# 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 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 5th annual report produced as part of this work. This report contains preliminary results from a subset of our work, including recent efforts to monitor moose with patch occupancy modeling of hunter sightings data, as well as results from the first 4 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 accounting for variation in the probability of detecting moose, estimated statewide average probabilities of occupancy ranged from 0.30–0.31 during the 4 autumns of 2012–2015 (Figure 3). These results show encouraging degree of precision in monitoring statewide occupancy, and a stable overall trend over the 4-year period.

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 3$^{rd}$ 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 and low 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 (2016-2017)

For the 2016-2017 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). For example, hunter sightings data have been used to monitor statewide populations of bobcats in New Hampshire (Mahard et al. 2016), wolves in Montana (Rich et al. 2013), and most recently moose in New York (Crum et al. 2017). Rich et al. (2013) estimated wolf occupancy by collecting hunter sightings of wolves and subdividing them into sampling sessions according to each week of Montana's 5-week hunting season. During 2012–2016 we similarly collected hunter sightings data for moose, with the intention of evaluating this approach as a means to monitor statewide trends in moose presence and distribution.

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. Over the past 5 years, 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 (Figure 1). We then used occupancy modelling to assess covariates related to both the occupancy of a given area by moose and the probability of detecting moose, given occupancy, when sampling deer-elk hunters for sightings of moose over a 5-week general hunting season. The best preliminary model was then used to predict the statewide probability of occupancy each autumn, during 2012-15 (Figure 2). These results are preliminary and subject to change with further analysis.

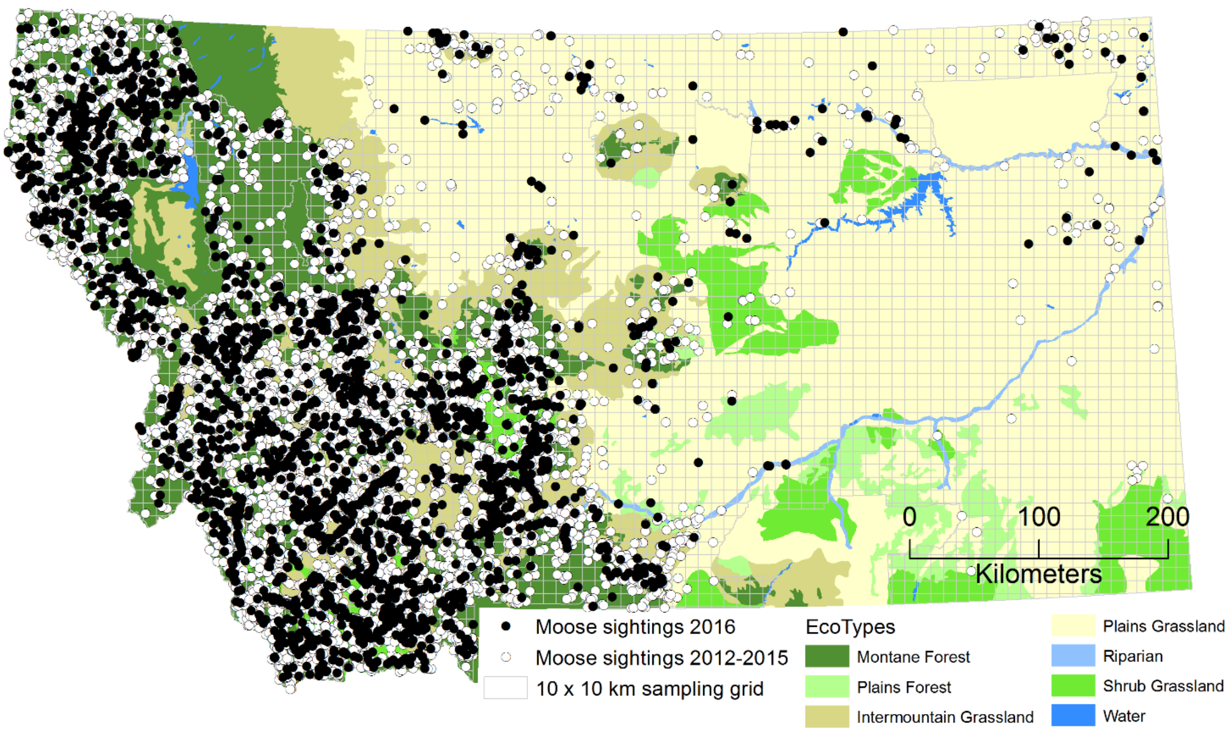


**Figure 1**. *Moose sightings collected using phone surveys of deer and elk hunters and a 10 x 10 km grid for sampling statewide occupancy during the fall, 2012–2016, Montana.*

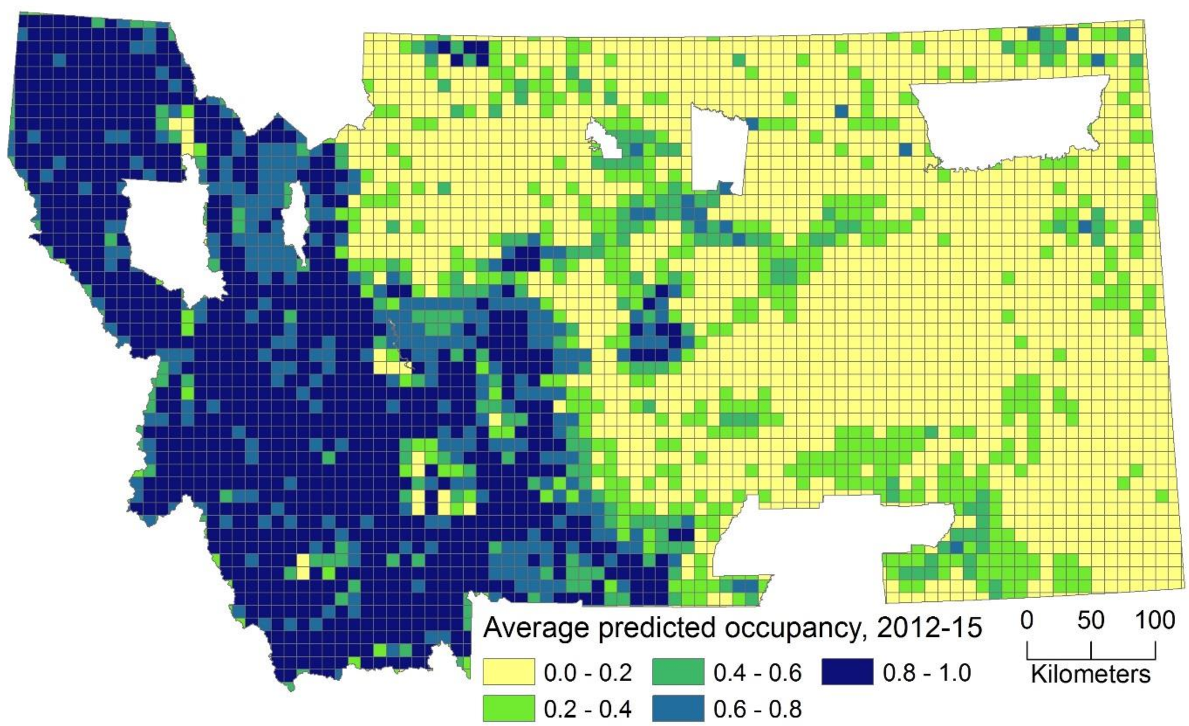


**Figure 2.** *Average predicted probabilities of occupancy by moose for each 10 x 10km cell during the 5-week autumn hunting seasons of 2012-2015 in Montana. Note the 2016 data have not been analyzed yet.*

Preliminary results indicated that the probability of occupancy by moose increased in sampling cells with higher proportions of forest, regenerating forest (i.e., following wildfire or logging), and shrub-riparian landcover types. Occupancy was also higher within cells at intermediate average slopes, indicating lower occupancy in predominately flat or steep areas. The probability of moose being detected by hunters increased broadly in years with higher samples of hunters called, and also increased spatially in areas with more public land and closer proximity to roads. Detection probabilities decreased in forested and regenerating land cover types, and increased in shrub-riparian areas.

After accounting for variation in the probability of detecting moose, estimated statewide average probabilities of occupancy ranged from 0.30–0.31 during the 4 autumns of 2012–2015 (Figure 3). These results show encouraging degree of precision in monitoring statewide occupancy patterns, and a stable overall trend in occupancy over the 4-year period.

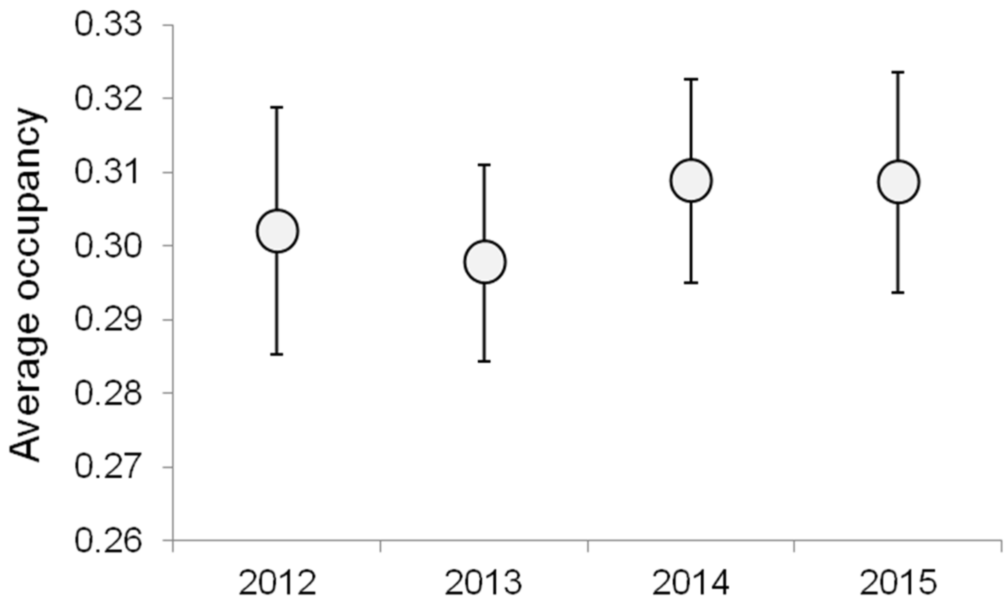


**Figure 3.** *Average predicted probabilities of occupancy by moose across all 100 km$^2$ grid cells within Montana, during the autumn 5-week general hunting season, Montana, 2012–2015.*

While the preliminary results are encouraging, certain limitations are also evident. Estimating occupancy in a given area provides robust information regarding the presence of moose, but does not necessarily distinguish among relative abundances over space or time. Given that our hunter sightings data include counts of moose per sighting, and counts of moose sightings per sampling cell, we are now exploring other analysis techniques (such as n-mixture modeling) which will perhaps make best use of these count data. Estimates of relative abundance, if feasible, would conceivably provide a more sensitive metric to monitor changes in Montana's moose populations as compared to measures of occupancy, or presence, alone.

## **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 2017, 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 2013–2017 a total of 137 adult female moose have been captured and radio-marked, and as of August 1, 2017, 81 are currently being monitored (Table 1, Figures 5,6). A target sample size of 30 individuals/study area is sought 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 |
| **Total captures** | **41** | **49** | **41** | **131** |
| Moose currently on–air | 29 | 27 | 25 | 81 |

**Figure 4.** *Post-capture release of 6-year-old moose F415 in the Rocky Mountain Front study area, February 2017.*

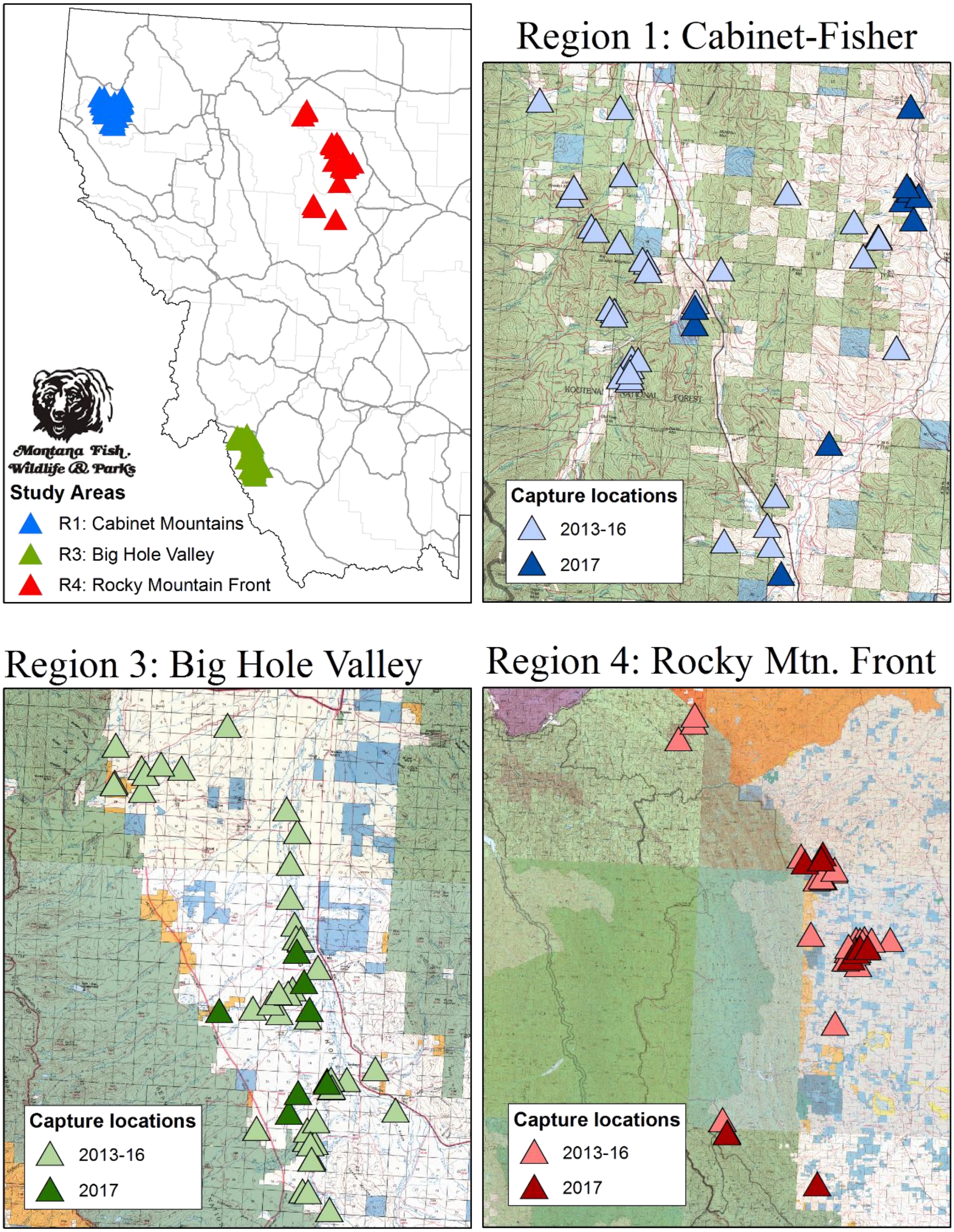


**Figure 5**. *Moose winter capture locations during 2013–2017 across 3 study areas in Montana.*

## 2.2. Monitoring vital rates

<u>*2.2.1. Adult female survival*</u>.— Our study of adult female survival to date includes 131 radio-collared adult female moose, with a staggered-entry design of individuals entering into the study across 5 winter capture seasons (*see* 2.1 Animal capture and handling). Animals have been deployed with both VHF (*N*=71) and GPS (*N*=60) collars. For this analysis, we estimated Kaplan-Meier annual survival rates for each study area during each biological year as well as across the 4 biological years pooled together in a recurrent-time format.

Pooled annual survival estimates for each study area were 0.924 (SE=0.026, 95% CI=[0.88,0.98]) in the Cabinet-Fisher, 0.837 (SE=0.036, 95% CI=[0.77,0.91]) in the Big Hole Valley, and 0.927 (SE=0.027, 95% CI=[0.88,0.98]) on the Rocky Mountain Front (Figure 7). In comparison to these 4-year averages, survival during the 2016-17 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 (0.84), though without statistical confidence.

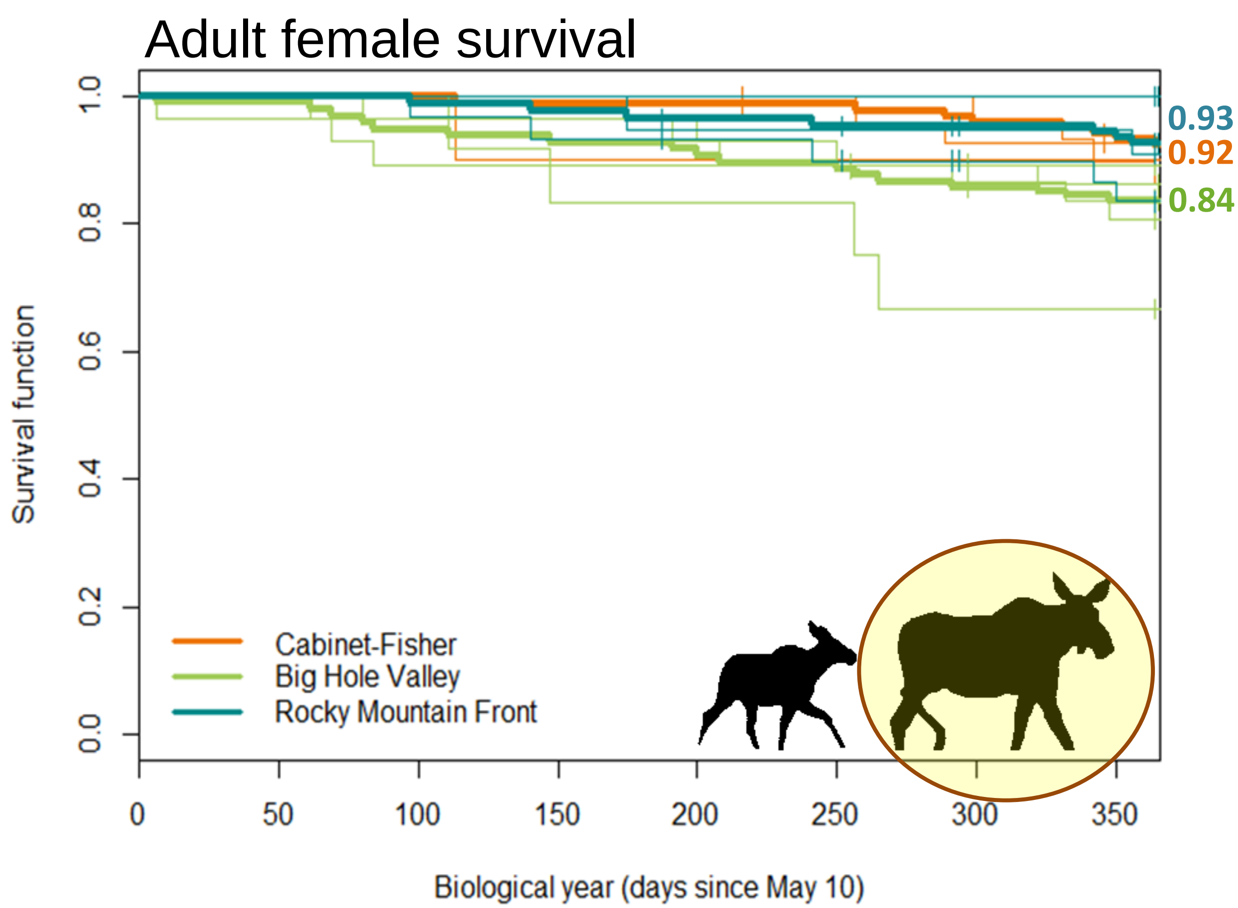


**Figure 6.** *Kaplan-Meier estimates of annual adult female survival within each study, where bolded lines are pooled estimates across 4 biological years for each study area and thin lines are annual estimates for each study area and year, Montana, 2013–2017.*

During the first 3 biological years of monitoring, we have documented 32 mortalities of collared adult moose across all study areas: 8 in the Cabinet-Fisher, 17 in the Big Hole Valley and 7 in the Rocky Mountain Front (Table 2). The Big Hole has experienced relatively high mortality due to disease or health-related causes (Figure 8). 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 2016, Montana.*

| Cause of Mortality | Study area | | |
|---|---|---|---|
| | Cabinet-Fisher | Big Hole Valley | Rocky Mountain Front |
| Health-related (e.g., disease, malnutrition, …) | 3 | 16 | 3 |
| Hunter harvest | 0 | 1 | 0 |
| Poaching | 0 | 0 | 1 |
| Predation, wolf | 3 | 0 | 1 |
| Unknown | 2 | 0 | 2 |

**Figure 7.** *An example health-related mortality site of F435 on the Rocky Mountain Front study area, 2016. Specific cause of death was not determined with certainty, but the mortality occurred in late September, when nutritional condition is typically near its peak. Effects of scavenging by coyotes and birds are evident in the photo.*

*2.2.2 Calf survival*.— We used aerial telemetry to visually search for calves-at-heel with each collared adult female at approximately weekly intervals during 15 May – 15 July. Flights were conducted with exclusively fixed-wing aircraft in the Big Hole Valley, rotary-wing in the Cabinet-Fisher, and a mix of both on the Rocky Mountain Front. We documented 20 calves from 19 litters in 2013, 40 calves from 39 litters in 2014, 59 calves from 56 litters in 2015, and 64 calves from 59 litters in 2016. We then monitored the fates of these calves by visually locating them with their dams throughout their first year of life.

Over the first 4 biological years (May 2013 – May 2016), pooled Kaplan-Meier survival estimates of calves-at-heel were 0.314 (SE=0.065, 95% CI=[0.21,0.47]) in the Cabinet-Fisher, 0.437 (SE=0.063, 95% CI=[0.33,0.58]) in the Big Hole Valley, and 0.507 (SE=0.063, 95% CI=[0.40, 0.65]) on the Rocky Mountain Front (Figure 10). Study area-specific survival curves suggest lowest calf survival in the Cabinet-Fisher relative to the other two study areas, though confidence intervals overlap.

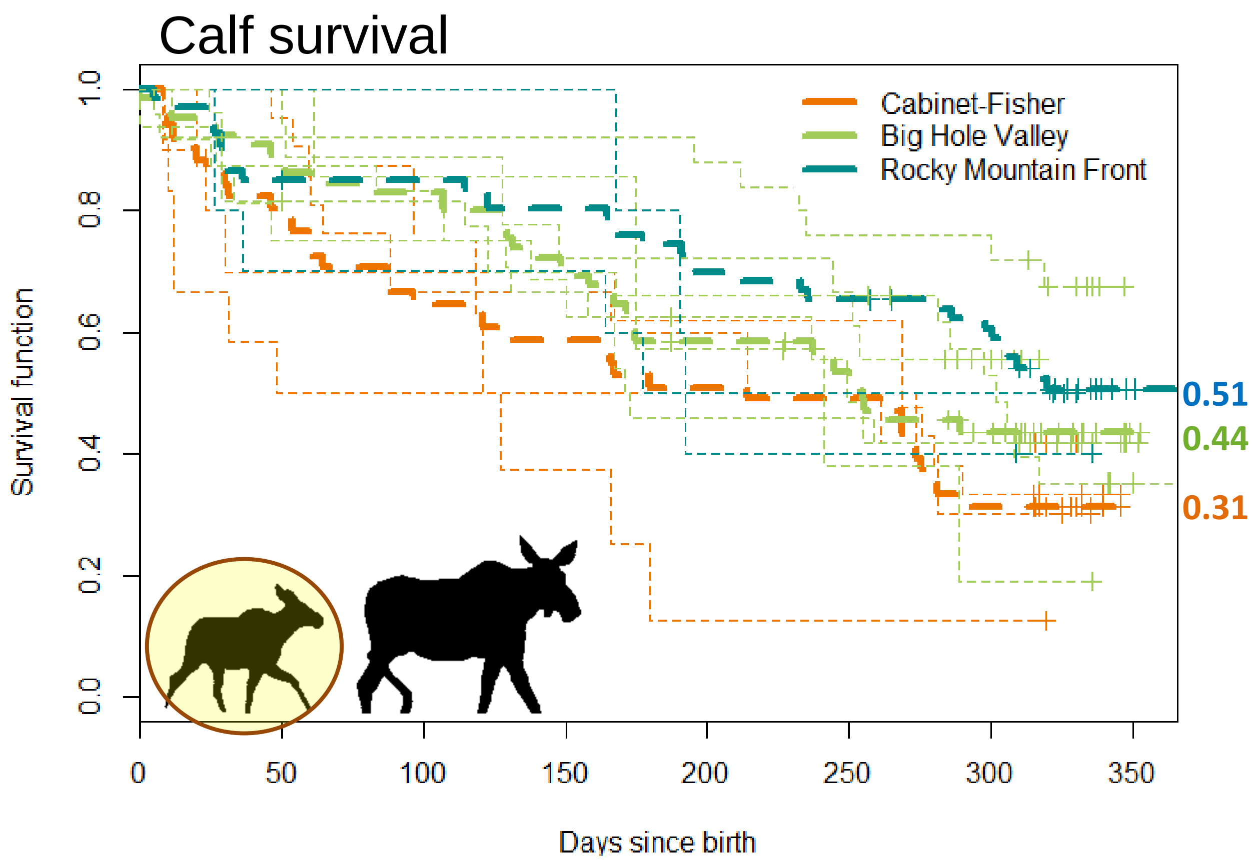


**Figure 8.** *Kaplan-Meier estimates of annual calf survival for the first year of life within each study area, where bold lines are pooled estimates across 4 biological years and thin lines are annual estimates per year, Montana, 2013–2017.*

*2.2.3 Adult female fecundity.*—Fecundity for moose is the product of pregnancy rate, survival rate of fetuses to parturition, 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). We measured fecal progestagen (FP) concentrations with two sampling techniques: 1) capturing animals and collecting fecal samples concurrent with blood sampling, and 2) using ground-tracking of free-ranging radio-collared moose throughout the winter (January–April) to collect fecal samples from the snow.

*Pregnancy rates*: Pooled across 3 study areas and 4 years (2013-2016) of monitoring pregnancy with both PSPB and fecal progestorene, we have thus far estimated an average adult (ages ≥2.5) pregnancy rate of 81.4% without much variation across study areas (Figure 9). Yearling (age 1.5) pregnancy rates, to the contrary, 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). Adult pregnancy has been consistently below the 84.2% average of adult moose pregnancy rates across North American (Boer 1992). Low pregnancy rates from 48%–75% have been reported in other Shiras moose populations (Oates et al. 2012), and this may reflect generally lower productivity of this subspecies, or the habitat within which it resides, compared to northern populations.

*Observed parturition rates*: Following winter pregnancy testing, we monitor radio-collared cows with aerial telemetry flights during the birthing season to document the presence and timing of birthed calves. We use visual observation of neonate calves to estimate an "apparent parturition" rate, representing the proportion of pregnant cows with which we detected 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 is left truncated (Gilbert et al. 2014), and our Kaplan-Meier based estimates of calf survival should be considered as optimistic (potentially biased positive) estimates of survival of only those calves who survived long enough to be detected. However, measurements of observed parturition help inform our estimates of overall fecundity, as well as calf survival estimates (Figure 9). Apparent parturition rates have been higher in the Big Hole Valley (89%) and Rocky Mountain Front (87%), and lower in the Cabinet-Fisher (73%; Figure 12). 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 their detection during spring.

*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 4.2% in the Cabinet-Fisher ($N$=48 litters), 0% in the Big Hole Valley ($N$=65 litters), and 13.8% in the Rocky Mountain Front study areas ($N$=58 litters), leading to average litter sizes of 1.04, 1.0, and 1.14, respectively (Figure 9).

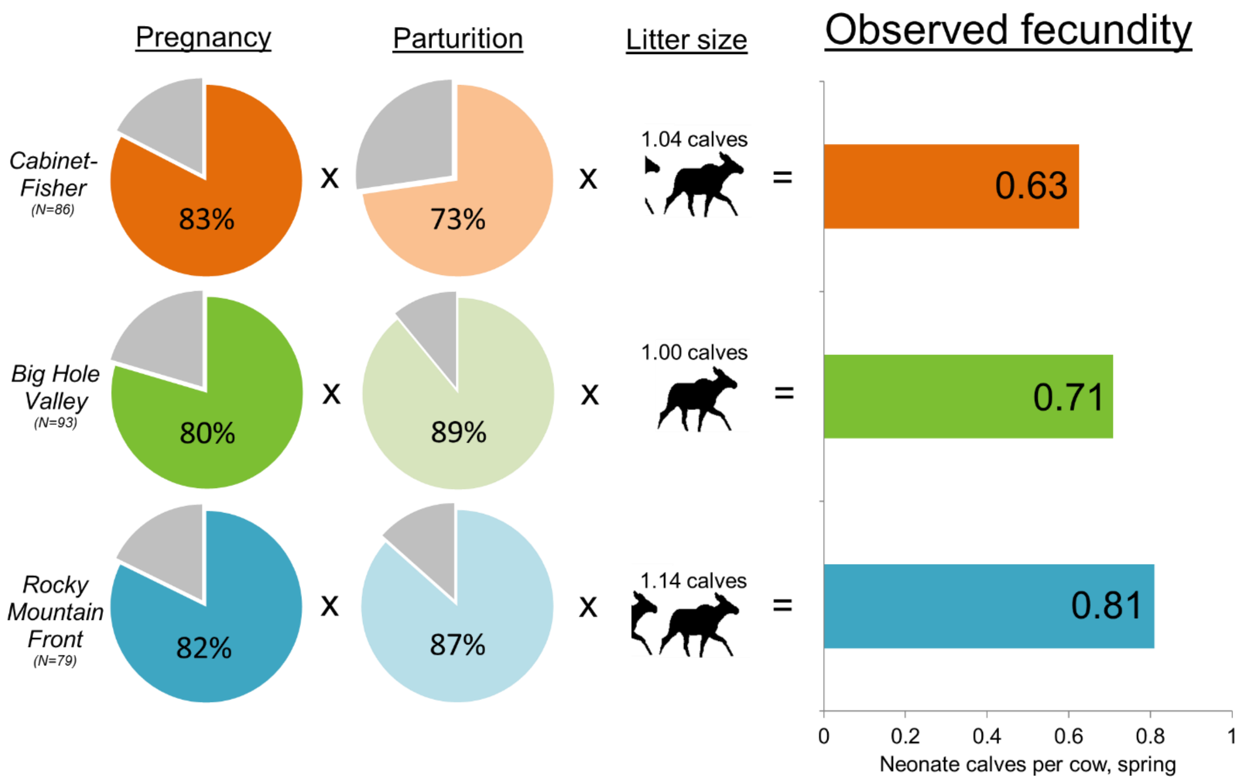


**Figure 9**. *Estimated adult (aged≥2.5) pregnancy rates, observed parturition rates, observed average litter sizes, and net observed fecundity of calves-at-heel during the spring May-June period for moose in 3 study areas of Montana during 4 biological years, 2013–2016.*

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 3 biological years, 2013–2016 (Figure 10).

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 1.02, or an 2% 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 1.12. To the contrary, the Big Hole Valley population has shown relatively high calf survival, but the lowest adult survival rate, which resulted in an estimated population growth rate of 0.98, or an average of 2% decline per year.

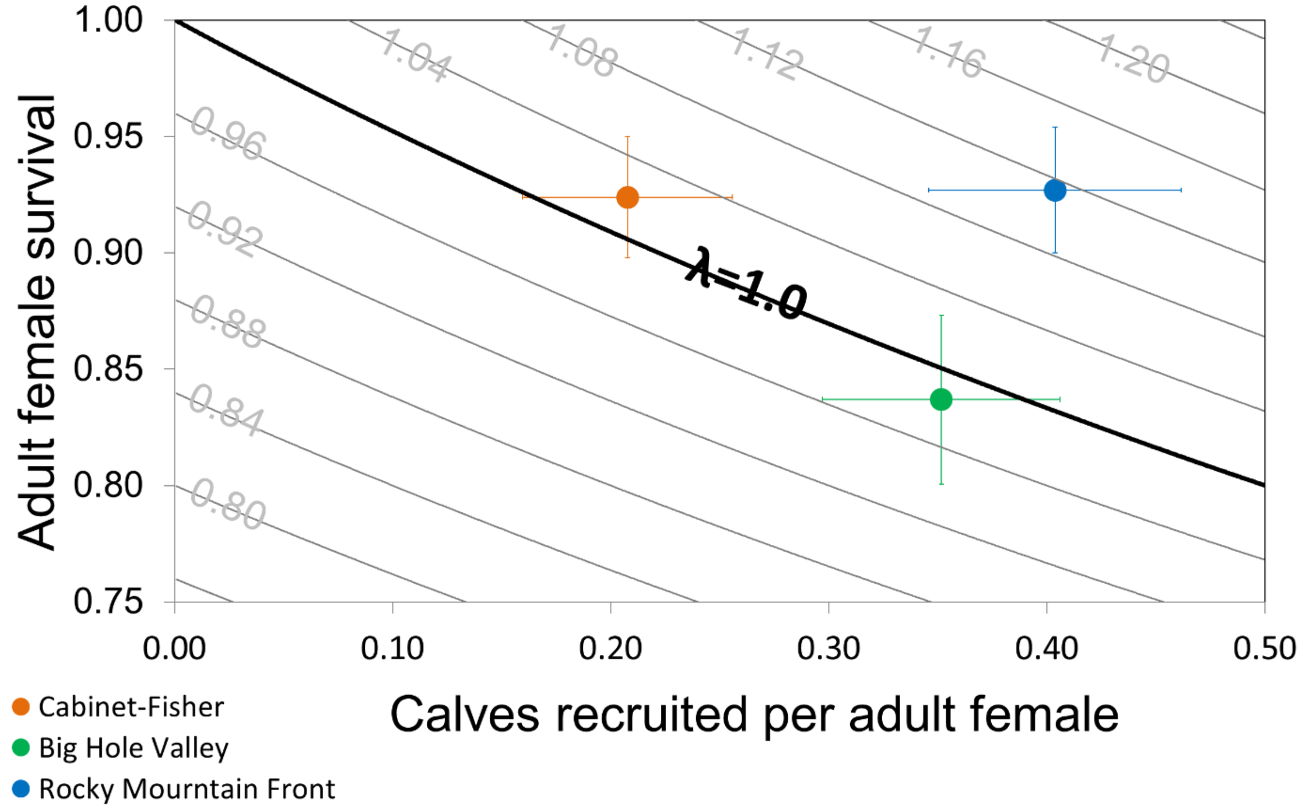


**Figure 10**. *Contour plot showing the estimated mean annual population growth rates (λ, represented as contour lines) resulting from two-dimensional combinations of adult female survival and spring recruitment of calves (integrating rates of pregnancy, parturition, litter size, and calf survival through 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 4 pooled biological years, 2013–2017. Growth rates above the bold line (where $\lambda = 1$) indicate a growing population, growth rates below $\lambda = 1$ indicate declining populations.*

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

### *2.3.1. Hunter-based sampling of disease*

In 2012, we began sending sample kits to all Montana moose hunting license-holders. Hunters were asked to voluntarily assist our study by collecting samples and information regarding their hunts and harvested moose. Included in kits were tubes for collecting blood, which were then sent to the MFWP health lab in Bozeman. Once received, samples were spun in a centrifuge to extract serum. Not all samples yielded useable serum, and viable serum samples were frozen and later sent for serological analysis.

During 2012–2016, we received an average of 108 blood samples per year (range 94–120), representing 30–33% of license-holders. Of those, nearly half (mean=49%, range 42–54%) yielded useable serum samples. This resulted in a total of 265 samples statewide during the 5-year period (Figure 11). We used serum to test for exposure to 5 diseases: 1) brucellosis, 2) anaplasmosis, 3) eastern equine encephalitis (EEE), 4) epizootic hemorrhagic disease (EHD), and 5) leptospirosis. Results were entirely negative for brucellosis (265 negatives from 265 samples). However, we did find ≥1 positive titer for each of the other 4 diseases, which indicated exposure to the pathogens but not necessarily symptomatic disease (Figure 12).

Exposure to anaplasmosis was the most common among those we tested, being positive in 43% of moose and having ≥1 positive result from 75% of districts tested. Anaplasmosis is caused by multiple species of *Anaplasma* spp. bacteria that can affect red and white blood cells in the host. It is generally transmitted to wildlife through multiple species of ticks, though the effects of infection are not fully understood. We detected exposure to EEE in just one moose in northwest Montana (0.4% of samples), and EEE has also been detected in moose in Vermont and elsewhere in the US (Mutebi et al. 2012). We detected exposure to EHD in 2.6% of moose in 1.4% of districts, and we detected exposure to leptospirosis in 16% of moose in 42% of districts.

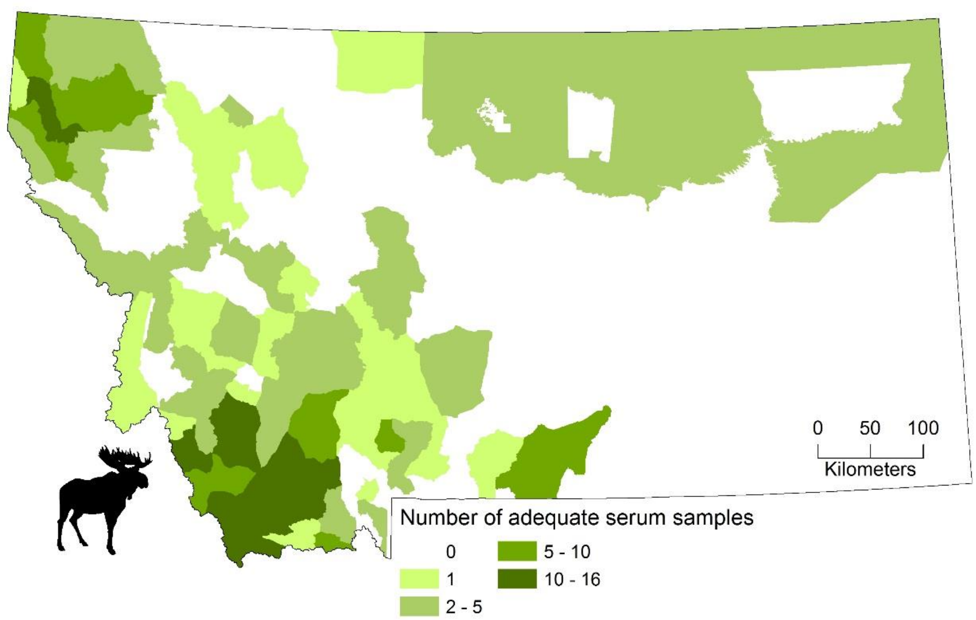


*Figure 11. Number of adequate serum samples collected from hunter-killed moose per HD for laboratory testing of exposure to bacterial or viral disease agents during 2012–2016, Montana.*

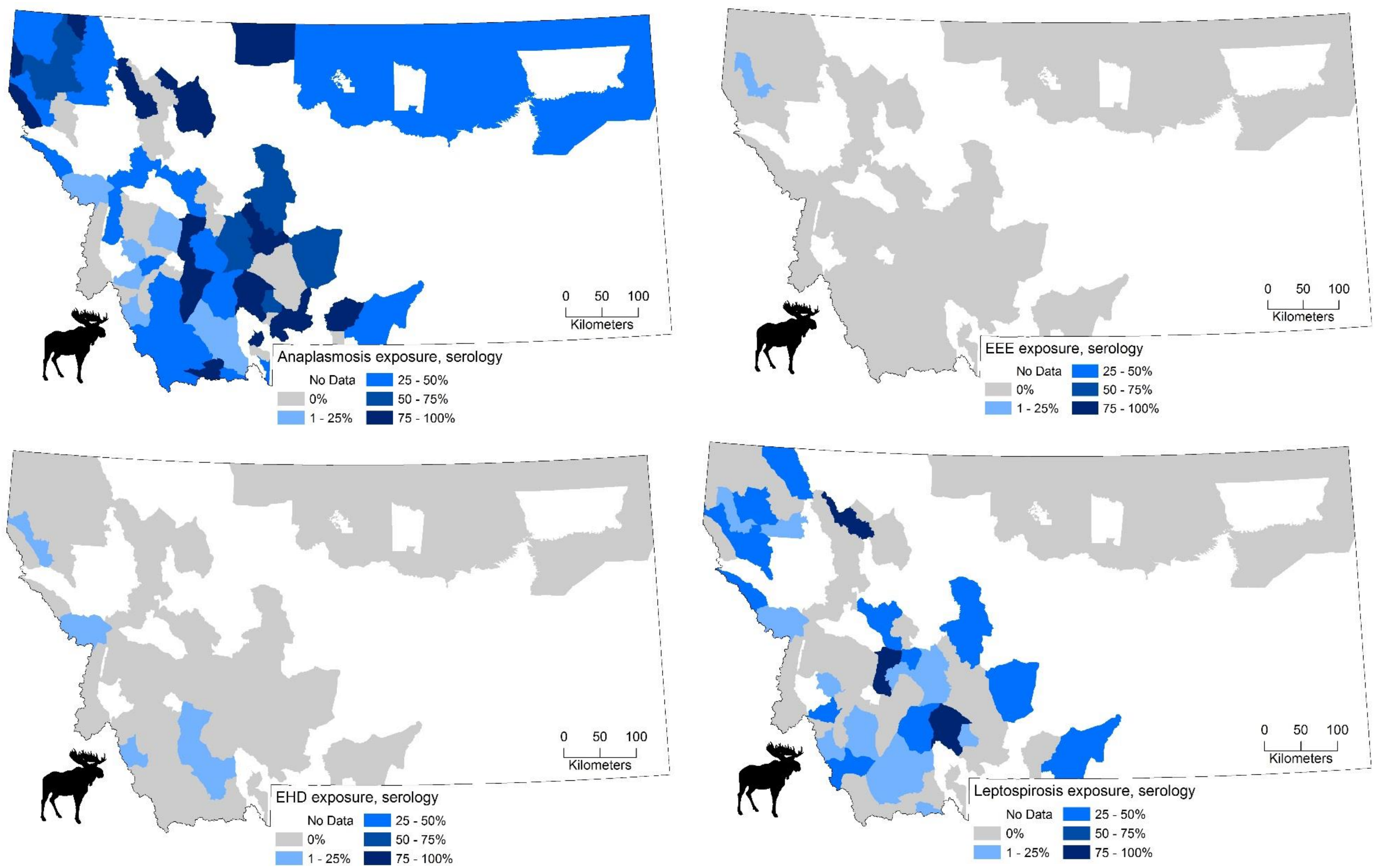


*Figure 12. Rates of positive testing for exposure to four disease agents from N=265 serum samples from moose, averaged per hunting district during 2012–2016, Montana.*

*2.3.2. 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 loss in rump fat depth among bull moose across all 4 years ($P<0.001$), whereas fat among cows did not change with day of season ($P=0.90$; Figure 13).

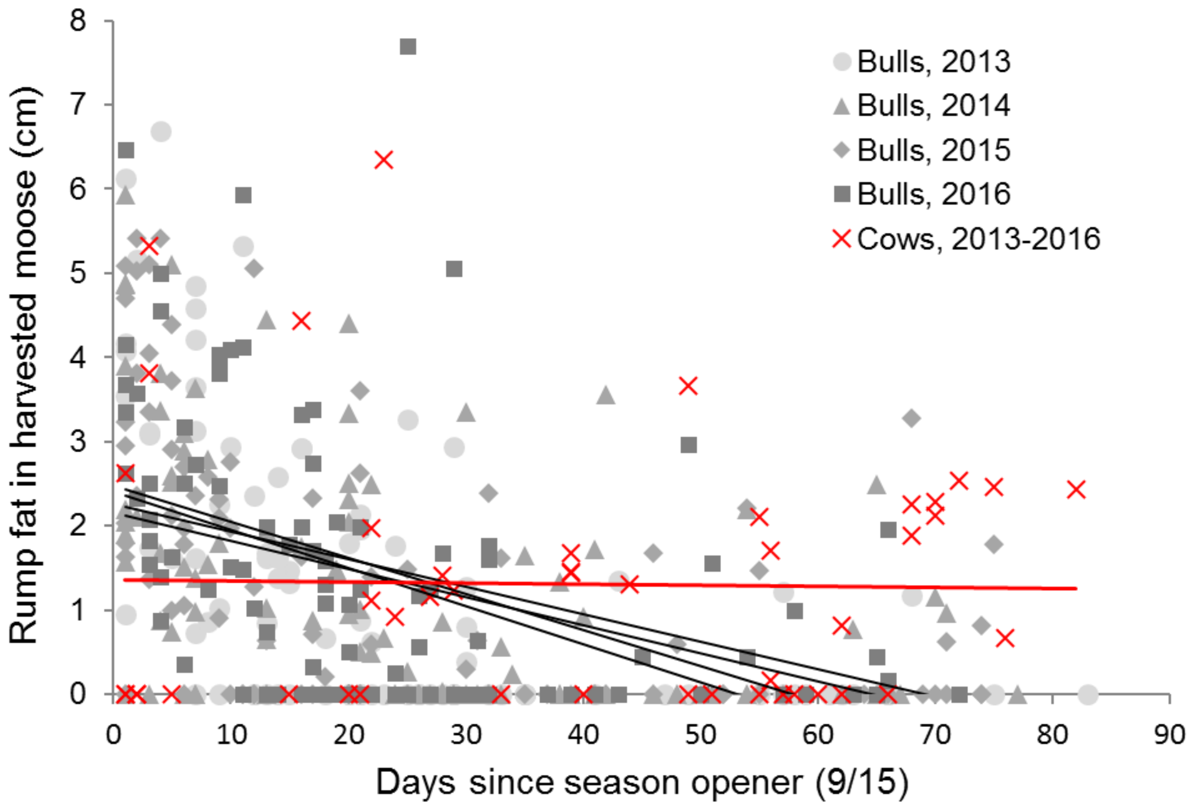


**Figure 13.** *Depth of rump fat declined consistently among harvested bull moose according to the date of harvest during the past 4 hunting seasons (see 4 black trend-lines), whereas average fat depths among cow moose did not significantly change (red trend-line) during the hunting season, Montana, 2013–2016.*

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 22. 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 14).

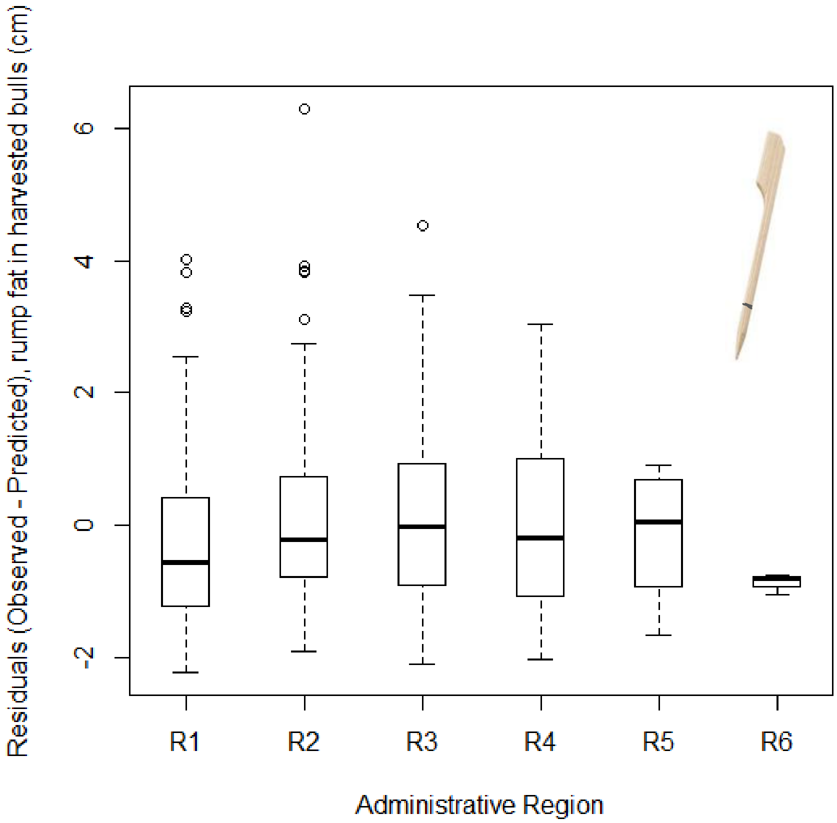


**Figure 14.** *Average residual values comparing the thickness of rump fat in hunter-killed moose among regions while controlling for the date of harvest. These data were collected by hunters by marking a toothpick (inset photo) included in sampling kits mailed to all license-holders, Montana, 2013–2016.*

*2.3.3. Hunter-based monitoring of the rut*

For the lucky few (1.4% of applicants in 2016) 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). In 2016, 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 (39% of license-holders), including the recording of 908 hunter-days and 129 observations of rutting activity. Hunter-days decreased gradually throughout the season, with recurrent weekly spikes of hunting activity during weekends (Figure 15). To the contrary, the proportion of hunters observing rutting activity increased until the first week of October, after which it declined through the middle of October (Figure 15).

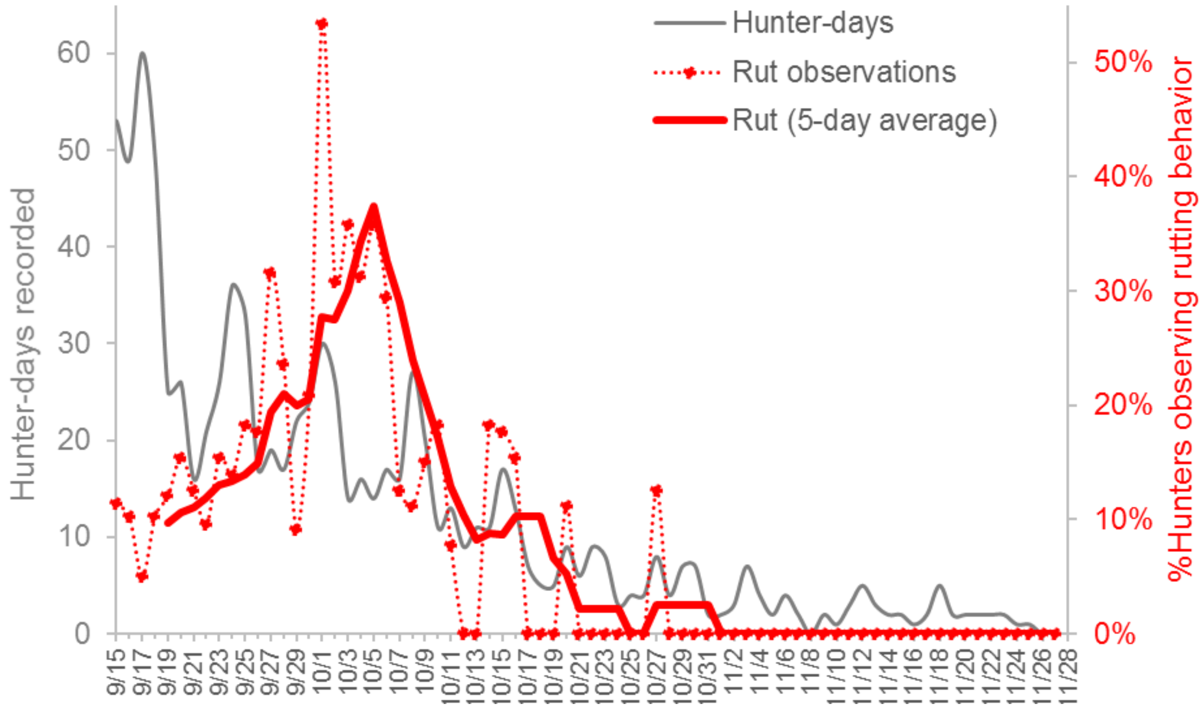


**Figure 15**. *Hunter-days and proportion of hunters observing moose rutting activity throughout the hunting season, 2016, Montana.*

We can also approximate timing of conception by backdating from the timing of births according to average gestation times for moose. In our 3 study areas of Montana, we estimate the average birth date of calves to be approximately the 25th of May each year, with a range of approximately 13 May – 12 June (note: these are preliminary estimates). The scientific literature suggests an average gestation period of 231 days for moose, ranging from 224–236. Backdating our observed birth dates with the 231-day gestation suggests an average conception date of October 6th, and range from September 24th to October 24th (Figure 16). These predicted conception dates correspond well with the set of rut observations made by hunters.

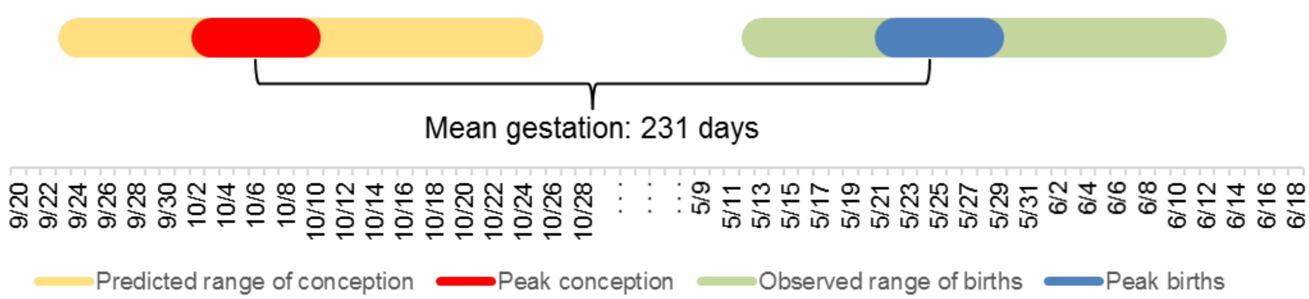


**Figure 16.** *Predicted range and peak conception dates in Montana based on observed range and peak of spring calf birth dates in 3 study areas of Montana and an average gestation period of 231 days from the literature. Note: these are preliminary results.*

## 2.4. Multi-species predator occupancy

Assessing the extent predation limits moose populations is of basic concern to Montana Fish, Wildlife & Parks' research on moose ecology. 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. Remote camera trapping, combined with emerging statistical models, are being used to provide a non-invasive and cost-effective means of estimating occupancy and relative densities of multiple species simultaneously (Brodie et al. 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. 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 17). We randomly selected 15 cells containing summer moose telemetry locations and 15 cells containing winter 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.

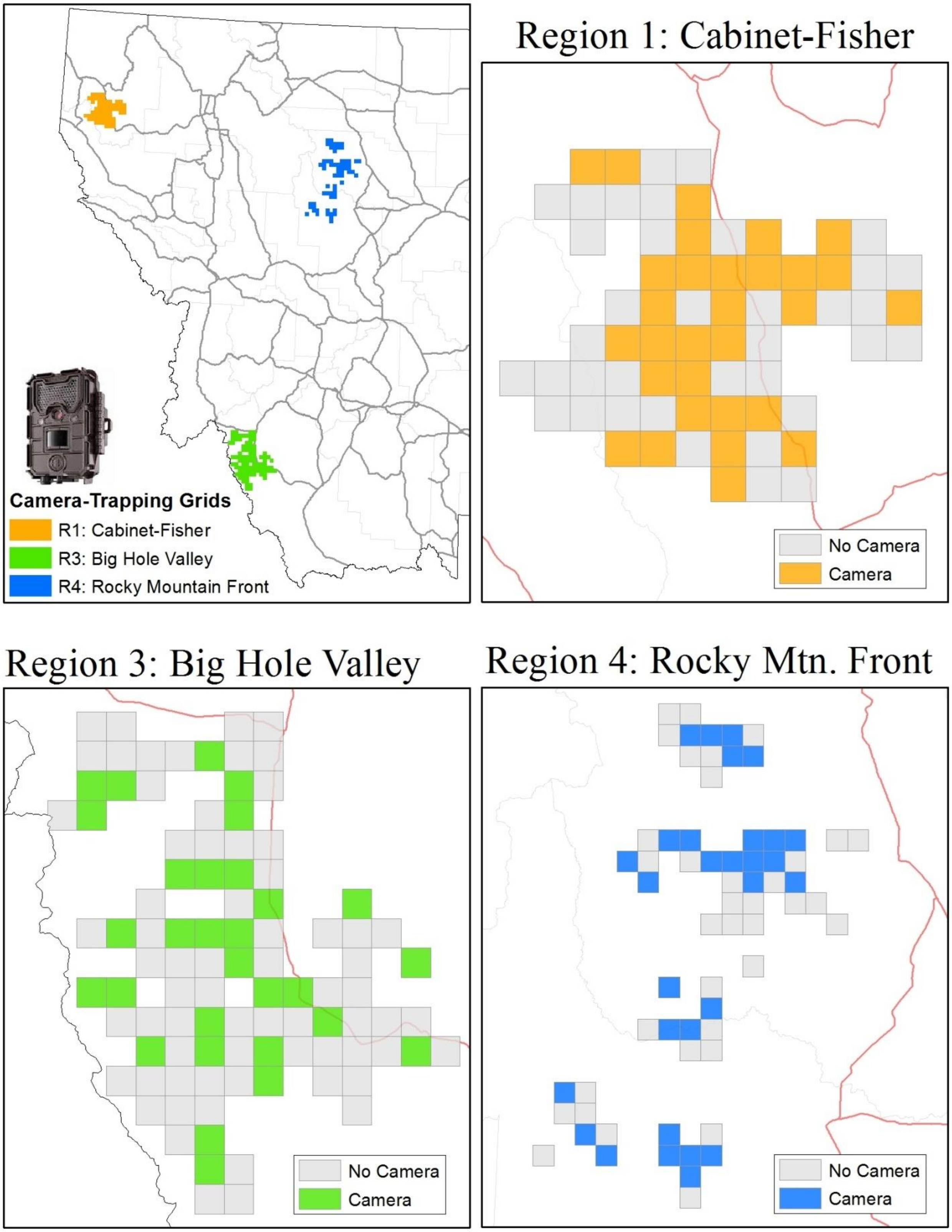


**Figure 17**. *Sampling grids (2 x 2 miles) for deployment of remote cameras for monitoring multi-species predator occupancy across areas occupied by moose, Montana, 2016.*

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).

Since September 2015 we have deployed remote cameras at 116 sites, 90 of which are currently active. To date we have retrieved and stored 1,642,611 images spanning roughly 23,348 camera trap-days. Only a small portion of these images (9,516) spanning approximately 1,245 trap-days have been formally classified within a database (CPW Photo Warehouse; Newkirk, E.S. 2014). This represents ~5% of camera-days downloaded from camera checks to date. Photos from an additional 2,197 camera-days have been sorted (eg. removing images without animals in view) and await final classification within the database. Classified images, along with photos incidentally observed during sorting, revealed a substantial number of detections for all target carnivore species, moose and ancillary species (Table 3, Figure 15).

A major challenge of using remote cameras to monitor species has been the large number of images to be classified. This impediment is now beginning to be addressed through the participation of Montana, Fish, Wildlife & Parks game wardens in reviewing and classifying photos. The CPW Photo Warehouse has the capability of generating separate modules of photos and associated database which allows individuals to classify images and then reintegrate information into the master database (Newkirk, E.S. 2014). We have begun supplying database modules and photos to wardens in August of 2017. The assistance of wardens is expected to greatly expedite photo classification with a group of experienced observers to accurately identify species.

**Table 3.** *Number of camera days in which select species were detected among 9 cameras over 1245 camera-days classified as of August 2017. Some totals of detections may be less than reported in 2016 due to the adoption of a new database system and associated changes in photo storage and classification protocols.*

| Species | # of days detected | % camera-days detected |
|---|---|---|
| Bear (total) | 19 | 3.64% |
| Black bear | 13 | 1.04% |
| Bobcat | 9 | 0.72% |
| Coyote | 69 | 5.54% |
| Elk | 37 | 2.97% |
| Grizzly bear | 6 | 0.48% |
| Moose | 26 | 2.09% |
| Mountain lion | 15 | 1.20% |
| Mule deer | 60 | 4.82% |
| White-tailed deer | 179 | 14.38% |
| Wolf | 32 | 2.57% |
| Camera-days | 1245 | |

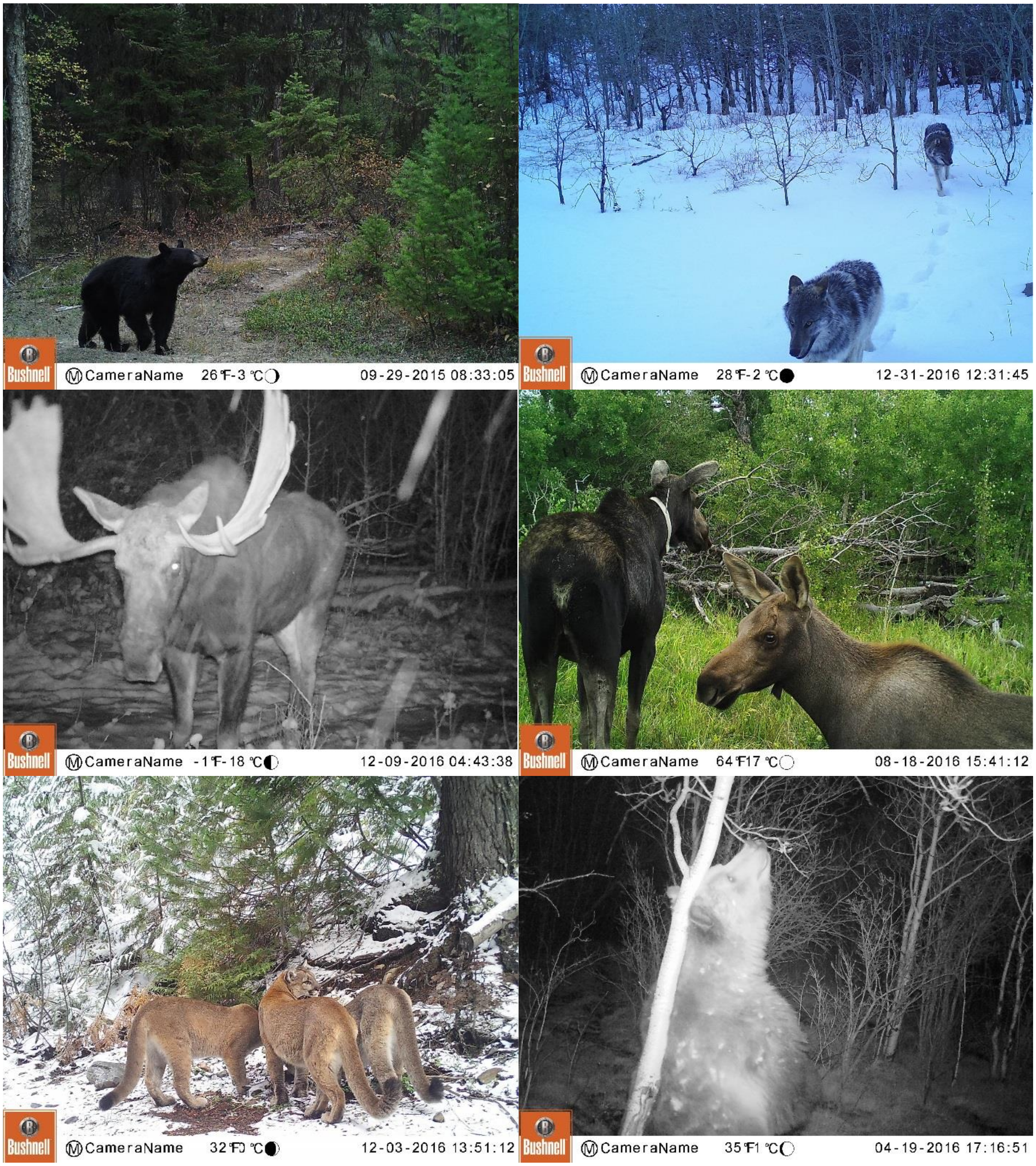


**Figure 18**. *Example photos from remote camera-traps set within seasonal ranges of each moose study area to monitor multi-species occupancy of carnivores and other species, 2015–2017, Montana.*

## Deliverables

Below we list project deliverables (publications, reports, presentations, media communications, and value-added collaborations) stemming from this moose research project, during FYs 13–16 (July 2012–June 2016). 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. 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-5.

**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. In press. *Status and trends of moose populations and hunting opportunity in the western United States*. Alces

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.

### 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 |

## 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 |

| | | | |
|---|---|---|---|
| 2017 | 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 |
| | 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 | Wildlife tracking | Magazine |

**7. Other Project-related Collaborations**

| Partners | Title | Activities during FY17 |
|---|---|---|
| Rick Gerhold & Caroline Grunenwald, University of Tennessee | Development of a serological assay for *Elaeophora schneideri* detection and surveillance in cervids | *Labwork is ongoing<br>*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* | *Lab analyses are completed<br>*Final analyses and writing during FY18 |
| Ky Koitzsch, K2 Consulting, LLC | Estimating population demographics of moose in northern Yellowstone National Park using non-invasive methods | *Providing MT scat samples for fecal pellet morphometry |
| Jason Ferrante & Margaret Hunter, USGS – Gainseville, FL | Genetic approaches to understanding moose health | *Providing blood and tissue samples for genomic analyses |

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