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WILDLIFE RESEARCH REPORT

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ABSTRACT

A large scale moose research project was initiated in November of 2013. This progress report covers the time period of the 3rd field season (2015–2016). Field efforts were centered on 2 objectives. The first was helicopter darting of moose during December (2015), and the second was continued estimation of parturition rates of pregnant adult female moose. Capture efforts were again focused in 3 study areas in Colorado — along the Laramie River (NE Colorado), the southern portion of North Park and in the Williams Fork drainage (NW Colorado), and near Creede and the Rio Grande Reservoir (SW Colorado). Moose captured in NE and NW Colorado were fitted with satellite GPS collars. Moose in SW Colorado were fitted with satellite monitoring collars. Ultrasonographic body condition measurements, thyroid hormone concentration data, pregnancy status, and calf-at-heel status of each captured animal was also evaluated at the time of capture. As opposed to the first two years of the study, pregnancy rates were higher in NE Colorado and comparable to NW Colorado. Measured maximum rump fat of animals in NE and NW Colorado during 2015–2016 was similar to measurements from 2014–2015, although 2015–2016 from SW Colorado were higher than previous years. Survival status of all collared animals was monitored through June 2016. Survival rates were high with little variation observed among study areas (91%–100%). During 2015–2016, moose parturition rates were variable, ranging from 53%–70%, which was in contrast to the previous year when parturition rates were consistent between areas (80%). During 2015–2016, no twins were observed in the northeast or northwest study areas, although a twinning rate of 33% was observed in southwest Colorado.

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Evaluation and incorporation of life history traits, nutritional status, and browse characteristics in Shira's moose management in Colorado

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PROJECT NARRATIVE OBJECTIVES

Many of Colorado's moose management decisions are made in the absence of abundance data. However, abundance data are difficult and costly to attain. This project is designed to address this need for information and to develop alternative decision making processes to support Colorado's moose herd management, and specifically harvest management. During this study we are collecting and analyzing population vital rate data (i.e., survival rates, pregnancy rates, parturition rates and twinning rates) from moose herds across Colorado. Likewise, we are collecting fecal samples from moose to evaluate browse selection and nutritional quality of species eaten by moose. Moose vital rates and browse quality data will ultimately be merged with hunter harvest success and harvested animal attributes to develop informed decision making processes. Finally, due to opportunities stemming from the capture and handling of moose, data on disease and wildlife health related issues will also be collected and evaluated.

SEGMENT OBJECTIVES

1. Capture and collar up to 20 adult female moose in each of 3 study areas.
2. Evaluate body condition and pregnancy data from captured animals.
3. Monitor survival of radio-collared moose.
4. Conduct preliminary investigations of parturition and twinning rates in the NE and NW study areas.

INTRODUCTION

Wildlife managers are commonly confronted with the challenge of meeting multiple conservation needs under the constraint of finite resources. For example, financial resources can be invested on a plethora of management activities including: land acquisition, species translocations, population monitoring, law enforcement, or research. Managers may opt to invest resources proportionate to species abundance, according to endangered or threatened status, or according to the revenue that a species generates. Thus, the decisions as to how resources are allocated are complex and the development of more efficient processes needs to be an inherent goal of applied research.

Moose (*Alces alces*) are a species that exemplifies this management dilemma. Moose are less abundant than mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*), and contribute only nominally to Colorado's big game hunting opportunity. Accordingly, the relative investment, in terms of effort and money, in moose population management has been low. Despite this, demand for the moose hunting licenses that Colorado offers is exceptionally high, and of equal importance, moose receive a great deal of attention from wildlife watchers and wildlife enthusiasts. Thus, while moose management necessitates direct and deliberate decisions by biologists, annual management decisions are not typically informed by consistent data collection or standardized procedures.

The primary objective of this research is the development and validation of a moose harvest management process that is not structured around abundance estimation or abundance modeling. While not intuitive, in the absence of abundance estimates or knowledge of range carrying capacity, ecological cues on the interaction between moose herd productivity and the ability of the vegetative landscape to support more animals can still be gathered and utilized. The perspective that wildlife populations experience a sequential set of survival and reproductive adjustments as they approach the carrying capacity for their range has been present in the literature for several decades. While the original hypotheses about the sequence of these density-dependent effects were made for marine mammals (Eberhardt 1977a, 1977b), they have subsequently been applied to several ungulate species (Gaillard et al. 1998, Gaillard et al. 2000). A body of evidence from Alaska, Canada, and Europe has further evaluated relationships between habitat condition, animal nutrition, and reproductive output (Sæther and Andersen 1996, Keech et al. 2000, Boertje et al. 2007, Paragi et al. 2008), thus providing the opportunity to capitalize on life history characteristics in the moose population management process. This body of evidence has identified several attributes that moose populations near their carrying capacity demonstrate as resources available to individual animals decline. Specifically, the cascading effects of nutritional limitation can: 1) cause declines in the survival rates of calves (0–12 month old animals), 2) result in reduced body weights of 10-month old animals, 3) cause reduced pregnancy rates of yearling animals (12–24 months old), 4) cause reductions in the twinning rates of mature animals (≥25 months old), 5) cause declines in the pregnancy rates of mature animals, and ultimately, 6) reduce the survival of adult animals. While it is neither realistic nor practical to measure all of these parameters, some offer the potential to cost-effectively inform management decisions. However, as noted above, the majority of research establishing the link between moose life history characteristics, nutritional status, and habitat conditions has been conducted on the Alaskan (a.k.a, Yukon and Tundra) subspecies (*Alces alces gigas*) and the Eurasian subspecies (*Alces alces alces*) of moose. While these relationships are expected to be consistent for the Shira's (a.k.a., Yellowstone) subspecies (*Alces alces shirasi*) that inhabits Colorado, the ecological relationships of interest need to be validated as part of refining Colorado's moose population and harvest management processes.

Of particular interest in Colorado, and based on examples of moose management elsewhere (Paragi et al. 2008, Seaton et al. 2011), the parameters warranting validation are: 1) survival of adult females (>12 months old), 2) pregnancy rates of adult females, 3) early-winter body condition of adult females, 4) fine scale habitat use, 5) twinning rates of mature females (≥24 months old), and 6) utilization of current-annual-growth (CAG) for key browse species. Once the relationships between these ecological parameters are validated, they can be incorporated into a harvest management model. In addition to these ecological considerations, effective population and harvest management accommodates social desires. Within hunted species in which licenses are highly coveted and difficult to obtain, managers typically strive to maximize opportunity by increasing the number of available licenses, while also managing for high quality hunts that are defined by high encounter rates with legally harvestable animals, low encounter rates with other hunters, and the opportunity to harvest trophy animals that are typified by older age class animals with more developed antler structure. These social factors of moose management can also be incorporated into harvest management decisions by setting clear objectives for each factor and collecting data to inform how well those objectives are being met. Data such as the unit of effort needed to harvest an animal (catch per unit effort; CPUE), average age of harvested animals, and antler characteristics of harvested animals are already collected as part of the mandatory check process that moose hunters must comply with as part of Colorado's moose hunting regulations. Thus, data on these social factors can be built into harvest management models that will provide a more informed decision making process.

Harvest Management Model Inputs

Survival of Adult Females — As noted for many ungulate species, the survival of adult females is typically high (Gaillard et al. 1998, Gaillard et al. 2000). Similarly, the year-to-year variation (i.e., process variation) among estimates for many large herbivores is commonly low (Gaillard et al. 1998, Gaillard et al. 2000). This provides evidence that as animals reach the adult age class, survival rates become less sensitive than those of younger animals. However, spatial variation among estimates may be higher. Preliminary evidence from Colorado suggests that moose herds in the northern part of the state may benefit from higher survival rates than those in the southern part of the state (Kufeld and Bowden 1996, Olterman and Kenvin 1998). While survival rates in all regions of Colorado are expected to be high, this hypothesis is in need of validation. Likewise, documented geographic variation in Colorado's moose survival rates are not robust and any differences are in need of direct validation.

Adult Female Pregnancy Rates **—** As is the case with survival of adult females, evaluation of pregnancy rates in the literature provides evidence that rates tend to be relatively constant ($\bar{x}$ = 84.2%) and resilient among years (Boer 1992). Despite this, it was not intuitive as to why annual pregnancy rates were not higher (Boer 1992). Based on this evidence, we speculate that a biologically meaningful difference in pregnancy rates will not be observed among moose herds in Colorado. However, if large differences in overall population dynamics among herds in the northern and southern parts of Colorado are observed, it is expected that spatial variation in pregnancy rates may be a key source of variation.

Early Winter Body Condition **—** The evaluation of moose body condition using ultrasonagraphy was developed in the early 1990s and since that time has proven to be useful as a research technique (Stephenson et al. 1998, Keech et al. 2000, Cook et al. 2010). The use of ultrasonagraphy in Colorado has primarily been focused on mule deer, and more specifically, as a tool for evaluating late-winter body condition (Bishop et al. 2009a, Bishop et al. 2009b, Bergman 2013). When body condition scores, based on hand palpation, are combined with estimates of rump fat, estimates of total ingesta-free body fat can be derived (Stephenson et al. 1998, Cook et al. 2010). While preliminary data don't exist, it is expected that the majority of moose in Colorado are capable of surviving through winter while maintaining measurable levels of rump fat (R. Cook, National Council for Air and Stream Improvement – J. Crouse, Alaska Fish and Game –T. Stephenson, California Fish and Game; personal communication). However, it is also expected that by the end of winter, the majority of moose will have similar levels of fat reserves remaining. Alternatively, based on the plasticity of moose reproduction and the differences in lactation and energetic burdens faced by adult females with 0, 1, 2, or 3 calves, it is expected that the widest range in moose rump fat will be observed during early winter periods (R. Cook, J. Crouse, and T. Stephenson, personal communication). Nutritional status, as defined by body condition and rump fat measurements, will be collected on 2 subsets of moose. The first subset will be comprised of individual moose that will be captured during every year of the study, thereby allowing the tracking of individual nutritional status through time and allowing that status to be linked to past habitat use and past reproductive output. These measurements will help validate the relationship between nutritional condition, browse availability (discussed below), and reproductive success (discussed below). The second subset of moose to be sampled for nutritional status will be comprised of individuals who are captured a single time during the course of the study. The assessment of body condition and rump fat from this second subset of randomly selected individuals will minimize bias due to the lack of randomization that occurs from repeatedly sampling the first subset of individuals. These unbiased estimates will thereby allow for population level estimation of nutritional status on an annual basis.

Habitat Use **—** Documenting fine scale habitat use by adult female moose will be a fundamental step in validating the relationship between life history traits and range conditions. In order to link individual reproductive success to on-the-ground habitat conditions, we need to insure that the areas used by moose define the spatial sampling frame from which browse data are collected. This assessment is further necessitated by the fact that moose habitat across Colorado is diverse, ranging from monotone willow communities to upland shrub communities.

Twinning Rates **—** The sensitivity of moose twinning rates to changes in the vegetative environment, and subsequently to maternal nutritional condition, has been expressly noted as part of multiple studies (Franzmann and Scwartz 1985, Boer 1992, Schwartz and Hundertmark 1993, Boertje et al. 2007). Accordingly, the utility of this parameter has been highlighted in regards to moose harvest and population management (Boertje et al. 2007). While in need of validation in Colorado and for the Shira's subspecies, the use of this parameter in Colorado's moose management holds particular promise. Specifically, annual data from twinning rates can be obtained as part of road surveys, but it can also be collected as ancillary data from aerial surveys that are flown for deer and elk management purposes. Similarly, recent literature has identified the utility of hunter observation surveys as a tool for making inference about moose herds (Solberg et al. 2010). While none of these approaches emulate the unbiased results that stem from sampling based population survey strategies, their overall lack of cost warrants evaluation and possible inclusion in Colorado's moose harvest and population management decision making.

Moose Fecal Sampling: browse selection and fecal histology — Preliminary plans for this research included a concerted effort to quantify moose browse characteristics through the field measurement of both annual growth and the removal of annual growth in key willow communities. As part of a focused workshop at the 49th North American Moose Workshop and Conference (held in Granby, Colorado during April 2015), moose researchers and managers from across North America were asked to provide a critical review of Colorado's proposed moose habitat assessment techniques. This review led to a great deal of feedback. Most of this feedback was focused on shifting field efforts away from vegetation measurements and towards the collection and assessment of moose fecal samples. The primary reason for shifting away from field measurement of vegetation characteristics was expense, and more specifically, the fact that applying these techniques at a broad enough spatial scale that data could adequately be inferred to an entire Moose DAU likely isn't feasible. The collection of fecal samples, and the subsequent fecal analysis, from radio-collared moose is believed to be a more efficient mechanism to evaluate both the species of plants being selected, but also microhistological analysis (i.e., % nitrogen, % fecal NDF, DAPA) of the species selected.

Capture Per Unit Effort (CPUE) **—** In addition to biological parameters, successful population and harvest management of big game species is also dependent on meeting the desires and expectations of hunters. In Colorado, hunters are allowed to harvest one adult male moose during their life. Based on drawing odds, the probability of a hunter drawing an adult male moose license on any given year is <1%. Thus, when tags are drawn, hunters have the expectation that they will have a high probability of harvesting a mature animal (e.g., an animal ≥3 years old), and ideally, they will have the opportunity to observe several legal animals during the course of their hunt. To accommodate these expectations, metrics that pertain to animal maturity, such as age and antler structure, but also metrics that account for hunter effort, such as CPUE, can be built into any modeling and decision making process.

As opposed to statewide success rates for elk and deer, which are ~20% for elk and ~50% for deer, hunter success is typically >90% for moose hunters. Thus, the traditional metric of hunter success is not an informative parameter. Likewise, there is a wide range in hunter desires. Some hunters are willing to harvest the first legal animal they encounter, whereas other hunters specifically target trophy animals. Similarly, some hunters utilize the services of paid outfitters and guides, who typically put in scouting effort to locate animals and identify potential trophy harvest opportunities for upcoming seasons. From an ecological perspective, annual variation in the overlap of timing between hunting seasons and the moose rut may also increase variation in the effort needed to harvest an animal. Thus, while a metric such as CPUE can be informative in the population management process (Hatter 2001, Schmidt et al. 2005, Boyce et al. 2012), it needs to be refined and modified to have a the greatest utility in Colorado. In particular, many harvest models rely on CPUE as an index towards animal abundance. A shortcoming of these models is that they assume that hunter effectiveness is constant. However, this assumption is violated if hunters can change the intensity of their effort based on encounter rates or observations they make in the field. While better documented in fisheries management (Hilborn et al. 1995), the fact that hunting moose in Colorado is typically a once-in-a-lifetime experience adds to the potential for hunter effort to be highly dynamic.

Average Age of Harvest and Antler Characteristics **—** For one subset of moose hunters, the opportunity to harvest any legal animal satisfies their criteria for a high quality hunting experience. However, a different subset of hunters are focused on harvesting a trophy animal that is typified by highly developed antler structure. For moose, annual antler structure progressively develops through the first 4–5 years of life (Franzmann and Schwartz 2007). Thus, a direct relationship between animal age and trophy quality exists. However, this relationship may not be robust during the first 1–3 years of life, nor during the later years of life (≥14 years old) during which senescence in antler structure can occur (Franzmann and Schwartz 2007). In managing for trophy quality, the most effective approach would be to set objectives based on antler structure. However, this approach isn't practical as it fails to recognize factors such as genetics, nutrition, and weather, all of which influence antler growth (Solberg and Sæther 1994, Schmidt et al. 2007, Monteith et a. 2013). As such, age can be used as a surrogate parameter for quality. Moose hunters in Colorado are already required to participate in a mandatory harvest reporting process, which could potentially result in age and antler measurement data for all harvested moose. These data can be used to validate the relationship between age and antler structure, ideally leading to incorporation of age of harvested animal into herd management plans.

STUDY AREA

Colorado moose management is currently broken into 5 herds that are spread between 3 geographic regions. This research follows that pattern with 1 study area in each of those 3 regions (Figure 1). The study area located in northwest Colorado is centered on the Rabbit Ears mountain range that stretches between Muddy Pass and Willow Creek Pass (Figure 2). Moose were captured in drainages flowing north into North Park, and to the south into Middle Park. Moose will continue to be captured in North Park along the Illinois River, in Middle Park along the foothills of the Gore Range and in the Williams Fork River area. The study area located in northeast Colorado is centered along the Laramie River drainage, but also in the upper portions of the Cache la Poudre River (Figure 3). Moose will continue to be captured in drainages flowing east out of the Rawah Mountains, but also in the vicinity of Long Draw Reservoir. Areas locally known as Dead Man and Sand Creek (located to the east of the Laramie River) will remain a focal point for the northeast study area. The study area located in the southwest region is centered on the upper portions of the Rio Grande River, but also in the vicinity of Creede and stretching as far south as South Fork. Moose were also captured in the vicinity of Lake City, along the headwaters of Cebolla Creek and further east in the northern portions of the San Luis Valley (Figure 4).

METHODS

Moose were captured via ground darting and aerial darting from helicopters. Ground based captures of adult female moose (>12 months of age) were conducted by a team of 4–6 individuals. Moose were located from vehicles and on foot. Once an individual moose was located and identified as a suitable candidate for capture, it was stalked and darted by 1 person. After delivery of the dart, but prior to induction, all members of the capture team helped observe the individual from a safe distance, thereby minimizing disturbance and the potential for flight of the animal. Once anesthetized, all individuals on the capture team moved to the animal to help with processing. During ground based captures, all moose were darted with a combination of butorphanol (52 mg), azaperone (24 mg), medetomidine (BAM). After handling, capture drugs were antagonized with antisedan (2.5 mg/mg of medetomadine) and tolazine (4mg/kg). Helicopter capture was conducted by a team of 2 individuals, plus the helicopter pilot and gunner. As with ground capture, any adult female moose (>12 months of age) was considered a viable target animal. Once an individual moose was located and identified as a suitable candidate for capture, the helicopter briefly landed at a temporary staging area to prepare the pilot and gunner for capture and to unload unnecessary personnel and equipment for the capture process. Active pursuit of individual animals was restricted to <5 minutes. After induction, the helicopter pilot left the gunner with the sedated animal for observation purposes, while the pilot returned to the staging area to collect the remaining members of the team and equipment. During helicopter-based captures, moose were darted with either BAM or carfentanil (50–100mg) in combination with xylazine (50–100mg). After handling, carfentanil was antagonized with naltrexone (400mg, 100mg administered via intravenous injection and 300mg administered via subcutaneous injection).

Regardless of capture method, all animals were handled in the same way. All animals were fitted with either: 1) a VHF radio-collar, 2) a store-on-board GPS collar, or 3) a satellite GPS collar. Once anesthestized, animals were positioned sternally recumbent with the head above the torso, thereby minimizing the potential for aspiration and inhalation of rumen contents. Body condition of all animals was evaluated using hand palpation techniques, and rump fat measurements were collected via ultrasonagraphy (Stephenson et al. 1998, Cook et al. 2010). Up to 50ml of blood was drawn from all animals to evaluate various health attributes including pregnancy via pregnancy specific protein B (PSPB; Wood et al. 1986), concentrations of trace elements such as selenium, but also presence of elaeophora (*Elaeophora schneideri*). Ear tags were placed through the ear punch site and the forehead biopsy site was left to heal by secondary intention. Biopsy samples were placed in both ears. Tick presence was documented and quantified using a modified sampling approach (Sine et al. 2009). Upon completion of data collection, capture drugs were immediately antagonized and the capture team departed the area. The status and alertness of animals was periodically monitored during the remainder of the day by capture crews or the spotter plane. Total handling time was typically <25 minutes.

Survival rates of adult females were estimated on a monthly basis facilitated by collar satellite technology and intensive weekly ground monitoring. All mortalities that were detected via telemetry were investigated to determine the cause of death, but also to collect biological samples for disease and health related purposes. Twinning rate data were collected during May and June in both the NE and NW study areas. Twinning rate data were collected by observation of radio-collared animals and estimating the number of calves-at-heel.

RESULTS AND DISCUSSION

A total of 42 moose were captured during the 2015–2016 field season; of these, 25 were recaptures of animals that were first caught during the 2013–2014 or 2014–2015 field seasons. Twenty moose were captured in the NW study area (14 recaptures) 15 moose were captured in the NE study area (11 recaptures), 7moose were captured in the SW study area (0 recaptures). The 7 moose captured in the SW study area were located in an area that had previously contained 0 radio-collared animals. Thus, the 2015–2016 capture effort in SW successfully resulted in a better distribution of collared animals in this study area. All moose were captured via helicopter darting during the 2015-2016 field season. One non-target animal (a mature bull with shed antlers) was captured in the northwest study area. No known mortalities or injuries occurred during the 2015–2016 capture effort. All captures occurred between 28 December (2015) and 1 January (2016).

During the course of this study, survival of radio collared animals has been high in all study areas (84%-96%). On average, 2 radio collared moose have been harvested each hunting season. Of the remaining mortalities that occurred, 1 was determined to be a road kill, 2 were due to malnutrition, and the cause of death could not determined for 4 animals. Scavenging by coyotes, bears, and mountain lion was documented, although there was no evidence that predation was the cause of death.

Less regional variation in pregnancy rates was documented during 2015–2016 than during previous years of the study. Pregnancy rates ranged between 71% and 95% during 2015–2016. However, the lowest rate (71%) was observed in the SW study area where only 7 animals were captured. Of these 7 animals, 2 were yearlings which rarely breed. Thus, the low pregnancy rate for the SW study area was most likely an artifact of the particular sample and less attributable to a regional decline in pregnancy. Alternatively, as opposed to earlier years of the study, the NE study area had a marked increase in pregnancy rate (increasing from 68% and 78% during the first 2 years of the study to 93% during 2015–2016). Whereas parturition rates of 80% were observed for pregnant, radio collared cows in the NE and NW study areas during 2014–2015, parturition rates were lower and more variable during 2015–2016. In the NW study area, parturition rates for this year were 53%. In the NE study area, parturition rates were 70%, but parturition rates in the SW study area were 82%. No twins or triplets were observed in the NE or NW study area, although 2 sets of twins and 1 set of triplets was observed in the SW study area during 2015–2016.

During 2015–2016, mean measured rump fat at the time of capture ranged from 5.0 mm to 11.0mm among study areas. This range was higher than values measured during 2013–2014 or 2014–2015 (Figure 5). Mean measured loin depth at the time of capture ranged between 43.1mm and 51.6mm among study areas (Figure 5).

Across all years, pregnancy status was best predicted by measured rump fat (Figure 6). Despite variation within data, no regional or annual effect in pregnancy models was observed.

SUMMARY

Moose data collected during this period largely met expectations. Survival rates were high in all study areas. However, it was also assumed that not all of Colorado's moose herds are equally productive. This assumption was largely validated by variation in pregnancy rates. However, additional years of data collection are needed to confirm this result. Within this, the age of captured animals remains unknown and could partially explain the variation in pregnancy data.

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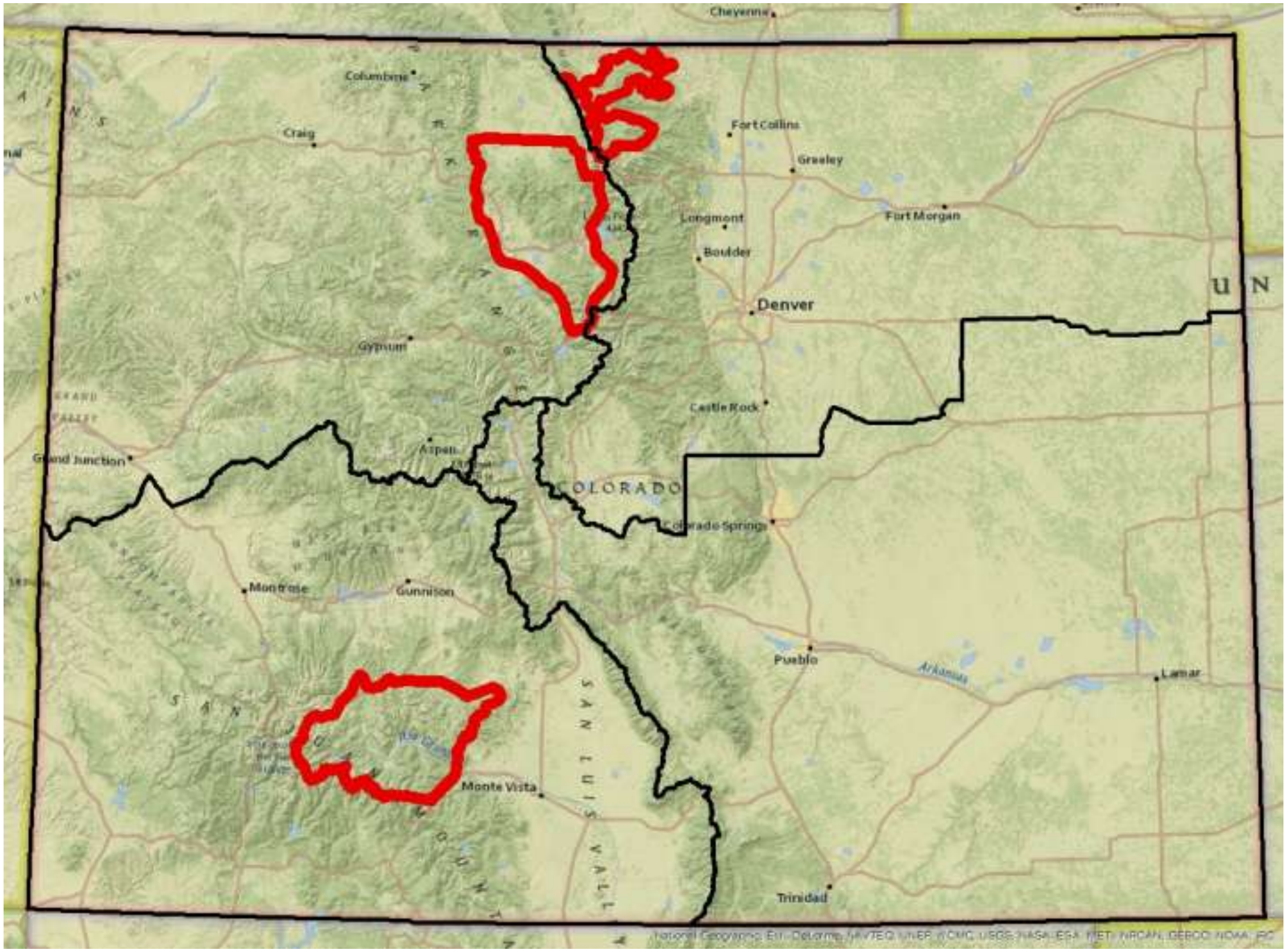

Figure 1. Map of Colorado moose study area locations (red polygons). Colorado Parks and Wildlife regions, and state boundaries, are depicted by heavy black lines.

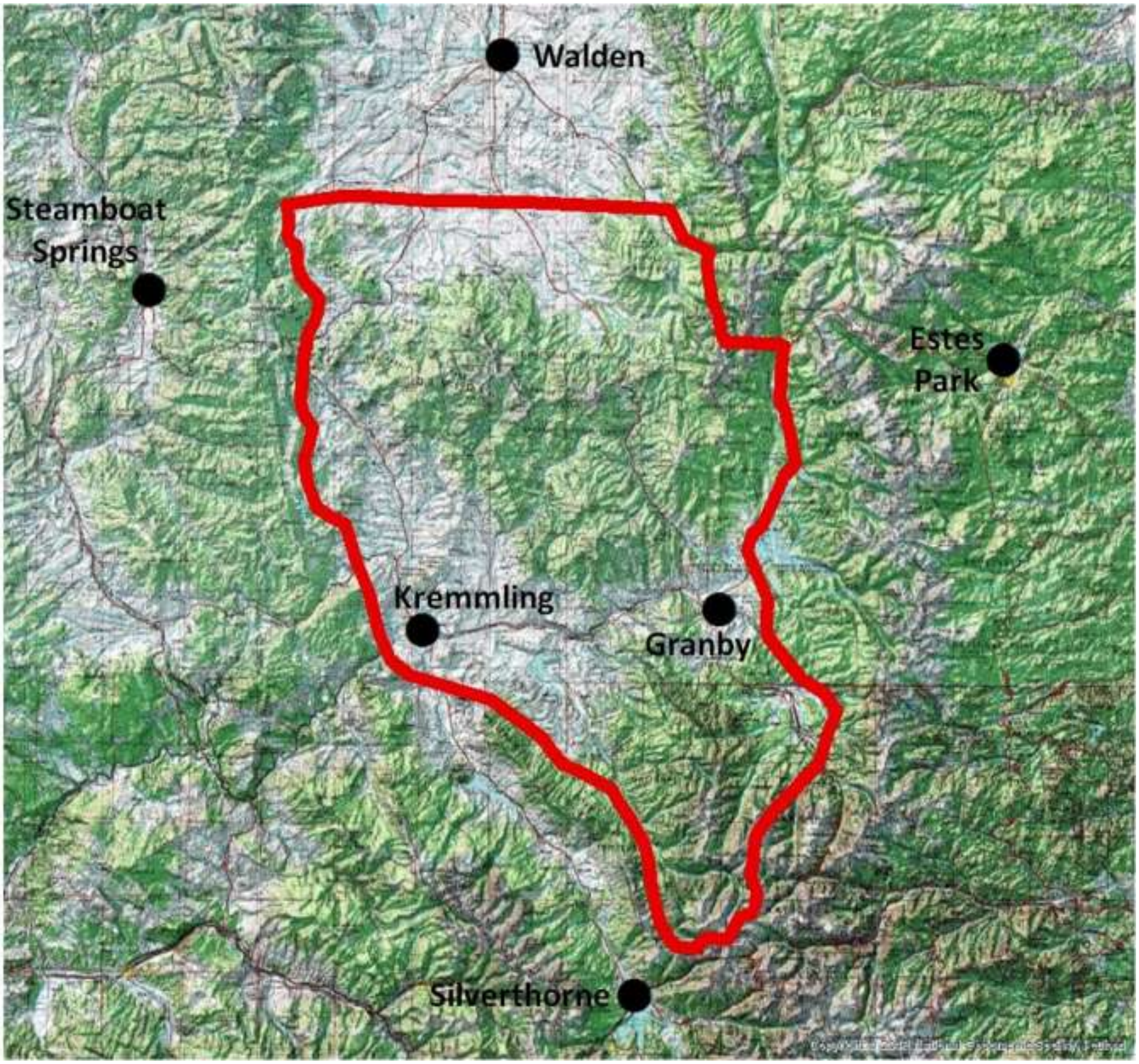

Figure 2. Northwest Colorado moose study area (red polygon), in relation to local communities and centered on the Rabbit Ears Mountains. The majority of moose capture will be located in the central portion of the study area, although capture locations may also expand into the southern portion of North Park, as well as the central portions of Middle Park, include the Williams Fork River drainage, as well as the valley including Tabernash and Fraser, Colorado.

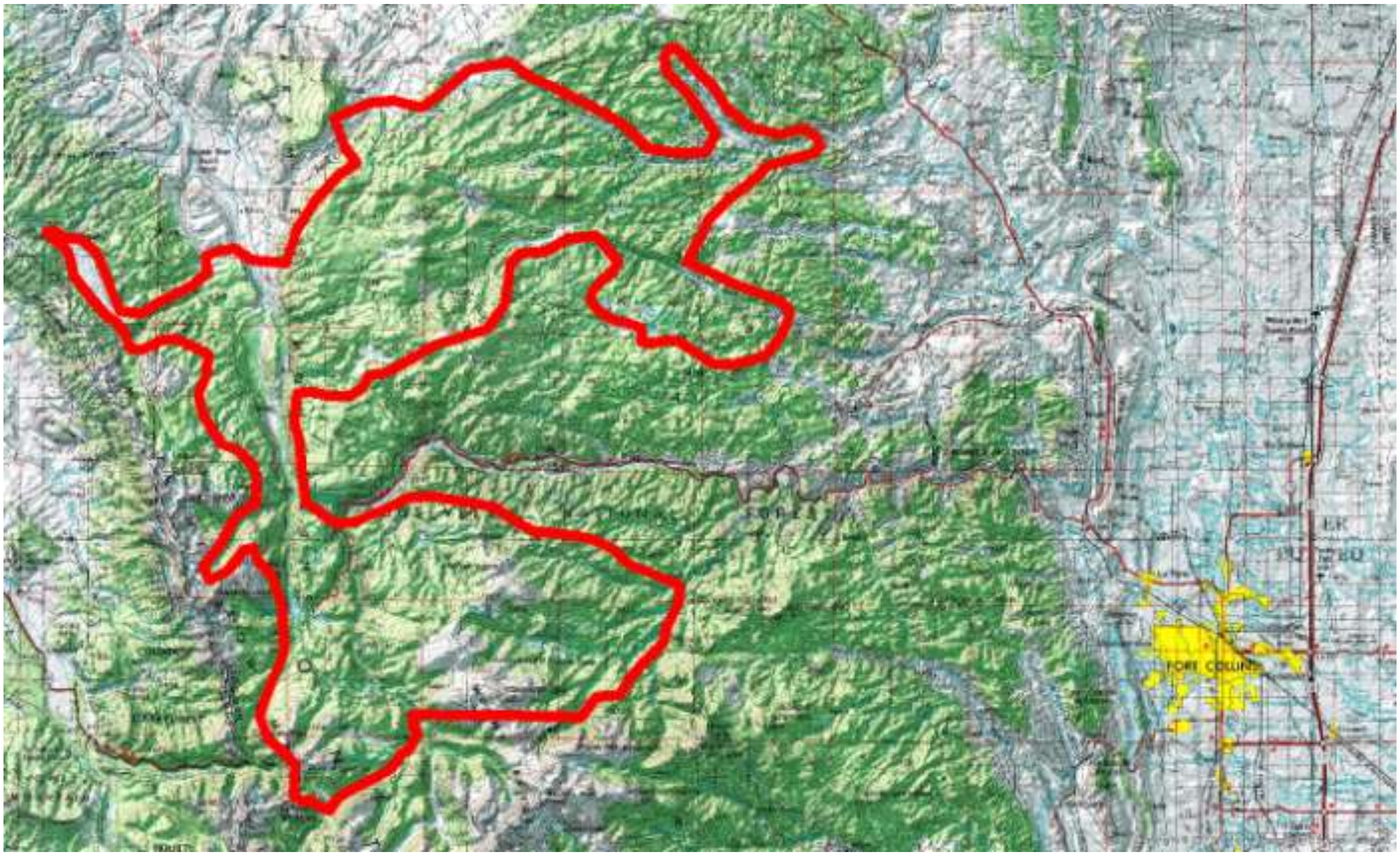

Figure 3. Northeast Colorado moose study area (red polygon), in relation to local communities. The study area is centered on the Laramie River, the upper portions of the Cache la Poudre River, and the Dead Man and Sand Creek areas located to the east of the Laramie River.

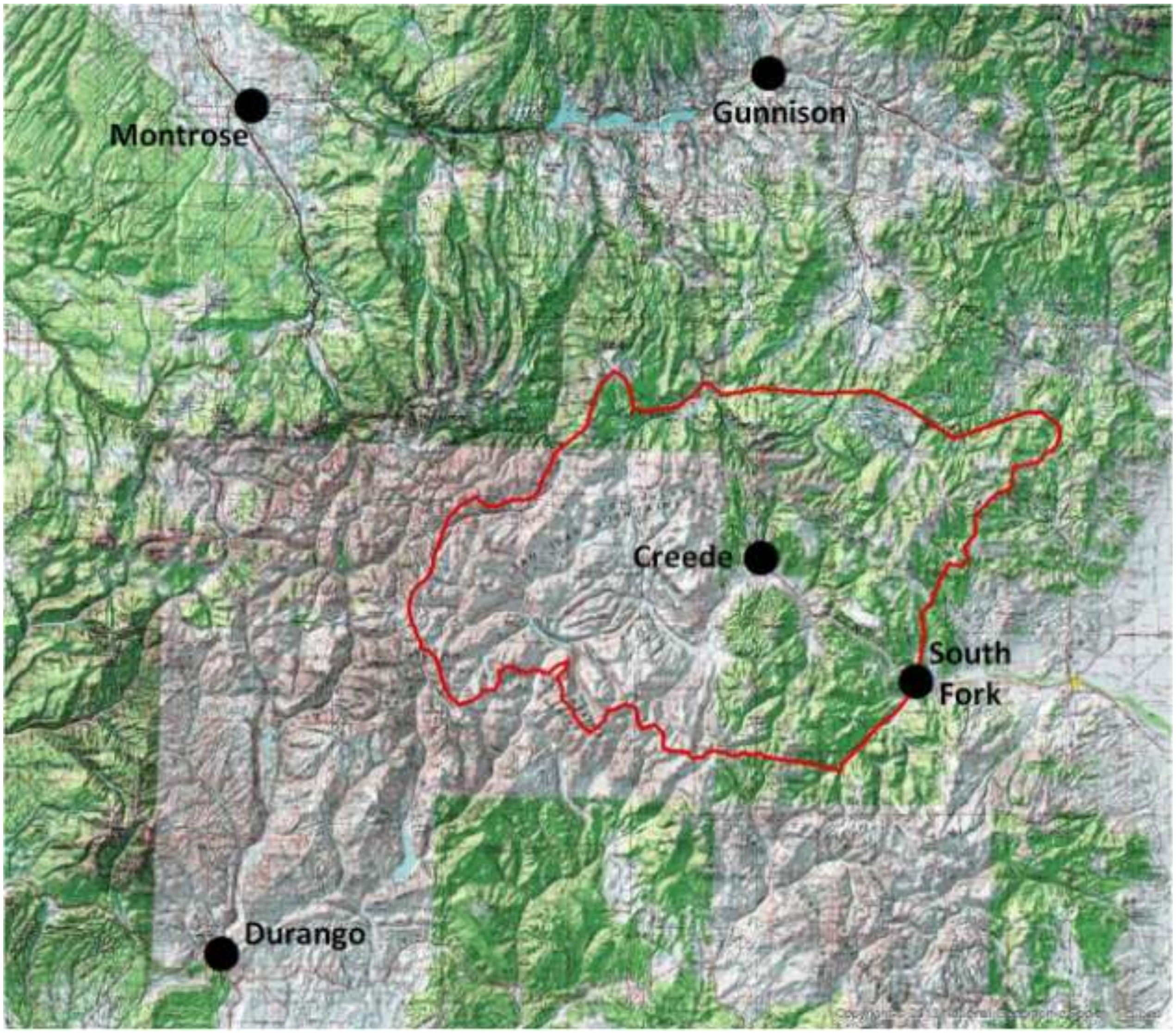

Figure 4. Southwest Colorado moose study area (red polygon), in relation to local communities. The study area is centered on the upper portions of the Rio Grande River, including the Rio Grande Reservoir. As needed, moose will also be captured in the upper portions of Cebolla Creek, and to the east in the vicinity of Carnero Creek. As needed and dependent on approval from the United States Forest Service, moose may also be captured in the Weminuche Wilderness Area to the south of Rio Grande Reservoir and west of the community of South Fork, Colorado.

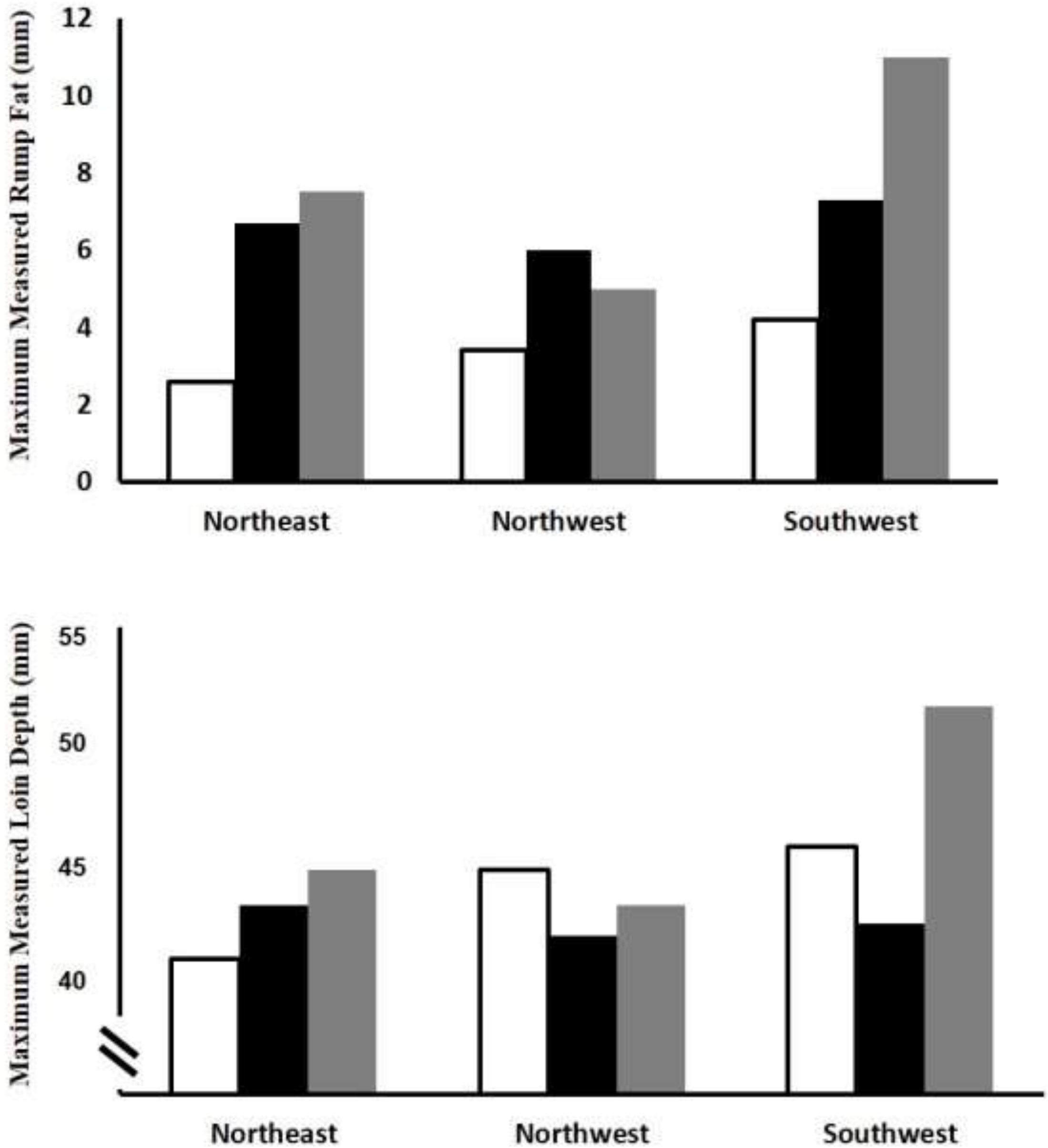

Figure 5. Body condition measurements from adult female moose, collected from 3 study areas and during 3 winters in Colorado. Measurements reflect the mean of maximum measured values among animals for each study area. Mean rump fat estimates are depicted in panel A. Mean loin depth estimates are depicted in panel B. White boxes reflect values from the 2013–2014 winter, black boxes reflect values from the 2014–2015 winter, and gray boxes reflect values from the 2015–2016 winter.

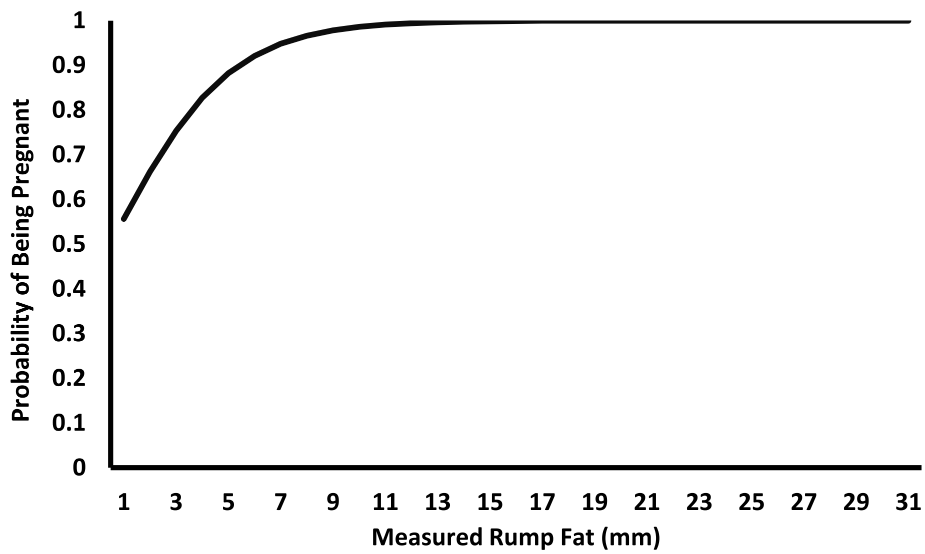

Figure 6. Probability of being pregnant, as predicted by measured maximum depth of rump fat, in moose from 3 study areas across Colorado. Pregnancy status and rump fat measurements were collected during the winters of 2013–2014, 2014–2015, and 2015–2016.