Vital rates, limiting factors and monitoring methods for moose in Montana

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Note: All results should be considered preliminary and subject to change; please contact the authors before citing or referencing these data.

Background and summary

In 2013, Montana Fish, Wildlife, & Parks (MFWP) began a 10-year study designed to improve our understanding of: 1) cost-effective means to monitor statewide moose (*Alces alces*) populations, and 2) the current status and trends of moose populations and the relative importance of factors influencing moose vital rates and limiting population growth (including predators, disease, habitat, and weather). We are using a mechanistic approach to hierarchically assess which factors are drivers of moose vital rates (e.g., adult survival, pregnancy, calf survival), and ultimately influence annual growth of moose populations.

This document is the 8th annual report produced as part of this work. This report contains preliminary results from a subset of our work, including results from the first 7 biological years of moose research and monitoring. All results should be considered preliminary as both data collection and analyses are works in progress.

In this report, we bring special attention to a study of moose genetics we conducted across western North America, as an offshoot of our primary moose studies, focused within Montana. In this study we evaluated the evidence for genetic population structure in North American moose, with specific attention to the designation of Shiras moose as a subspecies. While the Shiras moose of the Rocky Mountain West are notably smaller and less productive compared to their largest relatives in Alaska, genetic analysis indicated moose across western North America are all be quite closely related (more so than other species like deer or caribou). Some local population structure is evident, though likely as a function of recent bottlenecks and range expansions in the past few hundred years. Otherwise, the observed differences in size or productivity were judged more likely to be the result of climate- or habitat-relationships than genetic distinctions.

Moose vital rates measured with collaring studies continue to indicate stable to increasing average annual population trends (Cabinet-Salish, Big Hole Valley and Rocky Mountain Front). These estimated trends are largely driven by adult female survival rates, which have been variable year by year, but generally have averaged moderate rates of 0.87–0.90 over the full study period. Calf survival appears to have less influence on the overall trajectory of the population but does induce variation among study areas and years. For example, while adult survival is highest in the Cabinet-Salish population, calf survival here is its lowest of the 3 areas and is perhaps the most limiting vital rate. While the population appears numerically stable (because of high adult female survival), it is unlikely to show any substantial growth without improved calf survival beyond what we've observed. Monitoring vital rates and limiting factors (predation, disease, and nutrition) will continue for the remainder of this 10-year study.

Web site: We refer readers to our project website for additional information, reports, publications, photos and videos. The direct website for this moose study is: http://fwp.mt.gov/fishAndWildlife/diseasesAndResearch/research/moose/populationsMonitoring/default.html

Or alternatively, go to **fwp.mt.gov**. Click on the "Fish & Wildlife" tab at the top… then near the bottom right click on "Wildlife Research"… and follow links for "Moose".

Location

Moose vital rate research is focused primarily within Beaverhead, Lincoln, Lewis and Clark, Pondera, and Teton counties, Montana. Other portions of monitoring (e.g., genetic and parasite sampling) involve sampling moose from across their statewide distribution.

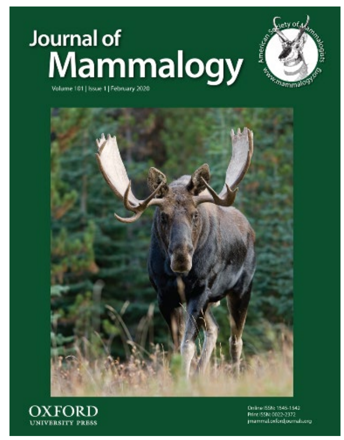
Study Objectives (2019-2020)

For the 2019-2020 field season of this moose study, the primary objectives were;

1) Continue to evaluate moose monitoring data and techniques.
2) Monitor vital rates and limiting factors of moose in three study areas.

Objective #1: *Moose monitoring methods*

1.1. Evaluating genetic support for the Shiras subspecies of moose, *A. a. shirasi*



The taxonomic designation of subspecies is often brought to bear in the management and conservation of species, yet the definition and delineation of subspecies units have suffered from inconsistency across taxa and over time. We recently completed and published a manuscript at the *Journal of Mammalogy* titled "Phylogeography of moose in western North America," which applies a broader lens to the genetic structure of moose in the West. This manuscript received the honor of being featured both as of the cover article of the journal issue, as well as being the topic of the *Editors Choice* essay written by journal editor-in-chief Luis Ruedas (2020).

Specifically, we used both genetics and the fossil record to evaluate the evolutionary history and contemporary relatedness of moose from Colorado up to Alaska. We applied contemporary guidelines of subspecies delineation according to mitochondrial genomics to evaluate the southernmost subspecies of moose, *Alces alces shirasi*. We sequenced the complete mitochondrial genome (*N*=60) as well as 13 nuclear microsatellites (*N*=253) from moose across western North America to evaluate the genetic distinction of moose within the putative range of the *A. a. shirasi* subspecies. Fossil records were consulted to supply phylogeographic context to genetic structure.

Some key results from this study include:

1. Unlike the case for other cervid species (deer, elk, and caribou), there is no firm evidence of moose occurring south of the glacial ice extent prior to the last ice age (Figure 1). While separation by glacial ice has given rise to some notable subspecies distinctions in other cervids (woodland vs. barren-ground caribou; or black-tailed vs. mule deer), there does not appear to be a parallel division among moose. It is thus likely that all moose in western North America originate from colonization(s) and spread into this continent only in the last 15,000 years.

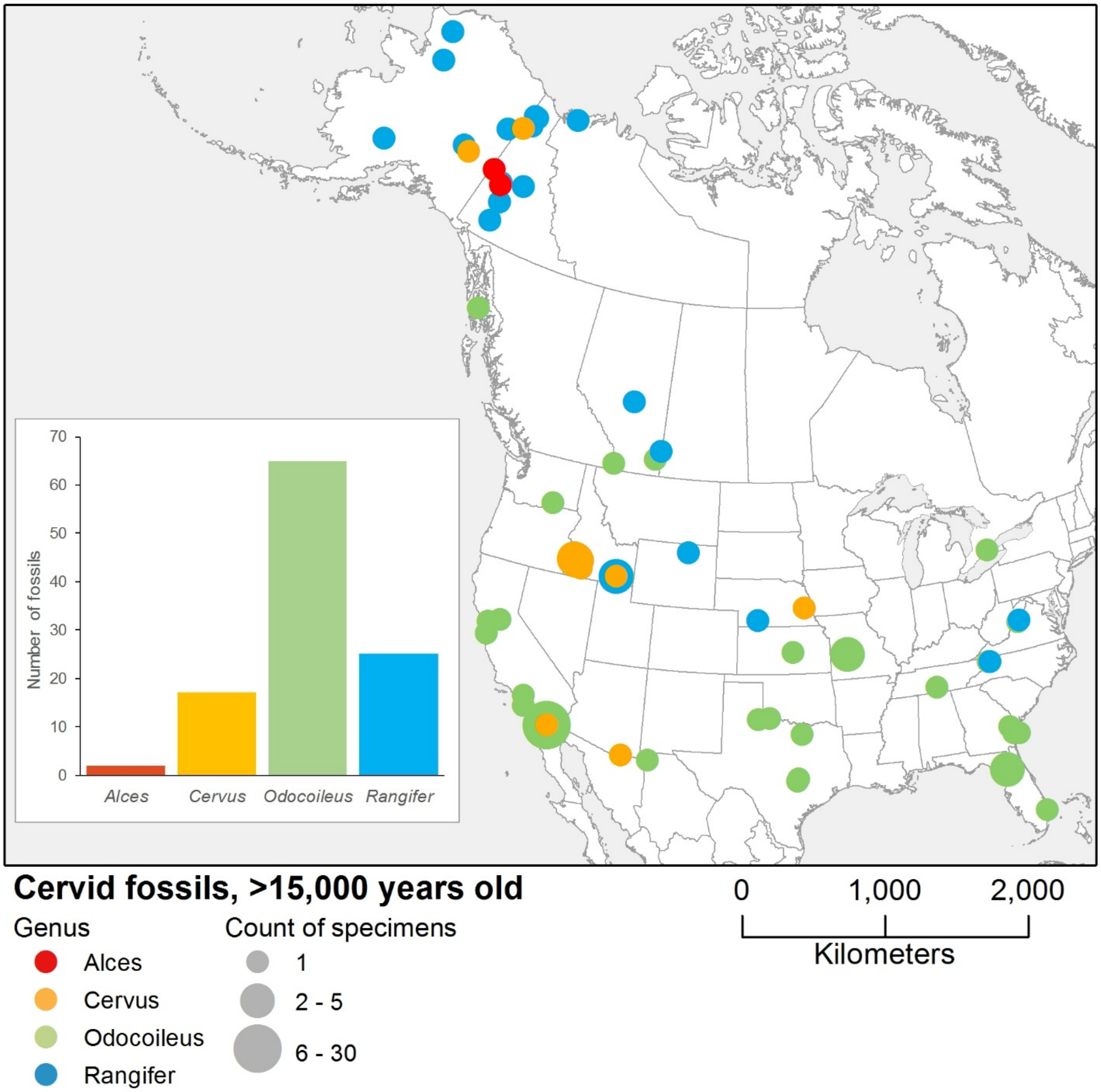


Figure 1. *Quantities and locations of fossil remains in the FAUNMAP database for four North American cervid species, and for which minimum age estimates were ≳15,000 years before present. The key observation here is that moose were not present south of the glacial ice that once spanned most of contemporary Canada.*

2. We also found that mitochondrial DNA suggest close relatedness amongst all moose in western North America. In fact, the same identical mitochondrial genome measured according to all ~16,000 base pairs (mitome #39; Figure 2) was found in moose sampled from several jurisdictions including Colorado, Wyoming, Montana, Washington, and British Columbia.

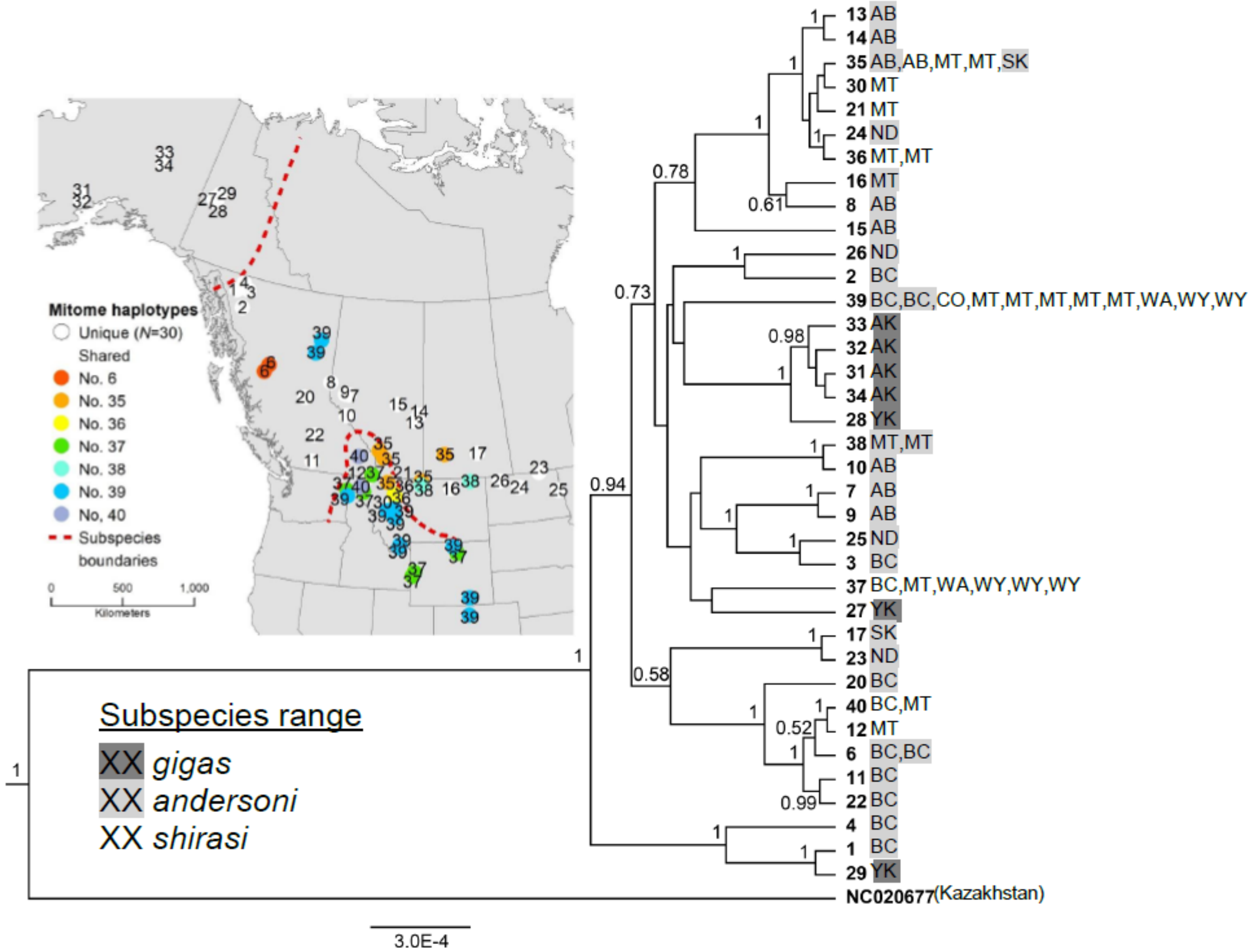


Figure 2*. Bayesian maximum clade credibility tree showing 37 mitochondrial genome haplotypes from 60 moose and an inset of sample locations. Notable here, animals of different subspecies designations in some cases had the same haplotypes; haplotypes in general did not distinctly group by subspecies; and all haplotypes were relatively shallow in their evolutionary history, suggesting only recent divergence.*

3. Finally, despite the lack of evidence for deep divergence amongst moose in western North America, we did find recent structuring of 2 to 5 groups, which likely correspond to bottleneck and colonization events in the past few hundred years. In these results, moose of southwestern Montana lumped together with those of Wyoming and Colorado, while those in northwestern Montana lumped with Canadian populations. This likely mirrors recolonization of moose from distinct source populations (e.g., Yellowstone NP vs. remnant Canadian populations) after Montana's population was nearly extirpated (~100 moose statewide) in the early 1900s.

Objective #2: *Monitor moose vital rates and potential limiting factors*

2.1. Animal capture and handling

In January - February of 2020 we worked with a contracted helicopter capture company (Quicksilver Air) and local landowners to conduct captures and increase the sample of monitored moose. A total of 18 adult females were captured in 3 study areas in 2018, with the goal of maintaining 30 collared animals in each area. Moose were fit with GPS radio-collars (Lotek LifeCycle and Vectronic Survey Globalstar). During 2013–20, we have conducted a total of 205 captures of 180 individual adult female moose, and as of December 1, 2020, 76 are currently being monitored (Table 1, Figure 2). A target sample size of 30 individuals/study area is sought to achieve moderate precision in annual survival estimates, while minimizing capture and monitoring costs.

Table 1. *Captures of adult female moose by study area and year, excluding 6 capture-related mortalities, and the number of adult females being monitored as of December, 2020.*

	Study Area			
	Cabinet-Salish	*Big Hole Valley*	*Rocky Mtn Front*	*Total*
2013 captures	11	12	11	34
2014 captures	7	20	8	35
2015 captures	13	6	7	26
2016 captures	0	4	6	10
2017 captures	10	7	9	26
2018 captures	7	8	11	26
2019 captures	8	6	10	24
2020 captures	8	6	4	18
Total captures	**56**	**63**	**62**	**199**
Moose currently on–air	26	26	24	76

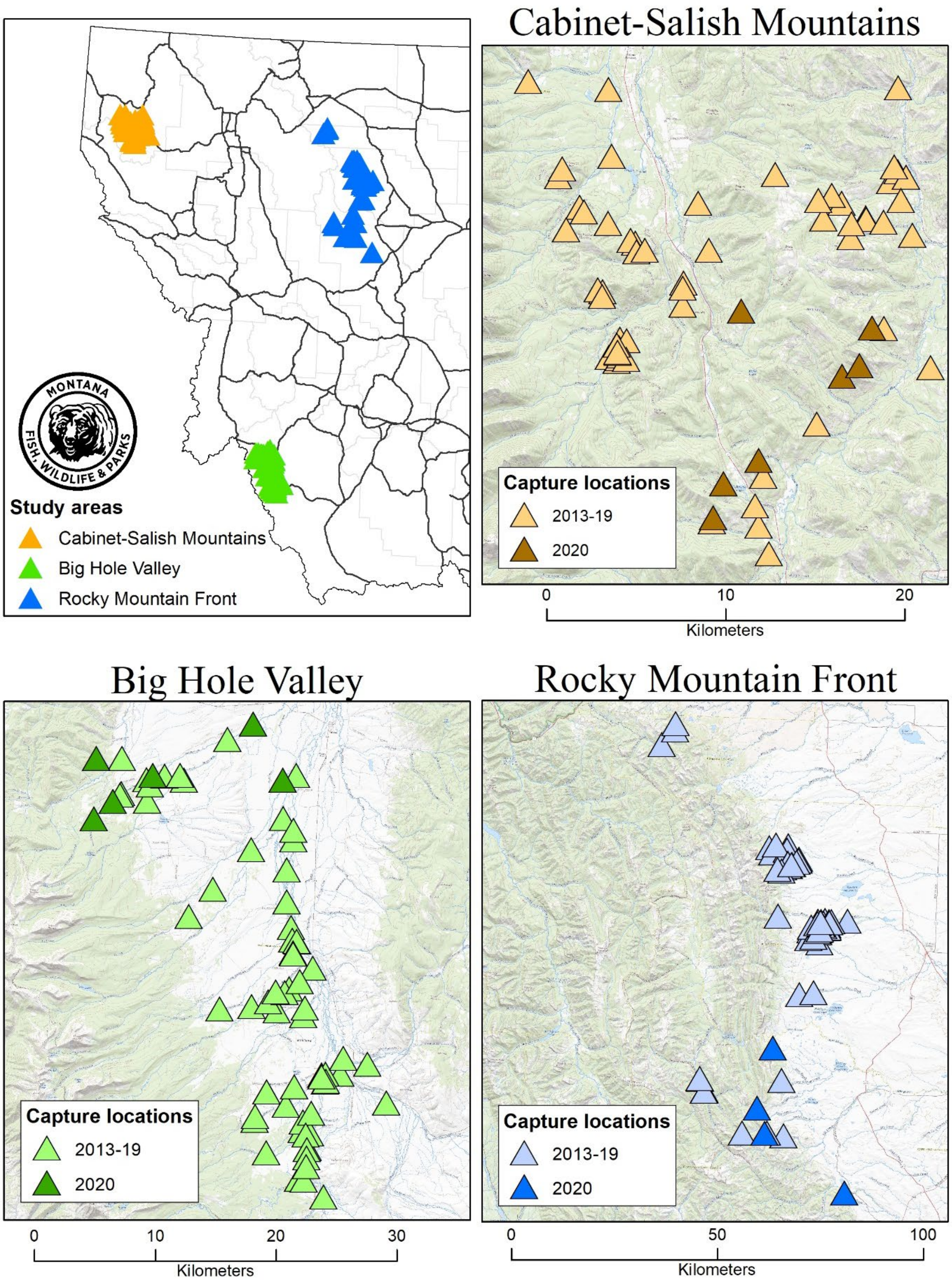


Figure 2. *Moose winter capture locations during 2013–2020 across 3 study areas in Montana.*

2.2. Monitoring vital rates

2.2.1. *Adult female survival*.— Our study of adult female survival to date includes 141 radio-collared adult female moose and 466 animal-years of monitoring, with a staggered-entry design of individuals entering into the study across 6 winter capture seasons (*see* 2.1 Animal capture and handling). Animals have been deployed with both VHF (N=76) and GPS (N=86) collars. We estimated Kaplan-Meier annual survival rates for each study area during each biological year as well as across the 5 biological years pooled together in a recurrent-time format.

Pooled annual survival estimates across the entire monitoring period for each study area were 0.896 (SE=0.021, 95% CI=[0.86,0.94]) in the Cabinet-Salish, 0.868 (SE=0.024, 95% CI=[0.82,0.92]) in the Big Hole Valley, and 0.886 (SE=0.022, 95% CI=[0.84,0.93]) on the Rocky Mountain Front (Figure 3). In comparison to these 7-year averages, survival during the 2019-20 biological year was higher than average in all 3 study areas, the Cabinet-Salish (0.93), Big Hole Valley (0.89), and Rocky Mountain Front (0.93). While differences among study areas appeared more pronounced during the early years of this study, the mean estimates in each area have gradually grown closer to one another as we continue to accumulate data. These estimates do not account for differences in age distribution of our collared sample, which we will address in more detail upon completion of the study (Prichard et al. 2012).

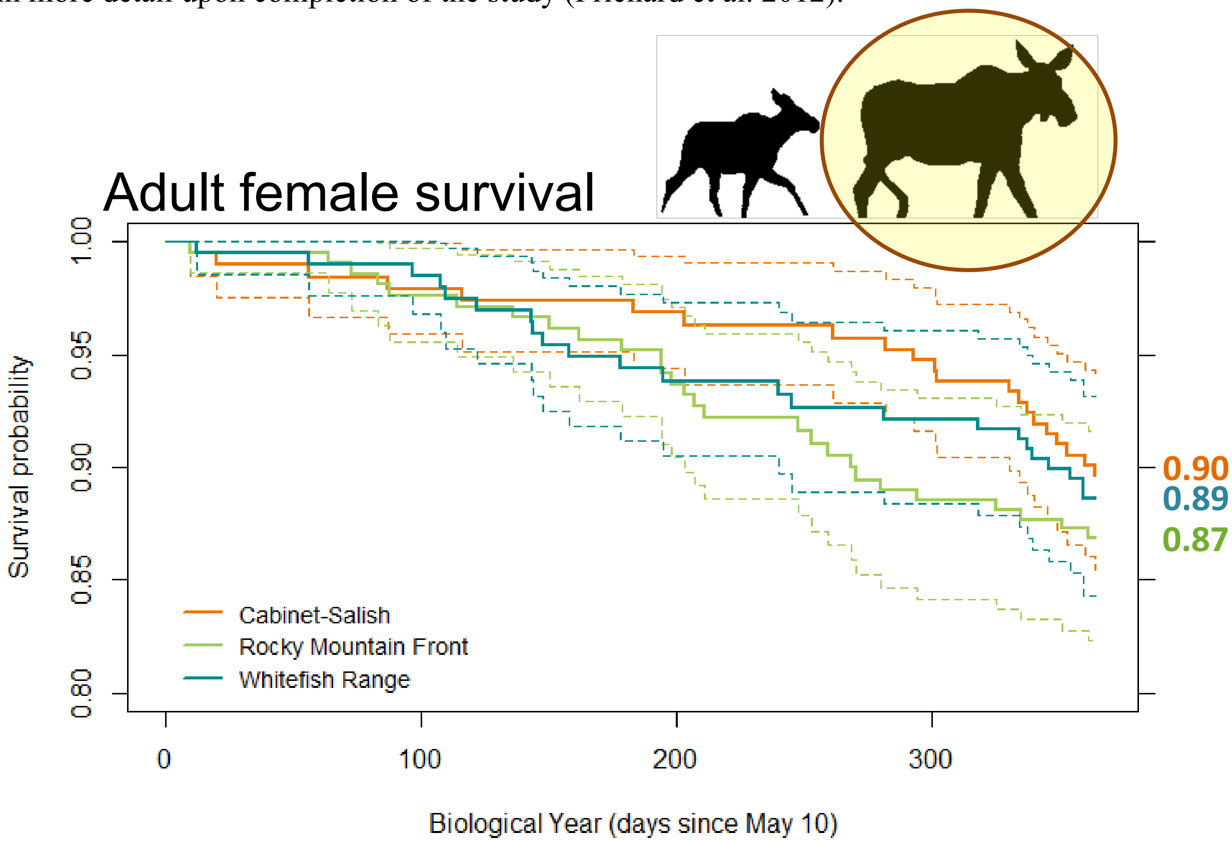


Figure 3. *Kaplan-Meier estimates and 95% confidence limits of annual adult female survival within each study, across 7 biological years for each study area, Montana, 2013–2020.*

During 7 biological years of monitoring, we have documented 71 mortalities of collared adult moose across all study areas: 21 in the Cabinet-Fisher, 27 in the Big Hole Valley and 23 in the Rocky Mountain Front (Figure 4). While determining the causes of adult female moose mortality was not initially a key objective of this study, the relatively high proportion of health-related (non-predation) mortalities has prompted greater emphasis on prioritizing collar technology and staff time to document cause of death when logistics permit.

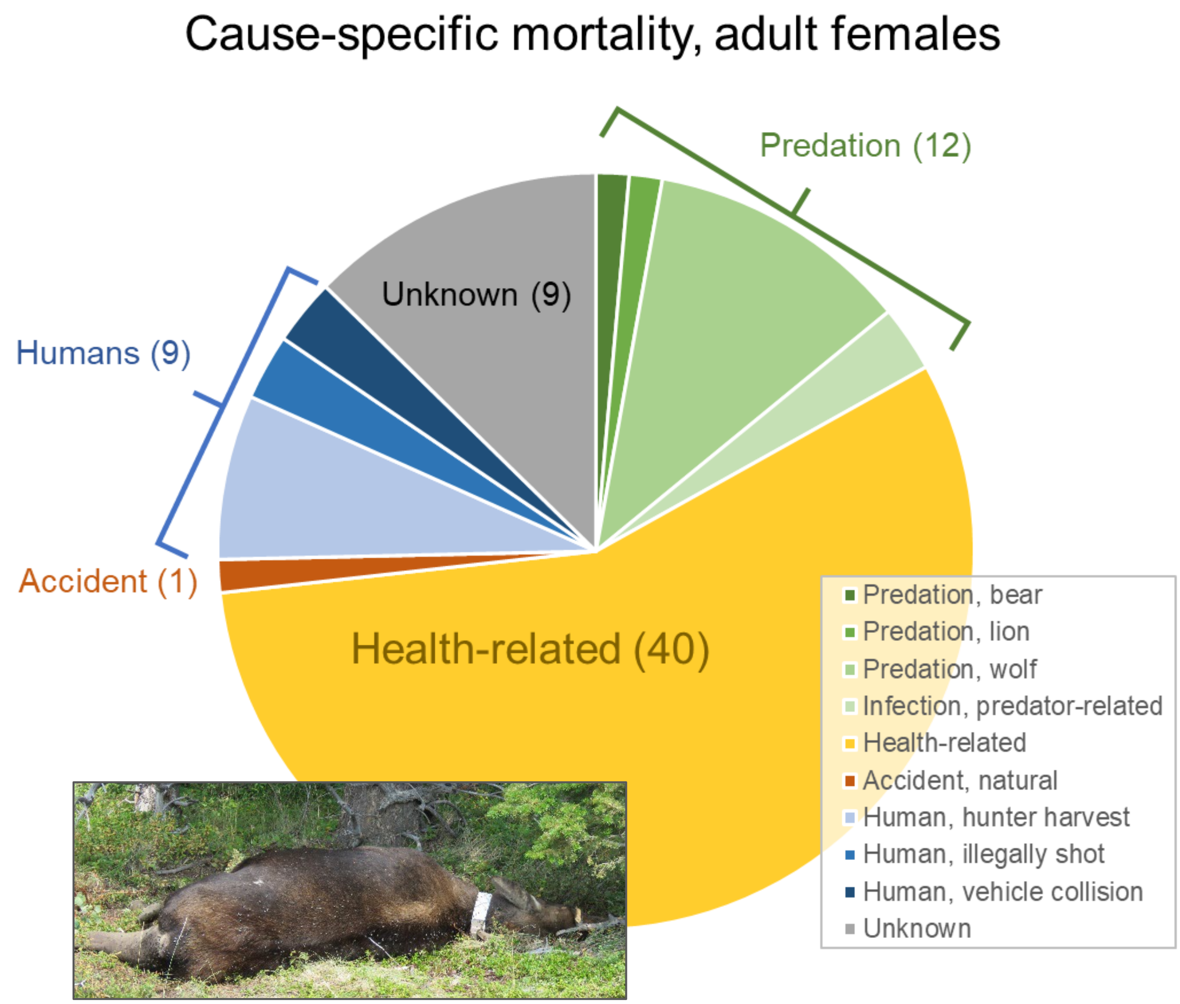


Figure 4. *Counts of radio-collared adult female moose by cause-of-mortality across all 3 focal study areas. Note, this summary does not account for variations in sample size and timing that can affect the perceived relative risk to each cause. Such concerns will eventually be accounted for using formal cumulative incidence analyses as part of this study.*

2.2.2 Calf survival.— We decompose calf survival into 2 components: 1) observed parturition rate – the proportion of pregnancies that result in a neonate calf-at-heel during spring; and 2) calf survival – the proportion of documented calves that survive through their first year of life.

Observed parturition rates: Following winter pregnancy testing, we use weekly aerial telemetry flights during 15 May – 15 July to estimate an "observed parturition" rate, representing the proportion of pregnant cows with neonate calves each spring. One limitation to this approach comes with the unknown proportion of the true number of calves born that die before we visually confirm them. Thus, our sample for subsequent study of calf survival is left truncated (Gilbert et al. 2014), and our Kaplan-Meier based estimates of calf survival should be considered as optimistic to the extent that they don't account for mortality of calves prior to initial detection. Observed parturition rates have been higher in the Big Hole Valley (87%) and Rocky Mountain Front (91%), and lower in the Cabinet-Fisher (77%; Figure 5). These results are similar to those of other studies (e.g,, Becker 2008) where parturition rates are lower than pregnancy rates due to presumed fetal losses throughout winter and/or death of neonatal calves prior to detection.

Calf survival: As a result of spring monitoring of neonate calves, we have documented 372 calves from 341 litters during 2013–2019. We then monitored the fates of these calves by visually locating them with their dams throughout their first year of life. Over the first 7 biological years (May 2013 – May 2020), pooled Kaplan-Meier survival estimates of calves-at-heel were 0.393 (SE=0.048, 95% CI=[0.31,0.50]) in the Cabinet-Fisher, 0.446 (SE=0.046, 95% CI=[0.37,0.55]) in the Big Hole Valley, and 0.490 (SE=0.044, 95% CI=[0.41, 0.58]) on the Rocky Mountain Front (Figure 5). Calf survival results mirror those of observed parturition, suggesting observed parturition rates are strongly influenced by mortality of neonates prior to detection, more so than fetal losses.

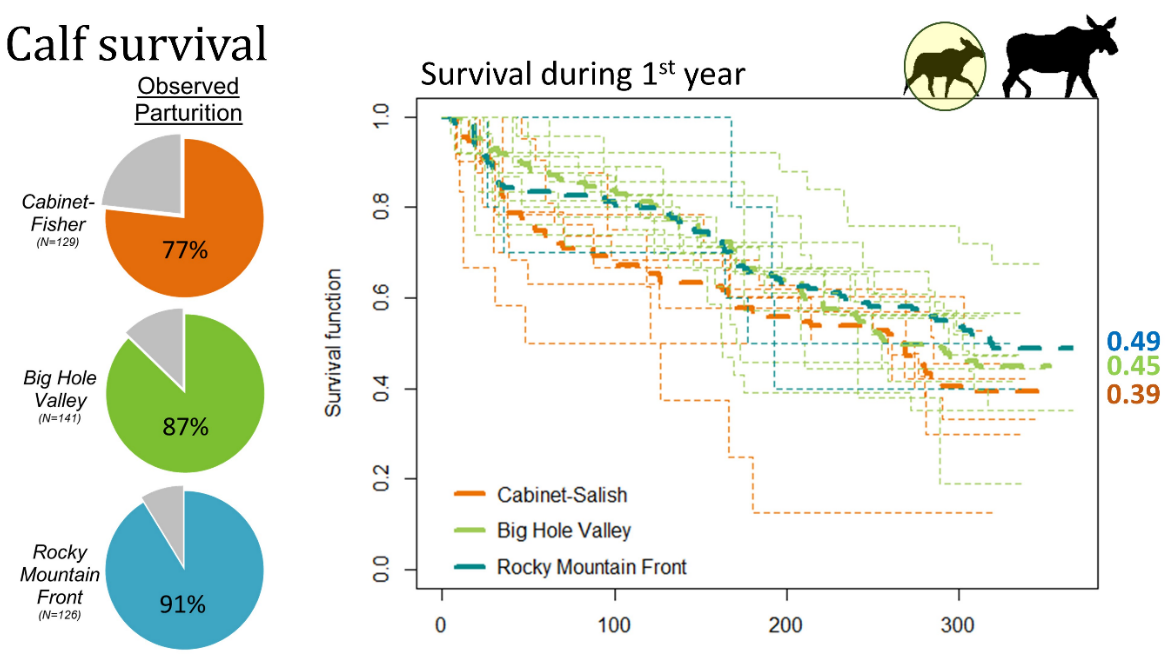


Figure 5. *Observed parturition (proportion of pregnant cows with calves-at-heel during spring) and Kaplan-Meier estimates of annual calf survival for the first year of life within each study area, where bold lines are pooled estimates across 7 biological years and thin lines are annual estimates per year, Montana, 2013–2020.*

2.2.3 Adult female fecundity.—Fecundity for moose is the product of age-specific pregnancy rates and litter size. We monitor pregnancy of animals during winter with laboratory analyses of both blood (serum PSPB levels; Huang et al. 2000) and scat (fecal progestagens; Berger et al. 1999, Murray et al. 2012). To estimate pregnancy in absence of handling animals each winter, we use fecal progestagens from samples collected via ground-tracking.

Pregnancy rates: Pooled across 3 study areas, 6 years (2013-2018), and 417 animal-years of monitoring, the average adult (ages ≥2.5) pregnancy rate was 82%, varying from 80–85% across study areas (Figure 6). Yearling (age 1.5) pregnancy rates appear to vary by region, with 0% pregnancy in both the Cabinet-Fisher and Big Hole Valley study areas compared to 36% yearling pregnancy on the Rocky Mountain Front; however, sample sizes for yearling pregnancy are small (N = 3, 8, and 14 in the 3 areas, respectively).

Observed twinning rates: Moose are capable of giving birth to 1–3 calves, though litters are most commonly composed of either 1 or 2 calves (Van Ballenberghe and Ballard 2007). Twinning rates in North American populations can vary from 0 to 90% of births (Gasaway et al. 1992), with variation linked to nutritional condition (Franzmann and Schwartz 1985) and animal age (Ericsson et al. 2001). Twinning rates for Shiras moose are typically low (e.g., <15%; Peek 1962, Schladweiler and Stevens 1973, Becker 2008). Thus far our observed twinning rates are 9% in the Cabinet-Fisher (N=107 litters), 1% in the Big Hole Valley (N=124 litters), and 21% in the Rocky Mountain Front study areas (N=136 litters; Figure 6).

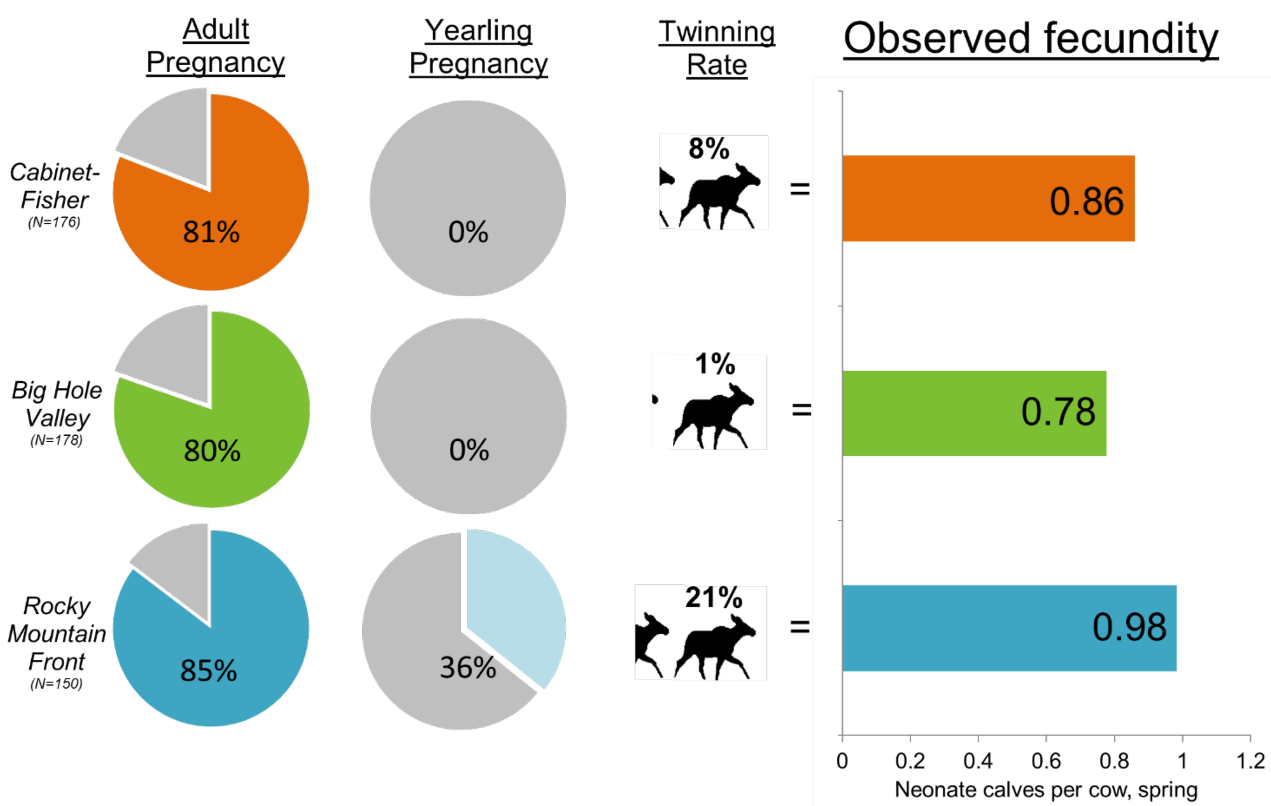


Figure 6. *Estimated adult (age≥2.5) pregnancy rates, yearling (aged 1.5) pregnancy rates, observed twinning rates, and net observed fecundity of calves per adult female in 3 study areas of Montana during 7 biological years, 2013–2019.*

2.2.4. Population growth rates. The overall status of a population may be best characterized by the annual growth rate. This parameter can be estimated by inserting key vital rates into mathematical models, most importantly the annual survival of adult females and the per capita number of calves born and surviving their first year. We estimated recruitment per cow as the integrated product of pregnancy rates, parturition rates, litter size, and calf survival rates. We then estimated annual population growth rates, following DeCesare et al. (2012), for each study population across the first 6 biological years, 2013–2019 (Figure 7).

Given the high elasticity of adult female survival in long-lived, iteroparous species (Eberhardt 2002), adult female survival is the most important vital rate for determining population growth rates. High adult survival, on average, in the Cabinet-Fisher translated to a mean population growth rate of 1.01, or an 1% increase per year, despite consistently seeing the lowest calf survival of all 3 areas. The Rocky Mountain Front moose have seen very high survival rates of both adults and calves as well as high fecundity of adults, resulting in an estimated annual growth rate of 1.12. While vital rates in the Big Hole Valley population were indicative of a declining population for several years, higher adult survival in recent years has increased the overall average to show a stable to increasing population growth rate (1.02) for the first time of the study.

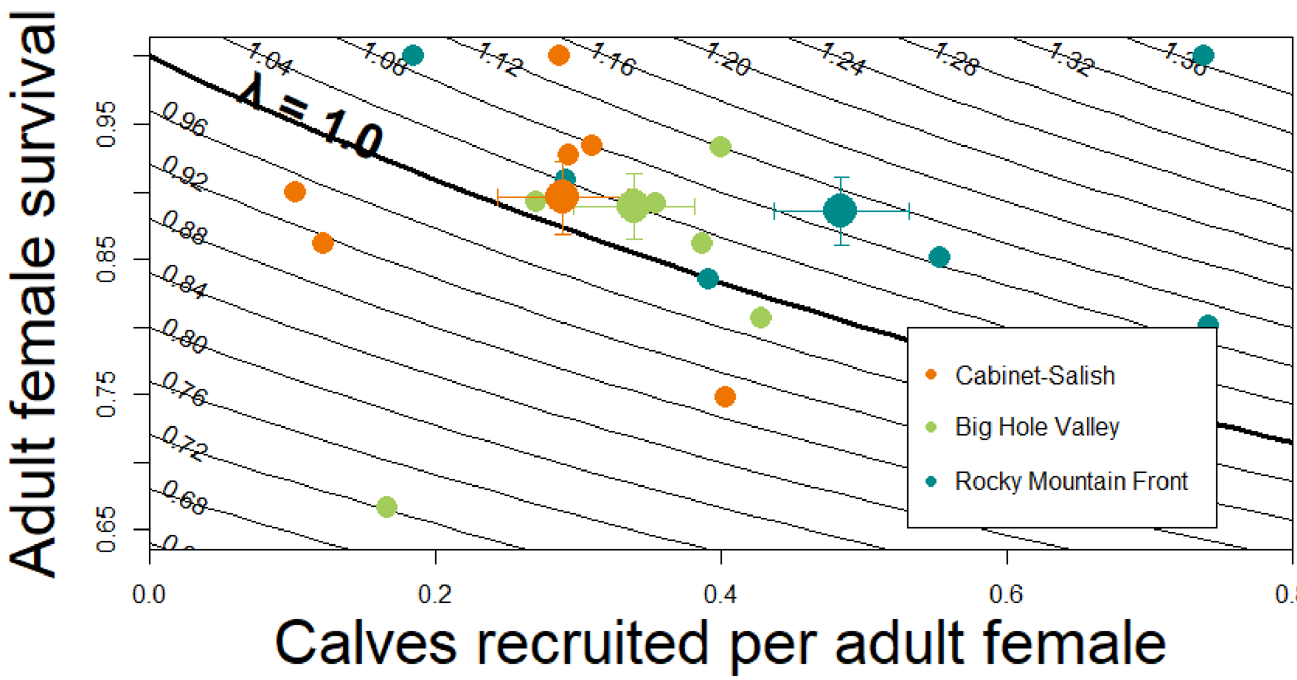


Figure 7. *Contour plot showing the estimated mean annual population growth rates (λ, represented as contour lines) resulting from two-dimensional combinations of adult female survival and spring recruitment of calves (integrating rates of pregnancy, parturition, litter size, and calf survival through the first year). Smaller dots show annual rates for each of 7 biological years, and larger dots and error bars show the pooled averages and standard errors, 2013–2020. Growth rates above the bold line (where λ = 1) indicate a growing population, growth rates below λ = 1 indicate declining populations. Results are preliminary and subject to change.*

2.3. Monitoring nutritional condition, antler spreads, and rutting behavior with the voluntary help of moose hunters

<u>*2.3.1. Hunter-based sampling of nutritional condition.*</u>
(Note, we are waiting for age results from samples collected in 2019. Results for fat measurement and antler spread x age have not been updated since the 2019 report)

Nutritional condition of ungulates can impact both survival (Roffe et al. 2001, Bender et al. 2008) and fecundity (Testa and Adams 1998, Keech et al. 2000, Testa 2004), and generally provides an indication of the extent to which habitat condition and density dependent effects drive ungulate dynamics (Franzmann and Schwartz 1985, Bertram and Vivion 2002). Rump fat thickness has a strong linear relationship with total body fat in moose (Stephenson et al. 1998).

Moose hunters measured rump fat by marking a toothpick within provided sampling kits for 393 bull and 47 cow moose. Before comparing fat measurements across regions of Montana, we first assessed the relationship between the date each moose was harvested and its respective fat levels, as bull moose are known to lose fat with high energy expenditure during the rutting season (Cederlund et al. 1989). While there was much variation, we found a significant and consistent loss in rump fat depth among bull moose during each of the 5 years ($P<0.001$), whereas fat among cows did not change with day of season ($P=0.68$; Figure 8).

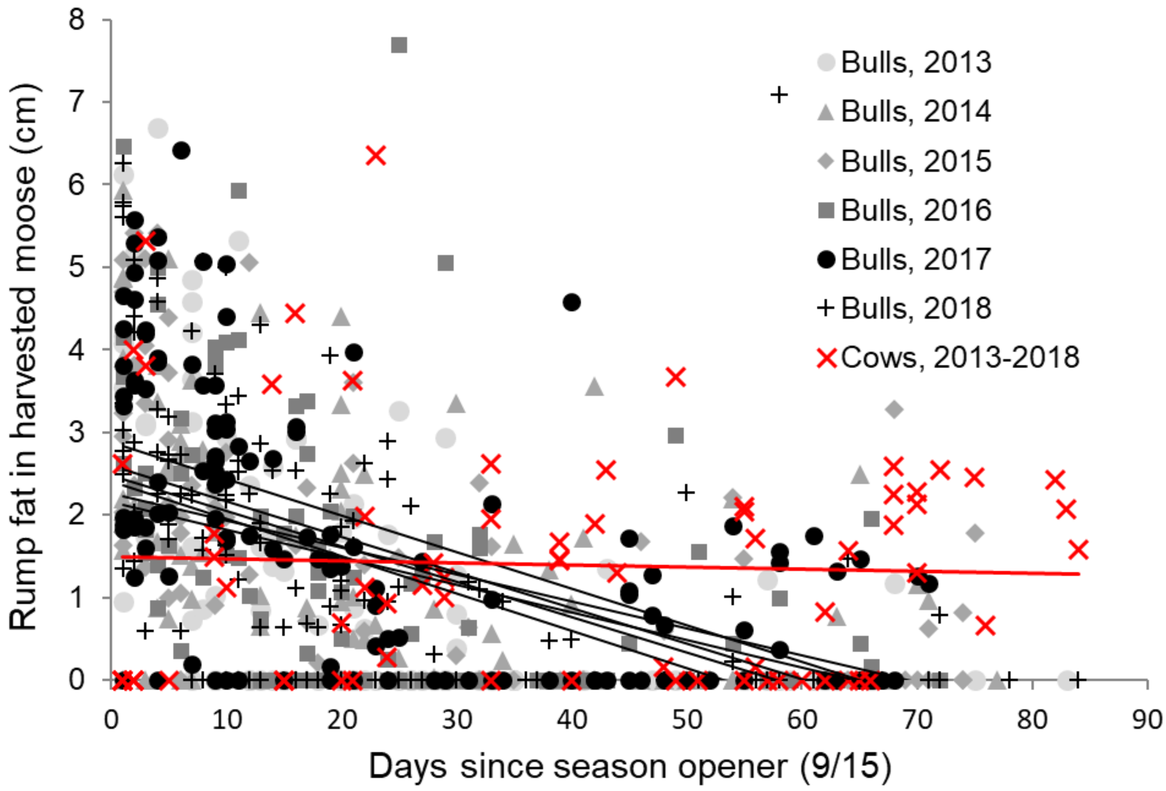


Figure 8. *Depth of rump fat declined consistently among harvested bull moose according to the date of harvest during the past 6 hunting seasons (see 6 black trend-lines), whereas average fat depths among cow moose did not significantly change (red trend-line) during the hunting season, Montana, 2013–2018.*

After assessing how average fat levels changed during the season, we compared observed measurements of fat for each moose to the average expected amount of fat following the trend lines in Figure 8. We then estimated the residuals between observed and predicted values, where a positive value suggested an animal with more fat than expected given the date of harvest, and a negative value an animal with less fat than expected. We compared these residual values among all MFWP regions and found no evidence for statistical differences in the nutritional conditions of bull moose among regions (Figure 9). However, we did find evidence of a difference in the rate at which bulls deplete their fat stores, according to their size (Figure 10). We also found evidence that moose increase in antler spread size up until about the age of 6 years old, at which point antler spreads generally are not affected by age (Figure 11).

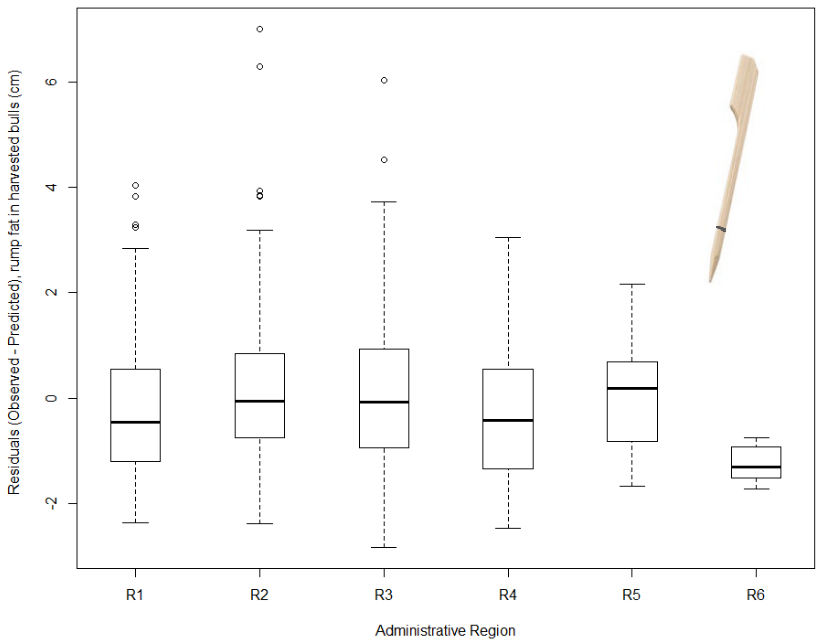


Figure 9. *Average residual values comparing the thickness of rump fat in hunter-killed moose among regions while controlling for the date of harvest. These data were collected by hunters by marking a toothpick (inset photo) included in sampling kits mailed to all license-holders, Montana, 2013–2018.*

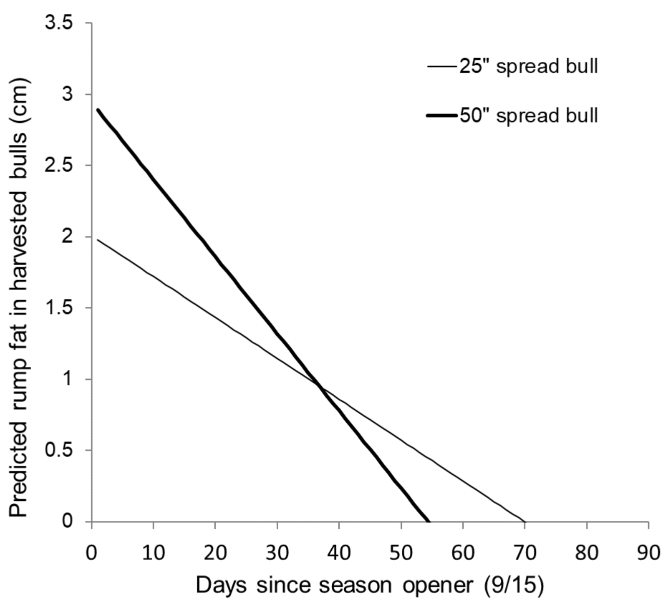


Figure 10. *We also continue to find evidence from hunter-collected measurements of both rump fat and antler spread that larger bulls generally start the rutting season with more fat, but deplete their fat stores at a faster rate than smaller bulls, ending the rut in poorer nutritional condition, Montana, 2013–2018.*

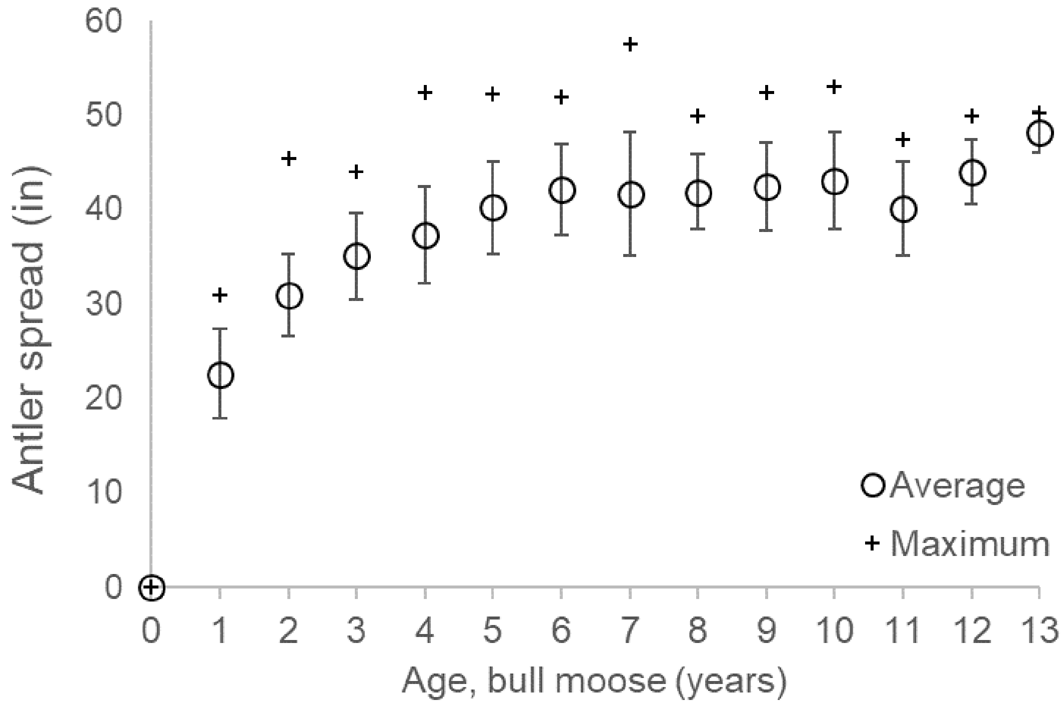


Figure 11. *Hunter self-reported, unofficial, antler spreads (inches) show a gradual increase in the average spread across all moose statewide until about the age of 6, at which point average antler spread holds steady with age.*

2.3.2. Hunter-based monitoring of the rut

For the lucky few (1.1% of applicants for the 2020 season) who draw a moose license each year, one of the first considerations in hunt planning is the timing of the rut for moose in Montana. Mean breeding dates for moose in other studies have included October 5–10 in British Columbia, September 29 in Manitoba, and October 5 in Alaska (Schwartz 2007). During 2016–19, we asked moose hunters to mark on a calendar which days they hunted, and which days they observed rutting activity by moose (e.g., calling, sparring, wallowing). We have received samples and/or information from roughly 150 hunters each year, including the recording of 5,098 hunter-days and 738 observations of rutting activity. Hunter-days decrease gradually throughout the season each year, with recurrent weekly spikes of hunting activity during weekends (Figure 12). To the contrary, the proportion of hunters observing rutting activity increased until the first week of October across all years, after which it declined through the middle of October (Figure 12). These observations are in accordance with our estimates of peak breeding based on estimated average parturition dates for radio-collared cows (May 23rd) and a 231-day gestation (Schwartz & Hundertmark 1993).

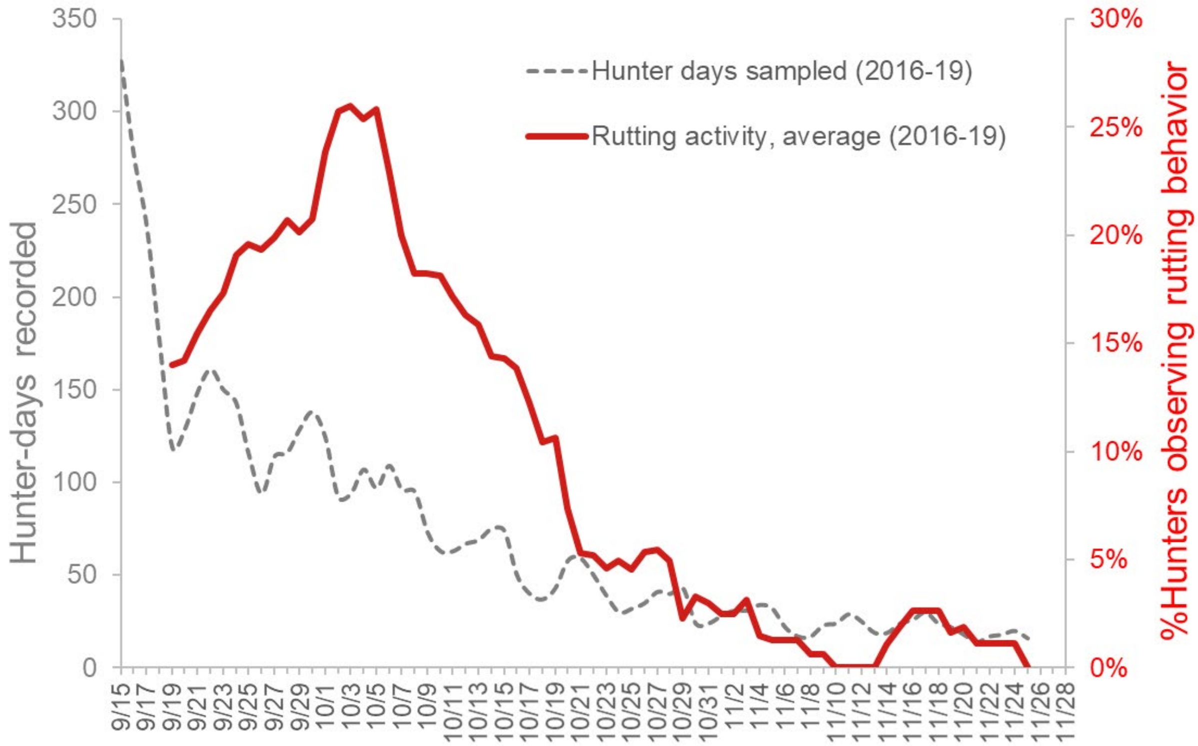


Figure 12. *Hunter-days recorded from voluntary return of data cards and proportion of hunters observing moose rutting activity (using a 5-day moving average) throughout the hunting season, 2016-19, Montana.*

2.4. Multi-species predator occupancy

Predation is among the hypothesized factors potentially limiting moose vital rates in Montana, and the extent to which predation limits moose populations is of widespread interest. Past research has found predation by grizzly bears, black bears and wolves could have potentially significant effects on moose populations, under some circumstances (Messier and Crête 1985, Larsen et al. 1989, Ballard et al. 1990). In addition, mountain lions are known to predate on moose and even coyotes may take calves (Ross and Jalkotzy 1996, Bartnick et al. 2013, Benson and Patterson 2013). Given the potential role of these carnivores in moose population dynamics, and perhaps more importantly the effects of the predator guild as a whole (Sih et al. 1998, Griffin et al. 2011, Keech et al. 2011), we are assessing the relationship between predator densities and moose vital rates. Camera trapping is a promising means of obtaining estimates of occupancy and relative density for multiple species simultaneously in a manner that is non-invasive and cost-effective (Rovero & Marshal 2009, Brodie et al. 2014, Steenweg et al. 2016). Accurate estimates of annual abundances of each predator species would be ideal; however, a precise index which detects spatial and temporal heterogeneity in predator abundance/activity would also be useful in assessing the potential influence of predators on moose vital rates (Parsons et al. 2017, Keim et al. 2019). Our camera trapping efforts were designed to use occupancy-based models and their extensions to estimate probability of occurrence over the study areas (Royle 2004, Brodie et al. 2014, Fiske & Chandler 2017).

Since September 2015 we have continuously operated remote camera grids on 3 moose field study areas to evaluate the ubiquity of predators, and the relationship between predator populations and moose vital rates. Remote cameras are deployed year-round in randomly selected cells within the trapping grid (Figure 13). Within the selected cell, unbaited cameras sets are established on trails, closed roads and other travel routes to maximize detection of multiple carnivore species. Local landowners and managers have played an important role in the successful implementation of this research component. Along with providing access to areas, landowners and managers have contributed their knowledge and participation in field work to successfully establish and maintain camera sets. This work continues to foster new and existing relationships with landowners and managers in these areas.

As of September 2020, we have deployed remote cameras at 141 sites (44 sites Cabinet-Salish study area; 51 Rocky Mountain Front study area; 46 Big Hole Valley study area) 85 of which are currently active (30 Cabinet-Salish; 28 Rocky Mountain Front; 27 Big Hole Valley). To date we have retrieved and stored >5 million images spanning ~125,000 active camera trap-days. Classification of images to species, with focus on carnivore detections, is ongoing (Figure 14).

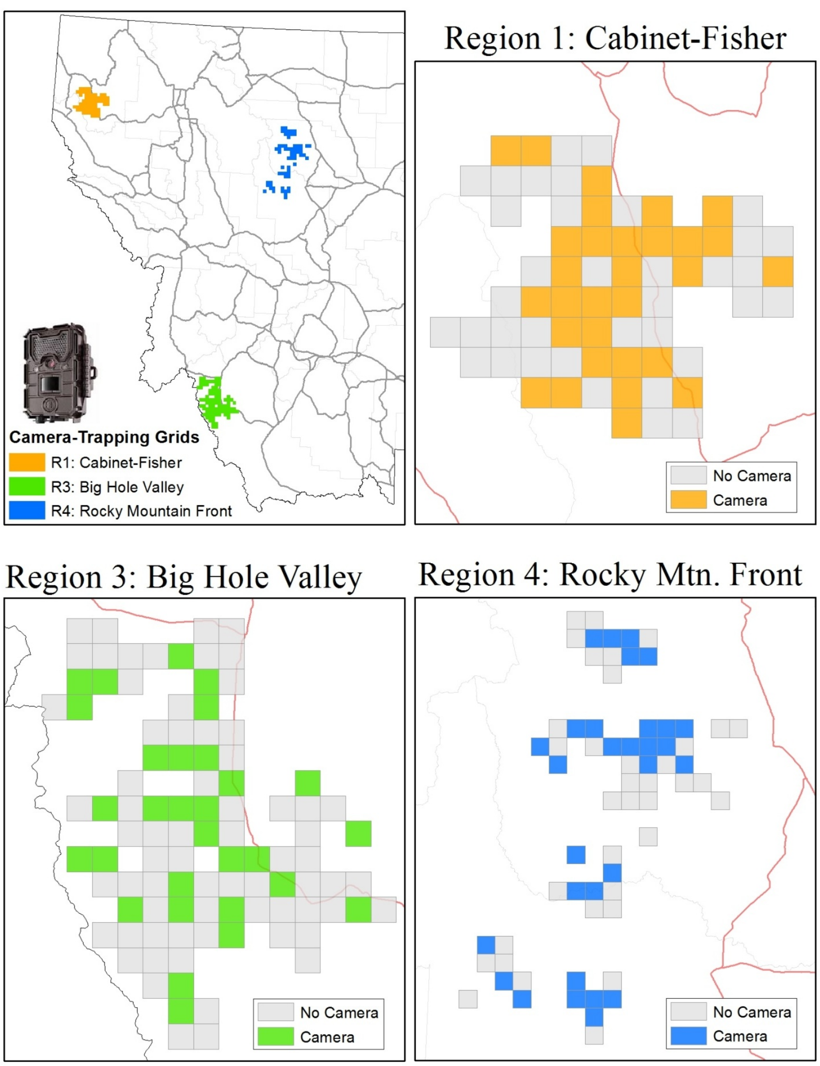


Figure 13. *Sampling grids (2 x 2 miles) for deployment of remote cameras for monitoring multi-species predator occupancy across areas occupied by moose.*

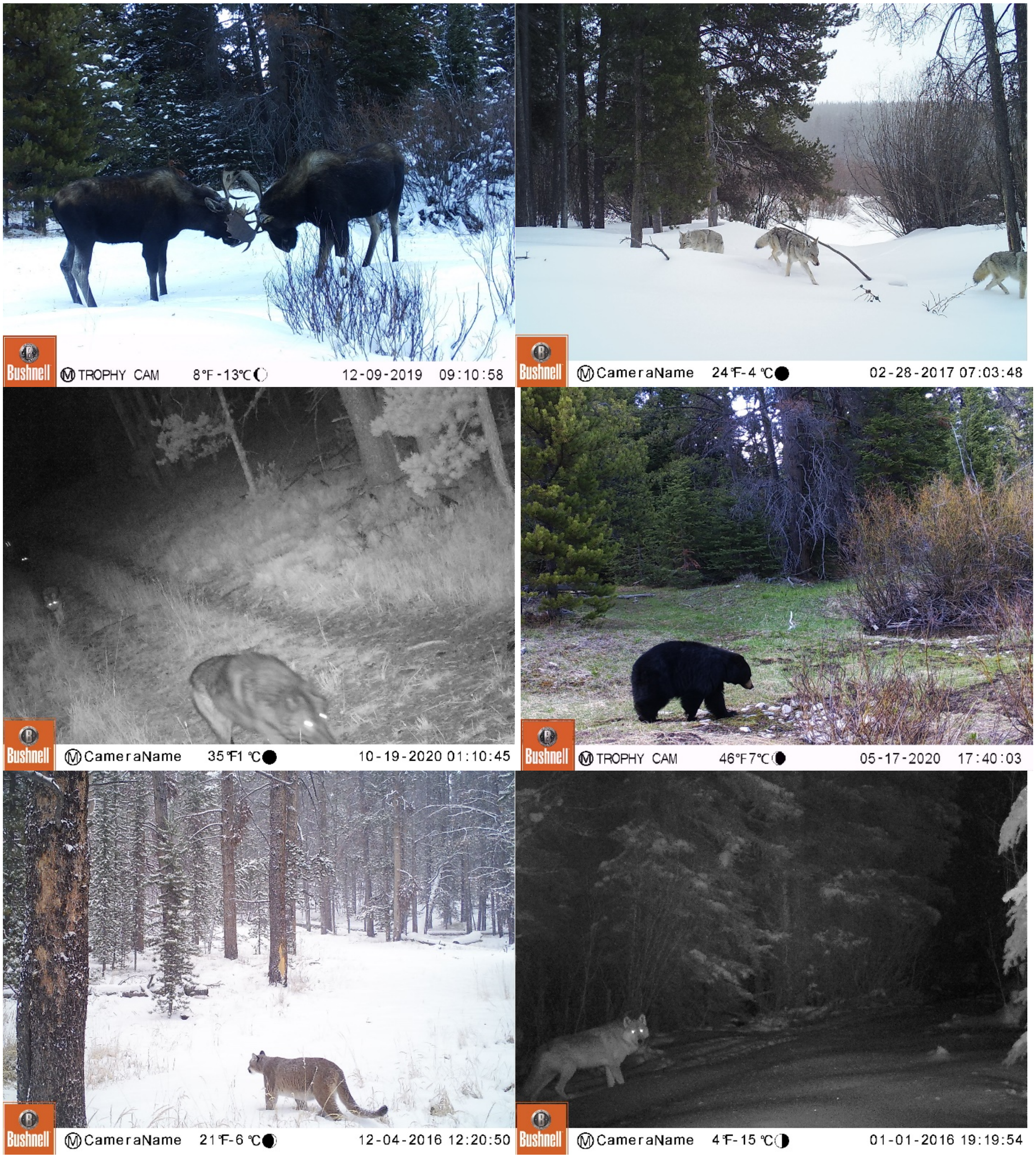


Figure 14. *Example photos from remote camera-traps set within seasonal ranges of each moose study area to monitor multi-species occupancy of carnivores 2015–2020, Montana.*

Deliverables

Below we list project deliverables (publications, reports, presentations, media communications, and value-added collaborations) stemming from this moose research project, during FYs 13–19 (July 2012–June 2019). In addition to those communications listed below, are frequent discussions with moose hunters statewide. Copies of reports and publications are available on the moose study's website (note: the web address is case-sensitive): http://fwp.mt.gov/fishAndWildlife/diseasesAndResearch/research/moose/populationsMonitoring

1. **Annual Reports**:

2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020. DeCesare, N. J., and J. R. Newby. *Vital rates, limiting factors and monitoring methods for moose in Montana*. Annual reports, Federal Aid in Wildlife Restoration Grant W-157-R-1 through R-7.

2. Peer-reviewed Publications

Burkholder, B. O., N. J. DeCesare, R. A. Garrott, and S. J. Boccadori. 2017. *Heterogeneity and power to detect trends in moose browsing of willow communities*. Alces 53:23–39.

DeCesare, N. J., T. D. Smucker, R. A. Garrott, and J. A. Gude. 2014. *Moose status and management in Montana*. Alces 50:31–51.

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3. Other Publications

DeCesare, N. J. 2013. *Research: Understanding the factors behind both growing and shrinking Shiras moose populations in the West*. The Pope and Young Ethic 41(2):58–59.

DeCesare, N. J. 2014. *Conservation Project Spotlight: What and where are Shiras moose?* The Pope and Young Ethic 42(4):26–27.

DeCesare, N. J. 2020. *Is there such thing as a Shiras moose?* Big Hole Breeze, June 2020 Issue.

4. Professional Conference Presentations

DeCesare, N. J., J. Newby, V. Boccadori, T. Chilton-Radant, T. Their, D. Waltee, K. Podruzny, and J. Gude. 2015. *Calibrating indices of moose population trend in Montana*. North American Moose Conference and Workshop, Granby, Colorado.

Nadeau, S., E. Bergman, N. DeCesare, R. Harris, K. Hersey, P. Mathews, J. Smith, T. Thomas, and D. Brimeyer. 2015. *Status of moose in the northwest United States*. North American Moose Conference and Workshop, Granby, Colorado.

DeCesare, N. J., J. R. Newby, and J. M. Ramsey. 2015. *A review of parasites and diseases impacting moose in North America*. Montana Chapter of the Wildlife Society. Annual Meeting, Helena, Montana.

DeCesare, N. J., J. Newby, K. Podruzny, K. Wash, and J. Gude. 2016. *Occupancy modeling of hunter sightings for monitoring moose in Montana*. North American Moose Conference and Workshop, Brandon, Manitoba.

Newby, J. R., N. J. DeCesare, and J. A Gude. 2016. *Assessing age structure, winter ticks, and nutritional condition as potential drivers of fecundity in Montana moose*. Montana Chapter of the Wildlife Society. Annual Meeting, Missoula, Montana.

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DeCesare, N. J., J. Newby, K. Podruzny, K. Wash, and J. Gude. 2017. *Occupancy modeling of hunter sightings for monitoring moose in Montana*. Montana Chapter of the Wildlife Society. Annual Meeting, Helena, Montana.

DeCesare, N. J., and J. R. Newby. 2018. Moose population dynamics in Montana: results from the halfway point of a 10-year study. Montana Chapter of the Wildlife Society. Annual Meeting, Butte, Montana.

Oyster, J. H., N. J. DeCesare, et al. 2018. An update on *Elaeophora schneideri* in western North American moose. North American Moose Conference and Workshop, Spokane, Washington.

DeCesare, N. J., and J. R. Newby. 2018. Moose population dynamics in Montana. North American Moose Conference and Workshop, Spokane, Washington.

DeCesare, N. J., et al. 2019. Phylogeography of a range edge subspecies: is there such thing as Shiras moose? Montana Chapter of the Wildlife Society. Annual Meeting, Helena, Montana.

5. Public and/or Workshop Presentations

FY	Organization (*Speaker*)	Location
2013	Helena Hunters and Anglers Association (*DeCesare*)	Helena, MT
	Marias River Livestock Association (*DeCesare*)	Whitlash, MT
	Plum Creek Timber Company, Staff meeting (*DeCesare*)	Libby, MT
	Sun River Working Group (*DeCesare*)	Augusta, MT
2014	Big Hole Watershed Committee (*DeCesare*)	Divide, MT
	Flathead Wildlife Incorporated (*DeCesare*)	Kalispell, MT
	MFWP R1, Regional Citizens Advisory Council (*Newby*)	Kalispell, MT
	MFWP R1, Biologists' Meeting (*Newby*)	Kalispell, MT
	MFWP R1, Bow Hunter Education Workshop	Kalispell, MT
	MFWP R2, Regional Meeting (*DeCesare*)	Missoula, MT
	MFWP, Wildlife Division Meeting (*DeCesare*)	Fairmont, MT
	Plum Creek Timber Annual Contractors Meeting (*DeCesare*)	Kalispell, MT
	Rocky Mountain Front Land Managers Forum (*DeCesare*)	Choteau, MT
	Swan Ecosystem Center Campfire Program (*Newby*)	Holland Lake, MT
	WCS Community Speaker Series (*Newby*)	Laurin, MT
2015	Big Hole Watershed Committee (*Boccadori*)	Divide, MT
	Flathead Chapter of Society of American Foresters (*Newby*)	Kalispell, MT
	Libby Chapter of Society of American Foresters (*Newby*)	Libby, MT
	MFWP R1, Regional Citizens Advisory Council (*Newby*)	Kalispell, MT
	MFWP R2, Bow Hunter Education Workshop (*DeCesare*)	Lolo, MT
	MFWP R2, Regional Citizens Advisory Council (*DeCesare*)	Missoula, MT
	Rocky Mountain Front Land Managers Forum (*Newby*)	Choteau, MT
	Sanders County Commission Meeting (*DeCesare*)	Thompson Falls, MT
	Sheridan Wildlife Speaker Series (*DeCesare*)	Sheridan, MT
	Univ. Montana Guest Lecture – WILD105 (*DeCesare*)	Missoula, MT
2016	Confederated Salish & Kootenai Tribe, Nat Res Commission (*Newby*)	Marion, MT
	Ducks Unlimited State Convention (*Newby*)	Lewistown, MT
	Helena Hunters and Anglers Association (*DeCesare*)	Helena, MT
	MFWP R1 Law Enforcement Annual Meeting (*Newby*)	Kalispell, MT
	Montana State University, Ecology Seminar Series (*DeCesare*)	Bozeman, MT
	Ravalli County Fish and Wildlife Association (*DeCesare*)	Hamilton, MT
	Univ. Montana Guest Lecture – WILD480 (*DeCesare*)	Missoula, MT
	Upper Sun River Wildlife Team Meeting (*DeCesare*)	August, MT
2017	Big Hole Watershed Committee (*Boccadori*)	Divide, MT
	Mountain Bluebird Trails Conference (*DeCesare*)	Dillon, MT
	Swan Valley Connections Speaker Series (*DeCesare*)	Condon, MT
	University of Montana, STEAMfest (*DeCesare*)	Missoula, MT
	Univ. Montana Guest Lectures – WILD180, WILD480 (*DeCesare*)	Missoula, MT
	WCS Community Speaker Series (*DeCesare*)	Dillon, MT
	Flathead Valley Lions Club (*Newby*)	Kalispell, MT
	Flathead Wildlife Incorporated (*Newby*)	Kalispell, MT

	North Fork Inter-local (*Anderson*)	Polebridge, MT
2018	Bitterroot College (*DeCesare*)	Hamilton, MT
	Clearwater Resource Council (*DeCesare*)	Seeley Lake, MT
	MFWP R1, Regional Citizens Advisory Council (*Newby*)	Kalispell, MT
	Montana Forest Landowner Conference (*DeCesare*)	Helena, MT
	Montana Audubon Chapter (*Newby*)	Polson, MT
	Science on Tap (*Newby*)	Bigfork, MT
2019	MFWP HQ, Brown Bag Seminar (*DeCesare*)	Helena, MT
	MFWP Wildlife Manager Meeting (*DeCesare*)	Helena, MT
	Hellgate Hunters and Anglers (*DeCesare*)	Missoula, MT
	Rocky Mountain Front Land Managers Forum (*Newby*)	Choteau, MT
	Upper Sun Wildlife Team (*DeCesare*)	Fairfield, MT
	Univ. Montana Guest Lectures – WILD240 (*DeCesare*)	Missoula, MT
	Idaho Fish & Game/MFWP Joint Meeting (*Newby*)	De Borgia, MT
2020	Flathead Wildlife Incorporated (*Newby*)	Kalispell, MT
	Devil's Kitchen Working Group (*DeCesare*)	Cascade, MT
	Lake County Conservation District (*DeCesare*)	Polson, MT

6. Media Communications

FY	Organization (Location)	Topic	Media
2013	Bozeman Chronicle (MT)	Moose research	Newspaper
	Liberty County Times (MT)	Moose research	Newspaper
	MFWP Outdoor Report (MT)	Moose research	Television
2014	Carbon County News (MT)	Moose research	Newspaper
	Flathead Beacon (MT)	Moose research	Newspaper
	Helena Independent Record (MT)	Moose research	Newspaper
	High Country News, blog	Moose research	Blog
	KPAX (MT)	Moose-human conflict	Television
	MFWP Outdoor Report	Moose research	Television
	Missoulian (MT)	Urban moose	Newspaper
	The Monocle Daily (London, UK)	Moose research	Radio
	Nature Conservancy Magazine (VA)	Moose research	Magazine
	New York Times (NY)	Moose research	Newspaper
	NWF Teleconference (MT)	Climate change	Newspaper
	Radio New Zealand (New Zealand)	Moose research	Radio
	Summit Daily (CO)	Moose research	Newspaper
	UM Science Source (MT)	Moose research	Newspaper
2015	KOFI (MT)	Moose research	Radio
	MFWP Outdoor Report (MT)	Moose research	Television
	Western News (MT)	Moose research	Newspaper
2016	Missoulian (MT)	Climate & moose	Newspaper
	Bozeman Daily Chronicle (MT)	Climate & moose	Newspaper
	Montana Standard (MT)	Climate & moose	Newspaper
	Billings Gazette (MT)	Climate & moose	Newspaper
	Daily Interlake (MT)	Moose research	Newspaper
	Ravalli Republic (MT)	Moose research	Newspaper
	Montana Public Radio (MT)	Moose research	Radio
	Montana Public Radio – Field Notes (MT)	Moose taxonomy	Radio
	Post Rider (MT)	Moose research	Newsletter

	KAJ18 (MT)	Moose research	Television
2017	Dillon Tribune (MT)	Moose research	Newspaper
	Billings Gazette (MT)	Moose research	Newspaper
	Missoulian (MT)	Moose research	Newspaper
	Great Falls Tribune (MT)	Moose research	Newspaper
	Weather Network (Canada)	Moose sightings	Website
	The Nature Conservancy Magazine (VA)	Wildlife tracking	Magazine
2018	Hungry Horse News (MT)	Moose research	Newspaper
	Missoulian (MT)	Moose research	Newspaper
2019	Missoulian (MT)	Moose hunting	Newspaper
2020	Bugle magazine (MT)	Moose conservation	Magazine
	MFWP Facebook (MT)	Moose genetics	Social Media

7. Other Project-related Collaborations

Partners	Title	Activities during FY18
Rick Gerhold University of Tennessee	Development of a serological assay for *Elaeophora schneideri* detection and surveillance in cervids	*Labwork is ongoing *Providing MT blood samples and worm samples for lab work
Biologists from western states and provinces (AB, BC, CO, ID, MT, OR, SK, UT, WA, WY)	Assessing range-wide genetic differentiation and spatial distribution of a moose subspecies, *Alces alces shirasi*	*Completed, manuscript published, 2020.
Biologists from western states (CO, ID, MT, OR, UT, WA, WY)	Summarize status and management of western states moose.	*Completed, manuscript published, 2017.
Ky Koitzsch, K2 Consulting, LLC	Estimating population demographics of moose in northern Yellowstone National Park using non-invasive methods	*Final report in development
Jason Ferrante & Margaret Hunter, USGS – Gainseville, FL	Genetic approaches to understanding moose health	*Analyses ongoing

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