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

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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 9th annual report produced as part of this work. This report contains preliminary results from a subset of our work, including results from the first 8 biological years of moose research and monitoring. All results should be considered preliminary as both data collection and analyses are works in progress.

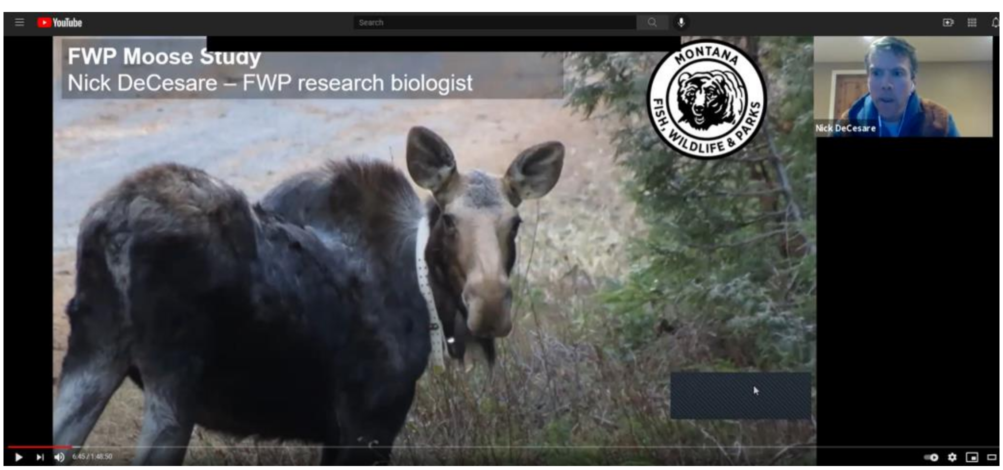
In this report, we provide updates on:

- Estimating moose abundance using statewide hunter sightings data
- Capture and vital rate monitoring of moose in 3 study areas
- Forage quality and diet sampling during both summer and winter
- Hunter-based monitoring of moose nutrition and rutting activity

Web site: We refer readers to our the FWP website for additional information, reports, publications, photos and videos. More information on this study specifically can be found under the "Research" heading at this page:

https://fwp.mt.gov/conservation/wildlife-management/moose

Additionally, a recent presentation, hosted by Swan Valley Connections, regarding moose and this study is available here:



https://youtu.be/QfJ9rNWxp4U

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 (2020-2021)

For the 2020-2021 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. Estimating moose abundance from hunter sightings

An important goal of this study is to evaluate and apply techniques for monitoring moose at a statewide scale and over the long-term. One such approach that we've reported on previously is the use of hunter phone surveys to collect sightings of moose. Hunter sightings have been used to monitor moose in other jurisdictions, including to estimate moose occupancy in New York (Crum et al. 2017) and as an index of moose density (moose seen per unit effort) in Norway (Ueno et al. 2014). Additionally, in Montana, there is a precedent for using such data to estimate the spatial distribution and abundance of wolves by applying occupancy models (Rich et al. 2013) and subsequently translating occupancy estimates into abundance using additional territory area and pack size information.

While the small number of 300–350 hunters targeting moose each year offer relatively few data with limited scientific utility (DeCesare et al. 2016), the much larger population of ~110,000 elk hunters and ~150,000 deer hunters represent a great deal of time and effort spent looking for big game each fall. Each year MFWP conducts phone surveys of a large sample of resident deer and elk hunters in Montana to estimate 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 17,403 sightings of moose over the 5-year period, ranging from 2,334–4,675 sightings per year. We initially conducted occupancy analyses of the presence-absence of moose across the state with these data (see 2017 Annual Report). However, occupancy estimates alone may not offer enough information to managers wishing to monitor trends in moose population size; thus, we subsequently began exploring n-mixture models (Kéry et al. 2018) as a means to count moose at a statewide scale.

Preliminary results from this work indicate potential to monitor abundance (or relative abundance) at the hunting-district scale (Figure 1). We evaluated a suite of covariates likely to be predictive of both the probability of detecting moose and underlying patterns of moose abundance. Thus far, we have found that detection probability varied according to the number of hunters sampled via phone calls each year, the number of hunter days of effort estimated per hunting district, and the specific week of the general hunting season. Covariates related to moose abundance included forest canopy cover and the amount of shrub and forest habitat.

While we are encouraged by these preliminary results, we have identified some additional analysis steps to improve the utility of population estimates. First, review by a small group of FWP area biologists identified some hunting districts where moose numbers were likely being over-estimated and others under-estimated. We hypothesize that these differences likely relate variation in detection probability that has gone unmeasured thus far. We will re-run statistical analyses including a few new covariates that may improve the resolution of detection probability estimates.

Second, while sightings and hunter effort information are collected in reference to the spatial layout of deer and elk hunting districts, moose are managed according to moose hunting districts. To more directly link results to management, we will also re-run these statistical models changing the spatial sampling to align with moose hunting districts.

Lastly, while moose populations do occur outside of moose hunting districts, we will also explore the effects of including all statewide data vs. a focused analysis on just open moose HDs where harvest management is actively occurring. We expect these analyses to be finalized in FY22, and we also we will resume collection of moose sighting data again following the 2021 general hunting season.

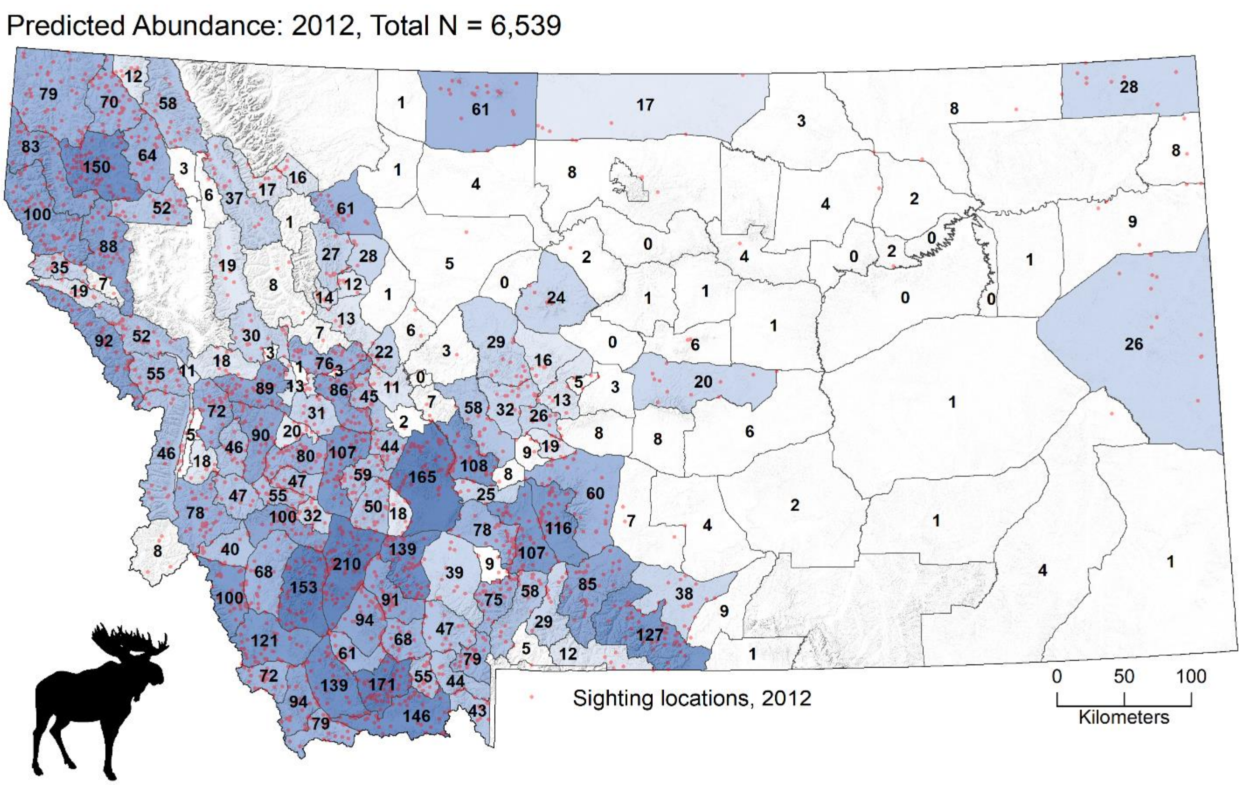


Figure 1. *Preliminary moose population estimates (bold numbers) for each deer-elk hunting district, estimated using n-mixture modeling of hunter sightings data (red dots) for one year of data (2012) from the general hunting season. Results are preliminary and will change pending re-analysis of data with additional covariates to improve detection probability estimates.*

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

2.1. Animal capture and handling

In February of 2021 we worked with a contracted helicopter capture company (Quicksilver Air) and local landowners to capture moose. A total of 24 adult females were captured in 3 study areas in 2021 including both new animals and recaptured study animals for collar replacement. Moose were fit with GPS radio-collars (Lotek GPS-Globalstar). During 2013–21, we have conducted a total of 229 captures of 193 individual adult female moose, and as of September 1, 2021, 82 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 September 1, 2021.*

	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
2021 captures	6	7	11	24
Total captures	**62**	**70**	**73**	**229**
Moose currently on–air	30	25	27	82

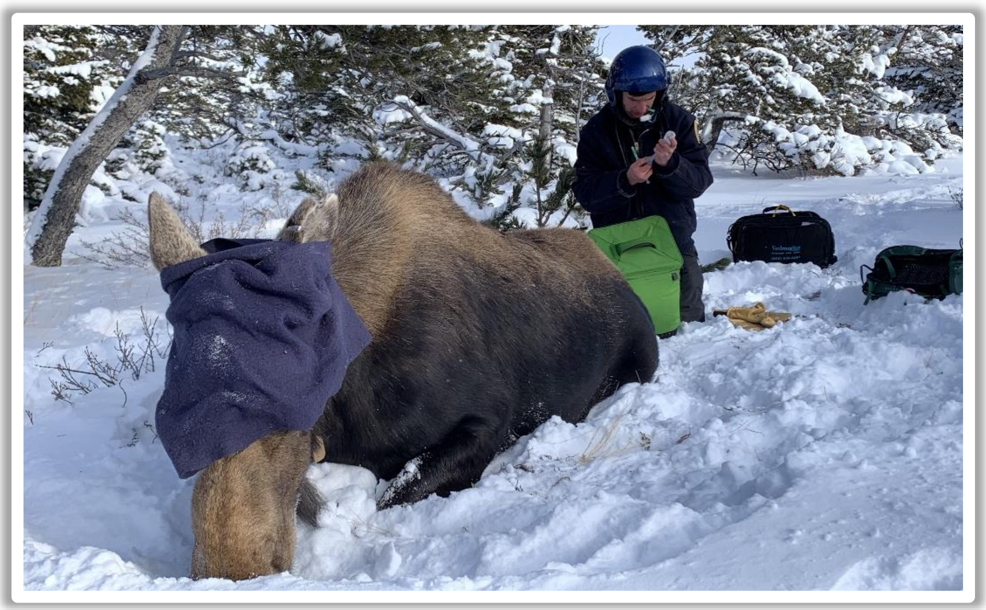


Figure 2. FWP *Research technician Collin Peterson loading syringes with reversal drugs after handling moose F422 in the Rocky Mountain Front study area, 2021.*

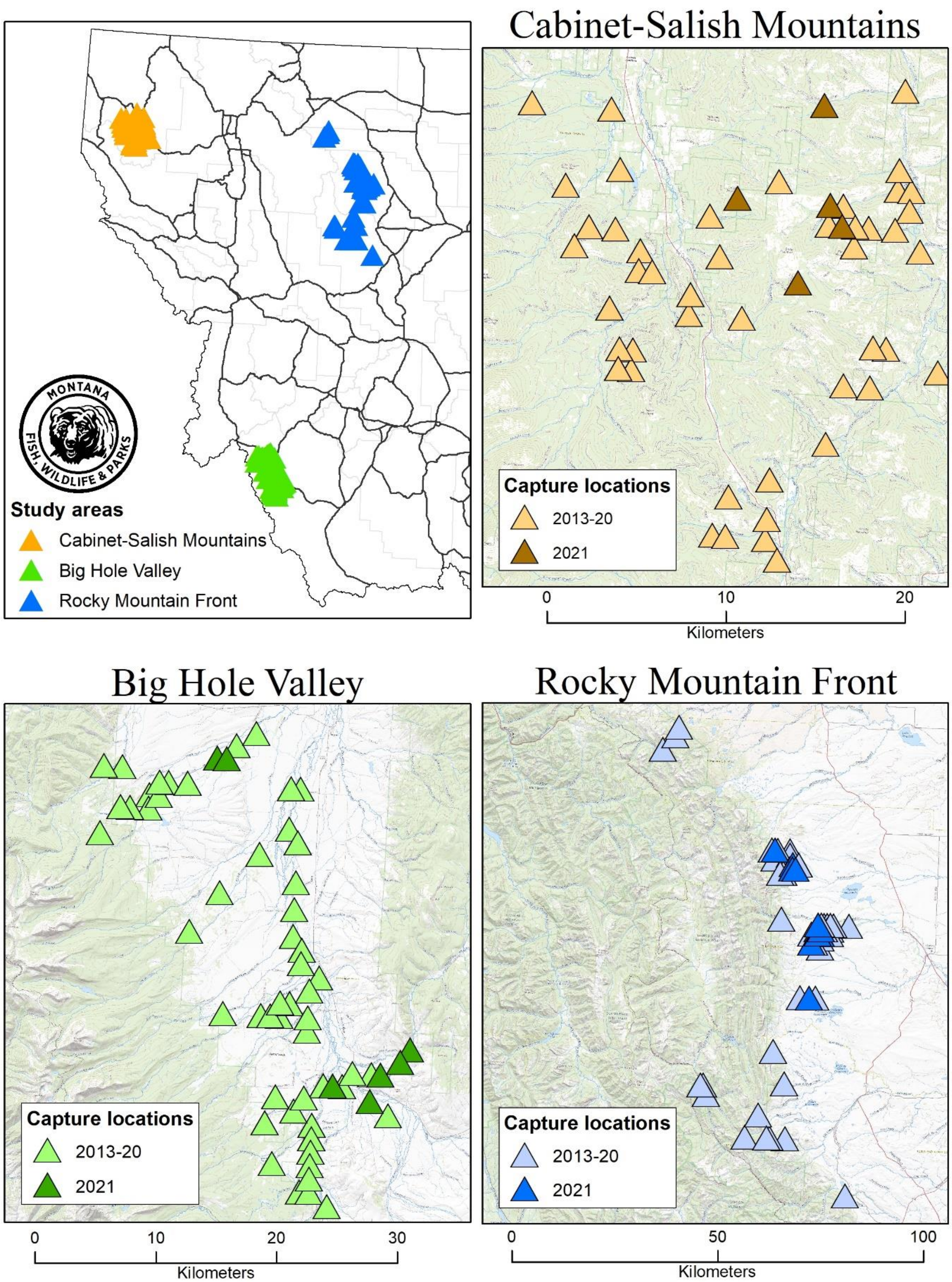


Figure 3. *Moose winter capture locations during 2013–2021 across 3 study areas in Montana.*

2.2. Monitoring vital rates

<u>*2.2.1. Adult female survival*</u>.— Our study of adult female survival to date includes 186 radio-collared adult female moose and 630 animal-years of monitoring, with a staggered-entry design of individuals entering into the study across 9 winter capture seasons (*see* 2.1 Animal capture and handling). Animals have been deployed with both VHF (*N*=73) and GPS (*N*=150) collars. We estimated Kaplan-Meier annual survival rates for each study area during each biological year as well as across the 8 biological years pooled together in a recurrent-time format.

Pooled annual survival estimates across the entire monitoring period for each study area were 0.900 (SE=0.020, 95% CI=[0.86,0.94]) in the Cabinet-Salish, 0.860 (SE=0.023, 95% CI=[0.82,0.91]) in the Big Hole Valley, and 0.889 (SE=0.021, 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 the Cabinet-Salish (0.93), but lower in both the Big Hole Valley (0.82) and Rocky Mountain Front (0.77). 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).

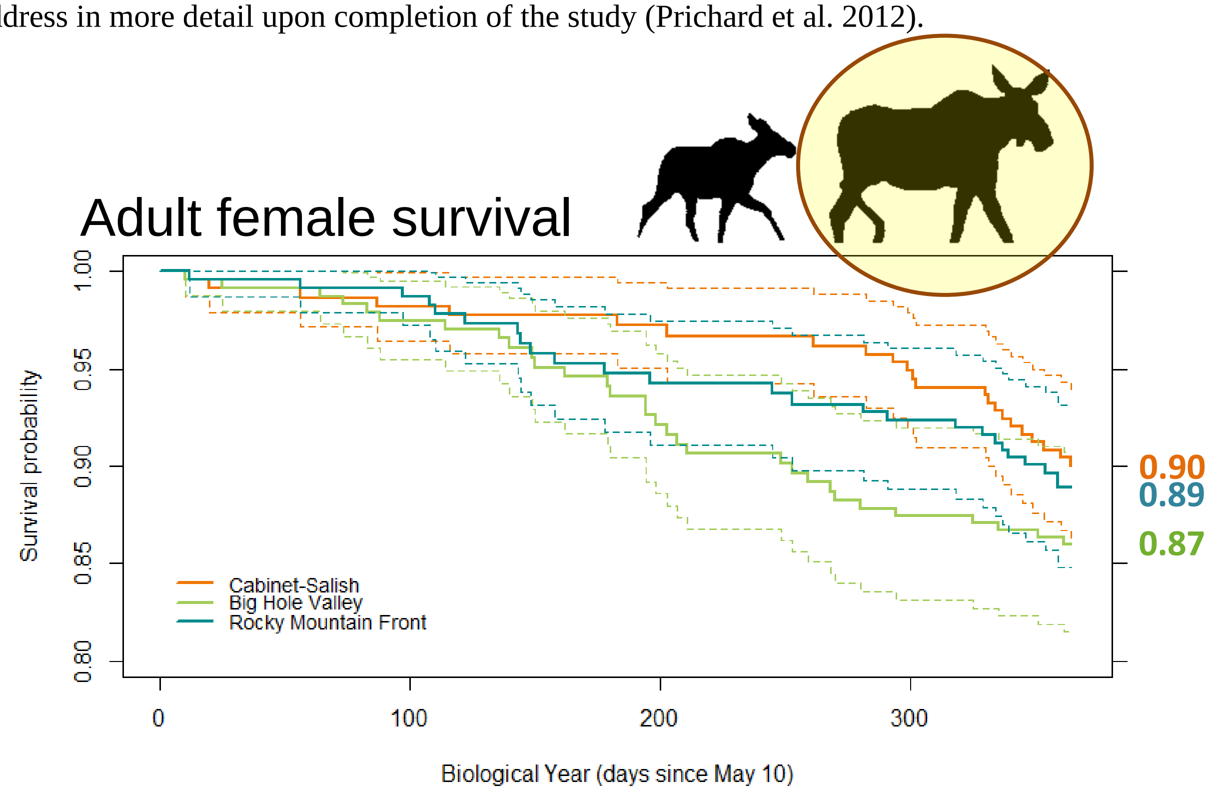


Figure 4. *Kaplan-Meier estimates and 95% confidence limits of annual adult female survival within each study, across 8 biological years for each study area, Montana, 2013–2021.*

During 8 biological years of monitoring, we have documented 79 mortalities of collared adult moose across all study areas: 23 in the Cabinet-Fisher, 31 in the Big Hole Valley and 25 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.

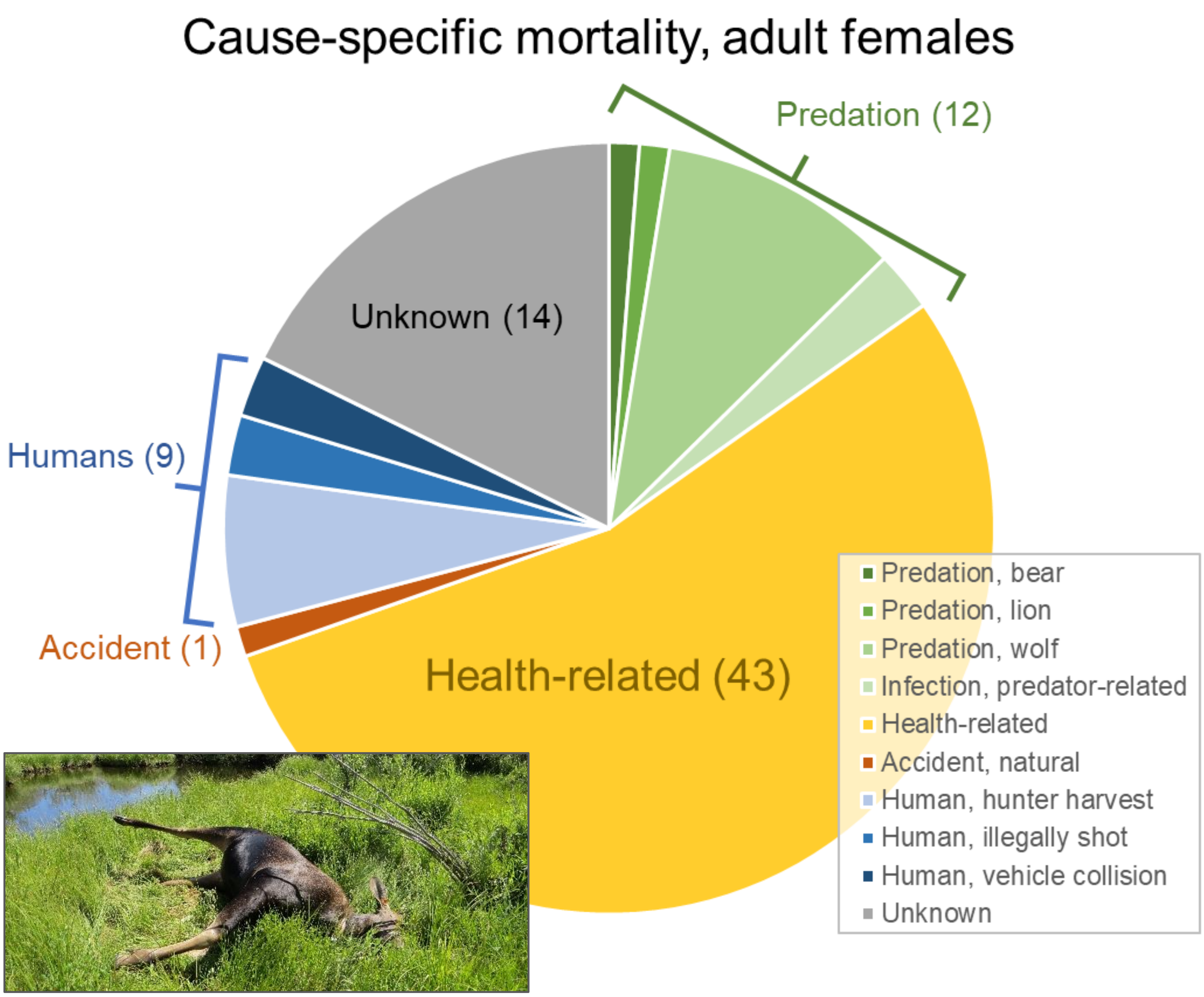


Figure 5. *Counts of radio-collared adult female moose by cause-of-mortality across all 3 focal study areas. Note, this summary does not account for variations in sample size and timing that can affect the perceived relative risk to each cause. Such concerns will be accounted for using formal cumulative incidence analyses upon completion 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 aerial telemetry during 15 May – 15 July to estimate an "observed parturition" rate, representing the proportion of pregnant cows with neonate calves each spring. A limitation of this approach is the unknown proportion 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 calf survival estimates are optimistic in that they don't account for mortality of calves prior to initial detection. These data have yet to be updated with 2020–2021 litters, pending final pregnancy analyses. Through 2019, observed parturition rates have been higher in the Rocky Mountain Front (91%) and Big Hole Valley (87%), 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 and/or death of neonatal calves prior to detection.

Calf survival: As a result of spring monitoring of neonate calves, we have documented 440 calves from 401 litters born during 2013–2020. We then monitored the fates of these calves by visually locating them with their dams throughout their first year of life. Over the first 8 biological years (May 2013 – May 2021), pooled Kaplan-Meier survival estimates of calves-at-heel were 0.419 (SE=0.045, 95% CI=[0.34,0.52]) in the Cabinet-Fisher, 0.461 (SE=0.043, 95% CI=[0.39,0.55]) in the Big Hole Valley, and 0.476 (SE=0.040, 95% CI=[0.40, 0.56]) on the Rocky Mountain Front (Figure 5). Calf survival results mirror those of observed parturition, suggesting observed parturition rates are likely influenced by mortality of neonates prior to detection, more so than fetal losses.

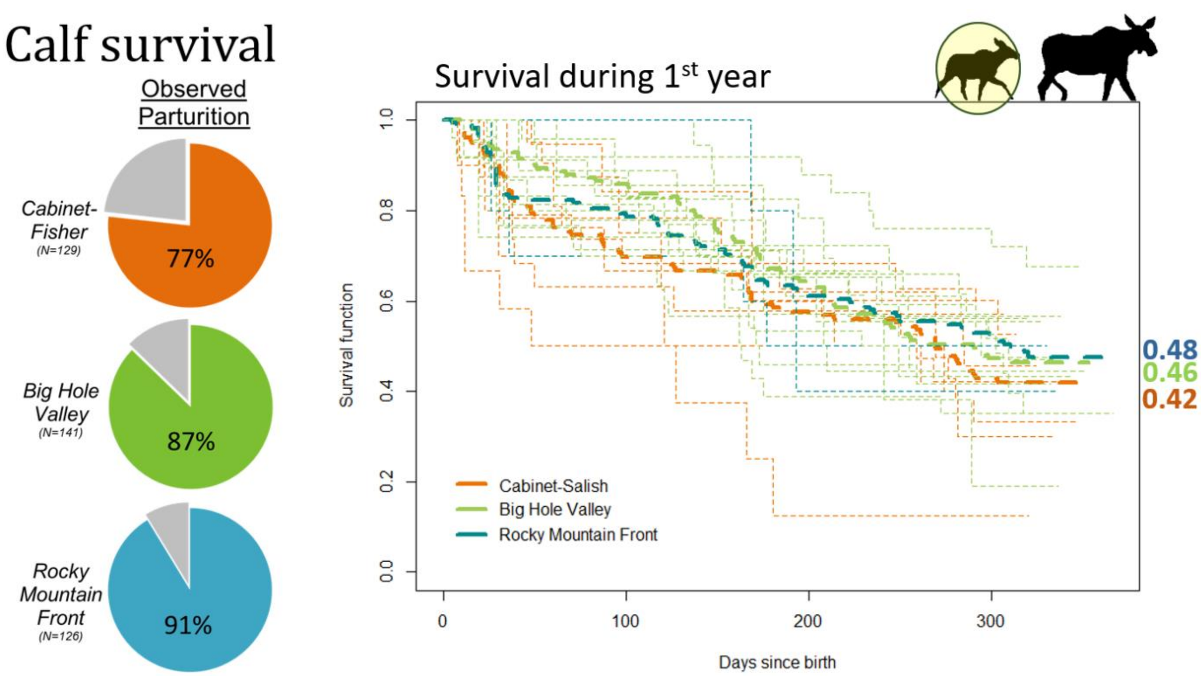


Figure 6. *Observed parturition (proportion of pregnant cows with calves-at-heel during spring) and Kaplan-Meier estimates of annual calf survival for the first year of life within each study area, where bold lines are pooled estimates across 8 biological years and thin lines are annual estimates per year, Montana, 2013–2021.*

2.2.3 <u>Adult female fecundity.</u>—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 telemetry guided snow-tracking.

Pregnancy rates: Final pregnancy data from the springs of 2020 and 2021 are not yet available, pending fecal progestogen lab results. Pooled across study areas, 7 years (2013-2019), and 501 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 7% in the Cabinet-Fisher (N=118 litters), 1% in the Big Hole Valley (N=141 litters), and 21% in the Rocky Mountain Front study areas (N=138 litters; Figure 6).

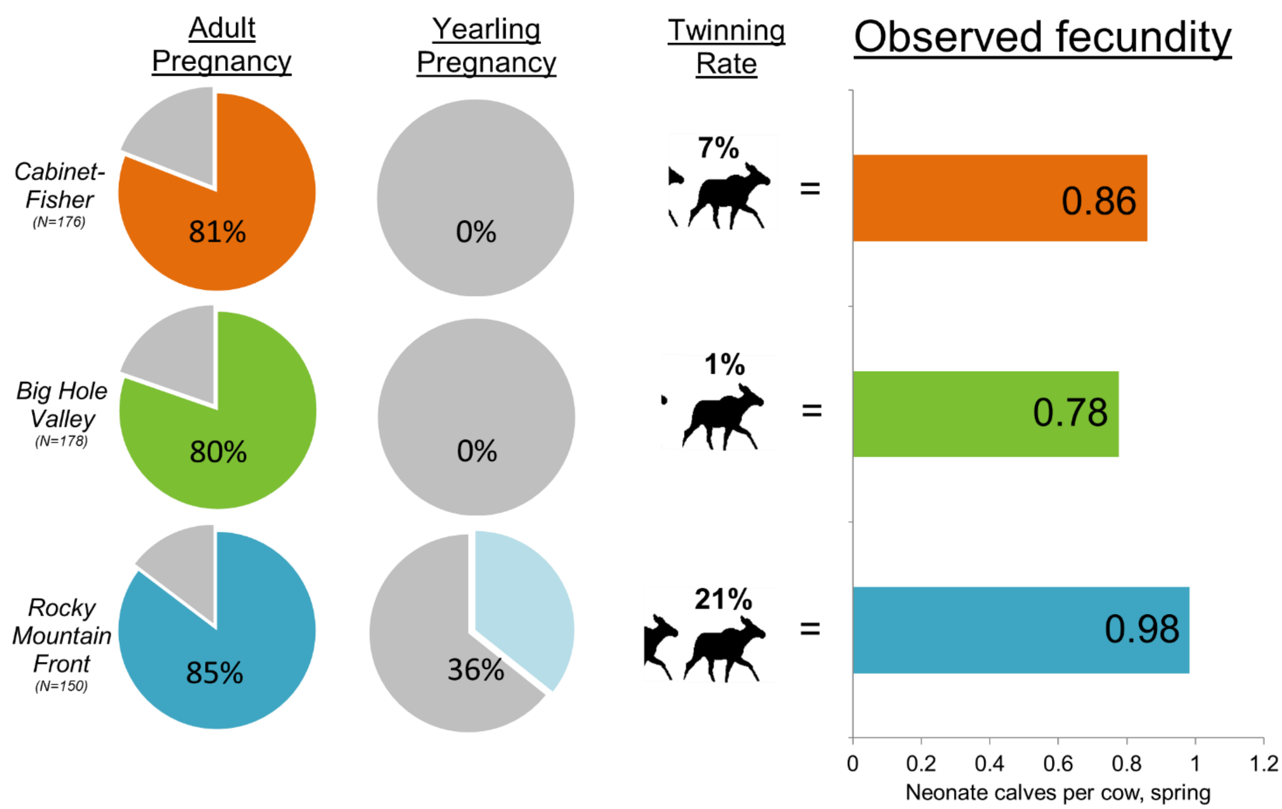


Figure 7. *Estimated adult (age≥2.5) pregnancy rates, yearling (aged 1.5) pregnancy rates, observed twinning rates, and net observed fecundity of calves per adult female in 3 study areas of Montana to date, 2013–2021.*

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 7 biological years, 2013–2019 (Figure 7). *Growth rate analyses for 2020 are still awaiting final pregnancy lab results, and thus are not included here.*

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.

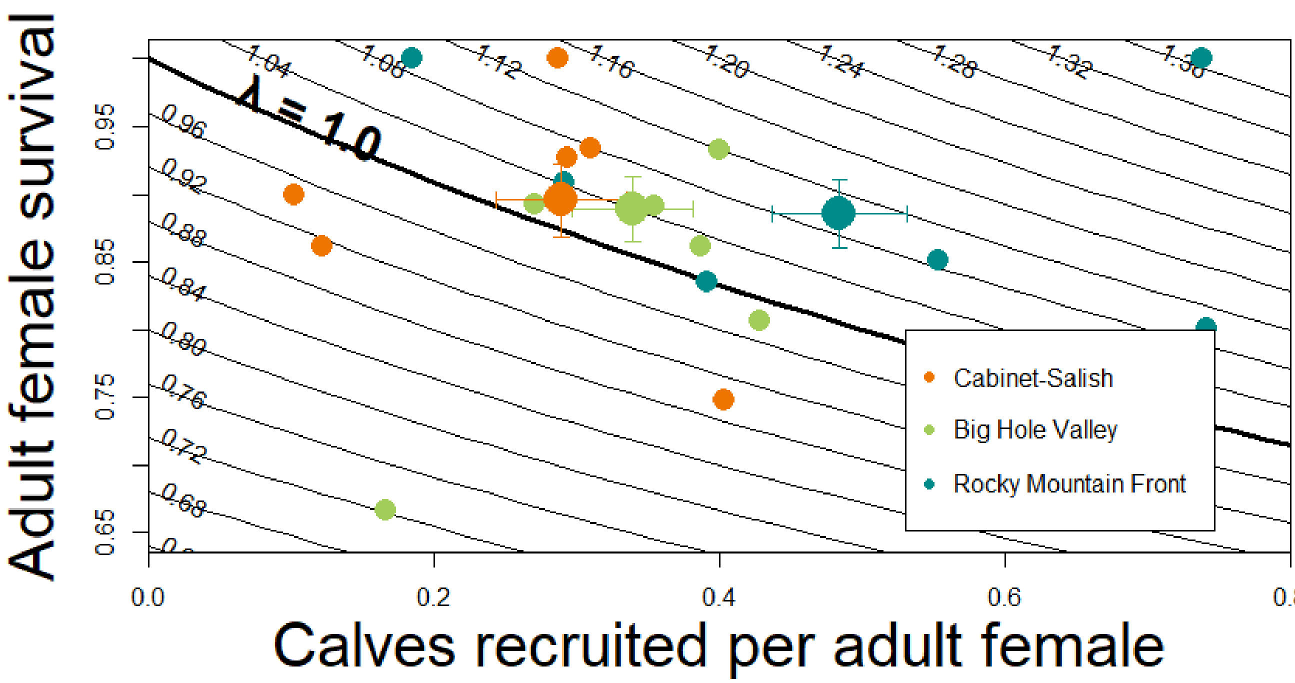


Figure 8. *Contour plot showing the estimated mean annual population growth rates (λ, represented as contour lines) resulting from two-dimensional combinations of adult female survival and spring recruitment of calves (integrating rates of pregnancy, parturition, litter size, and calf survival through 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 Composition and nutritional quality of moose diets

The nutritional quality of the diets of moose ultimately affects adult survival, pregnancy, and parturition rates (McArt et al. 2009, Milner et al. 2013). To better understand the effects of forage nutrition on vital rates of moose, we are assessing the composition and quality of the diets of moose during 2 important life-history stages: post-parturition during summer and late winter. We will be determining the digestible energy content (kilocalories/gram), digestible protein content, and concentration of tannins (which influences forage digestibility) of plants in moose diets during these time periods as well as assessing diet composition at the individual level.

2.3.1 Summer forage surveys. — Between 15 June and 15 July 2021, we surveyed the locations of GPS-collared moose for evidence of recent browsing activity by moose on trees, shrubs, and forbs within the vicinity of each location (Figure 9). For each species with evidence of browse, we located 3-5 individual plants with browse evidence and clipped the new growth of 5-10 stems and their leaves from each individual plant. We stored samples within paper bags in a freezer. We will compile samples by browse species, study area, elevational zone, and time of collection, and submit them for quality analyses within the coming year. In total, we surveyed 117 locations from 48 GPS-collared moose (47 locations among 18 moose in Cabinet-Salish, 30 locations among 14 moose in the Big Hole, and 40 locations among 16 moose on the Rocky Mountain Front). We collected 150 plant samples among 29 unique species browsed in Cabinet-Salish, 59 samples among 11 species in the Big Hole, and 77 samples among 19 species on the Rocky Mountain Front (Table 2). We also collected fresh fecal samples (*N*=81, to date) to determine the composition of individual diets during summer through DNA metabarcoding techniques.

Figure 9. *Collin Peterson samples willow leaves and twigs at a moose feeding site in the Big Hole study area, 2021.*

Table 2. *Summer plant species with evidence of browsing by moose and clipped for forage quality analyses at locations of GPS-collared moose between 15 June and 15 July 2021.*

Study area	Common name	Genus	Species	Family	Lifeform
Big Hole	Cow parsnip	Heracleum	maximum	Apiaceae	forb
Big Hole	Twinberry honeysuckle	Lonicera	involucrata	Caprifoliaceae	shrub
Big Hole	False azalea	Menziesia	feruginea	Ericaceae	shrub
Big Hole	Black swamp gooseberry	Ribes	inerme	Grossulariaceae	shrub
Big Hole	Barclay's willow	Salix	barclayi	Salicaceae	shrub
Big Hole	Booth's willow	Salix	boothii	Salicaceae	shrub
Big Hole	Drummond's willow	Salix	drummondiana	Salicaceae	shrub
Big Hole	Geyer's willow	Salix	geyeriana	Salicaceae	shrub
Big Hole	Lemmon's willow	Salix	lemmonii	Salicaceae	shrub
Big Hole	Plane-leaf willow	Salix	planifolia	Salicaceae	shrub

Table 2 (cont).

Study area	Common name	Genus	Species	Family	Lifeform
Cabinet-Salish	Black cottonwood	Populus	balsamifera	Salicaceae	deciduous tree
Cabinet-Salish	Quaking aspen	Populus	tremuloides	Salicaceae	deciduous tree
Cabinet-Salish	Aster	Aster	sp	Asteraceae	forb
Cabinet-Salish	Hooker's fairybells	Prosartes	hookeri	Liliaceae	forb
Cabinet-Salish	Rocky Mountain maple	Acer	glabrum	Sapindaceae	shrub
Cabinet-Salish	Grey alder	Alnus	incana	Betulaceae	shrub
Cabinet-Salish	Serviceberry	Amelanchier	alnifolia	Rosaceae	shrub
Cabinet-Salish	Snowbrush ceanothus	Ceanothus	velutinus	Rhamnaceae	shrub
Cabinet-Salish	Red osier dogwood	Cornus	sericea	Cornaceae	shrub
Cabinet-Salish	Hawthorne	Crataegus	douglasii	Rosaceae	shrub
Cabinet-Salish	Oceanspray	Holodiscus	discolor	Rosaceae	shrub
Cabinet-Salish	Utah honeysuckle	Lonicera	utahensis	Caprifoliaceae	shrub
Cabinet-Salish	False azalea	Menziesia	feruginea	Ericaceae	shrub
Cabinet-Salish	Mock orange	Philedelphus	lewisii	Hydrangeaceae	shrub
Cabinet-Salish	Chokecherry	Prunus	virginiana	Rosaceae	shrub
Cabinet-Salish	White-stem gooseberry	Ribes	inerme	Grossulariaceae	shrub
Cabinet-Salish	Black swamp gooseberry	Ribes	lacustre	Grossulariaceae	shrub
Cabinet-Salish	Prickly wild rose	Rosa	acicularis	Rosaceae	shrub
Cabinet-Salish	Dwarf rose	Rosa	gymnocarpa	Rosaceae	shrub
Cabinet-Salish	Woods' rose	Rosa	woodsii	Rosaceae	shrub
Cabinet-Salish	Thimbleberry	Rubus	parviflora	Rosaceae	shrub
Cabinet-Salish	Pussy willow	Salix	discolor	Salicaceae	shrub
Cabinet-Salish	Drummond's willow	Salix	drummondiana	Salicaceae	shrub
Cabinet-Salish	Scouler's willow	Salix	scouleriana	Salicaceae	shrub
Cabinet-Salish	Buffaloberry	Sheperdia	canadensis	Elaeagnaceae	shrub
Cabinet-Salish	Mountain ash	Sorbus	scopulina	Rosaceae	shrub
Cabinet-Salish	Birchlead spirea	Spiraea	betulifolia	Rosaceae	shrub
Cabinet-Salish	Douglas' spirea	Spiraea	douglasii	Rosaceae	shrub
Cabinet-Salish	Snowberry	Symphoricarpos	albus	Caprifoliaceae	shrub
Rocky Mountain Front	Quaking aspen	Populus	tremuloides	Salicaceae	deciduous tree
Rocky Mountain Front	Firweed	Chamerion	angustifolium	Onagraceae	forb
Rocky Mountain Front	Birch	Betula	nana	Betulaceae	shrub
Rocky Mountain Front	Red osier dogwood	Cornus	sericea	Cornaceae	shrub
Rocky Mountain Front	Chokecherry	Prunus	virginiana	Rosaceae	shrub
Rocky Mountain Front	Black swamp gooseberry	Ribes	lacustre	Grossulariaceae	shrub
Rocky Mountain Front	Bebb's willow	Salix	bebbiana	Salicaceae	shrub
Rocky Mountain Front	Booth's willow	Salix	boothii	Salicaceae	shrub
Rocky Mountain Front	Undergreen willow	Salix	commutata	Salicaceae	shrub
Rocky Mountain Front	Pussy willow	Salix	discolor	Salicaceae	shrub
Rocky Mountain Front	Drummond's willow	Salix	drummondiana	Salicaceae	shrub
Rocky Mountain Front	Coyote willow	Salix	exigua	Salicaceae	shrub
Rocky Mountain Front	Geyer's willow	Salix	geyeriana	Salicaceae	shrub
Rocky Mountain Front	Lemmon's willow	Salix	lemmonii	Salicaceae	shrub
Rocky Mountain Front	Dusky willow	Salix	melanopsis	Salicaceae	shrub
Rocky Mountain Front	Plane-leaf willow	Salix	planifolia	Salicaceae	shrub
Rocky Mountain Front	False mountain willow	Salix	pseudomonticola	Salicaceae	shrub
Rocky Mountain Front	Scouler's willow	Salix	scouleriana	Salicaceae	shrub
Rocky Mountain Front	Autumn willow	Salix	serissima	Salicaceae	shrub

2.3.2 Winter forage surveys and diet composition. —

Winter forage quality also influences important moose vital rates like calf recruitment and adult survival (Testa 2004, Milner et al. 2013). During winters of 2021-22 and 2022-23, we will replicate our summer forage monitoring methods by visiting the locations of GPS-collared females and sampling plants with browse evidence. Because many of these plants are deciduous and unidentifiable during winter, we will return to each plant sampled during summer and identify to species. Clipped samples will be analyzed for nutritional quality and combined with diet composition data to estimate the quality of individual winter diets.

During the winters of 2013-2020, we collected fecal samples from captured moose. We used DNA barcoding to estimate diet composition of 197 individual samples, and the collective diet composition of moose throughout our 3 study areas (Figure 10). In Cabinet-Salish, moose primarily consumed evergreen and deciduous shrubs and coniferous trees. Snowbrush ceanothus (*C. velutinus*) was the most heavily consumed species during winter (42% of diet), followed by willow (*Salix* spp., 16%) and Douglas fir (*Pseudotsuga menziesii*, 13%, Figure 10). In the Big Hole, moose primarily foraged on willows but were also subsidized by haystack vegetation (grasses, rushes, and sedges) during the winter. Willows were the most consumed forage item (71%) followed by grasses (*Poaceae*, 14%), black swamp gooseberry (*Ribes lacustre*, 4%), rushes (*Juncus* spp., 2%) and sedges (*Carex* spp.; 2%). On the Rocky Mountain Front, winter browse primarily occurred on deciduous shrubs and trees. Willows were the most consumed forage item (38%) followed by red osier dogwood (*Cornus sericea*, 24%), birch (*Betula* spp., 15%), members of the rose family (*Rosaceae*, 8%, most likely comprising wild rose [*Rosa* spp.] and serviceberry [*Amelanchier alnifolia*]), and cottonwood and aspen trees (*Populus* spp., 5%).

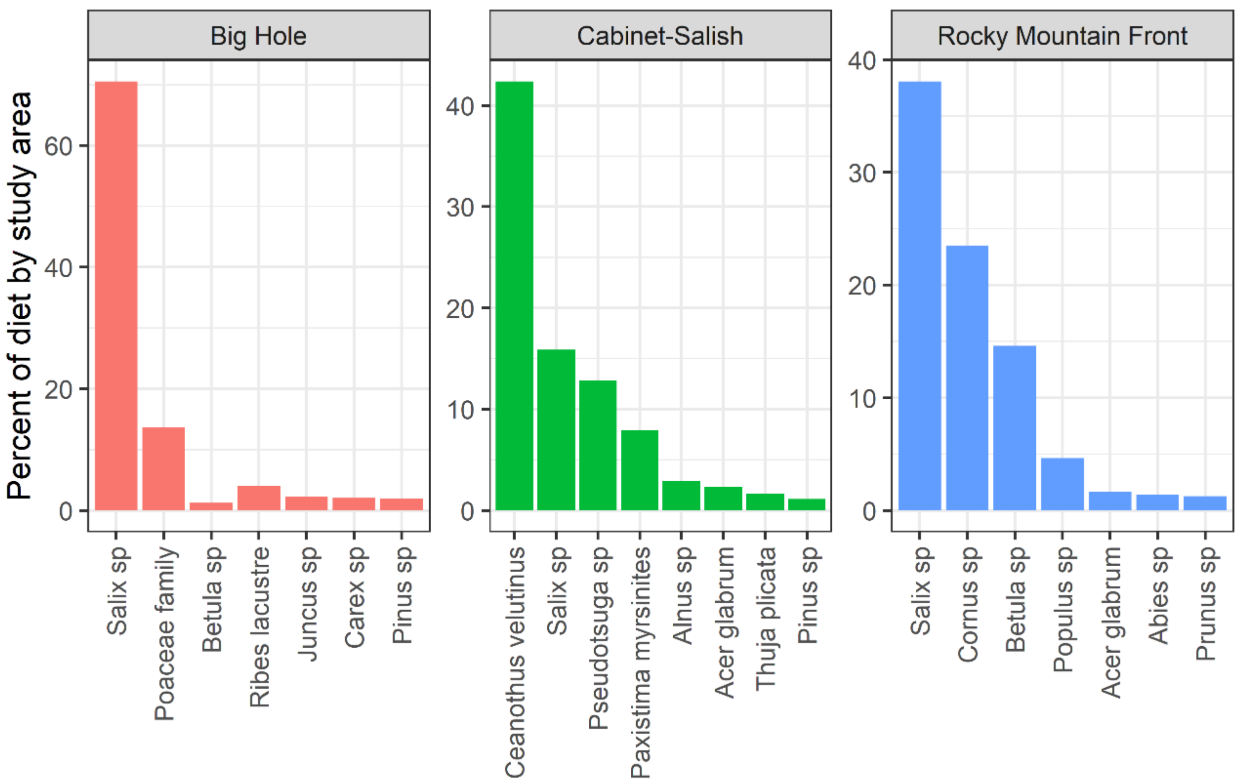


Figure 10. *Winter diet composition (plants exceeding 2% of total) across 197 individuals in the Big Hole, Cabinet-Salish, and Rocky Mountain Front study areas, 2013-2020.*

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>

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 have measured rump fat by marking a toothpick within provided sampling kits for 887 bull and 103 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 8 years ($P<0.001$), whereas fat among cows did not change with day of season ($P=0.72$; Figure 11).

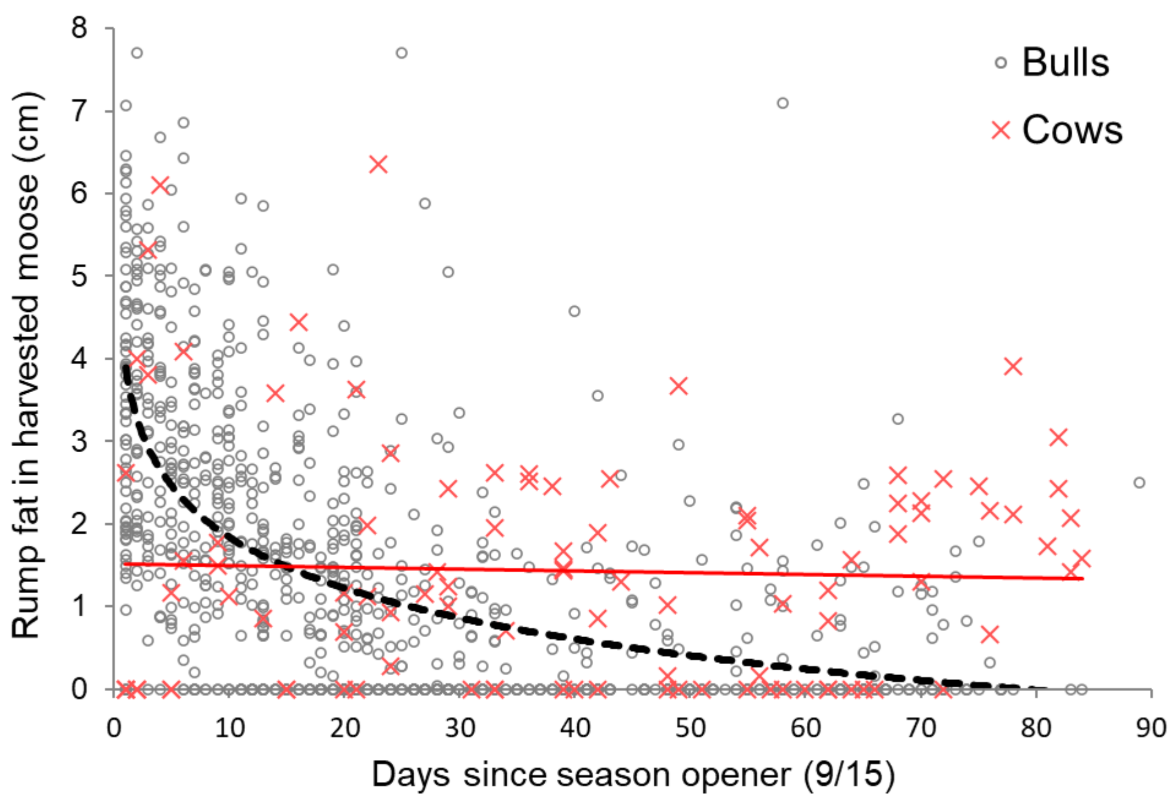


Figure 11. *Depth of rump fat declined consistently (due to rutting activity) among harvested bull moose according to the date of harvest during the past 8 hunting seasons (see black trend-line), whereas average fat depths among cow moose did not significantly change (red trend-line) during the hunting season, Montana, 2013–2020.*

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, though using a linear trendline for this exercise. 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. Lastly, we summarized the average residual scores and compiled a preliminary index to map relative fat measurement by moose hunting district (Figure 12). Some patterns emerge from this exercise, though these results are exploratory and subject to change based on inclusion of non-linear relationships between date and fat, as well as interacting effects of moose size (Figure 13). Regarding such interactions, we also found evidence of a difference in the rate at which bulls deplete their fat stores, according to their size (Figure 13), which is not accounted for in the mapped index thus far. Lastly, with regards to angler spread itself, we 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 14).

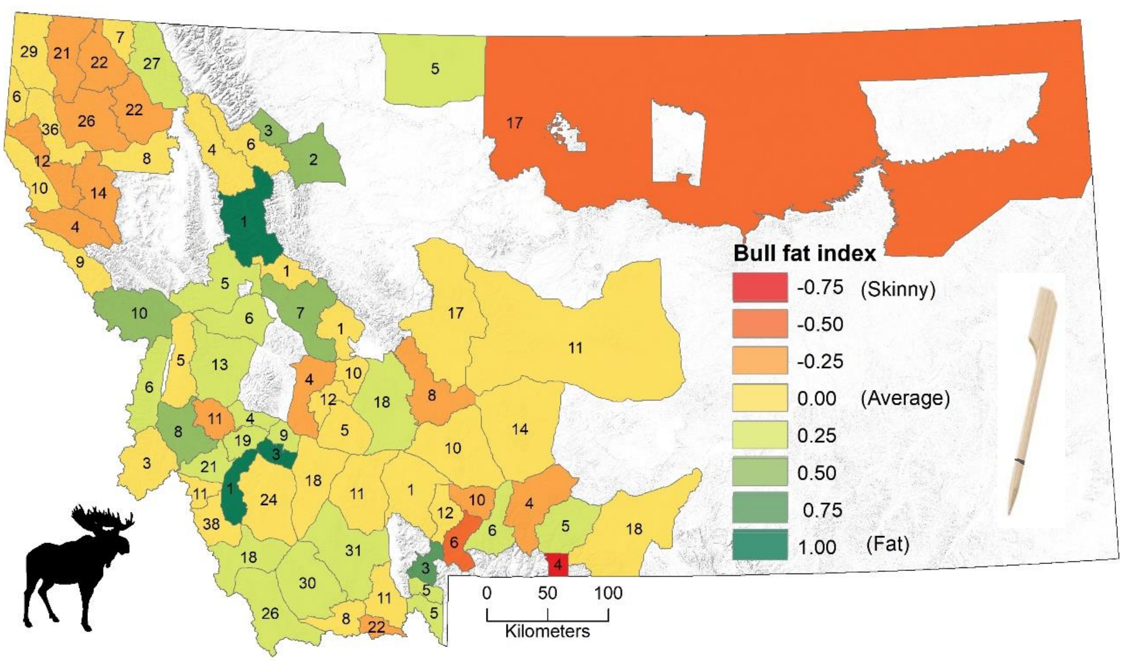


Figure 12. *A preliminary index of bull moose fat measurements after accounting for date of harvest, summarized by moose hunting district, with sample sizes labeled for each district. These data were collected by hunters by marking a toothpick (inset photo) included in sampling kits mailed to all license-holders, Montana, 2013–2020.*

Note: these results are preliminary and will be further refined after accounting for additional effects of date and moose size that are not currently included.

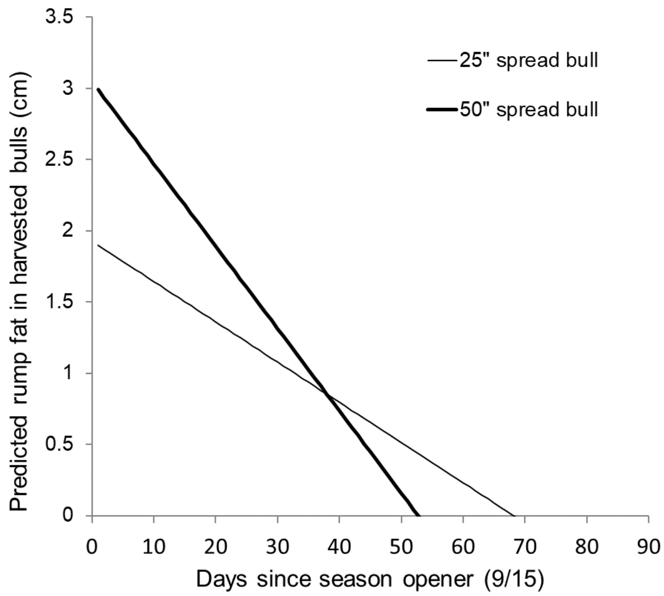


Figure 13. *We also continue to find evidence from hunter-collected measurements of both rump fat and antler spread that larger bulls generally start the rutting season with more fat, but deplete their fat stores at a faster rate than smaller bulls, ending the rut in poorer nutritional condition, Montana, 2013–2020.*

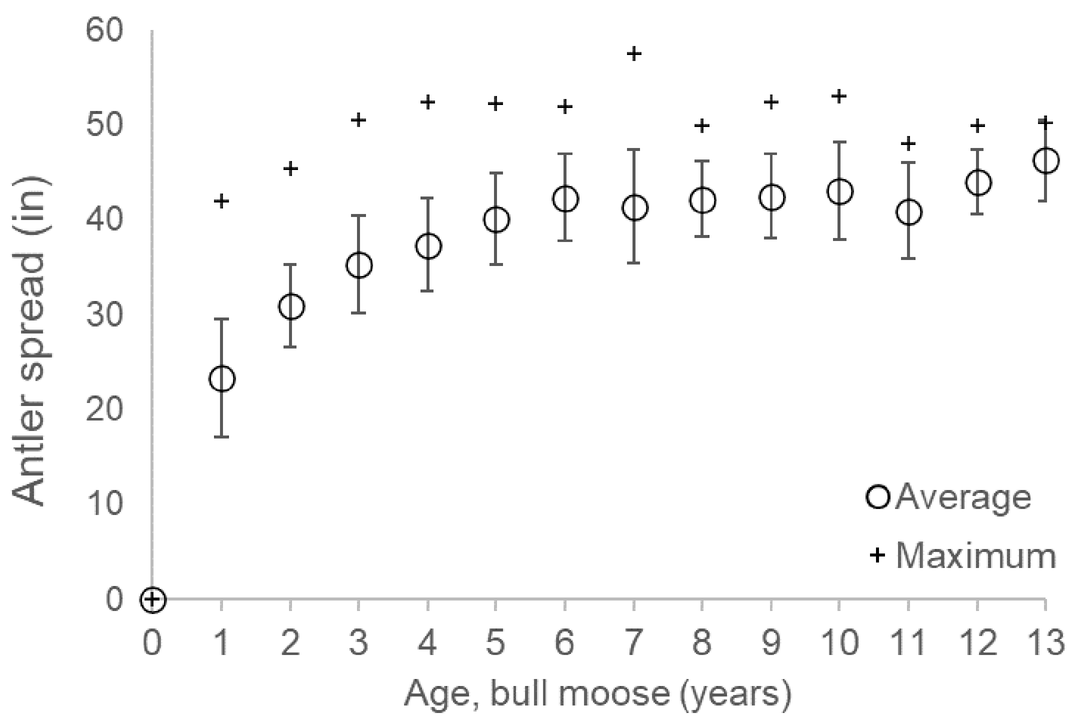


Figure 14. *Hunter self-reported, unofficial, antler spreads (inches) show a gradual increase in the average spread across all moose statewide until about the age of 6, at which point average antler spread holds steady with age, 2013–2019.*

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 2016–20, 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 6,454 hunter-days and 957 observations of rutting activity. Hunter-days decrease gradually throughout the season each year (Figure 15). 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 15). 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).

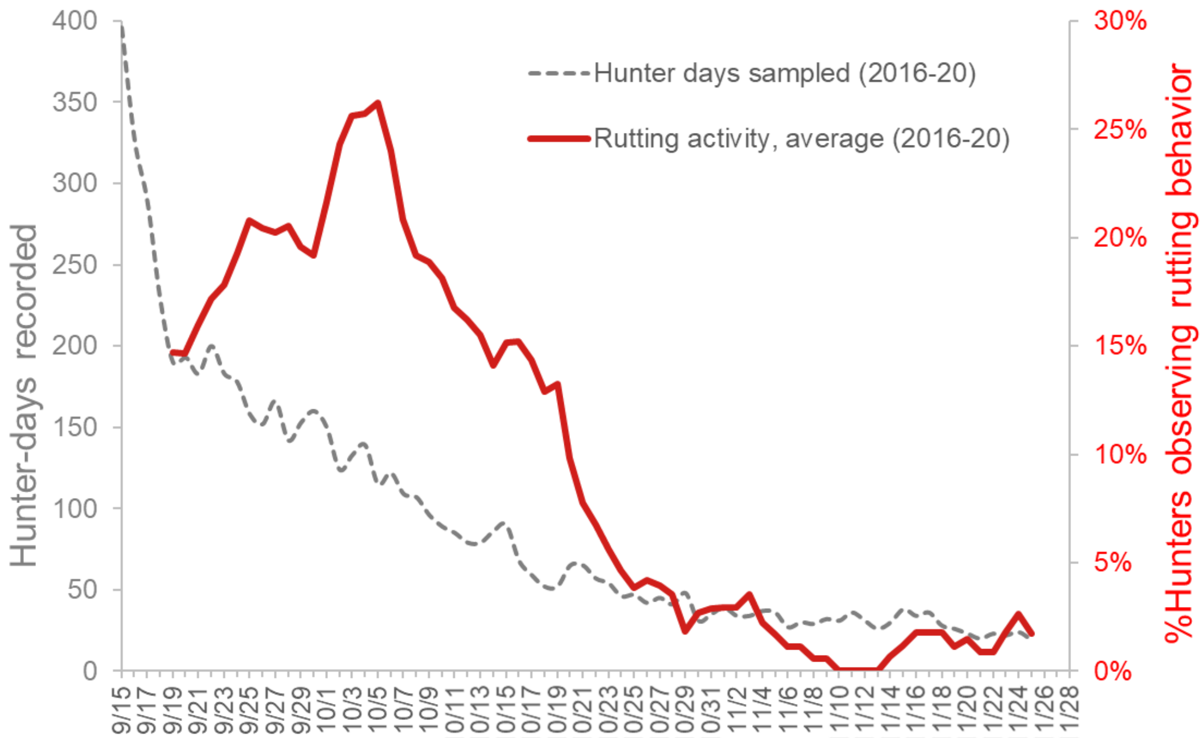


Figure 15. *Hunter-days recorded from voluntary return of data cards and proportion of hunters observing moose rutting activity (using a 5-day moving average) throughout the hunting season, 2016-20, Montana.*

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, 2021. 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.

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.

DeCesare N. J., B. V. Weckworth, K. L. Pilgrim, A. B. D. Walker, E. J. Bergman, K. E. Colson, R. Corrigan, R. B. Harris, M. Hebblewhite, B. R. Jesmer, J. R. Newby, J. R. Smith, R. B. Tether, T. P. Thomas, M. K. Schwartz. 2020. Phylogeography of moose in western North America. Journal of Mammalogy 101:10–23.

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.

Newby, J. R., and N. J. DeCesare. 2020. Multiple nutritional currencies shape pregnancy in a large herbivore. Canadian Journal of Zoology 98:307–15.

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.

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.

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.

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
2021	Big Hole Watershed Committee (*Newby*)	Divide, MT (remote)
	Swan Valley Connections (*DeCesare*)	Condon, MT (remote)

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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This project is a large collaboration among many FWP biologists. These begin with Jesse Newby, who was integral to this work for 7 years, and also include but are not limited to Justin Gude, Jennifer Ramsey, Neil Anderson, Keri Carson, Kevin Podruzny, Keri Wash, Jim Williams, Howard Burt, Graham Taylor, Tonya Chilton-Radant, Kent Laudon, John Vore, Vanna Boccadori, Brent Lonner, Gary Olson, Jessy Coltrane, and Ryan Rauscher. Undoubtedly this list should be larger to fully incorporate the many biologists and other personnel who have assisted with coordination of hunter sample collection, harvest statistics, opportunistic sampling of other moose throughout the state. We also acknowledge a great deal of help from other cooperating biologists and agency personnel including Nathan Birkeland, Dave Hanna, Dan Carney, Lorin Hicks, Allison Kolbe, Jenna Roose, Michael Munoz, and Eric Eneboe, Alissa Anderson and Kaitlyn Farrar. Thanks also to Caryn Dearing, Adam Brooks, Kari Shinn, Quentin Kujala, and others at FWP-HQ for their help with project administration.

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