MOOSE STATUS AND MANAGEMENT IN MONTANA

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ABSTRACT: Moose (*Alces alces*) are currently widespread across Montana where regulated moose hunting has occurred since 1872, >140 years ago. The number of annual moose hunting permits has averaged 652 over the past 50 years. The popular permits are allocated via a random drawing, with an annual average of ~23,000 applicants in 2008–2012 who faced a 1.9% chance of success. Monitoring of moose largely occurs through annual harvest statistics collected via post-season phone surveys. Recent harvest statistics indicate lower hunter success, increased effort, and lower kill per unit effort, concurrent with >50% reduction in available permits since the 1990s. Aerial surveys also show decline in calf:adult ratios. In combination, these data suggest a declining trend in the statewide population, despite some ambiguity of certain data. Potential limiting factors include harvest, predation, vegetative succession and degradation, parasites, and climatic conditions, which were all identified as concerns in surveys of state biologists. Accordingly, Montana Fish, Wildlife and Parks will direct funds derived from moose permit auctions toward calibrating and refining statewide monitoring methods and research of population dynamics and potential limiting factors of Montana moose.

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Moose (*Alces alces*) colonized North America roughly 14,000 years ago and have since occupied much of Alaska, Canada, and northern portions of the contiguous United States (Hundertmark et al. 2002, Hundertmark and Bowyer 2004). Considered rare throughout the U.S. Rocky Mountains until the mid-1800s (Karns 2007), their earlier presence in several regions of Montana were documented by the Lewis and Clark expedition in 1805–1806, Alexander Ross in 1824, and others (reviewed by Schladweiler 1974). Widespread prevalence of moose in Montana during early settlement is supported to some extent by a review of place names throughout the state, including at least 22 creeks and 6 lakes bearing "moose" in their names (Schladweiler 1974).

Regulation of moose hunting in Montana began in 1872, yet after subsequent decline brought near extirpation, hunting was closed statewide for almost 50 years from 1897–1945 (Stevens 1971). In 1910, the state warden estimated a rebounding population of 300 moose as the result of "ten years of careful protection" (State of Montana 1910). Allowable harvest began again in 1945 with 90 permits issued. Subsequently, annual permit numbers rose quickly to a maximum of 836 in 1962, and thereafter averaged 652 until 2012 (Fig. 1a). The limited number of permits have been allocated via a random drawing process. In 2008–2012, an average of ~23,000 hunters applied annually for <600 permits, with a 1.9% chance of success. Beginning in 1988, one

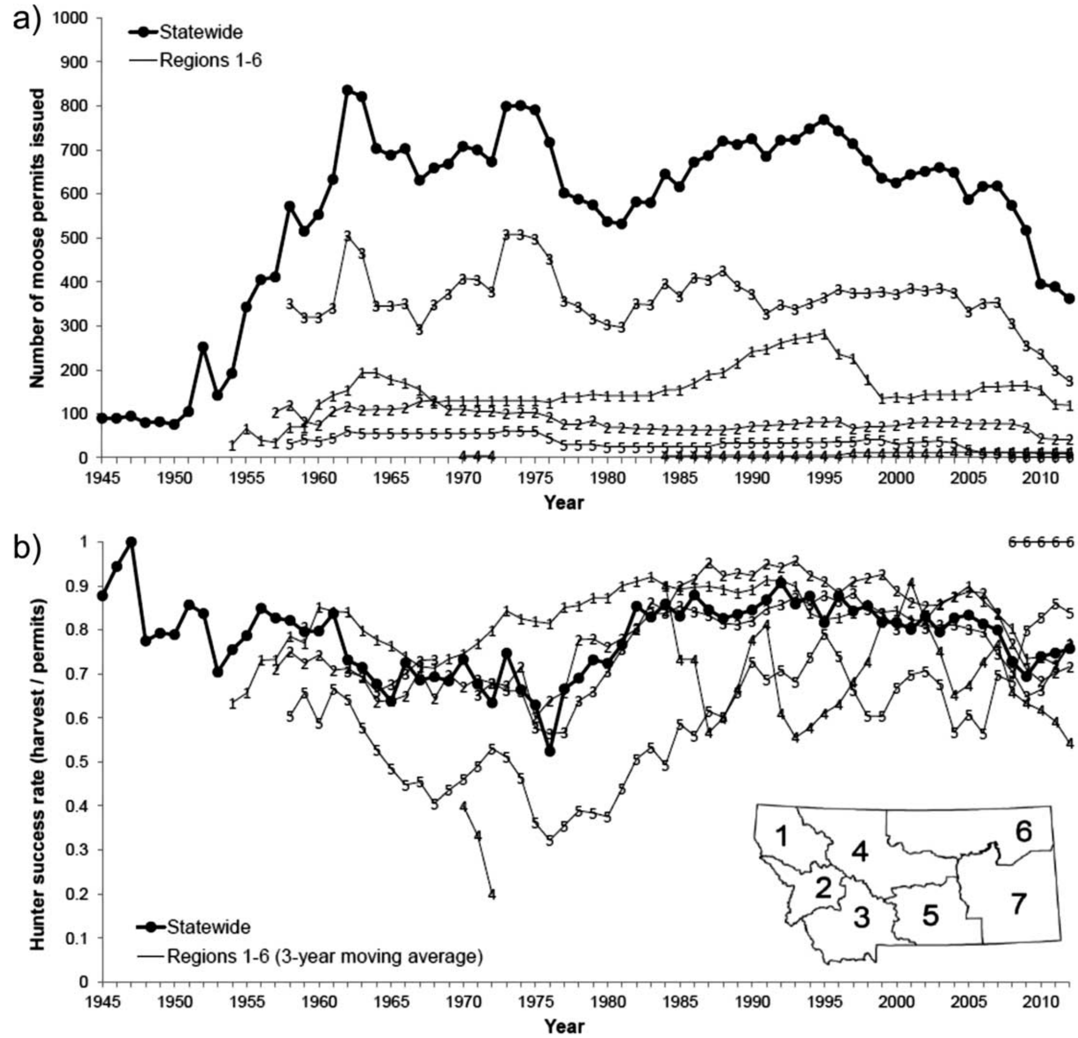

Fig. 1. Statewide and regional trends of a) number of permits issued and b) hunter success rates (number harvested/number of permits issued) for moose in Montana, 1945–2012.

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.

Moose in Montana typically occur at relatively low density and are vastly outnumbered by seasonally sympatric elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*O. hemionus*) populations. Relative ungulate densities are reflected in their harvest level; in 2012 hunters harvested ~274 moose versus >20,000 elk, 37,000 mule deer, and 49,000 white-tailed deer. Rigorous statewide abundance estimates of moose are lacking, but based on professional opinion among regional management biologists in 2006, the estimated statewide population was 4,500–5,500, albeit without estimable accuracy or precision

(Smucker et al. 2011). Moose are distributed widely across western portions of the state, with lower density extending to the east, as reflected by the current distribution of allowable harvest (Fig. 2). The majority of annual permits are offered in the southwest (56% in Region 3) and northwest (25% in Region 1). In recent decades moose have continued to colonize, or re-colonize, portions of central and eastern Montana allowing for added harvest opportunity.

Moose occupy forested landscapes throughout western Montana ranging from regenerating areas within dense mesic forest, such as the Cabinet Mountains in the northwest, to areas with extensive willow fen habitat, as found within the Centennial and Big Hole Valleys in the southwest. Moose in the prairie landscapes of the east inhabit wetlands, particularly along the Missouri river, other riparian corridors, and areas supporting healthy willow communities.

TAXONOMY

Moose within the Rocky Mountains of the United States have historically been classified as Shiras moose (*A. a. shirasi*). The subspecies was first described in Wyoming (Nelson 1914), and subsequent morphological sampling by Peterson (1952) suggested its range to extend northward through Montana and into a zone of intergradation with the northwestern subspecies (*A. a. andersoni*) in western Alberta and eastern British Columbia. While genetic evaluation of subspecies designations using mitochondrial haplotypes 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 in northern and northeastern Montana from expanding populations in southern Alberta and Saskatchewan. For example, the Boone and Crockett Club has traditionally used the Canadian border to distinguish Shiras from "Canada" moose (a designation that essentially lumps northwestern and eastern [*A. a. americana*] subspecies into a

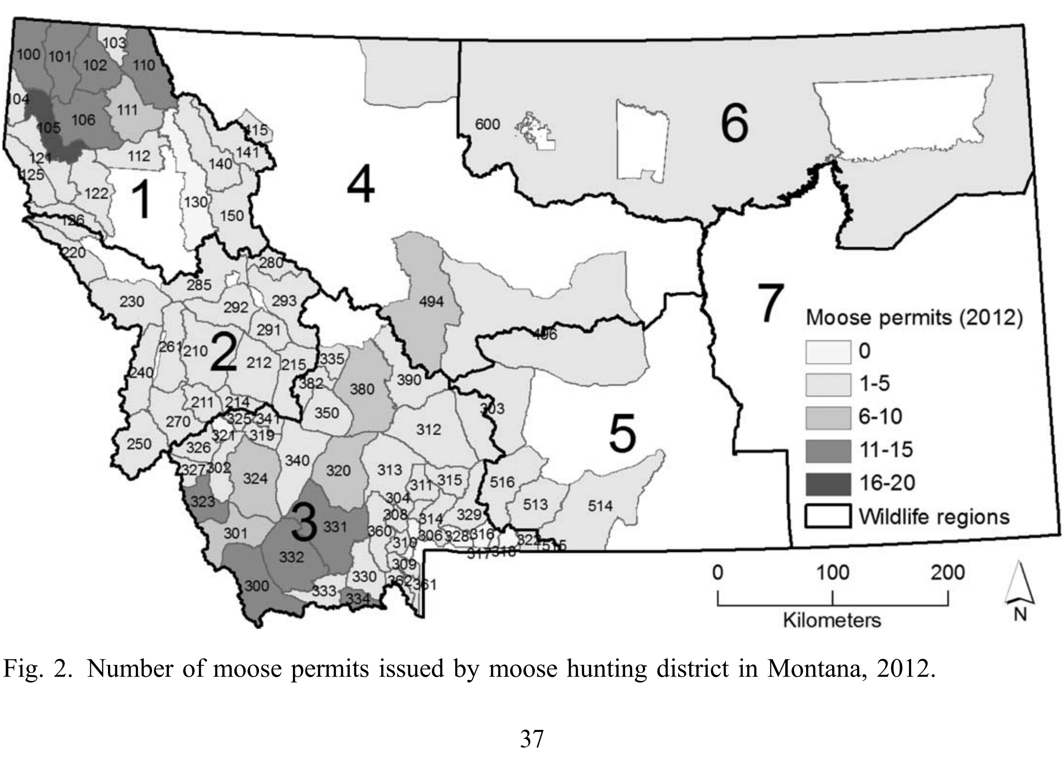

Fig. 2. Number of moose permits issued by moose hunting district in Montana, 2012.

single category) in scoring and record keeping of trophy animals. The advent of hunting in northeastern Montana's hunting district 600 has prompted informal discussion of classifying moose harvested within northern Montana and east of interstate highway I-15 as Canada moose, though none have been submitted for scoring to date (personal communication, J. Spring, Boone and Crockett Club, Missoula, Montana). Further sampling and analysis of population genetic structure of moose within and surrounding Montana may be needed to evaluate and update the subspecies range extents in the region.

MONITORING METHODS AND DATA

Resources have been limited for monitoring moose given their relatively low abundance and hunting opportunity compared to other Montana ungulates. Post-season surveys of permit holders have been used to estimate wildlife harvest since 1941 (Cada 1983, Lukacs et al. 2011), and in recent years phone surveys are used to collect annual harvest data. Montana Fish, Wildlife & Parks (MFWP) attempts to survey every permit holder to measure hunter success and effort, and adjusts harvest estimates according to annual hunter responses and rates. During 2005–2012, surveys yielded hunter response rates of 81–96% and statewide harvest estimates with coefficients of variation of 0.6–2.3%. These are the most consistent monitoring data through time and across the state, and are estimated distinctly for each district and permit type. Though potentially less precise than more intensive aerial survey methods, hunter statistics provide a cost-effective means for monitoring moose population trend (Boyce et al. 2012). 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).

Beyond harvest statistics, MFWP biologists in most regions have made at least intermittent efforts to conduct aerial surveys, but sustained survey efforts are limited to the few areas with historically higher density. In the northwest (Region 1), December helicopter surveys have been conducted annually since 1985 in a subset of moose hunting districts centered around the Cabinet, Purcell, Salish, and Whitefish Mountains. Moose in this densely forested region selectively use and are more visible in regenerating (15–30 years old) stands during early winter, but move into mature, closed-canopy forest as winter progresses (Matchett 1985). While an explicit model with sightability covariates has not been developed for the area, an early 1990s mark-resight study with 81 neck-banded individuals produced average 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 calf:adult ratios and uncorrected minimum counts, and their timing (September–May) has varied considerably by year and district. Sporadic helicopter and fixed-wing aircraft surveys have occurred in other lower-density regions of the state including Regions 2, 4, and 5. The MFWP is currently exploring the utility and cost-effectiveness of standardizing and coordinating survey efforts.

The MFWP is also exploring the utility of cheaper monitoring methods including hunter sighting surveys at voluntary hunter check stations, and post-season phone surveys used to measure deer and elk harvests. While both the observation rate and age ratios collected from hunter sightings can be indicative of population trends (Ericsson and Wallin 1999, Bontaities et al. 2000), there is potential to incorporate spatial and temporal attributes of sightings data into a patch occupancy modeling framework similar to recent efforts with hunter sightings of wolves (*Canis lupus*; Rich et al. 2013). Additionally, the MFWP is exploring the cost-effectiveness of estimating population trends using the fates and reproductive status of marked individuals (*sensu* Lukacs et al. 2009) which can be integrated into population models that estimate annual growth rate (DeCesare et al. 2012).

MOOSE HARVEST STATISTICS AND TREND

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% (769 to 362) between 1995 and 2012 (Fig. 1a). Most reductions were in areas with traditionally the most available permits (Regions 1 and 3). In contrast, the first 2 permits ever offered in northeastern Montana (Region 6) were added in 2008. Notably, the 2010 hunting season was the first in more than 50 years when the number of statewide permits was <500 (Fig. 1a).

Statewide hunter success is estimated as the number of moose harvested relative to the number of permits issued, averaging 78.4% during regulated moose hunting in Montana (1945–2012; Fig. 1b). This success rate is similar to that in adjacent Idaho (61–85%; Toweill and Vecellio 2004), but relatively higher than in 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). From 2008–2012, success rates (average = 73.4%) were lower than the previous 20-year average (83.7%; $t = 2.07$, 23 df, $P < 0.001$). Additionally, hunter effort, defined as the number of days spent hunting moose per hunter, increased from 6.3 in 1986 to ≥11 days/hunter in 2010–2012 (Fig. 3). Similarly, kill per unit effort (KPUE) that integrates hunter success and effort statistics into a metric of

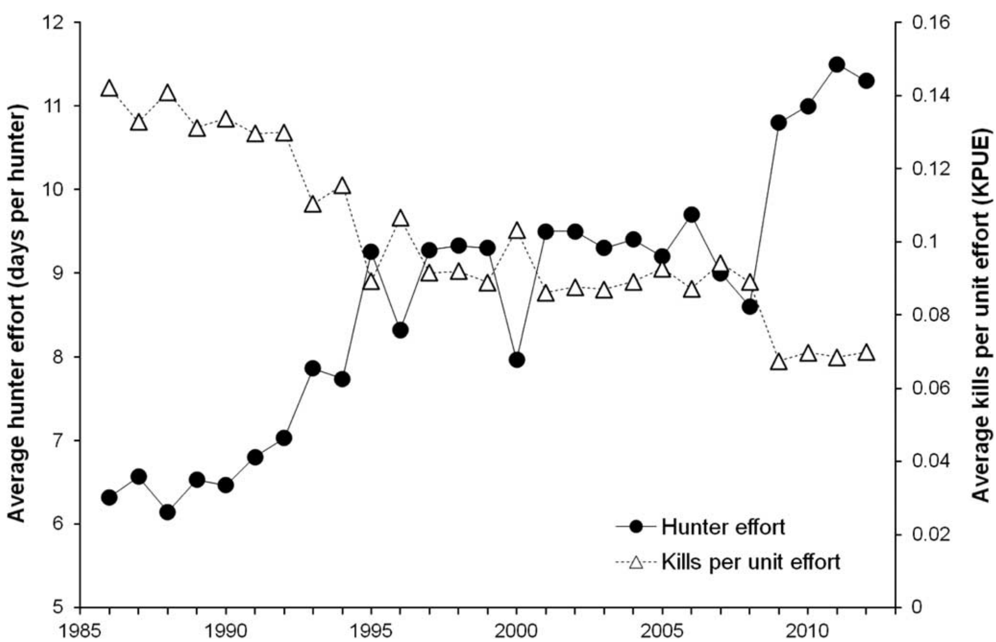

Fig. 3. Statewide annual averages of moose hunter effort (days per hunter) and moose kill per unit effort (KPUE) in Montana, 1986–2012.

hunter efficiency, declined >50% from >0.14 to <0.07 moose killed per hunter-day over the same time period (Fig. 3). The KPUE for antlered bull-specific tags also varied by hunting district level (Fig. 4), reflecting regional differences in moose distribution and ecotypes (e.g., more closed forests in the northwest compared to more open foothills and large riparian complexes in the southwest).

In combination, lower hunter success and KPUE, increased hunter effort, and a concurrent >50% reduction in available permits are indicative of a declining statewide population trend. In Ontario, years with fewer permits resulted in increased hunter success rate, even after accounting for changes in underlying moose density (Hunt 2013), which suggests that hunter behavior can complicate interpretation of hunter statistics (Bowyer et al. 1999, Schmidt et al. 2005). Change in permit type over space and time (e.g., shifting between antlered bull, antlerless, or either-sex permits) can also complicate or confound interpretation of hunter statistics. For example, recent (2008–2012) increases in KPUE also coincide with a prescribed reduction in the antlerless harvest that may reduce KPUE by limiting the proportion of animals hunters are allowed to harvest, regardless of underlying population dynamics. Thus, we cautiously interpret harvest statistics as imperfect indices. Concurrent declines in available permits, success rates, and KPUE may result from population decline and/or reflect other confounding factors.

In addition to statewide hunter statistics, regional calf:adult ratios in areas with consistent aerial survey data indicate decline in recruitment (Fig. 5). Three distinct survey areas show significant ($P < 0.05$) overall declines in ratios since 1980, though the temporal pattern of decline may be non-linear with subsequent stability at a lower level in recent years (Fig. 5). Low or declining recruitment is often associated with declining ungulate populations (e.g., DeCesare et al. 2012), so these data may be corroborative with harvest statistics that indicate a

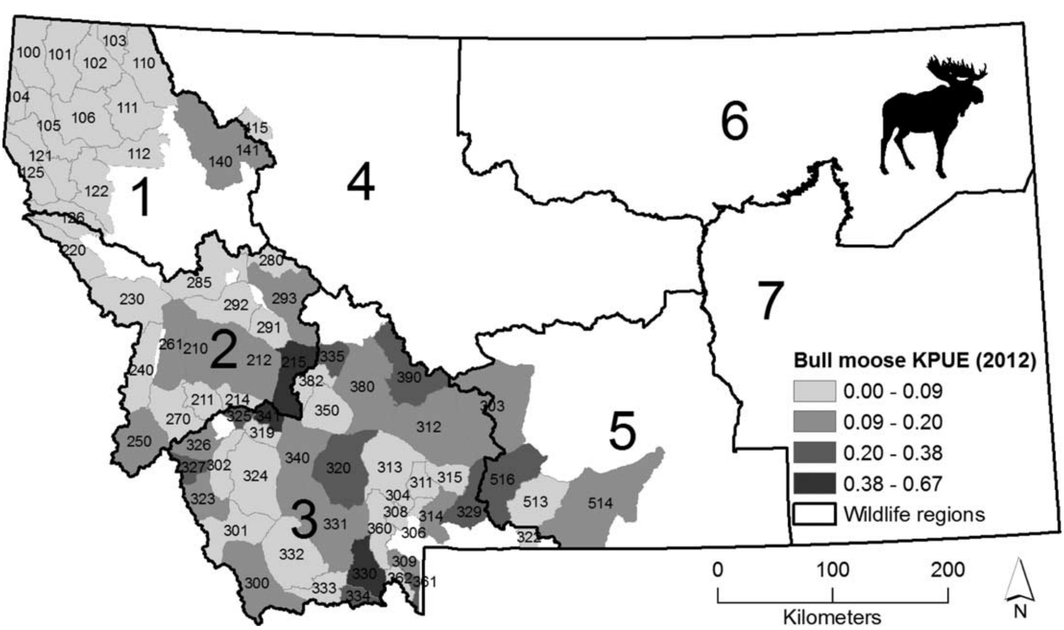

Fig. 4. Bull moose kills per unit effort (KPUE; effort recorded in days) per moose hunting district by hunters carrying antlered-bull-only permits in Montana, 2012.

declining moose population. However, declining recruitment may also reflect an ungulate population approaching carrying capacity (Gaillard et al. 1998, Eberhardt 2002), so this index also does not unambiguously indicate decline.

Biologist interviews: local trends and management

In 2010, we used structured interviews of 20 MFWP and cooperating agency biologists to assess the state of knowledge regarding moose population status, management, and factors of concern within Montana (Appendix A). A majority (63%) of responding biologists reported "decreasing" or "stable to decreasing" trends in their populations, with stable and increasing trends reported in some areas. These trend assessments are tempered, however, because only 10% of biologists had adequate data for making management decisions; 55 and 35% described their data as partially inadequate and inadequate, respectively. Lastly, when asked about factors that potentially limit local moose populations, biologist listed predation (70%), habitat succession (45%), MFWP-permitted hunter harvest (45%), parasites and/or disease (40%), Native American hunter harvest (30%), and habitat loss or fragmentation (15%).

POTENTIAL LIMITING FACTORS

Many factors may currently limit moose abundance and distribution including hunter harvest, predation, habitat succession, parasite and disease prevalence, and climatic conditions. The relative importance of these factors has likely changed over time. Overharvest may have been responsible for decline in moose numbers in the late 1800s (Stevens 1971). By the early 1970s, research

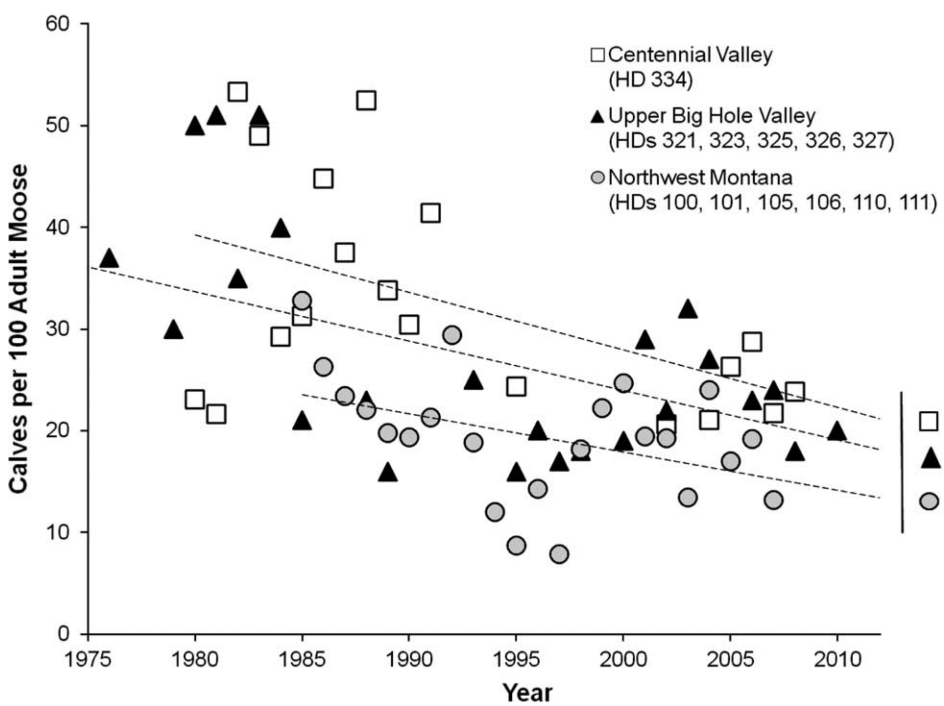

Fig. 5. Annual moose calves per 100 adult recruitment data and associated linear regression trend lines calculated from fixed-wing and helicopter late winter aerial surveys in 3 regions of Montana, 1976–2010.

in southwest Montana indicated that hunter harvest and nutritional inadequacies were the most important factors limiting moose populations, whereas parasites, disease, and predation had little direct effect on mortality rates (Schladweiler 1974). Presently there is a need to re-evaluate the relative importance of potential limiting factors in light of recent changes in many of these factors and subsequent monitoring and research in Montana and elsewhere.

Hunter harvest

The goals and objectives behind moose hunter harvest quotas vary somewhat across MFWP regional jurisdictions. Managers in Regions 1 and 3, where populations are largest, generally aim to sustainably maximize hunter opportunity and minimize landowner conflicts (e.g., greater numbers of permits that include either-sex or antlerless opportunities), whereas regions 2, 4, 5, and 6 manage harvest with less intent to affect moose population dynamics (e.g., bull-only hunting or low permit numbers). During the past 2 decades, numbers of antlerless permits were increased substantially in certain areas, particularly in Region 3, in response to depredation complaints, perceptions that moose were unfavorably limiting vegetative growth (i.e., riparian plants), and high moose counts on aerial surveys. These prescriptive increases in moose permits were intended to induce local declines in some hunting districts.

Statewide, the sex ratio of harvested adult moose (i.e., excluding calves) averaged 28% female in 1971–2008, but dropped to an average of 14% in 2009–2012; female harvest is through either-sex and antlerless-only permits. In Region 1, either-sex tags were issued historically, and harvest was typically skewed heavily towards males; the 1984–2004 harvest was 78% bulls, 19% cows, and 3% calves. As of 2012, all permits in this region were changed to antlered-bull only. In Region 3, permits have been typically specified as antlered- or antlerless-only, which is more restrictive to hunters but facilitates targeted management.

Additional moose harvest by members of the Confederated Salish and Kootenai Tribes (CSKT) is permitted off-reservation by the Hellgate Treaty of 1855. One permit per year is allowed to each interested Tribal member for hunting on primarily federal land, with mandatory reporting to CSKT officials. While the sample size of animals harvested is lower than that regulated by MFWP, these harvest data provide additional opportunity for indexing population trend and are without confounding changes in permit number and type. Trends in tribal harvest are similar to that of the MFWP (Fig. 6); total harvest peaked in 1991 at 97 representing an additional 16.3% to the MFWP harvest of 595, and in 2012 the Tribal harvest was only 18, an additional 6.6% to the MFWP harvest of 274 moose. We point out that interpretation of tribal harvest statistics with respect to the rate of population change is also not unambiguous. While some evidence exists of reduced success by tribal hunters (Fig. 6), a portion of the decline can probably be attributed to fewer permit requests. Also, these data do not include information about hunter effort or tribal interest in hunting other game species as allowed by treaty rights.

Illegal harvest of moose also occurs but has not been quantified to date. Data from Idaho suggest that illegal harvest can represent upwards of 31–50% of mortality (Pierce et al. 1985, Toweill and Vecellio 2004), warranting explicit monitoring and documentation of such in Montana.

Predation

After decades of predator control in the early and mid-1900s, and subsequent recovery efforts in the late 1900s, Montana currently hosts widespread populations of

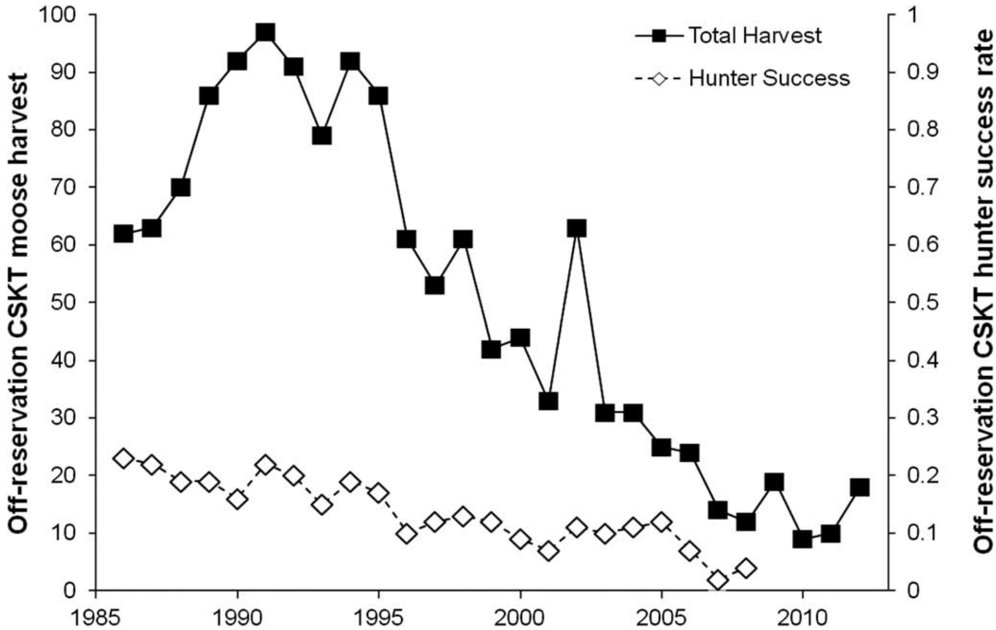

Fig. 6. Moose harvest and hunter success rates by members of the Confederated Salish and Kootenai Tribes (CSKT) off-reservation (primarily on federal lands in western Montana), 1986–2012.

grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), wolves, mountain lions (*Puma concolor*), and coyotes (*Canis latrans*). While predation was not considered a concern 40 years ago (Schladweiler 1974), the expanded composition and abundance of predator species may have the potential to limit local moose populations. Predation was the most common concern of regional biologists relative to moose population dynamics.

Research on winter prey selection by recolonizing wolves in the North Fork of the Flathead River drainage from 1986–1996 indicated that while wolves disproportionately used areas where deer were concentrated, they preferentially killed larger moose and elk over more abundant deer. Moose, particularly calves and cows, comprised a greater proportion of wolf kills as winter progressed (Kunkel et al. 2004). However, annual survival of 32 adult female moose monitored concurrently in the North Fork (1990–1992) was relatively high (0.9137 ± 0.0773; Langley 1993), with 3 mortalities attributable to predation (1 wolf and 2 grizzly bear). In a recent dietary study of 12 wolf packs in northwest Montana, moose was the most common prey item based on stable isotope analysis, constituting an average of 41% of the diet; however, these results were not supported by scat analysis from a sub-set of 4 packs in which moose averaged 18% of the diet (Derbridge et al. 2012).

High densities of elk and deer throughout much of the Rocky Mountain region may support higher predator populations and facilitate increased predation rates on sympatric moose via apparent competition (Holt 1977). In such cases, a less abundant, secondary prey species can become more vulnerable to depensatory predation when faced with predator populations boosted by more numerous primary prey species (Messier 1995, Garrott et al. 2009). While moose across much of Canada have been attributed with the role of a primary prey species driving predator-mediated declines in less abundant woodland caribou (*Rangifer tarandus caribou*) populations (DeCesare et al. 2010), they may in fact be vulnerable themselves to such a mechanism within the elk- and deer-dominated prey populations of Montana. The effects of apparent competition from increased predation risk may be reduced somewhat by differential selection of winter and calving habitat among ungulates. Moose in Montana typically use higher elevations during winter and may accordingly spatially separate themselves from increased predation risk in some cases (Jenkins and Wright 1988, Burcham et al. 2000, Kunkel and Pletscher 2001).

The ultimate effect of predators on prey dynamics varies according to predation rates on different age classes (Gervasi et al. 2011), as well as with differences in the nutritional quality of prey habitat (Melis et al. 2009). Because moose may have colonized many areas of western Montana when predators were largely reduced, it is uncertain to what extent recolonized and expanding predator populations pose an additive source of mortality on local populations. In such cases, management of moose populations may require that predation rates be accounted for when deriving sustainable harvest quotas (Hobbs et al. 2012).

Vegetative succession and degradation

Moose habitat requirements and preferences have been well documented (reviewed by Peek 2007, Shipley 2010). Moose in Montana use a variety of mid to high elevation forest types in summer, including closed canopy lodgepole pine (*Pinus contorta*) and subalpine fir (*Abies lasiocarpa*) forests, as well as aspen (*Populus tremuloids*) and willow (*Salix* spp.) stands, mountain parklands, and alpine meadows (Knowlton 1960, Peek 1962, Schladweiler 1974). During winter, they often forage on willow where available, and snow depth can either restrict local use and movement (Burkholder 2012) or shift use to conifer forests (Tyers 2003).

Many studies of Shiras moose in the Rocky Mountains have documented the importance of early successional habitats (Peek 2007). Large-extent wildfires in 1910, 1919, and 1929 converted much of the conifer forest in northwest Montana to early-seral stages and moose populations in the state appeared to increase in response (Brown 2006). While the positive association with early successional habitat following wildfires is well documented, negative impacts of the 1988 fires in Yellowstone National Park contradict this tenant (Tyers 2006; Vartanian et al. 2011). During the 1950s–1980s, timber harvest became the dominant form of disturbance shaping conifer forests in the West and was generally favorable to moose, particularly 10–30 years following harvest (Eastman 1974, Matchett 1985, Telfer 1995). It is believed that the high amount of timber harvest combined with fire history may have set the stage for abundant moose populations through the early 1990s (Brown 2006). A time-lagged decrease in early-seral forests has presumably resulted from reduced timber harvesting since the late 1980s (Spoelma et al. 2004).

Riparian areas have been severely degraded globally by a variety of stressors (Richardson et al. 2007), and in some parts of the western United States, cottonwood-willow riparian habitats have been reduced by as much as 90–95% (Johnson and Carothers 1982). Historically, persistent riparian habitat along rivers and streams may have provided long-term stability to moose populations and functioned as corridors to allow moose to expand into ephemeral post-fire habitats (Peek 2007). In many areas of Montana, habitat management has focused on restoration of riparian areas via fencing and grazing management with the goal of restoring robust willow communities.

Parasites

Moose are exposed to a suite of parasites with potential implications for population dynamics. Winter ticks (*Dermacentor albipictus*) are known to occur in moose range across much of North America south of 60° N latitude (Samuel 2004), and have been detected in disparate regions and vegetation types of Montana (N. DeCesare, unpublished data). While data are not available concerning the demographic impact of ticks on moose in Montana, negative effects of ticks on moose populations have been well documented elsewhere (Samuel 2007, Musante et al. 2010). Given that die-offs have been known to occur synchronously across various portions of moose range (DelGiudice et al. 1997), impacts of tick epizootics on moose in Montana seem likely.

Giant liver flukes (*Fascioloides magna*) were reported as the greatest single source of mortality for a declining moose population in northwest Minnesota (Murray et al. 2006, Lankester and Foreyt 2011). Such effects of flukes on moose mortality may be accentuated when individuals are malnourished (Lankester and Samuel 2007). Both *F. magna* and the common liver fluke (*F. hepatica*) have been documented widely within Montana's cattle populations (Knapp et al. 1992), and multiple species of lymnaid snails, the intermediate host, are also known to occur (Dunkel et al. 1996). Data concerning infection rates or impacts of flukes on moose or other wild ungulates in Montana are lacking.

Also of concern in Minnesota and elsewhere in eastern North American is the meningial worm (*Parelaphostrongylus tenuis*). Prevalent in central and eastern moose populations, this parasite is carried by white-tailed deer, transmitted by terrestrial gastropod intermediate hosts, and is commonly associated with moose declines in areas of high overlap with dense deer populations (Lankester 2010). While *P. tenuis* has not been documented in Montana, detection of infected white-tailed deer in western North Dakota suggest the possibility of intermittent spread into portions of Montana (Maskey 2008).

The arterial worm (*Elaeophora schneideri*) is a filarioid nematode found in the common carotid and internal maxillary arteries of ungulates in the west and southwestern US (Henningsen et al. 2012). Mule deer are definitive hosts of carotid worms, while moose and other ungulates are aberrant hosts, susceptible to blockage of blood to the optic nerve, ears, and brain and related symptoms such as blindness, ataxia, necrosis of the muzzle and nostrils, and emaciation (Hibler and Metzger 1974). *E. schneideri* was first detected in moose in Montana in 1971 (Worley et al. 1972), and subsequent sampling of 74 harvested moose detected carotid worms in 3 (4.0%; Worley 1975). More recently, approximately 30% prevalence was detected in Montana among 94 moose harvested in 2009–10 (J. Ramsey, MFWP, unpublished data) and 49% prevalence (n = 165) was detected in Wyoming (Henningsen et al. 2012). While infection is not necessarily lethal, increasing prevalence and the potential for subclinical effects warrant further investigation.

Climate

Moose in North America occur across a great range of latitudes (40° N to 70° N), though generally are best-adapted for cold climates (Renecker and Hudson 1986). Winter severity can affect physical condition (Cederlund et al. 1991) and fecundity (Solberg et al. 1999) of moose, yet recent attention has been given largely to concerns over warm temperatures. A small sample (n = 2) of captive moose in Alberta exhibited metabolic and respiratory signs of heat stress at temperatures above −5°C and 14°C in winter and summer, respectively (Renecker & Hudson 1986). In Minnesota, a heat stress index based on these thresholds explained >78% of the annual variability in moose survival (Lenarz et al. 2009), and annual population growth rates decreased with increasing summer temperatures (Murray et al. 2006). Concerns over heat stress effects on moose are compounded by predicted patterns of future climatic warming across southern moose ranges (Lenarz et al. 2010), yet much remains unclear and the relationships in Minnesota were strictly correlative.

It is not known whether the mechanism linking temperature to demography is a direct link between heat stress and malnutrition (Murray et al. 2006) or an indirect link via parasites or other mortality agents (Samuel 2007). Increased mortality as a result of heat stress is likely to result in decreased abundance and a contraction in moose distribution along the southern range extent, yet local expansions of moose in other southern jurisdictions (e.g., Base et al. 2006, Wolfe et al. 2010, Wattles and DeStefano 2011) and an Ontario field study (Lowe et al. 2010) do not directly support this hypothesis. Within Montana it is unclear whether any climatic variables underlie spatial variation in the productivity of local populations.

RESEARCH NEEDS AND FUTURE DIRECTIONS

Comprehensive review of the current status of moose and methods in practice for monitoring and management revealed 3 primary research needs in Montana: 1) calibration of various trend indices to evaluate agreement and uncertainty regarding moose population trends, 2) development or refinement of monitoring programs to produce consistent data at appropriate scales to inform harvest or habitat management decisions, and 3) research into rates of adult survival and recruitment and the potential limiting factors of each. Accordingly, during fiscal year 2012–2013 the MFWP began directing moose permit auction funds toward a new research program to address these research needs. Generally speaking, the work aims to provide rigorous and reliable information as a foundation for understanding moose population dynamics and management practices in Montana.

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APPENDIX A: MOOSE MANAGEMENT SURVEY QUESTIONS PROVIDED TO 20 MFWP BIOLOGISTS IN 2010.

1. In your experience and professional judgment, what are the major concerns or limiting factors for moose in your area of responsibility (can choose more than one)?
   - [ ] Disease
   - [ ] Predation
   - [ ] Hunter harvest
   - [ ] Habitat loss/ fragmentation
   - [ ] Habitat succession
   - [ ] Other: ____________
2. How would you describe the current status of moose within your area of responsibility?
   - [ ] Decreasing
   - [ ] Stable
   - [ ] Increasing
3. What type of moose management decisions are you typically required to make?
   - [ ] Harvest quota recommendations
   - [ ] Habitat enhancement
   - [ ] Habitat conservation
   - [ ] Large carnivore harvest recommendations
4. What information do you currently have and use for moose management (this information should be collected at the time of interview)?
   - [ ] Landowner reports
   - [ ] Hunter reports
   - [ ] Unadjusted trend counts
   - [ ] Sightability-corrected population estimates
   - [ ] Recruitment ratio counts
   - [ ] Bull: Cow ratio counts
   - [ ] Harvest estimates
   - [ ] Habitat condition
5. Which limiting factors have you addressed with moose management programs or decisions (this question will be accompanied by collection of past management actions: season proposals & rationales, regulations, specific habitat enhancement projects, land management plans, etc.)?
   - [ ] Disease
   - [ ] Predator harvest or control
   - [ ] Moose harvest
   - [ ] Habitat management
   - [ ] Habitat conservation
   - [ ] Other: __________
6. How would you describe your moose survey and inventory information?
   - [ ] Adequate to make decisions for moose management
   - [ ] Adequate in some ways, not adequate in others
   - [ ] Not adequate to make moose management decisions
7. What information would most help you in your efforts to conserve and manage moose populations in your area?
8. Can you list previous research projects and products from your area, and describe how results have been applied in your current management program?