7th WESTERN STATES AND PROVINCES

DEER AND ELK WORKSHOP PROCEEDINGS

Estes Park, Colorado
May 13-16, 2007

7th Western States and Provinces Deer and Elk Workshop Proceedings

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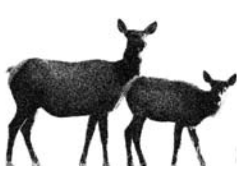

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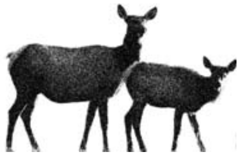

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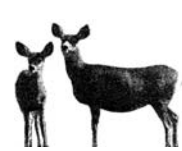

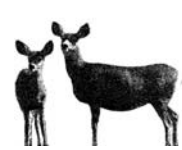

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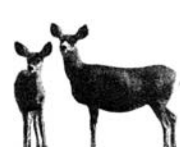

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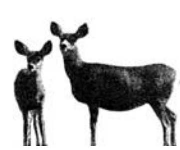

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DEER MANAGEMENT IN THE WEST: CHANGES AND SCHISMS IN AGENCY AND PUBLIC PERSPECTIVES

Moderator: LEN H. CARPENTER, Wildlife Management Institute

BIOLOGICAL, SOCIAL, AND ECONOMIC EFFECTS OF TOTALLY LIMITED DEER LICENSES IN COLORADO

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During the past 15+ years, management of mule deer in Colorado has shifted away from a system focused on maximizing hunter opportunity. Largely driven by an apparent decline in the total number of deer, management shifted from one of unlimited opportunity in most Data Analysis Units (DAU) to being limited statewide. The first year of statewide limited draw deer licenses occurred in 1999, with reductions on the magnitude of 50%-90% occurring in most DAU's. Despite an overall trend of increasing posthunt fawn:doe ratios between 1999 and 2006, our post hoc analysis indicates that the statewide limited draw system has likely had a negative impact on fawn:doe ratios.. However, between 1999-2006, both total mule deer population, as well as buck:doe ratios have steadily risen. as a result of limiting buck licenses statewide. Our analysis indicates that the majority of population growth is attributable to the mature buck population segment and there is little or no indication that herd productivity has been improved by harvest management actions. An overall trend of increasing buck:doe and buck:hunter ratios has made Colorado an increasingly desirable place for deer hunters to draw tags. Colorado deer hunters appear to be very supportive of totally limited deer licenses and current sex ratio objectives that approach a statewide average of ~30 bucks/100 does posthunt. Despite being a limited draw state, ~95% of deer licenses in Colorado can be drawn with 0 or 1 preference points. As such, it appears that hunter opportunity did not decline as expected. Rather, we feel that a large number of hunters stopped hunting deer as a result of statewide limitation of deer tags. The immediate economic impact from implementing the statewide limited management process was a reduction in deer license revenue by ~50%.

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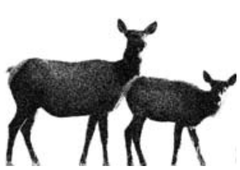

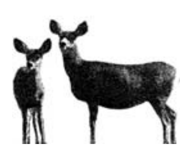

MULE DEER HUNTING: PUBLIC ATTITUDES AND AGENCY MANAGEMENT

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***Abstract*:** Wildlife agencies manage hunting opportunities within biological limits of the individual species. Specific hunting opportunities are developed using social desires that are generally more restrictive than are biological limits. In addition to social desires, agencies must also consider other aspects when setting seasons like sustaining hunter opportunity for those that are less engaged in public process and do not attend meetings or submit comments. Public perception is critical to implementing management strategies. Eleven states and provinces responded to a mule deer (*Odocoileus hemionus*) hunting perception survey request in association with the 2007 deer-elk workshop (AZ, CO, ID, ND, NM, NV, OR, SD, SK, UT, and WY). Management strategies employed by these agencies differed somewhat throughout the states and provinces, but all limited nonresident participation in deer hunts to some degree. Use of antler point restrictions was uncommon. Most states provided very limited mule deer hunting during the breeding season. Most states used buck to doe ratios as a management objective, with the exception of NM. Most states indicated greater interest by hunters in higher buck to doe ratios. In states that hold few antlerless hunts, proposing such hunts tends to be controversial. Most states base their perceptions on hunter attitude surveys.

Although there are many differences among public attitudes in various states that have completed surveys, some similarities exist. Publics that respond to surveys often differ from those that attend public commission meetings and voice their opinion. In Arizona, about two thirds of the people surveyed believed that increasing permits would decrease mean hunt success. With that caveat, two thirds of the respondents still preferred increasing permit numbers so that their chances to go hunting would increase. Most respondents in Arizona and Nevada listed harvesting a trophy well below getting to go hunting in importance when considering hunting opportunities. In both surveys, hunters were largely satisfied with the process for drawing permits (draw process), although the dissatisfied portion was widely divergent on how to improve the process. In Arizona, difficulty in getting a permit and cost were the 2 most oft cited reasons for suggesting the applicant would not apply the following year. Over one third of the respondents in Arizona did not belong or donate to any organized sportsmen's group.

Managing hunt opportunity is critical to maintaining hunters and social support for wildlife management. Hunters are essential to the North American Model of Wildlife Management. Hunter numbers are declining nationwide. Vocal minorities tend to prefer more elite hunting opportunities, whereas silent majorities seem to want the opportunity to go while unwilling to speak out. Educating hunters and managing hunting opportunity in the next decades may be the most critical and delicate elements to the continuation of the North American Model of Wildlife Management. Recognizing that hunting customers comprise at least 2 distinct public segments is critical to providing suitable products.

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Key Words: attitude, hunting, management, mule deer, *Odocoileus hemionus*, opinion, survey

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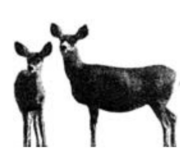
Wildlife agencies manage hunting opportunities using data that reflects social desires, while considering the biological limits of hunted species. Public perception is critical to



implementing management strategies. Yet some management strategies, such as increasing permits to address hunter recruitment and retention objectives, can at times meet with opposition from the public because they perceive greater hunter numbers with decreased hunt quality (e.g., greater hunter crowding) and harvest quality (e.g., fewer big bucks available).

For example, White et al. (2001) determined that Colorado's surveyed mule deer (*Odocoileus hemionus*) buck to doe ratios had to dip below 10:100 before a substantial impact to fawn to doe ratios could be detected. This implies that hunter opportunities, which have been linked to hunter recruitment and retention, can be increased to a point where buck to doe ratios decline to relatively low levels without having a biological impact. However, hunter attitudes often oppose agency management when hunting recommendations are more aggressive than their (social) perception of acceptable hunting experiences (e.g., Freddy et al. 2004, Wakeling 2007).

Our objective was to survey the member states of the Western Association of Fish and Wildlife Agencies to determine their perceptions regarding hunter opinions in their state and their management. We also compared agency perceptions with results from recently completed hunter surveys conducted by public opinion survey firms.

Methods

We designed and sent an 18-question survey via email to states and provinces that belong to the Western Association of Fish and Wildlife Agencies during spring 2007. Follow up reminders were sent to each agency. Three questions identified the individual state response source and 15 dealt specifically with management of mule deer in that state (Appendix 1). We formulated questions to determine agency perspectives on hunter attitudes about mule deer hunting in the west.

Results

Eleven states and provinces responded to a mule deer hunting perception survey request in association with the 2007 deer-elk workshop (AZ, CO, ID, ND, NM, NV, OR, SD, SK, UT, and WY). Opinions about hunter attitudes were based in part on varying levels of surveys conducted in each state (Table 1). Five of the 11 states have surveyed hunter attitudes within the last 3 years and a sixth will survey hunter attitudes by year end. Of the 11 states that responded, 5 limit (e.g., lottery draw) virtually all hunting opportunities for deer (AZ, CO, NM, NV, UT), whereas 2 states primarily limit nonresident hunting opportunities (ID, WY) (Table 2). North Dakota limits few hunting opportunities and SD and SK vary on their limitations. Eight of the 11 states (exceptions were NM, ID and OR) do not use antler point restrictions to regulate take (Fig. 1). States that limited hunting opportunities had shorter seasons for archery, muzzleloader, and rifle seasons than did those which did not or varied in limitations on hunting opportunity. Archery deer seasons are generally longer than are seasons for general or muzzleloader deer seasons (Table 3). Eight of the 11 states (AZ, CO, ID, NM, NV, OR, UT, and WY) provided very limited mule deer hunting during the breeding season, whereas 2 indicated little difference in opportunity between breeding season and non-breeding season opportunity (ND and SD) (Fig. 2). Saskatchewan did not indicate how much opportunity was available during the breeding season.

Table 1. *Agency responses to the frequency with which they have surveyed mule deer hunters in their state.*

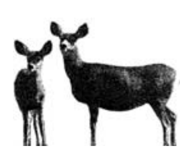
State-Province	Number of Surveys	Year(s)
Arizona	7	1980, 1985, 1990, 1995, 2000, 2005, 2006
Colorado	2	1991, 1999
Idaho	3	1987, 2004 WT, 2007 MD
Oregon	1	2003
Nevada	2	1982, 2000
New Mexico	4	1990, 1997, 2000, specific regulation setting issues -2006
North Dakota	0	
Saskatchewan	0	
South Dakota	13	1994 to present
Utah	2	1989, 1999
Wyoming	2	1989, 2006

Table 2. *Mule deer hunting opportunity provided by agencies responding to questionnaire in spring 2007.*

Management	Number of States or Provinces	States or Provinces
All deer licenses are limited	5	AZ, CO, NV, NM, UT
Most resident buck licenses are unlimited but most non-resident buck licenses are limited	2	ID, WY
A large proportion of resident and non-resident buck licenses are unlimited	1	ND
The amount of buck license limitation varies depending on deer species or sub-species	3	OR, SA, SD

Table 3. *Median and mean season lengths by season type reported by agencies responding to questionnaire in spring 2007.*

Season	Range	Median	Mean
Archery	22 to 129 days	33 days	49 days
Muzzleloader (only 10 states)	7 to 31 days	10, 16 days	15.8 days
Rifle	5 to 27 days	15 days	16.1 days



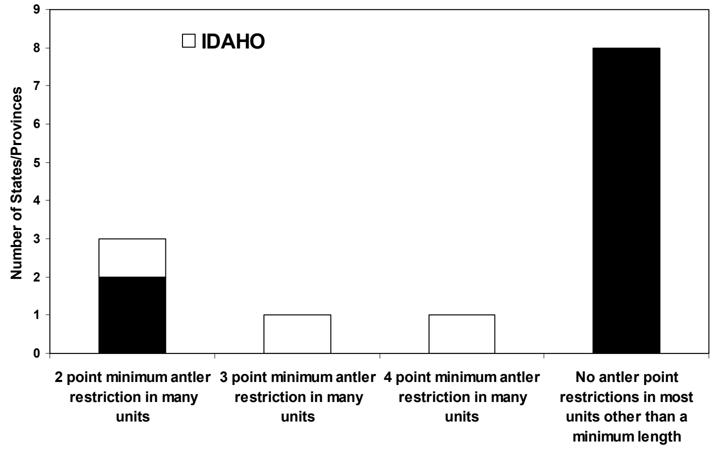


***Figure 1.** Frequency of use of antler point restrictions in mule deer management reported by agencies responding to questionnaire in spring 2007. Idaho is divided among 3 categories.*

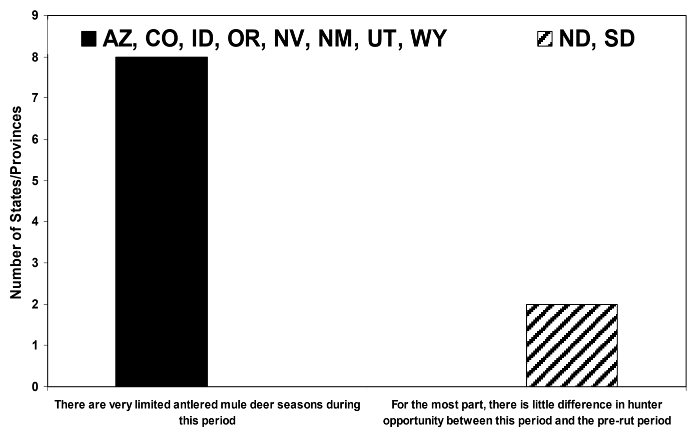


***Figure 2.** Distribution of hunting opportunities within mule deer breeding periods reported by agencies responding to questionnaire in spring 2007.*

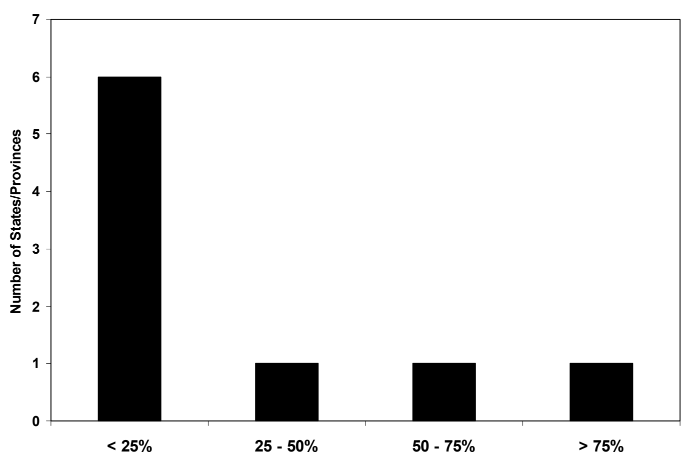
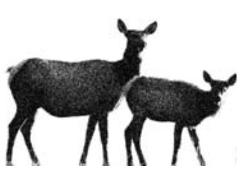
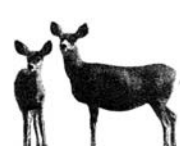


***Figure 3.** Frequency and range in which states manage for post hunt buck to doe ratios reported by agencies responding to questionnaire in spring 2007.*





Most states use buck to doe ratios as a management objective, with the exception of NM. For those states that do use buck to doe ratios, 3 (AZ [2%], ID [17%], and WY [no precise information]) manage fewer than 25% of the state for >25:100 (Fig. 3). South Dakota (25-50% of state), CO (67%), and NV (100%) are more conservative in buck to doe ratio management (Table 4). Colorado, NV, ID, and WY all indicated that the proportion of units managed toward this objective increased over the past 10 years, whereas AZ, ND, and SD indicated no change in proportion of state with this objective. No state reported decreasing the proportion of units managed for higher buck to doe ratios (Fig. 4). Antlerless hunts are relatively rare in AZ (1% of units), NV (10%), OR, where as ID, UT (25-50%), CO, SK, and WY (>75%), and SD (100%) more commonly hold antlerless hunts (Fig. 5). Arizona, NM, ID, NV, OR, and UT find antlerless harvests controversial, as CO found it to be in some areas. North Dakota, SD, and SK do not find antlerless harvests to be controversial. All states limit nonresident participation to some degree (1% cap in ND to 35% in CO). Eight of the 11 states expressed concern with the increased expressed desire for quality harvests.

Table 4. *Responses of individual states about the proportion of their area managed for >25 bucks for every 100 does based on the questionnaire in spring 2007.*

State or Province	Response
Arizona	2%
Colorado	67%
Idaho	17%
Oregon	<25%
Nevada	100%
New Mexico	Buck to doe ratios not used as mgmt obj
North Dakota	None
Saskatchewan	Only use prehunt numbers for mgmt obj
South Dakota	25-50%
Utah	23%
Wyoming	<25%

Resident and nonresident hunters differed in desires about mule deer hunting opportunity in western states. Resident hunters (Fig. 6) frequently want higher quality hunting and more resident opportunity than do nonresidents, but most states were largely uninformed about nonresident hunter desires (Fig. 7).

When asked how public input is obtained, states selected open public meetings or forums first, letters, emails, and testimony to the Wildlife Commission or a similar rule-making second, harvest survey report cards, check-station surveys, or field hunter surveys third, Sportsmen's Advisory Groups or committees fourth, and telephone, internet, or mail surveys fifth.

Discussion

Agencies seem to perceive that their management strategies are often designed in response to vocal publics, although these management strategies may not favor most hunters or the agencies themselves (e.g., Bergman in this volume, Freddy this volume). Although there are differences among public attitudes in various states that have completed surveys, many similarities exist. Publics that respond to surveys often differ from those that attend public commission meetings and voice their opinion. In Arizona, about two thirds of the people surveyed (n = 15,156) believed that increasing permits would decrease mean hunt success (Responsive Management 2006). With that caveat, two thirds of the respondents still preferred increasing permit numbers so that their chances to go would increase. Most respondents in

Arizona and Nevada (*n* = 1,028; Research and Polling, Inc. 2000) listed harvesting a trophy well below getting to go hunting in importance when considering hunting opportunities. In both surveys, hunters were largely satisfied with the process for drawing permits (draw process), although the dissatisfied portion was widely divergent on how to improve the process. In Arizona, difficulty in getting a permit and cost were the two most oft cited reasons for suggesting the applicant would not apply the following year. Over one third of the respondents in Arizona did not belong or donate to any organized sportsmen's group.

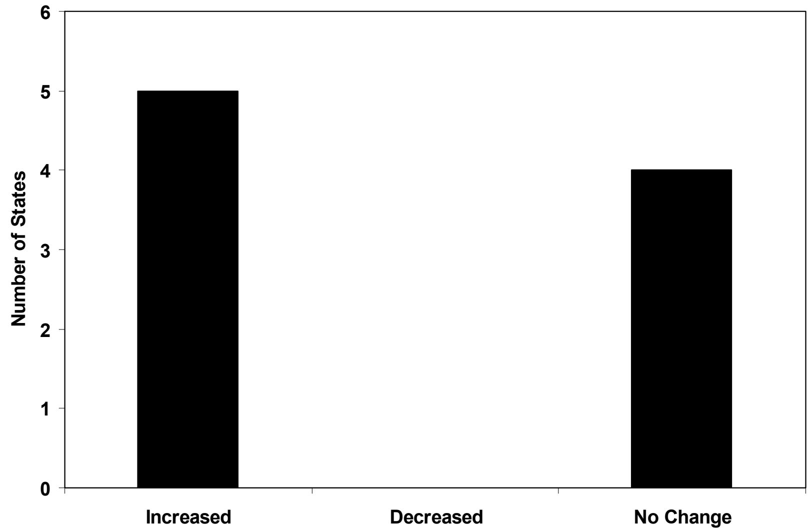


Figure 4. *Frequency of states that have increased, decreased, or not changed the proportion of their area managed for higher buck to doe ratios based on data from the questionnaire in spring 2007.*

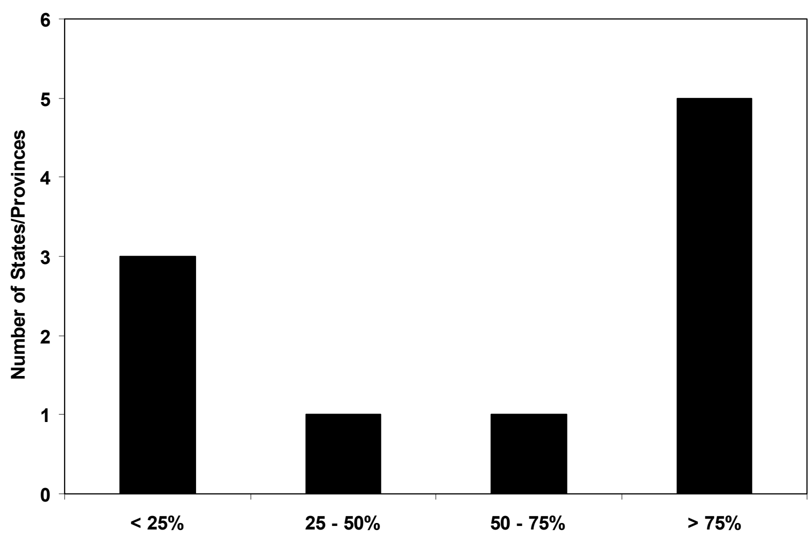
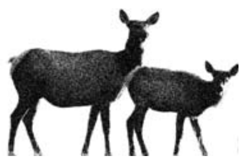


Figure 5. *Frequency with which states regularly hold antlerless mule deer hunts based on data from the questionnaire in spring 2007.*



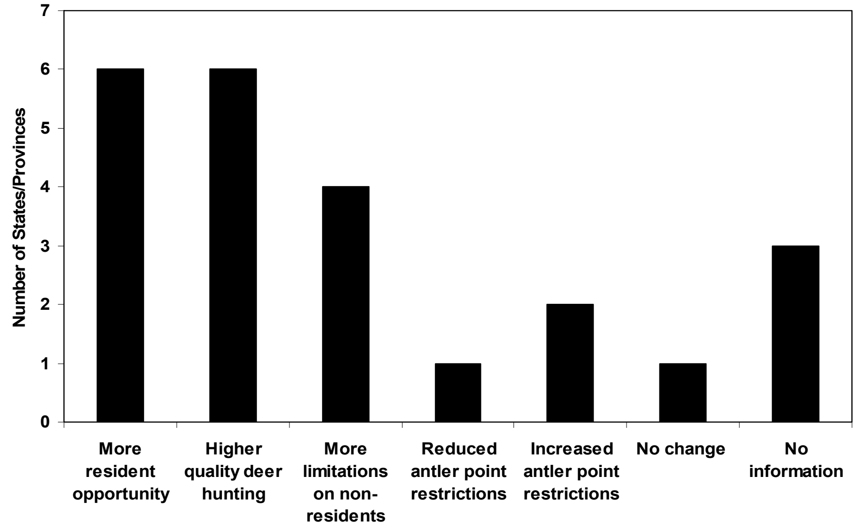


Figure 6. *Frequency with which states indicate expressed desires by resident hunters regarding mule deer hunting as reported from data in the questionnaire in spring 2007.*

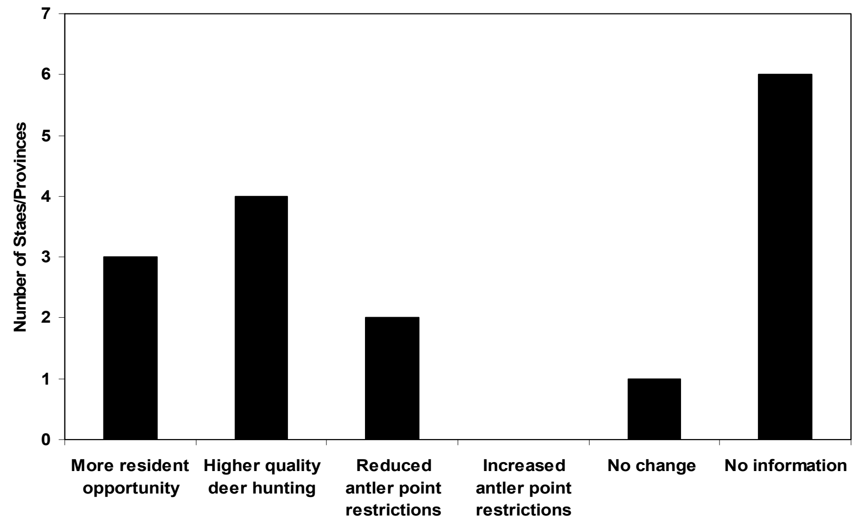


Figure 7. *Frequency with which states indicate expressed desires by nonresident hunters regarding mule deer hunting as reported from data in the questionnaire in spring 2007.*

Surveys from Arizona and Nevada also confirmed that the primary interest in hunting was to harvest a deer for meat or recreation. But hunting for quality animals or experiences were important to a substantial portions of hunters in both states as well.

Managing hunt opportunity is critical to maintaining hunters and social support for wildlife management. Hunters are essential to the North American Model of Wildlife Management. Hunter numbers are declining nationwide and many projections indicate hunters may be relatively scarce by the year 2030. Vocal majorities tend to prefer more elite hunting opportunities, whereas silent majorities seem to want the opportunity to go while unwilling to speak out. Growing human populations place ever greater demands on all natural resources and public recreation areas. Educating hunters and managing hunting opportunity in the next decades may be the most critical and delicate elements to the continuation of the North American Model of Wildlife Management.

Essentially, surveys reflect that wildlife management agencies have a minimum of 2 publics when providing hunting opportunity: hunters that simply want the opportunity to hunt and hunters that desire a high quality hunt and are willing to wait to receive it. Those that simply want the opportunity to hunt are important customers because they are the ranks from which recruitment and retention is most important; they vote and interact socially with others that may not hunt. The vocal minority that seeks quality hunting opportunities is the segment that routinely attends Commission meetings, legislative hearings, and most often vocally supports initiatives that benefit wildlife conservation. Wildlife agencies are challenged to provide suitable products for both customer segments.

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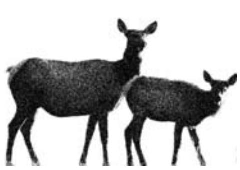
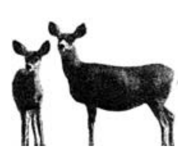
***Appendix 1.** Questions asked via email survey of states belonging to the Western Association of Fish and Wildlife Agencies during spring 2007.*

1. State or Province:
2. Person Completing the Survey:
3. Title:
4. Which of the following best represents your state's or province's deer harvest management:
    a. All deer licenses are limited
    b. Most resident buck licenses are unlimited but most non-resident buck licenses are limited.
    c. A large proportion of resident and non-resident buck licenses are unlimited.
    d. The amount of buck license limitation varies depending on deer species or sub-species.
5. Which of the following best represents your state's or province's antler point restrictions for mule deer? (select all that apply)
    a. 2 point minimum antler point restriction in many units
    b. 3 point minimum antler point restriction in many units
    c. 4 point minimum antler point restriction in many units
    d. No antler point restrictions in most units other than a minimum length.
    e. Other:
6. What are the typical season lengths (days) in most units for mule deer? (If there are multiple seasons for a method of take, enter the days for the longest single season).
    Archery
    Muzzleloader
    Rifle
7. How much hunting opportunity does your state or province offer during the mule deer rut (i.e., late November-early January)?
    a. There are no antlered mule deer seasons during this period
    b. There are very limited antlered mule deer seasons during this period.
    c. Most units have limited antlered mule deer seasons during this period.
    d. For the most part, there is little difference in hunter opportunity between this period and the pre-rut period.
8. What proportion of units is currently managed for ≥ 25 bucks/100 does posthunt?
    a. Actual percentage:
    b. None
    c. < 25%
    d. 25-50%
    e. 50-75%
    f. > 75%
    g. All
    h. Buck/doe ratios are not used as a management objective
9. In the last 10 years, how has the number of deer units managed for at least 25 bucks/100 does posthunt changed?
    a. Increased
    b. Decreased
    c. No change
    d. Buck/doe ratios are not used as a management objective
10. What proportion of deer units typically has antlerless harvest excluding damage hunts?
    a. Actual percentage:
    b. None
    c. < 25%





   d. 25-50%
   e. 50-75%
   f. > 75%
   g. All

11. How controversial is antlerless deer harvest in your state or province?
   a. It is seldom controversial when antlerless harvest is proposed
   b. It is often controversial when antlerless harvest is proposed
   c. It is usually controversial only in certain units.

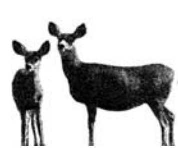
12. Does your state or province cap the number of non-resident deer hunters?
   a. No
   b. Yes. Actual percentage cap in most units:
   c. Yes (< 25% of hunters)
   d. Yes (25-50% of total hunters)
   e. Yes (>50% of total hunters)
   f. Yes (varies by unit). Range:

13. List each year statewide deer hunter attitude surveys have been completed in your state or province since 1980.

14. Overall, how would you characterize the results of the hunter attitude survey(s) with regard to buck hunting based on **resident** respondents? (select all that apply)
   a. Increased desire for more resident deer hunting opportunity (i.e., less license limitations for residents)
   b. Increased desire for higher quality deer hunting (i.e., greater license limitation if it would result in less crowding, higher success, and older age class bucks).
   c. Increased desire for more limitations on non-resident deer hunters.
   d. Increased desire for reduced antler point restrictions
   e. Increased desire for increased antler point restrictions
   f. No change
   g. No information

15. Overall, how would you characterize the results of the hunter attitude survey(s) with regard to buck hunting based on **non-resident** respondents? (select all that apply)
   a. Increased desire for more non-resident deer hunting opportunity (i.e., less license limitations for residents)
   b. Increased desire for higher quality deer hunting (i.e., greater license limitation if it would result in less crowding, higher success, and older age class bucks).
   c. Increased desire for reduced antler point restrictions
   d. Increased desire for increased antler point restrictions
   e. No change
   f. No information

16. Which of the following are commonly raised as issues by deer hunters in your state or province? (select all that apply and rank by relative importance – high to low)
   a. Too few deer or declining deer populations
   b. Habitat loss
   c. Predation
   d. Desire for larger bucks
   e. Desire for more deer hunting opportunity
   f. Hunting during the rut and late seasons
   g. Season length
   h. Too many non-resident hunters
   i. Competition with elk
   j. White-tailed deer – mule deer interaction



k. Concerns about antlerless harvest
l. Increased commercialism of deer hunting
m. Problems with shed antler hunting
n. Concerns about chronic wasting disease
o. Other:

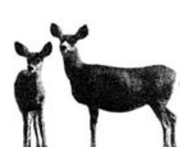
17. Is your agency concerned about a shift toward quality harvest management of deer and therefore reduced hunter participation?
    a. No. No significant shift towards quality management has occurred.
    b. No. A shift towards quality management has occurred but it is not a major concern.
    c. Yes.
18. Which of the following are used by your agency to monitor public opinion regarding deer hunting season structure and harvest management? (select all that apply and rank by relative importance – high to low)
    a. Open public meetings or forums
    b. Sportsmen's Advisory Groups or committees
    c. Telephone, internet, or mail surveys
    d. Letters, e-mails, and testimony to the Wildlife Commission or a similar rule-making, government oversight entity.
    e. Harvest survey report cards, check-station surveys, or field hunter surveys
    f. Other:

HAS RESPONSIVE DEER AND ELK HUNTING MANAGEMENT PLACED AGENCIES IN A BOX CANYON?

DAVID J. FREDDY, Colorado Division of Wildlife, Research Center, 317 West Prospect Road, Fort Collins, CO 80526, USA

Abstract: Since the early 1990s, Colorado has experienced a significant decline in numbers of mule deer (*Odocoileus hemionus*) hunters. Much of this decline is correlated with regulations to limit total numbers of hunters and numbers of non-resident hunters in response to demands from hunting factions to provide more quality buck hunting opportunities. These demands have also had some parallel restrictive effects on elk hunting management. By positively responding to these demands, agency revenue from deer hunting has plummeted and interest in deer hunting has become more focused on a limited share of the market while abundant elk populations have effectively served as alternate revenue prey to sustain agency budgets. The elk financial buffer is now shrinking as elk populations are reduced to acceptable social carrying-capacities. I explore some reasons and opinions as to why I think the Colorado Division of Wildlife, in particular, may be facing a difficult future in sustaining the broad-spectrum popularity of hunting. Creating an overall agency business plan and market analysis would seem to offer a strategy to assess how to sustain future revenues and wildlife management programs.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:22.



STRATEGIES FOR MANAGING DEER WITH OIL AND GAS DEVELOPMENT

Moderator: STEVEN R. BELINDA, Theodore Roosevelt Conservation Partnership

MULE DEER AND ENERGY- ARE WE FACING THE PROBLEM?

ROLLIN D. SPARROWE, Theodore Roosevelt Conservation Partnership, PO Box 415 Daniel, WY 83115, USA

Abstract: The current boom in energy development in the Northern Rockies continues to expand and take on a larger scale and scope than any before. While attention has been on sage grouse because of potential listing, mule deer are in the crosshairs especially on winter ranges critical to survival. Initial research and monitoring has demonstrated how impacts can occur, yet the state and federal bureaucracy is divided in its willingness to use the science we have. Even public processes designed to monitor and take corrective action have failed to raise the level of concern to a point of effective action. New projects appear poised to enlarge the geographic spread of damage, and a new answer has emerged that suggests that we accept damage and go on to off site mitigation to "enhance" our way out of the problem. The professional community appears split on the value of knowledge so far gathered, and is not coordinated in its appraisal of the situation, or what to do about it. Politics have been and will be in play. We need to grapple with this problem now and craft a science-based strategy for its resolution for the sake of mule deer, hunting, and professional management of this important resource.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:24.

MULE DEER HABITAT IN WESTERN WYOMING: FUTURE CHALLENGES.

NICK T. SCRIBNER, Wyoming Game and Fish Department, P.O. Box 850, Pinedale, WY 82941, USA

Abstract: Healthy, functional habitat is a critical component to mule deer (*Odocoileus hemionus*) survival in western Wyoming where harsh weather is common and long migration routes occur between seasonal ranges. Mule deer populations in western Wyoming peaked during the 1950s and have been unable to reach those numbers since that time, in particular, since the severe winter of 1991-1992. The lack of recent mule deer productivity can be largely attributed to poor habitat conditions caused by various factors including fire suppression, drought, fragmentation, excessive browsing, and loss of habitat due to housing and energy development. With development activities projected to increase substantially over the next 25 years in western Wyoming, it is imperative to develop sound management strategies to improve the quality and maintain the quantity of habitat.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:25.

EVALUATING IMPACTS OF NATURAL GAS DEVELOPMENT ON MULE DEER IN WESTERN WYOMING

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Abstract: Increased levels of natural gas exploration, development, and production across the Intermountain West have created a variety of concerns for wildlife populations and their habitats. In July of 2000, the Bureau of Land Management approved development of 700 producing wells, 400 miles of access roads, and 276 miles of pipeline to develop gas reserves in the Pinedale Anticline Project Area (PAPA). The PAPA provides important winter habitat to 4,000-5,000 mule deer that summer in portions of 4 different mountain ranges of northwest Wyoming. We used a variety of data collected prior to and during gas development to examine the potential impacts of natural gas development on mule deer in the PAPA. We discuss results from the first 5 years of gas development, including: 1) estimated acreage and sources of direct habitat losses, 2) changes in mule deer habitat selection patterns and indirect habitat losses, and 3) population performance of mule deer in the PAPA. Through 5 years of gas development we documented: 1) > 1,300 acres of direct habitat losses to access roads and well pads, 2) changes in deer distribution (i.e., avoidance of gas wells), and 3) a 45% reduction in mule deer abundance. Our study suggests that habitat selection patterns and population performance of mule deer wintering in the PAPA have been affected by natural gas development. Mitigation measures designed to minimize impacts to wintering mule deer should consider development strategies that reduce direct habitat losses (e.g., directional drilling) and human activity (e.g., fluid collection systems). Further, reducing disturbance to wintering mule deer may require approaches that limit human activity during both production and development phases of wells.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:26.

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DEER GENERAL SESSION

Moderator: ERIC J. BERGMAN, Colorado Division of Wildlife

DESERT MULE DEER LIMITING FACTORS IN CENTRAL ARIZONA

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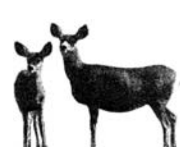
STAN CUNNINGHAM, Arizona Game and Fish Department, Phoenix, AZ 85023, USA
JAMES DEVOS JR., Arizona Game and Fish Department, Phoenix, AZ 85023, USA

Abstract: Mule deer (*Odocoileus hemionus*) populations in the western United States have declined in many areas. Deer numbers are limited by some combination of factors such as weather, food supplies, predation, hunting, parasites, diseases, and human activities. Desert mule deer (*O. h. eremicus*) populations in central Arizona had declined from densities of about 11 deer/kilometer^2 in the early 1960's, to about 2 deer/kilometer^2 today. Mule deer research has been conducted on the Three Bar Wildlife Area (TBWA) in central Arizona since the 1960s. In the 1970s an experimental mule deer herd was studied in a 244 hectare predator proof enclosure in the TBWA. Fawn:doe ratios were consistently higher inside the enclosure and deer densities were maintained around 11 deer/kilometer^2. We started a new study in 1997 and the deer herd inside the enclosure grew from 17 individuals in 1997 to 89 in 2006 while densities outside remained low. Our objectives were to compare deer performance (i.e., body condition, fecundity, recruitment, and deer survival) and plant species composition and forage production between inside and outside the enclosure. We captured and radio-collared 8 does inside the enclosure and 8 does outside the enclosure. We monitored body condition and productivity for a 3 year period. Preliminary analyses indicate there were no differences in body condition, pregnancy rates, or twinning rates but fawn survival was much lower outside the enclosure. Deer diets inside the enclosure had higher levels of diaminopimelic acid (DAPA) than outside the enclosure and FN was not different inside from outside the enclosure. Preliminary analyses indicate there were no differences in the vegetation parameters that we measured. Our results indicate that food resources are not a limiting factor for mule deer populations in the TBWA. Low fawn survival probably due to predation may be the greatest limiting factor but exact causes of mortality are unknown and should be studied.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:28.



TAILS WITH A DARK SIDE: WHITE-TAILED X MULE DEER HYBRIDIZATION IN NORTH AMERICA

JAMES R. HEFFELFINGER, Arizona Game and Fish Department, 555 N. Greasewood Road, Tucson, AZ 85745, USA

Abstract: Different species of animals, even those closely related, are normally kept from breeding with one another by being geographically isolated, by using different types of habitat, or by having different courtship and breeding behavior. In the case of whitetails and mule deer, all 3 of these factors help keep the 2 species from interbreeding. These differences have worked remarkably well throughout their evolutionary coexistence. However, in rare cases this system breaks down and hybridization occurs. Hybrids have been reported from captive facilities as early as 1898 when a whitetail x mule deer cross was produced at the Cincinnati Zoo. The male hybrids are sterile, however, female hybrids are fertile and can breed back to 1 of the parental species. Whitetail x mule deer hybrids have also been reported in the wild from Alberta, British Columbia, Saskatchewan, Nebraska, Kansas, Colorado, Washington, West Texas, Wyoming, New Mexico, and Arizona. This hybridization between the 2 different deer species is extremely rare in most areas, but does occur in where their ranges overlap. Hybrid deer show characteristics that are intermediate between mule deer and whitetails. The tails are more often very dark on the dorsal side and white underneath. Ears are larger than a whitetail, but smaller than a mule deer. The preorbital gland in front of the eye is also intermediate between the deep pits found in mule deer and the shallow depression of whitetails. Most hybrids have whitetail-like antlers, but it is impossible to diagnose a hybrid by antlers alone. The most informative physical feature to diagnose a hybrid in the wild is the size and location of the metatarsal gland on the *outside* of the lower portion of the rear legs. A whitetail x mule deer hybrid has metatarsal glands that are intermediate between the long, brown mule deer glands (>3 inches) and the small white glands of a whitetail (<1 inch). Two loci visualized by protein electrophoresis have been used in the past as a genetic test of hybridization. This test is at least 95% accurate in diagnosing a first generation hybrids, but requires fresh/frozen tissue. Newer, more advanced genetic techniques are now being employed to learn more about hybridization in *Odocoileus*.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:29.

DEER DENSITY ESTIMATION IN WEST-CENTRAL TEXAS: OLD VERSUS NEW GROUND TECHNIQUES WITH MARK-RESIGHT AS A COMPARATIVE BASELINE

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Abstract: Population estimation is an important yet often difficult task for wildlife managers. Convenience methods such as spotlighting deer (Cervidae) from roads are often used as trend indices, but with nonrandom survey design, inference is restricted to the area adjacent to roads. The relationship to a greater spatial extent remains unknown. Our primary objective was to examine 'presumable biases' in density estimates from road-based nighttime deer surveys in west-central Texas using an area-conversion technique assuming 100% detectability and line-transect distance sampling. We used mark-resight, demographic, and radiotelemetry data to generate a population-level density estimate as an independent comparative standard at the study-site spatial extent. We also compared spotlighting (SL) and thermal infrared imaging (TIR) methods. We hypothesized that deer habituation behavior interacting with roads as semi-permeable barriers to movement would cause clustering near roads at a spatial extent greater than the effective strip width of road survey transects. We predicted that deer density estimates by distance sampling, although descriptive of the area next to roads, would be biased high in comparison to the mark-resight estimate at the spatial extent of the study site. Also, area-conversion density estimates, although biased low due to incomplete detection, may actually provide accurate density estimates at the study-site spatial extent due to deer clustering near roads. We falsified the latter prediction but found support for the former. For inference to the study-site spatial extent, area-conversion estimates consistently appeared biased low, but distance sampling by TIR appeared biased high. Mean group size was greater by TIR than SL affecting density estimates by distance sampling similarly, thus increasing positive bias over SL. Spotlight distance sampling with the hazard-rate model appeared to provide the least biased deer density estimate at the study-site spatial extent. Similar results may be expected in other areas where habituated terrestrial mammals are surveyed from roads. Further study is needed to investigate road effects on deer distributions both within and beyond the effective strip width. This pilot study may be used to design and make predictions for a broad-scale calibration study relating nonrandom survey data to more defensible population estimates.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:30-47.

Key words: area-conversion, density estimation, distance sampling, *Odocoileus* spp, mark-resight, spotlight, techniques, Texas, thermal infrared, transect

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Reliable estimates of animal abundance or density over time are regularly required for effective management but are often expensive and difficult to obtain (Caughley and Sinclair 1994, Lancia et al. 2000, Rabe et al. 2002). There are a variety of methods to estimate animal abundance, and biologists compare techniques to suit their needs (Schwarz and Seber 1999, Borchers et al. 2002, Witmer 2005, Fickel and Hohmann 2006, Msoffe et al. 2007, Wiewel et al. 2007). However, many studies do not present a theoretically unbiased estimate of animal abundance or density to which alternative methods of interest can be compared (e.g., Garner et al. 1995, Naugle et al. 1996, Koerth et al. 1997, Smart et al. 2004, Drake et al. 2005, Collier et al. 2007); in such cases, comparisons among methods are only relative and true accuracy or bias cannot be assessed (Gill et al. 1997).

Indices from convenience methods such as spotlight counts of deer (Cervidae) may be useful as trend data, but with nonrandom survey design, inference cannot be extended past the area adjacent to roads (Thompson et al. 1998). Nonrandom survey estimates could be calibrated to more defensible population-level estimates by regression analysis of paired data (Eberhardt and Simmons 1987). These latter data are more rare and difficult to obtain, and unaccounted heterogeneous detectability among surveys may confound results (Lancia et al. 1996, 2000; Pollock et al. 2002; Anderson 2001, 2003). Regardless, spotlighting continues to be a common technique receiving review and refinement without attempts at calibration (McCullough 1982, Fafarman and DeYoung 1986, Cypher 1991, Scott et al. 2005, Collier et al. 2007).

Before 2005, Texas Parks and Wildlife Department (TPWD) used a strip transect area-conversion technique to estimate deer densities assuming 100% detectability at distances out to 229 m from roads (Young et al. 1995). Following Wildlife Management Institute ([WMI]; 2005) recommendations to use probability theory in sampling methods, TPWD changed their white-tailed deer (*Odocoileus virginianus*) road survey protocol to line-transect distance sampling (Buckland et al. 2001). Our main objective was to examine bias in the former and revised TPWD white-tailed deer nighttime survey techniques at our study site in west-central Texas. Also, we used spotlighting (SL) and thermal infrared imaging (TIR) methods simultaneously for comparative purposes. Because detectability of deer in brush habitats is likely to be <100%, we predicted that the old area-conversion technique would underestimate deer density near roads (Burnham and Anderson 1984). However, at a spatial extent greater than the effective strip width, habituation behavior may result in a clumped distribution of deer near roads if roads are semi-permeable barriers to movement (Haskell et al. 2006), and particularly so if data are collected during environmental conditions that promote deer movement.

Therefore, we predicted that: 1) negative bias of the old area-conversion technique may offset positive bias created by deer habituation behavior, and 2) density estimates based on distance sampling, although more representative of deer densities near roads, would be positively biased for inference to the study-site spatial extent. We present an independent, theoretically unbiased mark-resight population estimate, converted to density using deer location data, as a density estimate at the study-site spatial extent for confirmation of results. Without replication, inference from this study is limited but may be informative and useful as a hypothetico-deductive pilot study (Witmer 2005).

Study Area

We conducted our study on 4 contiguous private ranches (261 km^2) in northwest Crockett County, Texas (lat/long: 31.00°N, 101.73°W), during 2004–2006. Topography was varied with southern and eastern portions being mostly flat, while the western and northern portions included mesas (Fig. 1). Elevation ranged from 730–880 m ASL in the southern riparian corridor to mesa tops, respectively. At the nearest National Oceanic and Atmospheric Administration (NOAA) weather station (Big Lake, Texas; ~32 km), the mean daytime high temperature for November 1971–2000 was 18.7°C, and the mean nighttime low was 4.0°C (NOAA 2005). Mean annual precipitation was 47.5 cm (NOAA 2005).

In the intermittent riparian corridors, herbaceous vegetation was common with some grasses and forbs growing >0.5 m tall under scattered thickets of hackberry (*Celtis reticulata*) and walnut trees (*Juglans microcarpa*). Outside of the riparian corridors, bottomlands had two dominant shrub communities: mesquite (*Prosopis glandulosa*) on relatively mesic soils and a creosote (*Larrea tridentata*)-tarbush (*Flourensia cernua*) mix on well-drained soils. Prickly pear (*Opuntia* spp) and other cactus species occurred in the lowlands, much of which had been heavily grazed by cattle and sheep. Algerita (*Mahonia trifoliolata*), catclaw acacia (*Acacia greggi*), lotebush (*Ziziphus obtusifolia*), and tasajillo (*Opuntia leptocaulis*) were also interspersed primarily throughout the lowlands. The slopes and mesa tops were dominated by juniper (*Juniperus pinchotii*) communities with sparse varying herbaceous vegetation. Slopes and rim-rock areas often contained sotol (*Dasylirion wheeleri*) and yucca (*Yucca* spp).

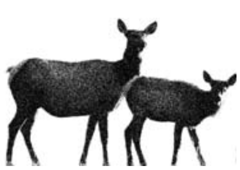
Land-use was primarily livestock ranching, but low-pressure lease hunting (Butler and Workman 1993, Brown and Cooper 2006) and oil and gas extraction were also common. Secondary roads were dense, and road quality varied from a paved county road to two-track unimproved ranch roads, but maintained caliche roads of intermediate quality were also present (Fig. 1). Both white-tailed and desert mule deer (*O. h. eremicus*) were present at the site in near equal abundance (Brunjes et al. 2006). White-tailed deer tended to select lowland habitats, and mule deer tended to select habitats near mesas, but there was considerable overlap in space use (Avey et al. 2003, Brunjes et al. 2006).

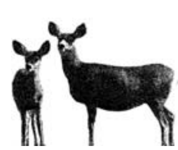
Methods

Field data

In April 2004 and 2005, we captured 50 adult does (25 mule deer and 25 white-tailed deer) using a net-gun fired from a helicopter (Holt Helicopters, Uvalde, Texas, USA; Krausman et al. 1985). We determined pregnancy by ultrasonography (Smith and Lindzey 1982, Stephenson et al. 1995). We fitted each pregnant doe with a vaginal implant transmitter (VIT; Advanced Telemetry Systems [ATS], Isanti, Minnesota, USA; Carstensen et al. 2003, Bishop et al. 2007), a radiocollar (Telonics, Mesa, Arizona, USA and ATS, Isanti, Minnesota, USA), and a numbered ear-tag. We used the VITs to help locate true neonates for capture, with birthing period peaks near 20 June for white-tailed deer and 20 July for mule deer (Haskell et al. 2007, 2008). When neonates were found, we fitted them with expandable radiocollars (ATS, Isanti, Minnesota, USA; Diefenbach et al. 2003) and numberless ear-tags placed in opposite ears for twins. We used a telescopic vehicle-mounted null-peak antenna system (Balkenbush and Hallett 1988) to radio-track deer year-round. We estimated radiotelemetry locations by weighted-incenter and maximum likelihood methods (Haskell and Ballard 2007). We recorded incidental observations of marked deer with a handheld global positioning system (Model GPS 76; Garmin International Inc., Olathe, Kansas, USA). Radiocollared deer provided estimates of reproductive and survival rates from 2004–2007.

For mark-resight population estimation, we recorded all observations of deer from 22 October 2004–5 February 2005 as the first "closed" primary sampling period (i.e., year) and again from 8 October 2005–29 January 2006 as the second "closed" primary sampling period. We opportunistically recorded deer by age class (i.e., fawn or adult), gender, and species while traveling roads. We were careful not to allow our knowledge of an animal's location while radio-tracking affect our visual search patterns by standardizing search patterns. Radio-tracking deer was usually performed >1 km away from the animal (Haskell and Ballard 2007), but roads would at times lead us closer which should not in itself violate the assumption of equal sightability of marked and unmarked deer where surveyed. We did not record observations when backtracking dead-end roads to achieve independent observations within secondary sampling





periods (i.e., days). We only made observations from roads within the home-ranges of our marked deer (Fig. 1). When a radiocollared deer was observed, we used binoculars to read the ear-tag on adults and verify ear-tag location on fawns and a VHF radio-receiver with the null-peak dual-yagi antenna to identify which individual was spotted.

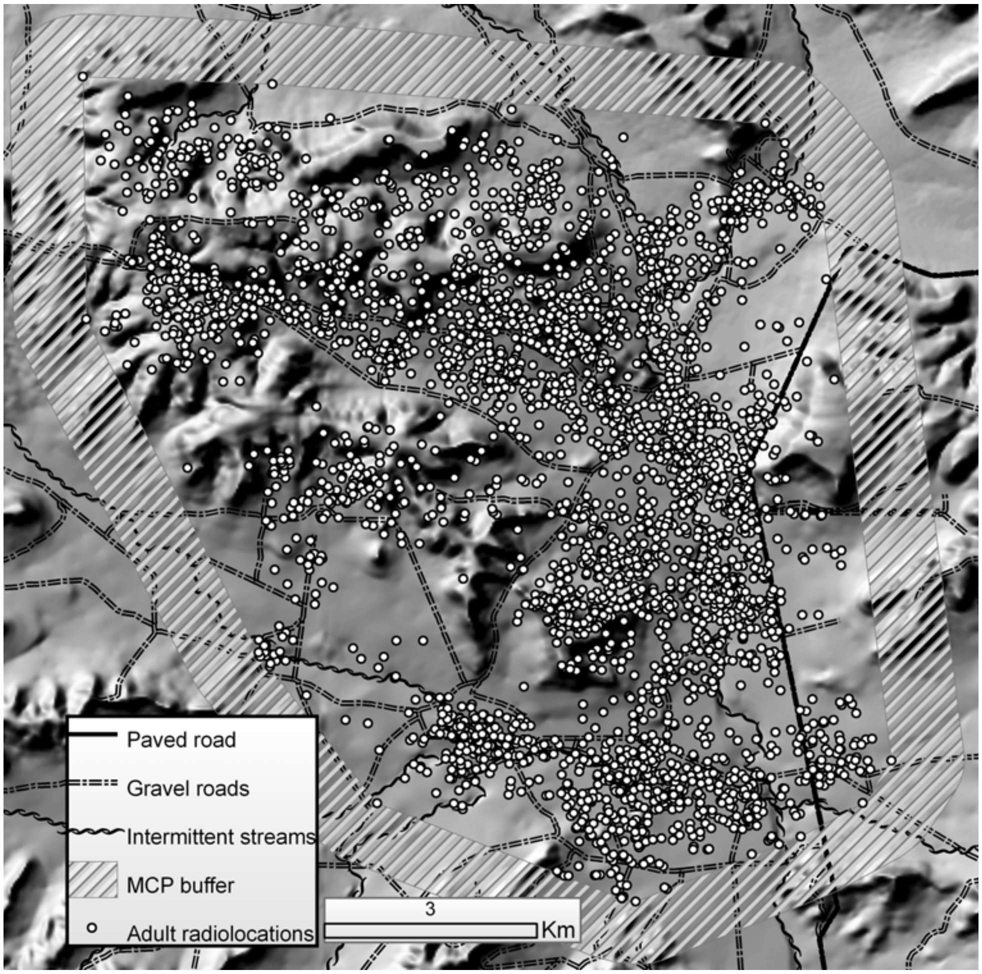


Figure 1. *Study site for 2004–2005 deer surveys in northwest Crocket County, Texas, showing topography, individual deer locations, and minimum convex polygon (MCP) of all locations with 884-m buffer as effective sample area estimates. Main secondary caliche road surveyed leaves paved road near northeast corner, heads west, and splits through two mesa valleys headed northwest and southwest. All secondary ranch roads including some across mesas not available for plotting from available databases (e.g., ESRI and USDOT Bureau of Transportation Statistics).*

We conducted night surveys from 4–6 November 2005 consistent with TPWD protocols except that TPWD surveys were typically conducted from August–October (Shult and Armstrong 1999, Young et al. 2005); we surveyed later in the season to be closer to the breeding period when deer should be more active (S. Haskell, unpublished data). We limited surveys to environmental conditions that may promote deer movement and feeding behavior (e.g., low winds and no precipitation). We began surveys about 1 hr after sunset (1900 hrs) and stopped by midnight. We used spotlighting (SL) and thermal imagery (TIR) simultaneously to compare number of deer observed and overall density estimated by each method. Because it was easier to survey a greater area by SL than TIR at a given speed, we only observed one side of a road during a survey. We selected 5 roads that ranged across the study site within the home-ranges of our marked deer. We selected the most used and best maintained roads including the north-south paved road and the 2 main east-west caliche roads (Fig. 1). Effective strip width of all selected roads included all vegetation community types. We surveyed the 3 main roads in both directions and the other 2 one-way only. Because the same roads were surveyed on different nights and opposite sides contained differing proportions of habitat types, we considered each pass as a separate transect. During 1 evening temperatures dropped to near freezing, and we observed deer bedded more than during previous surveys, so we stopped the survey short about halfway through a transect and considered this survey to be a unique transect. Thus, we surveyed 9 transects with mean length of 5.83 km (range = 3.19–7.58 km). We used a Suunto® Navigator sighting compass (Suunto, Vantaa, Finland), a Bushnell® Yardage Pro Scout laser range-finder (Bushnell Performance Optics, Bausch & Lomb, Inc., Overland Park, Kansas, USA), a portable thermal infrared imaging camera (PalmIR® 250 Digital, Raytheon Commercial Infrared, Dallas, Texas, USA), and a 100,000 candle power spotlight (SHO-ME® model #:08.0375.012, Wistol Supply, Dallas, Texas, USA) to locate deer groups and find the direction and distance (m) to the center of groups. The spotlight used was lightweight with sharp beam focus effective for shining eyes at long distances and was keeping with TPWD protocols. Most groups were identifiable by species but several were not. To maximize precision of density estimates we did not stratify data by species, and we could not hypothesize any a priori cause to do so for our current objectives.

Our crew consisted of 4 people: a driver, a TIR observer, a SL observer, and an additional data recorder. We drove at 11–13 kph (7–8 mph). The driver helped spot deer on and adjacent to the road to help ensure 100% detectability on the transect line and recorded location data by GPS when observations were made. We mounted the thermal imaging camera onto an adjustable tripod and placed it on the cab of the truck (~3 m AGL). We routed the display to a portable DVD player (Model: IS-PD101351, Insignia, Richfield, Minnesota, USA) with a 22.9 cm screen. The TIR observer stood at the front of the truck bed and searched for deer by watching the TIR monitor. The additional data recorder estimated distances to deer and recorded TIR data only. The SL observer was positioned at the rear of the truck bed and did not watch the TIR monitor. When deer were observed, the observers found reference points (e.g., shrub, large stone, sign, fence post, etc.) at the animal's initial location because the truck was not immediately stopped to allow the other observer a chance to find the group of deer; we measured distances to reference points. Texas Parks and Wildlife Department procedures call for 80% of observation effort to be in the front half of the viewing area (i.e., 0–90° in relation to the vehicle's heading) and only 5% in the last quarter (135–180° to the vehicle's heading), so the truck was stopped when a group of deer had entered the last quarter of the viewing area to maximize independence of observations between observers. At that time the reference point's azimuth and distance were recorded as was the deer count by each observer successfully locating the group. For comparative purposes, we considered observations between nighttime methods suitably independent with identically distributed deer.

Mark-resight density estimation

We used the robust design beta-binomial closed population mark-resight model to estimate deer abundance at our study site (McClintock et al. 2006). We used model averaging results with log-normal confidence intervals (McClintock et al. 2006). This model allowed for heterogeneity in sighting probabilities among individuals, as we opportunistically surveyed some roads more frequently than others. The robust design model used data from both primary sampling periods (i.e., years) to estimate sighting probability parameters, thus maximizing precision. Demographic closure within primary sampling periods was violated due to the length of time necessary to obtain adequate sample sizes. To account for deer mortality within primary sampling periods, we used known-fate data from radiocollared deer and estimated the total number of marked deer as the sum of individual proportions of survey availability. We calculated individual survey availability as the number of secondary sampling occasions (i.e., days) an individual was alive divided by total number of secondary sampling occasions.

The assumption of geographic closure was also violated. Methods to account for potential bias in density estimation using telemetry data to adjust the abundance estimate were not possible for our opportunistic surveys (White and Shenk 2001), so we used radiotelemetry data to estimate a range of effective area sampled (Soisalo and Cavalcanti 2006). Omitting two brief prepartum (i.e., springtime) extralimital forays, we drew a minimum convex polygon (MCP) around radiotelemetry locations of all 50 adult marked deer captured in 2004 and available for sampling in 2005. Because the roads used for mark-resight observations were widespread within this area with some exception at the western edge (Fig. 1), we considered this a minimum estimate of the effective area sampled. Next we calculated MCP home-range areas for each marked individual excluding point location outliers by groups of 1, 2, or 3 that accounted for at least 15%, 30%, and 45%, respectively, of total home-range size for an individual. Assuming a circular home-range shape, we calculated a home-range radius for each individual and used the overall mean to draw a buffer around the original MCP (Fig. 1). The area within the outer edge of the MCP buffer was our maximum estimate of effective area sampled.

We estimated the 2004 population size based on the doe mark-resight estimate. Because surviving marked fawns were few, resighting probabilities were low, and fawn:doe mark-resight ratios were much lower than predicted by known-fate data, we estimated the fawn population according to reproductive rates (1.9 fetuses/doe) and cumulative survival (57%) by Cox regression through the mid-survey period (S. Haskell, unpublished data). We estimated the adult buck population according to the 1:2.5 observed buck:doe ratio. In all cases where a portion of the population was estimated from the mark-resight doe estimate, we extrapolated 95% confidence intervals and point estimates, so confidence intervals grew with each estimated parameter. To predict and refine the subsequent 2005 mark-resight population estimate, we projected the 2004 estimate 1 year forward using vital rate data from radiocollared adult does and fawns. We estimated doe survival at 95% which was conservative given that only 1 of 50 does died between birthing periods of 2004 and 2005. We estimated buck survival at 90% given minimal hunting pressure (~1 buck taken/6 km^2). We estimated fawn recruitment from 2004–2005 similarly as before from the 2004 mark-resight doe estimate with annual fawn survival (55%) and doe productivity data. We estimated the surviving 2005 fawn population present during the mid-survey period as the additive product from adult does surviving from 2004 and the product from yearling females. We assigned lower productivity (1.1 fawns/doe) and fawn survivorship (37%) to yearling does than for adult does (1.9 fawns/doe, 47% fawn survivorship; S. Haskell, unpublished data).

Because the separate mark-resight fawn:doe ratios were in concordance with known-fate data in 2005 (S. Haskell, unpublished data), we used the combined doe-fawn mark-resight estimate to maximize precision of the base estimate for 2005. To this we added the buck portion of the population based on the 1:2.5 buck:doe ratio observed again in 2005.

Night survey density estimation

We used prior TPWD protocol for the area-conversion density estimator (Young et al. 1995). Any deer group observed beyond 229 m (250 yd) was discarded from the analysis. Every 161 m (0.1 mi) along a transect, we used the laser-rangefinder to estimate the distance perpendicular to the road that a deer could be seen by spotlight through brush; this estimate was subjective but has been shown to be similar among observers (Whipple et al. 1994). If topography caused 0% detectability at some mid-range of distance, then distance was taken to the near-side of the obstruction and no deer groups were recorded beyond. Perpendicular distance estimates were averaged within transects; this mean was considered the effective strip width and multiplied by the length of the transect to estimate the effective area surveyed; the number of deer observed was divided by the area estimate to obtain the density estimate for the transect. Means and measures of variability were calculated among transects as the final descriptive statistics for deer density by area-conversion. We present statistics for SL and TIR independently and in combination where the greater number of deer observed between the 2 methods was assigned to each group.

For line-transect distance sampling analyses of clustered data, we used combinations of the 3 key functions with 2 series expansions recommended by Buckland et al. (2001:47) and selected models within and among key functions by lowest Akaike's information criterion (AIC). Based on a larger region-wide dataset collected by TPWD in 2005 and 2006 (M. Lockwood, TPWD, personal communication) and the results of Gill et al. (1997), we did not use a group size adjustment for estimating the detection function. Similar to the area-conversion technique, we right-truncated data at the farthest observation <229 m. Sampling fraction was 1/2 because we only surveyed one side of a transect. We present chi-square goodness-of-fit statistics based on default software results considering the data distribution with greatest number of distance bins while allowing some pooling at farthest distances. Also, this data distribution was preferred to illustrate a peculiarity identified in our data during preliminary inspection. Given the many assumptions underlying our data, violated and remediated to varying degrees, we made qualitative comparisons among methods by examining expectations of means and 95% confidence intervals (Cherry 1998).

We used MapSource™ 4.09 (Garmin Inc.) to measure transect lengths and generate stopping points to estimate sightable distances for the old TPWD method; SAS® 9.1 (SAS Institute Inc., Cary, North Carolina, USA) to execute the mark-resight estimator; MATLAB® 6.5 (The MathWorks, Natick, Massachusetts, USA) to estimate radiotelemtry locations, locate MCP hull points, and calculate individual MCP home range areas; ArcGIS™ 9.1 (ESRI, Redlands, California, USA) for mapping and generating an MCP buffer; Distance© 5.0 Beta 5 (Thomas et al. 2005) for distance sampling analyses; and S-Plus® 7.0 (Insightful Corp., Seattle, Washington, USA) for data plots.

Results

Mark-resight density estimation

In 2004, we had 31 secondary sampling occasions and included does with live radiocollars from a previous study that were known to live in the core study area. We began the primary sampling period with 59 marked does and 22 marked fawns in the survey area. Zero does and 1 fawn died during the sampling period, and 1 fawn emigrated for 13 of 31 secondary sampling occasions. Thus, we estimated 59 marked does and 21 marked fawns available during the primary sampling period. We recorded 433 observations of deer of which 167 and 15 were unmarked and marked does, respectively, and 134 and 4 were unmarked and marked fawns, respectively. We were unable to classify 30 unmarked adults by gender, so we assigned them to gender according to the observed 1:2.5 buck:doe ratio which included more observation data from outside the survey area. Individual resighting frequencies of the 59 marked does were low and were 46, 11, and 2 for 0, 1, and 2 resight occasions, respectively. The doe population was estimated to be 779 individuals (95% CI = 531–1157, CV = 0.201), and variability around the total population estimate was even larger (Fig. 2). The population estimate projected from these data into 2005 was 2661 individuals (95% CI = 1793–3953, Fig. 2); we considered this estimate conservatively low given demographic vital rates used.

In 2005, we had 28 secondary sampling occasions and also included surviving marked female fawns from the previous year in our adult marked sample. We began the primary sampling period with 58 marked does and 27 marked fawns. Three does and 6 fawns died and 1 fawn dropped a collar during the sampling period resulting in an estimated 56 and 25 marked does and fawns, respectively, available during the primary sampling period. Two does were shot in a single incident after the 18th secondary sampling period; these does were 2 of our most sightable individuals, so the mark-resight estimate may have been slightly biased high. We recorded 704 observations of deer of which 298 and 14 were unmarked and marked does, respectively, and 232 and 6 were unmarked and marked fawns, respectively. We were unable to classify 32 unmarked adults by gender, and we assigned them to gender as above. Individual resighting frequencies of the 56 marked does were low and were 44, 10, and 2 for 0, 1, and 2 resight occasions, respectively. The combined doe-fawn population estimated by mark-resight was 2440 individuals (95% CI = 1731–3453, CV = 0.178). To this we added the buck portion based on the doe-only mark-resight estimate of 1382 individuals (95% CI = 932–2064, CV = 0.205) to yield a total population estimate of 2993 individuals (95% CI = 2104–4279, Fig. 2).

We used 3478 point location estimates, with mean estimated linear error by beacon study equal to 94.4 m, to calculate the MCP study-site home-range of the 50 deer captured and marked in 2004 (mean = 70 locations/deer, range = 40–117; Fig. 1). The area within the MCP was 85.3 km^2 which was our minimum estimate of effective area sampled. From the original 3478 point locations we identified 55 outliers within individual home-range plots. These outliers represented 1.6% of the total number of points but accounted for 37.8% of total individual home-range areas. After removing the outliers, mean individual home-range radius was 884.3 m (SE = 30.1, range = 511–1525). The area of the outer MCP including this buffer was 119.5 km^2 which was our maximum estimate of effective area sampled (Fig. 1). Considering both the projected and mark-resight population estimates in 2005, we considered a population range of 2600–3050 deer in 2005 to be reliable given predicted potential biases in dual estimates for 2005 (Fig. 2). By dividing the lower population estimate by the higher effective sample area estimate, and conversely, the higher population estimate by the lower effective sample area estimate, we obtained a robust estimate of deer density at our study site of 21.8–35.7 deer/km^2 (Fig. 3).

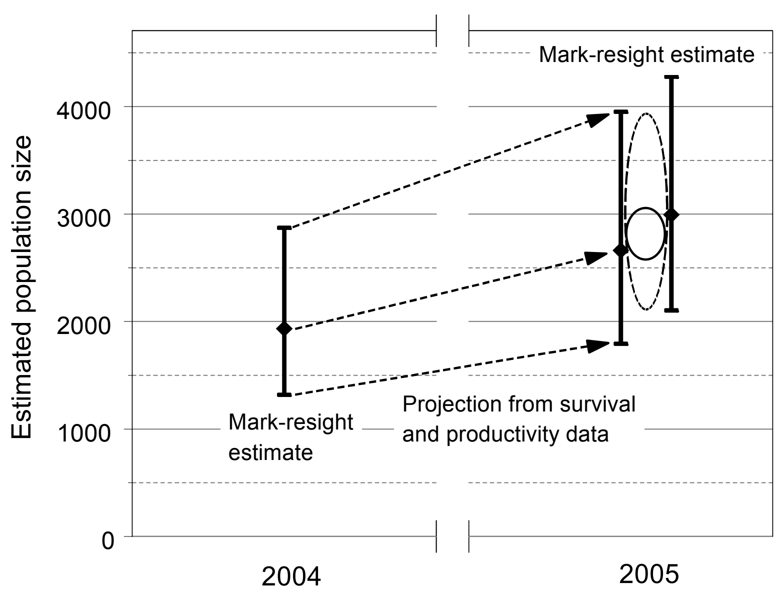
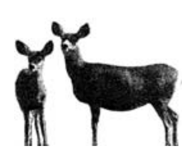


Figure 2. *Mark-resight population estimates from winter deer surveys in northwest Crockett County, Texas, 2004 and 2005. Estimate from 2004 projected into 2005 based on unpublished demographic vital rate data for a priori prediction and post hoc refinement of 2005 estimate. Larger ellipse illustrates combined 95% confidence intervals, and smaller ellipse illustrates subjective determination of a reliable estimated range of 2600–3050 deer in 2005.*



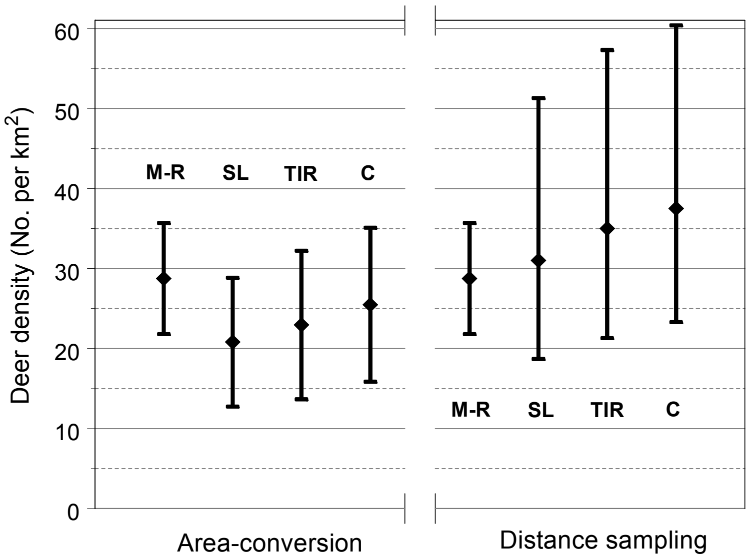


Figure 3. *Deer density estimates by nighttime surveys in northwest Crockett County, Texas, during November 2005 with a mark-resight (M-R) estimate as an independent comparative baseline. Estimates are from area-conversion (assuming 100% detectability) and distance sampling techniques using spotlighting (SL), thermal infrared imaging (TIR), and combined (C) methods. Error bars are 95% CIs around expected means.*

Night survey density estimation

We observed 86, 86, and 101 deer groups by SL, TIR, and combined SL-TIR, respectively. Each method failed to detect 15 groups detected by the other. We detected 179, 198, and 219 individuals resulting in mean group (i.e., cluster) sizes of 2.08 (SE = 0.21), 2.30 (SE = 0.24), and 2.17 (SE = 0.21) by SL, TIR, and combined SL-TIR, respectively. Effective strip width estimates among the methods were similar (Table 1). Thus, the main difference between SL and TIR was the ability of TIR to detect more individuals within groups on average. Of the 21 individuals detected by SL and missed by TIR, 0, 3, and 8 were within the first 3 SL goodness-of-fit distance intervals (i.e., <52.2 m), respectively (Fig. 4). Of the 40 individuals detected by TIR and missed by SL, 0, 3, and 11 were in similar TIR distance intervals <48.0 m (Fig. 4). These results suggested that detection probability within about 20 m of the line was excellent for both methods but did decrease consistently out to 50 m contrary to the preferred hazard-rate model expectations with relatively wide shoulders of $g(x) = 1$ (Fig. 4). Therefore, the hazard-rate model may be biased low when describing the density of deer next to roads (Table 1). There appeared to be a micro-scale redistribution of deer relative to roads with some avoidance out to about 30 m and clumping from 35–55 m (Fig. 4).

Among transects, the mean sightability distance estimated for the area-conversion technique was 122.4 m (SE = 8.5 m, range = 81.4–155.5 m). Estimated mean density varied among methods (Fig. 3), but using the more popular SL method as an example, density estimates among transects varied widely (mean = 20.8 deer/km^2, SE = 4.3, range = 6.1–42.6 deer/km^2). Our area-conversion density estimate by SL was significantly less than that by mark-resight (Fig. 3). Locating more deer, the TIR point estimate was greater than SL, but only when the two methods were combined to maximize the number of deer observed did an estimate approach that of mark-resight (Fig. 3); such an approach would be logistically prohibitive in large-scale application. Precision for both the area-conversion and distance sampling techniques was poor due to few transects with relatively large variability among transects (Table

1, Fig. 3). Due to influences of human use (e.g., livestock water tanks and feed) and other habitat heterogeneity, substantial variability among transects was probably legitimate.

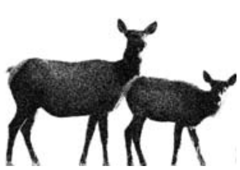
For all methods, the distance sampling hazard-rate key function was the best fit model, required no series expansion, and seemed to split the lack-of-fit area <60 m from the road transect well (Table 1, Fig. 4). Fit was poor in all models due mostly to the peak at 35–55 m. The difference in expected density between the SL and TIR hazard-rate models was due primarily to the difference in mean group size, whereas the difference in expected density between TIR and combined methods was due primarily to estimated density of clusters with the additional 15 deer groups (Table 1). Overall, the hazard-rate distance sampling model by SL technique appeared to provide the least biased point estimate of density at the study-site spatial extent using the mark-resight data for confirmation (Table 1, Fig. 3).

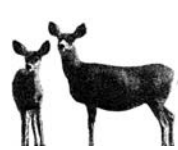
Table 1. *Results from nighttime distance sampling of deer from roads in west-central Texas, November 2005, including method used (SL = spotlight, TIR = thermal infrared imagery), model (HN = half-normal, HR = hazard-rate, U = uniform), series expansion (CO = cosine with no. orders of adjustment in parentheses, NA = not any), no. estimated parameters (K), goodness-of-fit p-value, AIC difference, and expectations of deer density (no. per km^2), effective strip width (ESW; m), and cluster density (no. deer groups/(no. km surveyed×ESW×0.1)). Coefficients of variation (CV; SE/mean) given after ESW and density estimates. Different observations preclude AIC comparisons among methods.*

Method	Key model	Series expansion	K	Pr>χ^2	ΔAIC	Deer density	CV	ESW	CV	Cluster density	CV
SL	HR	NA	2	0.125	0.00	31.0	0.242	99.18	0.09	0.149	0.221
	U	CO(2)	2	0.056	1.25	35.0	0.240	87.74	0.08	0.168	0.219
	HN	NA	1	0.070	3.96	33.2	0.235	92.23	0.07	0.160	0.213
TIR	HR	NA	2	0.328	0.00	35.0	0.239	97.12	0.10	0.152	0.215
	HN	NA	1	0.253	0.80	37.6	0.233	90.29	0.08	0.163	0.208
	U	CO(2)	2	0.196	1.69	38.3	0.236	88.72	0.09	0.166	0.212
Combined	HR	NA	2	0.107	0.00	37.5	0.229	100.14	0.09	0.173	0.208
	U	CO(2)	2	0.022	2.38	42.3	0.223	88.75	0.07	0.195	0.200
	HN	NA	1	0.026	3.43	39.9	0.223	94.06	0.07	0.184	0.200

Discussion

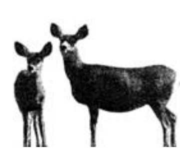
There is a need for simulation and field studies assessing methods to estimate effective area sampled in geographically open populations sampled without trapping grids. Given the relatively small home ranges and spatial concentration of marked deer at our study site and predefined survey boundaries within a comprehensive road system, we feel that our estimated range of effective area was justified (Fig. 1). This coupled with our dual approach to estimating population size in 2005 (Fig. 2) should have produced a robust estimated range of true overall deer density. Furthermore, our general predictions of potential bias in the former TPWD area-conversion and revised TPWD distance sampling techniques appeared validated. Due to disproportionate observation effort near the center of our study site and generous estimates of





individual home-range areas, we suspect that the outer MCP buffer may have overestimated effective area sampled. Thus, the true central tendency of the mark-resight density range may have been at least 30 deer/km^2 rather than 29 deer/km^2 and very near the distance sampling point estimate of 31 deer/km^2 by SL (Fig. 3). Without replication in time and space, we restrict inference from our results to northwest Crockett County, Texas, on the nights we conducted our surveys. However, apparent technique biases were as predicted a priori, and we expect that they will hold true for future analyses of deer density estimation from nighttime road surveys. Distance sampling from line transects assumes 100% detectability on the survey line, accurate distance and angle measurements, animals are not counted twice during a survey, detection of animals at initial locations, and randomly located transects (Buckland et al. 2001). Our methods should have satisfied the first 3 listed assumptions with little question. However, the data indicated fewer deer observed <35 m than would be expected with a tall peak from 35–55 m (Fig. 4), thus raising concerns for the last 2 assumptions. Others observed fewer deer than expected on and directly adjacent to roads (Kie and Boroski 1995, Ward et al. 2004), and it appears to be a statewide phenomenon in Texas (M. Lockwood, TPWD, personal communication). Previous observations were that deer were not moving away from the transect line before initial detection during surveys (Kie and Boroski 1995, Ward et al. 2004). Based on our careful attention to initial locations and deer movement behavior, we concur. We believe that these data distributions (Fig. 4) were the result of micro-scale avoidance of roads by deer before potential disturbance by observers. This relates to the last and most violated assumption of distance sampling from roads – randomness.

Roads do not offer a random sample of the landscape and can affect results in several ways (Rost and Bailey 1979, Varman and Sukumar 1995, Yost and Wright 2001, Ruette et al. 2003, Haskell et a. 2006). Wildlife managers such as those in Texas often rely on road surveys to cost-effectively sample large areas, although arguments have been made for less data that are more reliable (Rabe et al. 2002, WMI 2005). The wide detectability shoulder of the hazard-rate model characteristically produced the lowest (Buckland 1985) and apparently least biased density estimates (at the study-site spatial extent) compared to the uniform and half-normal models despite the fact that neither the SL or TIR method exhibited 100% detection from 18–50 m (Table 1, Figs. 3 & 4). The hazard-rate model may provide a more efficient estimate of the expected probability density function at distance = 0 than other models when relatively few animals are seen directly adjacent to the centerline (Buckland 1985). A pre-survey micro-scale avoidance behavior affecting results may be synonymous to movement in response to the observer but may be less correctable. Left truncation seems unjustified because distributional consequences of such a behavioral effect may inversely influence densities at farther distances as suggested by our peaked data (Fig. 4; Buckland et al. 2001). Turnock and Quinn (1991) explored a decomposition approach for movement towards the centerline which is a plausible scenario for deer habitat selection in certain circumstances, and Buckland and Turnock (1992) developed a dual platform method to record auxiliary data for movement away from the line which was refined by Palka and Hammond (2001); none can be applied to our case study. We used a monotonically decreasing detection function to reduce the bias introduced by animals avoiding the survey line (Laake 1978, Turnock and Quinn 1991). However, a standard solution to this problem seems unavailable without grouping data, thereby sacrificing accuracy and precision (Southwell and Weaver 1993, Buckland et al. 2001), but this may be acceptable for large datasets. Further investigation into this problem seems warranted (Cassey and McArdle 1999).



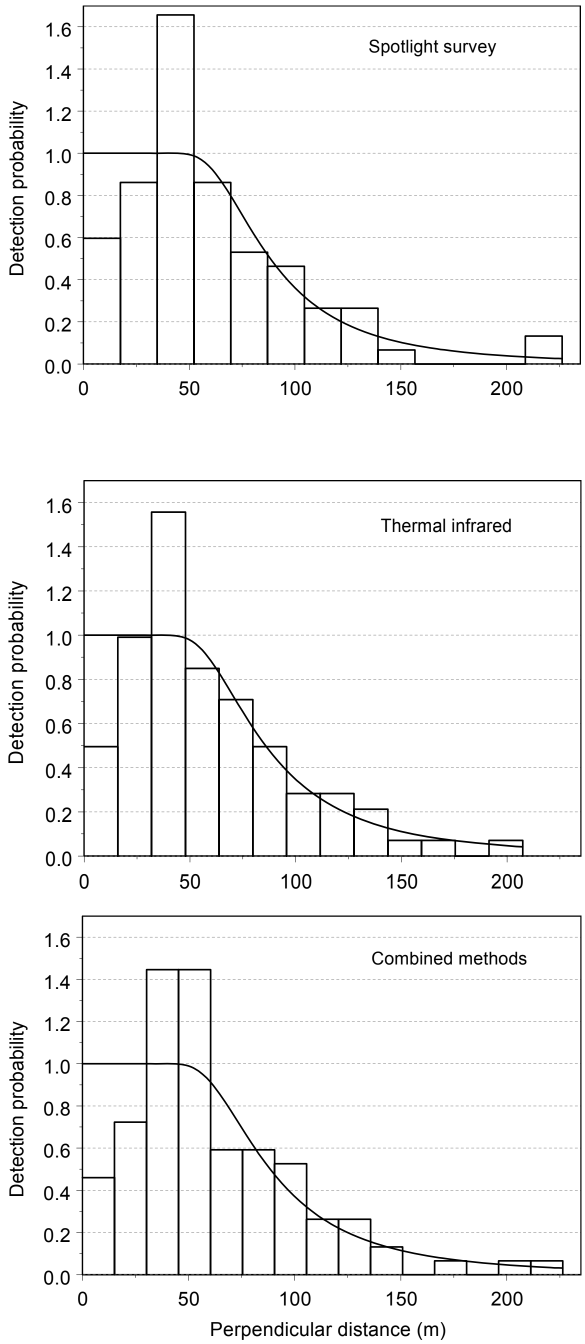
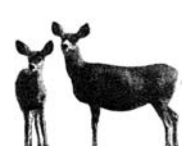


Figure 4. *Detection probabilities versus distance from roads resulting from preferred hazard-rate distance sampling models of nighttime deer survey data from northwest Crockett County, Texas, in November 2005 by spotlighting (SL), thermal infrared imaging (TIR), and combined methods. Histogram bins scaled according to goodness-of-fit test as observed frequency divided by expected. Interval cut-points are multiplicative of 17.4 m for SL, 16.0 m for TIR, and 15.1m for combined as default output data from the program Distance.*



Criticisms of nonrandom road surveys usually cite habitats and human use as two principle potential confounding factors (Buckland et al. 2001). Similar to Gill et al. (1997), we felt that our road transects included representative habitats of our study site. Also, hunting was minimal and distributed as much away from our roads as it was near so should not have induced large-scale avoidance. These concerns should be considerations for all nonrandom surveys in design and analyses. Instead, we had an a priori reason to consider a large-scale (i.e., beyond the survey strip width) clumping effect near roads as the result of habituation behavior in deer interacting with roads as semi-permeable barriers to movements (Haskell et al. 2006). The micro-scale avoidance effect (Fig. 4) and overall positively biased density estimates by distance sampling from these relatively high-use roads supported this hypothesis (Table 1, Fig. 3); deer densities may have been lesser near less traveled ranch roads. Also, with known reduced detectability after 20 m by both SL and TIR methods, the wide-shouldered hazard-rate model may have been the least biased distance sampling density estimator at the study-site spatial extent because it was negatively biased for predicting observed densities of deer next to roads. Standardizing surveys during environmental conditions that are likely to promote deer movement could allow comparability of results among surveys in this regard, but replication and calibration to more reliable estimators is necessary to help identify and control other confounding factors such as season and habitats (Progulske and Duerre 1964, Eberhardt and Simmons 1987, Whipple et al. 1994, Buckland et al. 2001, Butler et al. 2005).

Biologists have explored the use of TIR to monitor game populations for at least 40 years (Croon et al. 1968, Graves et al. 1972, Wyatt et al. 1980). Technological advancements have included improved resolution and portability of imaging systems, so biologists continue to explore the utility of these systems (Wiggers and Beckerman 1993, Gill et al. 1997, Havens and Sharp 1998, Haroldson et al. 2003, Bernatas and Nelson 2004). Efficacy of TIR may be site-specific (Ditchkoff et al. 2005, Butler et al. 2006). Regardless, comparative evaluations found greater detectability of TIR over SL in nighttime ground-based surveys (Belant and Seamans 2000, Focardi et al. 2001, Collier et al. 2007). Our results also demonstrated that TIR on average detected more deer in groups than SL for which eye-shine is the key to detectability. With greater mean group size for TIR, density estimates by distance sampling were also greater than those by SL. However, if deer cluster near roads relative to a larger spatial extent as appeared evident in our study, the detectability advantage of TIR may increase positive bias in density estimates inferred to the larger extent and thus would be undesirable (Fig. 3).

Research and Management Implications

Nonrandomness in animal surveys is often an undesirable property introducing unexplained variability and limiting scope of inference. However, if care is taken to standardize and calibrate nonrandom survey data to reliable estimates, desirable results may be achieved; this study provides an optimistic beginning. Successful integration of such survey methods will require biologists to recognize, document, and remediate potential confounding factors during design, data collection, and analyses. Spotlight survey data are often used to allot harvest permits on private lands in Texas. Texas landowners often perform their own spotlight surveys using the old area-conversion technique, while TPWD biologists survey the same regions from public roads using the new distance sampling protocols. While our results suggest that landowner estimates should be multiplied by about 1.4, a broader study examining potential methodological, biological, and anthropogenic influences is needed. If spotlight data are collected from paved roads with environmental conditions promoting deer movements, the hazard-rate distance sampling model may be accurate to estimate local deer densities in west-central Texas. These predictions may be true in other areas where habituated wildlife are surveyed from roads. However, more study is warranted to determine effects of roads on deer distributions within and beyond the effective strip width. Results from this pilot study (*n*=1) may be used to design and make predictions for a broad-scale calibration study pairing density estimates from roads with estimates from more defensible techniques (e.g., Potvin et al. 2002, 2004; Potvin and Breton 2005).

Acknowledgements

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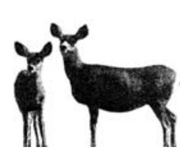

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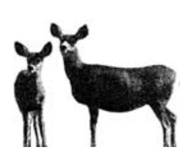

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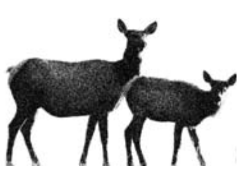

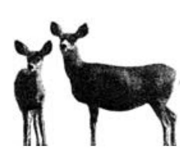

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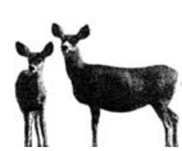

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FACTORS AFFECTING BIRTH DATES OF SYMPATRIC DEER IN WEST-CENTRAL TEXAS

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Abstract: During the course of a fawn mortality study, we investigated proximate factors affecting birth dates of sympatric desert mule deer (*Odocoileus hemionus eremicus*) and white-tailed deer (*O. virginianus*) in west-central Texas from 2004–2006. We treated this aspect of the case study as time-to-event survival (i.e., pregnancy to birth) and modeled the process with accelerated failure-time regression. Our best model included effects from 3 hierarchal levels: 1) within year variation among individuals within species, as older and heavier females birthed earlier, 2) among year variation at the population level, as greater rain during the previous pre-rut and rut periods resulted in earlier birthing, and 3) a chronic inter-generational effect also at the population level because even after previous effects were accounted for in regression models, deer birthed later on more overgrazed ranches. After accounting for weight, female age as a significant predictor may suggest a behavioral phenomenon. We did not find meaningful relationships between birth dates and either offspring gender or rain during gestation. Overall, Kaplan-Meier product-limit estimates indicated that white-tailed deer birthing peaked on 20 June (31-day 90% CI) and mule deer birthing peaked on 21 July (45-day 90% CI). We suggest that the 1-month separation between birthing and breeding periods of these sympatric deer species was due to some degree of phylogenetic constraint from parent populations and not localized adaptation with selection against hybridization. Prevention of genetic introgression may be a result by coincidence. Information from this study can be used to help determine the timing of deer surveys in autumn.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:48.

MULE DEER HABITAT IMPROVEMENT—CAN WE MITIGATE OUR LOSSES?

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Abstract: The accelerated loss of mule deer habitat across the West prompts mule deer managers to seriously consider how to better manage what is left or how might altered habitats be restored? The potential for millions of dollars to be made available and spent for so-called habitat improvements or mitigation is frightening if managers are not sure benefits can be produced. The basic questions of where, what, when, and how must be addressed before a habitat manipulation project is initiated. The first step is to decide what needs to be manipulated and for what purpose? Is cover or food (nutrition) the target of the manipulation? If food is the objective of the habitat manipulation will efforts be directed towards forage quality, forage quantity, or both? Timing of the treatments must consider moisture availability and season of predicted use. If treatments are to be effective at the population level they must be sufficiently extensive to influence the population. Thought must also be given to how the individual treatments will blend into the landscape as treatments should not be intrusive to the viewscape. To maximize success, herbivore use should be controlled on the treatment area immediately after treatment. Obviously, we cannot design our habitat manipulations with only mule deer in mind. It must be realized that what is habitat improvement for one wildlife species may be habitat destruction for another. Each of the common treatments available to managers has its pros and cons. To determine if the manipulation did any good, our habitat management actions must be designed as experiments. Evaluations including monitoring of both mule deer populations and habitats treated must be rigorous and on-going. Research has shown that one of the best population measures is fawn survival during the first year of life.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:49.

USING VAGINAL IMPLANT TRANSMITTERS TO AID IN CAPTURE OF MULE DEER NEONATES

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Abstract: Estimating survival of the offspring of marked female ungulates has proven difficult in free-ranging populations yet could improve our understanding of factors that limit populations. We evaluated the feasibility and efficiency of capturing large samples (i.e., >80/year) of neonate mule deer (*Odocoileus hemionus*) exclusively from free-ranging, marked adult does using vaginal implant transmitters (VITs, n = 154) and repeated locations of radio-collared does without VITs. We also evaluated the effectiveness of VITs, when used in conjunction with in utero fetal counts, for obtaining direct estimates of fetal survival. During 2003 and 2004, after we placed VIT batteries on a 12-hour duty cycle to lower electronic failure rates, the proportion that shed ≤3 days prepartum or during parturition was 0.623 (SE = 0.0456), and the proportion of VITs shed only during parturition was 0.447 (SE = 0.0468). Our neonate capture success rate was 0.880 (SE = 0.0359) from does with VITs shed ≤3 days prepartum or during parturition and 0.307 (SE = 0.0235) from radio-collared does without VITs or whose implants failed to function properly. Using a combination of techniques, we captured 275 neonates and found 21 stillborns during 2002–2004. We accounted for all fetuses at birth (i.e., live or stillborn) from 78 of the 147 does (0.531, SE = 0.0413) having winter fetal counts, and this rate was heavily dependent on VIT retention success. Deer that shed VITs prepartum were larger than deer that retained VITs to parturition, indicating a need to develop variable-sized VITs that may be fitted individually to deer in the field. We demonstrated that direct estimates of fetal and neonatal survival may be obtained from previously marked female mule deer in free-ranging populations, thus expanding opportunities for conducting field experiments. Survival estimates using VITs lacked bias that is typically associated with other neonate capture techniques. However, current vaginal implant failure rates, and overall expense, limit broad applicability of the technique.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:50.

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PREDICTING WINTER MULE DEER FAWN SURVIVAL FROM LANDSCAPE ENVIRONMENTAL VARIABLES

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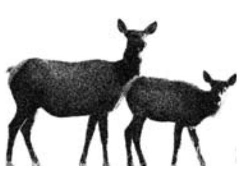
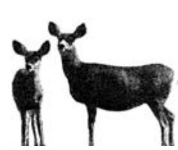
Abstract: Over-winter mule deer fawn (*Odocoileus hemionus*) survival exhibits high annual variation and thus is a major component of population change. To account for this annual variation, Idaho's mule deer monitoring program has included measures of winter fawn survival since 1998. From 185 to 253 6-month old fawns were marked with radio-collars within 6 permanent and 3-4 roving sites each year. Monthly precipitation and temperature spatial data modeled across the landscape at 2 km resolution were obtained from Climate Source Inc., Corvallis, OR. The climate data were combined into time periods based on plant phenology and biological significance to mule deer, primarily nutritional intake or energy expenditure. Habitat maps of large-scale ecological systems (developed by NatureServe) were used to characterize the diverse mule deer habitat in Idaho. We estimated seasonal 95% kernel home ranges (April through September and October through March) from the cumulative sample of radio collared fawn locations for each site, 1998-2006. The spatial climate and habitat layers were clipped with the seasonal home ranges to provide information specific to the study site by season. Known fate survival models were constructed in a stepwise regression fashion with a sample of 1093 fawns marked in the 6 permanent study sites. Variables were included if they were statistically significant ($P < 0.05$) and AIC scores were declining. The remaining 758 fawns captured in 16 roving study sites will be used to validate models. Winter survival was divided into 5 month-long time periods beginning 15 December and ending 15 May. The first preliminary modeling effort examined all climate and habitat variables. The variables significantly related to fawn survival were: minimum winter monthly temperature, January-March precipitation, October precipitation, previous winter precipitation, April-July precipitation, and a winter dispersion and juxtaposition index for the sagebrush cover type. The fitted model explained 67.2% of the overall variability in fawn survival estimates. The model explained 94% of the variability after adjusting for sampling error. Individual covariates of fawns; mass, chest girth, hind foot length, and sex were also collected upon capture. A second preliminary model was produced using the same criteria to enter the individual covariates into the above fitted model, except a likelihood ratio test was used to identify significance. Mass, chest girth, and sex significantly improved the first model. A third model examined only climate and habitat variables available prior to 1 January. The variables entered into this model included: October temperature, April-July precipitation, percent shrub cover on winter range, August-September precipitation, and percent





forest cover on winter range. This model explained 56.85% of the total variability in fawn survival and 79.5% of the variability when corrected for sampling variance. In the search for patterns contributing to fawn survival, landscape environmental variables were useful for predicting winter fawn survival with a high degree of certainty. Even more promising was the ability to predict fawn survival prior to the upcoming winter, allowing managers the lead time needed to change management direction prior to the next hunting season.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:51-52.

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BUILD IT AND THEY WILL COME: THE REALITIES OF QUALITY MULE DEER MANAGEMENT IN THE GUNNISON BASIN

BRANDON DIAMOND, Colorado Division of Wildlife, 300 W. New York Ave., Gunnison, CO 81230, USA

Abstract: The Gunnison Basin is made up of three Data Analysis Units which are comprised of five Game Management Units. When all Colorado mule deer licenses became limited in 1999, buck licenses in the Gunnison Basin were reduced by 90%, which at the time was based largely on public sentiment. These drastic reductions resulted in rapidly increasing buck:doe ratios and the abundance of older age class bucks. Trophy mule deer bucks are perhaps the most sought after big game animal in the west and hunters are continuously seeking opportunities to hunt trophy deer. Technological and societal changes over the last ten years (i.e., internet, hunting media, hunting consultants) have led to an environment where hunting "hot-spots" may be quickly disseminated to the hunting community. The Gunnison Basin has received national notoriety as one of the premier places in the west to find a trophy mule deer buck, which has resulted in several unforeseen consequences. The number of applicants for limited licenses has more than doubled since 1999 which has greatly diminished hunting opportunities for deer hunters. Human activities on important seasonal mule deer ranges have increased many-fold over the last five years and are of great concern to local resource managers. Shed antler hunting in particular is resulting in undesirable levels of disturbance not only to wintering mule deer but to other sagebrush obligate species such as the Gunnison sage grouse. The escalating cost of landowner vouchers in these units and hunting by "Governor's tag" holders in the Basin is fostering the perception that hunting is becoming a rich man's sport, which has led to debate pertaining to the philosophy behind "trophy" hunting. Law enforcement issues are ever present, and violations such as harassing wildlife with aircraft during scouting flights, illegal outfitting, and "high grading" are becoming more common. Mixed opinions regarding mule deer management has led to community strife, and in certain instances, bitter rivalries between families and individual constituents. There are recent indications that some Colorado hunters are willing to sacrifice hunting opportunity for quality management, however many hunters may not understand the long-term impacts of those decisions. Hunters and managers alike should recognize and preemptively discuss the realities of quality management prior to initiating such prescriptions.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:53.

EVALUATION OF A "TEST & CULL" STRATEGY FOR MANAGING CHRONIC WASTING DISEASE IN URBAN MULE DEER

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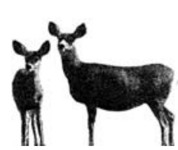
Abstract: Chronic wasting disease (CWD) is a contagious prion disease of native North American deer and elk that has been targeted for control in most jurisdictions where it has been detected. Relatively high CWD prevalence occurs in mule deer populations associated with urban areas along Colorado's northern Front Range. Although hunting may be the preferred means of controlling CWD in many areas, this strategy has limited application in controlling most urban and suburban deer populations. Moreover, epidemic models suggest that selective culling may be more effective than random culling (e.g., harvest) in rapidly lowering CWD prevalence when a large proportion (>50%) of the population can be tested reliably and when infected individuals can be removed relatively early in the course of disease. Over a 5-year period from 2002–2007, field personnel from the Colorado Division of Wildlife and National Park Service annually darted and tonsil biopsied about half of the estimated mule deer population wintering in Estes Park and Rocky Mountain National Park in an attempt to lower prevalence. Prior to release, each animal was marked with ear tags and radio telemetry; test-positive deer were located and either shot or recaptured and euthanized. This study will be completed in June 2007; although our data set is incomplete and remains to be analyzed, we will report preliminary findings on CWD prevalence trends in the Estes Park area over the course of this study.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:54.



THE INFLUENCE OF SUMMER AND AUTUMN FORAGE QUALITY ON BODY CONDITION AND REPRODUCTION OF LACTATING MULE DEER AND THEIR FAWNS (*ODOCOILEUS HEMIONUS*)

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LISA A. SHIPLEY, Department of Natural Resource Sciences, Washington State University, Pullman, WA 99164-6410, USA
WOODY MYERS, Washington Department of Fish and Wildlife, 2315 Discovery Place, Spokane Valley, WA 99216, USA

Abstract: Mule deer populations have been declining in the western United States for several decades, but until now most studies have focused on either predation or over-winter survival without considering the importance of summer and autumn nutrition. A decrease in the quantity and/or quality of forage in the months proceeding the breeding season has been linked to decreased fertility in several ungulate species and domestic livestock. We simulated the decline in the digestible energy content of forages during summer and fall under a range of habitat conditions, and measured intake, nursing behavior, milk quality, body condition, blood hormones, estrus and pregnancy in captive mule deer and examined how these factors influenced fawn production, growth, and survival. Both lactating does and their fawns increased their dry matter intake (DMI) to try and compensate for a decrease in digestible energy (DE) content of the diet, but did not consume as much DE per day as those feeding on higher quality feed. Probability of pregnancy and twinning increased when does ingested more DE and had more body fat. Measures of the blood hormones insulin growth factor 1 and leptin taken at the beginning of November provided a weak index of pregnancy, twinning and DEI intake. Fawns on the lower DE diet nursed more often, which corresponded with a decline in body condition, and their nursing attempts were rejected more often by their mothers. They also had poorer survival until weaning. Mule deer may fail to become pregnant when forage quality in summer and autumn is especially poor, but our data suggest that food quality has a more drastic effect on fawn growth and survival, therefore, potentially reducing recruitment into the adult population.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:55.

NORTH AMERICAN MULE DEER HABITAT GUIDELINES

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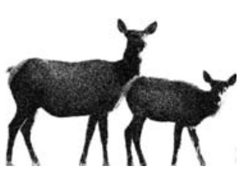
Abstract: In 1997, the Western Association of Fish and Wildlife Agencies (WAFWA) established a Mule Deer Working Group (MDWG) consisting of a representative from each of the 23 member states and Canadian provinces. Since that time, the working group has been successfully addressing mule and black-tailed deer concerns shared among wildlife agencies in western North America. The many accomplishments of the MDWG include a book summarizing the current knowledge, challenges, and opportunities for the important issues identified by leading mule deer experts (*Mule Deer Conservation: Issues and Management Strategies 2003*), a popularized version of this book for easy reading by non-biologists (*Mule Deer: Changing Landscapes, Changing Perspectives*), the *North American Mule Deer Conservation Plan*, assistance with the development and maintenance of a mule deer information website (www.muledeernet.org later replaced by www.muledeerworkinggroup.com), and an interactive GIS map of North American black-tailed and mule deer habitat features. One of their current projects has the potential to provide for the greatest benefit to mule deer habitat on a landscape scale. The working group is in the process of producing a set of mule deer habitat guidelines for each of the 7 ecoregions they identified in North America. When complete, these will have the potential to improve black-tailed and mule deer habitat on a landscape scale by allowing federal, state, local, private, and tribal land managers to fold mule deer habitat requirements into land management plans. The Mule Deer Habitat Guidelines for the *Southwest Deserts Ecoregion* have already been published and the other 6 are now being written simultaneously for the *Intermountain West, Northern Forest, Coastal Rainforest, Colorado Plateau, California Woodland and Chaparral,* and *Great Plains*. This presentation will serve to highlight the main issues mule deer and blacktails face in each ecoregion and discuss some of the guidelines for habitat management. The content and potential use of this 7-part series will be illustrated to allow the MDWG to receive feedback on how best to implement these guidelines most effectively.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:56.



A STATE'S PERSPECTIVE ON IMPLEMENTING MULE DEER CONSERVATION FROM GUIDELINES PROVIDED

MIKE COX, *Nevada Department of Wildlife, 1100 Valley Road, Reno, NV 89512, USA*

Abstract: The Western Association of Fish and Wildlife Agencies Mule Deer Working Group (MDWG) has provided guidance and valuable information to assist state mule deer and habitat managers in the proper management of mule deer herds and their habitats. Motivated by the MDWG's efforts and faced with major habitat challenges, the Nevada Department of Wildlife (NDOW) has recently focused a considerable amount of time on mule deer management planning and programming to help prevent further mule deer population declines. The first major exposure to the MDWG for NDOW big game biologists was the Mule Deer Mapping Project. It was a valuable experience to update mule deer herd's seasonal habitat boundaries but more importantly it forced each biologist to identify the current and future limiting factors to each habitat area. A copy of the technical book "Mule Deer Conservation: Issues and Management Strategies" published in 2003 was provided to each field biologist as a critical reference and guide to appreciating the primary factors that influence mule deer herds westwide. In 2004, NDOW biologist Tony Wasley, authored the scientific bulletin, "Nevada's Mule Deer Population Dynamics: Issues and Influences". This publication provided an important historic perspective on Nevada mule deer trends, evaluation of habitat factors and associated climate/weather data, a compilation of decades of survey and harvest data, review of major mortality factors, and a flowchart displaying how all the factors and issues interact to influence mule deer population dynamics and habitat. Tony was then asked to lead the development of the Intermountain West Mule Deer Habitat Guidelines, which provided a great perspective and conformation to NDOW on issues and viable solutions to mule deer habitat conservation and restoration that Nevada shares with the rest of the ecoregion. The work on the ecoregion habitat guidelines directly led to the logical extension and crafting of NDOW's Mule Deer Management Prescriptions for individual management units. The prescriptions focus on specific needs to improve mule deer habitats at an individual herd basis. For example, strategies and actions are identified to reverse plant senescence with the use of a Dixie harrow or roller chopper for decadent browse on specifically named benches, slopes, and creek bottoms with actual acreage values. Or for urbanization concerns, specific ranches and properties are named for potential conservation easement or acquisition efforts. Along with the completion of the "North American Mule Deer Conservation Plan" and Nevada's first ever "Management Plan for Mule Deer" completed in 2006, the framework and blueprint for Nevada's mule deer conservation is nearing completion. Now the hard part begins with sharing all this information and guidance with land managers and sportsmen, increasing staffing levels, championing and encouraging project planning and approval processes on public and private lands, pooling available funding to support the work, and establishing monitoring programs to assess the success of these on-the-ground projects.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:57.

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DEER & ELK GENERAL SESSION

Moderator: BRUCE E. WATKINS, Colorado Division of Wildlife

COMBINED INTERNET AND TELEPHONE HARVEST SURVEYS: EXAMINING RESPONSE DIFFERENCES BY MODE AND EFFORT

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Abstract: Big game harvest surveys are an important tool for obtaining data on harvest. The Colorado Division of Wildlife (CDOW) traditionally used live operator telephone surveys to estimate harvest. The cost of conducting telephone surveys has increased rapidly while the response rate has decreased. For these reasons, CDOW switched to a combination internet, interactive voice response and live operator telephone survey. Despite significant implementation hurdles, the survey was successful. The survey was considerably less expensive to implement. Results were very similar to past years' surveys. The response rate dropped from approximately 55% with the telephone surveys to 45% with the new design. The new survey design allowed additional data to be collected on hunter response behavior. Hunter responses were compared across survey mode type and by effort required to contact a hunter. No differences were found by survey mode, but differences were detected by survey effort suggesting nonresponse bias may exist.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:59.

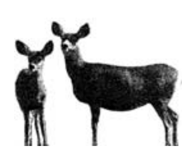
PRIONS IN THE WILD: EPIDEMIOLOGY AND ECOLOGY OF CHRONIC WASTING DISEASE

MICHAEL W. MILLER, Colorado Division of Wildlife, Wildlife Research Center, Fort Collins, Colorado, USA.

Chronic wasting disease (CWD) occurs naturally in North American deer (*Odocoileus* spp.), wapiti, and moose (Cervidae). CWD presently occurs in scattered foci throughout North America, both in the wild and in commercial facilities (Williams 2005), and its true distribution is undoubtedly underestimated. CWD is contagious among its natural hosts. Epidemics can persist under both captive and free-ranging conditions, resulting in remarkably high infection rates. Empirical study has recently demonstrated infectivity in both saliva and blood from CWD-infected mule deer (Mathiason et al. 2006), suggesting there are at least two plausible sources of contagion; accumulations of disease-associated prion protein in lymphatic tissues associated with the gastrointestinal tract suggest that shedding via feces also is likely, and infectivity in blood also could be a source of shedding via urine. Analyses of epidemic data suggest that indirect (animal-environment-animal) transmission may be the dominant force in epidemic dynamics (Miller et al. 2006), and the CWD agent has been shown to persist in environments contaminated by excreta or carcass remains for years. Variation in cellular prion protein appears to influence CWD pathogenesis (Fox et al. 2006), and may provide a biological mechanism for emergence of variant strains within and among the four naturally susceptible species. The long-term implications of CWD for public, livestock, and wildlife health remain uncertain; however, it appears possible that unmanaged CWD epidemics could do substantial harm to ecosystems in which they occur. Unfortunately, limitations of existing technology available to combat prion diseases make control of CWD ineffective or infeasible under most conditions.

Fox, K. A., J. E. Jewell, E. S. Williams, and M. W. Miller. 2006. Patterns of PrP^{CWD} accumulation during the course of chronic wasting disease infection in orally inoculated mule deer (*Odocoileus hemionus*). Journal of General Virology 87:3451-3461.
Mathiason, C. K., J. G. Powers, and S. J. Dahmes, D. A Osborn, K. V. Miller, R. J. Warren, G. L. Mason, S. A. Hays, J. Hayes-Klug, D. M. Seeling, M. A. Wild, L. L. Wolfe, T. R. Spraker, M. W. Miller, C. J. Sigurdson, G. C. Telling, and E. A. Hoover. 2006. Infectious prions in the saliva and blood of deer with chronic wasting disease. Science 314:133-136.
Miller, M. W., N. T. Hobbs, and S. J. Tavener. 2006. Dynamics of prion disease transmission in mule deer. Ecological Applications 16: 2208–2214.
Williams, E. S. 2005. Chronic wasting disease. Veterinary Pathology 42:530-549.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:60.



ANALYSIS OF CARBON AND NITROGEN ISOTOPES IN LARGE MAMMALS: A FOUNDATION FOR FUTURE RESEARCH

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TERESA J. ZIMMERMAN, Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007, USA

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Abstract: Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes in tissues can be used to identify photosynthetic pathways (C_3 vs. C_4) of plants consumed and potential nutritional consequences. We assessed $\delta^{13}C$ and $\delta^{15}N$ in various tissue samples to highlight the usefulness of stable isotopes for large-mammal research. Liver samples from mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*) differed in $\delta^{13}C$ and $\delta^{15}N$ for deer using burned versus unburned habitats. Annual variations in diets of deer were documented 2–3 years post-fire in response to lag-time affects of vegetative response to burning. Carbon and nitrogen isotopes in tissues of varying metabolic activity (i.e., muscle, hoof) differed among 3 subpopulations of Rocky Mountain elk (*Cervus elaphus*) indicating temporal dietary shifts of individuals occupying disparate native range and human-derived agricultural landscapes. Stable isotopes of carbon and nitrogen in 2-cm intervals along elk hooves identified temporal shifts in dietary selection in a single tissue type. Carbon isotopes of the composite hoof were similar to the 3-cm interval (i.e., 3 cm from the distal end of hoof) but the complete hoof differed in $\delta^{13}C$ from 1-cm and 5-cm intervals. Elk fecal $\delta^{13}C$ and $\delta^{15}N$ also identified differences in consumption of C_3 versus C_4 plants. Analyses of isotopes in various tissues can elucidate aspects of foraging and nutritional ecology of sympatric ungulates and conspecifics.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:61.

EXTREME WEATHER AS A MORTALITY FACTOR IN DEER AND ELK

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ABSTRACT Mortality and stress from severe weather are common phenomena in wildlife populations. Prolonged periods of high temperatures and droughts may cause mortality and reduce recruitment in populations as well as modify habitat which may influence populations for prolonged periods after the drought. Periodic blizzards through much of the range of mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) reset their population levels. The winter of 2006-07 was exceptionally severe for the high plains of Kansas. Livestock losses in the thousands were reported, however, reports of mortality in mule deer were uncommon. Fat indices in femur marrow from mule deer killed near the end of the yarding period showed that the majority were in good or fair condition. Mule deer coped with that storm. Short duration events such as flash floods, hail storms, ice storms, lighting storms, and high winds may cause localized high mortality. This presentation examines literature for lightning and tornado deaths in deer and elk populations. It also documents a tornado on March 28, 2007 in Cheyenne County, Kansas that killed at least 18 adult mule deer.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:62.

ELK MANAGEMENT SYMPOSIUM. DECLINING CALF/COW RATIOS: ARE ELK POPULATIONS APPROACHING K?

Moderator: DAVID J. FREDDY, Colorado Division of Wildlife

EVIDENCE OF DENSITY DEPENDENCE IN COLORADO ELK POPULATIONS

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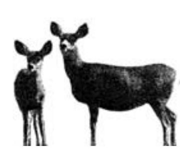
BRUCE E. WATKINS, Colorado Division of Wildlife, 2300 South Townsend Avenue, Montrose, CO 81401 USA

Abstract: Elk (*Cervus elaphus*) populations in Colorado are expected to show density-dependent responses in recruitment if these populations are approaching *K* carrying capacity. We examined calf:cow ratios from 36 data analysis units (DAU) for evidence of density dependence. Recruitment (calves:100 cows) estimated from Dec–Jan helicopter surveys showed a clear downward trend since 1980 for the combined data, with −0.36 (SE = 0.048) fewer calves per 100 cows each year. For the 36 DAU with at least 10 years of data, 29 had negative estimates of the trend in calf:cow ratios. Thus, recruitment is clearly declining with time. However, elk density covariates do not clearly explain this decline. We regressed calf:cow ratios against annual population size from elk management models for 32 DAU with at least 10 years of data. Only 17 of these regressions had negative slopes, indicating density dependence, but of these, 14 DAU had significantly ($P < 0.2$) negative slopes. We also regressed calf:cow ratios against over-the-counter bull harvest as a surrogate of population size for 31 DAU with at least 10 years of data. Only 9 of these regressions had negative slopes, and only one was marginally significant ($P = 0.08$). Thus, increases in over-the-counter bull harvest did not predict the negative decline in calf:cow ratios on a DAU basis. However, this analysis lacks statistical power in that 31 separate estimates of the effect of bull harvest on calf:cow ratios were generated. To achieve higher power, the calf:cow ratios and bull harvest values were standardized within each DAU by subtracting off the mean value and dividing by the standard deviation. The result is that all of the DAU estimates are now comparable. To test for density dependence, all 461 of the standardized calf:cow ratios were predicted by the standardized bull harvest using a quadratic model with no intercept. The resulting equation demonstrated density dependence with the quadratic term negative (−0.0593, SE = 0.0288, $P = 0.040$). This equation predicts maximum calf:cow ratios at 1.57 SD above the current mean bull harvest for each DAU, and 0.148 SD above the current mean calf:cow ratio. We conclude that Colorado elk populations are approaching *K* carrying capacity in some DAU, reflected by reduced calf:cow ratios.

Elk data from Idaho, Nevada, Oregon, Utah, and Wyoming were also examined. Idaho, Oregon, and Wyoming data showed clear declines in calf:cow ratios through time, but data from no state showed a relationship of calf:cow ratios to bull harvest.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:64.



DECLINING ELK CALF RECRUITMENT IN IDAHO AND THE SEARCH FOR DENSITY DEPENDENCE

GEORGE R. PAULEY, Idaho Department of Fish and Game, Rt 2 Box 192, Kamiah, ID 83536, USA

Abstract: I examined the downward trend of elk (*Cervus elaphus*) calf recruitment in Idaho using composition surveys conducted 1973 to 2006, and sightability surveys conducted from the late 1980's to 2007. There was no relationship between year-round elk densities among Game Management Units (GMU's) and recruitment represented by winter calf:cow ratios ($r^2 = 0.004$, $F = 1.13$, $P = 0.289$). There was a weak, positive relationship between recruitment and scaled abundance, and a somewhat stronger relationship when only GMU's with a minimum 50% change in abundance were included in the analysis ($r^2 = 0.07$, $F = 8.86$, $P = 0.004$). I found 22 declines in elk abundance that were detectable with sightability estimates. Six abundance declines were caused by low recruitment, and 16 declines were caused by substantial antlerless harvests. Following recruitment caused abundance declines (mean = -50%), recruitment rates declined further from a mean of 26 calves:100 cows to 18:100 ($t = 4.90$, $P = 0.004$). Following harvest caused population declines (mean = -40%), recruitment rates declined from a mean of 37 calves:100 cows to 29:100 ($t = 4.99$, $P < 0.001$). Recruitment rates remained low and failed to return to pre-decline levels for 6 years. These results imply an inverse density dependent relationship (recruitment declines with declining density) that cannot be explained by short-term time lags. Additionally, population models revealed that the presence of inverse density dependence cannot be explained by adult cow senescence. Declining recruitment was strongly associated with increasing mountain lion (*Felis concolor*) harvests and wolf (*Canis lupus*) abundance in Idaho ($r^2 = 0.64$, $F = 54.58$, $P < 0.001$). Idaho elk populations may largely exist below optimum yield thresholds where inverse density dependent effects of predation might overwhelm density dependent responses to resource limitations.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:65.

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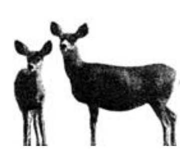

FACTORS AFFECTING ELK RECRUITMENT IN OREGON

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Abstract: Elk (*Cervus elaphus*) recruitment and estimates of calf elk survival in Oregon have varied widely across time and space. Since 1967, Oregon hunters have collected nearly 10,000 reproductive tracts, kidneys and associated fat, mammary tissue, and lower jaws from cow elk killed during hunting seasons in late autumn and early winter. These samples provide data on pregnancy and lactation status, age, and body condition of populations of both Rocky Mountain and Roosevelt elk. Concomitantly, Oregon Department of Fish and Wildlife (ODFW) biologists have estimated yearly spring calf-to-cow ratios and population numbers. Cougars (*Felis concolor*), a predator of elk in Oregon, were declared a game species in the state in 1965, and sport hunting of cougars began in 1970. The cougar population in Oregon has expanded from an estimated 200 animals in 1965 to >3,000 in 2006. In 2001, ODFW initiated research to investigate factors affecting elk calf survival by measuring nutritional condition of cow elk and their reproductive status, survival of their calves, causes of mortality of elk calves, and densities of cougars and black bears (*Ursus americanus*). I will present a brief summary of broad patterns evident in these data sets and a case example from our ongoing research in northeastern Oregon.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:66.

MULTI-REGIONAL NUTRITIONAL CONDITION EVALUATION FOR ELK: PRELIMINARY RESULTS AND IMPLICATIONS

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Abstract: Over the last decade, population declines in elk herds have been reported in the northwestern U.S., and it is possible that inadequate nutrition might play a role in some instances. However, very little is known of the extent of nutritional influences on herds of the western United States. From 1998-2007, we measured body fat and other indices of nutritional condition, pregnancy and lactation status, age, body mass, and other variables from adult female elk in 21 herds from southern Colorado to western South Dakota and to Northwest Washington and Southwest Oregon. Total number of capture operations per herd ranged from 1 to 15 ($n \geq 10$ to 100 elk per capture event), and in most cases, the operations were conducted twice annually (Mar and Nov) using a repeated measures approach. Substantial variation existed in nutritional condition as indexed by body fat levels, with herd averages ranging from 2.5 to 9% body fat in spring and, for lactating females, 5 to 13% in autumn. Body mass of adult cows in autumn ranged from 200 to 250 kg and winter weight loss averaged 10 to 15% in most

herds. Autumn lactation rates ranged from 20 to 70% and pregnancy rates of the lactating cows ranged from 50 to 95%. All-in-all, our data indicate that inadequate nutrition in both summer and winter is a widespread phenomenon across the regions of our study, the magnitude of its effects are highly variable among herds and regions, and that, ultimately, its effects often may involve complex interactions with other potentially limiting factors.

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ELK GENERAL SESSION

Moderator: CHAD J. BISHOP, Colorado Division of Wildlife

ELK MOVEMENTS IN RESPONSE TO HUNTING PRESSURE IN THE GREAT SAND DUNES AREA, COLORADO

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Abstract: The elk (*Cervus elaphpus nelsoni*) population in the northeastern portion of the San Luis Valley of south-central Colorado has reached a population size that exceeds population management objectives of the Colorado Division of Wildlife. The Great Sand Dunes Complex (GSDC), comprised of 5 different land administrative agencies and policies, has potentially created a refuge for elk which reduces opportunities to harvest elk and alters distribution. Two primary entities of the GSDC were the Great Sand Dunes National Park and the Baca National Wildlife Refuge, referred to in this study as the park-refuge complex (PRC), which formed a large area effectively closed to all hunting. We monitored movements and distribution of elk having GPS and VHF radio collars that were associated with the GSDC from February 2005 to March 2006. Movement paths of elk indicated movements into the PRC corresponding to the onset of fall hunting seasons. Using PROC NLMIXED in SAS, we examined models of elk use of PRC relative to the initiation of hunting season. For both GPS and VHF elk location data, models which included hunting season + random effects had the lowest AIC and greatest model weight, indicating that the elk were likely using the PRC area as a refuge to avoid hunting pressure. Without any type of active elk population management within the GSDC, land managers may be running the risk that the elk population will continue to increase in number and cause negative impacts on native plant ecosystems and nearby highly-valued agricultural crops.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:70-89.

Keywords: *Cervus elaphus nelsoni*, Colorado, Great Sand Dunes, hunting pressure, movement, radiotelemetry, San Luis Valley.

During the last 20 years, the elk (*Cervus elaphpus nelsoni*) population in the northeastern portion of the San Luis Valley (SLV) has grown to a suspected minimum size of 6,000 elk with nearly 4,000 animals concentrated within the Great Sand Dunes Complex (GSDC) during winter. During the last several years, post hunting season (January) calf to adult cow ratios have varied between 20–30 calves:100 cows, which are among the lowest ratios observed in Colorado. These low ratios reinforce the concern that elk may be exceeding nutritional carrying capacities of some critical habitats, especially during the current 6-year period of prolonged natural drought (Doesken 2004).

High densities of elk in Rocky Mountain National Park (RMNP) and Yellowstone National Park (YNP) have been shown to be correlated to negative impacts on plant species and their related ecosystems including willows (*Salix* spp.), aspens (*Populus tremuloides*), cottonwoods (*Populus* spp.), and grasses (Peinetti et al. 2002, Zeigenfuss et al. 2002, Weisberg and Coughenour 2003, Schoenecker et al. 2004, Beschta 2005, Gage and Cooper 2005, Larsen and Ripple 2005). These vegetation impacts include plant community structure, succession, productivity, species composition, and overall habitat quality. A tropic cascade effect can then negatively impact other vertebrate and invertebrate communities associated with the affected vegetation. With the newly created Great Sand Dunes National Park (GSDNP) and Baca National Wildlife Refuge (BNWR), there are potential refuges for elk during hunting season similar to those of RMNP and YNP which result in limited checks on population growth and areas of high elk density. Vegetation damage and ecosystem alteration in the GSDC will likely mirror those of these other parks if the population of elk is allowed to grow at its current pace. Currently, elk are thought already to be causing damage to native plant communities in some areas within the GSDC (Schoenecker et al. 2006).

High-value agricultural crops produced with center-pivot irrigation lie just a few miles west of high elk density areas associated with the GSDC. In recent years, an estimated 200 – 700 elk have been using the agricultural lands between Colorado Highway 17 and US Highway 285 during April through September. Elk in this area between the highways have the potential to cause several hundred thousand, if not millions of dollars of agricultural damage by consuming and trampling crops and indirectly by spreading crop diseases into certified seed fields.

Elk within the GSDC represent a major portion of the elk in the Colorado Division of Wildlife (CDOW) population Data Analysis Unit E-11 (DAU E-11). In the northern portion of DAU E-11, where public access hunting is best, elk harvest during the fall has been disappointing despite an increase in antlerless elk permits over the past several years (personal communication, B. Watkins, CDOW). Thus, there may have been a redistribution of elk that confounds the ability of managers to harvest elk. Elk respond to hunting pressure by moving to areas of refuge where hunting pressure is less or non-existent (Burcham et al. 1999, Millspaugh et al. 2000, Conner et al. 2001, Vieira et al. 2003), such as areas within the GSDC. Such refuges may reduce the effectiveness of traditional hunting seasons and harvest strategies to adequately control population size. Implementing herd reduction strategies is confounded by complex land-use and hunting restriction policies of the different public and private agencies that create refuges for elk which effectively reduce the vulnerability of elk to traditional hunting or herd reduction actions.

To justify the hypothesis that harassment methods similar to hunting will redistribute elk, we must first establish a probable correlation between hunting seasons and movement into the GSDC. Elk movements as a result of future potential harassment experiments on elk within the GSDC could then be compared to this one-year baseline movement pilot study. This pilot study addressed the issue of elk using the GSDC as a refuge during hunting season and attempted to assess whether hunting pressure was a likely cause of elk movement onto the GSDC during the fall.

Study Area

Our study was focused on movements of elk inhabiting the eastern portion of the San Luis Valley (DAU E-11) from 1 July 2005 to 31 December 2005, an area of approximately 2010 mi^2 (520,774 ha). The GSDC area was defined by the southern border of the Medano-Zapata ranch to the south, Saguache County Road T to the north, Colorado Highway 285 to the west, and the summit of the Sangre de Cristo Range to the east (Fig. 1).

Within the study area there are 5 different land management agencies including: Colorado Division of Wildlife (CDOW), U.S. Department of Interior (GSDNP-Greater Sand Dunes National Park), U.S. Fish and Wildlife Service (BNWR-Baca National Wildlife Refuge), The Nature Conservancy (TNC-Medano-Zapata Ranch), and the Department of Agriculture (U.S. Forest Service-San Isabel and Rio Grande National Forests). There are also private lands which border these agency lands. The main agricultural area of concern lies just west of Colorado Highway 17, which adjoins lands managed by TNC, GSDNP, and BNWR (Fig. 1). GSDNP and most of the BNWR were not open to elk hunting during the 2005 hunting season.

For the purpose of this paper, this area which was not hunted will be referred to as the park-refuge complex (PRC).

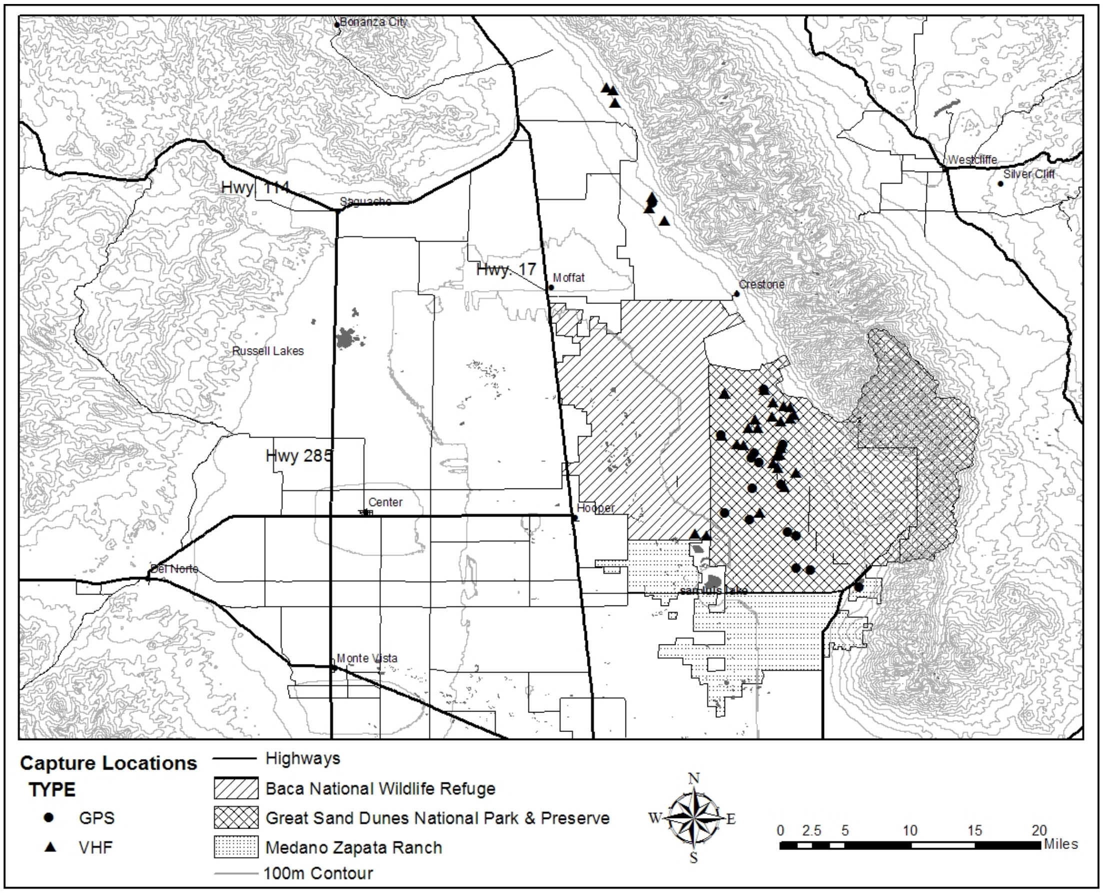


Figure 1. *Capture locations, location of study area, and primary administrative land units involved within the park-refuge complex (PRC) of central interest to movements of elk in the San Luis Valley, Colorado, USA, July – December 2005. PRC refers to the combined areas of the Great Sand Dunes National Park and the Baca National Wildlife Refuge.*

Methods

We captured and radio-collared 66 adult female elk (age > 1 year). We used a net-gun fired from a helicopter (Quicksilver Air, Inc., Fairbanks, AK) (Barrett 1982) to capture 44 elk in the eastern portion of the SLV during 3 consecutive days from 2 February 2005 to 21 February 2005 (Fig. 1). The helicopter capture crew placed collars on groups according to group size: if less than 30, 1 animal was collared; if group size was 50 to 99, 2 elk were collared; if group size was greater than 99, 3 to 4 elk were collared. The crew attempted to saturate groups in the periphery of the population, especially to the north, to attempt to obtain a representation of animals outside of the core herd winter area inside the PRC. We used corral traps (Rempel and Bertram 1975) to capture 19 elk during 9 days from 17 January 2005 to 1 February 2005. We used a Clover trap (Clover 1954) to capture 4 elk on 3 consecutive days from 29 January 2005 to 31 January 2005. We fitted 48 elk with VHF radio collars and 18 elk with collars having store-on-board Global Positioning System (GPS) units (5 ATS®, Advance Telemetry Systems, Inc., Isanti, Minnesota, USA; and 13 Lotek®, Lotek Engineering, Newmarket, Ontario, Canada) in addition to VHF transmitters. Coordinates of capture sites were identified with a handheld GPS using Universal Transverse Mercator (UTM) coordinates. We released the elk at the site of capture. All collars were equipped with mortality sensors that were activated when a collar remained motionless for 6 hours. GPS collars obtained locations every 4 hours and were programmed to release and drop-off elk after 50 weeks. Locations obtained by GPS collars were not differentially corrected. All capture and handling techniques followed protocols previously approved by the CDOW Animal Care and Use Committee.

We conducted 16 bimonthly flights from 17 March 2005 to 10 November 2005 to obtain fixes on VHF collars and on the VHF signals from GPS collars. We recorded all aerial flight locations in NAD 27 and then re-projected into NAD 83. We recorded GPS data in NAD 83. Due to release malfunctions of the GPS collars, we recaptured 15 elk via helicopter net gunning during March 2006 to obtain the store-on-board GPS locations of these elk.

Effect of Hunting Season on Elk Movement – GPS Data

To satisfy the assumption of independence of animal locations, the time period between fixes should be greater than the time required for the animal to move to any other point within its home range (Minta 1992, McNay and Bunnell 1994). Assuming that elk in the SLV can move across their home range in a 24-hr period, we generated estimates using only one GPS location-fix per day to assure biological independence (*n* = 16 elk, 1743 locations). Because we were concerned with movements into or out of the PRC, and the collared elk did not move into and out of the PRC within daily periods, it was not necessary to randomly select fixes within each day. Therefore, we selected the first fix of each day to use in our analysis.

There were several hunting seasons in the study area which started on different dates (Table 1). Therefore it was difficult to assign 1 day as a division between what would be considered before and after hunting season. We chose the 2-month time period from 1 July 2005 to 31 August 2005 as the before hunting season time period and the 2-month time period from 1 November 2005 to 31 December 2005 as the after hunting season time period for GPS locations of elk. For this method, no GPS locations within the time period 1 September 2005 to 31 October 2005 were used for the analysis comparing before and after hunting season. This 2-month period allowed time for elk to react to hunting pressures from dispersal, archery, and the first 2 rifle hunts. Therefore, "after hunting season" refers to the time period after the elk had moved in response to hunting season even though there were still rifle hunts occurring.

To compare trends among models of elk movements before and after hunting season, we did not include locations within this 2-month period. We classified locations as either inside or outside the PRC as well as before or after hunting season. We evaluated random effects models using PROC NLMIXED in SAS (SAS Version 9.1 2006) and Akaike's Information Criterion (AIC) (Burnham and Anderson 2002) to evaluate the most parsimonious models. Random effects models allowed modeling using elk as a sampling unit which allowed individual elk to have unique intercepts corresponding to the probability of an elk being in the PRC prior to hunting seasons. We calculated probabilities and confidence intervals for elk being in the PRC after hunting season given the probability of being in the PRC before hunting season for each of the 3 models considered in our analysis.

1. Hunting Season + Random effects for elk. This model considers the probability of each individual elk being within the PRC to be constant for each of the 2 time periods (before and after hunting season).
2. Time Trend + Random Effects for Elk. This model uses time (Julian date) as a covariate rather than before or after hunting season. This allows for a varying probability of each individual elk being within the PRC depending on day of location.
3. Random Effects Only. This model considers being within the PRC only as a function of individual elk and not time or hunting season.

Table 1. *Hunting seasons in the San Luis Valley, Colorado, USA, 27 August 2005 to 28 February 2006.*

Hunting Season	Start Date	End Date
Dispersal Hunts to reduce elk damage to agricultural crops. Either-sex elk	15 Sep 2005	28 Feb 2006
Archery-Unlimited either-sex	27 Aug 2005	25 Sep 2005
Muzzleloading Rifle-limited entry antlered and antlerless	10 Sep 2005	18 Sep 2005
1st Rifle-limited entry antlered and antlerless	15 Oct 2005	19 Oct 2005
2nd Rifle-unlimited antlered, limited antlerless	22 Oct 2005	30 Oct 2005
3rd Rifle-unlimited antlered, limited antlerless	5 Nov 2005	11 Nov 2005
4th Rifle-limited entry antlered and antlerless	16 Nov 2005	20 Nov 2005

Effect of Hunting Season on Elk Movement – VHF Data

We analyzed VHF elk locations using 2 sub-sets of data. Our first sub-set of VHF data included 5 aerial flights (Table 2) (n = 48 VHF elk + VHF locations from 18 GPS elk; 275 locations). To remain reasonably consistent with dates used to define before and after hunting season in the GPS analysis, we excluded data from 4 flights which occurred during September and October. For the second sub-set of VHF data, we used elk locations obtained during all 9 flights from 7 July 2005 to 10 November 2005 to maximize the number of locations used in a modeling analysis (Table 2) (n = 48 VHF elk + VHF locations from 18 GPS elk; 469 locations). We considered 7 July 2005 to 30 September 2005 as before hunting season, and 17 October 2005 to 10 November 2005 as after hunting season (Table 2). For both sub-sets of the VHF elk locations, we considered the 3 models used previously for GPS data.

Table 2. *Flight dates of the 2 VHF datasets used for modeling elk movements from 7 July 2005 to 10 November 2005, San Luis Valley, Colorado, USA.*
after hunting season for this analysis

2005 Flight Dates	
5 Flight Dataset	**9 Flight Dataset**
7 July[a]	7 July[a]
21 July[a]	21 July[a]
8 August[a]	8 August[a]
23 August[a]	23 August[a]
10 November[b]	15 September[a]
	30 September[a]
	17 October[b]
	25 October[b]
	10 November[b]

[a] Considered before hunting season for this analysis
[b] Considered after hunting season for this analysis

We used ArcGIS 9 (ESRI 2006) to map elk locations, and used Hawth's Tools extension to ArcGIS (Beyer 2006) to calculate movement paths and mean daily distances traveled. Mean daily distances were then averaged over 1-month periods to compare across months.

Results

Using 1 location fix per day, there were 1743 locations for 16 GPS collared elk from 1 July 2005 to 31 August 2005 and 1 November 2005 to 31 December 2005 (Fig. 2). Due to failure of 2 VHF transmitters on 2 GPS collars (frequencies 163.80 and 162.529), data from 2 elk having GPS collars were not obtained. There were 275 VHF locations for 66 elk (46 VHF, 18 GPS with VHF) obtained from 5 flights (4 flights between 7 July 2005 and 23 August 2005 and 1 flight on 10 November 2005) (Fig. 3), and there were 469 VHF locations for 66 elk (46 VHF, 18 GPS with VHF) obtained from 9 flights between 7 July 2005 and 10 November 2005 (Fig. 4).

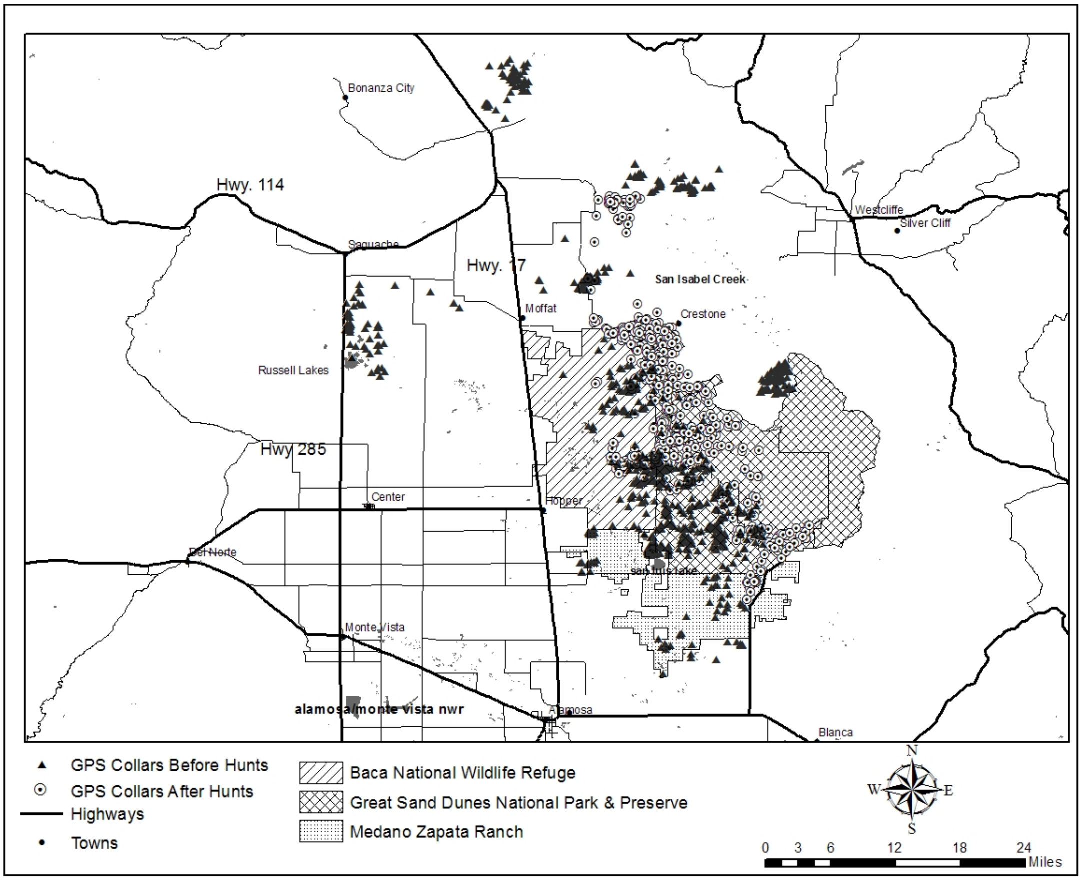
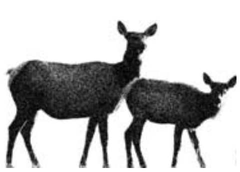
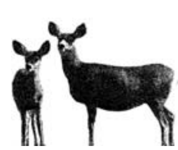


Figure 2. *Locations of elk before and after hunting seasons as obtained from downloads of GPS collars (n=16 elk), 1 July 2005 to 31 August 2005 and 1 November 2005 to 31 December 2005, San Luis Valley, Colorado, USA. Locations limited to using 1 location from each elk per day.*





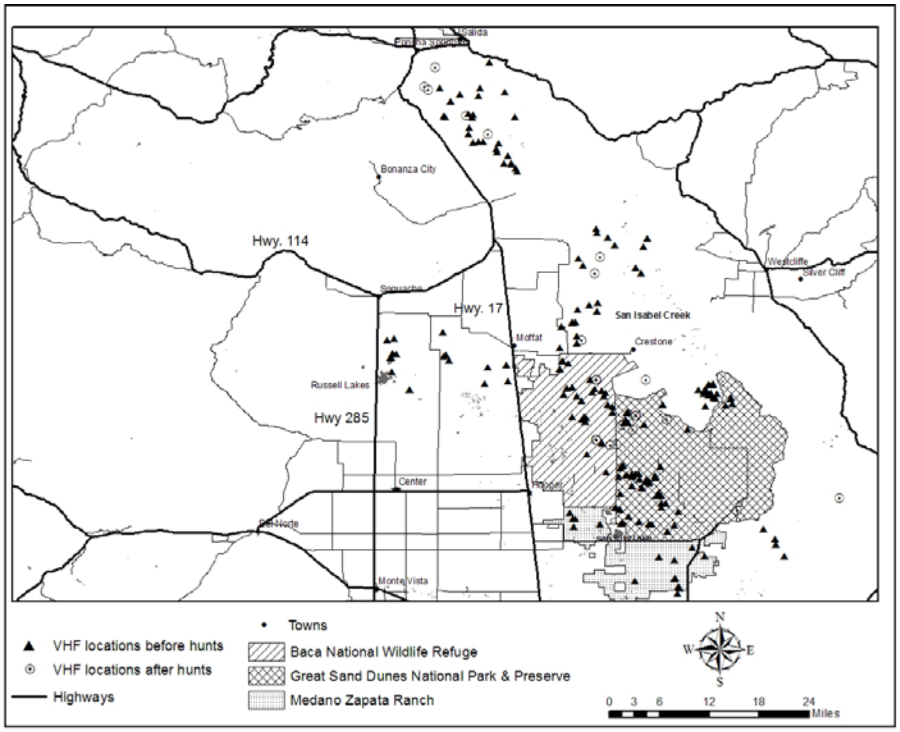


Figure 3. *Locations of elk before and after hunting season as obtained from VHF collars (n= 66 elk) obtained during 5 aerial flights (4 flights between 7 July 2005 and 23 August 2005 and 1 flight on 10 November 2005).*

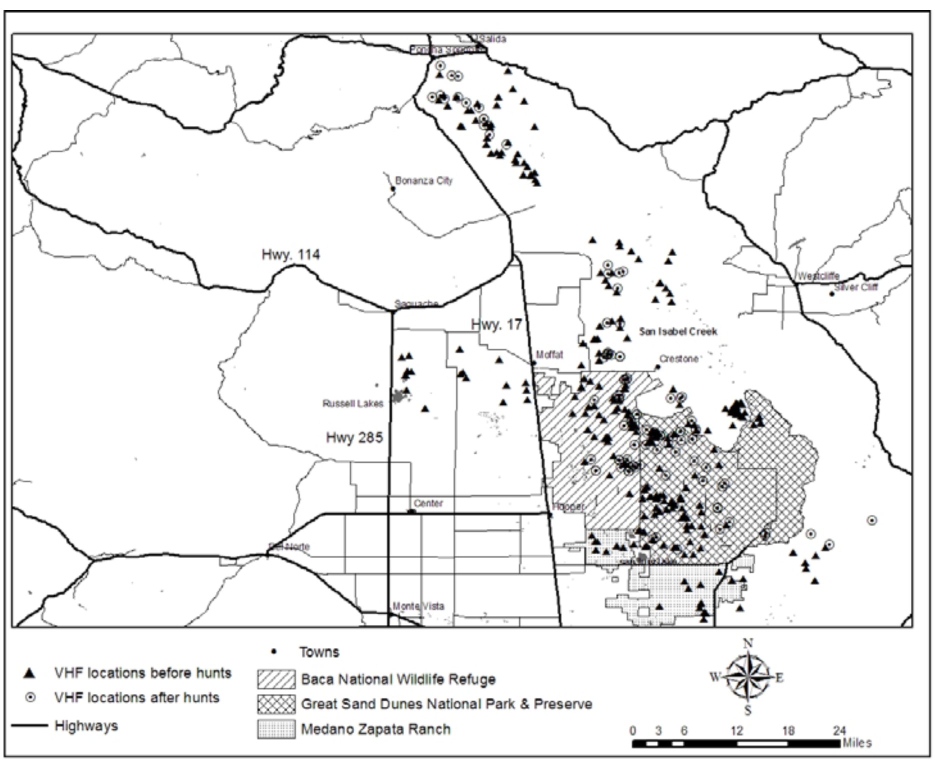


Figure 4. *Locations of elk before and after hunting season as obtained from VHF collars (n= 66 elk) for 9 aerial flights between 7 July 2005 and 10 November 2005, San Luis Valley, Colorado, USA.*

Effect of Hunting Season on Elk Movement - GPS Data

Random effects models provided evidence for elk moving into the PRC as a result of hunting seasons. The model *Hunting Season + Random Effects* had the lowest AIC and the highest weight of 100%. The models *Time Trend + Random Effects* and the null model Random *Effects* both had relative weights of 0% (Table 3). Based on the model *Hunting Season + Random Effects*, the probability of being in the PRC after hunting season increased from 0.004 to 0.910 as the probability of being in the PRC before hunting season increased from 0 to 0.1 (Fig. 5). For elk with probabilities of being in the PRC before hunting season greater than 0.09, the probability of being in the PRC after hunting season was greater than 0.90.

Table 3. *AIC and Akaike weight (w_i) values for 3 models to estimate the probability that elk would be on the PRC before and after hunting seasons based on elk locations obtained from GPS fixes for collared elk, 1 July 2005 to 31 August 2005 and 1 November 2005 to 31 December 2005, San Luis Valley, Colorado, USA.*

Model	**AIC**	**ΔAIC**	**w_i**
Hunting Season + Random effects for Elk	772.9	0	1.00
Time Trend + Random Effects for Elk	850.4	77.5	0.00
Random Effects Only	1311.0	538.1	0.00

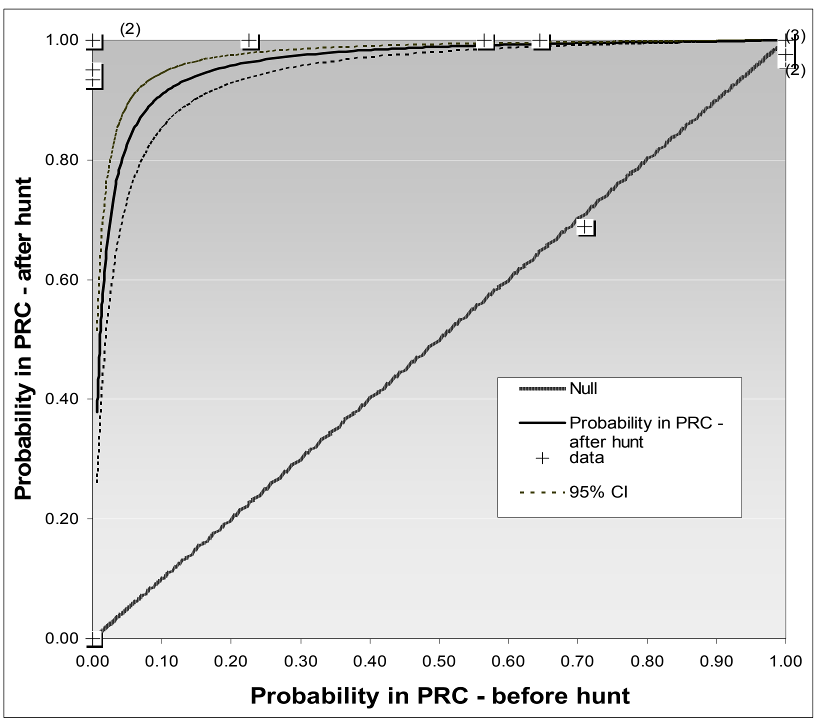
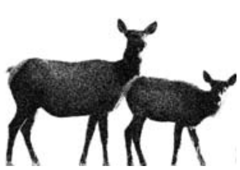
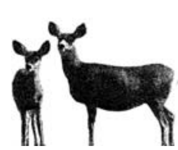


Figure 5. *GPS data results for the best AIC weighted model Hunting Season + Random Effects, 1 July 2005 to 31 August 2005 and 1 November 2005 to 31 December 2005, San Luis Valley, Colorado, USA. The solid black line represents the probability of elk being in the PRC after hunting season given an elk's initial probability of being on PRC before hunting season. Data points from sampled elk are represented by the black tics, with numbers in parentheses indicating the number of data points with the same coordinates. The 45 degree line represents the null model where the probability of being in the PRC is equal before and after hunting seasons.*





Effect of Hunting Season on Elk Movement - VHF Data – 5 flights

As with the previous analysis based on GPS locations, evidence for elk moving into the PRC as a result of hunting seasons was supported by the VHF locations. The model *Hunting Season + Random Effects* had the lowest AIC and the highest weight of 76.0%. The models *Time Trend + Random Effects* and the null model Random *Effects* had relative weights of 24% and 0% respectively (Table 4). Based on the model *Hunting Season + Random Effects*, the probability of being in the PRC after hunting season increased from 0.043 to 0.990 as the probability of being in the PRC before hunting season increased from 0 to 0.1 (Fig. 6). The coefficient of variation for hunting season effect was 36.3%, resulting in wide confidence intervals of predictions for the probability of being in the PRC after hunting season.

Table 4. *AIC and Akaike weight (w_i) values for 3 models to estimate the probability that elk would be on the PRC before and after hunting seasons based on VHF collared elk locations obtained during 5 aerial flights (4 flights between 7 July 2005 and 23 August 2005 and 1 flight on 10 November 2005), San Luis Valley, Colorado, USA.*

Model	AIC	ΔAIC	w_i
Hunting Season + Random Effects for Elk	205.2	0	0.760
Time Trend + Random Effects for Elk	207.5	2.3	0.240
Random Effects Only	262.3	57.1	0.000

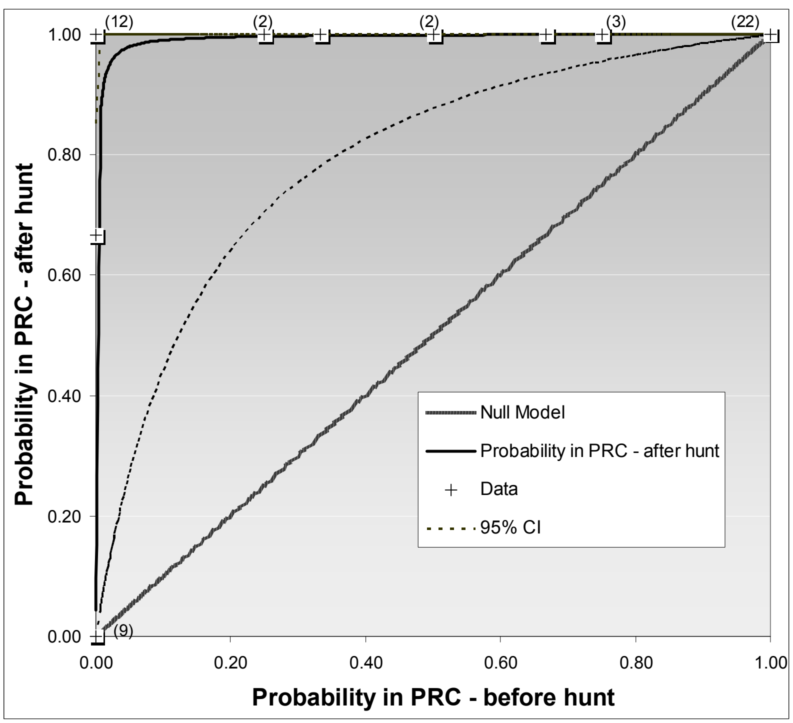


Figure 6. *Flight data results from 5 aerial flights for best AIC weighted model Hunting Season + Random Effects, 7 July 2005 to 10 November 2005, San Luis Valley, Colorado, USA. The solid black line represents the probability of elk being in the PRC after hunting season given an elk's initial probability of being on PRC before hunting season. Data points from sampled elk are represented by the black tics, with numbers in parentheses indicating the number of data points with the same coordinates. The 45 degree line represents the null model where the probability of being in the PRC is equal before and after hunting seasons.*

Effect of Hunting Season on Elk Movement - VHF Data – 9 flights

The highest ranking models, *Hunting Season* + *Random Effect* and *Time Trend* + *Random Effect* had AIC values within 1.5, but model weight for *Hunting Season* was 2x that of *Time Trend* (Table 5). As with the GPS data, there was no support for the null model. Based on the model *Hunting Season* + *Random Effects*, the probability of being in the PRC after hunting season increased from 0.001 to 0.735 as the probability of being in the PRC before hunting season increased from 0 to 0.1 (Fig. 7). For the same model, the increase of the probability of being in the PRC after hunting season was smaller than that of the GPS data and VHF data from 5 flights (Figs. 5, 6, 7). The probability of being in the PRC after hunting season reached 0.90 when the probability of being in the PRC before hunting season was 0.26 (Fig. 7).

Data points which fall below the line for the null model (Figs. 5 and 7) represent elk whose probability of being in the PRC was lower after hunting season than it was before hunting season. These 6 elk were either in areas just north of the PRC near the town of Crestone or just south of the PRC near the GSDNP headquarters. Although these areas were not within the PRC, both of these areas were potential refuges for elk during hunting season.

Table 5. *AIC and Akaike weight (w_i) values for 3 models to estimate the probability that elk would be on the PRC before and after hunting seasons based on VHF collared elk locations obtained during 9 aerial flights which occurred between 7 July 2005 and 10 November 2005, San Luis Valley, Colorado, USA.*

Model	**AIC**	**ΔAIC**	**w_i**
Hunting Season + Random Effects for Elk	369.6	0	0.679
Time Trend + Random Effects for Elk	371.1	1.5	0.321
Random Effects Only	436.2	67.1	0.000

Movement Analysis Results

Maps of elk locations before and after hunting seasons revealed 6 elk which never went into the PRC. Five of these were VHF collared elk and 1 was a GPS collard elk, raising concern that VHF and GPS collars may not have been distributed similarly among elk groups at capture. However, there were no differences in proportions of VHF and GPS collared elk that were always outside the PRC (PROC FREQ, $P = 0.4261$).

Movement paths visually indicated fall movements of elk into the PRC by elk which were outside the PRC during the summer months (Appendix I). However, movements of elk having GPS collars did not show differences in mean daily distances traveled each month for elk which were outside of the PRC before hunting season compared to elk which were inside the PRC before hunting season (Fig. 8).

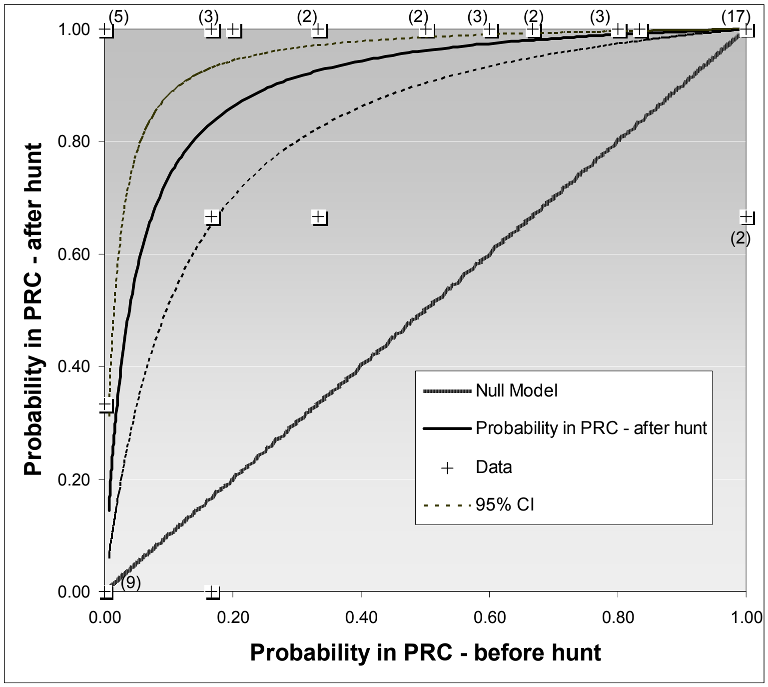


Figure 7. *Flight data results from 9 aerial flights for best AIC weighted model Hunting Season + Random Effects, 7 July 2005 to 10 November 2005, San Luis Valley, Colorado, USA. The solid black line represents the probability of elk being in the PRC after hunting season given an elk's initial probability of being on PRC before hunting season. Data points from sampled elk are represented by the black tics, with numbers in parentheses indicating the number of data points with the same coordinates. The 45 degree line represents the null model where the probability of being in the PRC is equal before and after hunting seasons.*

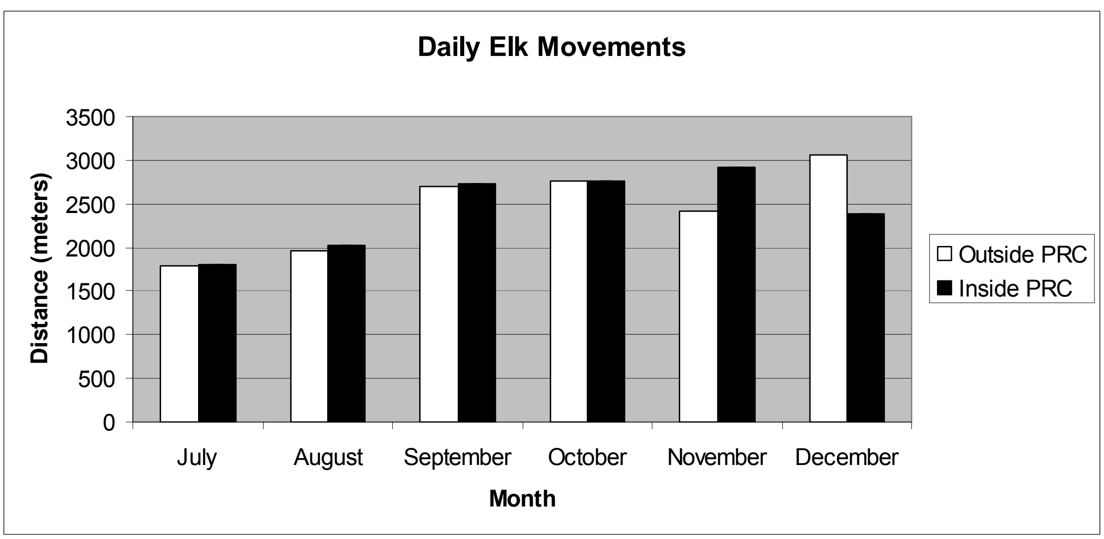
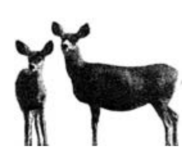


Figure 8. *Mean daily elk movements averaged by month for July – December 2005 for elk which were inside and outside the Park Refuge Complex (PRC) before hunting season. San Luis Valley, Colorado, USA.*



Discussion

Random effects models allow us to make inferences to the population of elk from which our sample elk were drawn, suggesting that the elk in this area were using the PRC as a refuge during hunting season. Other factors correlated to this same time period of hunting season, such as changes in vegetation nutritional quality due to curing during fall, cannot be dismissed as alternative reasons for elk movement into the PRC. However, previous studies have demonstrated that elk respond to disturbances such as hunting by seeking a refuge from the disturbance (Burcham et al. 1999, Millspaugh et al. 2000, Conner et al. 2001, Vieira et al. 2003).

For the GPS and VHF data, the best AIC weighted models supported the hypothesis that hunting pressure was likely causing elk to move into the PRC, and that elk movement into the PRC is not simply a linear trend over time for the same time period. For the VHF data analysis using 5 flights, model *Hunting Season + Random Effects* carried less weight than the same model using the GPS data (0.76 compared to 1.0) possibly because power to detect effect of hunting season was limited due to lack of data available for after hunting season (1 flight). For the VHF data analysis using 9 flights, model *Hunting Season + Random Effects* also carried less weight than the same model using the GPS data (0.68 compared to 1.0) likely because of the shorter time period considered as hunting season. Because this time period did not encompass as much of the hunting time period as the GPS analysis, elk movements as a result of hunting could have occurred before and after what we considered hunting seasons in this VHF analysis. This would have resulted in less support for the best AIC weighted model and an increased support for the *Time Trend + Random Effects* model.

Analysis of daily movements by month did not support our hypothesis that elk outside of the PRC move greater distances as a result of hunting season. This could be due to the elk balancing out energetic output over a smaller time period than the monthly time period at which mean daily movements were averaged.

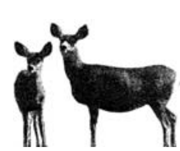
With only 1 year of data, we could not determine if the same elk which summered in the area between Highways 17 and 285, near Russell Lakes, return to same specific area every year. An intensely focused hunting season (antlered and antlerless) in the Russell Lakes area may reduce agricultural damage caused by this group of elk, as these elk displayed a propensity to respond to hunting pressure by moving east into the PRC.

Coordinated hunts or harassment techniques might be successful in reducing elk densities in sensitive areas and in moving the elk from the PRC to areas of greater vulnerability to public hunting. An experimentally designed study is needed to determine the types and length of harassment methods which would be most effective in changing the tendency for elk to seek refuge with the PRC area.

Management Implications

Without active elk population management in areas providing refuges to elk during hunting season, the elk population is likely to continue to increase in numbers and land managers share the risk in allowing negative impacts on native plant ecosystems and agricultural crops. Given that the current estimate is more than 6,000 elk, accomplishing the current management objective of a population size of 1,500 elk in DAU E-11 will require cooperation of federal and state agencies and private land owners as well as altering current management techniques. Designing hunting seasons outside of the PRC, without concurrent control and or disturbance of elk within the PRC, may encourage elk to intensify their use of the PRC as a refuge and consequently, negate efforts to effectively reduce the size of the elk population.

Acknowledgments



This study was funded by the Colorado Division of Wildlife Habitat Partnership Program and the Colorado Division of Wildlife in cooperation with USGS and NPS. We thank CDOW personnel C. Wagner, B. Weinmeister, R. Basagoitia, and B. Watkins for project support and J. Mao of the USGS for field support.

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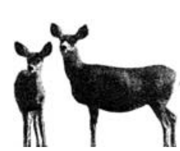

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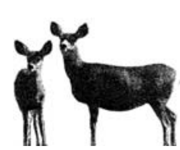
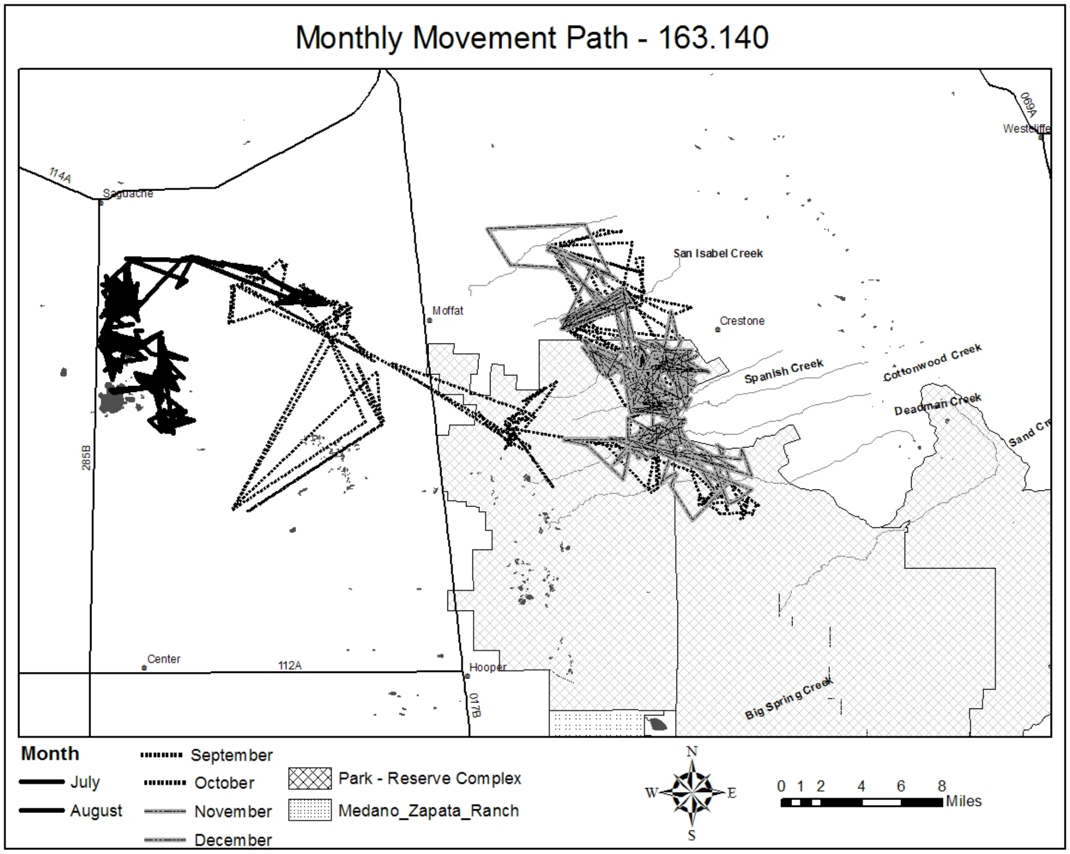
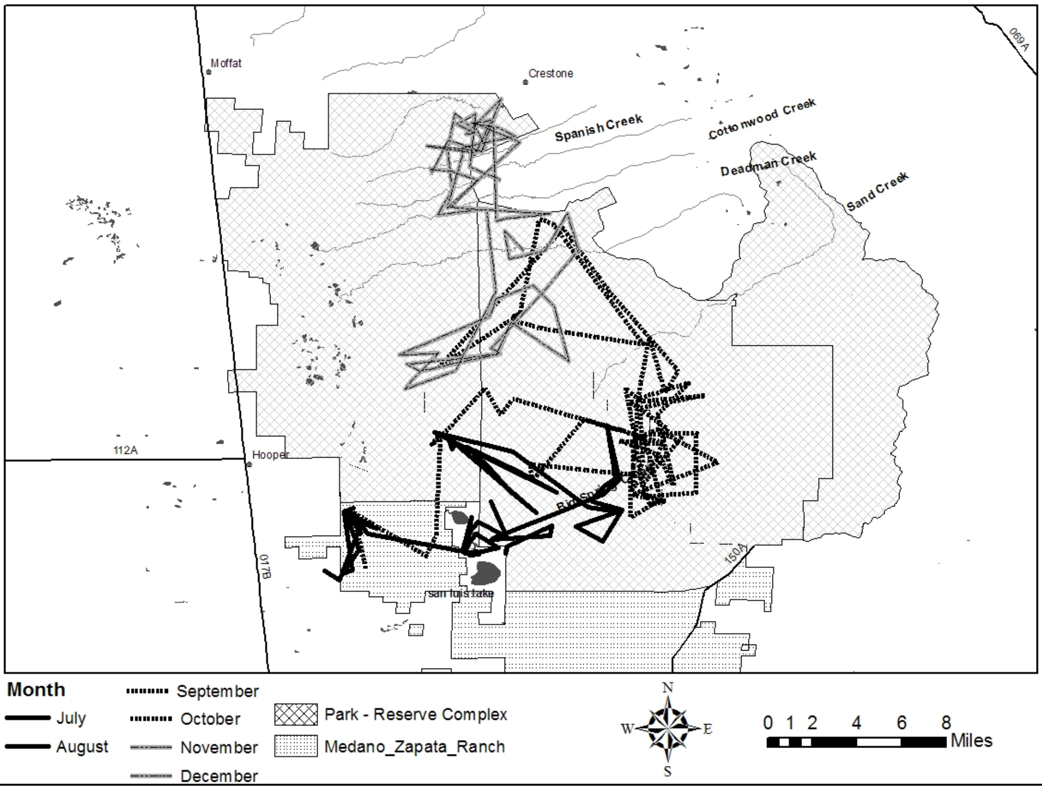


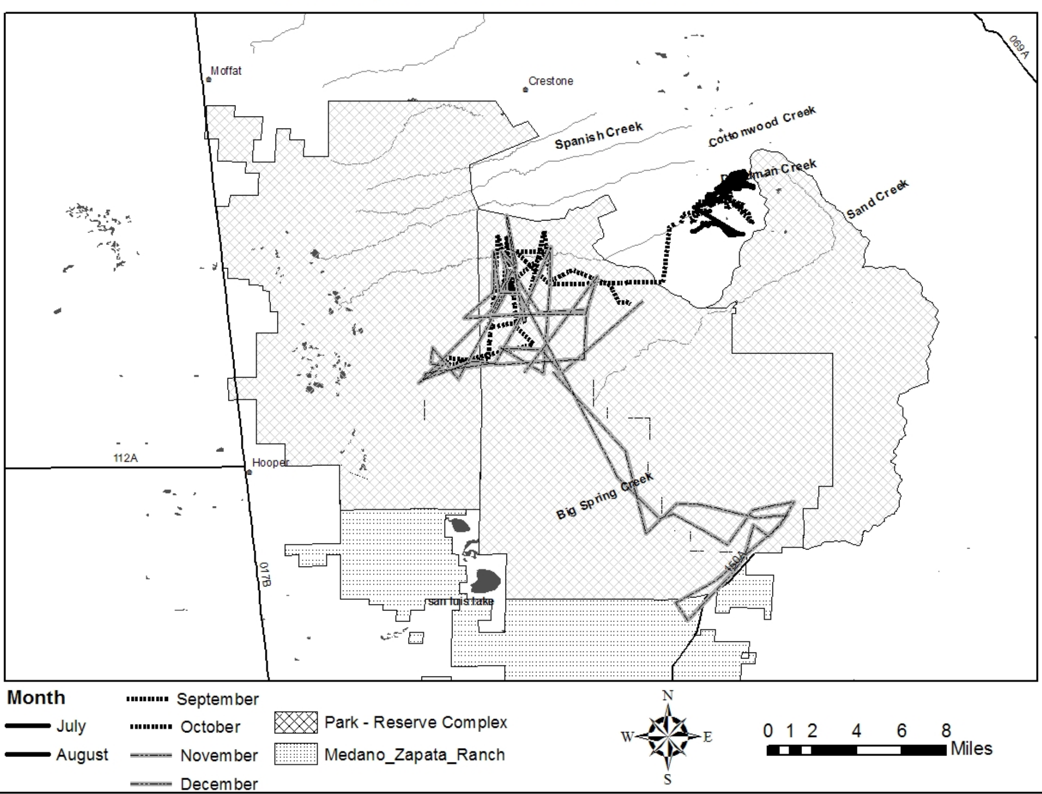
Appendix I. *Movement paths of elk whose home range extends beyond the Park Refuge Complex (PRC) from 1 July 2005 to 31 December 2005, San Luis Valley, Colorado. PRC refers to the combined areas of the Great Sand Dunes National Park and the Baca National Wildlife Refuge. Elk whose home range was within the PRC are not included.*

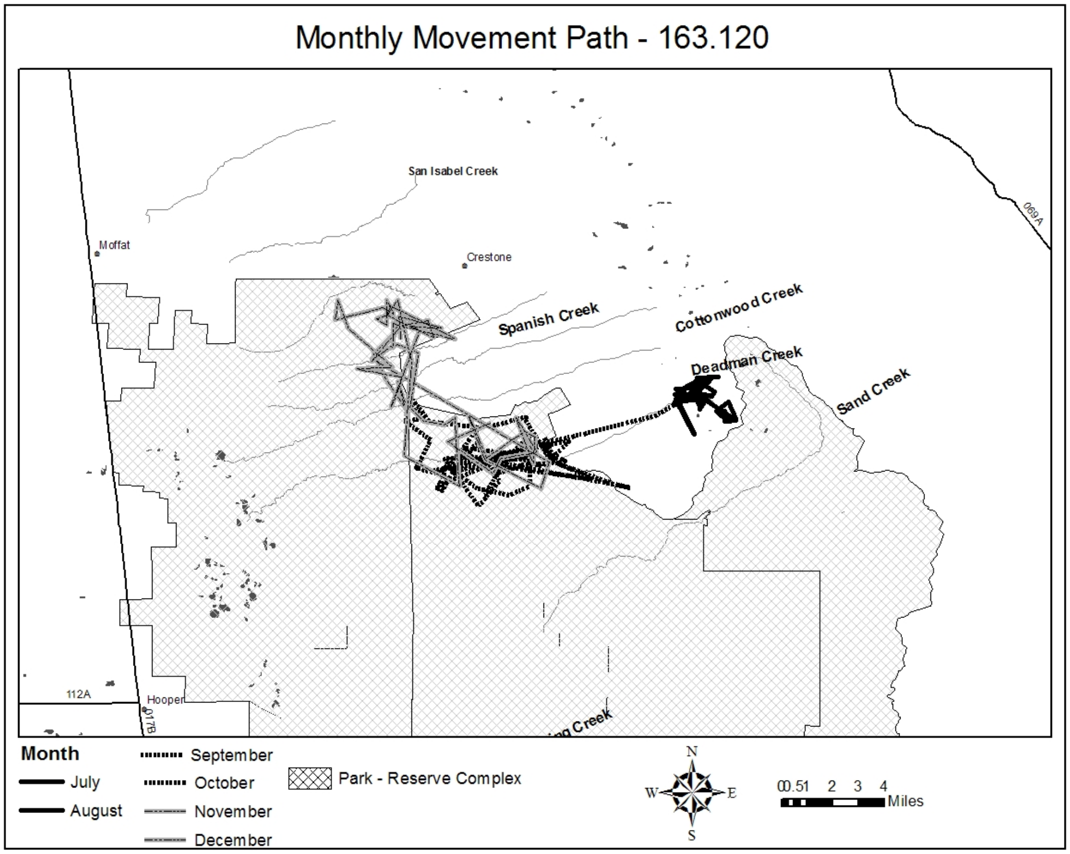


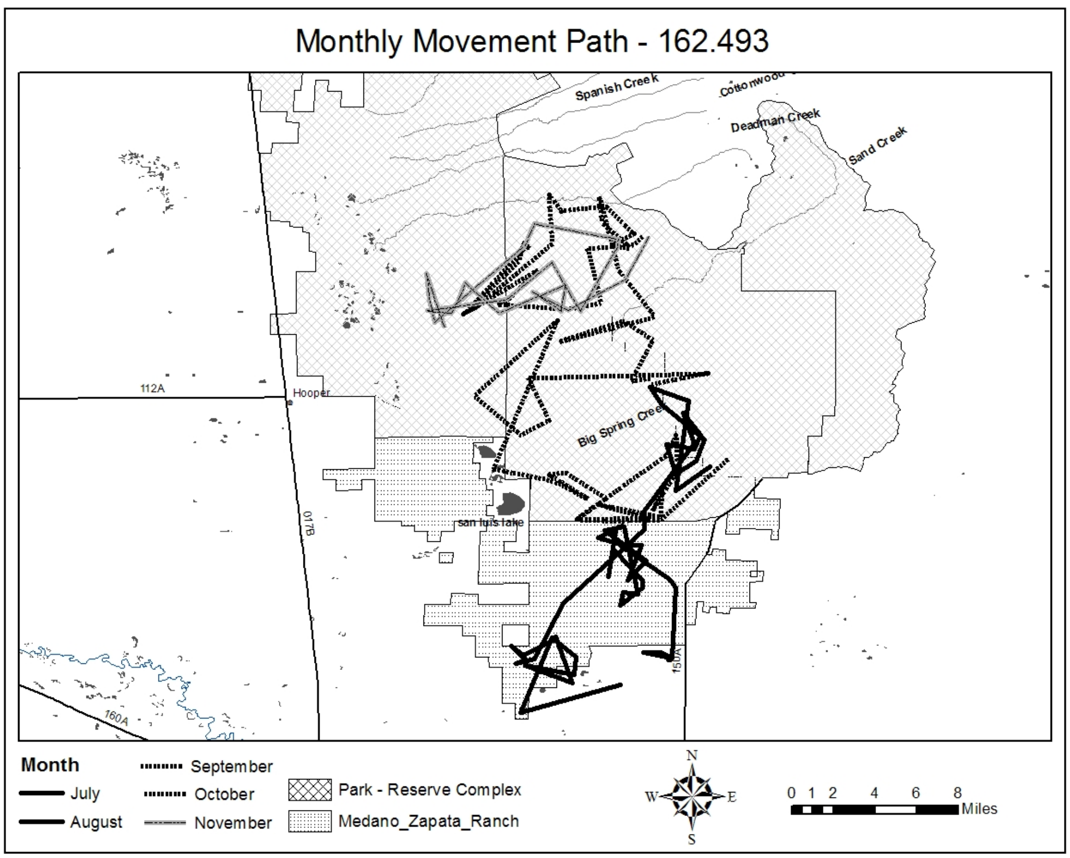
Monthly Movement Path - 163.170

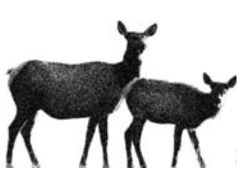


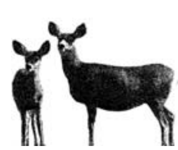
Monthly Movement Path - 163.130

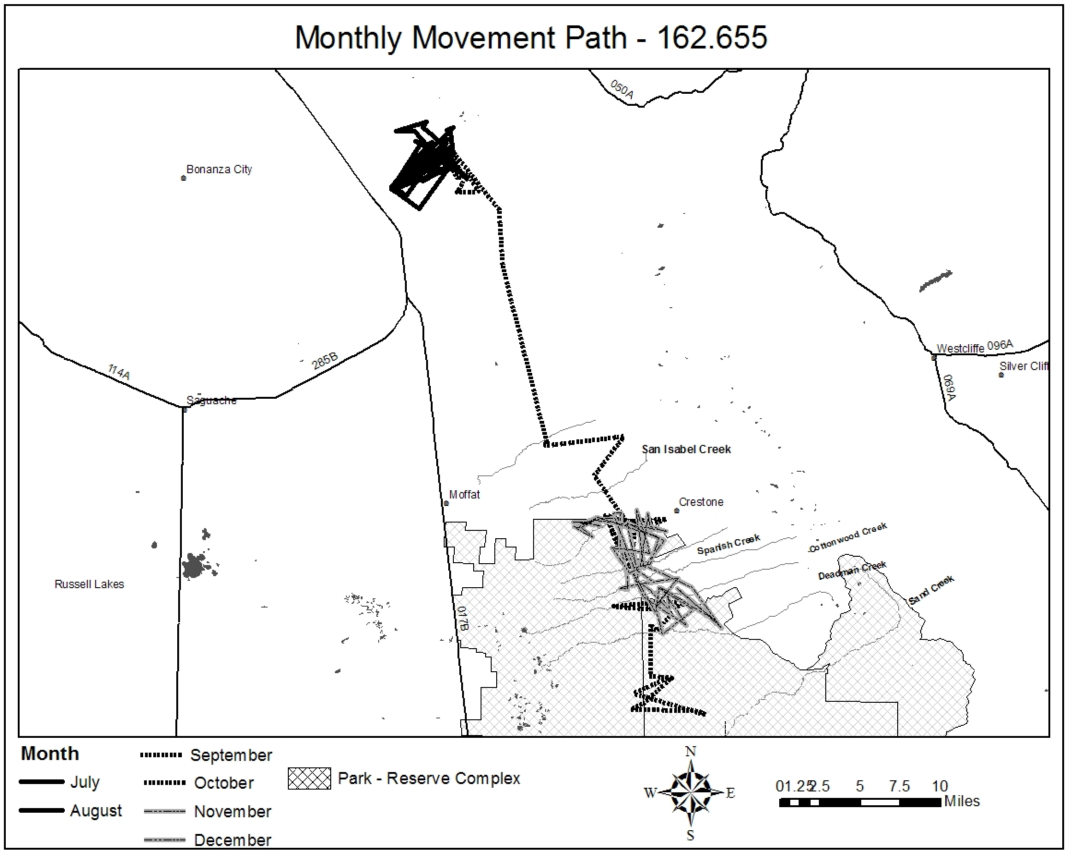



Monthly Movement Path - 163.120
San Isabel Creek
Moffat
Crestone
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
069A
112A
Hooper
017B
Month
July
August
September
October
November
December
Park - Reserve Complex
N
W
E
S
0 0.51 2 3 4
Miles

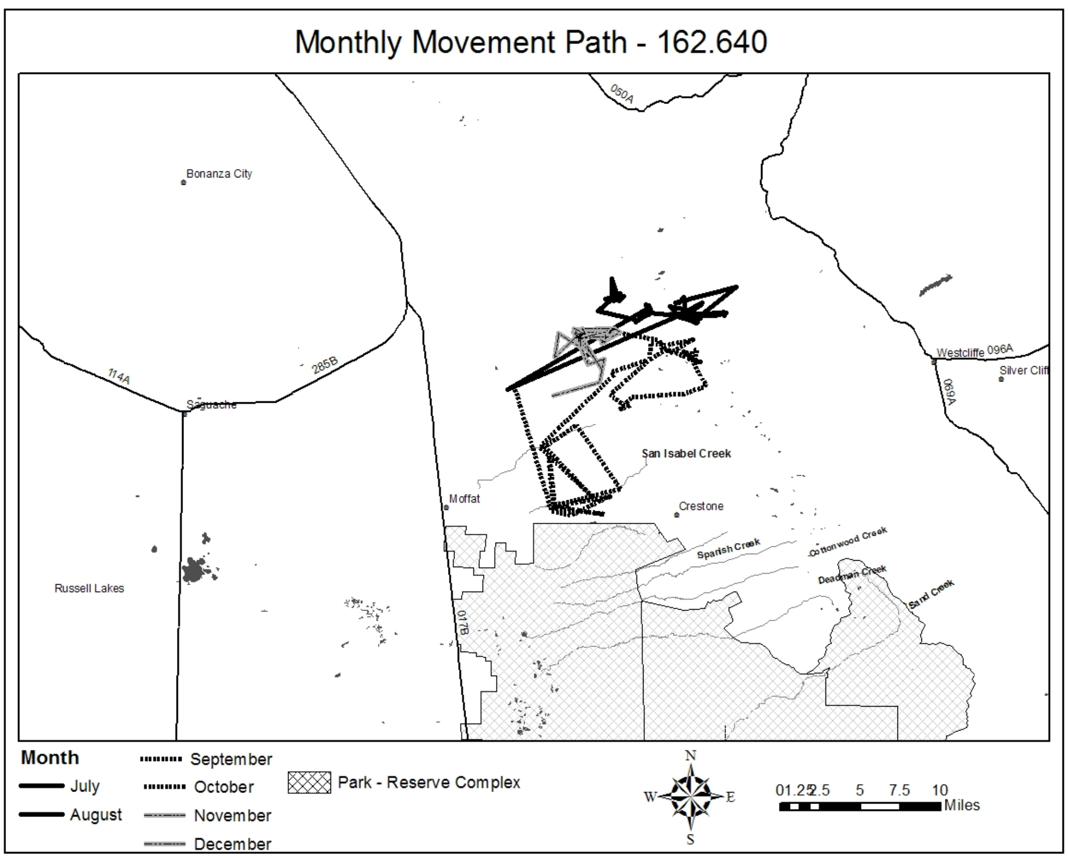

Monthly Movement Path - 162.493
Spanish Creek
Deadman Creek
Sand Creek
112A
Hooper
017B
Big Spring Creek
san luis lake
150A
160A
Month
July
August
September
October
November
Park - Reserve Complex
Medano_Zapata_Ranch
N
W
E
S
0 1 2 4 6 8
Miles



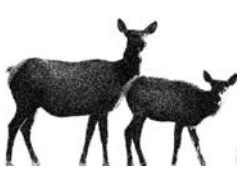


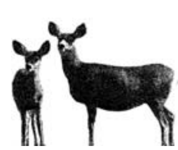


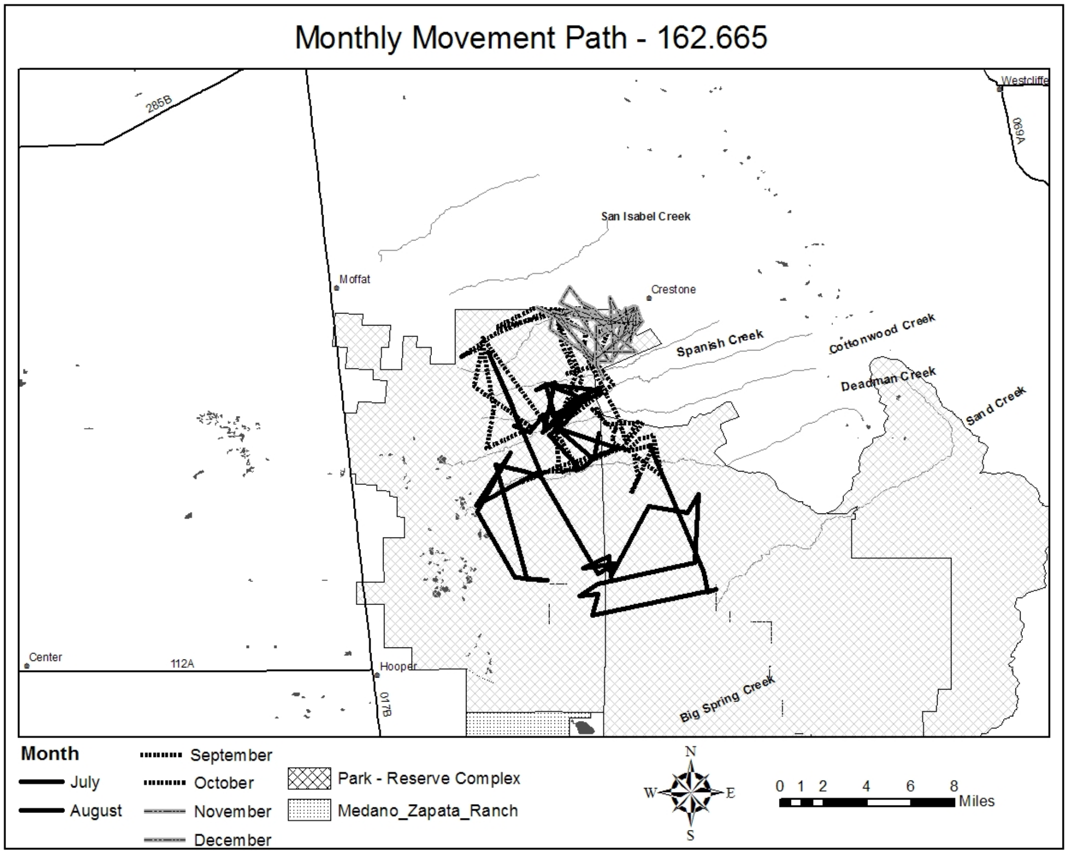
Monthly Movement Path - 162.655
Bonanza City
Saguache
Moffat
Crestone
San Isabel Creek
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
Russell Lakes
Westcliffe
Silver Cliff
050A
114A
285B
096A
069A
017B
Month
July
August
September
October
November
December
Park - Reserve Complex
N
S
W
E
0 1.25 2.5 5 7.5 10
Miles

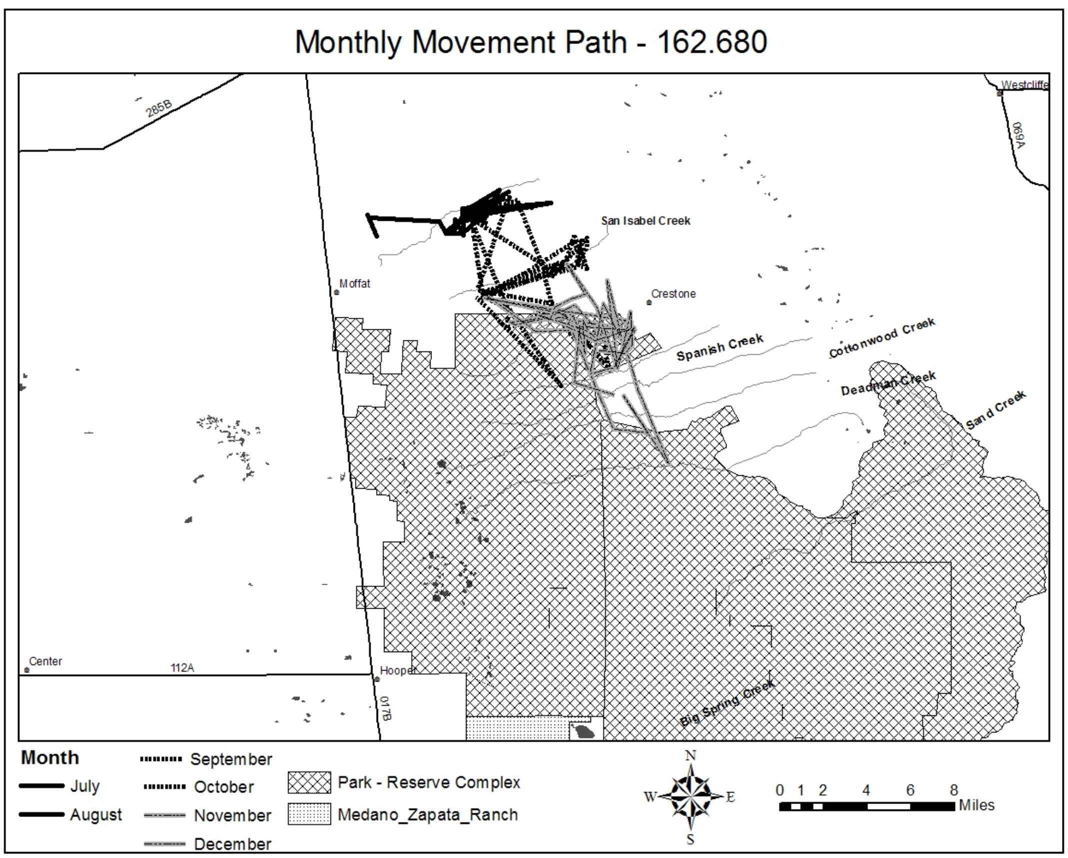


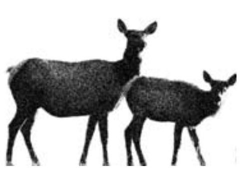
Monthly Movement Path - 162.640
Bonanza City
Saguache
Moffat
Crestone
San Isabel Creek
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
Russell Lakes
Westcliffe
Silver Cliff
050A
114A
285B
096A
069A
017B
Month
July
August
September
October
November
December
Park - Reserve Complex
N
S
W
E
0 1.25 2.5 5 7.5 10
Miles

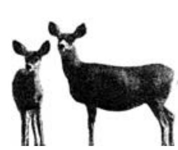


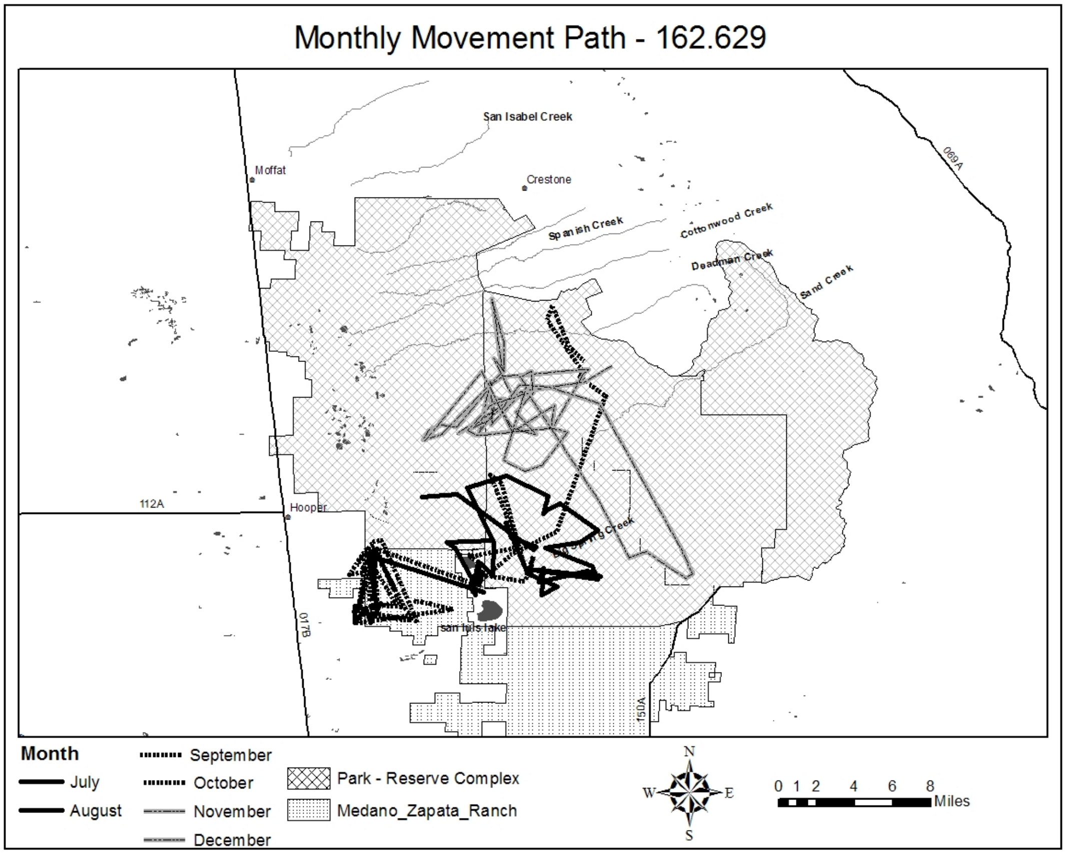


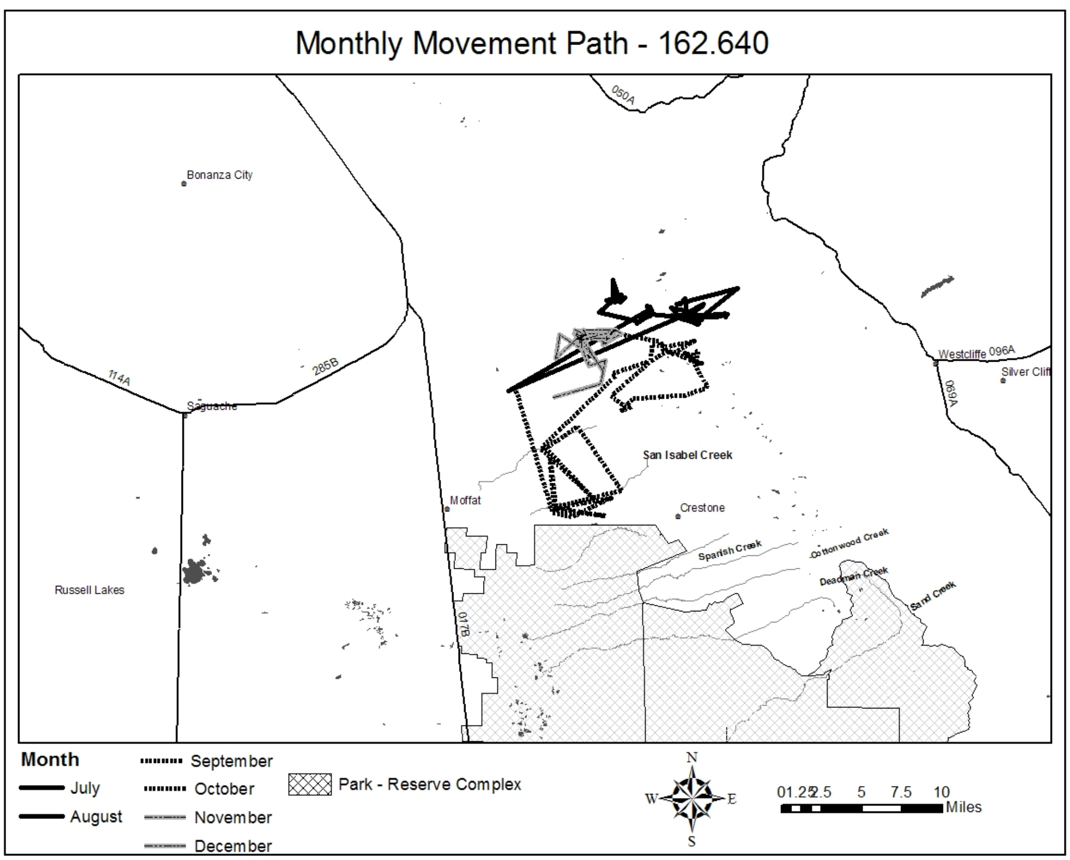

Monthly Movement Path - 162.665
285B
Westcliffe
069A
San Isabel Creek
Moffat
Crestone
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
Center
112A
Hooper
017B
Big Spring Creek
Month
July
August
September
October
November
December
Park - Reserve Complex
Medano_Zapata_Ranch
N
W
E
S
0 1 2 4 6 8
Miles


Monthly Movement Path - 162.680
285B
Westcliffe
069A
San Isabel Creek
Moffat
Crestone
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
Center
112A
Hooper
017B
Big Spring Creek
Month
July
August
September
October
November
December
Park - Reserve Complex
Medano_Zapata_Ranch
N
W
E
S
0 1 2 4 6 8
Miles






Monthly Movement Path - 162.629
San Isabel Creek
Moffat
Crestone
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
069A
112A
Hooper
017B
san luis lake
150A
Month
July
August
September
October
November
December
Park - Reserve Complex
Medano_Zapata_Ranch
N
W
E
S
0 1 2 4 6 8
Miles


Monthly Movement Path - 162.640
050A
Bonanza City
114A
285B
Saguache
Westcliffe 096A
Silver Cliff
069A
San Isabel Creek
Moffat
Crestone
Spanish Creek
Cottonwood Creek
Deadman Creek
Sand Creek
Russell Lakes
017B
Month
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October
November
December
Park - Reserve Complex
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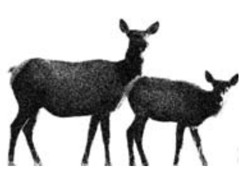
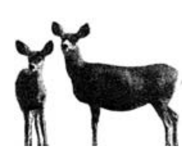
S
0 1.25 2.5 5 7.5 10
Miles





ELK BEHAVIORAL RESPONSES TO THE REESTABLISHMENT OF WOLVES: THE INDIRECT CONSEQUENCES OF LIVING IN A RISKY ENVIRONMENT.

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P.J. WHITE, Yellowstone Center for Resources, Yellowstone National Park, WY 82190, USA.
NIGEL G. YOCCOZ, Department of Biology, University of Tromsø, N-9037 Tromsø, Norway

Abstract: It is well-documented that predators limit prey populations in many systems through the direct killing and consumption of prey. What is less well studied and understood are the indirect consequences of predators on the behavior of prey that are attempting to minimize predation risk. We conducted an intensive telemetry-based study of the Madison-Firehole elk (*Cervus elaphus*) herd and colonizing wolves (*Canis lupus*) in the central portion of Yellowstone National Park from 1991-2006 to test the prediction that wolves have altered various elk behavioral responses including group size, winter home range size, activity patterns, and habitat selection. Prior to significant wolf reestablishment of the study area (1991-1997), we randomly collected approximately 6000 elk locations, representing 5000 elk groups, with associated group size, activity budgets, and habitat selection attributes. These data are complimented by more than 5000 elk locations, representing 3500 elk groups and associated data when wolves had an established presence in the study system from 1998 through 2006. After wolf re-introduction elk that formally lived in a predator-free environment for many decades were subjected to varying levels of predation risk thus allowing us to investigate how these behaviors change at different temporal and spatial scales. Comparison of pre-wolf and post-wolf data demonstrates changes in elk behavior at a variety of spatial and temporal scales; presumably due to elk responses to predation risk. It is unclear whether these behavioral changes result in decreased individual fitness or reductions in population vital rates, however, we hope that continued monitoring as this predator-prey system develops will provide additional insights.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:90.

ELK TRANSLOCATIONS INTO RISKY LANDSCAPES: WHAT MATTERS FOR RETENTION AND SURVIVAL?

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Abstract: When conducting translocations, whether to reintroduce species or augment local populations, release landscapes will include unfamiliar habitats and potentially novel risks. If managers know the spatial variability of risks in release areas and the pre-release experiences of source populations, they may be able to strategically select release locations to optimize translocation success. We experimentally evaluated factors influencing success of elk translocations to the central east slopes of the Rocky Mountains of Alberta from 4 sources over the winters of 2000-2005. Translocated elk originated from the town sites of Banff and Jasper (where elk had habituated to humans), from an agricultural fringe area southwest of Calgary (where animals had some previous experience with hunters but not wolves), and Elk Island National Park (where individuals were protected from both hunters and wolves). Release sites covered a range of habitat quality, human access levels and wolf predation levels, and resident elk served as controls. We related the survival and retention of individuals in release areas to their *exposure* to environmental variability in these areas in a competing risks framework. Forage availability was not related to elk survival or retention, perhaps because we released animals only into areas where forage was sufficient or because costs of foraging require a longer period to accumulate. Although wolf predation was the largest initial source of mortality, humans (native legal harvest and poaching) were the largest cause of death overall, and the relative risk varied by source population. Areas adjacent to roads remained consistently risky over time for both translocated and resident elk. We identify potential release areas across the landscape for each population source by mapping areas of high joint probability of survival and retention.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:91.

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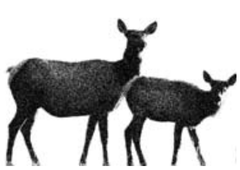

A FENCE DESIGN FOR EXCLUDING ELK WITHOUT IMPEDING OTHER WILDLIFE

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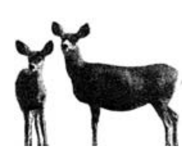
Abstract: Concentrated herbivory by elk (*Cervus elaphus*) can degrade vegetative communities and alter ecosystem processes. Areas severely damaged by elk are commonly protected with woven wire fence which may exclude other animals. Complete exclusion and prevention of large mammal herbivory may not always be necessary to restore vegetative communities. We designed and evaluated a simple fence that excluded elk, but maintained access for deer and other species. We enclosed a 1-ha stand of quaking aspen (*Populus tremuloides*) with our fence in an area with a high density of elk. We monitored effectiveness of the fence with trackplots, animal-activated cameras, and changes in aspen stem height and density. We documented only 1 elk within the exclosure in 2 years of monitoring. Deer (*Odocoileus* spp.) freely used the enclosure as did beaver (*Castor canadensis*), black bear (*Ursus americanus*), bobcat *(Lynx rufus*), coyote (*Canis latrans*), mountain lion (*Puma concolor*), raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), and lagomorph (Leporidae). After 1 year of protection, mean aspen stem height increased 14.5 cm more inside the exclosure than outside, but stem density in the exclosure changed little compared to outside. Our fence design effectively excluded elk and has potential for protecting a variety of resources.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:92.



EVALUATING ELK CARRYING CAPACITY IN THE GREAT SAND DUNES COMPLEX OF LANDS

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BRUCE LUBOW, Natural Resources Ecology Lab, Colorado State University, Fort Collins, CO 80523, USA
GARY WOCKNER, Natural Resources Ecology Lab, Colorado State University, Fort Collins, CO 80523, USA
LINDA C. ZEIGENFUSS, U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Fort Collins, CO 80526, USA
JOHN COOK, National Council for Air and Stream Improvement, La Grande, OR 97850, USA
RACHEL COOK, National Council for Air and Stream Improvement, La Grande, OR 97850, USA

Abstract: To determine whether elk have approached or are approaching carrying capacity in and around Great Sand Dunes National Park and Preserve, Colorado, we are evaluating several types of ecological models, including a forage-based accounting model, a nutrition-based model, and population modeling. Data for the forage-based and nutritional models are being collected through 2008, as are data on plant production responses to grazing and elk utilization of key vegetation communities to evaluate severity of offtake. We modeled the elk population using elk classification survey data provided by CDOW from 1983 to the present and several recent population surveys. We are conducting analyses of elk body condition to evaluate herd health and gain further insight into carrying capacity. We intend to use the information from all of these models to provide resource managers with greater information than would be available using any single method or model. Our main objective is to provide resource managers with a range of tools to assess the potential impacts to the elk population and vegetation communities for a variety of elk management scenarios.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:93.

IDENTIFYING THE NON-RESIDENTS. RESULTS FROM THE 2007 COLORADO NON-RESIDENT ELK HUNTER SURVEY.

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Abstract: To address an over abundance of elk in the state, the Colorado Wildlife Commission reduced fees and liberally issued licenses for cow elk. As Colorado's elk herd reaches population objective, changes in the availability and fees for cow licenses will have to be addressed. To better understand how possible changes might affect non-resident hunters, a mail survey was administered in the spring of 2007 (response rate 79%, n=4142). The survey focused on differences between non-resident bull and cow elk hunters and contained questions pertaining to: their history of elk hunting in Colorado and other states/provinces; reasons for choosing Colorado; their 2006 Colorado elk hunting experience, and; their attitudes towards possible cow elk license fee changes. Results indicate that the majority of Colorado's non-resident elk hunters viewed their 2006 hunt as an important recreational activity that they plan on continuing under the current fee structure. Increased cow license fees would affect the intent of many non-residents return to Colorado. Most indicated they would return albeit at either a reduced frequency or with a different license type. Findings provide insight into possible CDOW revenue changes resulting from adjustments to cow elk fees and availability. A full report of the survey findings is available from the Public Involvement Section, Colorado Division of Wildlife.

WESTERN STATES AND PROVINCES DEER AND ELK WORKSHOP PROCEEDINGS 7:94.

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PRELIMINARY RESULTS OF MONTANA WOLF-UNGULATE STUDIES

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Abstract: We present preliminary results for intensive wolf-ungulate studies in Montana. Analysis is only starting for more extensive studies within Montana and results are not presented here. However, certain results are likely foreshadowed by results of intensive studies. Where wolf density has been high relative to prey within and near Yellowstone National Park, we have observed significant contributions of wolves to elk population dynamics and behavior. Where wolf densities are relatively low, effects are less pronounced or minimal. Other factors such as human hunting and other natural predators (especially bears) also play a role. In most of Montana, because of depredations in agricultural environments, wolves are being killed at higher rates than in Idaho and Wyoming. Thus, wolf density for most of Montana has not reached levels where significant ungulate population impacts might be expected. Many elk population numbers remain above management objective level. This is especially true in agricultural areas where neither wolves nor elk (except bulls) are especially beloved.

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