research Unit, evaluated the energetic and nutritional status of caribou in Denali during 1978-1980 (Boertje 1981; 1984; 1985a, b; 1990). Troyer (1977, 1978) reported mid-June ratios of 12-18 calves: 100 cows and yearlings in post-calving aggregations in 1976-1977 and estimated the population at 900-1,200 animals. The hunting season was closed on the Denali Herd effective 1 July 1977 (Adams et al. 1989). Beginning in 1978, June calf: cow and yearling ratios indicated improved calf production/survival. Boertje (1981) determined that nutritional status of caribou in Denali appeared to be high and suggested that early predation on calves, independent of nutritional condition of the herd, was the key factor maintaining the population at low levels.

Several caribou herds in Alaska experienced significant declines during the late 1960s-early 1970s, and although some declined to the same degree, none reached such low absolute numbers and all had recovered substantially by the early 1980s. Severe winters, heavy predation losses, and overharvest have been implicated as contributing to these declines, and reduced harvests and/or wolf control were responsible to some degree for the observed recoveries (Bergerud 1978; Davis et al. 1980, 1983; Doerr 1980; Gasaway et al. 1983; Lieb et al. 1988; Valkenburg and Davis 1988; Van Ballenberghe 1985).

By 1978, Troyer (1979) estimated that the Denali Herd had increased to number 1,200-1,500 caribou. Following the end of Troyer's studies in 1980, NPS staff continued to monitor post-calving aggregations to determine caribou distribution and calf:cow and yearling ratios (Duff and Singer 1982; Singer 1986, 1987; Van Horne 1983; Van Horne and Dalle-Molle 1981). Work conducted during this time was focused on assessing the Dunkle Mine area to understand its importance to Denali caribou as calving and post-calving range relative to a potential land trade with the State. Although 1,297 caribou were counted in April 1982, no attempts were made to estimate the herd size again until 1984.

In November 1983, because of the perception that the Denali Herd was not recovering from the decline of the 1970s, NPS assembled a panel of caribou biologists from Alaska and Canada to evaluate population dynamics of the herd, identify research needs, and recommend a long-term monitoring program (Singer 1983). Although there was much discussion over the possible causes of the herd's previous declines, the committee concluded that available historic data were not sufficient to point to a specific cause of the declines in the 1940s. In the 1970s however, several observers reported poor recruitment (Trent 1974, Troyer 1981, Singer 1986) sufficient to explain the population decline during the late 1960s and early 1970s. The committee recommended a reevaluation of all historic data on the herd, research to focus on the causes and extent of calf mortality, and a long-term effort to monitor population size, sex/age composition, and calf production/survival. Further it was recommended that efforts to monitor the park's wolf population be initiated and that wolf/caribou relationships be evaluated. Following the panel meeting, Singer initiated a thorough review of NPS

records, Adolph Murie's diaries, and field notes of other biologists involved in monitoring Denali caribou (Singer 1986). In May 1984, he began calf mortality studies that he directed through summer 1985 (Singer 1987), when he left Alaska for Yellowstone National Park. Singer completed a thorough count of the herd in fall 1984 arriving at an estimated 2,200 caribou, confirming that the Denali Herd was in fact recovering from the low levels reached in the mid-1970s.

In 1986, Layne Adams took over what was planned to be the third and final year of the calf mortality studies initiated by Singer. Adams completed the original calf mortality project (Adams et al. 1995a) and was successful at expanding the caribou research into a broader investigation of calf production (Adams 1996, Adams and Dale 1998a,b), calf growth and development (Adams 2003, 2005), as well as broader evaluation of calf survival (Adams et al. 1995a,b). Adams also established a monitoring program to annually determine herd size and adult sex ratios, assess calf production and recruitment, and estimate adult female survival.

Since initiation of intensive investigations in 1984, much has been learned about the interactions between predation and weather that drive the dynamics of the Denali Caribou Herd. In the mid-1980s, the Denali Herd was increasing at about 7%/year during a period of relatively mild winters. Survival of caribou cows was high (96%/year) and about 50% of the calves produced survived to fall and were recruited into the population. With the onset of a period of severe winters in 1988, caribou numbers leveled off at 3,200 in fall 1989, then declined by a third over 2 years to approximately 2,300 caribou by fall 1992. During the period of decline, adult cow survival dropped substantially, to an average of 85%/year, and calf recruitment dropped to just 5%. Of note, most adult females > 10 years-old (83%) died during the severe 1992-93 winter alone. During 1993-2003, with a return to moderate winter snowfall, the caribou herd continued to decline, but at a much slower rate of about 3% annually. Adult cow survival was comparable to the period of herd growth in the mid-1980s, but calf recruitment to fall continued to be very low (mean = 15%). With low calf recruitment during 1990-2003, the female age structure became heavily weighted towards older females, a harbinger of impending population declines regardless of winter snowfall patterns. In May 2002, an estimated 24% of the females in the herd were ≥ 13 years old. As a result of these old females dying, adult female survival was low in the 2002-03 and 2003-04 winters (average = 83%) even though winter snowfalls were substantially below average. These survival rates are comparable to rates measured during the extreme winters of 1990-93.

During the last 9 years (2004-12), calf recruitment to fall has improved to an average of 22 calves:100 cows and recruitment of female calves has essentially balanced adult female mortality. The age structure is still weighted disproportionately to older females (16% females ≥ 13 years old in May 2011), thus the herd is at risk for a sizable decline should the region experience one or more severe winters.

Historical development of caribou monitoring

Prior to the 1960s, attempts to monitor caribou populations in Alaska were somewhat limited and based primarily on a plethora of anecdotal observations (Skoog 1968). A notable exception was the effort by Adolph Murie in 1941 to enumerate what is now the Denali Caribou Herd (Murie 1944). By the 1960s, winter aerial surveys to document caribou distribution and develop crude estimates of

their numbers became more common (Olson 1958, Skoog 1968). In 1962, ADF&G conducted the first statistically-based attempt to enumerate a caribou population in the state, applying a stratified random sampling approach to winter aerial surveys of the Nelchina Herd (Siniff and Skoog 1964).

During the late 1960s and early 1970s, the major caribou herds across Alaska declined markedly resulting in heightened interest in assessing caribou herd sizes and trends, and acquiring basic understanding of caribou population dynamics (Valkenburg 2001). At about that time, radiotelemetry was becoming a cost-effective and reliable technology, providing a great boon for regularly locating caribou, identifying distinct herds and their ranges based on movements and distribution of radiocollared individuals, and acquiring the necessary information to estimate population size, composition, and trends, as well as the vital rates that drive population dynamics. Prior to the use of radiotelemetry, Skoog (1968) identified 11 herds in Alaska based on aerial surveys and general observations. Such information provided insights on the larger, more obvious herds but little understanding of the smaller, sedentary herds in the state. Over the last 40 years, with the broad application of radiotelemetry (Valkenburg 2001), the number of caribou herds recognized in the state has increased to 31 (Valkenburg et al. 2002; Harper 2007), primarily through better information on the smaller, more sedentary herds scattered throughout the mountain ranges of the state.

Currently, caribou herd sizes in Alaska are generally derived from fixed-wing or helicopter aerial surveys, either by directly tallying animals that are observed or by photographing post-calving aggregations (i.e., photo census; Davis et al. 1979, Rivest 1998, Valkenburg et al. 1985). The photo census approach is most effective for the larger caribou herds that form a few dense aggregations for each herd during late-June and early-July. Generally, population estimates derived from these aerial survey methods are minimum counts, commonly inflated by a subjective estimate of the number of caribou that were missed during the survey.

Estimating herd sizes in smaller, mountain populations presents several challenges. Many small herds tend to aggregate following calving and these large groups can be predictably located in traditional areas of insect relief habitat where caribou are easily observable. However, it is not unusual to find a sizable proportion of adult females scattered well beyond the aggregations throughout much of a herd's summer range, while bulls tend to not aggregate with the females. Further, calves often experience continued mortality over the summer so their numbers in early summer are not indicative of actual recruitment into the population. Counts during the fall breeding season minimize these issues, but unpredictable and incomplete snow conditions can influence caribou distribution and limit sightability of caribou groups. Also, unstable weather and migratory movements of caribou in the fall can complicate completing adequate counts. Another potential problem is associated with the tendency for observers (especially the less experienced) to undercount large aggregations (-30) of ungulates from the air. Motion-stabilizing cameras have been used very successfully to photograph and obtain reliable counts of large aggregations in other protocols. It's not entirely clear whether that source of bias needs addressing because it's not clear how prevalent are large caribou groups during the peak of calving.

Given the peripatetic lifestyle of caribou, a monitoring plan utilizing radiotelemetry is the only reasonable option for estimating population abundance and other population level metrics.

Radiocollared individuals provide the basis for assessing calf production, female age structure, adult female survival, and seasonal distribution, as well as greatly facilitate locating caribou for composition surveys and census efforts.

Sampling Design

Measurable objectives

The CAKN has identified primary objectives for caribou monitoring as determining changes in abundance, distribution, and demographics, with focus on estimating calf survival and recruitment (MacCluskie and Oakley 2005). Specifically the objectives:

1. Estimate the population size in late September;
2. Determine age-specific calf production and herd productivity;
3. Assess calf recruitment (calf:cow ratios) and adult sex ratios in late September;
4. Determine adult female survival patterns and age structure;
5. Determine trends over time for the above 4 population metrics and;
6. Document seasonal distribution of caribou throughout the year.

Protocol overview

Caribou research methods developed over the last 25 years at DENA serve as the basis for this monitoring protocol. Our approach involves monitoring a large sample (> 50 individuals) of radiocollared adult females that is representative of the herd's age structure to assess their productivity and survival, and to facilitate conducting annual censuses and age/sex composition surveys. Caribou are captured via helicopter darting; instrumented with radiocollars; weighed, measured, and blood-sampled; and then released. We have standardized methods for estimating herd size each year based on an estimate of cow numbers in early June, obtained via helicopter surveys and corrected for sighting bias relative to group size, and extrapolation of that estimate to a fall herd size using summer survival rates of radiocollared females and fall age/sex composition ratios. All radioed females ≥ 2 years old are located by helicopter in mid-May to determine their reproductive status via observation of a calf at heel, retained hard antlers, or a distended udder (Whitten 1995), in order to assess annual herd productivity and age-specific productivity. Standardized helicopter surveys in late September provide information on calf recruitment to fall and adult sex ratios. Caribou are radiolocated approximately 8 times a year to determine survivorship and seasonal distribution patterns, and to facilitate other surveys.

Rationale for selecting this sampling design

Given that CAKN has focused on monitoring abundance and distribution of selected wildlife species, including caribou, this protocol is designed to meet those goals by estimating herd size annually and determining seasonal distribution for the Denali Herd. As discussed in the Introduction, the Denali herd is a small Calf production, particularly in young age-classes, is closely tied to influences of severe weather and forage availability on nutritional status of caribou (Adams et al. 1998a) and is necessary information for annually assessing calf survival. Productivity can be determined by close observation of radiocollared caribou at about the peak of calving in mid-May (Whitten 1995). For small caribou herds like the Denali Herd, calf recruitment is an important, if not primary, determinant of population trend (Adams et al. 1995a,b; Farnell and Gardner 2002; Jenkins and Barten 2005) and is commonly assessed by determining calf:cow ratios during fall composition surveys. These fall

surveys also provide estimates of adult sex ratios, important for assessing trends in the bull component of the population and allowing for inclusion of bulls in population estimates. Adult female survival is an important vital rate contributing to herd trends (Gaillard et al. 1998) and can be estimated by regular monitoring of radiocollared individuals throughout the year. Recruiting short-yearling females into the radiocollared sample annually in proportion to older females based on sex/age ratios provides an assessment of the herd's female age structure and ensures that productivity and survival estimates are indicative of the population and not biased by a divergent age structure of the radiocollared sample. Further, regular assessments of the locations of radiocollared individuals provide information on seasonal distributions of the herd. During captures to install radiocollars on caribou, immobilized individuals can be easily weighed, measured, and blood-sampled to provide additional information on trends in body size, nutritional status, disease exposure, genetic relationships, etc. The ages of caribou are determined by capturing 10-month-old individuals that are then of known age, or by extracting canines from older individuals for aging via analyses of cementum annuli (Reimers and Nordby 1968, Miller 1974).

Field Methods

Preparation and planning

Caribou monitoring efforts that serve as the basis of this protocol have been in place at DENA since 1986 and equipment required for animal darting and radiotelemetry is the same as that used in the DENA wolf monitoring program. Thus, basic equipment is available at the park and personnel are well aware of procedures for operating a radiotelemetry program. In brief, any chemical immobilization/radiotelemetry project requires substantial planning, advance purchasing of equipment and supplies, and arranging of aircraft logistics well in advance of field operations. In particular, the capture and handling of wildlife carries with it the ethical responsibility that project staff are adequately trained and have appropriate experience to carry out the capture operations safely, humanely, and efficiently. This caribou monitoring program requires appropriate NPS and NEPA compliance, as well as an ADF&G scientific permit and approval by an Institutional Animal Care and Use Committee. Procurement of radiocollars and immobilizing drugs must be initiated several months before any planned capture operations. Arrangements to line up skilled pilots, particularly helicopter pilots adept at animal capture and caribou composition surveys, must also occur well in advance.

Capture and radiocollaring of caribou

Caribou are captured by helicopter darting and radiocollared to monitor their survival and movements, and to aid in conducting composition surveys and herd counts. Generally, caribou are captured in Denali during March when air temperatures are cooler and to avoid late pregnancy, however, captures can also be conducted in late-September – early November when air temperatures are cool and day length is still reasonable for field operations.

All aircraft and pilots must be carded for the mission and procured according to NPS, USDI's Aviation Management Directorate (AMD), and USDI Interagency Helicopter Operations Guide (IHOG) regulations. Animal handling personnel must become certified for the Aerial Capture, Eradication and Tagging of Animals (ACETA), as well as obtaining appropriate training in animal anesthesia and handling techniques and aircraft safety. Flight plans and flight following according to federal Aviation Administration (FAA) and NPS regulations are important for safe operations. Clothing and equipment specifications are determined by NPS ACETA and IHOG guidelines. Permits for animal capture will be obtained from the ADFG, if needed. Capture operations will also get NPS Institutional Animal Care and Use Committee (IACUC) approval. Monitoring staff must perform internal and inter-agency scoping to assure that the project meets National Environmental Policy Act (NEPA) requirements.

Through experience we have concluded that a sample of ≥ 50 radiocollared caribou is necessary to meet the objectives of this monitoring protocol. Further, we have maintained a sample of radiocollared females that reflects the age structure of the female component of the herd since 1987 (Adams and Dale 1998b); maintaining this sample requires the capture of 10-month-old females, as well as adults. For the age-structured sample, we started with 34 females > 1-year-old captured during winter 1986-87 and annually recruited 12-month-old females into the sample

on 1 May, the beginning of the biological year for caribou in Denali. The number of recruits each year was based on the ratios of female calves: older females from late September composition counts, thus assuming that survival of calves and adults is similar during October-April. We added additional females > 1-year-old captured at random from the population as needed to maintain sample size during periods of herd decline, given that the age-structured sample declines in sync with the population as a whole. Although this has not occurred to date, should the age-structured sample increase beyond reasonable size with a marked increase in the population, the sample can be pared down by removing the appropriate number of randomly-selected individuals. Once an individual is included in the age-structured sample it remains until it dies or is removed to reduce the sample size.

To maintain a sample of ≥ 50 radiocollared caribou in the age-structured sample requires annual captures of about 12 adult females to replace old radiocollars and about 8 10-month-olds (≈ 6 recruits plus a couple extra to allow for mortalities between March captures and 1 May recruitment). Individual caribou are recollared at 4-year intervals to replace radiocollars to minimize risks of radio failure. Occasionally additional captures will be required to boost the adult sample size or remove individuals from the sample that are no longer needed (e.g., extra individuals collared at 10 months of age). Ideally, captures of new caribou are distributed throughout the range of the herd as determined by the current distribution of radiocollared caribou or aerial surveys.

Currently, we are using a combination of carfentanil citrate and xylazine hydrochloride for immobilizing caribou. A PA-18 Super Cub, working closely with the capture helicopter, locates caribou for darting, monitors darted caribou during induction, and checks on caribou that have been captured on previous days. Once a caribou is immobilized, it is fitted with a mortality-sensing radio collar. A blood sample is drawn for disease screening and archiving for emerging analyses and future opportunities. Caribou are weighed by being placed in a weighing net and lifted with a weighing bar or tripod/come-a-long combination attached to a digital load cell or strain gauge. A canine tooth is extracted for age determination (Reimers and Nordby 1968, Miller 1974) from individuals ≥ 1 year old at their initial capture. Standard body measurements are taken. Once processing is complete, caribou are given naltrexone hydrochloride and yohimbine hydrochloride to antagonize the effects of carfentanil and xylazine, respectively. At the end of each day, blood samples are centrifuged, the serum removed, and blood fractions are stored frozen until submitted for analyses. Each caribou that is handled is relocated within 3 days of capture to determine that they survived the capture event.

Radiotracking to assess seasonal distribution and survival

To determine the distribution of the herd and survival of individuals, radiocollared caribou are relocated by aerial radio tracking from fixed-wing aircraft on the following schedule:

- early May: Assess survival of individuals on 1 May, the beginning of the new biological year (May-April);
- mid-May: Determine productivity of individual radiocollared females by close observation and approximate calving distribution;

- early June: Determine distribution for post-calving census and composition survey;
- late July: Document survival and summer distribution;
- late September: Assess distribution for fall composition surveys, survival to fall, and rutting distribution;
- late November: Determine survival and early winter distribution;
- late January: Document survival and midwinter distribution; and
- mid-March: Ascertain survival and late winter distribution.

During these radiotracking bouts, information collected for each caribou located include the date and time located, a general location description, the mode of the signal (active or mortality), estimated group size, and coordinates of the location from the onboard GPS on the aircraft. 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 radiotracking bout. 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 range of the radio signal 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.

Investigating mortalities is important and commonly requires a helicopter to access these sites. Given the long interval between radiotracking bouts, it is unlikely that the actual cause of death can be determined in many cases, so retrieving the mortalities can wait until a reasonable opportunity to use a helicopter is available. It is important that each is investigated to confirm that the individual is actually dead (and not a slipped or malfunctioning collar) and to retrieve the collar for future use. Radios left in the field can last for years on mortality and will eliminate the use of that frequency until they go off the air. Occasionally, radiocollars cannot be retrieved because of dangerous locations (e.g. avalanche chutes, crevasse fields) or difficult retrieval conditions (e.g. buried in avalanche debris, a long distance from reasonable helicopter access). These frequencies must be noted and not used until the irretrievable radiocollars go off the air with battery failure, which can take up to a decade.

With information on the survival of individual radiocollared caribou through the biological year (1 May – 30 April) and the mortalities that occur throughout the year, survival rates can be easily calculated using standard methods (e.g., Pollock et al. 1989). Adult female survival for the herd is determined by evaluating survival of individuals included in the age-structured sample of radiocollared females, whereas age-specific survival estimates are based on all radiocollared females.

Assessing annual calf production

During 13-17 May, at approximately the peak of calving for the Denali Caribou Herd (Adams and Dale 1998b), all female caribou ≥ 2 years old are located primarily by helicopter to determine if they have a calf at heel, hard antlers, or an obvious swollen udder, all indicators of recent or impending

parturition (Whitten 1995). For efficiency, a Super Cub crew works along with the helicopter to locate caribou in advance of the helicopter. Females with calves that are alone or in very small groups may be classified as parturient by the Super Cub crew, thus not requiring closer observation by the helicopter crew. Once all radioed adult females are observed and their reproductive status determined, herd productivity is determined from the proportion of adult females in the age-structured sample that are deemed parturient plus the yearling females recruited in the age-structured sample. Age-specific productivity is evaluated based on all radioed females observed.

Post-calving survey

For the Denali Herd, population estimates have been based on helicopter surveys conducted in late May – early June since 1987. This approach grew out of post-calving composition surveys during 1984-97 when calf mortality in the herd was being intensively investigated (Adams et al. 1995a,b), and we recognized that a large portion of the cows in the herd could be enumerated in a couple of days. At this time of year, cows and calves tend to be in large groups that are highly visible, the majority of caribou are concentrated in a relatively small portion of their annual range, and daily movements of caribou are limited. By counting caribou in the regions where they are most concentrated we have been able to count, on average, nearly 60% of the females in the herd in about 2 days. Based on the distribution of radioed females relative to the survey area, we extrapolate the number of females counted in the survey to an estimate of cows in the entire population. Beginning in 2003, we instituted procedures during the post-calving survey to apply a sightability-model approach (Bodie et al. 1995, Samuel et al. 1987, Udevitz et al. 2006) to determine detection probabilities relative to group size based on whether groups including radiocollared individuals are observed or missed during the visual helicopter survey, and thus account for caribou missed during the survey.

Prior to the post-calving survey, the distribution of radiocollared female caribou is determined and survey areas are delineated with the goal of including > 50% of the marked females in the survey areas with reasonable buffers around their locations defined by obvious geographic features. The total area surveyed usually consists of 2 to 4 large blocks of mountainous terrain along the main Alaska Range. With a helicopter, we intensively search each survey block without the aid of radiotelemetry. Caribou in groups we encounter are counted and classified as cows, calves, or bulls, and we determine the occurrence of marked individuals within groups via radiotelemetry. Simultaneously, a Super Cub crew locates all the radiocollared females in and adjacent to the survey block. As portions of a survey block are completed, we periodically compare notes between the 2 aircraft crews to determine if marked groups were missed by the helicopter crew; those groups are then located by the helicopter and counted. Information on the size 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 (Samuel et al. 1987). The resulting detection probabilities relative to group size are used to account for caribou groups missed. Upon completion of the survey, the total number of cows in the herd is calculated based on the estimated number of cows in the area surveyed divided by the proportion of radiocollared cows within the survey area. With the estimate of cows in the herd at the time of the survey in early summer, we determine the fall population estimate by applying the adult female survival rate from radiotelemetry for June-

September and using the fall herd composition to account for bulls and calves. Confidence intervals associated with population estimates are approximated via Monte Carlo simulation (Manley 1991) employing parameters used to derive the population estimate and their associated variances.

Fall age/sex composition survey

Annual helicopter surveys to assess age/sex composition of the herd are conducted in late September during the peak of rutting activity when caribou are in mixed-sex aggregations. During these surveys, either a survey area is identified based on the distribution of radiocollared caribou and then the area is thoroughly searched by helicopter, or radiotelemetry can be used to locate groups containing radiocollared individuals. If caribou are relatively concentrated and sightability is good, it is often easier to locate sufficient caribou without radiotracking groups. However, if caribou groups are scattered or sightability is poor due to patchy snow cover, radiotelemetry may be required. In those cases, working with an airplane that is doing the radiotracking and directing the helicopter to groups can greatly facilitate the survey. Commonly, a large number of caribou (> 1,000) can be classified in 1-2 days.

Caribou that are encountered are classified as cows, bulls, or calves; bulls are classified into 3 size classes (small, medium, large) and calves are sexed. Data are recorded on a small hand-held tape recorder that can be replayed at reduced speed to aid in tallying the results. Primary results of the survey are the calf:cow, calf sex, and bull:cow ratios.

Data Management

Data collected as a part of this caribou monitoring protocol can be divided into 4 categories:

- **Capture data:** Data includes records for each caribou capture event such as the unique animal number; capture date; information on drugs used (dosages of immobilizing drugs/dart, dart hits); induction, handling, and recovery times; status post-capture (survived or not); age (known age if captured at 10 month old or estimated from cementum annuli), body mass, and measurements. These data are entered and stored in Excel spreadsheets.
- **Individual status records:** To facilitate survival analyses and keep track of the radio collaring history of individual caribou, we maintain a database of the status of each individual that is captured. Maintained in spreadsheet form, each radiocollared individual is represented by 1 row in the spreadsheet and data recorded in columns include the unique animal number, original capture date, the individual's birth year (useful in determining age in any given year), re-collaring status (last time recollared; useful for determining which individuals are due for re-collaring), and status information (alive or dead?, date of death, cause of death).
- **Radiolocation data:** The radiotelemetry database includes radiolocations of all individuals throughout the year. Data recorded per observation include the animal number, date, time, transmitter mode (active or mortality), a brief descriptive location (useful for error checking data), and coordinates of the location. Although all radiolocations are added to the database, it is important to screen the locations to eliminate extra locations of some individuals within a radiotracking period. For each radiotracking period, only 1 location per collared individual is included for evaluating seasonal distribution. However, it is not unusual for multiple locations to be acquired for an individual, particularly during censuses or capture operations. These extra locations must be screened out prior to any analysis.
- **Surveys:** Data for productivity surveys, composition surveys and population censuses are maintained in original files or spreadsheets specific to each survey, and summarized in annual reports or survey-specific reports.

Analyses and Reporting

An annual report is produced by the USGS Scientist each February covering monitoring activities during the previous fiscal year. Each annual report provides information on the herd status and trends, vital rates, and other data summaries, as well as briefly describes plans for the upcoming year. The intended audience for the annual report includes park superintendents, park resource managers, network staff, and external wildlife managers/scientists. Reports are designed to be promptly produced, appropriate for the target audience, widely available, and visually accessible. Graphical methods, maps, and other visual aids are used to make results readily understood. Scientific publications are developed on topics of particular interest.

Personnel Requirements and Training

The USGS Scientist will serve as principal investigator for caribou monitoring in DENA for the Central Alaska Network. Capture efforts will primarily be conducted at Onion Portage in cooperation with biologists from other agencies lead by the ADFG, if possible. Radio tracking efforts will be conducted by AMD certified pilots with the Principal Investigator or wildlife technicians as observers. When NPS personnel take part in telemetry flights, they must have appropriate aircraft safety training as specified by the AMD, and wear PPE suitable for Special Use flights under AMD guidelines. Personnel needs for caribou monitoring are not great enough to require additional park staff, though a dedicated technician would reduce the data management work load substantially. The greatest need for specialized expertise will come if the need for aerial capture and radio collaring of caribou arises. NPS personnel involved in capture operations must have certification in ACETA, proper training in animal immobilization and handling, and appropriate aircraft safety and management training under IHOG regulations. The selection of aircraft and pilots is of great importance for the safe and economical capture and monitoring of caribou. A project aviation safety plan will be prepared and approved prior to operations.

Operational Requirements

Annual workload and field schedule

As described above, this caribou monitoring protocol includes essentially 5 activities that occur throughout the year:

- Captures: Captures generally occur during March and require about 2-3 days with good weather for the 20 captures per year needed to meet the goals of this monitoring protocol. Captures will require the involvement of a helicopter pilot, a fixed-wing pilot, and 1-2 biologists.
- Radiotracking: Radiotracking is expected to occur about 8 times a year on roughly a bimonthly schedule. Some radiotracking is done in conjunction with other caribou monitoring activities (e.g. captures, surveys, and census). We expect that on average, each bout of radiotracking will take 2-3 days, and can often be completed in conjunction with wolf radiotracking. In most cases, we expect this workload to be handled by the individual pilots.
- Productivity survey: Productivity surveys must be conducted 13-17 May each year in sync with the annual peak of calving. This survey effort requires a helicopter pilot with an experienced observer, and a Super Cub pilot.
- Post-calving survey: The post-calving survey is conducted in early June and requires 3-4 days to complete with 2 pilots (1 helicopter, 1 fixed-wing) and 1-2 observers.
- Fall composition survey: Conducting annual fall composition survey requires 1-2 days in late September and involves a helicopter pilot and 1-2 biologist-observers. This survey is conducted immediately following or in conjunction with a radiotracking bout to define the distribution of caribou for the helicopter survey.

Facility and equipment needs

No specialized facilities are required for caribou monitoring. Currently, adequate equipment for the conduct of this work is available.

Startup costs and budget considerations

Caribou monitoring efforts, as well as other projects that involve aerial darting and radiotelemetry of large mammals, are ongoing at DENA; thus an adequate sample of caribou are currently radiocollared in the herd and the basic equipment is currently available. Based on estimates from 2012, costs summarized below cover full implementation of this monitoring protocol (Table 1). Cost estimates include aircraft, fuel, radiocollars, drugs, and handling supplies only and do not include any personnel, travel/per diem, equipment replacement costs, or any indirect costs (e.g. aviation assessments, interagency overhead, etc.) that may be incurred in the conduct of this work.

Table 1. Estimates for annual radio collaring and tracking costs.

Activity	Time of Year	Aircraft	Aircraft Rate	Fuel/Supplies	Cost
Radiotracking	Nov, Jan, mid-Mar, early May, late July	Cub	100 hrs @ \$215/hr	860 gal @ \$5/gal	\$25,800
	Nov, Jan, mid-Mar, early May, late July	Helicopter (mortality retrieval)	4 hrs @ \$640/hr	–	\$2,560
	Subtotal	–	–	–	\$28,360
Captures (12 adult females, 8 female calves)	March	Cub	24 hrs @ \$215/hr	370 gal @ \$5/gal	\$7,010
	March	Helicopter	12 hrs @ \$640/hr	–	\$7,680
	March	–	–	Radiocollars, drugs, supplies @ \$600/caribou	\$12,000
	Subtotal	–	–	–	\$26,690
Productivity survey/radio tracking	Mid-May	Cub	20 hrs @ \$215/hr	400 gal @ \$5/gal	\$6,300
	Mid-May	Helicopter	16 hrs @ \$640/hr	–	\$10,240
	Subtotal	–	–	–	\$16,540
Post-calving census/radio racking	Early June	Cub	32 hrs @ \$215/hr	500 gal @ \$5/gal	\$9,380
	Early June	Helicopter	16 hrs @ \$640/hr	–	\$10,240
	Subtotal	–	–	–	\$19,620
Fall composition survey/radiotracking	Late Sept.	Cub	20 hrs @ \$215/hr	340 gal @ \$5/gal	\$6,000
	Late Sept.	Helicopter	12 hrs @ \$640/hr	–	\$7,680
	Subtotal	–	–	–	\$13,680
Total					\$104,890

Procedure for revising the protocol and archiving previous versions

Over time, revisions to both the Protocol Narrative and to specific Standard Operating Procedures (SOPs) are to be expected. Careful documentation of changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis. Databases for each monitoring component contain a field that identifies which version of the protocol was being used when the data were collected.

The rationale for dividing a sampling protocol into a Protocol Narrative with supporting SOPs is based on the following:

- The Protocol Narrative is a general overview of the history, justification, sampling methods, but does not provide all of the methodological details. The Protocol Narrative will only be revised if major changes are made to the protocol.
- The SOPs, in contrast, are very specific step-by-step instructions for performing a given task. They are expected to be revised more frequently than the protocol narrative.

- When a SOP is revised, in most cases, it is not necessary to revise the Protocol Narrative to reflect the specific changes made to the SOP.
- All versions of the Protocol Narrative and SOPs will be archived in a Protocol Library.

The steps for changing the protocol (either the Protocol Narrative or the SOPs) are outlined in SOP #4, “Revising the Protocol”. Each SOP contains a Revision History Log that should be filled out each time a SOP is revised to explain why the change was made, and to assign a new Version Number to the revised SOP. The new version of the SOP and/or Protocol Narrative should then be archived in the LTEM Protocol Library under the appropriate folder.

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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.

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