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

Concern has arisen in recent years over widespread declines of North American moose (*Alces alces*) populations along the southern extent of their range. Populations in Montana appear to have declined since the 1990's, as evidenced by aerial survey trends and hunter harvest statistics. While declining populations have clear implications for hunting opportunity, moose management in Montana also suffers from a lack of rigorous data and methods with which to monitor population trends and prescribe actions.

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 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, parasites, 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 which factors are most important to annual growth of moose populations.

This document is the 6th annual report produced as part of this work. This report contains preliminary results from a subset of our work, including results from the first 6 biological years of moose research and monitoring. All results should be considered preliminary as both data collection and analyses are works in progress.

Monitoring moose with hunter observations may offer a promising new approach to gathering statewide data. To date, we have collected >4,300 statewide moose sighting locations per year during 2012–2016 through the addition of questions about moose to big game hunters during annual hunter phone surveys. After conducting preliminary occupancy analyses of these data (summarized in our 2017 annual report), we are in process of moving analyses of these data into a count-based arena in attempt to upgrade our results from moose occupancy to moose abundance. Results from this work will become available during FY19.

Moose vital rates measured with radio-collar studies currently indicate stable to increasing population trends in 2 study areas (Cabinet-Fisher and Rocky Mountain Front) and a potentially declining population trend in the 3rd study area (Big Hole Valley). These estimated trends are largely driven by differences in adult female survival rates, which are relatively high in the first two areas but fair in the third. To the contrary, calf survival rates appear lowest in the Cabinet-Fisher study area, but with less influence than adult survival on the overall trajectory of the population. Monitoring of moose vital rates as well as potential 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, 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 (2017-2018)

For the 2017-2018 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. Monitoring moose with sighting rates and patch occupancy modeling

Occupancy modeling allows biologists to estimate the spatial distributions of animals and trends of such over time, while controlling for variation in the probability of detection that can confound many sources of spatial data (MacKenzie et al. 2002, 2003). Because it does not require marked animals, occupancy modeling lends itself well to data collected by various means, including citizen science data collected by the general public (Hochachka et al. 2012, van Strien et al. 2013). Each year MFWP conducts phone surveys of a large sample of resident deer and elk hunters in Montana to facilitate estimation of various hunter harvest and effort statistics. Following the 2012–2016 hunting seasons, a subsample of these hunters were also asked to describe the location and group size of any moose sightings that occurred while hunting. These efforts resulted in an average of >4,300 statewide moose sighting locations per year with approximately of 15% of sampled hunters reporting at least one moose sighting. After completing initial occupancy analyses of the presence-absence over time and across the state (see 2017 Annual Report), we have now moved analyses of these data into a count-based arena. As such, we are using n-mixture models (Kéry et al. 2018) to analyze the numbers of moose seen by hunters while accounting for variation in detection rates. Results from this work will become available during FY19.

1.2. 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 are currently in the final stages of a side-project with ties to this study that applies a broader lens to the genetic structure of moose in the West. Specifically, we are applying 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. Results from this study will be finalized and become available during FY19.

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

2.1. Animal capture and handling

In February of 2017 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 26 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 2013–18, we have conducted a total of 157 captures of 141 individual adult female moose, and as of August 1, 2018, 84 are currently being monitored (Table 1, Figures 1,2). 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 radio-marked adult female moose by study area and year, excluding 6 capture-related mortalities, and the number of adult females being monitored as of August, 2017.*

	Study Area			
	Cabinet-Fisher	*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
Total captures	**48**	**57**	**52**	**157**
Moose currently on–air	28	29	27	84

Figure 1. *Post-capture release of moose F146 in the Cabinet-Fisher study area, February 2018.*

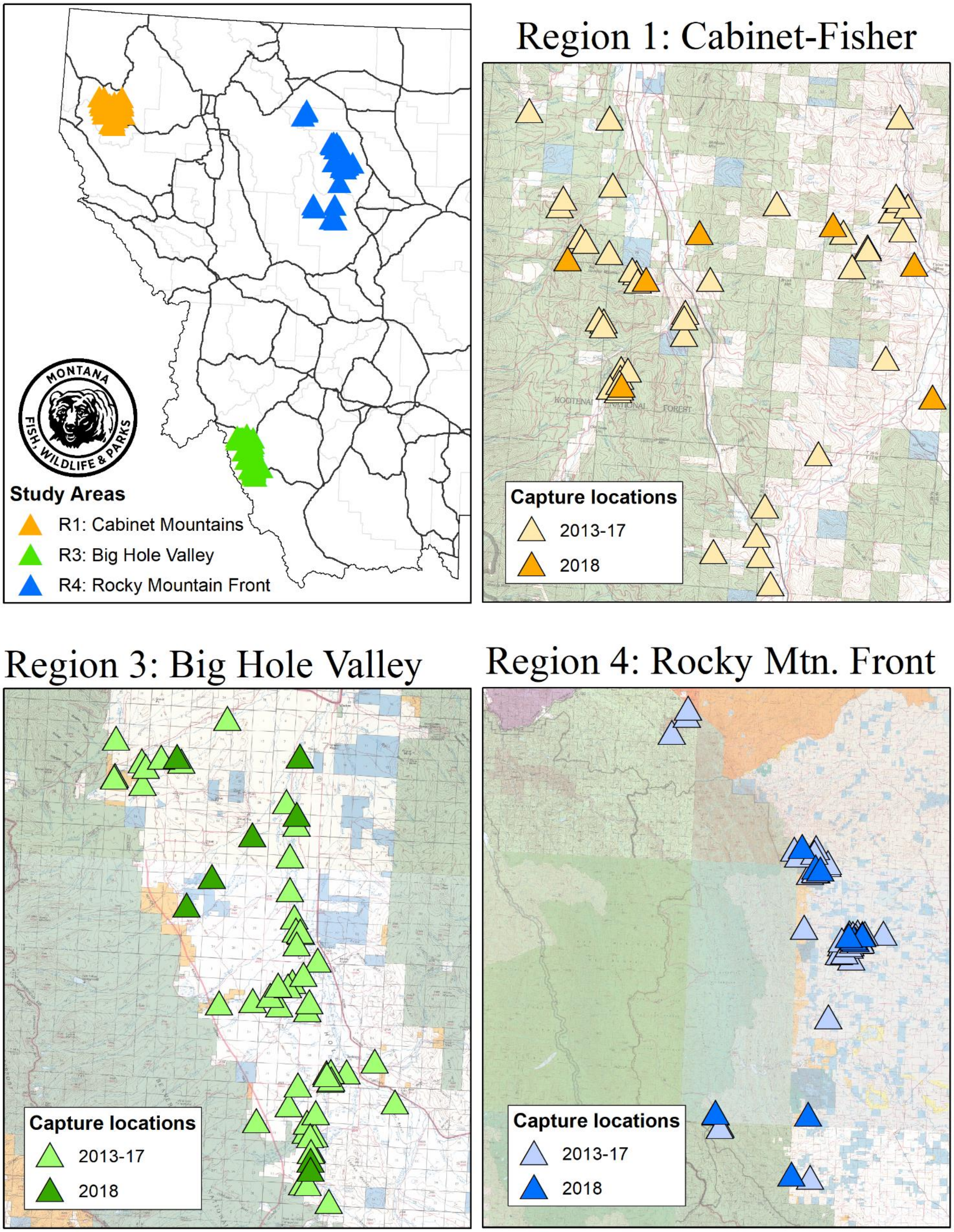

Figure 2. *Moose winter capture locations during 2013–2018 across 3 study areas in Montana.*

2.2. Monitoring vital rates

<u>*2.2.1. Adult female survival*</u>.— 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 for each study area were 0.926 (SE=0.023, 95% CI=[0.88,0.97]) in the Cabinet-Fisher, 0.848 (SE=0.032, 95% CI=[0.79,0.91]) in the Big Hole Valley, and 0.904 (SE=0.027, 95% CI=[0.85,0.96]) on the Rocky Mountain Front (Figure 3). In comparison to these 5-year averages, survival during the 2017-18 biological year was similar to average in the Cabinet-Fisher (0.93), higher than average in the Big Hole Valley (0.89), and lower than average on the Rocky Mountain Front (0.83), though without statistical confidence.

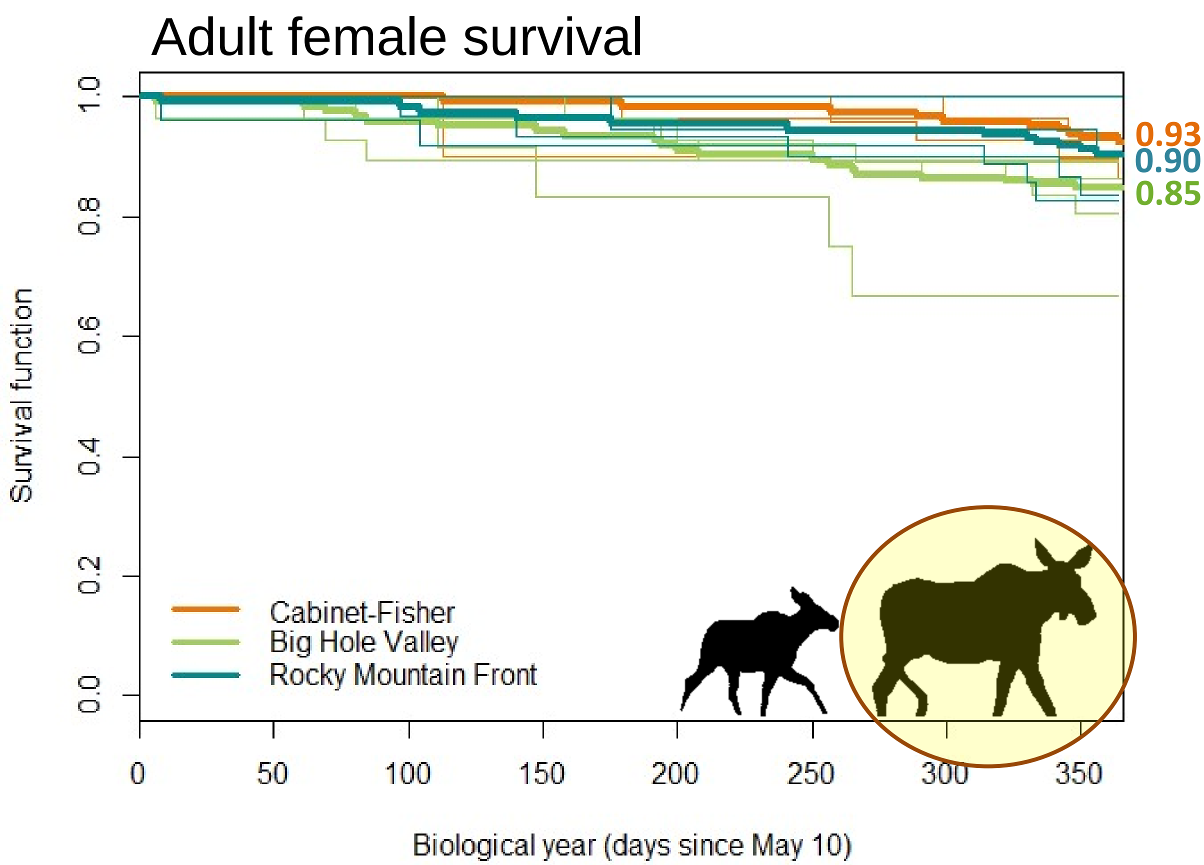

Figure 3. *Kaplan-Meier estimates of annual adult female survival within each study, where bolded lines are pooled estimates across 5 biological years for each study area and thin lines are annual estimates for each study area and year, Montana, 2013–2018.*

During 5 biological years of monitoring, we have documented 32 mortalities of collared adult moose across all study areas: 12 in the Cabinet-Fisher, 20 in the Big Hole Valley and 14 in the Rocky Mountain Front (Table 2, Figure 4). Ongoing research will attempt to better understand the causes and consequences of these mortalities.

Table 2. *Numbers of mortalities by cause for radio-collared adult female moose documented during February 2013–June 2018, Montana.*

Cause of Mortality	Study area		
	Cabinet-Fisher	Big Hole Valley	Rocky Mountain Front
Accident	1	0	0
Health-related (e.g., disease, malnutrition, …)	3	18	5
Human (e.g., harvest, poaching, vehicle collision)	0	2	1
Predation, bear	0	0	1
Predation, mountain lion	1	0	0
Predation, wolf	4	0	2
Predation, wound infection	1	0	0
Unknown	2	0	5

Figure 4. *Mortality site of F140 in the Cabinet-Fisher study area, 1 July 2018. This individual appeared to have succumbed to infected wounds from an earlier but unsuccessful predator attack. The predator involved was most likely wolf.*

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 (92%), and lower in the Cabinet-Fisher (76%; 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 260 calves from 245 litters during 2013–2017. We then monitored the fates of these calves by visually locating them with their dams throughout their first year of life. Over the first 5 biological years (May 2013 – May 2018), pooled Kaplan-Meier survival estimates of calves-at-heel were 0.343 (SE=0.057, 95% CI=[0.25,0.47]) in the Cabinet-Fisher, 0.442 (SE=0.056, 95% CI=[0.35,0.57]) in the Big Hole Valley, and 0.524 (SE=0.054, 95% CI=[0.43, 0.64]) on the Rocky Mountain Front (Figure 5). Study area-specific survival curves suggest lowest calf survival in the Cabinet-Fisher relative to the other two study areas, though confidence intervals overlap. These results mirror those of observed parturition, suggesting that differences among study areas in parturition rates may, in fact, be due to mortality of neonates prior to detection.

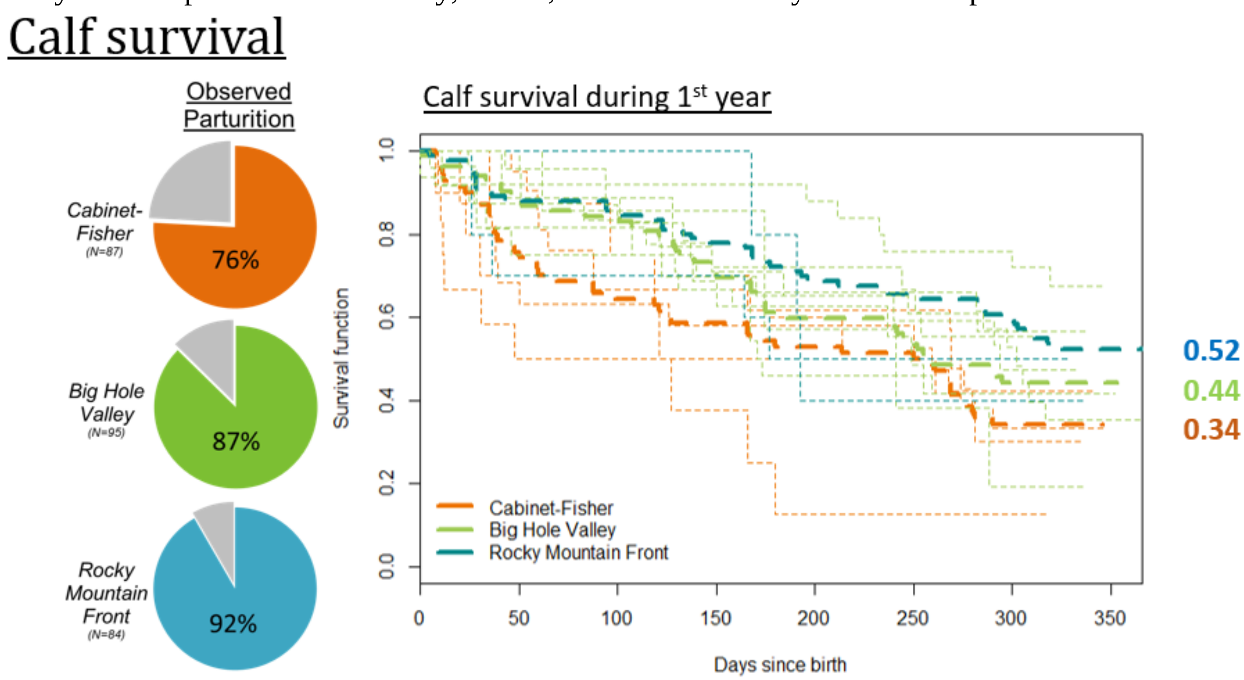

Figure 5. *Observed parturition (proportion of pregnant cows with calves-at-heel during spring) and Kaplan-Meier estimates of annual calf survival for the first year of life within each study area, where bold lines are pooled estimates across 5 biological years and thin lines are annual estimates per year, Montana, 2013–2018.*

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, 5 years (2013-2017), and 346 animal-years of monitoring, we have thus far estimated an average adult (ages ≥2.5) pregnancy rate of 82.7%, varying from 80–87% 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 44% yearling pregnancy on the Rocky Mountain Front; however, sample sizes for yearling pregnancy are small (*N* = 1, 7, and 9 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 4.5% in the Cabinet-Fisher (*N*=66 litters), 0% in the Big Hole Valley (*N*=83 litters), and 15.6% in the Rocky Mountain Front study areas (*N*=77 litters; Figure 6).

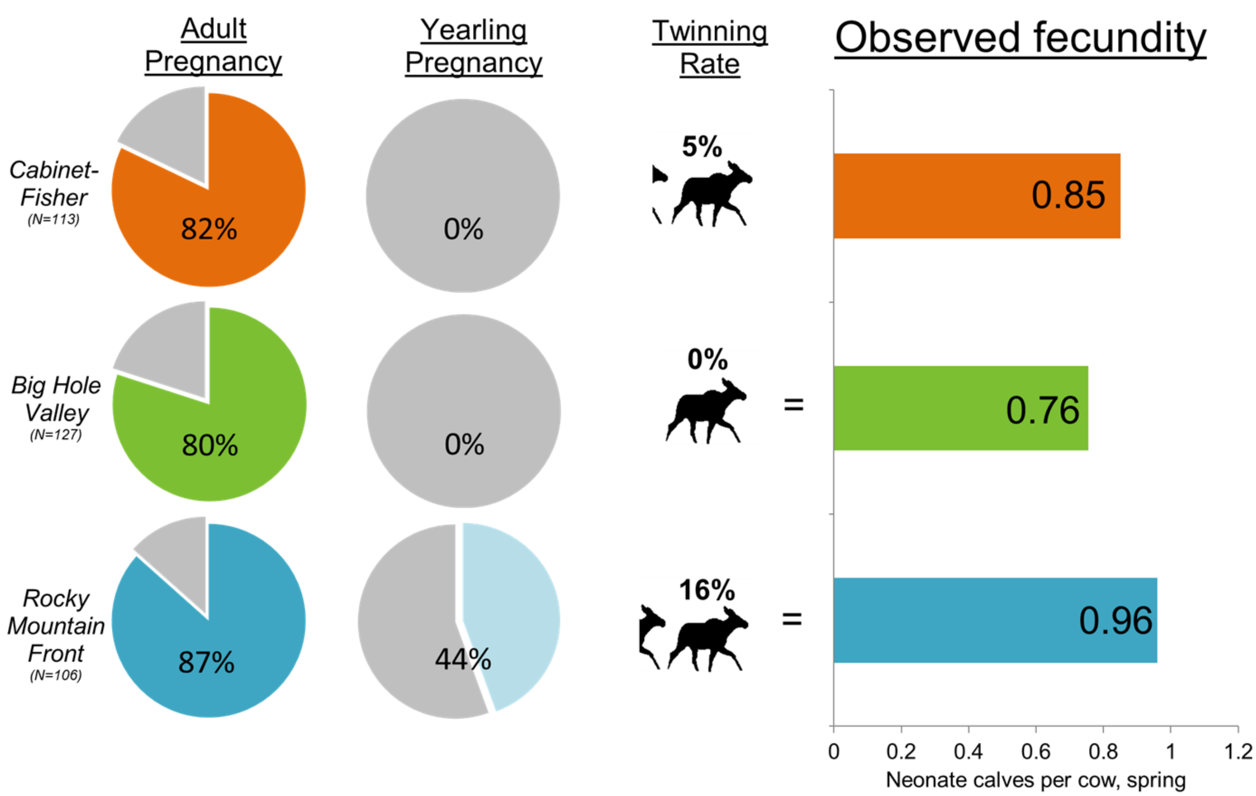

Figure 6. *Estimated adult (aged≥2.5) pregnancy rates, yearling (aged 1.5) pregnancy rates, observed twinning rates, and net observed fecundity of calves per adult female in 3 study areas of Montana during 5 biological years, 2013–2017.*

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 rates of pregnancy, parturition, litter size, and calf survival. We then estimated annual population growth rates, following DeCesare et al. (2012), for each study population across the first 5 biological years, 2013–2018 (Figure 7).

While moose on the Cabinet-Fisher study area have seen the lowest calf-survival rate of the 3 areas thus far, they have also shown relatively high adult survival. 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 in the Cabinet-Fisher translated to a mean population growth rate of 1.028, or an 2.8% increase per year. 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 1.11. To the contrary, the Big Hole Valley population has shown relatively fair calf survival, but the lowest adult survival rate, which resulted in an estimated population growth rate of 0.971, or an average of 2.9% decline per year.

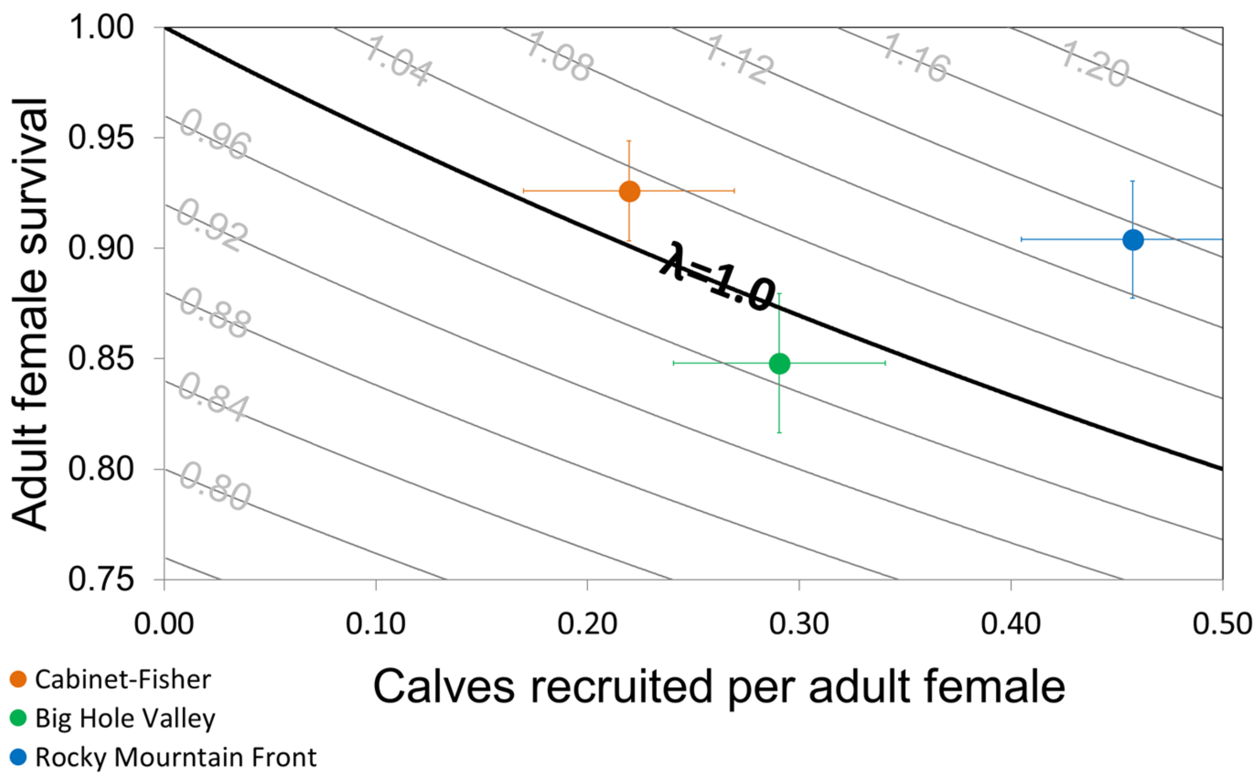

Figure 7. _Contour plot showing the estimated mean annual population growth rates (λ, represented as contour lines) resulting from two-dimensional combinations of adult female survival and spring recruitment of calves (integrating rates of pregnancy, parturition, litter size, and calf survival through the first year). Dots and error bars show the annual means and standard errors of these vital rates for 3 moose populations in Montana during 5 pooled biological years, 2013–2018. Growth rates above the bold line (where λ = 1) indicate a growing population, growth rates below λ = 1 indicate declining populations._

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

2.3.1. Hunter-based sampling of nutritional condition.

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). In addition to measuring rump fat among all captured adult females, we have asked hunters to measure rump fat of harvested moose, beginning in 2013.

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).

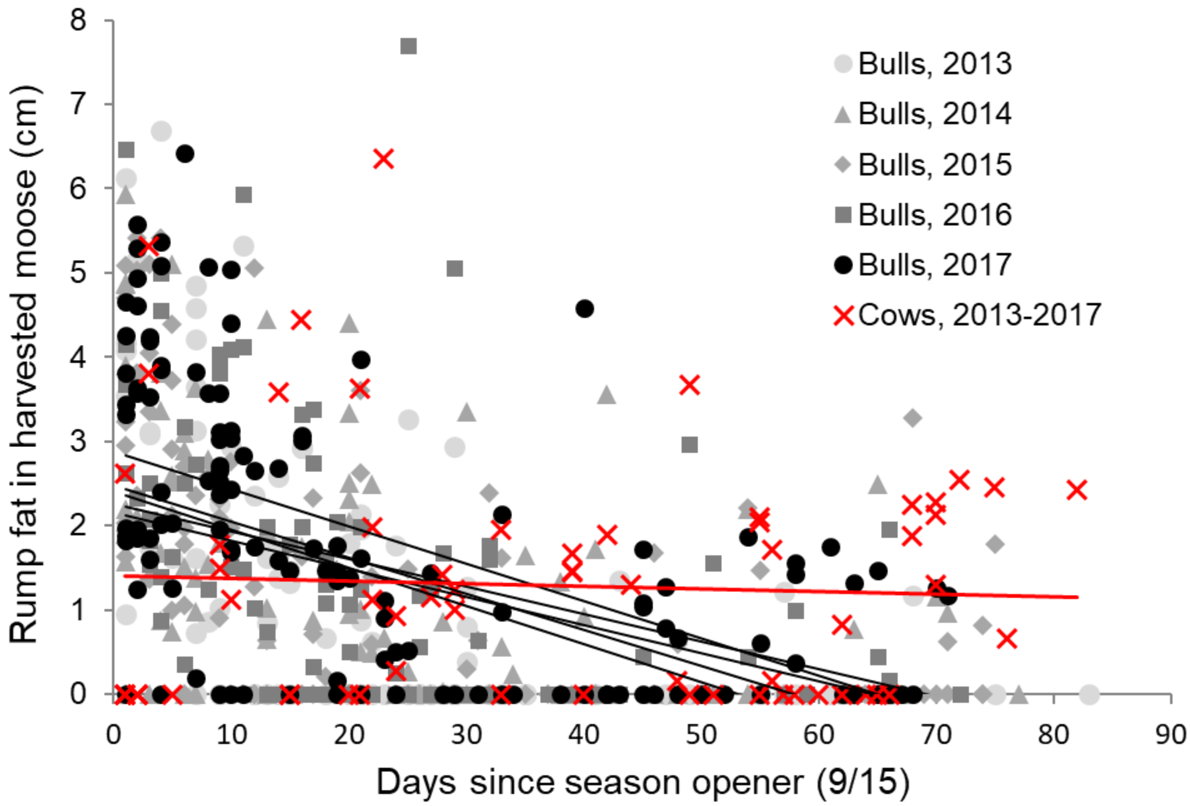

Figure 8. *Depth of rump fat declined consistently among harvested bull moose according to the date of harvest during the past 5 hunting seasons (see 5 black trend-lines), whereas average fat depths among cow moose did not significantly change (red trend-line) during the hunting season, Montana, 2013–2017.*

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).

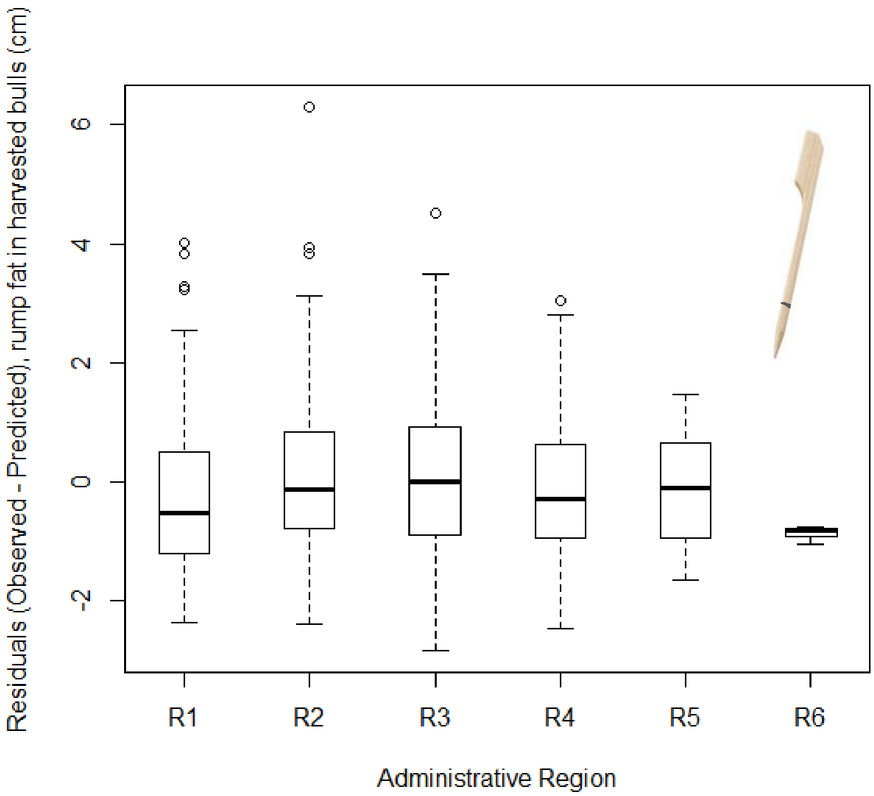

Figure 9. *Average residual values comparing the thickness of rump fat in hunter-killed moose among regions while controlling for the date of harvest. These data were collected by hunters by marking a toothpick (inset photo) included in sampling kits mailed to all license-holders, Montana, 2013–2017.*

2.3.2. Hunter-based monitoring of the rut

For the lucky few (1.3% of applicants in 2017) 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 2016–17, we added a new question to the data cards that are included within the sampling kits sent to moose hunters. We asked them to mark on a calendar which days they hunted, and which days they observed rutting activity by moose (e.g., calling, sparring, wallowing). We received samples and/or information from 140 moose hunters in 2016 and 167 hunters in 2017, including the recording of 2,371 hunter-days and 355 observations of rutting activity. Hunter-days decreased gradually throughout the season, with recurrent weekly spikes of hunting activity during weekends (Figure 10). To the contrary, the proportion of hunters observing rutting activity increased until the first week of October during both years, after which it declined through the middle of October (Figure 10). 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).

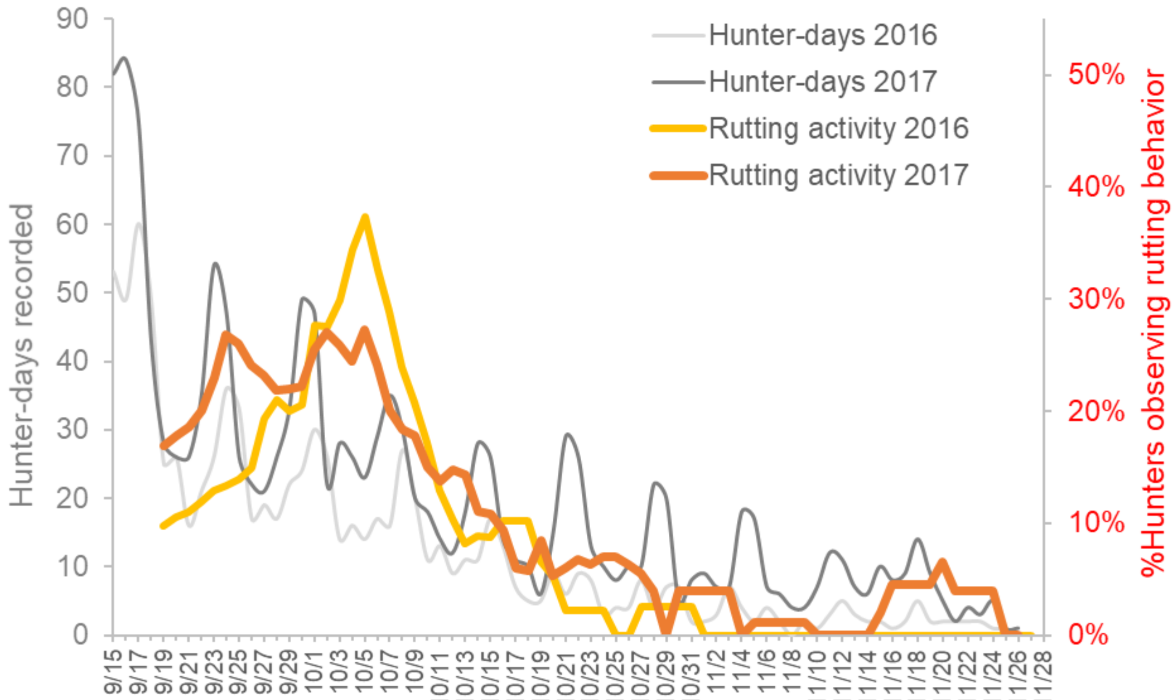

Figure 10. *Hunter-days recorded from voluntary return of data cards and proportion of hunters observing moose rutting activity (using a 5-day moving average) throughout the hunting season, 2016-17, Montana.*

2.4. Multi-species predator occupancy

Predation is one of the hypothesized factors potentially limiting moose vital rates, and thus populations in Montana. Predator/prey relationships have been a major area of interest in moose ecology and management across their range. Primarily research has focused on the effects of brown bear (*Ursus arctos*), black bear (*Ursus americanus*) and wolf (*Canis lupus*) predation (Van Ballenberghe and Ballard 2007). Past research has found these predator species to have potentially significant effects on moose survival under some circumstances (Messier and Crête 1985, Larsen et al. 1989, Ballard et al. 1990). In addition, mountain lions (*Puma concolor*) are known to predate on moose and even coyotes (*Canis latrans*) 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 in Montana. Predation effects on moose calf survival, which appears to differ between study areas, is of particular interest (see section 2.2.2).

Camera trapping, along with its concomitant statistical models, is a promising means of obtaining estimates of occupancy and relative density for multiple species simultaneously in a non-invasive and cost-effective manner (Rovero & Marshal 2009, Brodie et al. 2014, Steenweg et al. 2016). This has led to rapid expansion of camera trapping for wildlife research and management, as well as the number of publications reporting the use of camera traps (Meek & Fleming 2014, Burton et al. 2015).

Beginning in September of 2015 we deployed remote cameras traps (Bushnell, low-glow Aggressor Trophy Cameras) across the 3 moose field study areas to moose and potential predators; wolf, coyote, mountain lion black bears and grizzly bears. Camera traps were distributed by establishing a sampling grid over the area with known summer and winter locations of marked moose and randomly selecting grid cells (Figure 11). We randomly selected an equal number of cells containing summer and winter moose telemetry locations within each study area. This approach was taken to ensure cameras were distributed effectively across seasonal ranges, though there was much overlap among seasons. Within each selected cell, we established un-baited camera sets along trails, roads, and topographical features to maximize detections 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. Our relationships with landowners and wildlife managers has continued to open new opportunities for their involvement with this work over the past year.

Analytical methods for estimating predator densities over space and time using detections of unmarked species is an active area of research (MacKenzie et al. 2002, Royle 2004, Chandler et al. 2013). Camera trapping efforts were implemented to take advantage of recent extensions of occupancy-based models to estimate mean abundance of unmarked species at camera site while accounting for detectability (Royle 2004, Brodie et al. 2014). These efforts are also amenable to alternative approaches, such as random encounter and time-to-event models, that also estimate abundance while attempting to account for detection probability (Rowcliffe et al. 2008, Moeller 2017).

Since September 2015 we have deployed remote cameras at 128 sites, 92 of which are currently active. To date we have retrieved and stored images spanning 44,336 active camera trap-days. The large number of images obtained during these efforts provides a major challenge in using remote cameras to monitor species. Namely, the time required to review and classify each image and enter the information into a functional database. This impediment has begun to be addressed through the participation of University of Montana students and Montana, Fish, Wildlife & Parks game wardens. In the past year 4 wardens and 1 university student have participated in reviewing and classifying images using photo id modules generated in CPW Photo Warehouse (Newkirk, E.S. 2014). This has resulted in classification of photos for 4,186 camera-days (Big Hole 1,139; Cabinet-Fisher 774; Rocky Mountain Front 2,273 camera-days). Images classified to date demonstrate consistent detections of moose and all target carnivore species, and begin to reveal potential differences between study areas (Figure 12, 13).

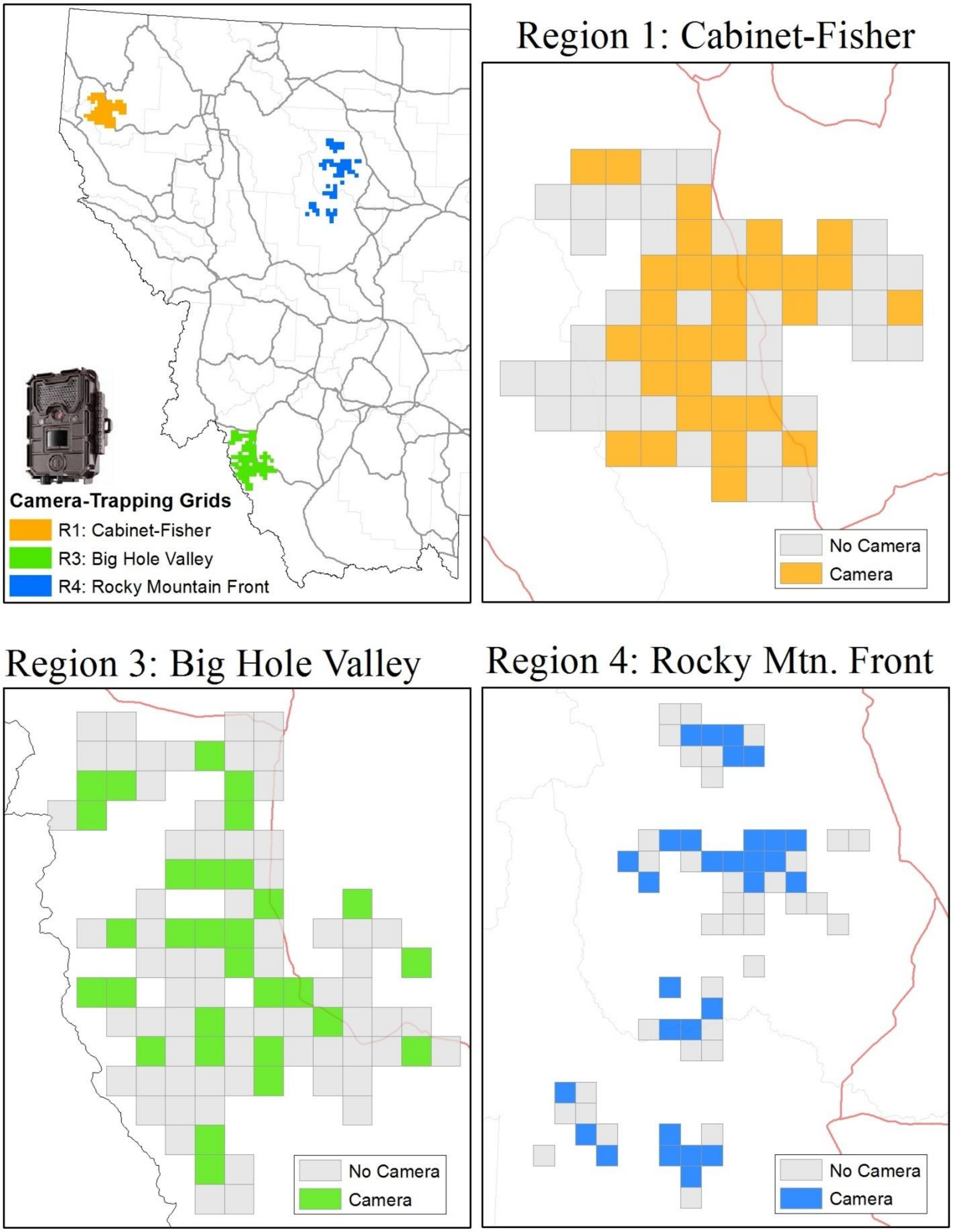

Figure 11. *Sampling grids (2 x 2 miles) for deployment of remote cameras for monitoring multi-species predator occupancy across areas occupied by moose, Montana, 2016.*

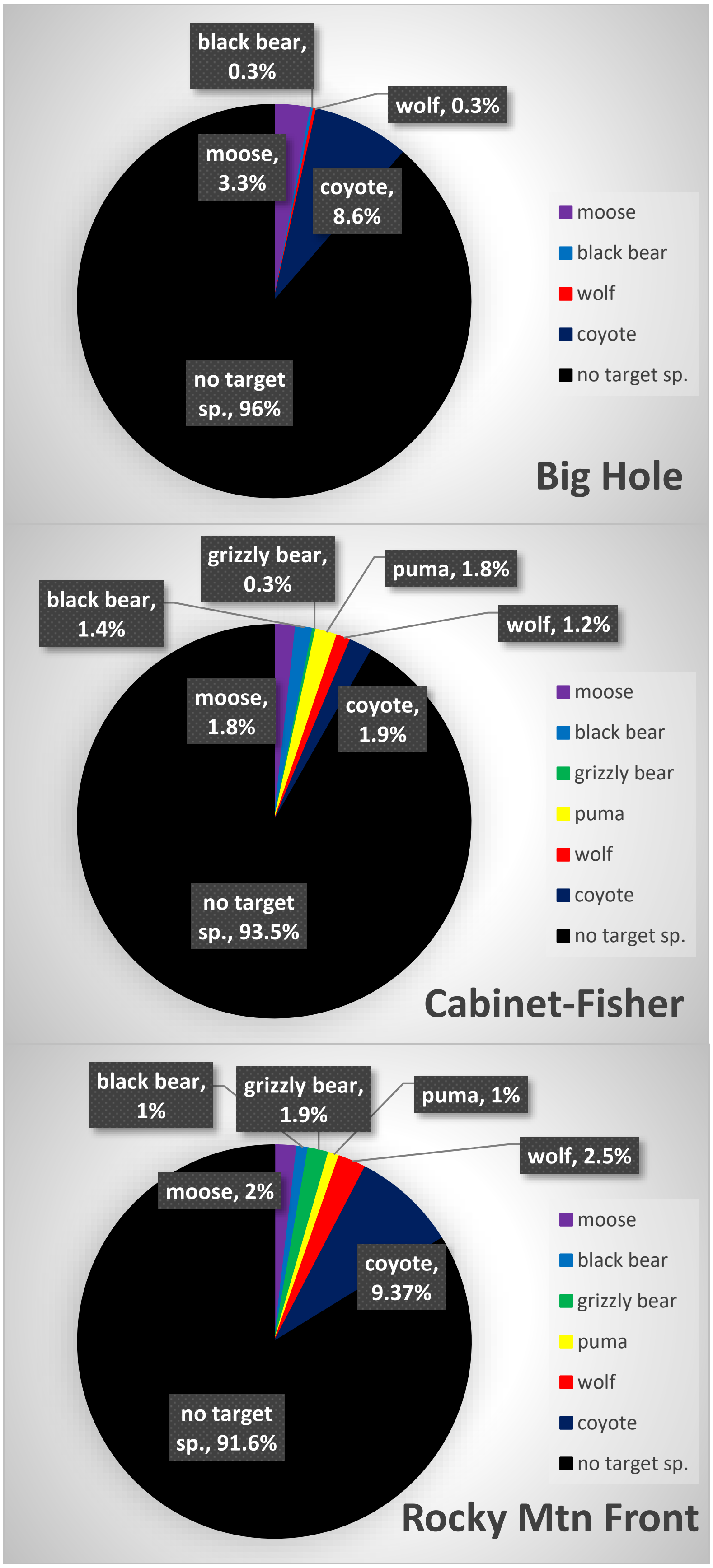

Figure 12. *Proportion of reviewed and classified camera-days with occurrence of target species as of July 2018. Note that a relatively small number of camera-days from 17 camera sites have been reviewed to date (Big Hole 6 sites, 1,139 camera-days; Cabinet-Fisher 5 sites, 774 camera-days;, Rocky Mtn Front 6 sites, 2,273 camera-days). Therefore, these results are preliminary and not necessarily representative of the study areas overall.*

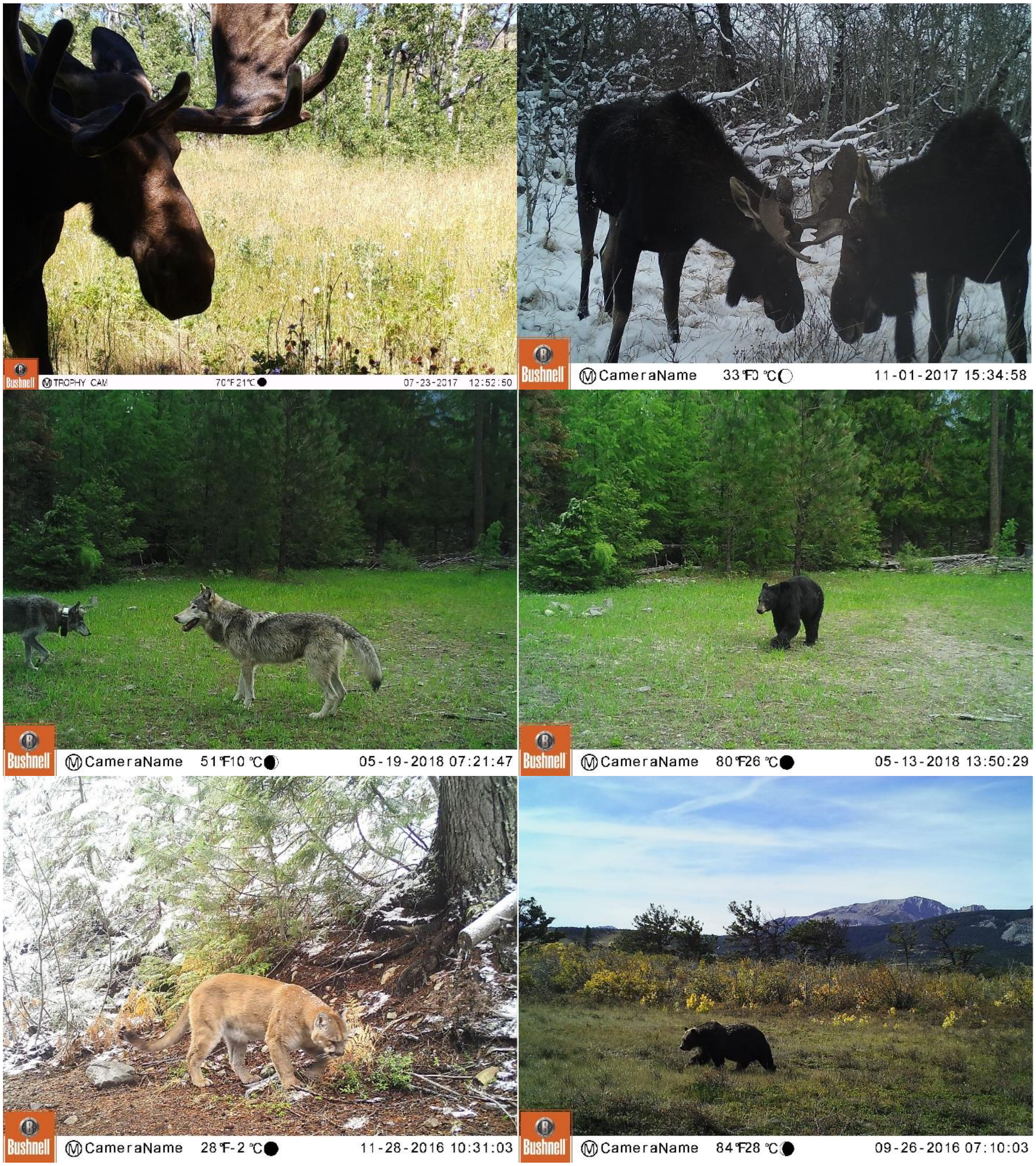

Figure 13. *Example photos from remote camera-traps set within seasonal ranges of each moose study area to monitor multi-species occupancy of carnivores 2015–2018, Montana.*

Deliverables

Below we list project deliverables (publications, reports, presentations, media communications, and value-added collaborations) stemming from this moose research project, during FYs 13–18 (July 2012–June 2018). 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. 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-6.

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.

DeCesare, N. J., J. R. Newby, V. Boccadori, T. Chilton-Radandt, T. Thier, D. Waltee, K. Podruzny, and J. A. Gude. 2016. *Calibrating minimum counts and catch per unit effort as indices of moose population trend*. Wildlife Society Bulletin 40:537–547.

Nadeau, M. S., N. J. DeCesare, D. G. Brimeyer, E. J. Bergman, R. B. Harris, K. R. Hersey, K. K. Huebner, P. E. Matthews, and T. P. Thomas. 2017. *Status and trends of moose populations and hunting opportunity in the western United States*. Alces 53:99–112.

Ruprecht, J. S., K. R. Hersey, K. Hafen, K. L. Monteith, N. J. DeCesare, M. J. Kauffman, and D. R. MacNulty. 2016. *Reproduction in moose at their southern range limit*. Journal of Mammalogy 97:1355–1365.

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.

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.

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*. North American Moose Conference and Workshop, Brandon, Manitoba.

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.

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

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

7. Other Project-related Collaborations

Partners	Title	Activities during FY18
Rick Gerhold & Caroline Grunenwald, 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*	*Analyses completed *Manuscript in preparation

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	*Field work and analyses completed *Final report in development
Jason Ferrante & Margaret Hunter, USGS – Gainseville, FL	Genetic approaches to understanding moose health	*Analyses ongoing

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