

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



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

## Background and summary

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

This document is the 11th annual report produced as part of this work and will be followed only by our final report in 2024. This report contains preliminary results from a subset of our work. All results should be considered preliminary. Data collection is now complete, but laboratory analyses and statistical analyses remain works in progress.

In this last annual report, we will take a different approach from previous reports by excluding and postponing analysis of our final data set concerning moose vital rates. Those final results are pending additional analyses and will be presented in our 2024 final report. Instead, we provide updates on some new subsets of our overall research that have not been previously described in past annual reports:

- Hunter-assisted monitoring of genetic structure
- Quantifying spatiotemporal variation in ambient temperature
- Winter tick loads faced by moose across the western US
- Forage quality and diet sampling during both summer and winter
- Multi-species occupancy of predator species

**Web site:** For additional information, reports, publications, photos and videos, please see the “Research” heading at this page: <https://fwp.mt.gov/conservation/wildlife-management/moose>

## Location

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

## Study Objectives (2022-2023)

For the 2022-2023 field season of this moose study, the primary objectives were;

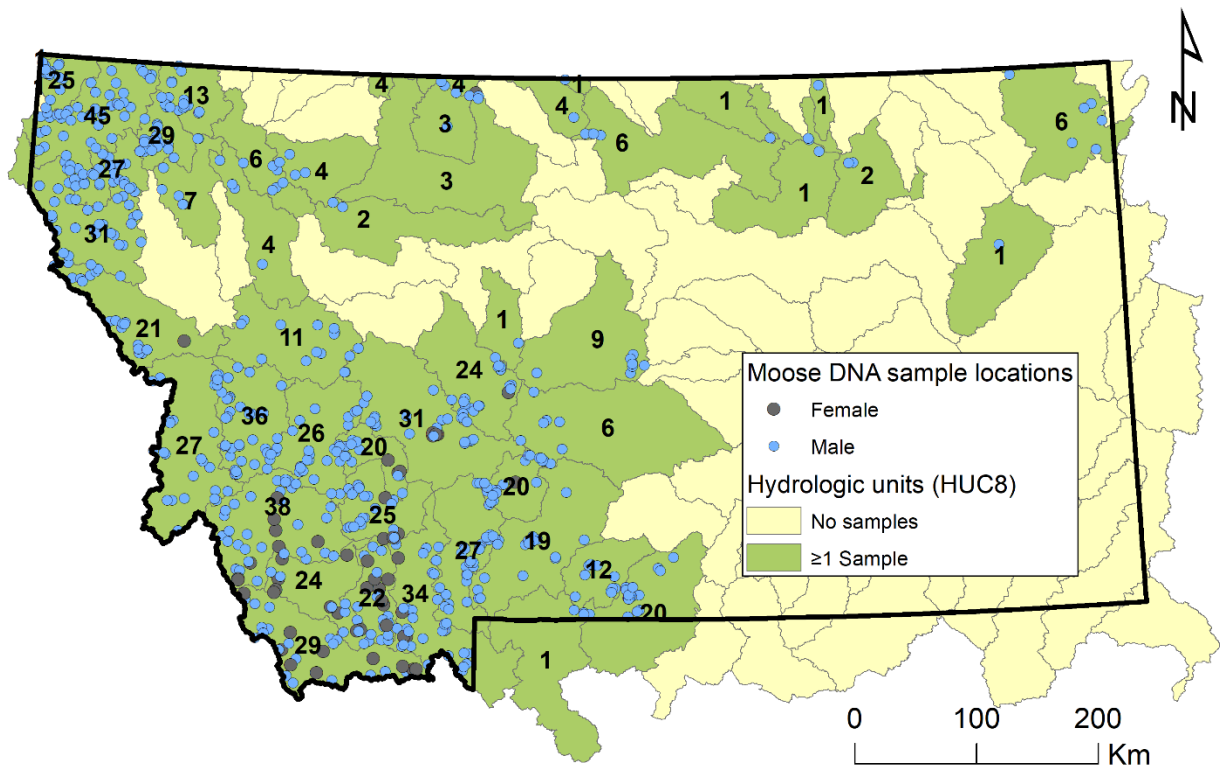
- 1) Evaluation of moose monitoring data and techniques.
- 2) Monitoring of vital rates and limiting factors of moose in three study areas.

## Objective #1: *Moose monitoring methods*

### 1.1. Genetic population structure of moose across Montana

We are using hunter-collected tissue samples across the statewide distribution of moose to study the spatial structure and connectivity of Montana’s contemporary moose population. Genetic analysis of DNA extracted from tissues will allow us to assess biologically relevant population units and potential barriers to gene flow among local populations. In combination with hunter-sightings based methods to monitor moose abundance (DeCesare et al. 2023), these results will have implications for the spatial arrangement of future monitoring data and population assessment. The beginnings of our work on this topic led to a collaboration with neighboring states and provinces to study moose genetic structure across the entire range of Shiras moose. This work was summarized in our 2020 annual report and published in the *Journal of Mammalogy* (DeCesare et al. 2020).

Currently, we are underway with more detailed assessment of genetic structure within Montana, specifically. We have submitted 699 hunter-collected tissue samples for single nucleotide polymorphism (SNP) genotyping via collaboration with the National Genomics Center for Wildlife and Fish Conservation. To the extent possible, we sampled an even distribution of moose harvested across their extent in Montana, divided by 8<sup>th</sup> order hydrologic unit codes (HUC8; Figure 1). Lab analyses are ongoing with statistical analysis of genetic population structure and connectivity to follow.



**Figure 1.** Spatial arrangement and counts of moose DNA samples, by hydrologic unit, 2012–2022.

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

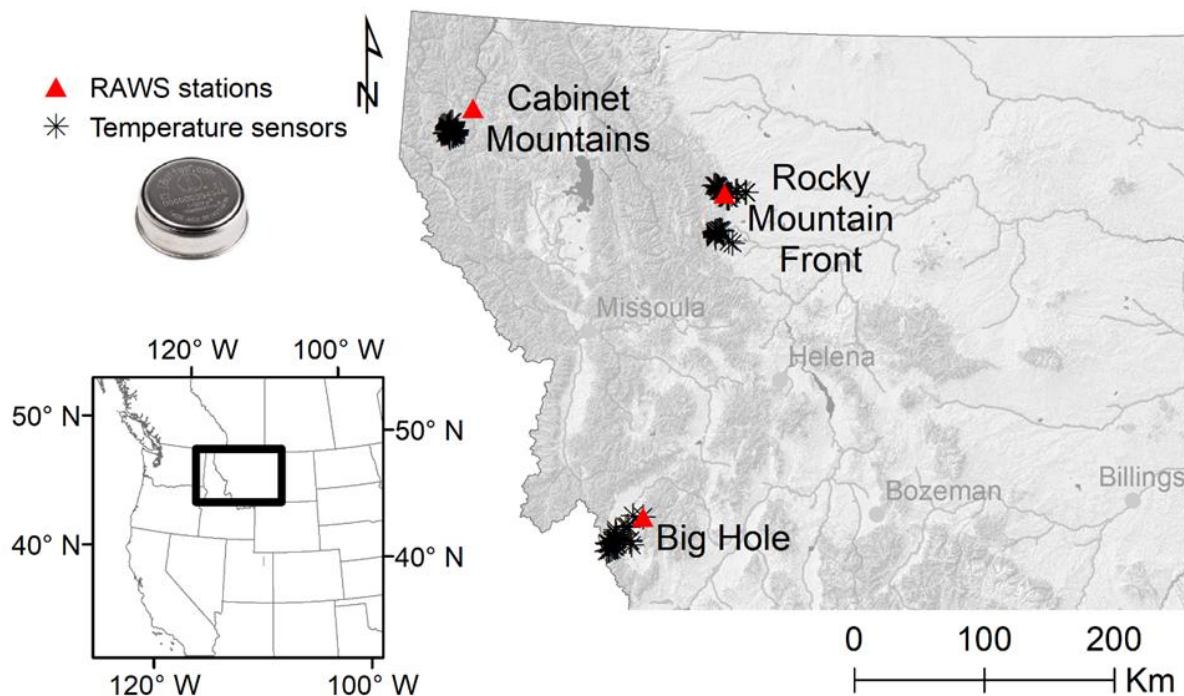
*\*Note: With this 2023 annual report we focus on a subset of research questions related to potential limiting factors, including temperature, parasites, and forage quality. We do not present vital rate data as we have done in past reports, postponing analyses of the complete data set for our final report.*

### **2.1. Spatial and temporal variation in ambient temperature**

*\*\*This portion of study has been accepted for publication at a peer-reviewed journal. Below is an abridged summary; see manuscript for full details -- DeCesare NJ, Harris RB, Newby JR, Peterson CJ (2023) Spatial and temporal heterogeneity in thermal conditions for wildlife. Alces 59:33–49.*

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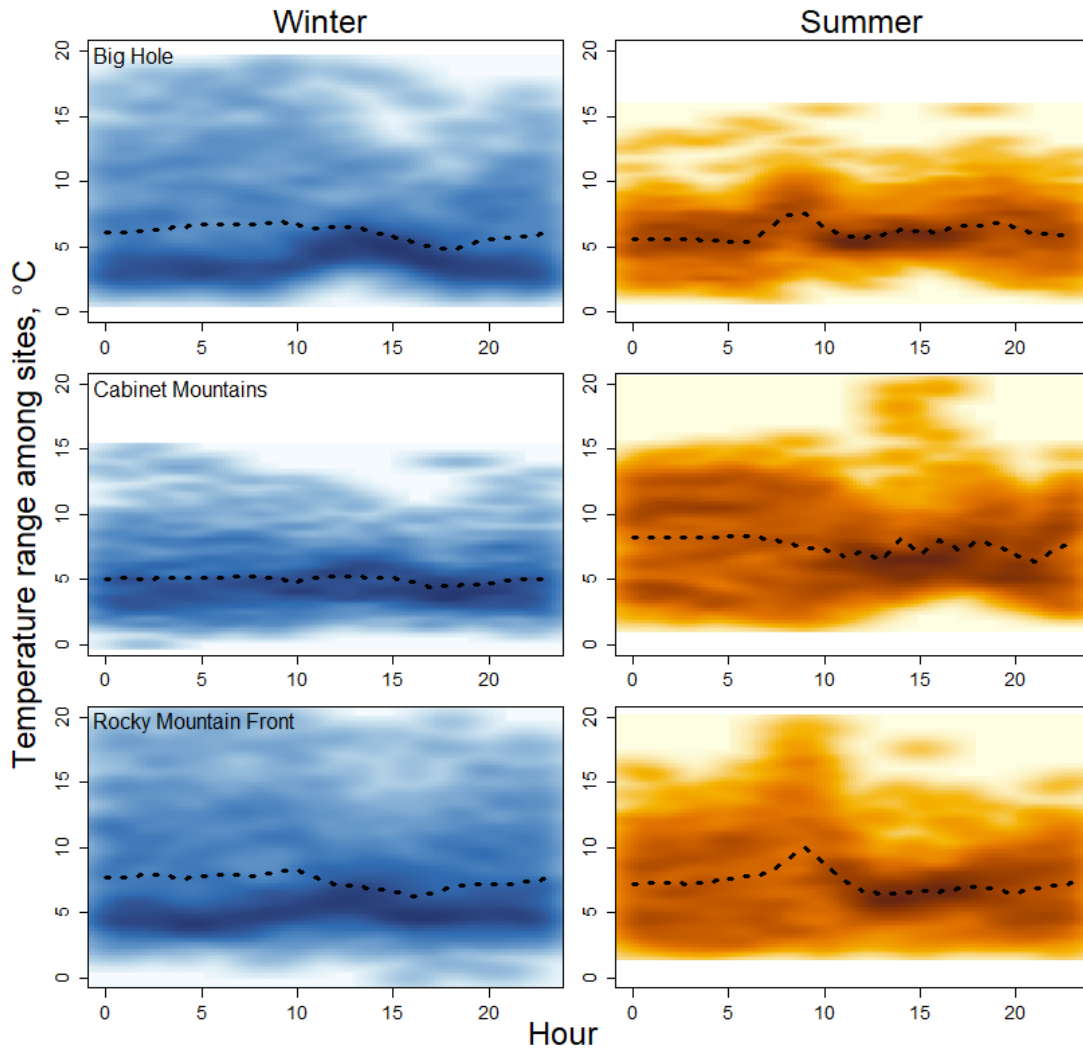
Among ungulates, the cold-adapted moose has received particular attention with regards to impacts of temperature on physiology, habitat selection, and fitness. In addition to intrinsic adaptations to thermal stress (Thompson et al. 2019, 2020), moose commonly employ thermoregulatory behavior through micro- and macro-habitat use at high summer temperatures (Schwab and Pitt 1991, Dussault et al. 2004, Broders et al. 2012, van Beest et al. 2012, 2013, Melin et al. 2014, Street et al. 2015, Ditmer et al. 2018, Alston et al. 2020, Borowik et al. 2020) and during winter (Burkholder et al. 2022). We measured spatiotemporal variation in ambient temperatures during both winter and summer within three study areas of western Montana (USA) in support of concurrent studies of moose ecology and population dynamics. Our objectives were to assess the thermal conditions available to wildlife in these areas, to understand the effects of environmental covariates on temperature across time and space, and to predict thermal landscapes as a function of those covariates.



**Figure 2.** Locations of study areas, temperature sensors and weather station sites for monitoring ambient temperature, western Montana, 2013–2015.

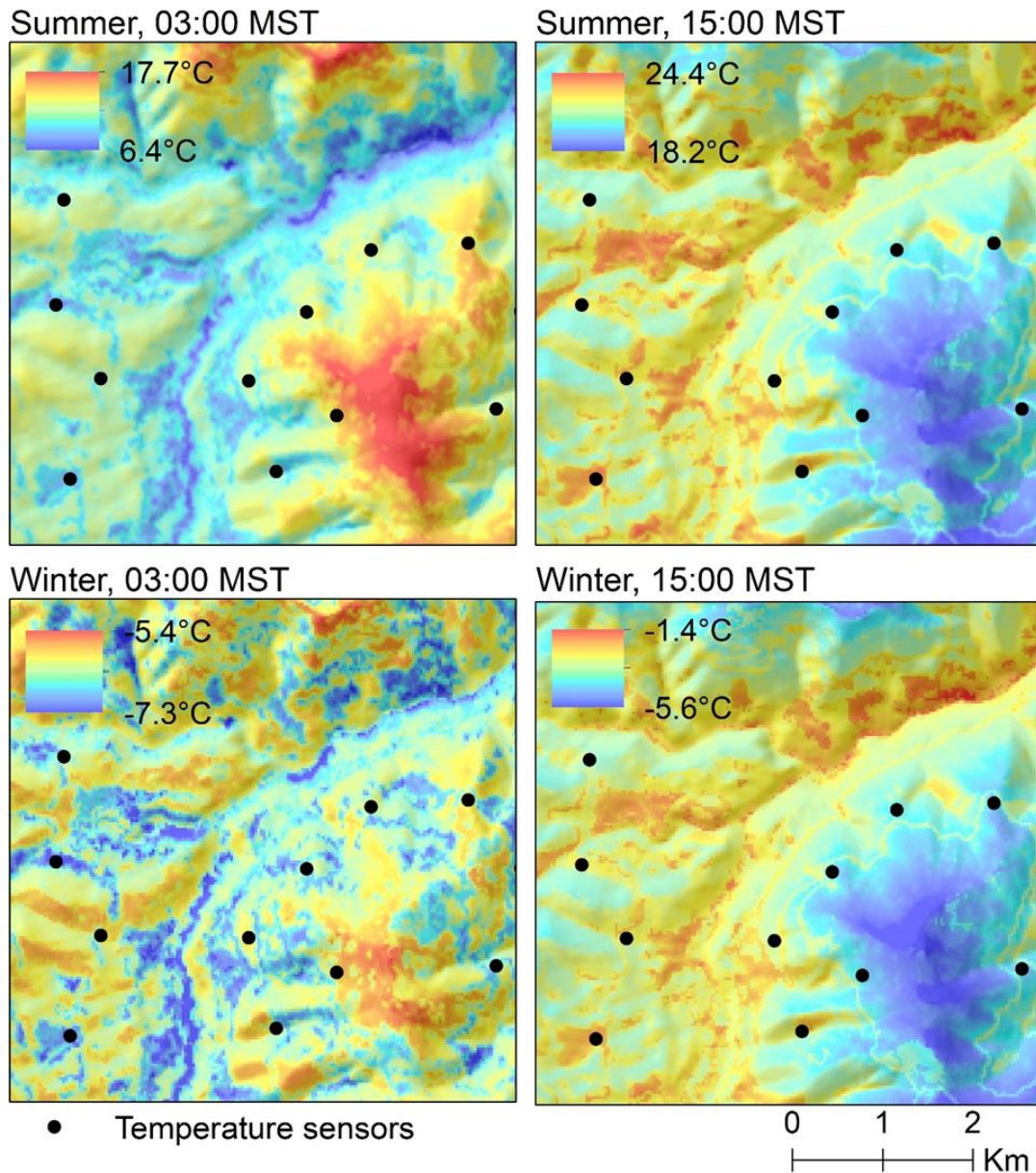
To quantify relationships between biophysical variables and local air temperatures, we used temperature sensors (iButton Model DS1921G-F5; Maxim Integrated, San Jose, California) to measure ambient temperature at selected, non-random locations within each of the 3 study areas (Figure 2). Sensors ( $n = 96$ ; 32 per study area) were deployed a minimum of 1 km apart during one winter and one summer session lasting 85 days each, as dictated by memory limitation of the sensors.

There was substantial potential for thermal refuge according to the temperature ranges observed among sites per study area, season, and hour (Figure 3). On average, sites varied by  $7.0^{\circ}\text{C}$  during summer (Big Hole  $6.1^{\circ}\text{C}$ , Cabinet Mountains  $7.6^{\circ}\text{C}$ , Rocky Mountain Front  $7.3^{\circ}\text{C}$ ) and by  $6.1^{\circ}\text{C}$  during winter (Big Hole  $6.1^{\circ}\text{C}$ , Cabinet Mountains  $5.0^{\circ}\text{C}$ , Rocky Mountain Front  $7.4^{\circ}\text{C}$ ; Figure 2). However, we observed considerable heterogeneity in the magnitude of temperature variation among sites on a given day and hour (Figure 3), ranging from  $0^{\circ}\text{C}$  (e.g., identical temperatures across all sites in a given area) to maximum temperature ranges of 19, 20.5, and  $22.5^{\circ}\text{C}$  observed among sites at a single time in each study area, respectively.



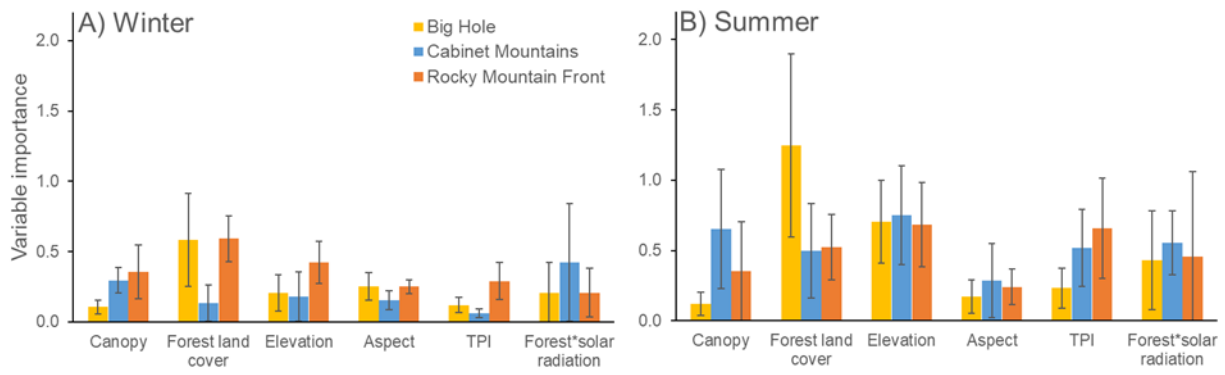
**Figure 3.** Scatter density plot and average (dashed line) of the maximum range in ambient temperature measured concurrently across days at hourly intervals among sensors within 3 study area 2 seasons, western Montana, 2013–2015.

We conducted statistical analyses to assess spatial drivers of variation in temperature across study area, season, and time of day. The effects of predictor variables on ambient temperatures not only varied in a cyclic fashion during the 24-hour diel cycle, but in many cases, exhibited reversed effects between day and night. Such patterns were most pronounced during summer in the Cabinet Mountains, where conditions such as high canopy cover, forest land cover type, high elevation, northerly aspects, and convex topographic positions (i.e., ridges) tended to yield cooler temperatures during the day, but warmer temperatures at night (Figure 4).



**Figure 4.** Predicted ambient temperature from global generalize linear models in an example portion of the Cabinet Mountains study area during two times and seasons and relative to the average recorded temperature at Remote Automatic Weather Station (RAWS) sites during the study period, 2013–2015.

Conditional  $R^2$  values showed considerably higher ability to explain variation in the data with models for summer temperature (average  $R^2 = 0.51, 0.55, 0.56$  among study areas) compared to those estimated for winter (average  $R^2 = 0.09, 0.23, 0.14$  among study areas). Lastly, all six variables (5 main effect terms and an interaction between land cover and solar radiation) made relatively similar contributions to model performance (Figure 5).



**Figure 5.** Average importance of 6 variables (canopy, forest land cover, elevation aspect, topographic position index [TPI], interaction of forest land cover forest and solar radiation), in explaining spatial variation in ambient temperature in 3 study areas and 2 seasons, western Montana, 2013–2015.

In contrast to McGraw et al. (2012) who found no differences  $> 2^{\circ}\text{C}$  in radiant temperature using black globe sensors in Minnesota, we found average differences in ambient air temperatures of  $6\text{--}7^{\circ}\text{C}$  at all 3 study areas during both seasons. Under the most extreme conditions, differences between locations potentially available to moose approached  $20^{\circ}\text{C}$ , depending on study area, season, and time-of-day. Furthermore, drivers of spatial pattern in these differences were not static, and covariates associated with cool conditions varied widely by study area, season, and time of day. Moose selection of sites as thermal refugia may therefore be conditioned temporally and spatially according to shifting patterns of heterogeneity that dictate where and when cooler conditions are available.

We used a relatively modest sample size of temperature sensors and were able to find a variety of complex relationships between temperature and topographic and vegetation conditions. While spatiotemporal temperature data are already available at coarse scales from various remote-sensing or interpolated data sets, multiple studies have shown that models using locally-derived empirical temperatures outperform general models (Macek et al. 2019, Estevo et al. 2022). We encourage researchers and managers to explore field collection and spatiotemporal modeling of temperature sensor data for cost-effect and baseline description and prediction of thermal environments for wildlife (Figure 4). The physiological effects of thermal environments are multi-faceted and complex, and improving our understanding and management of thermal environments is an important challenge for future conservation (Mitchell et al. 2018).

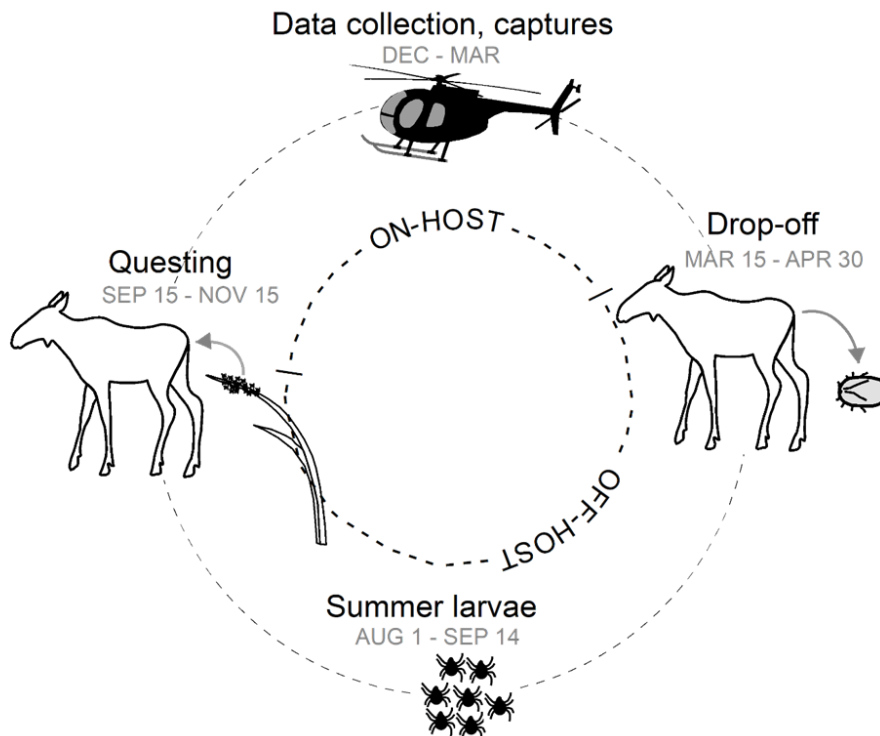
## 2.2. Winter tick loads faced by moose across the western US

*\*\*This portion of study has been submitted for publication at a peer-reviewed journal and is currently preliminary and under review. Below is an abridged summary.*

*Tentative citation: DeCesare NJ, Harris RB, Atwood MP, Bergman EJ, Courtemanch AB, Cross PC, Fralick GL, Hersey KR, Hurley MA, Koser TM, Levine RL, Monteith KL, Newby JR, Peterson CJ, Robertson S, Wise BL. In review. Warm places, warm years and warm seasons increase parasitizing of moose by winter ticks.*

Winter ticks parasitize multiple ungulate species across North America (Chenery et al. 2023) but have most strongly impacted moose (*Alces alces*) populations (Welch et al. 1991). Epizootics of winter ticks have been linked to decreased calf survival and population performance in New Hampshire, Maine, and Vermont (Jones et al. 2019, Ellingwood et al. 2020, DeBow et al. 2021), as well as to moose population crashes in Alberta (Samuel 2007). Furthermore, the negative effects of warming temperatures on moose may be indirectly mediated by parasites such as winter ticks and meningeal worm (*Parelaphostrongylus tenuis*), which themselves have complex responses to climate change (Pickles et al. 2013).

Winter ticks complete their life-cycle on a single host, questing for hosts as larvae each autumn, living and feeding on hosts throughout winter where they moult twice into nymph and adult life-stages, and finally detaching to lay eggs in the spring (Figure 6; Addison and McLaughlin 1988, Leal et al. 2020). This one-host strategy links the survival of each winter tick cohort to environmental conditions during 3 specific time periods when they are predictably vulnerable: spring detachment and egg-laying, summer larval stage, and fall questing.



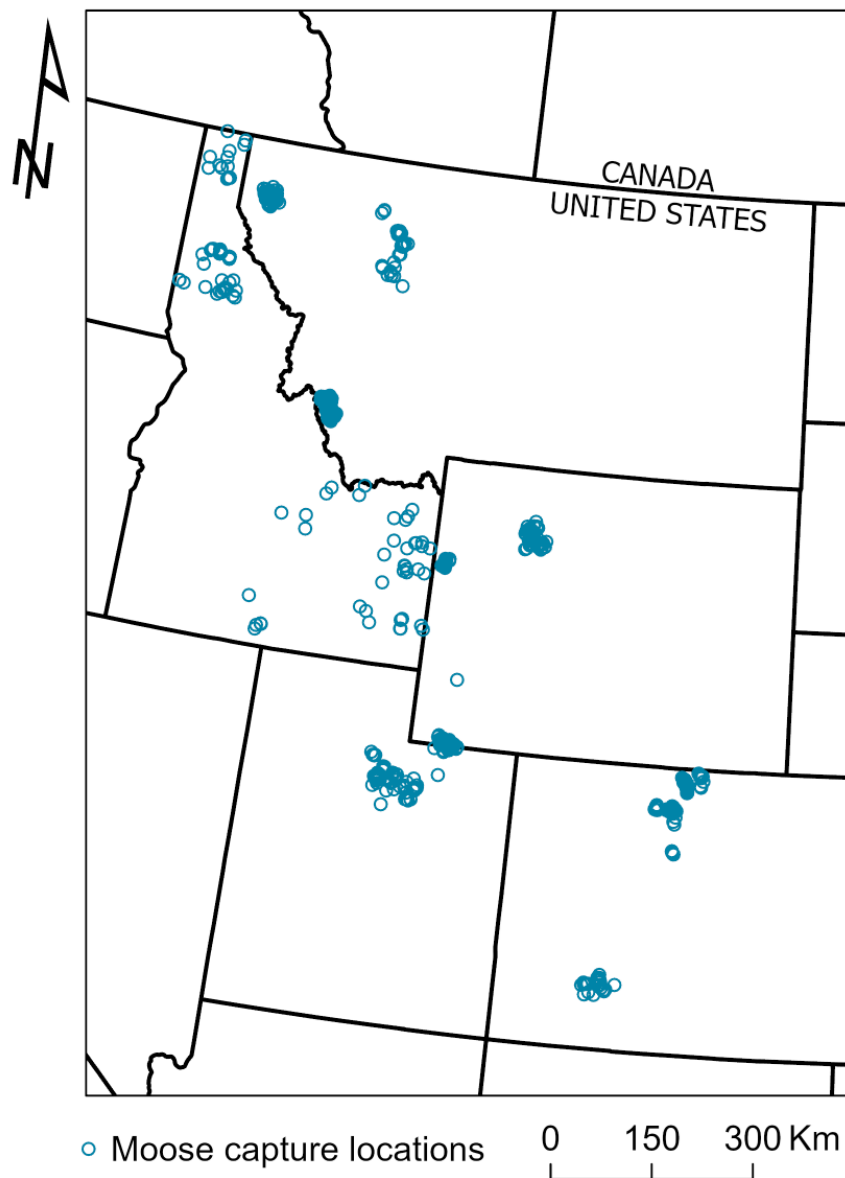
**Figure 5.** Schematic diagram of seasonal periods of study relating life cycle of winter ticks during 3 off-host periods (spring drop-off, summer larvae, and fall questing) to on-host measurements of tick loads on moose collected during live-capture efforts, western US, 2013–2022.



We currently lack research that clarifies conditions under which some moose in the mountainous west become heavily infested by winter ticks whereas others are unaffected. To that end, we investigated tick loads carried by moose across multiple years and study areas spread across the western United States with the objective of elucidating biotic and abiotic drivers of tick abundance. Counts of ticks on free-ranging moose are costly and time-intensive, but pooling data across multiple study areas and jurisdictions offered us a powerful and wide-ranging assessment of variation in tick loads in this less-studied ecoregion. Specifically, our objective was to quantify spatiotemporal drivers of variation in tick loads carried by moose across the western US, including hypothesized effects of spatial variation in climate, annual variation in weather, host density, and migration behavior.

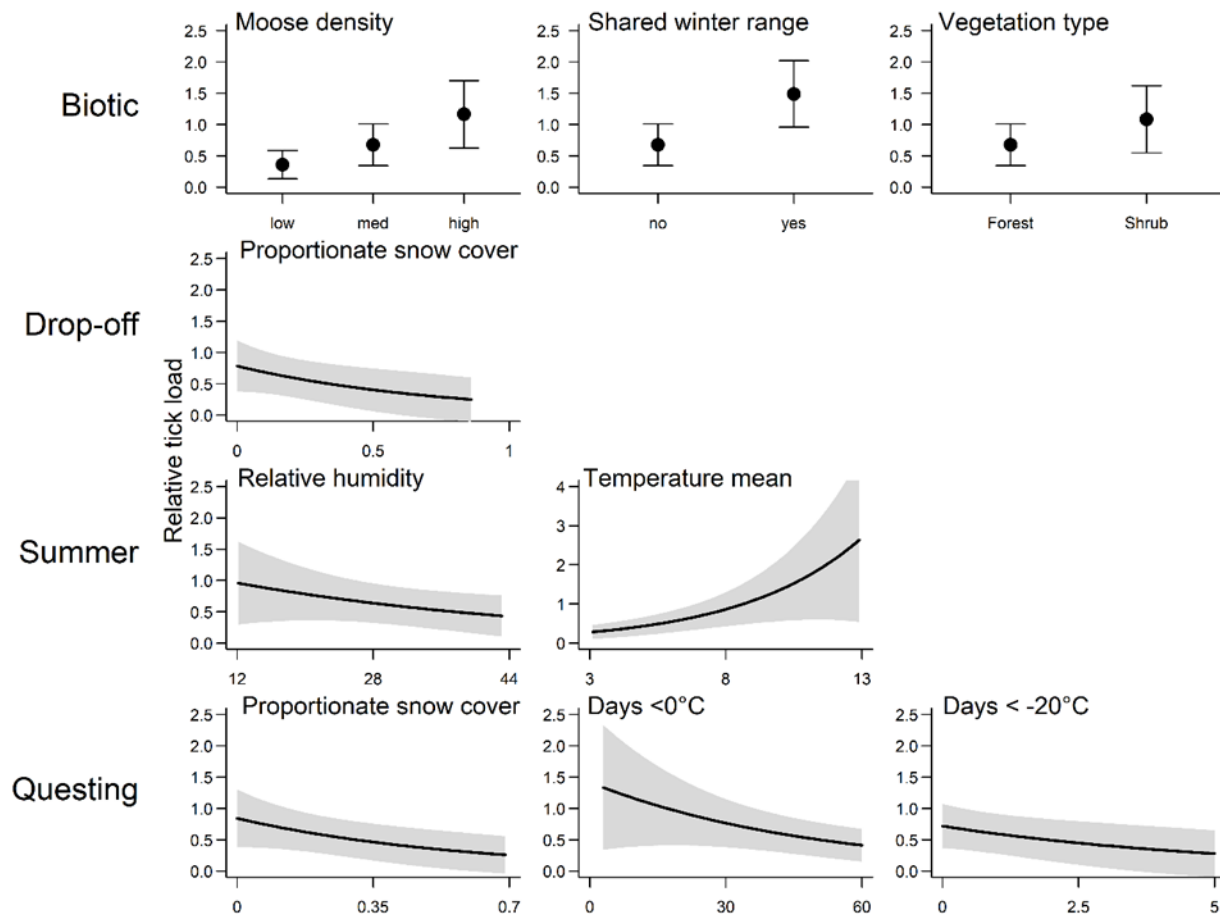
We collected tick load data from 750 free-ranging moose during research operations in 16 study areas distributed among montane regions of Montana, Idaho, Wyoming, Utah and Colorado during 2013–2022 (Figure 7). Tick counts were collected using quadrats or line-transects through parted hair of moose along the rump, scapular, and/or loin regions following Sine et al (2009).

We investigated putative drivers of winter tick loads on moose by evaluating 4 suites of candidate models corresponding to 4 hypothesized sources of variation: (1) biotic factors, and (2, 3, 4) spatiotemporal (remotely-sensed) weather metrics during spring drop-off, summer larvae, and fall questing life cycle stages.



**Figure 7.** Capture locations of 750 moose across 16 study areas for which tick load data were collected, 2013–2022.

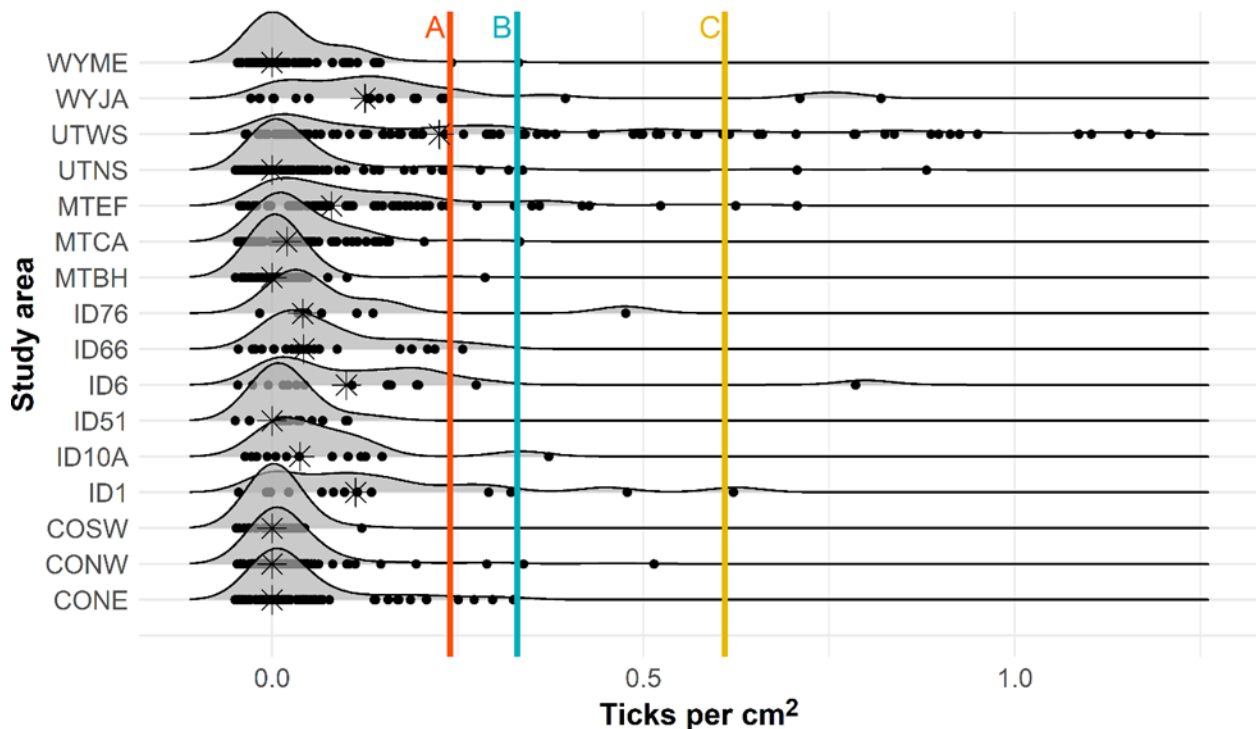
We found support for a number of metrics quantifying each of our 4 hypothesized drivers of winter tick loads on moose (Table 1; Figure 8). Winter tick loads were positively associated with moose density on winter range, with moose at high density predicted to have over twice the tick loads as those at low density. Similarly, moose sharing winter range with other cervids were predicted to have more than twice the tick load of moose that did not. Winter tick loads were negatively associated with proportion of snow-covered days during the questing period and during the drop-off period. Tick loads were positively associated with temperatures during both summer and autumn questing periods and weakly negatively associated with minimum relative humidity during the previous summer (Table 5). The top model was estimated to explain 33.1% of total variation, of which 23.8% came from the fixed effects of interest.



**Figure 8.** Predicted relative tick loads and confidence limits (y-axes) spanning the observed range of values for each covariate (x-axes) included in the final model and estimated using population-level predictions (i.e., random effects set to 0) and a 40-cm transect length. Predictions were made for each covariate while holding other continuous covariates at their means, categorical covariates at density = “medium”, shared winter range = “no”, and vegetation type = “forest”, and grouped by rows according to four hypothesized suites of covariates including biotic conditions, and weather conditions during the spring drop-off period, summer larvae period, and fall questing period, western North America, 2013–2022.

*Climate vs. weather:* We also evaluated the relative contributions of spatial variation in climate among study areas versus annual variation in weather among years. Positive associations with warm summer temperatures were associated with geography, with no difference arising from year-to-year variation. In contrast, annual variation in snowy conditions during spring drop-off, and, to a lesser extent, incidence of cold temperatures in fall, affected tick loads on an annual basis for any given locality. These results suggest that observed trends of reduced spring snow in western North America (Hamlet et al. 2005) have perhaps the highest potential to induce change in tick load dynamics in the immediate future of this region.

*Comparison to tick loads in northeast US:* Average tick densities in our study varied from  $0.007/\text{cm}^2$  –  $0.315/\text{cm}^2$ , with an overall mean of  $0.089/\text{cm}^2$  (SE = 0.007; Figure 9). In Vermont, where tick infestation was concluded to be the primary cause of moose mortality, median densities on adult and calf moose were 0.24 and 0.36 ticks/ $\text{cm}^2$ , respectively (DeBow et al. 2021). In New Hampshire, the mean tick density during a relatively average year (2008) was 0.33 ticks/ $\text{cm}^2$  (Bergeron and Pekins [2014]). Subsequently in New Hampshire and Maine, average tick densities at the time of capture for moose calves were 0.61 ticks/ $\text{cm}^2$ , with significant differences between calves that survived (0.51) versus those that died (0.65; Jones et al. 2019). Tick loads in our sampled moose were generally lower than in New England states, but approached densities associated with tick-caused mortality for some individuals.



**Figure 9.** Density distributions (lines and shading), raw data values (dots), and median values (asterisks) for winter tick density measurements collected on the rump of moose across each of 16 study areas in the western US, 2013–2022. Vertical reference values correspond to average tick densities in three studies from the northeastern US: A) adult moose in Vermont (DeBow et al. 2021), B) all moose in New Hampshire (Bergeron and Pekins 2014), and C) calves in New Hampshire and Maine (Jones et al. 2019).

### **2.3. Composition and nutritional quality of moose diets**

The composition and nutritional quality of the diets of moose is an important influence on adult survival, fecundity, and calf recruitment rates (Franzmann and Schwartz 2007, 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 of moose diets during 2 important life-history stages: post-parturition (during summer), and in late winter. We will assess 4 aspects of moose nutrition: (1) diet composition, (2) digestible energy (DE) content (in kilocalories/gram of forage), (3) digestible protein (DP) content (%), and (4) concentration of tannins. Digestible energy (the portion of total energy derived from carbohydrates, proteins, and fats that are digestible by an animal), and digestible protein are the most important nutrients for most ungulates (Wallmo et al. 1977).

The effects of forage nutrition on key vital rates vary seasonally. During winter, moose typically persist on a low-quality diet and descend into energy deficit, but consumption of higher energy foods may stave off weight-loss and death of adults and juveniles from starvation (Schwartz et al. 1988, Schwartz and Hundertmark 1993). Higher fat retention throughout winter can also increase fecundity and calf recruitment the following year (Ruprecht et al. 2016, Newby and DeCesare 2020). Inadequate protein intake during winter may result in loss of muscle in calves and adults, and may hinder development of fetuses in utero, reducing the viability of neonates in spring (Parker et al. 2005). In summer, females with calves face extremely high energetic demands from lactation, and consumption of high energy diets is necessary to meet maintenance energy requirements (Robbins et al. 1993). Furthermore, both energy and protein consumption during summer largely determine the nutritional condition of moose entering the winter (McArt et al. 2009), which has major influences on over-winter survival (Cook et al. 2021), parturition (pregnancy and twinning) rates (Milner et al. 2013), and recruitment of calves into the population (Testa 2004). In fact, twinning rates (a component of fecundity) are commonly invoked as an index of nutritional condition in moose populations (Franzmann and Schwartz, 1985). The diets of moose contain many willow and shrub species that contain high amounts of tannins, which reduce the digestibility of protein and therefore DE (Robbins et al. 1987a, 1987b). It is important to take tannins into account when assessing moose nutrition, as tannin content of browse species may vary regionally and can influence the overall diet quality of a population (McArt et al. 2009).



Given the range of variation in fecundity we have observed throughout our 3 study areas, we hypothesized that the quality (DE and DP) of moose diets during winter or summer limits fecundity of moose in Montana. We predicted that digestible energy and protein content of moose diets would be highest in study areas with the highest fecundity (the Rocky Mountain Front, in this case) and that tannin content would be the lowest.

*Methods:* During the summers (June 15 -August 31) of 2021-2022 and winters (December 15 – March 15) of 2021-22 and 2022-23, 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. For each plant species with evidence of browse, we located 3-5 individual plants and clipped the new growth of 5-10 stems and their leaves from each. We stored samples within paper bags in a freezer. We compiled these samples by browse species, study area, and year, and calculated their dry-matter digestibility (DMD), adjusted for tannin content, using an equation adapted from Robbins et al. 1987a, 1987b):

$$\text{DMD} = [(0.9231 e^{-0.0451 * \text{ADL}}) (\text{NDF})] + [(-16.03 + 1.02 \text{NDS}) - 2.8 * \text{P}],$$

where ADL is acid detergent lignin (%) NDF is neutral detergent fiber (%), NDS is neutral detergent soluble (%), and P is the reduction in protein digestion (%). We estimated P as  $11.82 \times \text{BSA}$ , where BSA is the level of bovine serum albumin (Robbins et al. 1987b); BSA is an index of the inhibiting effect of increasing tannins measured in milligrams of BSA precipitated per milligram of dry matter forage. We did not account for the reduction in DMD from acid-insoluble ash. We obtained ADL, NDF, and NDS values from Dairy One laboratories (Ithaca, NY, USA). We obtained BSA values for shrubs containing tannins from the Wildlife Habitat Nutrition Laboratory (Pullman, WA, USA) and assumed BSA values to be zero for forbs and graminoids that typically do not contain tannins.



We then estimated DE of each sample using an equation from Cook et al. (2016):

$$DE = (DMD/100) \times GE,$$

where GE is gross energy content estimated as 4.53 kcal/g for forbs, graminoids, and deciduous shrubs and 4.8 kcal/g for evergreen shrubs (Cook et al. 2016).

Lastly, we calculated percentage digestible protein of each sample using this equation from Robbins et al. 1987b):

$$\text{Digestible Protein (DP)} = -3.87 + 0.9238(\text{CP}) - 11.82(\text{BSA}),$$

where CP is the crude protein content of forages.

While surveying summer forage sites, we also collected fresh fecal samples of moose, which we will use to determine the composition of diets at a population-level through fecal DNA metabarcoding techniques. For winter diets, we will use fecal samples collected from collared moose at time of capture. We will then pair diet composition data with digestible energy and protein data, then weight estimates of taxa-specific diet quality by the proportion of that taxa in moose diets, providing an estimate of population-level diet quality (Becker et al. 2021).



Results: During summer, we surveyed 400 locations specific to moose \* forage taxa and collected clippings at each site, comprising 51 plant taxa. We aggregated these samples by taxa, year, and study area, totaling 101 summer forage samples (BH:  $n = 17$ ; CAB:  $n = 47$ ; RMF:  $n = 37$ ). For winter, we surveyed 234 moose \* forage taxa locations, collecting clippings from 40 distinct taxa and aggregated these into 73 winter forage samples. As of August 2023, forage quality assays have only been completed for summer forage samples, whereas diet composition assays have only been completed for winter fecal samples. Therefore, we are unable to determine weighted, population-level estimates of seasonal diet quality at this time. However, we estimated average DE (Table 2), DP (Table 3), and BSA (an index of tannin content; Figure 10) of forage samples collected during summer.

Preliminary evidence provides no support for our hypothesis that forage quality limits moose fecundity. In fact, we observed opposite trends. On the Rocky Mountain Front, where fecundity was highest, the digestible energy content of summer forage species was lowest (average DE = 3.31 kcal/g; 95% CI = 3.27, 3.35). In the Cabinet-Salish and Big Hole, where fecundity ranked second and third, respectively, average DE was 3.36 [3.30, 3.43] and 3.37 [3.21, 3.42], respectively. Therefore, average DE of forage plants was highest in the study area with the lowest fecundity rate, though confidence intervals overlapped substantially among study areas (Table 2). These patterns held true for digestible protein as well, where forage items in the Big Hole had the highest protein content, followed by the Cabinet-Salish and Rocky Mountain Front (Table 3).

As somewhat of a control for taxonomic differences in diet composition across study areas, we compared DE and DP of willows (*Salix* spp.) within each study area, and found the same patterns as described above (Figure 10). Thus, even within a genus, we observed differences in forage quality according to study area. For example, Drummond's willow (*S. drummondiana*) was consumed in all 3 study areas, and digestible protein content in the Cabinet-Salish was 9% higher than protein content in the Big Hole, and 36% higher than the Rocky Mountain Front (Table 3). These differences may have arisen, in part, due to varying levels of tannin content within species across study areas. Average BSA (an index of protein digestion inhibition from tannins) was highest on the Rocky Mountain Front, and roughly equivalent in the Big Hole and Cabinet-Salish (Figure 10).

The variation in DE, DP, and BSA we observed across study areas may partially be explained by differences in the species composition of diets. Within taxa, however, plant digestibility may vary as a function of abiotic conditions such as air and soil temperatures, soil nutrients, moisture, and solar radiation (Moore and Jung 2001, McArt et al. 2009). At present, the metrics of forage nutrients we have provided cannot be interpreted as representative of population-level diet quality until they are adjusted for % diet composition by species. However, given the inverse correlation between fecundity and summer forage quality we observed across study areas, our preliminary results suggest summer forage quality may not be a limiting factor on moose fecundity in our study system. Next, we will consider how diet selection and the quality of winter diets correlates with fecundity. Additionally, forage abundance and intake rates, which we have not assessed, could also account for the differences in fecundity we observed across study areas (Seaton et al. 2011).

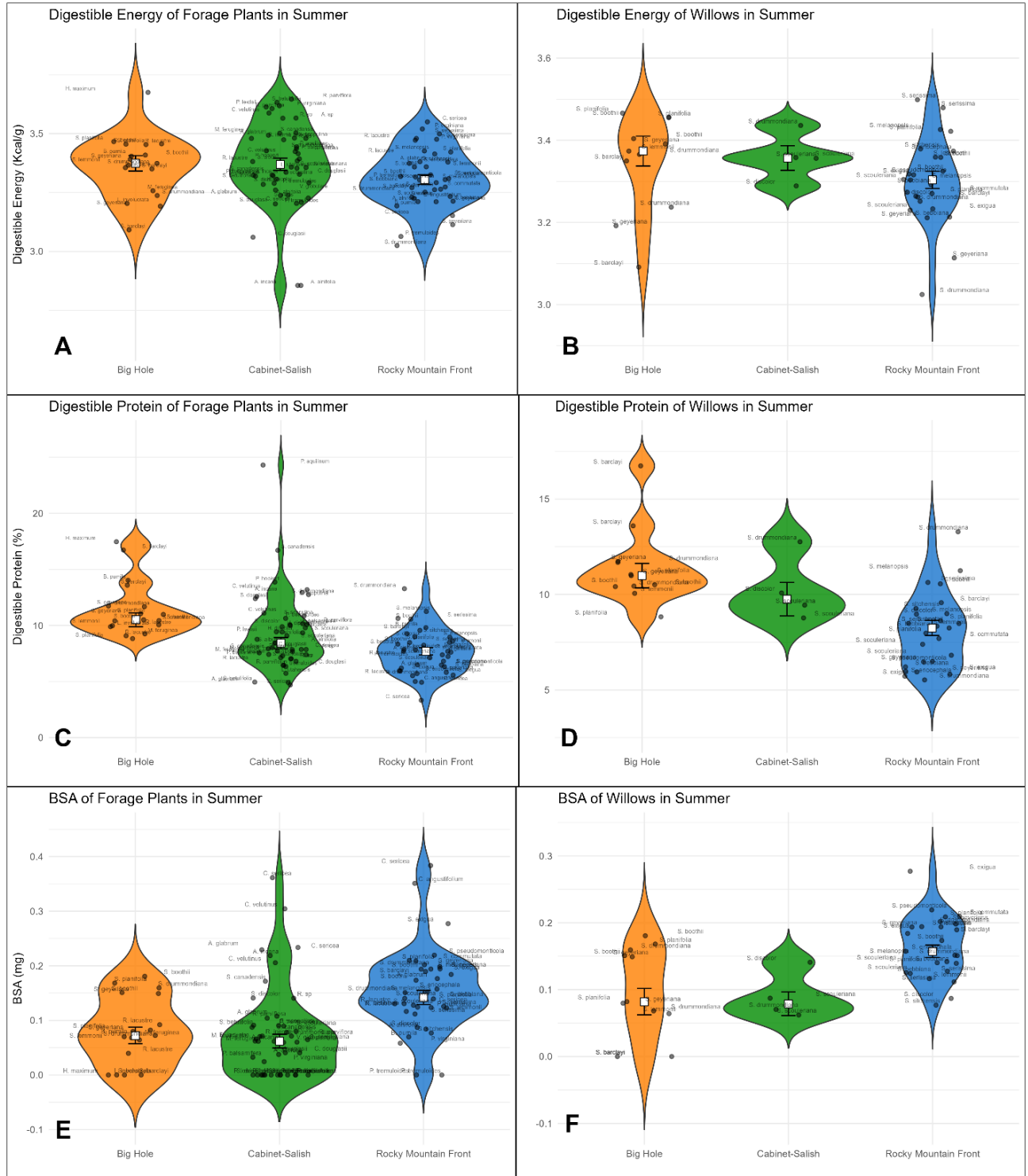
**Table 2.** Digestible energy (in kilocalories/gram) of browsed species surveyed at foraging locations of moose in 3 study areas throughout western Montana, USA, during the summers of 2021 and 2022.

Species	Cabinet-Salish			Big Hole			Rocky Mountain Front		
	2021	2022	Average	2021	2022	Average	2021	2022	Average
Acer glabrum	3.49	3.24	3.37	-	-	-	-	3.38	3.38
Alnus incana	2.86	3.32	3.09	-	-	-	-	-	-
Amelanchier alnifolia	3.24	2.86	3.05	-	-	-	-	3.21	3.21
Aster sp	3.57	-	3.57	-	-	-	-	-	-
Betula pumila	-	-	-	-	3.41	3.41	3.19	-	3.19
Ceanothus velutinus	3.59	3.42	3.50	-	-	-	-	-	-
Chamerion angustifolium	-	-	-	-	-	-	3.23	-	3.23
Cornus sericea	3.42	3.21	3.32	-	-	-	3.15	3.55	3.35
Crataegus douglasii	3.33	3.06	3.19	-	-	-	-	-	-
Heracleum maximum	-	-	-	3.67	-	3.67	-	-	-
Holodiscus discolor	3.48	3.29	3.39	-	-	-	-	-	-
Lonicera involucrata	-	-	-	3.20	-	3.20	-	-	-
Lonicera utahensis	3.35	-	3.35	-	-	-	-	-	-
Menziesia feruginea	3.50	3.32	3.41	3.26	-	3.26	-	-	-
Philedelphus lewisii	3.62	-	3.62	-	-	-	-	-	-
Populus balsamifera	3.32	3.43	3.38	-	-	-	-	-	-
Populus tremuloides	3.20	3.28	3.24	-	-	-	3.06	3.31	3.19
Prosartes hookeri	3.39	-	3.39	-	-	-	-	-	-
Prunus virginiana	3.61	-	3.61	-	-	-	3.47	3.52	3.50
Pteridium aquilinum	-	3.44	3.44	-	-	-	-	-	-
Ribes inerme	3.48	-	3.48	-	-	-	-	-	-
Ribes lacustre	-	3.38	3.38	3.45	3.36	3.40	3.48	3.41	3.44
Rosa sp	3.47	3.57	3.52	-	-	-	-	-	-
Rubus parviflora	3.65	3.61	3.63	-	-	-	-	-	-
Salix barclayi	-	-	-	3.09	3.35	3.22	-	3.26	3.26
Salix bebbiana	-	-	-	-	-	-	3.21	3.29	3.25
Salix boothii	-	-	-	3.40	3.46	3.43	3.36	3.32	3.34
Salix commutata	-	-	-	-	-	-	3.27	-	3.27
Salix discolor	3.29	-	3.29	-	-	-	3.26	-	3.26
Salix drummondiana	3.44	-	3.44	3.37	3.24	3.30	3.02	3.25	3.14
Salix eriocephala	-	-	-	-	-	-	-	3.37	3.37
Salix exigua	-	-	-	-	-	-	3.23	3.32	3.27
Salix geyeriana	-	-	-	3.39	3.19	3.29	3.21	3.11	3.16
Salix lemmonii	-	-	-	3.37	-	3.37	3.36	-	3.36
Salix melanopsis	-	-	-	-	-	-	3.43	3.30	3.36
Salix planifolia	-	-	-	3.47	3.46	3.46	3.42	3.27	3.35
Salix pseudomonticola	-	-	-	-	-	-	3.32	-	3.32
Salix scouleriana	3.36	3.36	3.36	-	-	-	3.30	3.23	3.27
Salix serissima	-	-	-	-	-	-	3.50	3.48	3.49
Salix sitchensis	-	-	-	-	-	-	-	3.38	3.38
Shepherdia canadensis	3.34	3.50	3.42	-	-	-	-	-	-
Sorbus scopulina	3.32	3.48	3.40	-	-	-	-	-	-
Spiraea betulifolia	3.31	3.63	3.47	-	-	-	-	-	-
Spiraea douglasii	3.20	-	3.20	-	-	-	-	-	-
Symphoricarpos albus	3.38	3.23	3.31	-	-	-	-	-	-
Vaccinium globulare	-	3.26	3.26	-	-	-	-	-	-
<b>Average Digestible Energy and 95% CI</b>	<b>3.37 (3.21, 3.42)</b>			<b>3.36 (3.30, 3.43)</b>			<b>3.31 (3.27, 3.35)</b>		



**Table 3.** Digestible protein (%) of browsed species surveyed at foraging locations of moose in 3 study areas throughout western Montana, USA, during the summers of 2021 and 2022.

Species	Cabinet-Salish			Big Hole			Rocky Mountain Front		
	2021	2022	Average	2021	2022	Average	2021	2022	Average
Acer glabrum	7.42	4.92	6.17	-	-	-	-	6.33	6.33
Alnus incana	12.95	7.68	10.32	-	-	-	-	-	-
Amelanchier alnifolia	9.08	8.45	8.76	-	-	-	-	7.70	7.70
Aster sp	7.86	-	7.86	-	-	-	-	-	-
Betula pumila	-	-	-	-	14.03	14.03	9.81	-	9.81
Ceanothus velutinus	13.19	11.10	12.15	-	-	-	-	-	-
Chamerion angustifolium	-	-	-	-	-	-	5.01	-	5.01
Cornus sericea	7.92	4.70	6.31	-	-	-	3.33	4.94	4.13
Cratageus douglasii	6.46	8.03	7.24	-	-	-	-	-	-
Heracleum maximum	-	-	-	17.47	-	17.47	-	-	-
Holodiscus discolor	9.89	9.43	9.66	-	-	-	-	-	-
Lonicera involucrata	-	-	-	9.89	-	9.89	-	-	-
Lonicera utahensis	5.74	-	5.74	-	-	-	-	-	-
Menziesia feruginea	7.56	7.71	7.64	9.25	-	9.25	-	-	-
Phileadelphus lewisii	9.34	-	9.34	-	-	-	-	-	-
Populus balsamifera	7.29	10.08	8.69	-	-	-	-	-	-
Populus tremuloides	10.63	6.33	8.48	-	-	-	7.86	7.12	7.49
Prosartes hookeri	13.87	-	13.87	-	-	-	-	-	-
Prunus virginiana	9.79	-	9.79	-	-	-	7.61	7.82	7.72
Pteridium aquilinum	-	24.31	24.31	-	-	-	-	-	-
Ribes inerme	7.85	-	7.85	-	-	-	-	-	-
Ribes lacustre	-	6.81	6.81	9.98	9.08	9.53	5.58	7.24	6.41
Rosa sp	7.03	7.03	7.03	-	-	-	-	-	-
Rubus parviflora	10.16	6.45	8.30	-	-	-	-	-	-
Salix barclayi	-	-	-	13.59	16.73	15.16	-	9.57	9.57
Salix bebbiana	-	-	-	-	-	-	6.20	8.24	7.22
Salix boothii	-	-	-	10.44	10.51	10.48	10.56	8.49	9.53
Salix commutata	-	-	-	-	-	-	7.69	-	7.69
Salix discolor	10.08	-	10.08	-	-	-	8.96	-	8.96
Salix drummondiana	12.76	-	12.76	11.68	10.41	11.04	5.52	13.28	9.40
Salix eriocephala	-	-	-	-	-	-	-	5.82	5.82
Salix exigua	-	-	-	-	-	-	5.97	5.71	5.84
Salix geyeriana	-	-	-	10.98	11.73	11.36	6.49	5.94	6.21
Salix lemmonii	-	-	-	10.06	-	10.06	8.33	-	8.33
Salix melanopsis	-	-	-	-	-	-	11.24	8.99	10.12
Salix planifolia	-	-	-	8.83	11.05	9.94	7.97	8.63	8.30
Salix pseudomonticola	-	-	-	-	-	-	6.47	-	6.47
Salix scouleriana	9.44	8.77	9.10	-	-	-	7.39	6.81	7.10
Salix serissima	-	-	-	-	-	-	8.48	10.63	9.56
Salix sitchensis	-	-	-	-	-	-	-	9.26	9.26
Sheperdia canadensis	7.87	16.71	12.29	-	-	-	-	-	-
Sorbus scopulina	10.85	12.57	11.71	-	-	-	-	-	-
Spiraea betulifolia	4.96	7.12	6.04	-	-	-	-	-	-
Spiraea douglasii	12.39	-	12.39	-	-	-	-	-	-
Symphoricarpos albus	8.42	7.40	7.91	-	-	-	-	-	-
Vaccinium globulare	-	10.00	10.00	-	-	-	-	-	-
<b>Average Digestible Protein and 95% CI</b>	<b>9.27 (8.29, 10.25)</b>			<b>11.51 (10.31, 12.72)</b>			<b>7.65 (7.01, 8.29)</b>		

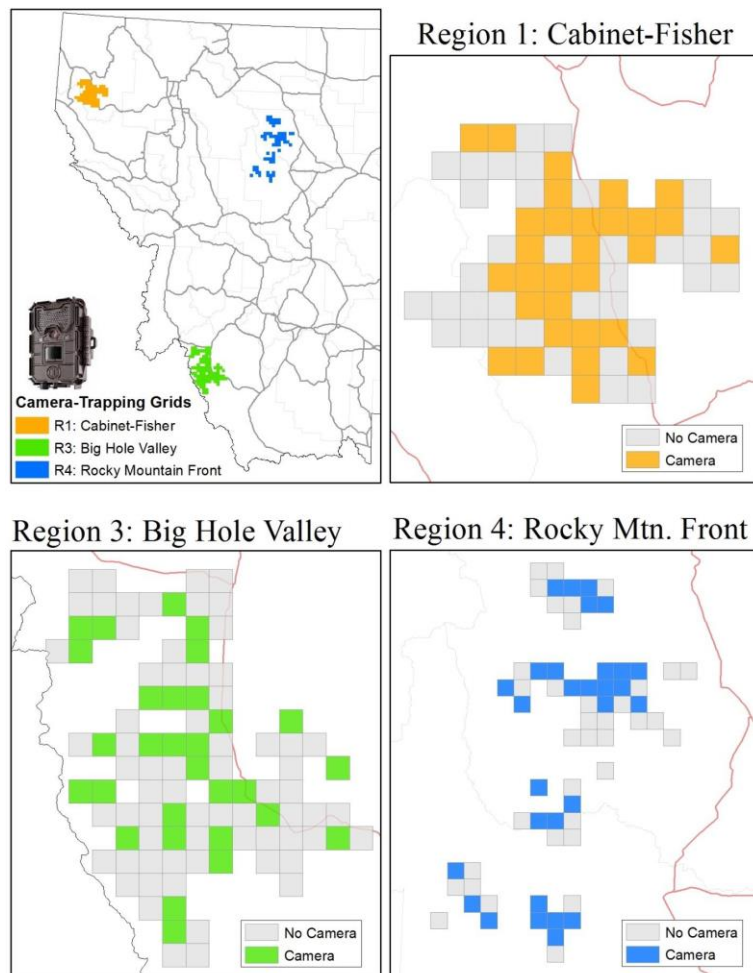


**Figure 10.** Digestible energy (kilocalories/gram; A and B), digestible protein (C and D) and Bovine Serum Albumin (BSA, an index of the inhibition of protein digestion due to tannins; E and F) in forage plants (left column) and willows only (*Salix* spp.) surveyed during summers of 2021 and 2022 in 3 study areas throughout western Montana, USA.

## 2.4 Multi-species predator occupancy

Predation is among the hypothesized factors potentially limiting moose vital rates in Montana, and the extent to which predation limits moose populations is of widespread interest. Past research has found predation by grizzly bears, black bears and wolves could have potentially significant effects on moose populations, under some circumstances (Messier and Crête 1985, Larsen et al. 1989, Ballard et al. 1990). In addition, mountain lions are known to predate on moose and even coyotes may take calves (Ross and Jalkotzy 1996, Bartnick et al. 2013, Benson and Patterson 2013). Given the potential role of these carnivores in moose population dynamics, and perhaps more importantly the effects of the predator guild as a whole (Sih et al. 1998, Griffin et al. 2011, Keech et al. 2011), we are assessing the relationship between predator occupancy and moose vital rates. Of particular interest is the effects of predation on moose calf survival, which differs between study areas (see the annual report from 2022). However, obtaining information on predator populations and their potential to effect moose survival is challenging because these species are cryptic and occur at low densities. Camera trapping is a promising means of obtaining estimates of occupancy and relative density for multiple species simultaneously in a manner that is non-invasive and cost-effective (Rovero & Marshal 2009, Brodie et al. 2014, Steenweg et al. 2016). This has led to rapid expansion of camera trapping for wildlife research and management, and concomitant statistical models to exploit camera data (Meek & Fleming 2014, Burton et al. 2015, Moeller et al. 2018).

Between September 2015 and October 2022, we continuously operated remote camera grids on 3 moose field study areas (Figures 11,12) to evaluate spatial variation in predator communities overlapping moose, and the relationship between predator populations and moose vital rates. Remote cameras were deployed year-round in randomly selected cells within the trapping grid (Figure 11). Within the selected cell, unbaited cameras sets were established on trails, closed roads and other travel routes to maximize detection of multiple predator species. Over the



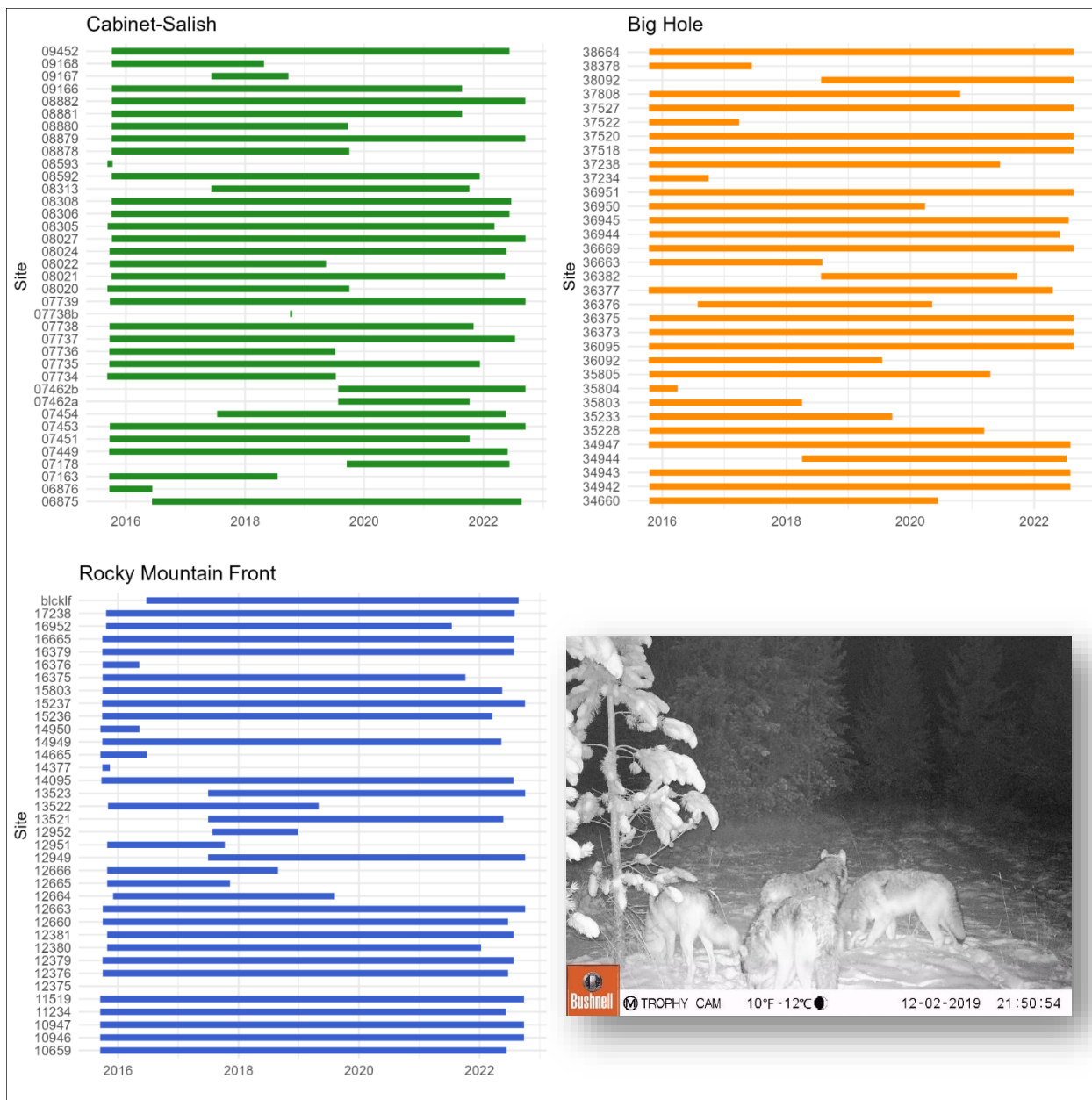
**Figure 11.** Sampling grids (2 x 2 miles) for deployment of remote cameras for monitoring multi-species predator occupancy across areas occupied by moose.

course of this study, we retrieved data from remote cameras at 106 sites (37 sites Cabinet-Salish study area; 36 Rocky Mountain Front study area; 33 Big Hole Valley study area; Figure 12). To date we have retrieved and stored images spanning ~160,000 active camera trap-days (56,000 Cabinet-Salish; 51,000 Rocky Mountain Front; and 53,000 Big Hole Valley). We captured and sorted through ~7 million images throughout this study; of these, we identified >2.6 million images capturing wildlife, humans, or livestock, including large predators like black bears (*Ursus americana*), grizzly bears (*U. arctos*), mountain lions (*Felis concolor*), and wolves (*Canis lupus*), medium-sized carnivores like coyotes (*Canis latrans*), ungulates like deer (*Odocoileus* spp.), elk (*Cervus canadensis*), and moose (*Alces alces*), humans (*Homo sapiens*), cattle (*Bos taurus*), and rare and cryptic species such as wolverines (*Gulo gulo*) and fishers (*Pekania pennantii*) (Table 4).

Among the large carnivores, we captured the most images of black bears, followed by wolves, mountain lions, and grizzly bears, though these rankings varied within study areas (Table 4). Across those 4 large carnivore species, most images were captured in the Cabinet-Salish study area (n = 17,803) followed by the Rocky Mountain Front (n = 8,117) and the Big Hole Valley (n = 2,655). Importantly, the number of raw images is not necessarily indicative of abundance or occupancy at a study area-scale. Accurate estimates of annual abundances of each predator species would be ideal; however, a precise index which detects spatial and temporal heterogeneity in predator activity would also be useful in assessing the potential influence of predators on moose vital rates (Parsons et al. 2017, Keim et al. 2019). We are currently initiating analyses to estimate probability of carnivore occurrence over the study area (MacKenzie et al. 2002, Fisher et al. 2018, Steenweg et al. 2023).

**Table 4.** Numbers of images of various animal species captured by remote cameras deployed in 3 study areas in western Montana, USA, between 2015 and 2022.

Animal	Cabinet-Salish	Big Hole Valley	Rocky Mtn. Front	Total
Black bear	10,780	1,755	1,876	14,411
Coyote	4,420	4,708	6,285	15,413
Deer	322,000	44,590	116,149	482,739
Elk	33,237	254,838	60,948	349,023
Fisher	31	0	0	31
Grizzly bear	668	44	3,602	4,314
Humans	32,483	31,583	32,216	96,282
Livestock	26	1,245,237	250,627	1,495,890
Moose	16,618	38,638	8,029	63,285
Mountain lion	2,892	125	1,459	4,476
Wolf	3,463	731	1,180	5,374
Wolverine	14	10	19	43
Total	426,632	1,622,259	482,390	2,531,281



**Figure 12.** Duration of deployment of remote camera traps for monitoring predator populations at numerous sites in 3 study areas throughout western Montana, USA, between 2015 and 2022.

## Deliverables

Below we list project deliverables (publications, reports, presentations, media communications, and value-added collaborations) stemming from this moose research project, during FYs 13–23 (July 2012–June 2023). In addition to those communications listed below, are frequent discussions with moose hunters statewide. Copies of reports and publications are available on FWP’s moose-specific website: <https://fwp.mt.gov/conservation/wildlife-management/moose>

### 1. Annual Reports:

2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023. DeCesare, N. J., C. J. Peterson, J. R. Newby, and R. B. Harris. *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.

Burkholder, B. O., R. B. Harris, N. J. DeCesare, S. J. Boccadori, and R. A. Garrott. 2022. *Winter habitat selection by female moose in southwestern Montana and effects of snow and temperature*. *Wildlife Biology* 2022:e01040

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.

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., K. M. Podruzny, and J. A. Gude. 2023. *Leveraging hunters as citizen scientists for monitoring non-target species*. *Ecological Solutions and Evidence* 4:e12260.

DeCesare, N. J., R. B. Harris, C. J. Peterson, and J. M. Ramsey. In press. *Prevalence and mortality of moose (*Alces alces*) infected with *Elaeophora schneideri* in Montana, USA*. *Journal of Wildlife Diseases* 59.

DeCesare, N. J., R. B. Harris, J. R. Newby, and C. J. Peterson. 2023. *Spatial and temporal heterogeneity in thermal conditions for wildlife*. *Alces* 59:33–49.

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

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.

### **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.
- DeCesare, N. J., et al. 2021. Phylogeography of moose in western North America. North American Moose Conference and Workshop, online.
- Peterson, C. J., N. J. DeCesare, R. B. Harris, and J. M. Ramsey. 2023. Prevalence and mortality of moose (*Alces alces*) infected with *Elaeophora schneideri* in Montana. North American Moose Conference and Workshop, Grand Portage, Minnesota.

## 5. Public and/or Workshop Presentations

FY	Organization ( <i>Speaker</i> )	Location
2013	Helena Hunters and Anglers Association ( <i>DeCesare</i> )	Helena, MT
	Marias River Livestock Association ( <i>DeCesare</i> )	Whitlash, MT
	Plum Creek Timber Company, Staff meeting ( <i>DeCesare</i> )	Libby, MT
	Sun River Working Group ( <i>DeCesare</i> )	Augusta, MT
2014	Big Hole Watershed Committee ( <i>DeCesare</i> )	Divide, MT
	Flathead Wildlife Incorporated ( <i>DeCesare</i> )	Kalispell, MT
	MFWP R1, Regional Citizens Advisory Council ( <i>Newby</i> )	Kalispell, MT
	MFWP R1, Biologists' Meeting ( <i>Newby</i> )	Kalispell, MT
	MFWP R1, Bow Hunter Education Workshop	Kalispell, MT
	MFWP R2, Regional Meeting ( <i>DeCesare</i> )	Missoula, MT
	MFWP, Wildlife Division Meeting ( <i>DeCesare</i> )	Fairmont, MT
	Plum Creek Timber Annual Contractors Meeting ( <i>DeCesare</i> )	Kalispell, MT
	Rocky Mountain Front Land Managers Forum ( <i>DeCesare</i> )	Choteau, MT
	Swan Ecosystem Center Campfire Program ( <i>Newby</i> )	Holland Lake, MT
WCS Community Speaker Series ( <i>Newby</i> )	Laurin, MT	
2015	Big Hole Watershed Committee ( <i>Bocadori</i> )	Divide, MT
	Flathead Chapter of Society of American Foresters ( <i>Newby</i> )	Kalispell, MT
	Libby Chapter of Society of American Foresters ( <i>Newby</i> )	Libby, MT



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	MFWP R1, Regional Citizens Advisory Council ( <i>Newby</i> )	Kalispell, MT
	MFWP R2, Bow Hunter Education Workshop ( <i>DeCesare</i> )	Lolo, MT
	MFWP R2, Regional Citizens Advisory Council ( <i>DeCesare</i> )	Missoula, MT
	Rocky Mountain Front Land Managers Forum ( <i>Newby</i> )	Choteau, MT
	Sanders County Commission Meeting ( <i>DeCesare</i> )	Thompson Falls, MT
	Sheridan Wildlife Speaker Series ( <i>DeCesare</i> )	Sheridan, MT
	Univ. Montana Guest Lecture – WILD105 ( <i>DeCesare</i> )	Missoula, MT
2016	Confederated Salish & Kootenai Tribe, Nat Res Commission ( <i>Newby</i> )	Marion, MT
	Ducks Unlimited State Convention ( <i>Newby</i> )	Lewistown, MT
	Helena Hunters and Anglers Association ( <i>DeCesare</i> )	Helena, MT
	MFWP R1 Law Enforcement Annual Meeting ( <i>Newby</i> )	Kalispell, MT
	Montana State University, Ecology Seminar Series ( <i>DeCesare</i> )	Bozeman, MT
	Ravalli County Fish and Wildlife Association ( <i>DeCesare</i> )	Hamilton, MT
	Univ. Montana Guest Lecture – WILD480 ( <i>DeCesare</i> )	Missoula, MT
	Upper Sun River Wildlife Team Meeting ( <i>DeCesare</i> )	August, MT
2017	Big Hole Watershed Committee ( <i>Bocadori</i> )	Divide, MT
	Mountain Bluebird Trails Conference ( <i>DeCesare</i> )	Dillon, MT
	Swan Valley Connections Speaker Series ( <i>DeCesare</i> )	Condon, MT
	University of Montana, STEAMfest ( <i>DeCesare</i> )	Missoula, MT
	Univ. Montana Guest Lectures – WILD180, WILD480 ( <i>DeCesare</i> )	Missoula, MT
	WCS Community Speaker Series ( <i>DeCesare</i> )	Dillon, MT
	Flathead Valley Lions Club ( <i>Newby</i> )	Kalispell, MT
	Flathead Wildlife Incorporated ( <i>Newby</i> )	Kalispell, MT
	North Fork Inter-local ( <i>Anderson</i> )	Polebridge, MT
2018	Bitterroot College ( <i>DeCesare</i> )	Hamilton, MT
	Clearwater Resource Council ( <i>DeCesare</i> )	Seeley Lake, MT
	MFWP R1, Regional Citizens Advisory Council ( <i>Newby</i> )	Kalispell, MT
	Montana Forest Landowner Conference ( <i>DeCesare</i> )	Helena, MT
	Montana Audubon Chapter ( <i>Newby</i> )	Polson, MT
	Science on Tap ( <i>Newby</i> )	Bigfork, MT
2019	MFWP HQ, Brown Bag Seminar ( <i>DeCesare</i> )	Helena, MT
	MFWP Wildlife Manager Meeting ( <i>DeCesare</i> )	Helena, MT
	Hellgate Hunters and Anglers ( <i>DeCesare</i> )	Missoula, MT
	Rocky Mountain Front Land Managers Forum ( <i>Newby</i> )	Choteau, MT
	Upper Sun Wildlife Team ( <i>DeCesare</i> )	Fairfield, MT
	Univ. Montana Guest Lectures – WILD240 ( <i>DeCesare</i> )	Missoula, MT
	Idaho Fish & Game/MFWP Joint Meeting ( <i>Newby</i> )	De Borgia, MT
2020	Flathead Wildlife Incorporated ( <i>Newby</i> )	Kalispell, MT
	Devil’s Kitchen Working Group ( <i>DeCesare</i> )	Cascade, MT
	Lake County Conservation District ( <i>DeCesare</i> )	Polson, MT
2021	Big Hole Watershed Committee ( <i>Newby</i> )	Divide, MT (remote)
	Swan Valley Connections ( <i>DeCesare</i> )	Condon, MT (remote)
2022	American Society of Foresters ( <i>Peterson</i> )	Libby, MT
	Flathead Lake Biological Station ( <i>Peterson</i> )	Polson, MT
	Upper Sun River Wildlife Team ( <i>Peterson</i> )	Augusta, MT
	Browning High School ( <i>Peterson</i> )	Browning, MT
2023	Flathead Lake Biological Station ( <i>Peterson</i> )	Polson, MT
	Flathead High School ( <i>Peterson</i> )	Kalispell, MT

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## 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
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
Billings Gazette (MT)		Moose research	Newspaper
Missoulian (MT)		Moose research	Newspaper
Great Falls Tribune (MT)		Moose research	Newspaper
Weather Network (Canada)		Moose sightings	Website
2018	The Nature Conservancy Magazine (VA)	Wildlife tracking	Magazine
	Hungry Horse News (MT)	Moose research	Newspaper
	Missoulian (MT)	Moose research	Newspaper
2019	Missoulian (MT)	Moose hunting	Newspaper
	Montana Outdoors	Moose research	Magazine
2020	Bugle magazine (MT)	Moose conservation	Magazine
	MFWP Facebook (MT)	Moose genetics	Social Media
2021	MFWP Facebook (MT)	Moose research	Social Media
2022	Montana Outdoors (MT)	Moose genetics	Magazine
	MFWP Outdoor Report (MT)	Moose genetics	Television
2023	Ravalli Republic (MT)	Moose research	Newspaper

## 7. Other Project-related Collaborations

Partners	Title	Status
Rick Gerhold University of Tennessee	Development of a serological assay for <i>Elaeophora schneideri</i> 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, <i>Alces alces shirasi</i>	*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	*Completed, manuscript published, 2021.
Jason Ferrante & Margaret Hunter, USGS – Gainesville, FL	Genetic approaches to understanding moose health	*Completed, manuscript published, 2021.

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