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

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**Nick DeCesare**
Research Wildlife Biologist, MFWP
3201 Spurgin Rd. | Missoula, MT 59804
406-542-5558 | ndecesare@mt.gov

**Jesse Newby**
Research Technician, MFWP
490 N. Meridian | Kalispell, MT 59901
406-751-4588 | jnewby@mt.gov



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## Location

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

## Study Objectives (Year 1 of 10 year-study)

For the 2012-2013 field season of this moose study, the primary objectives were;

1) Complete a literature and data review concerning the status of moose in Montana.
2) Capture animals and initiate data collection pertaining to vital rates and limiting factors.
3) Initiate an effectiveness evaluation of current moose monitoring methods.

## Objective #1: *Complete a literature and data review concerning the status of moose in Montana*

### 1.1. Background

Moose are considered to have been rare throughout the U.S. Rocky Mountains until the mid-1800s (Karns 2007), yet their earlier presence in several regions of Montana were documented by the Lewis and Clark expedition in 1805–1806 and others (reviewed by Schladweiler 1974). Regulation of moose hunting in Montana began in 1872, yet after a subsequent decline brought them near extirpation, hunting was closed statewide for almost 50 years during 1897–1945 (Stevens 1971). Allowable harvest began again in 1945 with 90 permits issued. Subsequently the annual number of permits issued rose quickly to a maximum of 836 in 1962, and thereafter averaged 652 per year during the 50 years leading up to present (1963–2012). The current distribution of moose harvest presumably reflects that of moose abundance (Figure 1), with animals spread widely across primarily western portions of the state and with lower densities extending to the east.

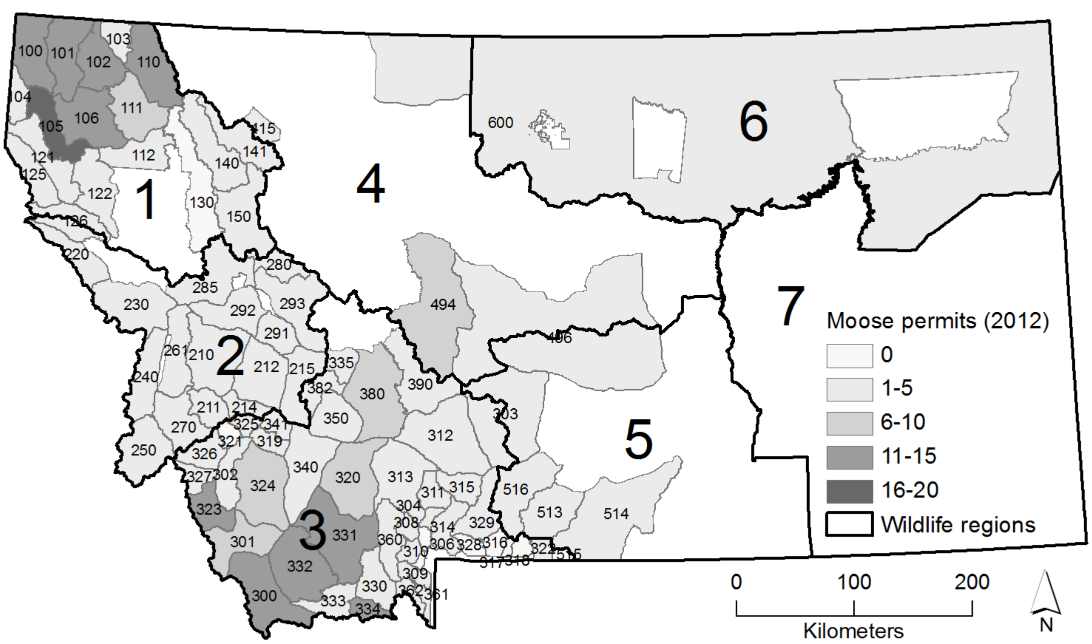



**Figure 1.** *Number of moose permits issued by moose hunting district in Montana, 2012.*

In Montana, moose typically occur at relatively low densities and are vastly outnumbered by seasonally sympatric elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) populations. Relative ungulate densities are reflected in numbers of animals harvested in Montana; in 2012 hunters harvested an estimated 274 moose versus over 20,000 elk, 37,000 mule deer, and 49,000 white-tailed deer. Rigorous statewide moose abundance estimates are lacking, but in 2006 a tally of professional opinion among regional management biologists yielded an estimated statewide total of 4,500–5,500 individuals, though with inestimable accuracy or precision (Smucker et al. 2011). The limited numbers of moose permits are allocated via a random drawing process. During 2008–2012, an average of almost 23,000 hunters applied annually for <600 permits, with a 1.9% chance of success. Beginning in 1988, one additional permit has been auctioned to the highest bidder, with revenue directly earmarked for moose management or research. Additionally, since 2006 applicants can purchase unlimited numbers of chances at drawing one available moose "super-tag," valid in any permitted hunting district. Along with super-tag chances for other species, revenue from these sales is earmarked for hunting access programs and wildlife habitat conservation.

### 1.2. Moose harvest statistics and trend

Post-season surveys of permit holders have been used to estimate wildlife harvest in Montana since 1941 (Cada 1983, Lukacs et al. 2011). For moose, Montana Fish, Wildlife & Parks (MFWP) attempts to survey every permit holder to gain information on hunter success and effort, and adjusts annual harvest estimates according to annual response rates. During 2005–2012, surveys yielded hunter response rates of 81–96% (mean=84.9%) and statewide harvest estimates with coefficients of variation of 0.6–2.3% (mean=1.6%). Generally, there are 4 statistics computed annually that provide insight into potential moose population trends: 1) number of permits issued, 2) hunter success rate, 3) days of moose hunter effort, and 4) kills per unit effort (KPUE).

*Number of permits:* As a consequence of perceived population declines and declining population indices from harvest data in recent decades, the number of moose permits issued in Montana was reduced by 53%, from 769 to 362, between 1995 and 2012, (Figure 2a). Most of the loss has occurred in areas with traditionally the greatest number of permits offered (Regions 1 and 3). In contrast, the first two permits ever offered in northeastern Montana (Region 6) were added in 2008. Notably, the 2010 hunting season was the first time in over 50 years when the number of moose permits issued statewide dropped below 500 (Figure 2a).

*Hunter success:* Statewide hunter success is estimated annually as the number of moose harvested relative to the number of permits issued and has averaged 78.4% during the history of moose hunting in Montana (1945–2012; Figure 2b). These success rates are comparable to those in neighboring Idaho (61–85%; Toweill and Vecellio 2004), but relatively high compared to other areas with typically more moose and moose hunters such as Alberta (30–50%; Boyce et al. 2012), Alaska (28–37%; Schmidt et al. 2005), Newfoundland (25–54%; Fryxell et al. 1988), and Ontario (36–40%; Hunt 2013). In the most recent 5 years (2008–2012), success rates appear to have declined (average = 73.4%) significantly below the previous 20-year average (83.7%; $t$ = 2.07, 23 df, $P < 0.001$).

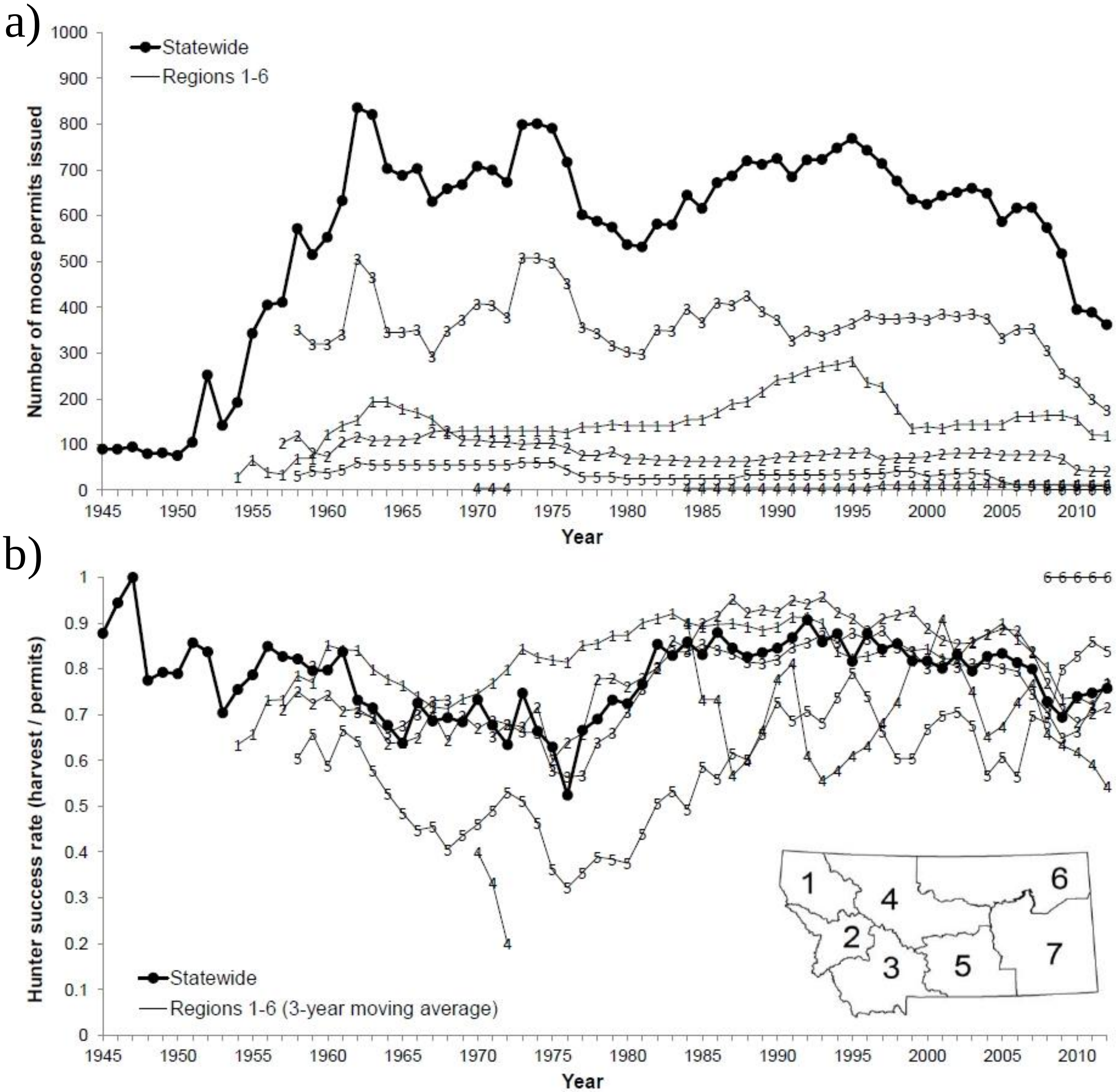
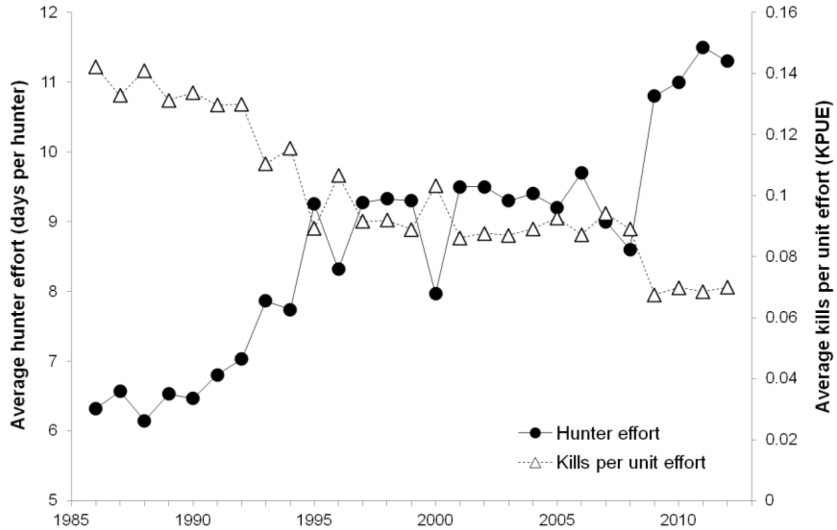



**Figure 2.** *Statewide and regional trends of a) number of permits issued and b) hunter success rates (number harvested / number of permits issued) for moose in Montana, 1945–2012.*

Additionally, hunter effort, defined as the number of days spent hunting moose per hunter, has been increasing since the mid-1980s from 6.3 days/hunter in 1986 to ≥11 days/hunter in 2010–2012 (Figure 3). Kills per unit effort (KPUE) integrates hunter success and effort statistics into a metric of hunter efficiency, which declined by >50% from >0.14 moose killed per hunter-day to <0.07 over the same time period (Figure 3). Mapping per-hunting district KPUE for antlered bull-specific tags also reveals some within-state variation in hunter efficiency (Figure 4), likely reflecting regional differences in moose distribution and ecotypes (e.g., more closed forests in western Montana compared to more open foothills and large riparian complexes in southwest Montana).

**Figure 3.** *Statewide annual averages of moose hunter effort (days per hunter) and moose kills per unit effort (KPUE) in Montana, 1986–2012.*



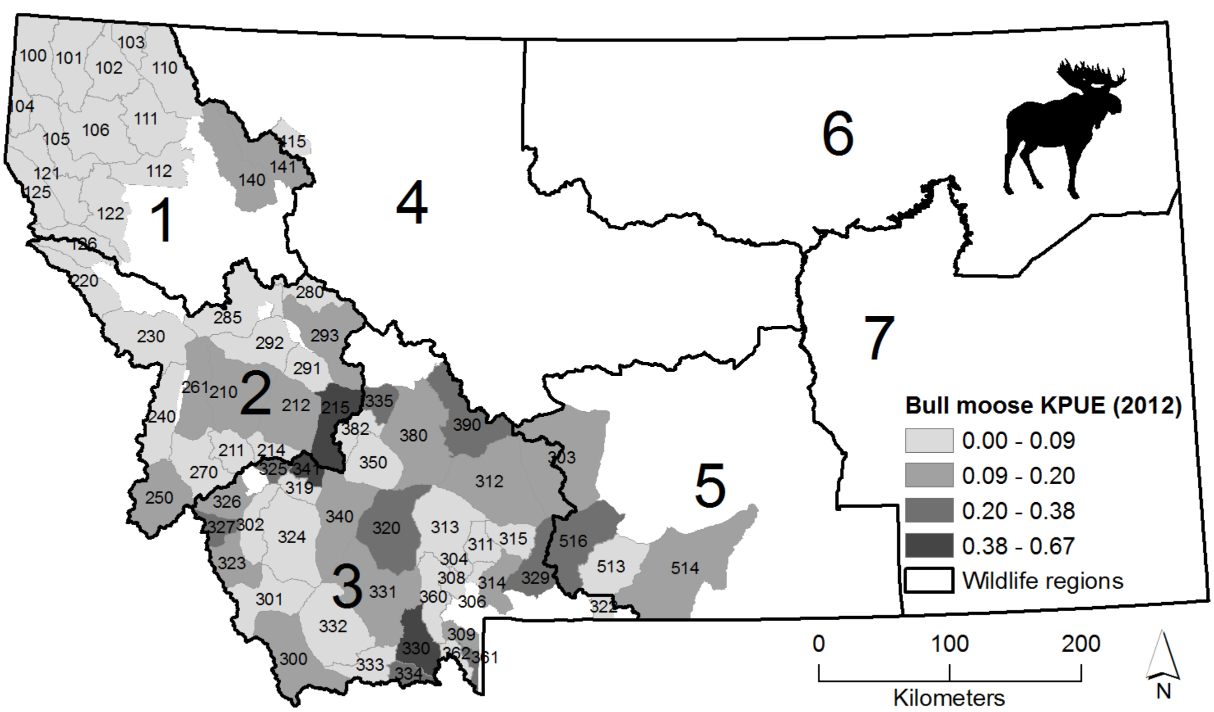




**Figure 4.** *Bull moose kills per unit effort (KPUE; effort recorded in days) per moose hunting district by hunters carrying antlered-bull-only permits in Montana, 2012.*

*Potential decline:* The combined evidence of decreased hunter success, increased effort, and decreased KPUE concurrent with >50% reduction in available permits may be indicative of a declining statewide population trend. In Ontario, years with fewer available permits resulted in increased hunter success rates, even after accounting for changes in underlying moose densities (Hunt 2013), which suggests that hunter behavior can complicate interpretation of trend from hunter statistics (Bowyer et al. 1999a, Schmidt et al. 2005). Changes in permit type over space in time (e.g., shifting between antlered bull, antlerless, or either-sex permits) can also complicate interpretation of changing hunter statistics. However, in the case of Montana's data, concurrent declines in permit availability, success rates, and KPUE seem to be compounding evidence that some form of decline has occurred.

**1.3. Aerial surveys and trends**

In addition to statewide hunter statistics, regional calf/adult ratios in areas with consistent aerial survey data are also indicative of recent declines in recruitment (Figure 5). MFWP biologists in most regions of the state have made at least intermittent efforts to conduct aerial surveys for moose, though sustained survey efforts have been limited to few areas with historically higher densities. In the northwest (Region 1), December helicopter surveys have been conducted annually in a subset of moose hunting districts, centered around the Cabinet, Purcell, Salish, and Whitefish Mountains, since 1985. While an explicit model of sightability covariates has not been developed in this densely forested area, an early 1990s mark-resight study involving 81 neck-banded individuals resulted in mean sightability estimates of 0.53–0.55 (Brown 2006). In the southwest (Region 3), fixed-wing aerial surveys have been conducted during most years since the 1960s in the hunting districts of the Big Hole and Centennial Valleys. These surveys typically yield young:adult ratios and uncorrected minimum counts, and their timing has varied considerably across both years and districts (September–May). Sporadic aerial surveys have also been conducted in other, lower-density, regions of the state, including within Region's 2, 4, & 5 using both helicopters and fixed-wing aircraft.

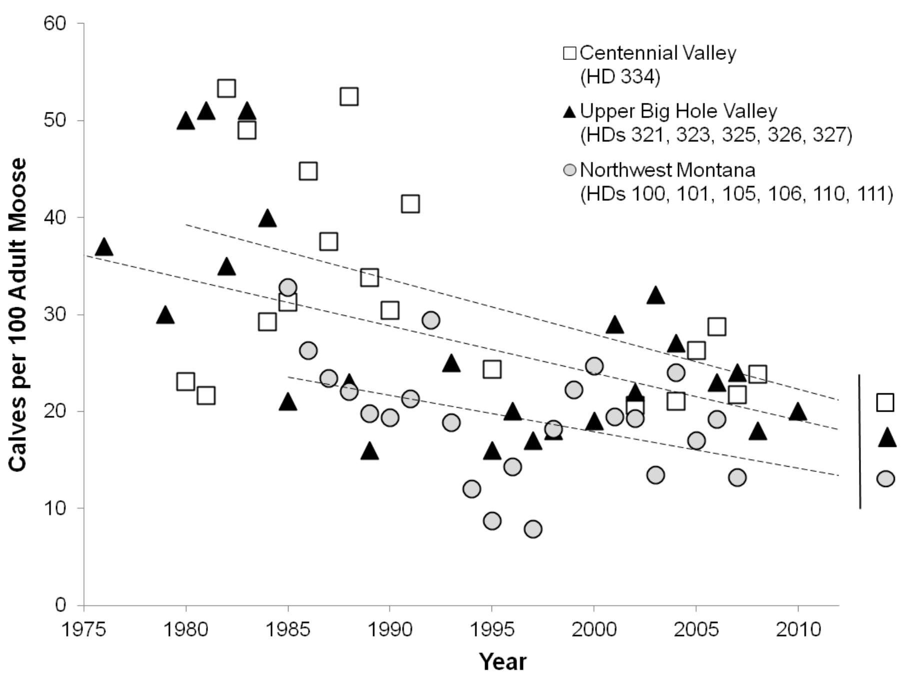



***Figure 5.*** *Annual moose calves per 100 adults recruitment data and associated linear regression trend lines collected during both fixed- and rotary-wing late winter aerial surveys in 3 regions of Montana, 1976–2010.*

## **Objective #2:** *Capture animals and initiate data collection pertaining to vital rates and limiting factors*

### 2.1. Study areas

This research project is designed to provide inferences using a comparative study design. This involves replicating field methods at several study areas that contrast in the hypothesized ecological drivers of interest. We are conducting field work in three study areas: the Cabinet Mountains, the upper Big Hole valley, and the Rocky Mountain Front (Figure 2), which vary considerably in the likely role of these factors.

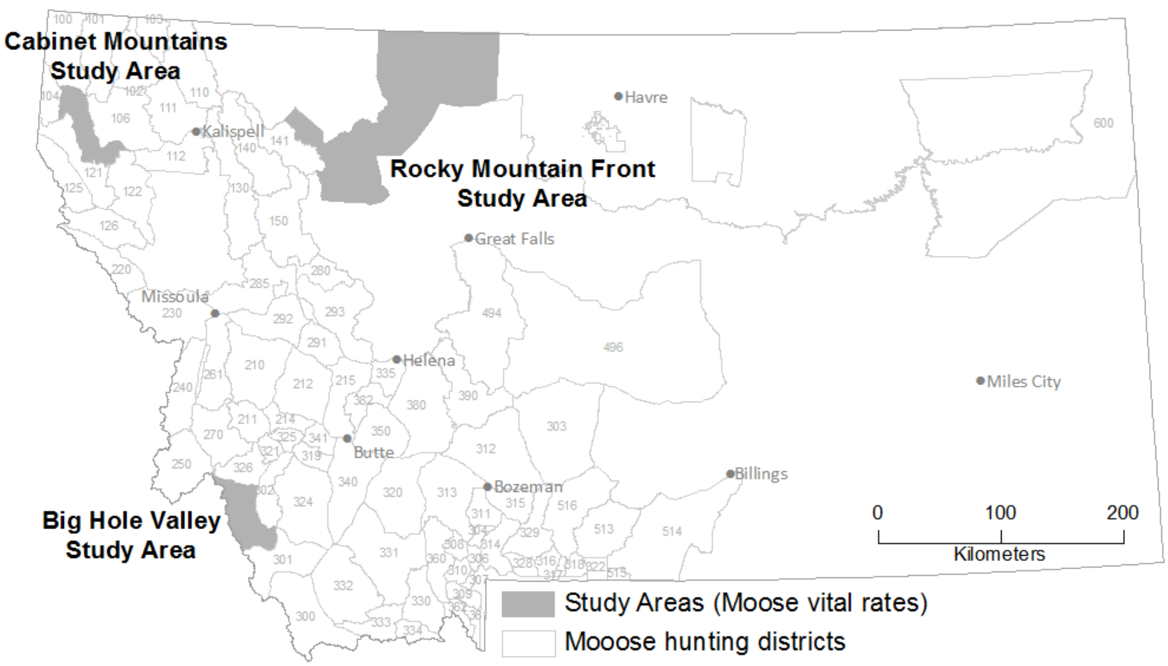



***Figure 6.*** *Three study areas for assessing moose vital rates and limiting factors in Montana*

### 2.2. Animal capture and handling

In February, 2012 we initiated capture efforts of adult female moose using helicopter darting to immobilize individuals with carfentanil (3.3–3.9 mg/adult) and xylazine (50 mg/adult). Carfentanil was reversed with 350–400 mg of naltrexone administered intramuscularly and xylazine reversed with 400–600 mg tolazolene. All capture and handling procedures followed protocols approved by Montana Fish, Wildlife & Parks Animal Care and Use Committee (Permit # FWP12-2012). Animals were kept in sternal recumbency with head higher than the body when possible to avoid rumen regurgitation and aspiration (Kreeger 2000), and baseline temperature, pulse, and respiratory rate (TPR) values were recorded following Franzmann et al. (1984). Animals were fitted with very high frequency (VHF) radio-telemetry collars (Model LMRT-4 [550g], Lotek Wireless, Newmarket, Ontario) with mortality sensors.

We estimated nutritional condition and total body fat of captured individuals using subcutaneous rump fat thickness measurements from ultrasonography and palpation-based body condition measurements. Live body weights are logistically difficult to record for moose given their size and weights (181–474 kg for females ≥1.5 years old); thus we recorded total body length, chest girth, hind foot length, and neck circumference to estimate body weight (Franzmann et al. 1978, Wallin et al. 1996, Franzmann 2007). We also estimated relative winter tick (*Dermacentor albipictus*) loads using line transect sampling along the rump and shoulder (Sine et al. 2009).

We collected 40 ml of blood from the jugular vein in addition to fecal and hair samples, and we used a dental elevator, dental forceps, and local anesthetic (lidocaine) to extract a lower canine (outermost tooth on incisor bar) for aging of individuals (Swift et al. 2002, Mansfield et al. 2006). While the collection of teeth from live animals does present some concerns for short-term animal welfare (Mansfield et al. 2006), the procedure has not been shown to subsequently affect animal health and provides critical age data for mitigating potential biases in vital rate estimation when ages are unknown (Prichard et al. 2012).

**Figure 7.** *Captured moose F305 lying sternally and waiting for the reversal drugs to take effect after being collared within the Big Hole study area, February, 2013.*

## 2.3. Monitoring vital rates

The study of vital rates allows important mechanistic insight into the factors driving population dynamics as well as the assessment of the growth rates and population trends themselves (DeCesare et al. 2012). The first-year of study will provide an initial glimpse into baseline vital rates and their relative variation among populations, with important implications for understanding which vital rates may be most important in driving variation across both space and time (*sensu* Wisdom et al. 2000). Given different findings of the importance of depressions in each of these vital rates as drivers of moose dynamics (Berger et al. 1999, Keech et al. 2000, Lenarz et al. 2010, Sivertsen et al. 2012), baseline estimates of each will be important for understanding dynamics in Montana.

*2.3.1. Adult female survival*.— Two collared moose died of apparently capture-related causes within 1–2 weeks following captures in February, 2013. In both cases no signs of struggle or trauma were observed, and the moose were <200 meters from their capture locations. Excluding these two, we have monitored 34 adult female moose since captures in early February, 2013. The average time between status (alive/dead) checks was 8.6 days, and we have collected spatial locations and additional vegetation data for roughly 62% of checks. At the time of this writing, animals have been monitored for an average of 172 days. The overall Kaplan-Meier survival estimate across this period and pooling all animals was 0.971 (SE=0.029). Assuming constant hazard of mortality throughout the year (which is highly unlikely), this would translate to an annual survival rate of 0.940. However, these values are quite preliminary and will benefit from additional study animals and monitoring time during the second year of study.

Thus far we have documented one natural case of adult female mortality. In April, 2013, one Cabinet Mountain study animal died of unknown causes. When this six-year-old female was captured in February she was in noticeably poor condition, with no measurable rump fat and infected sores in both hind legs. She was not pregnant nor with a calf from the previous year. Upon visiting the mortality site it was found that she had been completely consumed, leaving little evidence for investigation. Tracks and scats at the site indicated presence of avian scavengers, coyote, wolf and (most prominently) bear. It was not possible to ascertain whether a carnivore had killed the female or whether carnivores were scavenging.

*2.3.2 Adult female fecundity.*—Fecundity for moose is the product of pregnancy rate, survival rate of fetuses to parturition, and litter size. Pregnancy of animals during winter can be estimated with laboratory analyses of both blood and scat. Blood analyses are based on the presence of a pregnancy specific protein B (PSPB) within serum samples (Huang et al. 2000). As reported by the commercial lab where analyses were conducted (BioTracking, Moscow, Idaho), this test is quite accurate in its diagnoses of non-pregnant individuals (99.9%). However, animals diagnosed as pregnant can in fact be non- pregnant 5–7% of the time. Thus some false positives may be present within the PSPB-based diagnoses. Notably, higher rates of both false positives and false negatives have been reported in wild ungulates (Testa and Adams 1998, Cain et al. 2012). Using serum-based PSPB tests alone, we documented an average adult pregnancy rate of 81% of adults (75% including 2 non-pregnant yearlings; Figure 9).

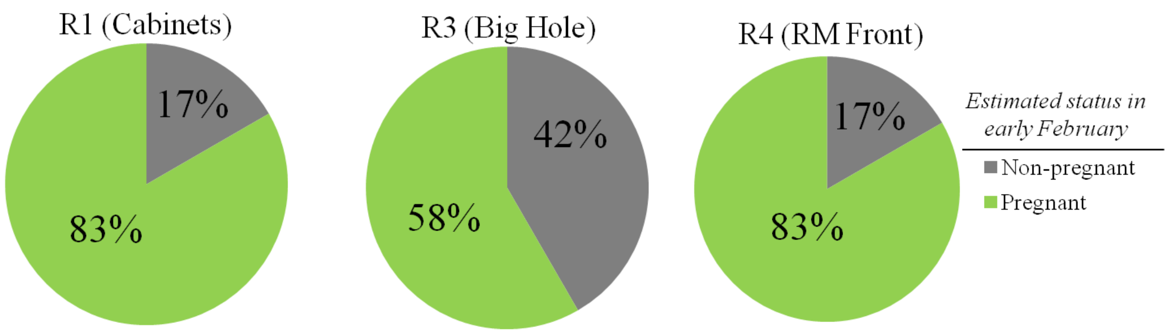



**Figure 8.** *Estimated pregnancy rates from 36 female moose in early February according to PSPB concentration in serum samples, Montana, 2013.*

The concentration of progesterone hormone metabolites in scat samples (i.e., fecal progestagens) can also be used to detect pregnancy in moose (Berger et al. 1999, Murray et al. 2012). We measured fecal progestagen (FP) concentrations during at two time periods: 1) during winter (February) captures, concurrent with blood sampling, and 2) during early spring (14 March–24April). Generally FP results were in agreement with PSPB results, though the correlation between PSPB and FP concentrations did deteriorate somewhat when comparing PSPB to winter vs. spring concentrations (Figure 10).

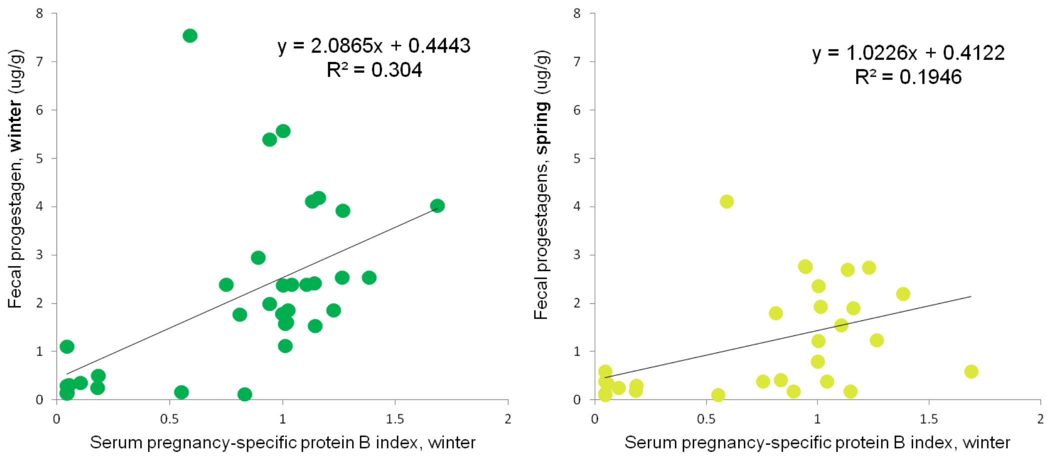



**Figure 9.** *Correlation among blood (PSPB) and scat (fecal progestagen)-based pregnancy assays for moose, Montana, 2013.*

In total, we collected 4 measures to indicate pregnancy status of collared moose: winter PSPB, 2) winter FP, 3) spring FP, and 4) weekly visual observation of cows during May and June to document the presence of calves-at-heel. Amongst all these measures, the only known truth regarding pregnancy status is that cows seen with calves were indeed pregnant with a fetus that survived to parturition. We thus analyzed the relationship between hormone concentrations and calves-at-heel with logistic regression (*sensu* Manly et al. 2002) to assess the relationship between hormone concentrations and the likelihood of a cow birthing a calf that we detected in spring (essentially lumping pregnancy rate and fetal survival into a single parturition rate). We generated a binary response variable coding individuals seen with calves as binary=1 and those without calves as binary=0. We used logistic regression to estimate a model predicting the probability of having birthed a calf based on all three endocrinology assays. We then applied this model to all samples to estimate the predicted probability of parturition during early spring ($w$) as:

$$w = \frac{\exp(\beta_0 + (\beta_1 * PSPB) + (\beta_2 * FP_w) + (\beta_3 * FP_s))}{1 + \exp(\beta_0 + (\beta_1 * PSPB) + (\beta_2 * FP_w) + (\beta_3 * FP_s))},$$

where $FP_w$ and $FP_s$ are the fecal progestagen concentrations during winter and early spring, respectively. We then assigned spring pregnancy status to each cow using a cut-off predicted probability value of 0.5, and re-estimated spring pregnancy rates for each population, or parturition rates (Figure 11).

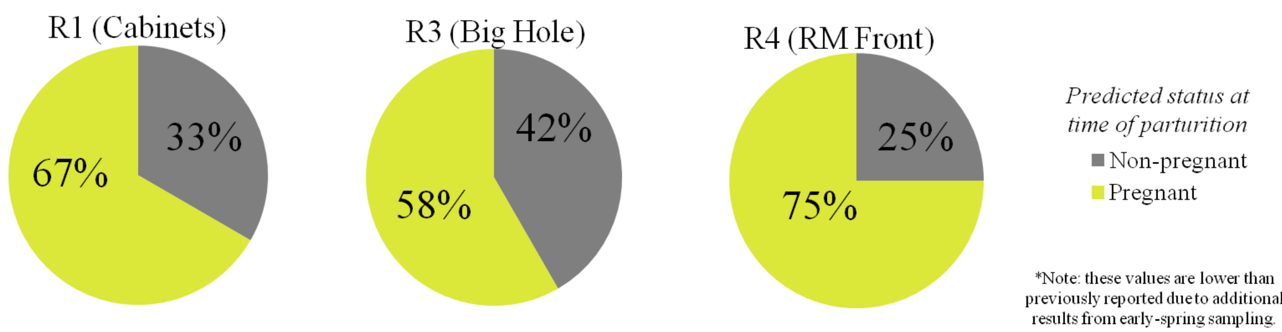



**Figure 10**. *Predicted parturition rates of 36 female moose in May using logistic regression modeling of multiple data sources, including PSPB concentration in serum, fecal progestagen metabolite concentrations in both winter and early-spring, and visual observation of calves-at-heel in May & June, Montana, 2013.*

Overall, our pooled winter pregnancy rate according to PSPB sampling was 81% of adults (75% including 2 non-pregnant yearlings), which is below the 84.2% average of adult moose pregnancy rates across North American (Boer 1992). When we combined additional hormone data available, including early spring fecal progestagen sampling, we predicted a pooled parturition rate of 71% of adults (67% including 2 yearlings). When specifically targeting parturition, or spring pregnancy, we classified 3 individuals as not-pregnant despite showing earlier evidence of pregnancy during winter sampling. This is similar to results of other studies (e.g,, Becker 2008) where parturition rates are lower than earlier winter pregnancy rates due to presumed fetal losses throughout winter. Low pregnancy rates from 48%–75% have been reported in other Shiras moose population-years (Oates et al. 2012), and combined with our results this may reflect generally lower productivity of this subspecies, or the habitat within which it resides, compared to moose further north in Alaska and Canada.

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 percent 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 observed for Shiras moose appear to be relatively low (e.g., <15%; Peek 1962, Stevens 1970, Schladweiler and Stevens 1973, Becker 2008), though it is unclear if this reflects a general difference in nutrition or other locally adapted trait.

Of 19 observed litters during 2013, we documented a single set of twins (Figure 12) and 18 singletons, or a twinning rate of 5.3%. Females carrying twins are known to produce higher pregnancy hormone concentrations in blood and fecal samples (Huang et al. 2000). In our case, fecal progestagens for this female were the highest among all moose sampled during both winter and early spring sessions, though PSPB concentration in blood was not notably higher.

**Figure 11.** *We observed only a single set of twins (above with F107 in the Cabinet Mountains study area) out of 19 litters, or a twinning rate of 5.3% among parturient moose during spring, 2013.*

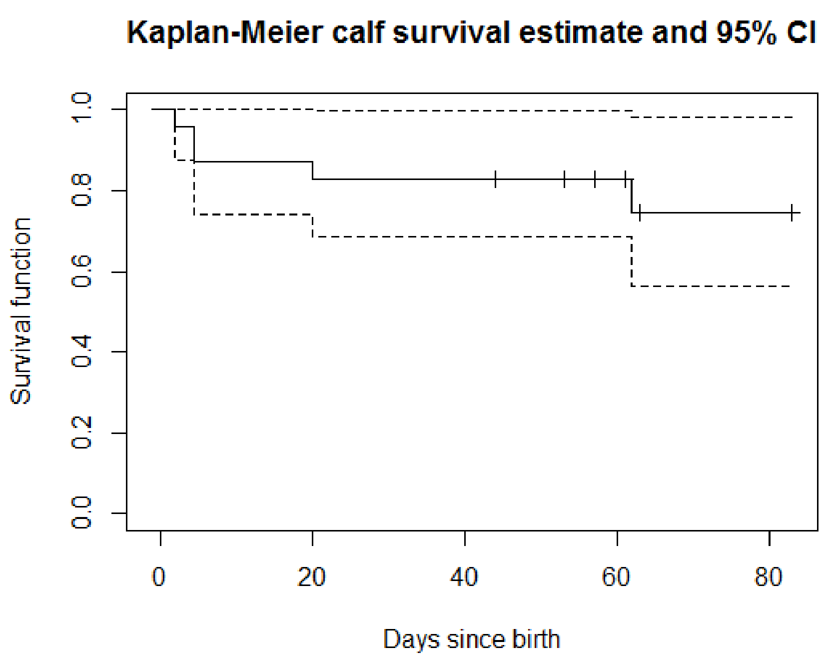
*2.3.3 Calf survival*.— We used aerial telemetry to visually search for calves-at-heel with each collared adult female at approximately weekly intervals during 15 May – 15 July. Aerial telemetry allowed efficient visual observation of cow-calf pairs with minimal disturbance, despite often dense habitats that obscure animals on the ground. Flights were conducted with a mix of fixed-wing and rotary-wing aircraft depending on terrain and forest cover (e.g., primarily fixed-wing in R3 and rotary-wing in R1). We documented 19 litters and 20 total calves born among 22 moose that were predicted to have given birth based on blood and fecal hormone assays (Table 1; see section 2.3.2). Thus, we likely failed to observe either fetal or early-life neonatal mortality for 3 calves of moose predicted to be pregnant during early spring. Notably, all 3 of these moose were from the Rocky Mountain Front study area, where bear densities are relatively high but also where moose were generally younger (see section 2.3.4) and in poorer nutritional condition (see section 2.4).

**Table 1.** *Comparison of predicted parturition status for adult female moose with observed litters (i.e., calves-at-heel) for the same sample of moose suggests that 14% of cows pregnant (and still alive) during early spring may have incurred fetal or calf mortality before we were able to visually document presence of a calf.*

| | Observed litters | |
|---|---|---|
| Predicted status at time of parturition | Litter | No Litter |
| Pregnant | 19 | 3 |
| Not pregnant | 0 | 11 |

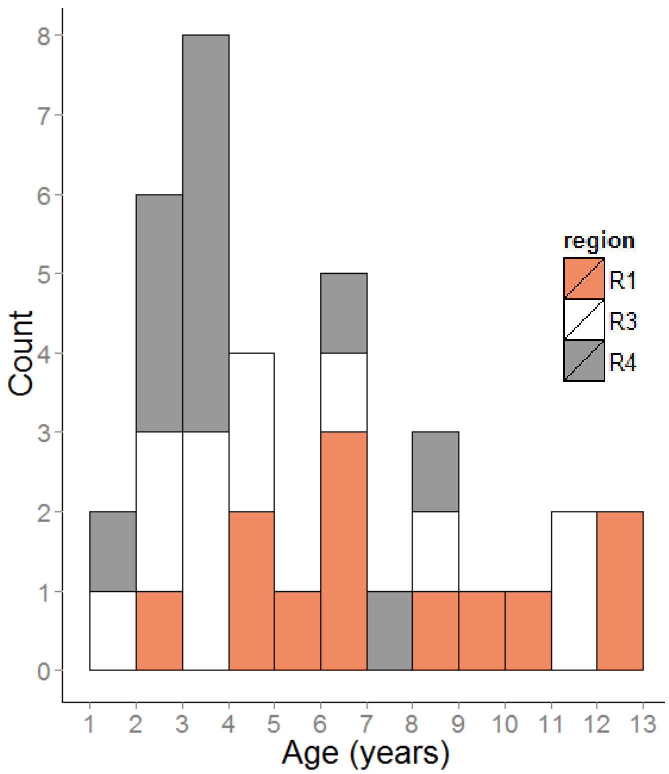
Of 20 calves observed and monitored since parturition, we have documented a preliminary tally of 2 additional mortalities. When combined with 3 predicted early mortalities (Table 1), these data result in a ***preliminary*** Kaplan-Meier pooled calf survival rate of 0.743 (SE=0.1058) during the first ~60 days of life (Figure 13). This value is subject to change pending further monitoring.

**Figure 12.** *Kaplan-Meier calf survival estimate during approximately the first 60 days of life. NOTE: this is using a preliminary data set subject to imperfect probabilities of detection. Values of both the number of animals at risk and dead will change with additional monitoring, which will alter these results substantially.*



However, we caution that because the probability of detecting calves-at-heel visually at each check is <100%, these calf survival data are preliminary and subject to change as additional repeated observations are collected for each litter.  Calves that are in fact alive may be unobservable and preliminarily recorded as dead, and calves that are either dead or alive may be of unknown status due to failure to visually locate the mother.  Thus these data are preliminary detection histories to be updated continually throughout monitoring of the first year of life.  As such, we refrain at this time from making any comparisons among study areas or relative to other published studies.

*2.3.4 Age composition*.— A single lower incisiform canine tooth was pulled from each captured moose for aging with cementum analysis.  Ages of captured female moose ranged from 1 to 12 years old.  While the overall average was 5.1 years old, there did appear to be regional mean differences (R1=7.0, R3=4.8, R4=3.6).  We are also still awaiting additional age results from teeth submitted by hunters after the 2012 season (expected in lateSeptember, 2013).



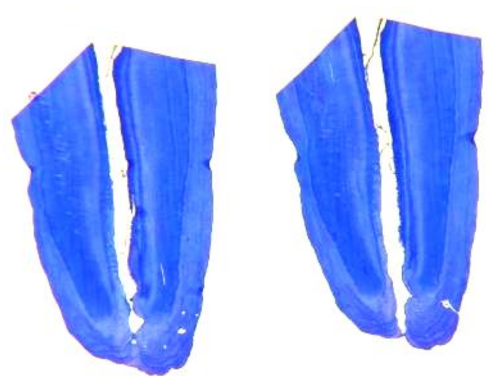



**Figure 13**.

***Above:*** *Moose tooth cross sections prepared by Matson's Lab (East Missoula, MT) and used for accurately aging each individual.*

***Left:*** *Age distribution of 36 female moose captured in February, 2013, from 1 to 12 years old, and colored according to study area.*

### 2.4. Nutritional condition and diet

*2.4.1. Nutritional condition*.— Nutritional condition of ungulates can impact both survival (Roffe et al. 2001, Bender et al. 2008) and fecundity (Testa and Adams 1998, Keech et al. 2000, Testa 2004), and generally provides an indication of the extent to which habitat condition may play a role in ungulate dynamics (Franzmann and Schwartz 1985, Bertram and Vivion 2002, Becker 2008). Assessment of nutritional condition across multiple study areas, potentially varying in local growth rates, will allow an initial depiction of habitat or forage quality as a potential limiting factor.

We used a portable ultrasound (Micromaxx, Sonosite, Inc., Bothell, WA) to measure rump fat thickness in live-captured moose. Rump fat thickness has been shown to have a strong linear relationship ($r^2$=0.96) with ingesta-free body fat (IFBF) in previous studies on moose (Stephenson et al. 1998). We measured rump fat thicknesses varying from 0–2.6cm, with some evidence of variation by study area (Figure 15), and by presence of calves-at-heel and winter pregnancy status (Figure 16).

**Figure 14.** *Variation in rump fat thickness and predicted ingesta-free body fat (IFBF) of 36 female moose captured by study area, 2013. Note: IFBF for moose with no measurable rump fat (y-axis=0) defaulted to the intercept prediction of 5.63% IFBF of Stephenson et al. (1998), though it is likely some may have been below this prediction.*

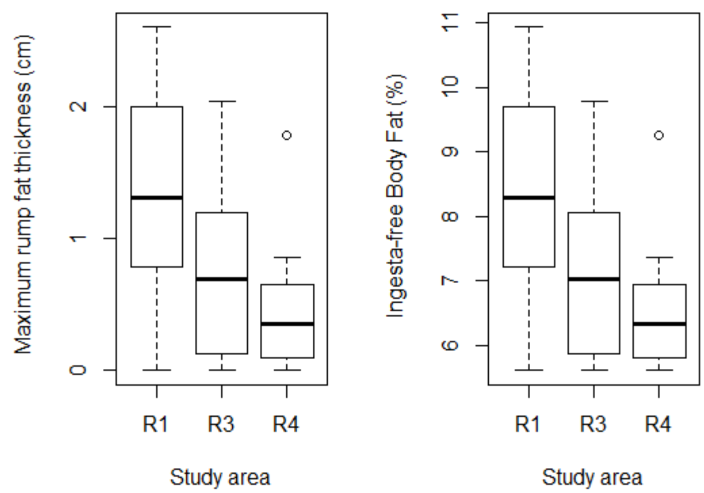
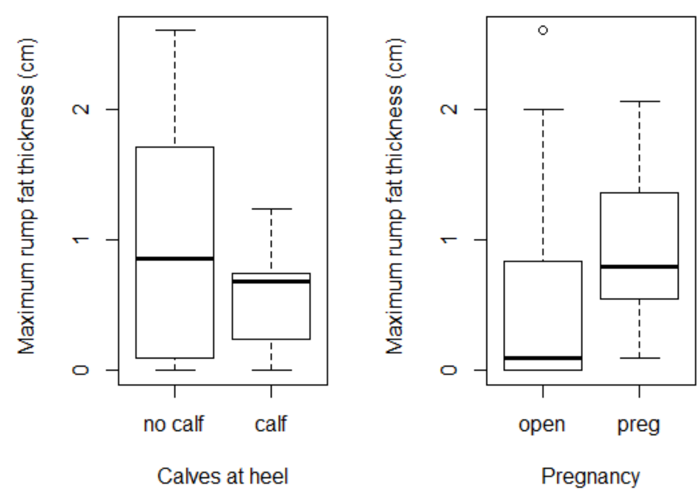



**Figure 15.** *Variation in rump fat thickness of 36 female moose according to those with and without calves at heel during February captures, and to February PSPB-based pregnancy status, 2013.*



*2.4.2. Diet*.— Estimation of diet composition across the study area will provide baseline information about potential variation in forage composition among study areas. Composites of fecal samples collected during 2 sessions across the winter season (February–April) have been submitted to the Wildlife Habitat and Nutrition Lab at Washington State University (Pullman, WA) for microhistological analysis of diet composition. Analyses of one composite sample per study area (further subdividing R4 study area according to moose in Pine Butte Swamp and Badger Creek) were submitted for species-level analyses with up to 200 microscopic views per sample. Similar sampling and analyses will be conducted for summer diet during the upcoming year.

We also collected blood samples for analysis of mineral concentrations in serum, including cobalt, copper, iron, manganese, molybdenum, selenium, and zinc. Copper has received some attention in past moose research after deficiencies were associated with decreased reproduction and faulty hoof keratinization (Flynn et al. 1977). Healthy reference ranges of most minerals are unclear for moose. Relative to reference concentrations for cattle, copper, iron, and zinc concentrations in captured moose were marginally below adequate levels, whereas selenium was noticeably deficient in Regions 1 and 3.

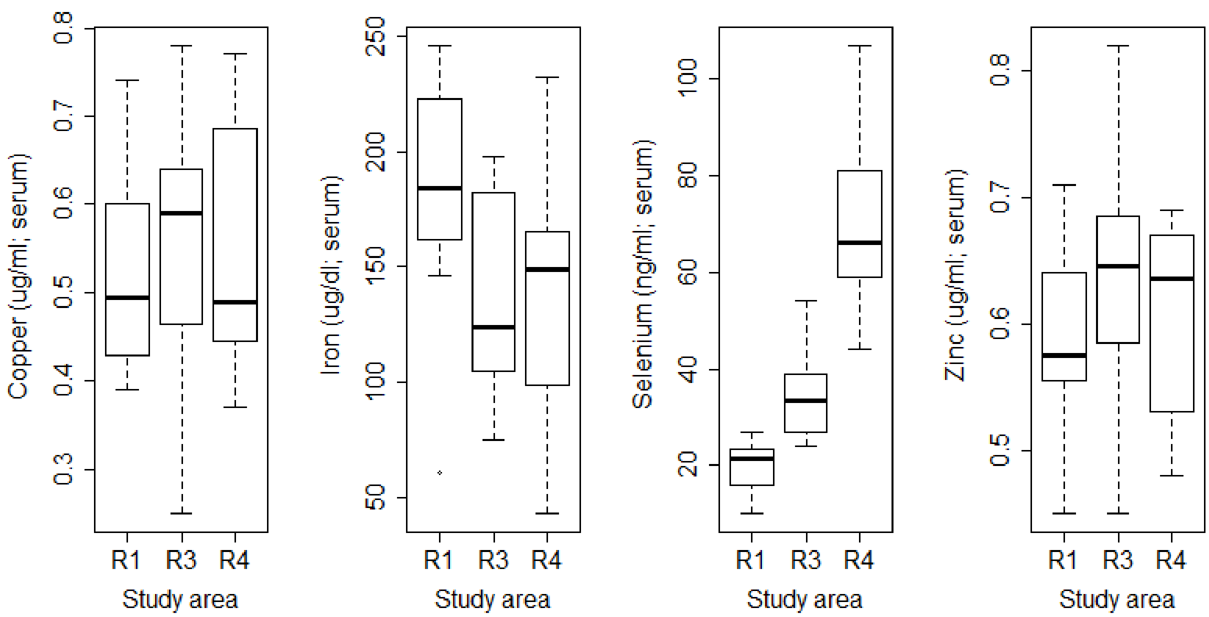



**Figure 16.** *Trace mineral concentrations in serum samples collected from 36 adult female moose captured at 3 study areas in February, 2013.*

### 2.5. Parasite and disease prevalence

Disease and parasite sampling provide valuable baseline information concerning the health and stressors of moose (and other ungulates) across the state, given reasons for concern about the effects of several parasites at the southern range extent (Samuel 2004, Murray et al. 2006, Henningsen et al. 2012).

We estimated a range of tick densities on captured moose from 0–0.5 ticks per $cm^2$, with apparent average differences among study areas (R1=0.058, R3=0.002, R4=0.201). Tick-induced hair loss is commonly experienced by moose during March–April when ticks reach their adult life form (Mooring and Samuel 1999), though some moose in R4 showed evidence of 10-60% hair loss in early February.

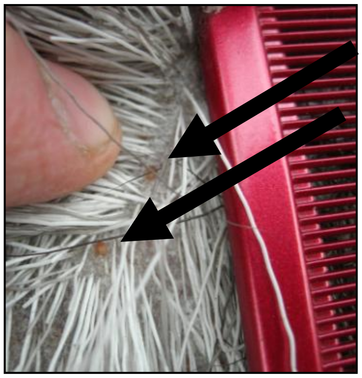


**Figure 17.** *We searched linear transects along the rump and shoulder to estimate the density of winter ticks within the coats of each moose. In February, ticks were still predominately in their nymph life stage. Some moose evidence of tick-induced hair loss of 10–60% of their February coats.*

In recent hunting seasons we have recruited moose hunters as collectors of data and samples across the statewide moose population. Of successful hunters, an estimated 56% (153 of 274) were gracious enough to provide data and/or samples from their hunt. In the 2012 season, this included 116 blood samples (of which 51 yielded serum of sufficient quality for serology), 48 liver samples for fluke screening, 11 heads for assessment of chronic wasting disease and *Elaeophora* spp. arterial worm specimens (Table 2).

**Table 2.** *Parasite and disease screening results from moose blood and head samples collected primarily by hunters during 3 of the past 4 seasons in addition to other opportunistic samples.*

| | 2009-10 | | 2010-11 | | 2012-13 | |
|---|---|---|---|---|---|---|
| | % Positive | *N* | % Positive | *N* | % Positive | *N* |
| Arterial worm (*Elaeophora schneideri*) | 36% | 73 | 10% | 21 | 27% | 22 |
| Chronic wasting disease | 0 | 74 | 0 | 18 | 0 | 18 |
| Evidence of extensive liver damage | - | - | - | - | 4% | 52 |
| **Serology** | | | | | | |
| Anaplasmosis (cf) | - | - | - | - | 45% | 53 |
| *Brucella abortus* | 0 | 114 | 0 | 51 | 0 | 55 |
| Bovine respiratory syncytial virus | 0 | 114 | 0 | 51 | 0 | 54 |
| Bovine viral diarrhea I | 0 | 114 | 0 | 51 | 0 | 55 |
| Bovine viral diarrhea II | 0 | 114 | 0 | 51 | 2% | 55 |
| Eastern equine encephalitis | - | - | - | - | 0 | 55 |
| Epizootic hemorrhagic disease | 1% | 114 | - | - | 0 | 55 |
| Infectious bovine rhinotracheitis | 0 | 114 | 0 | 51 | 0 | 54 |
| Leptospirosis (*L. canicola)* | - | - | - | - | 6% | 53 |
| Leptospirosis (*L. ictero)* | - | - | - | - | 9% | 54 |
| Leptospirosis (*L. grippo)* | - | - | - | - | 7% | 54 |
| Leptospirosis (*L. pomona)* | - | - | - | - | 5% | 55 |
| Leptospirosis (*L. hardjo)* | - | - | - | - | 2% | 54 |
| Parainfluenza-3 | 52% | 114 | 24% | 51 | 44% | 55 |

## 2.6. Temperature, heat stress, and snow conditions

Climate and weather conditions can directly and indirectly influence moose populations (Karns 2007, Van Ballenberghe and Ballard 2007). Climatic patterns determining the timing of spring green up, summer precipitation and winter snow conditions can influence survival and recruitment indirectly through effects on forage availability and quality (Van Ballenberghe and Ballard 2007, Brown 2011). Direct effects of climate on moose can be seen in their metabolic response to temperatures and the energetic costs of traveling through deep snow.

Moose are well adapted to cold temperatures, but they have been shown to become heat stressed at temperatures > -5.1 Celsius in winter, and >14 Celsius in summer (Renecker and Hudson 1986). Moose have been shown to modify their movements and habitat use at temperatures above these thresholds and recent research suggests reduced adult female survival is associated with increased temperatures (Murray et al. 2006, Lenarz et al. 2009, Broders et al. 2012). However, in other studies temperature has not played a significant role (Lowe et al. 2010, Murray et al. 2012).

We will assess the influence of climate and weather on moose survival, recruitment and body condition by simultaneously monitoring climate and weather variables within and between study areas. We will monitor spatio-temporal variation in ambient temperature using fine scale (30 m) daily estimates from spatial climate models developed by the University of Montana Climate Office (Holden et al. 2011). To test the accuracy and resolution of these models (*sensu* Brennan et al. 2013), we will validate model estimates by deploying 33 field-deployed temperature data loggers (Thermochrom ibuttons, DS1921G-F5; Dallas Maxim Corporation, Dalas, Texas) in each study area between August 2013-August 2015. Data-loggers deployed over this time will allow validation of models across seasonal and annual variations and help calibrate interpolated estimates appropriately to the moose study populations. Calibrated model estimates will be used to test the potential effects of climactic factors on moose vital rates (Table 2.6X).

Sites for 28 data-loggers have been determined within each study area at ≥1000 m intervals along elevational gradients spanning areas typical of winter and summer ranges. Final site placement will be determined on the ground so as to locate sites >100 m from roads and in cover typically used by moose. Sensors will be housed in custom radiation shields following Holden et al. (2013) and placed on North side of tree/shrub at 2 m height (Holden et al. 2011). To assess effects of vegetation canopy on ambient temperature, an additional 9 data-loggers will be deployed in open areas adjacent to established sites at a range of elevations. In addition, we deployed a single data-logger at a weather station located within or near each study area. Data-loggers are ready for deployment to their pre-determined sites and deployment will proceed once an adequate number of radiation shields are available.

Snow depth and density can influence energetic costs of travel, mobility, habitat use, and ultimately demography (Vucetich and Peterson 2004, Keech et al. 2011). We will use interpolated estimates of snow characteristics (snow depth, snow water equivalent, snowfall) from 1 km resolution SNODAS data (National Operational Hydrological Remote Sensing Center) to characterize snow conditions in the study areas. Snow variables will be examined to assess their potential influence on moose survival, recruitment and condition (Table 3).

We will also monitor snow conditions at temperature monitoring sites described above to refine estimates from SNODAS data. Snow measurements will be taken at 3 fixed locations surrounding each data-logger station monthly during the winter. Measurements will include snow depth, SWE and penetrability. Penetrability will be measured using a spring-loaded snow penetrometer which measures the depth of snow penetrated with incremental amounts of pressure (Matchett 1985). A penetrometer has been constructed and sampling is scheduled to begin winter of 2013/2014 and end winter of 2014/2015.

Penetrability may vary greatly within 24 hours, thus we will primarily focus on snow depth and temperature. However, we will record penetrability over the course of the winter to capture any interactions between depth, temperature and penetrability in characterizing snow parameters relevant to moose (Kelsall 1969).

**Table 3**. *Hypothesized influences of climate and weather on moose vital rates and condition. Table includes climatic variables to be measured along with the vital rate and/or condition index predicted to be affected. Note this table does not include possible time lags in the influence of weather on vital rates*.

| Potential Climate Effect | Response Variable | Explanatory Variable | Reference |
|---|---|---|---|
| Winter heat stress | Survival through spring green up, calving, late winter condition | $\sum$ degrees > -5C from all daily max temps Jan-Feb | Lenarz 2009, Murray et al. 2006 |
| Spring heat stress | Survival through spring green up, calving | $\sum$ degrees > 8C from all daily max temps Mar-April | Broders et al 2012 |
| Summer heat stress | Annual Survival, pregnancy/calving, late winter condition | $\sum$ degrees > 20C from all daily max temps Jul-Aug | Lenarz 2009, Murray et al. 2006 |
| Nutritional and energetic stresses from heavy snow | Survival through spring green up, calving, late winter condition | Mean Snow Water Equivalence Dec-April | |
| Energetic cost of deep snow | Survival through spring green up, calving, late winter condition | Mean penetration depth at $2000 g/cm^2$ Dec-April[1] | Matchett 1985 |
| Nutritional and energetic stresses from crusted snow | Survival through spring green up, calving, late winter condition | Days snow crusted (measurement of crust in $grams/cm^2$ until penetrated) Dec-April.[1] | |
| Summer precipitation improving nutritional condition | Annual Survival, pregnancy/calving, early winter condition | Total precipitation (cm) May-Aug | |
| Early onset growing season improving condition | Annual Survival, pregnancy/calving, early winter condition | Julian day (post-March) mean temp >5C for 5 days or more | Brown 2011 |
| Severe winter temps reduce overwinter calf survival | Winter Calf Survival through April | $\sum$ degrees < -30C from all daily min temps Jan-Feb | |

[1] Snow penetration may be estimated more efficiently from models based on air temperature and snow depth than direct measurements.

## **Objective #3:** *Initiate an effectiveness evaluation of current moose monitoring methods*

### 3.1. Assessing correlation among available population indices

*3.1.1 Aerial surveys*

Intensive aerial surveys are generally considered the preferred means of estimating moose abundance and recruitment over large areas (Timmermann and Buss 2007, Boyce et al. 2012). However, the accuracy and precision of estimates vary with moose densities, timing of surveys, weather, snow conditions, vegetation, terrain, personnel conducting surveys, and type of aircraft (Timmermann 1993). While these issues are well known and discussed in the literature, a persistent difficulty with aerial surveys is the expense of conducting them. The difficulties and costs of aerial surveying moose have limited its use in Montana.

We are currently in the process of compiling aerial survey data. Thus far, aerial survey data are available for 14 hunt districts in Regions 1-4 of Montana. The number of years surveys have been conducted in these areas varies from 1 to 26 years. For districts and years covered, aerial surveys provide counts of moose observed as well as age class composition (see section 1.3 above). We will assess the effectiveness of these aerial surveys to monitor population trend and recruitment, for areas they have been conducted regularly, and compare results to other population indices.

*3.1.2 Harvest records*

The most consistently collected data available to monitor moose populations comes from harvest data. Though potentially less precise than more intensive aerial survey methods, hunter statistics could provide a cost-effective means for monitoring moose population trend (Boyce et al. 2012).

Hunt records provide a variety of data for all hunt districts in Montana which could inform moose population indices. Available statewide data include:

| | |
|---|---|
| Number of permits offered | 1945-present |
| Number of total moose harvested | 1945-present |
| Number of bulls, cows & calves harvested | 1971-present |
| Number of hunters | 1970-present |
| Number of days hunted | 1986-present |

For each district these data provide baseline estimates for success rates for permits offered (Fig. 2), hunter success rates, hunter effort (Fig. 3) and kills per unit effort (KPUE; Fig. 3). These statistics are thought to provide an index of population dynamics of the underlying moose population (Bowyer et al. 1999b, Boyce et al. 2012). We will compare these statistics to data from other sources (eg. hunter/landowner sightings, aerial surveys) to assess their reliability for monitoring trends in Montana’s moose population. Compilation of these various forms of data is currently ongoing.

Once data compilation is complete, we will use linear regression to assess the relationship between hunter harvest indices and moose demography and abundance data from other sources.

### *3.1.3 Age at harvest and population reconstruction*

In addition to harvest statistics, ages of harvested moose have been estimated using wear patterns or cementum annuli counts in some areas of the state. We are currently compiling these age data from around the state to assess its ability to supply demographic information on moose (Table 4). We are exploring the use of statistical population reconstruction, and similar integrated population models, to capitalize upon the potential information nested within age at harvest data. When coupled with auxiliary data (e.g., survival data, population estimates, harvest rates, hunt effort) age at harvest data could inform estimates of population age structure, abundance and trend over time (Gove et al. 2002). An additional advantage to maximum likelihood based statistical population reconstruction is the ability to quantify the uncertainty in estimates based on different sources of data (Clawson et al. 2013). If these models prove effective they may allow us to integrate disparate sources of moose population data in a rigorous and unified manner.

**Table 4.** *Available age at harvest data for moose in Montana, including years and areas samples were collected. Age estimates were made using various methods over different time periods and areas. Cementum annuli estimates are the most accurate means of estimating age and supply fine resolution information on age at harvest distributions. Estimates based on tooth eruption patterns and wear may allow individuals to be classified into broad age classes. Statistical population reconstruction is robust to pooling age classes and could still potentially be useful in estimating demographic characteristics with broad age classes (Skalski et al. 2012).*

| Years | Area | Method of Aging | N |
|---|---|---|---|
| 1975-1989 | Region 1 | Wear | 1542 |
| 1990-2008 | Region 1 | Annuli | 1639 |
| 1987-1995 | CSKT Harvest (primarily region 1) | Hunter estimated | 469 |
| 1977 | Region 3 | Annuli | 46 |
| 1980-1990 | Big Hole | Wear | 112 |
| 1988-2006 | Ennis/Gallatin | Wear | 175 |
| 1995-1996 | Gallatin | Annuli | 32 |
| 2012 - | Statewide | Annuli | 120 |

While past efforts to collect teeth for cementum annuli counts have been limited, in 2012 we initiated statewide sampling of harvested moose teeth. This sampling is conducted through voluntary submission by hunters and resulted in submission of 120 useable incisors for aging from across the state (Table 4). We are continuing this sampling by sending sampling kits to all hunters with moose permits.

*3.1.4 Confederated Salish & Kootenai tribes off-reservation harvest*

The Confederated Salish and Kootenai Tribes (CSKT) of the Flathead Indian Reservation have the right to hunt moose on "open and unclaimed land" as stated in the 1855 Hellgate Treaty. CSKT provides records of harvest including harvest location, total number of moose harvested by tribal members (1986-present), proportion of females in harvest (1986-present) and hunter success rate (1986-2008). The applicability of these statistics for monitoring moose population will be assessed along with other indices.

It should be noted that the spatial distribution of off-reservation tribal harvest changed over time; with harvest predominately occurring in Region 1 prior to 1994 and expanding into Region 2 after this time. It will be necessary to account for these changes in harvest patterns when calibrating this CSKT harvest to other indices. In addition, estimations of success rate for CSKT members hunting moose must be used cautiously because many members do not actively hunt moose, but take them as opportunity provides.

Since the mid-1990's there has been a significant decline in the number of moose harvested by CSKT members equal to approximately 3.2 less moose/year (Fig 18). Success rates of tribal members actively and passively hunting moose also declined from approximately 12% to 2–4% during 1997–2008 (Fig. 18).

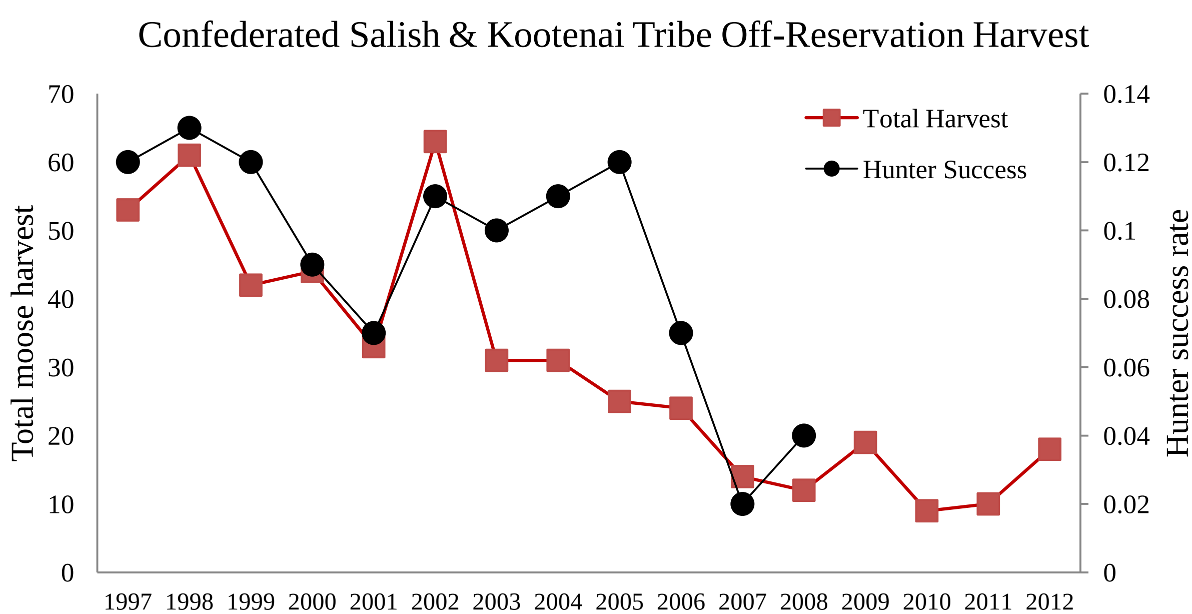



*Figure 18. Total number of moose harvested statewide by CSKT members (1997-2012) and hunter success rate (1997-2008). Hunter success rate is based on proportion of tribal members holding a moose permit that harvested a moose.*

### *3.1.5 Hunter surveys*

In 2012 we began surveying moose hunters to collect information on the number of moose they observed while hunting. Phone surveys were conducted to contact all individuals with a moose permit for that year (response rate for 2012 hunting season = 87%). Coincident with this survey effort, data cards were sent out to each permit holder to encourage them to return information on the number of moose they observed (response rate = 40.6%). Both survey techniques inquire from hunters the number of moose seen in separate age/sex classes (ie. Adult males, adult females, calves, and unknowns) and the general area they were observed. Previous research indicates the number of moose observed by moose hunters correlates well with independent measures of moose density (Solberg and Sæther 1999). In addition, observations of calves and cows by hunters have been found to be correlated with recruitment estimates based on radio-telemetery (Ericsson and Wallin 1999).

Moose hunter surveys are being continued and their effectiveness as an index of moose population dynamics will be assessed through comparison with other population indices and telemetry based research. Once calibrated to account for such factors as spatial variation in moose density and sightablity, these surveys may provide a cost effective means to estimate population trend and recruitment.

In addition to moose hunter surveys, moose sighting surveys have also been initiated with deer and elk hunters. One means of collecting moose observations from deer and elk hunters is at hunter check stations. In Region 1 check station surveys have been conducted since 2010. These provide information on the moose observed in different age/sex classes, along with number of days hunted and check station location.

Beginning in 2012 moose sightings have been included in annual post-season deer and elk hunter phone surveys. These provide information on total number of moose seen, number of days hunted, when sightings occurred, and the general location. Using deer and elk hunter sightings is an especially promising approach to developing a moose population monitoring tool. In part this is because of the large number of potential observations and the extensive area which can be sampled with relatively little expense. For example, phone surveys of deer and elk hunters for the 2012 hunting season provided 6,856 observations of moose from across Montana. Observation rates from these sightings may be indicative of population trends (Ericsson and Wallin 1999). However these observations, along with the spatial and temporal attributes of sightings, may be more effective in a patch occupancy modeling framework. Currently we are pursuing the use of survey data in patch occupancy models following a similar approach used to assess wolf (*Canis lupus*) populations in Montana (Rich et al. 2013).

## 3.2. Sampling statewide genetic population structure

An assessment of moose population genetic structure in Montana is lacking, yet may have implications for designating population units for future management and monitoring. Assessment of genetic variation in Montana's moose may also have implications for taxonomy of subspecies. Moose within Montana and the rest of the US Rocky Mountains have historically been classified as Shiras moose (*A. a. shirasi*), a subspecies whose range is believed to extend northward into a zone of intergradation with the northwestern subspecies (*A. a. andersoni*) in

Alberta and British Columbia (Peterson 1952). While mitochondrial haplotypes have generally upheld some level of differentiation between Shiras moose in Colorado and representative samples from other subspecies (Hundertmark et al. 2003), such methods have not been applied to evaluate moose in Montana. Particular interest in subspecies distinctions has arisen recently with anecdotal evidence of immigration of moose into north-central and -eastern Montana from expanding populations in southern Alberta and Saskatchewan.

The initial sampling of moose tissue through statewide hunter harvest is an important first step towards addressing this information gap. During the 2012 hunting season, we sent mailings to all moose permit-holders in an effort to recruit hunters as collectors of data and samples across the statewide moose population. Of an estimated 274 of hunters that harvested a moose in 2012, 136 were able to send tissue samples for genetics analyses. Combined with 36 blood samples from live-captured moose and 25 additional opportunistic samples, we collected a total of 197 genetic samples statewide during 2012-13 (Figure 18). We will collect additional samples during the 2013-14 season and laboratory analyses may begin during this upcoming year as well.

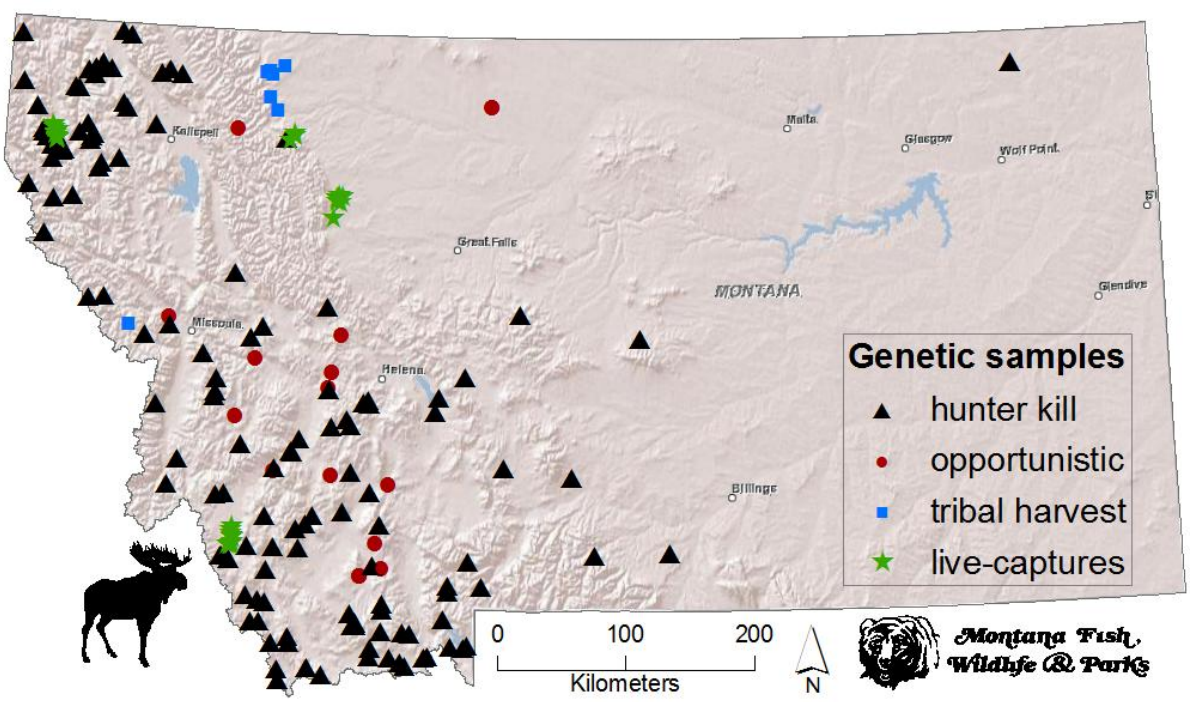



**Figure 19.** *Locations of 197 moose tissue or whole blood genetic samples collected across the state for delineating population structure and connectivity and with potential implications for understanding subspecies range boundaries.*

## Deliverables

1. A manuscript summarizing the status and management of moose in Montana to date (i.e., Objective #1 above) was submitted to the peer-reviewed journal, *Alces*, during the grant period (14 June 2013).

2. This Annual Report, dated 6 September, 2013, details preliminary results of this multi-year research program

## Acknowledgements

We are particularly thankful to many private landowners and area residents who graciously allowed us to conduct captures and ground telemetry monitoring on their properties. They also have provided much logistical support and local knowledge about moose distributions and local flora. We are very grateful for the privilege to work on these properties and for all the help.

This project is a large collaboration among many FWP biologists. These 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, 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, and Allison Kolbe.

Many thanks go to the pilots who have safely conducted capture and telemetry work thus far, including Rick Geiger, Ken Justus, Jim-Bob Pierce, Joe Rahn, Rick Swisher, Guy Terrill, and Trever Throop.

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