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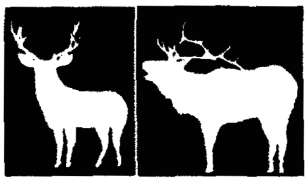
Western States and Provinces Deer and Elk Workshop



Wilsonville, Oregon

August 1-3, 2001

Proceedings

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Proceedings of the Western States & Provinces
Deer and Elk Workshop
Wilsonville, Oregon   August 1-3, 2001

Edited by
Jack A. Mortenson,
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Mary Jo Hendrick
Bruce K. Johnson

Sponsored by
Oregon Department of Fish and Wildlife
Rocky Mountain Elk Foundation
Bureau of Land Management
Oregon Chapter of The Wildlife Society
Hawkins & Powers Aviation, Inc.

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Western States & Provinces
DEER AND ELK WORKSHOP
Oregon 2001

WORKSHOP ANNOUNCEMENT

Held under the auspices of the Western Association of Fish and Wildlife Agencies
Host: Oregon Department of Fish and Wildlife
Sponsors: Rocky Mt. Elk Foundation and Mule Deer Foundation

INFORMATION

Meeting Location

- Holiday Inn Select - Located approximately 15 minutes south of Portland, Oregon.
- Conference room rates - Single/double occupancy at $59.00/night plus tax. For reservations, call 1-800-HOLIDAY or (503) 682-2211. Be sure to refer to the Deer and Elk Workshop.

Travel Arrangements

Hotel and conference facilities are 25 minutes from Portland International Airport (PDX). Hut Airport Transportation offers travel service between the airport and the conference facilities for $15.00 with hotel coupons 1-800-363-8059, 3-11pm PST. The hotel provides a complimentary shuttle service (for shopping and sight seeing) within a 6 mile radius of the hotel.

AGENDA

Wednesday - August 1, 2001

5:00 PM – 8:00 PM	Registration
6:00 PM – 8:00 PM	Icebreaker

Thursday - August 2, 2001

7:30 AM – 8:00 AM	Registration
8:00 AM – 8:15 AM	Welcome
8:15 AM – 9:00 AM	**States/Provinces Questionnaire/Summary Presentations**

Session One - Changing Landscapes
Bruce Johnson- Session Chair
Oregon Department of Fish and Wildlife

9:00 AM – 9:20 AM	A Test of a GIS-Based Habitat Effectiveness Model for Elk Mark Rumble USDA Forest Service
9:20 AM – 9:40 AM	Effects of Nutrition and Habitat Enhancements on Mule Deer Fawn Recruitment: Preliminary Results Chad Bishop Colorado Division of Wildlife

9:40 AM – 10:00 AM — Validation of Nutritional Condition Indices in Elk
Rachel Cook
National Council for Air and Stream Improvement

10:00 AM – 10:20 AM — Studies of Nutritional Influences on Elk: What We Have Learned So Far
John Cook
National Council for Air and Stream Improvement

10:20 AM – 10:40 AM — **BREAK**

10:40 AM – 11:00 AM — The Genetic Consequences of Elk Relocations and Subsequent Herd Growth: The Pennsylvania Elk Herd
Christen Williams
National Wildlife Research Center

11:00 AM – 11:20 AM — Conflict Resolution by Adaptive Management: Moving Elk Where They Want To Go
Tara Wertz
Oregon Department of Fish and Wildlife

11:20 AM – 12:00 PM — **Invited Speaker**
Changing Landscapes and Deer and Elk: How Do Large Ungulates Fit In
Martin Vavra
USDA Forest Service

12:00 PM – 1:00 PM — **LUNCH (included with registration)**

Session Two - Data Management and Population Ecology
Mary Jo Hedrick- Session Chair
Oregon Department of Fish and Wildlife

1:00 PM - 1:20 PM — Mule Deer Population Monitoring in Idaho
Hollie Miyasaki
Idaho Department of Fish and Game

1:20 PM- 1:40 PM — Ecology of Black-Tailed Deer in Greater Vancouver, Washington
Louis Bender
New Mexico Cooperative Fish and Wildlife Research Unit

1:40 PM – 2:00 PM — Performance of Global Positioning System Radio-Collars on Adult Mule Deer
Hall Sawyer
Colorado Division of Wildlife

2:00 PM – 2:20 PM — Estimating Mule Deer Population Size Using Colorado Quadrat System Corrected for Idaho Mule Deer Sightability: A Sportsmen's Issue
David Freddy
Colorado Division of Wildlife

2:20 PM – 2:40 PM — Is Merriam's Elk Really Extinct?
James Heffelfinger
Arizona Game and Fish Department

2:40 PM – 3:00 PM — **BREAK**

3:00 PM – 3:20 PM — The Impact of Harvest Rate on Antler Characteristics, Harvest Age, and Subsequent Economic Return on Properties with Restricted Access
Kenneth Clegg
Private Lands Consulting

3:20 PM – 3:40 PM — Effect of Adult Sex Ratio on Mule Deer and Elk Productivity in Colorado
Gary White
Colorado State University

3:40 PM – 4:00 PM — The Restoration of Elk in Ontario, Canada
Rick Rosatte
Ontario Ministry of Natural Resources

4:00 PM – 4:40 PM — **Invited Speaker**
Estimating Abundance and Composition of Deer and Elk Populations
Edward Garton
University of Idaho

4:40 PM — **Adjourn**

6:00 PM — **Banquet- Wallmo Award Presentation (included with registration)**

Friday - August 3, 2001

Session Three - Mortality Factors
Don Whittaker- Session Chair
Oregon Department of Fish and Wildlife

8:00 AM – 8:20 AM — Coyote Control and Mule Deer Management-An Example
Tom Watts
Jicarilla Game and Fish Department

8:20 AM – 8:40 AM — Mule Deer Survival Studies on the Uncompahgre Plateau, Colorado 1997-2001
Bruce Watkins
Colorado Division of Wildlife

8:40 AM – 9:00 AM — The Effects of Broadscale Predator Removal on Mule Deer Populations
Mark Hurley
Idaho Department of Fish and Game

9:00 AM – 9:20 AM — Survival and Cause-Specific Mortality of Buck Black-Tailed Deer in Washington
Louis Bender
New Mexico Cooperative Fish and Wildlife Research Unit

9:20AM – 9:40 AM	Summary of Mule Deer Survival Studies in Colorado, 1997-2001 Chuck Wagner Colorado Division of Wildlife
9:40 AM – 10:00 AM	Elk Recruitment in North Central Idaho- Does One Size Fit All? Peter Zager Idaho Department of Fish and Game
10:00 AM – 10:20 AM	**BREAK**
10:20 AM – 10:40 AM	Survival and Cause-Specific Mortality of Mule Deer Fawns During Summer in Western Colorado Thomas Pojar Colorado Division of Wildlife
10:40 AM – 11:20 AM	**Invited Speaker** Deer-Predator Relationships: A Review of Recent North American Studies with Emphasis on Mule and Black-Tailed Deer Warren Ballard Texas Tech University

Session Four - Interactions and Competition

DeWaine Jackson- Session Chair

Oregon Department of Fish and Wildlife

11:20 AM – 11:40 AM	Fine Scale Movements and Habitat Use by Elk and Mule Deer in Northeastern Oregon Alan Ager Pacific Northwest Research Center
11:40 AM – 12:00 PM	Ecological Relationships Between Columbian White-Tailed and Black-Tailed Deer in Southwest Oregon Lowell Whitney Oregon State University
12:00 PM – 1:30 PM	**LUNCH (included with registration)** **Workshop Committee Business Meeting**
1:30 PM – 1:50 PM	Mule Deer, Elk, and Livestock Interactions on Aspen Rangelands in the Intermountain West: A Preliminary Report Jessica Pettee Utah State University
1:50 PM – 2:10PM	Evidence for Competition Between Mule and White-Tailed Deer Metapopulations in North-Central Washington During the Past 19 Years Edward Garton University of Idaho
2:10 PM – 2:50 PM	**Invited Speaker** Interactions of Elk, Mule Deer and Cattle in Spring, Summer and Fall Priscilla Coe Oregon Department of Fish and Wildlife

POSTER PRESENTATIONS

Using Herbaceous Forage Distribution Analyses to Establish Annual Population Management Objectives for Elk in Arizona
Sharen Adams - Arizona Game and Fish Department

Preliminary Assessment of Paternity and Birth Dates of Calf Elk Sired by Mixed-Age Classes of Bulls
James Noyes - Oregon Department of Fish and Wildlife

Effect of Archery Hunting Seasons on Pregnancy Rates and Conception Dates of Elk: A Preliminary View
James Noyes -Oregon Department of Fish and Wildlife

Columbian Black-Tailed Deer Birth-Site Identification and Neonate Survival in Western Oregon
Nathan Pamplin - Oregon State University

Crepuscular Movement Patterns of Rocky Mountain Elk in Spring
Alan Ager - Pacific Northwest Research Station

Development of a Web-Based Mule Deer News and Information Network
Nevelyn Headrick - Utah State University

Habitat Use Patterns and the Effects of Human Disturbance on the Steamboat Elk Herd
Jacob Powell - Wyoming Cooperative Fish and Wildlife Research Unit

Compartive Ecology of Columbian White-Tailed Deer in Suburban and Wild Landscapes
Mark Ricca - US Geological Survey

Evaluation of Two Bull Elk Management Strategies in Northeast Oregon
Patrick Matthews - Oregon Department of Fish and Wildlife

Annual Reproductive Success of Elk With and Without Disturbance by Humans During Calving Season
Gregory Phillips - EDM International, Inc.

Inter- and Intraspecific Summer Foraging Dynamics of Mule Deer, Elk and Cattle
Scott Findholt - Oregon Department of Fish and Wildlife

Questions? Contact:

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Western States & Provinces

DEER AND ELK WORKSHOP

Oregon 2001

August 1-3, 2001

Holiday Inn Select, Wilsonville, Oregon

REGISTRATION FORM

PLEASE PRINT--- DUPLICATES OF THIS FORM MAY BE MADE FOR MULTIPLE REGISTRATIONS

INFORMATION

Name ______________________________

First Middle Initial Last

Affiliation/Mailing Address ____________________

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City State/Province Zip Country

Daytime Phone ______________________

Fax ______________________________

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PAYMENT

Mail this form with checks **payable to Western Association of Fish and Wildlife** to:
Northwest Rendezvous
11700 SW Ashwood Ct
Tigard, OR 97223

Registration $________

Guest Ticket(s) $________

Total Payment $________

Payment must accompany this form. Checks must be in U.S. funds drawn on an U.S. Bank. No credit cards or purchase orders will be accepted.

REGISTRATION

Early Registration – ***Received*** **by** ***June 30th***

- ☐ Regular \$130.00
- ☐ Student \$ 95.00

Late Registration – ***Received after June 30th***

- ☐ Regular \$150.00
- ☐ Student \$ 95.00

Registration \$________

GUEST TICKETS

Guest Name ______________________

_____ Banquet Dinner @ \$25.00 each

EVENTS

- ☐ I'm planning on attending the free social
- ☐ I'll be bringing a guest to the free social
- ☐ I'm planing on attending lunch on Aug. 2 - free with registration
- ☐ I'm planning on attending lunch on Aug. 3 - free with registration
- ☐ I'm planning on attending the banquet dinner - free with registration

❖ For questions concerning conference, location, or fees please contact Northwest Rendezvous: Phone: 503-590-4240; Email: Lizkraiter@aol.com

❖ Refunds will be issued on cancellations received before July 1, 2001.

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(Note: Formatted to reflect Workshop program chronology)

ORAL PRESENTATIONS

Mortality Factors

Session Chair – Don Whittaker

POSTER PRESENTATIONS

Additional Manuscript

(Included at the request of authors)

DEER AND ELK STATUS, AND MANAGEMENT, IN WESTERN NORTH AMERICA: SUMMARY OF STATE AND PROVINCE STATUS REPORT SURVEYS

A. COREY HEATH, Oregon Department of Fish and Wildlife, 61374 Parrell Road, Bend, OR 97702, USA
MARY JO HEDRICK, Oregon Department of Fish and Wildlife, P.O. Box 69, Summer Lake, OR 97640, USA
DOUGLAS F. COTTAM, Oregon Department of Fish and Wildlife, 2040 S.E. Marine Science Drive, Newport, OR 97365, USA
BRIAN T. FERRY, Oregon Department of Fish and Wildlife, 2042 S.E. Paulina Highway, Prineville, OR 97754, USA
PATRICK E. MATTHEWS, Oregon Department of Fish and Wildlife, 82119 Fish Hatchery Lane, Enterprise, OR 97828, USA

Abstract: We surveyed 19 Western Association of Fish and Wildlife Agencies (WAFWA) to collect information on deer (*Odocoileus* spp.) and elk (*Cervus* spp.) population status and management. We received responses from 18 agencies (95% return rate). Information and data are summarized by state or province, species or subspecies, and by issue. Our objectives were to: 1) collect and synthesize long term demographic data for deer and elk in western North America; and 2) illustrate current issues affecting deer and elk management.

Key Words: black-tailed deer, *Cervus elaphus,* mule deer, *Odocoileus hemionus, Odocoileus virginianus,* Rocky Mountain elk, Roosevelt elk, status, Tule elk, western North America, white-tailed deer.

Deer and elk populations in western North America have been intensively managed since recovery efforts began in the late 1800s, and early 1900s. There are many motives for the intense professional and non-professional interest in these species including scientific, religious, aesthetic, recreational, consumptive, and capitalistic values. Due to the challenges and difficulties of managing large ungulate populations for a variety of interests, an ever-changing political and socio-economic world, and a shrinking habitat base, wildlife researchers and managers strive to remain current on the latest developments in their field. The biennial Western States and Provinces Deer and Elk Conference is one venue professional biologists have to interact, and exchange data and ideas. The conference agenda historically includes a status report on deer and elk populations, and related management issues, provided by each participating Western Association of Fish and Wildlife Agency (WAFWA) member state or province. Our objectives with this report were to disseminate standardized, comprehensive information to participants on: 1) deer and elk population status; 2) hunter numbers and harvest; 3) provide a format that allows possible determination of long term trends; and 4) explore current issues and concerns related to deer and elk management in western North America.

METHODS

Surveys were sent to 19 WAFWA member states and provinces. Surveys were sent to agency directors for assignment to appropriate personnel for completion. We allowed late submission of surveys to ensure as complete a summary as possible.

The survey requested information on species specific demographic information, hunter numbers and harvest, population survey and management techniques, social perceptions, habitat issues, depredation policies, current research projects and published papers, disease incidence and concerns, cervid ranching, and data management and analysis. Responses were summarized and reported by state or province, year, and topic where possible. Due to incomplete responses and non-reporting, few statistical analyses were conducted. However, in many cases trends in various population and hunter parameters may be apparent in the tabularized information.

RESULTS

We received complete or partial responses from 18 of 19 surveys sent (95%). Only Texas did not respond. The number of states or provinces reporting specific data varied considerably and was inconsistent throughout the survey. However, all complete or partial responses were included in this report, resulting in slight differences within the data tables.

Deer Population Status and Harvest

Thirteen agencies provided population size or composition data for at least one species of deer (white-tailed deer: *Odocoileus virginianus*, mule deer: *O. hemionus hemionus*, and black-tailed deer: *O. hemionus columbianus/sitkensis*; Tables 1–3). Of those agencies providing data for 1995 and 2000, 71.4% (5 of 7) indicate slight to moderate increases in mule deer in the last 5 years (Table 1). However, only 40% (2 of 5) report mule deer populations increased between 1970 and 2000. Two agencies (Alaska and Oregon) reported black-tailed deer data and both suggest populations declined. Seven agencies supplied white-tailed deer estimates with 3 providing data for multiple years. Of those 3, all suggest stable (n = 1) or increasing (n = 2) white-tailed deer populations. Most states or provinces responded with information on deer population age and sex ratios (Table 2–3). However, variability in response type (e.g. mean vs. range for ratio data) precluded reasonable determination of trends. Most mule deer populations ranged from 5% to 25% below the desired management objective (Table 4).

All responding agencies indicated mule deer rifle hunter numbers and hunter days have declined since 1970 while white-tailed deer hunter numbers and hunting days have increased (Table 5). The trend in black-tailed deer hunter numbers varied with Alaska reporting a slight decline, Hawaii with a slight increase, and Oregon reporting a decline. Where agencies did not distinguish between deer species and reported data for multiple years (n=3), data also suggest a decline in deer hunter numbers since 1970. Reported trends in archery and muzzleloader deer hunting were variable (Table 6). Four agencies reported increases, 4 reported declines, and 3 reported relatively minor changes in archery deer hunters and hunter days. Six agencies reported increasing numbers, 3 reported declining numbers, 1 reported minor changes in number of muzzleloader deer hunters and hunter days.

Not surprisingly, reported trends in deer harvest mimics trends in hunter numbers. Rifle mule deer harvest has generally declined, rifle white-tailed deer harvest has generally increased, and trend in rifle black-tailed deer harvest varies by state or province (Table 7). Archery and muzzleloader deer harvest varied by state or province, but harvest trends were generally increasing for special weapons deer hunting (Table 8).

Population Status – Elk

Fourteen agencies provided population size or composition data for at least one subspecies of elk (Rocky Mountain elk: *Cervus elaphus nelsoni*, Roosevelt elk: *C. e. roosevelti*, or tule elk: *C. e. nannodes*; Tables 9–11). Seven of 10 states or provinces (70%) providing multiple years ($\geq$ 2 yr) of data report increasing Rocky Mountain elk populations.

Reported Roosevelt elk populations were increasing in 2 of 3 states, and Tule elk populations were increasing in California (Graph 9). Variability in the type and amount of data reported for sex and age ratios (Table 10–11) again precluded reasonable determination of trend for any elk species.

Reported trends in number of elk rifle hunters and hunter days were somewhat variable (Table 12). Six of 10 agencies reported Rocky Mountain elk hunter numbers increased, 1 reported a decline, and 3 reported a peak in hunter numbers during 1995 with a decline in 2000. Oregon reported declining numbers of Roosevelt elk hunters since 1985 and California reported recent increases in number of elk hunters for both Roosevelt and Tule elk. With some minor exceptions, it appears the general trend is for increasing numbers of archery and muzzleloader elk hunters and hunter days (Table 13).

Four agencies reported increases in Rocky Mountain elk rifle bull harvest until 1995, followed by a decline in 2000. Most agencies (83%) that reported multiple years of data also reported increases in rifle cow harvest through 2000 (Table 14). Interestingly, 2000 was the first reporting year where Rocky Mountain elk cow harvest exceeded bull harvest. Reported Roosevelt elk bull harvest declined in 3 of 5 states providing data and Tule bull elk harvest increased in California. Roosevelt and Tule cow elk harvest followed a pattern similar to that for Rocky Mountain elk with most agencies reporting an increasing trend. Archers increased bull elk harvest in 7 of 11 (63%) states or provinces and increased cow elk harvest in 5 of 10 (50%) states or provinces reporting for multiple years (Table 15). Muzzleloader bull elk harvest increased in 100% and muzzleloader cow elk harvest increased in 89% of the states or provinces providing data for more than one year.

Population Management

Agencies reported using a variety of methods to survey deer and elk populations. Fixed wing and helicopter aerial surveys were commonly reported techniques. Diurnal and nocturnal ground surveys using motor vehicle, and less often diurnal surveys by horseback, are also conducted. Two agencies conduct track counts and pellet group surveys to monitor trend. Survey data are usually used in models to estimate deer and elk populations and models ranged from very simple to complex. Several agencies simply use minimum numbers of animals observed as a minimum population estimate. Two agencies use mark-resight methods to estimate Rocky Mountain elk and British Columbia uses mark-resight methods to estimate Roosevelt elk populations in some areas. Only ½ of the states or provinces report using confidence intervals with their population estimates.

Deer and elk populations were affected by a variety of factors. Environmental conditions such as winter weather, drought, and habitat conditions were the most reported major factors influencing deer populations. Natural range expansion and trap and transplant were most often cited as the major factor influencing elk populations. Mild winter weather is also an important influence on elk numbers in Wyoming, Utah, South Dakota and Alberta.

Management and Social Perceptions

Sixteen of 18 agencies (89%) responded to several important questions regarding social issues related to deer and elk management (Table 16). Responses were provided by individuals within the agency and likely were not based on scientific opinion surveys. Respondents indicated antlerless deer hunting was favored by most agencies, a slight majority of hunters, and was opposed by most non-hunters. Perceptions were that antlerless elk hunting was unanimously favored by state agencies and hunters, but only slightly favored by non-hunters.

Predator control (coyotes, bears, cougars) to enhance ungulate populations was opposed by a majority of agencies and the non-hunting public. However, it was felt that hunters were heavily in favor of predator control. Agencies, hunters and non-hunters were all in favor of separate hunting seasons for different weapon types. Agencies and non-hunters were reported to oppose technological advancements for weapons. However, it was felt hunters were highly in favor of it. All groups were felt to be in strong opposition to hunting ungulates over bait. Finally, state agencies and non-hunters opposed the use of ATV's for hunting but agencies were divided on how the felt hunters perceived the issue.

Habitat

Seventeen agencies responded to questions regarding habitat issues and concerns. Most agencies (94%) agreed (12 strongly agreed and 3 agreed) that one of the most critical issues in the future health of deer and elk populations are maintenance of quality habitats (Table 17). Of the other two states, New Mexico strongly agreed for deer but disagreed for elk, and North Dakota had no opinion. Eleven (73%) agencies felt (4 strongly agreed, 7 agreed) that all agencies should identify key habitat characteristics required to maintain healthy deer and elk populations (Table 17). New Mexico agreed with the statement for deer but not for elk. No agency disagreed for deer and four (27%) had no opinion. Ten (63%) agreed (1 strongly agreed and 9 agreed) that a range-wide, reasonably detailed map of deer and elk habitats should be developed while 3 (19%) disagreed and 3 (19%) had no opinion (Table 17).

Most agencies (76%) believed they are losing deer and elk habitat. Nevada and New Mexico believe they are losing deer habitat but not elk habitat. North Dakota and Yukon responded they are not losing deer or elk habitat. Fifteen agencies listed what they felt were the three main causes of habitat loss in their respective state or province (Table 18). A wide variety of causes were given but several were repeated numerous times. Urbanization and development were identified by 11 (73%) states/provinces. Habitat management practices; i.e. logging, seral stage advancement, forest encroachment, and vegetation conversions were identified by 11 (73%) of the states and provinces. Fire suppression was listed by 7 (46%) agencies while 2 (13%) identified wildfires as a cause of habitat loss. Noxious weeds, increased road densities, agricultural development and recreational activities were each listed by 2 (13%) agencies. Nine (60%) characterized the rate of loss as critical (faster than ever before), 3 (20%) as the same as it always has been, and 3 (20%) said somewhere in between critical and same as it's always been (Table 19). Fourteen agencies (87%) are enhancing habitat, 12 (75%) are using education, 11 (68%) utilize land use planning laws and 10 (62%) are purchasing habitat/land and conservation easements (Table 20) as efforts to slow habitat loss. Twelve (75%) of the agencies are using 3 or more ways to slow the loss of habitat. No agency provided an acreage estimate of habitat loss (Table 21). However, 11 (65%) indicated they have historical habitat data available (Table 21). Of the 11 with historic data, 6 (54%) have surveys or transect data and 2 (18%) have habitat carrying capacity estimates.

Damage

Seventeen agencies provided information regarding depredation policies. Yukon does not have a depredation policy or at least did not report any. Subjective evaluation suggests most agencies have similar depredation policies. In general, agency policies require investigating complaints, providing acceptable assistance/solutions to landowners, and utilizing kill permits and/or depredation hunts. Several agencies have portions of their policies that are unique. In New Mexico, if after 1 year a landowner is not satisfied with how an elk complaint was handled, the complainant can legally shoot all elk on his property.

In British Columbia it is the responsibility of the landowner to maintain agricultural practices that discourage the entry of wild ungulates into agricultural areas. Nevada provides mule deer and elk tags to landowners receiving a certain level of damage. Landowners are then allowed to sell and receive proceeds from the tags.

Of 17 agencies responding, 10 (59%) do not provide any cash reimbursement to landowners for damage. Damage in Alberta is examined and adjusted by provincial hail and crop insurance experts and paid with monies from hunting license fees. Complaints in Colorado are investigated by the Division of Wildlife. Once agreement is reached with claimant on amount of settlement, a payment is issued from the wildlife cash fund. Idaho is required to pay for actual damages with a $1,000.00 deductible. In Nevada, cash reimbursement is provided for documented property or crop loss resulting from elk damage. Utah, Washington, and Wyoming each provide monetary compensation for damage, but did not describe specific parameters. Of 17 agencies providing information on landowner tags, 6 (35%: Alberta, California, North Dakota, Oregon, South Dakota, Utah) guarantee qualifying landowners a limited number of deer and or elk tags, 7 (41%) provide tags but do not guarantee specific landowners will receive tags, and 4 (24%) agencies (Arizona, British Columbia, Montana, Yukon) do not supply landowner tags in any form.

Current Research Projects

WAFWA agencies reported involvement in 33 deer studies and 19 elk studies (Table 22). Only 4 of 17 agencies responding (Hawaii, Nevada, North Dakota, Yukon) do not have any formal research for deer or elk. Eight of the 33 deer studies involve white-tailed deer with the remainder being mule and black-tailed deer projects. Most (35%) deer research projects are related to survival and causes of mortality with habitat related projects making up 26% of the deer studies. Elk project descriptions varied considerably and included habitat evaluations, survey techniques, diseases, nutrition, movements, predator/prey, survival/mortality, and elk/cattle competition. Involvement in research has led to numerous recent publications produced or contracted by agencies responding (Table 23). Complete information was not available for some citations. However, we listed incomplete information with the thought that this information may be of some use to the reader.

Disease

Seventeen agencies provided information regarding status of various diseases among wild and captive deer and elk (Table 24). Two agencies (Utah, Yukon) did not report any diseases of concern. Epizootic hemorrhagic disease (EHD) was the most commonly reported disease with 9 of 17 agencies (53%) reporting it. Bluetongue and chronic wasting disease (CWD) were reported by 4 agencies, brucellosis and tuberculosis by 3, and leptosprosis and hair slip syndrome by 2. Adenovirus hemorrhagic disease, elaeophorosis, and foot and mouth disease were each reported only once. Several agencies reported periodic disease occurrences in localized areas and reported potential impacts to management programs and populations. Oregon and Washington have initiated research efforts addressing hair slip syndrome and implications for black-tailed deer populations. Colorado reported bluetongue may be reducing fawn survival and recruitment, and New Mexico indicated EHD may have contributed to mule deer population declines.

With recent concerns regarding CWD, additional questions were asked regarding number of CWD cases to date, when it was first detected, presence of CWD monitoring programs, and what effects this or other diseases were having on wild deer and elk populations (Table 25).

Four states (Colorado, Montana, South Dakota, Wyoming) accounted for at least 250 confirmed cases, with the majority of cases in Colorado and Wyoming. All but one agency indicated they would monitor for CWD during 2001.

Game/Cervid Ranching

Seventeen agencies provided information regarding: 1) whether private holding, propagation, or recreational hunting of confined cervids was permitted; 2) what agency administers the program, what commercial uses are permitted, and how many facilities are present; and 3) whether adverse impacts to wild cervids have occurred as a result of interactions with captive cervids (Table 26). Sixteen agencies (94%) allow some form of commercial holding, propagation, and selling of cervid products. Washington was the only state/province completely prohibiting holding and commercial use of cervids. Two states (Oregon and Wyoming) have recently prohibited further facilities, with Wyoming enacting legislation which allows for only one facility. Of the 15 allowing commercial uses, 7 do not allow hunting of confined cervids, 4 do, and 4 could not be determined from their response. A total of 1,033 cervid facilities were reported in the 16 states/provinces. This should be considered a conservative estimate, as some agencies either did not provide a figure, or did not provide exact figures. Eleven of the 16 (69%) agencies reported no significant adverse interactions between captive and wild cervids. However, disease, escapes and interbreeding with wild stocks, illegal capture and sale of wild animals, and fence line interactions with wild bull elk were mentioned as concerns. Seven agencies (Montana, Wyoming, Utah, New Mexico, Oregon, Idaho, and Yukon) reported escapes or suspected escapes of captive cervids.

Administration of confined cervid programs varied with oversight in 6 states/provinces by natural resource agencies, 5 by agricultural-livestock agencies or boards, and 4 were jointly administered between agricultural, livestock, or natural resource agencies. One state did not report the administering agency.

Data Management and Analysis

Seventeen agencies responded to questions regarding standardization of population measurements, data management, and analysis (Table 27). The majority of agencies (94%) agreed (6 strongly agreed and 10 agreed) that managers and administrators should strive for standardized population measures and 11 (65%) agreed that all agencies should agree on the key population parameters to be measured. Further, 10 (59%) agreed that all agencies should establish standardized data collection protocols. Only 6 agencies (35%) agreed that harvest data collection and analysis guidelines and protocols should be followed by all agencies. Only 53 % of agencies (9 of 17) expressed support for consistent modeling guidelines and 71% (12 of 17) of responding agencies have no policies regarding adaptive harvest management strategies.

DISCUSSION

We attempted to summarize deer and elk status reports received from 18 western states and provinces in preparation for the Western States and Provinces Deer and Elk Workshop. We summarized data and information on population size and structure, hunter numbers and harvest, population management techniques, social issues, habitat variables, depredation policies, research projects, recent publications, disease, cervid ranching, and data management and analysis. Rigorous statistical analysis was not possible due to deficient data sets and variability in responses. In spite of these deficiencies, we believe this information in this format is valuable for deer and elk managers.

As a result of our efforts to compile and summarize these data we offer only 2 observations. First, despite the fact that the majority (94%) of the agencies believe the most critical issue facing deer and elk today is maintenance of quality habitats, no single agency provided an estimate of the amount of habitat lost and only 65% provided an estimate of historical habitat. We offer this as a suggestion for further work.

Although there appears to be strong support across agencies for consistency in the type and manner of data collection for deer and elk, there was a wide variety of sampling strategies and analytic approaches reported between agencies. Thus comparing data sets for deer and elk populations from across their range is difficult and appropriate inference is nearly impossible. New Mexico summarized it best "I firmly agree that peer reviewed parameters & techniques should be used in data collection and analysis. However, I believe each state has unique information needs, budget and staff constraints that make uniform application of any adopted methods a challenge." We offer this statement as a challenge for the future.

Table 1. Deer population estimates reported by western states and provinces in North America, 1970–2000. States or provinces not having a species or not reporting information for a species are not included.

State or Province	Year			
	1970	1985	1995	2000
Mule Deer				
Alberta		86,000		120,000
Arizona	130,000	155,000	110,000	105,000
Colorado		465,000	530,370	548,200
Nevada	75,000	156,000	118,000	133,000
New Mexico	300,000	250,000	200,000	150,000
Oregon		251,200	235,300	257,068
South Dakota				83,000
Utah	350,000	360,000	254,964	319,720
Wyoming		423,000	429,000	535,000
Yukon	150			700
Black-tailed Deer				
Alaska			355,000	315,000
Oregon		432,234	376,500	
White-tailed Deer[a]				
Alberta		115,000	150,000	200,000
Arizona	40,000	85,000	80,000	80,000
Colorado				8,780
New Mexico				10,000
South Dakota				175,000
Wyoming		48,000	37,000	58,100
Yukon		15		40
No Species Delineation				
California	1,000,000	850,000	760,000	677,000
Washington				320,000
Total Reported				
Mule Deer	1,895,150	2,146,200	1,877,634	2,251,688
Black-tailed Deer		432,234	731,500	315,000
White-tailed Deer	40,000	248,015	267,000	531,920
All Species	1,935,150	2,826,449	2,876,134	3,098,608

[a] No sub-species delineation is provided because it was not asked for in the survey.

Table 2. Average mule deer fawn ratio (fawns:100 does) and buck ratio (bucks:100 does) reported by western states and provinces in western North America, 1970–2000. States or provinces not reporting information are not included.

State or Province	1970		1985		1995		2000	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Fawns:100 Does								
Alberta								43–116
Arizona	48		54		33		44	
California						25–69		18–98
Colorado			67	56–75	52	32–71	49	31–78
Idaho		50–100		50–100		50–80		50–100
Montana								22–93
Nevada	68	36–96	68	26–90	58	31–85	54	31–87
New Mexico	62		42		40		47	
Oregon	64	51–84	54	25–94	58	22–94	51	0–82
South Dakota							150	139–160
Utah	75	33–119	80	50–114	63	28–96	58	25–79
Washington								44–88
Wyoming				44–108		41–81		56–96
Bucks:100 Does								
Alberta								5–62
Arizona	29		22		16		19	
California					27	9–51	29	11–41
Colorado			15	9–27	19	8–46	25	12–39
Idaho		5–40		5–40		5–40		5–40
Montana								4–50
Nevada	32	10–54	23	10–50	24	11–58	29	14–49
New Mexico	35		25		20		19	
Oregon	12		14	2–37	15	2–37	17	8–120
South Dakota							23	15–30
Utah	36		14	2–26	14	6–34	18	12–48
Washington								19–28
Wyoming				8–28		16–50		14–49

Table 3. Average black-tailed and white-tailed deer fawn ratio (fawns:100 does) and buck ratio (bucks:100 does) reported by western states and provinces in western North America, 1970–2000. States or provinces not having a species or not reporting information are not included.

State or Province	1970		1985		1995		2000	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Black-tailed Deer								
Fawns:100 Does								
California						25–69		18–98
Hawaii	20		33		33		50	
Oregon	54	33–83	57	33–81	42	12–106	51	25–82
Washington								48–88
Bucks:100 Does								
California								5–62
Hawaii	100							
Oregon	26	7–54	29	5–61	23	7–47	27	6–48
Washington								26–70
White-tailed Deer								
Fawns:100 Does								
Alberta								27–120
Arizona	31		50		26		36	
Montana								38–71
South Dakota							131	117–145
Washington								49–122
Wyoming				63–89		52–71		62–88
							23	15–30
Bucks:100 Does								
Alberta								5–47
Arizona	26		31		24		22	
Montana								17–41
South Dakota							31	19–43
Washington								16–22
Wyoming				22–35		24–30		28–43

Table 4. Mule deer population status relative to stated management objective for the year 2000 in five western states.

State	Population Estimate	Management Objective (MO)	Percent of MO (%)
Arizona	105,000	140,000	75
Colorado	548,200	629,000	87
Oregon	257,068	317,400	81
Utah	319,720	426,100	75
Wyoming	535,000	561,000	95

Table 5. Reported rifle deer hunter numbers and deer hunting effort in western North America, 1970-2000. States or provinces not allowing hunting for a species or not reporting information are not included.

		Number of Hunters				Number of Hunter Days			
Deer Species	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Mule Deer	Alberta		58,099	45,916	38,660		267,675	242,157	206,229
	Colorado	171,731	146,515	144,425	69,843		546,637	543,800	251,465
	Idaho	197,900	98,600	60,500			521,600	547,000	
	Nevada	23,781	30,846	16,420	22,628		120,766	77,087	89,533
	New Mexico	97,000	87,025	54,259	53,840		262,070	161,028	171,950
	North Dakota	9,721	6,956	9,015	3,971	20,017	19,685	28,397	13,978
	Oregon	166,350	100,387	66,127	69,605		395,869	302,856	309,210
	Utah	178,005	235,484	77,959	71,819	594,478	564,749	292,822	282,650
	Wyoming	126,189	87,794	62,981	67,509	436,719	605,779	585,723	499,567
Black-tailed Deer	Alaska		8,500	12,405	11,196		50,647	86,021	56,535
	Hawaii	99	1,033	1,224	1,949	178	1,538	2,149	3,451
	Oregon	100,870	155,669	135,291	116,861		1,301,609	1,085,557	863,752
White-tailed Deer	Alberta		79,819	74,511	81,795		396,857	499,329	503,879
	Idaho		38,000	79,300			207,000	533,000	
	North Dakota	37,610	60,024	75,187	80,800			299,279	335,111
	Wyoming		21,389	17,841	21,965		183,945	192,683	158,148
No Distinction	Arizona	97,257	84,809	58,980	42,811	396,248	336,348	243,731	169,739
	British Columbia							443,000	
	California	392,000	314,810	198,053	189,675				
	Montana	136,903	190,935	177,919	138,318		915,538	1,222,910	954,659

Table 6. Reported archery and muzzleloader deer hunter numbers and deer hunting effort in western North America, 1970-2000. States or provinces not allowing hunting with archery or muzzleloader equipment for a species, or not reporting information are not included.

		Number of Hunters				Number of Hunter Days			
Weapon Type	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Archery	Alberta			6,698				54,359	101,550
	Arizona	5,275	12,280	20,123					
	Colorado	9,292	18,622	22,088	10,331		134,100	181,263	78,403
	Hawaii		76	167	101		88	201	332
	Idaho		12,600	20,100			81,700	137,300	
	Montana	3,438	21,736	17,004			128,153	137,361	
	Nevada	766	2,237	2,570	2,579		11,509	14,393	14,562
	New Mexico	5,419	5,825	5,501	12,890			42,351	98,700
	North Dakota	3,500	10,249	11,370	10,603		131,039	129,239	124,736
	Oregon		16,012	25,154	34,326		64,485	201,148	277,198
	Utah	16,775	26,539	13,107	11,782	71,728	153,707	90,644	91,774
	Washington		13,187	20,108	17,396		135,712	214,556	
	Wyoming	1,397	7,034	6,478	6,790		40,952	35,682	44,718
Muzzleloader	Arizona				822				3,812
	California		379	510	660				
	Colorado		3,580	6,573	4,064		15,094	27,566	17,611
	Hawaii			204	186			288	298
	Idaho		2,500	4,550			10,600	2,800	
	Nevada		745	1,024	1,180		2,839	4,751	5,472
	New Mexico		7,030	5,331	7,113				
	North Dakota			646	1,440			2,586	7,476
	Oregon		1,040	2,646	2,842		4,702	13,584	15,232
	Utah		6,290	11,115	11,755		28,002	53,373	51,883
	Washington		2,350	10,654	6,913		11,079	63,036	
	Wyoming				348				

Table 7. Reported rifle deer harvest in western North America, 1970-2000. States or provinces not allowing hunting for a species or not reporting information are not included.

		Buck Harvest				Doe Harvest			
Deer Species	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Mule Deer	Alberta		9,346	10,347	8,586		8,586	8,815	8,265
	Arizona	13,177	23,688	9,001	5,192	420	383	0	0
	British Columbia			22,850					
	Colorado	50,140	44,299	35,576	26,611	20,114	8,358	40,128	5,768
	Idaho	44,700	25,800	14,800	20,900	33,400	8,900	2,900	8,100
	Montana		43,952	45,655	36,371		27,348	30,891	9,293
	Nevada	10,333	16,927	6,937	9,146	4,136	1,790	577	2,329
	New Mexico	34,313	24,015	10,809	13,760	3,546			0
	North Dakota	2,238	2,895	3,787	2,220	1,588	3,038	3,553	1,112
	Oregon	54,595	33,180	21,334	24,013	14,265	2,093	3,551	4,354
	South Dakota				3,120				891
	Utah	68,243	53,773	21,861	23,425	30,510	43,640	1,200	4,244
	Washington			7,691	7,031			3,466	2,374
	Wyoming	58,967	36,849	24,636	36,242	37,922	14,469	6,717	5,559
Black-tailed Deer	Alaska		11,571	16,174	10,410		3,606	4,022	3,100
	British Columbia			17,000					
	Hawaii	2	18	40	64	0	0	0	16
	Oregon	25,053	32,040	27,336	21,223	4,347	11,341	5,937	4,781
	Washington		15,309	13,588	9,973		2,781	3,286	3,192
White-tailed Deer	Alberta		12,347	25,219	24,283		8,158	9,800	12,354
	Arizona	2,207	6,792	4,894	4,204	35	110	0	0
	Idaho		9,200	20,400	10,000		3,100	8,100	3,700
	Montana	24,929	25,225	31,700	27,448		17,724	29,095	17,348
	North Dakota	13,675	23,450	25,625	24,800	8,590	24,624	26,566	27,350
	Oregon			405	680			230	234
	South Dakota				12,500				12,000
	Washington			6,004	8,407			3,731	4,784
	Wyoming	3,771	5,512	4,479	7,166	6,107	3,455	2,480	3,439
No Distinction	California	38,645	31,651	15,922	19,540	1,742	437	527	449

Table 8. Reported archery and muzzleloader deer harvest in western North America, 1970-2000. States or provinces not allowing hunting with archery or muzzleloader equipment for a species, or not reporting information are not included.

		Buck Harvest				Doe Harvest			
Weapon Type	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Archery	Alberta			538	1,127			327	779
	Arizona	228	755	1,230					
	California	331	303	1,214	1,393		621		4
	Colorado	1,127	1,894	2,326	1,640	414	2,206	1,934	320
	Hawaii	0	0	0	0	0	0	0	1
	Idaho		725	805	645		475	570	580
	Montana	290	965	1,080	3,952[a]	151	634	1,489	
	Nevada	63	420	308	480	55	0	0	0
	New Mexico	329	359	755	2,060				100
	North Dakota		1,414	2,378	2,470		1,460	2,147	1,380
	Oregon			3,065	4,414			997	979
	South Dakota				1,840				424
	Utah	1,819	4,097	1,963	2,575	1,189			130
	Washington		1,207	1,574	1,675		1,519	1,722	1,498
Muzzleloader	Arizona				137				0
	California		46	88	82		31	20	14
	Colorado		1,074	1,061	1,002		0	874	293
	Hawaii	0	0	6	7	0	0	0	0
	Idaho		350	500	525		200	300	300
	Nevada		383	292	482		0	0	0
	New Mexico		1,557	1,354	2,094				
	North Dakota			127	244			172	284
	Oregon			521	638			512	517
	Utah		1,175	1,770	4,478				
	Washington		336	1,012	751		620	1,511	725

Table 9. Elk population estimates reported by western states and provinces in North America, 1970–2000. States or provinces not having a species or not reporting information for a species are not included.

State or Province	Year			
	1970	1985	1995	2000
Rocky Mountain Elk				
Alberta			25,000	
Arizona	10,500	19,000	20,000	25,000
California	1,000	1,000	1,250	1,250
Colorado	80,000	132,500	203,000	263,300
Montana			93,401	99,627
Nevada	100	1,400	3,300	5,700
New Mexico	30,000	45,000	62,500	71,500
Oregon		52,250	64,003	60,934
South Dakota				5,200
Utah	7,500	30,000	59,355	62,635
Wyoming		70,300	110,000	99,000
Yukon		70		100
Roosevelt Elk				
Alaska			1,600	1,240
California	2,000	3,000	3,500	4,000
Oregon		42,800	55,700	62,752
Tule Elk				
California	500	1,470	2,900	3,600
Total Reported				
Rocky Mountain Elk	129,100	351,520	641,809	694,246
Roosevelt Elk	2,000	45,800	60,800	67,992
Tule Elk	500	1,470	2,900	3,600
All Species	131,600	398,790	705,509	765,838

Table 10. Average Rocky Mountain elk calf ratio (calves:100 cows) and bull ratio (bulls:100 cows) reported by western states and provinces in western North America, 1970–2000. States or provinces not reporting information for a year are not included.

State or Province	1970		1985		1995		2000	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Calves:100 Cows								
Alberta				26–49				
Arizona	55		44		41		45	
California		14–60		14–60		14–60		14–60
Colorado			50	47–67	50	36–64	48	26–59
Idaho		20–50		20–50		5–50		10–50
Montana						15–44		15–60
Nevada			56	47–62	46	42–66	46	
New Mexico	59		50		37		41	21–61
Oregon	47	39–61	39	18–58	38	18–68	31	12–52
South Dakota							55	50–60
Utah		40–45	51	39–60		40–45		45–55
Washington								21–56
Wyoming								23–64
Bulls:100 Cows								
Arizona	32		31		29		36	
California		25–60		25–60		25–60		25–60
Colorado			7	4–31	20	9–78	26	13–59
Idaho		5–40		5–40		5–40		5–40
Montana						8–40		4–38
Nevada							45	40–52
New Mexico	25		13		32		28	
Oregon	6	2–40	8	3–18	8	2–48	12	4–37
South Dakota							30	25–35
Utah			19		11		13	
Washington								9–43
Wyoming								11–53

Table 11. Average Roosevelt and Tule elk calf ratio (calves:100 cows) and bull ratio (bulls:100 cows) reported by western states and provinces in western North America, 1970–2000. States or provinces not having a species or not reporting information for a year are not included.

State or Province	1970		1985		1995		2000	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Roosevelt Elk								
Calves:100 Cows								
Alaska					22		19	
California		14–60		14–60		14–60		14–60
Oregon	37	32–58	33	17–51	33	25–57	30	11–47
Washington								21–56
Bulls:100 Cows								
California		25–60		25–60		25–60		25–60
Oregon	4	2–11	8	1–18	10	1–20	12	2–21
Washington								9–43
Tule Elk								
Calves:100 Cows								
California		17–65		17–65		17–65		17–65

Table 12. Reported rifle elk hunter numbers and elk hunting effort in western North America, 1970-2000. States or provinces not allowing hunting for a species or not reporting information are not included.

		Number of Hunters				Number of Hunter Days			
Elk Species	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Rocky Mountain	Alberta		37,412	19,701	27,113		179,002	132,000	175,373
	Arizona	5,677	10,323	14,713	16,113		51,195	51,095	57,154
	British Columbia							155,000	
	California			5	5				
	Colorado	84,595	122,597	185,382	192,629		599,171	889,833	839,382
	Idaho	72,800	67,200	101,500			455,000	661,000	
	Montana	77,819	89,182	109,860	99,921		579,772	884,203	785,345
	Nevada	15	95	232	619	88	285	1,024	5,084
	New Mexico	6,577	8,086	17,921	17,400				61,600
	North Dakota		5	51	167		107	315	752
	Oregon	52,190	76,075	70,674	59,687		349,514	368,347	200,916
	South Dakota				1,024				6,656
	Utah	10,354	24,751	33,964	26,729	40,203	126,011	133,028	141,456
	Wyoming	40,251	45,809	53,041	51,944	219,864	870,371	1,013,083	872,659
Roosevelt	Alaska			490					
	British Columbia							2,500	
	California	100		40	130				
	Oregon	21,370	52,126	46,846	44,718	110,340	247,252	224,428	202,285
Tule	California			73	157				

Table 13. Reported archery and muzzleloader elk hunter numbers and elk hunting effort in western North America, 1970-2000. States or provinces not allowing hunting with archery or muzzleloader equipment for a species, or not reporting information are not included.

		Number of Hunters				Number of Hunter Days			
Weapon Type	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Archery	Alberta			1,691				12,257	28,484
	Arizona		3,608	6,654	6,978		24,471	47,049	49,801
	Colorado	1,908	11,869	24,374	32,190		92,447	192,406	242,406
	Idaho		8,200	21,600			57,000	161,400	
	Montana	1,780	8,483	15,769			51,943	124,488	
	Nevada	0	0	66	360	0	0	360	2,198
	New Mexico		2,949	6,682	7,200				31,500
	Oregon		16,794	22,580	32,896			191,462	270,318
	South Dakota				130				1,664
	Utah		1,971	6,729	5,346		12,196	46,365	36,655
	Washington		9,707	14,182	11,356		90,339	110,865	
	Wyoming	545	4,605	6,331	7,478	4,905	35,324	53,048	61,042
Muzzleloader	Arizona			753	1,118			2,788	40,33
	California			73	157				
	Colorado		4,542	8,647	16,046		22,591	45,921	84,270
	Idaho	0	2,100	5,100		0	9,600	24,200	
	Nevada	0	0	0	200	0	0	0	955
	New Mexico		2,231	4,603	6,700				
	Oregon			801	1,906			3,970	9,975
	Utah	0	239	1,043	2,167	0	1,191	5,937	9,840
	Washington		2,341	10,886	10,917		13,644	66,872	
	Wyoming				173				

Table 14. Reported rifle elk harvest in western North America, 1970-2000. States or provinces not allowing hunting for a species or not reporting information are not included.

		Bull Harvest				Cow Harvest			
Elk Species	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Rocky Mountain[a]	Alberta		1,776	1,508	1,707		1,328	683	1,366
	Arizona	848	2,373	3,162	2,984	578	3,474	4,719	5,137
	California	0	0	1	0			4	4
	Colorado	12,544	12,496	17,233	24,678	4,515	8,697	14,180	28,590
	Idaho	6,950	11,100	13,100	7,800	7,200	3,800	7,450	10,100
	Montana	13,600	9,949	10,131	8,055	5,658	7,649	11,804	11,424
	Nevada	6	49	123	299		33	38	322
	New Mexico	1,584	1,667	4,584	3,600		579	2,878	4,500
	North Dakota		2	23	44		0	7	50
	Oregon	7,285	8,096	8,395	5,745	2,055	5,837	6,965	5,775
	South Dakota				435				234
	Utah	1,762	4,733	4,110	4,825	233	898	3,349	
	Washington		4,583	2,734	3,212		2,112	2,311	2,448
	Wyoming	9,871	7,580	9,063	9,837	8,141	6,229	8,632	12,945
Roosevelt	Alaska			56	34			40	46
	California	10		11	54	11		9	10
	Oregon	3,230	4,321	3,662	3,358	110	1,516	1,822	2,241
	Washington		1,416	772	682		903	612	453
Tule	California	0	0	34	56	0	0	19	63

[a] British Columbia reported a Rocky Mountain elk harvest of 3,800 elk in 1995 but did not distinguish sex of harvest.

Table 15. Reported archery and muzzleloader elk harvest in western North America, 1970-2000. States or provinces not allowing hunting with archery or muzzleloader equipment for a species, or not reporting information are not included.

		Bull Harvest				Cow Harvest			
Weapon Type	State or Province	1970	1985	1995	2000	1970	1985	1995	2000
Archery	Alaska	0	0	0	1				
	Alberta			48	143			42	65
	Arizona		325	1,034	804		485	800	1,077
	Colorado	116	810	1,841	2,481	61	595	1,311	1,632
	Idaho		350	1,375	1,000		150	400	325
	Montana	12	462	973		17	536	294	
	Nevada	0	0	11	24	0	0	11	68
	New Mexico		208	1,261	1,500		206	498	300
	Oregon			1,195	1,521			1,252	1,233
	South Dakota				25				4
	Utah		147	344	299		42	303	460
	Washington		412	334	441		465	834	496
	Wyoming	18							
Muzzleloader	Arizona			134	252			276	246
	California	0	0	34	56	0	0	19	63
	Colorado		593	940	1,452		151	666	1,287
	Idaho	0	60	45	175	0	90	65	475
	Nevada	0	0	0	31	0	0	0	60
	New Mexico		183	874	1,100		76	426	1,100
	Oregon			22	123			150	266
	Utah	0	52	80	379	0		186	201
	Washington		199	297	420		273	477	518

Table 16. Perceived acceptance of specific wildlife management actions by agencies, hunters, and non-hunters. Data represent number of responses where the agency representative felt respective groups were either supportive (Pro) or in opposition (Con) to an action or issue.

	Agency		Hunters		Non-hunters	
	Pro	Con	Pro	Con	Pro	Con
Antlerless Deer Hunting	13	2	7	5	3	7
Antlerless Elk Hunting	14	0	13	0	5	4
Limit Hunter Number	11	2	9	3	6	3
Coyote Control to Enhance Ungulate Populations	5	9	13	0	1	12
Cougar or Bear Control to Enhance Ungulate Populations	6	8	10	1	0	12
Separate Weapons Seasons	11	4	11	3	4	2
Improvements in Weapons Technology	1	10	11	1	0	8
Hunting Ungulates Over Bait	2	11	1	10	0	13
Off-road ATV Use for Hunting	1	13	4	4	0	12

Table 17. State and province responses to questions regarding habitat issues: '++' = Strongly Agree; '+' = Agree; '0' = No opinion; '-' = Disagree; '—' Strongly Disagree

State or Province	Maintaining quality habitat critical for future of deer and elk.	All states need to identify key habitat characteristics.	Range-wide habitat maps should be developed.
Alberta	++	++	+
Arizona	++	0	+
British Columbia	+	+	+
California	++	++	++
Colorado	++	+	-
Hawaii	++	0	0
Idaho	++	+	+
Montana	++	0	0
Nevada	++	+	+
New Mexico (Deer)	++	+	+
New Mexico (Elk)	-	-	+
North Dakota	0	0	0
Oregon	++	+	+
South Dakota	+	+	+
Utah	++	++	+
Washington	++	+	-
Wyoming	++	++	-
Yukon	+	0	0

Table 18. Main causes of deer and elk habitat loss reported by western states and provinces.

State or Province	Causes of Habitat Loss
Alberta	1) Agricultural intensification and expansion (clearing, cultivation, grazing).
	2) Forest encroachment.
	3) Increased road densities associated with a variety of land uses (timber harvest, oil and gas exploration and development, linear corridors, recreation). I find that it is quite limiting to isolate 3 reasons, in fact it is the continual cumulative erosion of habitat for all the things associated with increased human population (i.e. increased demands on the environment for a whole array of products that humans want). It may be one thing in one area and 10 things in another that need to be addressed.
Arizona	1) Urban Development.
	2) Recreational activities (OHV).
British Columbia	1) Logging of critical winter ranges.
	2) Forest fire suppression for creation of early seral habitats.
	3) Agricultural development.
California	1) Habitat management practices.
	2) Development.
	3) Fire suppression.
Colorado	1) Housing sub-divisions and developments.
	2) Urban sprawl and associated highway and road construction.
	3) Loss of productive vegetation due to many habitats reaching mature seral stages due to fire suppression.
Hawaii	1) Alien weeds spreading into habitat (non-palatable species encroachment).
Idaho	1) Seral stage advancement away from shrub/early stages.
	2) Urbanization.
	3) Fire conversion of shrub habitats to annual grasses.
Montana	1) Subdivision.
	2) Vegetation manipulation.
	3) Poor range management.
Nevada	1) Wildfires.
	2) Noxious weed invasion and expansion.
	3) Urbanization and associated infrastructure.
New Mexico	1) Juniper and pinyon pine encroachment.
	2) Fire suppression.
	3) Aging deer habitats.

Table 18. Continued.

State or Province	Causes of Habitat Loss
Oregon	1) Development of land.
	2) Forage degradation.
South Dakota	1) Lack of fire on public range.
	2) Urban development of private lands scattered on public land.
	3) Logging practices on public lands.
Utah	1) Vegetation conversions.
	2) Urbanization/recreation activities/population expansion.
	3) Lack of disturbance in some habitats particularly aspen, pinyon pine/juniper.
Washington	1) Human development.
	2) Reduction in timber harvest and fire suppression.
	3) Changes in industrial timber management.
Wyoming	1) Subdivision/ranchettes.
	2) Aging habitats/fire suppression/shrub control.
	3) Drought.

Table 19. How western states and provinces subjectively characterized rate of habitat loss for deer and elk.

State or Province	Alarming Rate	Critical, (faster than ever before).	Between critical and as it has always been.	As it has always been.	Slower than it has been.
Alberta				X	
Arizona			X		
British Columbia				X	
California		X			
Colorado		X			
Hawaii			X		
Idaho		X			
Montana		X			
Nevada		X			
New Mexico		X			
Oregon		X			
South Dakota				X	
Utah			X		
Washington		X			
Wyoming		X			

Table 20. How western states and provinces are trying to slow the loss of habitat.

State or Province	We are Not	Land Use Planning Laws	Purchase Land and Habitat	Education	Conservation Easements	Enhancing Habitat	Other
Alberta		X	X	X	X	X	X
Arizona		X	X	X	X	X	
British Columbia		X					
California	X	X	X	X	X	X	X
Colorado					X	X	
Hawaii						X	X
Idaho		X	X	X	X	X	
Montana			X	X	X	X	X
Nevada				X		X	X
New Mexico		X		X		X	
Oregon		X	X	X	X	X	
South Dakota			X		X	X	
Utah		X	X	X	X	X	X
Washington		X	X	X	X	X	
Wyoming		X	X	X		X	
Yukon		X		X			

Table 21. State and province responses to questions regarding loss of habitat estimates and historic measurements.

State or Province	Have habitat loss estimate.	Historic habitat data available?	Description of historic measurements.
Alberta	NO	NO	However, analysis of air photos over time could provide this.
Arizona	NO	YES	Some historic (10-20 years) range and density maps, but data is qualitative not quantitative.
British Columbia	NO	YES	Preliminary habitat capability (what the land can support under optimal conditions) and suitability (what the land currently can support in it's present state), draft maps available for all ungulates.
California	NO	YES	Old photographs and habitat surveys conducted in the 1940's and 50's.
Colorado	NO	YES	Has worked with the FS and BLM in the past to establish range exclosures and photo plots on public lands. Also, a limited amount of range transect data is available for a few areas of the state as well as attempts to quantify carrying capacity for a few areas.
Hawaii	NO	YES	Deer were first released on Kauai in 1961. Have conducted deer browse surveys since 1969. Deer are not native to Hawaii, so we have followed their impact on vegetation since their introduction. However, not all habitat changes are related to deer.
Idaho	NO	NO	
Montana	NO	YES	Vegetation exclosures (masters student currently evaluating) and transects.
Nevada	NO	YES	Estimated summer and winter range geographic areas that could be reassessed.
New Mexico	NO	YES	Statewide browse transects that should shed light on browse density, distribution health/vigor.
North Dakota	N/A	NO	
Oregon	NO	NO	
South Dakota	NO	NO	
Utah	NO	YES	Permanent range trend program that monitors 150-200 sites on a 5-year cycle. It has been in place 20+ years and has a significant database.
Washington	NO	YES	LANDSAT imagery yet to be analyzed.

Table 21. Continued.

State or Province	Have habitat loss estimate.	Historic habitat data available?	Description of historic measurements.
Wyoming	NO	NO	Has documentation of past problems, that is, mule deer destroying shrub winter ranges and winter ranges that no longer exist.
Yukon	N/A	NO	

Table 22. Current deer and elk research projects reported by WAFWA agencies.

Arizona – Evaluating chronic wasting disease. Mule deer habitat selection in relation to forest restoration. Nutrition in mule deer. Evaluating elk surveys.

Alberta – Studying impacts of coyote predation and different strategies used by mule and white-tailed deer to avoid predation. Elk habitat use and management plan for a herd that shares provincial park and private land.

British Columbia – Studies relative to deer winter cover requirements. Elk studies focus on methods to restore and maintain elk habitat and elk populations.

California – Mule and black-tailed deer studies involving predator/prey relationships, habitat use, population dynamics, and ecosystem dynamics. Elk habitat use involving GPS transmitters, and Tule elk physical condition monitoring.

Colorado – Determination of neo-natal fawn survival. Investigating affects of supplemental feeding to increase fawn survival. Investigations concerning chronic wasting disease and deer density. Elk studies involving cow and calf survival rates in different habitats. Developing methodology to provide reliable and precise estimates of elk density.

Idaho – Effects of coyote and cougar predation on deer populations. Developing landscape models to predict fawn survival. Studying effects of cougar and black bear predation on elk populations and productivity.

New Mexico – Coyote control and measuring population response. Spatial dynamics, conflict evaluation, and demographics for elk that winter near San Antonio Mountain.

Oregon – Black-tailed deer survival study and an evaluation of data collection methodology in southwest Oregon. Survival rates and causes of mortality for adult white-tailed deer. Two separate studies involving neonatal survival rates and causes of mortality of white-tailed and black-tailed deer. Black-tailed deer survival, causes of mortality, and impacts of harvest on populations in southwest Oregon. Validating models that link predation and nutrition with elk and mule deer recruitment in Oregon. Regional variation in recruitment of elk and mule deer: modeling animal condition and predator densities.

South Dakota – White-tailed deer fawn mortality and habitat use. Movement and home range use of mule and white-tailed deer. White-tailed and mule deer habitat use in Black Hills. White-tailed deer nutrition study.

Utah – Elk/cattle forage competition study. Studying effects of coal bed methane and natural gas drilling on wintering deer and elk.

Washington – Black-tailed deer adult male mortality study. Mule deer population study. Relating body condition to population dynamics in Roosevelt elk. Elk mark -resight estimation study. Hair slip syndrome in black-tailed deer. Roosevelt elk survival on the Olympic peninsula. Estimating deer numbers from DNA in pellets.

Wyoming – Evaluation of movements, range use, and migration bottle necks in western Wyoming. Evaluating vaccination of elk with strain-19 vaccine for brucellosis. Studying methods of transmission of chronic wasting disease in deer and elk. Evaluating methods to improve production and nutritional content of shrubs son summer and winter ranges of mule deer.

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Table 24. Ungulate disease and health concerns reported by western states and provinces.

State or Province	Reported Disease(s)[a]	Reported Concerns/Effects
Alberta	TB	Periodic, localized white-tailed deer die-offs.
Arizona	BR, BT, EHD, TB	None
British Columbia	EHD	None
California	AHD, EHD	Periodic, localized mule/black-tailed deer die-offs.
Colorado	BR, BT, CWD, EHD, EL, LE	Bt causing reduced fawn recruitment.
Hawaii	BT, LE	None
Idaho	BR, BT, EHD	None
Montana	CWD	None
Nevada	Unknown disease	Increased mule deer mortality in NW Nevada.
New Mexico	EHD	May have contributed to mule deer population decline.
North Dakota	EHD	Periodic white-tailed deer reductions.
Oregon	BT, EHD, FMD, HLS	Evaluating impacts to black-tailed deer populations.
South Dakota	CWD	None
Utah	None reported	None
Washington	HLS	Evaluating impacts to black-tailed populations.
Wyoming	CWD, EHD	Periodic, localized deer die-offs.
Yukon	None reported	None

[a] Diseases: Adenovirus hemorrhagic disease (ADH), Bluetongue (BT), Brucellosis (BR), Chronic wasting disease (CWD), Elaeophorosis (EL), Epizootic hemorrhagic disease (EHD), Foot and Mouth Disease (FMD), Hair Loss syndrome (HLS), Leptospirosis (LE), Tuberculosis (TB).

Table 25. Occurrence of Chronic Wasting Disease and surveillance programs reported by western states and provinces.

State or Province	Species Infected	Year	# of Cases	Monitoring Program
Alberta				Targeted and general sampling of harvested animals
Arizona				Sample hunter harvested animals.
British Columbia				Sample hunter harvested animals.
California				Sample hunter harvested animals.
Colorado	Wild and captive mule deer, white-tailed deer, and elk	1981	>100	Test animals with clinical signs. Targeted sampling of hunter harvested animals. Research into whether a regulating deer density affects infection rates.
Hawaii				None
Idaho				Monitor cervid facilities. Sample hunter harvested animals.
Montana	Captive elk	1998	<10	Similar to Colorado plus test any captive animal that dies.
Nevada				Sample hunter harvested animals.
New Mexico				Similar to Colorado plus monitor captive cervid facilities.
North Dakota				Test suspect animals.
Oregon				Test animals with clinical signs. Targeted and general sampling of hunter harvested animals planned for 2001.
South Dakota	Captive elk	1998	<10	Sample hunter harvested animals.
Utah				Monitored extensively in 1998-99, currently use targeted monitoring and sampling.
Washington				Targeted monitoring/sampling since 1995, expanding to general harvest and road kill sampling for 2001
Wyoming	Wild and captive white-tailed deer and elk.	1969	130	Sample hunter harvested animals. Research into methods of transmission
Yukon				Opportunistically sample road or predator kills.

Table 26. State and provincial agency responses to questions concerning cervid ranching: 1) Does your state or province allow private holding, propagation, or recreational harvest of confined cervids? 2) If yes to No. 1, describe how many facilities, who administers program, and what commercial uses are permitted. 3) If yes to 1), have documented interactions between captive and wild cervids occurred which resulted in adverse impacts to wild cervids?

State or Province	Question 1	Question 2	Question 3
Colorado	Yes	165 facilities for commercial propagation and/or hunting of deer and elk. 15 facilities administered by Colorado Department of Wildlife, 150 by State Department of Agriculture.	No
Montana	Yes	Approx. 100 facilities for propagation, possession, and selling of deer, elk, moose, caribou, and other wildlife. Administered by Dept. of Livestock. Recent initiative banned hunting of captive animals	No. Escapes of game farm animals have occurred.
Hawaii	Yes	1 or 2 on Maui Island. Elk and axis deer. Propagation, antler production, and hunting occurring. Administered by DLNR Division of Forestry & Wildlife.	No
Arizona	Yes	5 facilities allowing sale, propagation, and meat production of deer and elk; recreational hunting not permitted. Sika deer can be held without permit. Administered by Game and Fish Dept.	No
North Dakota	Yes	Administered by Board of Animal Health - no other information provided.	No
South Dakota	Yes	58 facilities for deer and elk allowing for commercial propagation and sale. Administered by Animal Industry Board.	No
Wyoming	No	1 facility grandfathered, otherwise not permitted. The one exception allows for the sale of elk antlers, meat, hides, and hunting. Administered by State F&G.	No. One escaped red deer shot during elk season.
Nevada	Yes	(no other information provided)	
California	Yes	16 facilities administered by State Dept. of Fish and Game permitting Fallow Deer propagation for breeding and meat production, hunting not allowed.	No
Utah	Yes	29 elk farms and 3 hunting parks administered through Utah Ag. Dept. with joint inspections by Division of Wildl.	Number of elk escaped. ~ 800 wild elk captured and sold by Native Americans.

Table 26. Continued.

State or Province	Question 1	Question 2	Question 3
Washington	No		
New Mexico	Yes	Approx. 12, antler/meat production, breeding, propagation, hunting allowed. Administered by State Dept. Fish & Game.	No; escapes have occurred and may compete with wild deer/elk.
Oregon	Yes	61 facilities for elk, sika deer, fallow deer, and reindeer. Propagation, sale, antler production allowed; hunting not permitted. Recent legislation allows elk meat production.	No; escapes have occurred and hunters have harvested some.
Idaho	Yes	126 facilities administered by State Ag. Dept. for elk, fallow deer, and reindeer. Another 50 facilities administered by State Dept. Fish & Game. Allows for propagation, meat and antler production, and parks. Hunting not permitted.	No. Escapes documented including sika deer harvested by deer hunter.
Alberta	Yes	Approx. 400 facilities administered by Department of Agriculture. Only indigenous cervids allowed (moose, elk, mule and white-tailed deer). Propagation and sale of meat and parts allowed; importation and hunting is not.	Some wild rutting bulls have had to be destroyed when they attempted to access facilities.
British Columbia	Yes	Bison, fallow deer and reindeer permitted, wild native cervid species are not . Administered by Ministry of Agriculture and Food. (Number of facilities not reported.)	Primary concern is to prevent disease, and interbreeding between wild and captive bison.
Yukon	Yes	5 landowners permitted for elk. Holding, propagation, production and sale of live animals, meat, and antlers permitted; hunting not allowed. Administered jointly by Fish & Wildlife and Agriculture Branch.	Some elk escapes suspected, fenceline interactions between wild and captive elk occur.

Table 27. State and province responses regarding standardized data collection, management, and analysis: '++' = Strongly Agree, '+' = Agree, '0' = No opinion, '-' = Disagree, '--' Strongly Disagree.

State or Province	Measures within states or provinces.	Measures between states or provinces.	Protocols for population measures.	Harvest data collection and analysis.	Computer modeling controls & parameters.	Adaptive harvest strategy parameters.
Alberta	++	+	+	0	+	+
Arizona	+	-	+	-	-	-
British Columbia	++	+	+	+	+	+
California	++	++	++	--	++	++
Colorado	+	+	+	+	-	-
Hawaii	0	0	0	0	0	0
Idaho	++	+	-	+	-	-
Montana	+	-	-	--	--	--
Nevada	+	+	+	-	+	+
New Mexico	++	+	+	+	+	0
North Dakota	+	-	0	-	-	0
Oregon	++	++	++	++	++	0
South Dakota	+	0	0	0	0	0
Utah	+	+	0	+	+	0
Washington	+	-	-	-	-	0
Wyoming	+	+	+	-	+	--
Yukon	+	+	+	0	+	0

WINTER ELK DISPERSION PATTERNS RELATIVE TO THE PREDICTIONS OF A SPATIALLY EXPLICIT HABITAT MODEL

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Abstract: ARC-HABCAP is an unpublished, spatially explicit habitat capability model that runs in a geographic information system. ARC-HABCAP is used by the Black Hills National Forest as a tool for biologists assessing the effects of land management actions for areas 400 – 2,000 ha in size that predicts the relative effectiveness (0 - 1.0) of land units to provide forage (FV), cover (CV), forage-cover juxtaposition (HDV), and habitat effectiveness (HE) for elk (*Cervus elaphus*) based on forest inventory data. HE is calculated as $FV \times CV \times HDV^{1/3}$. ARC-HABCAP removes areas adjacent to roads as ineffective habitat. The width of ineffective habitat adjacent to roads depends on the amount of vehicle traffic. The model displays FV, CV, HDV, HE, and areas of ineffective habitat adjacent to roads. We tested the predictions of the winter ARC-HABCAP model using radio telemetry locations of elk from November to April and from 1993 to 1997 in Custer State Park (CSP), South Dakota. FV, CV, HDV, and HE were categorized as good, fair, or poor for values of >0.7, 0.3-0.7, and <0.3, respectively. We tested hypotheses that proportional elk use of predicted FV, CV, HDV, and HE categories were similar to the proportion of CSP predicted in each category. Elk use in CSP differed ($P < 0.01$) from the proportion of predicted categories from ARC-HABCAP for FV, CV, HDV, and HE. Selection ratios differed ($P \leq 0.05$) from 1.0 for each of these components of the model. ARC-HABCAP predicted that most of CSP was fair or poor HE and elk used areas predicted to be good HE less ($P = 0.05$) than expected. Poor correspondence between elk use and HE resulted from the geometric mean method used to calculate HE. We propose a new formula for elk HE that emphasized forage 3 times more than cover and resulted in a better fit between elk dispersion patterns and predicted HE in CSP. Coefficients for HDV should be modified to reflect the data from CSP and the models from which ARC-HABCAP was originally derived. We recommend extending the area of negative influence on elk adjacent to primary roads to 300 m with modifications to the coefficients to reflect the negative influence of roads rather than treating these areas as ineffective habitat. Further testing and modification of ARC-HABCAP are also necessary.

Key Words: elk, *Cervus elaphus*, habitat, GIS model

The National Environmental Policy Act (1969) mandates that the Forest Service assess the effects of its land management activities such as timber harvest on the other resources on federal lands. Determining the effects of timber harvest on wildlife requires an assessment of a vast array of wildlife-habitat relationships.

Wildlife habitat models are simplifications of the complex animal habitat relations (Starfield 1997). They can be effective tools for wildlife managers, but need to be tested before using them to make decisions that commit long-term vegetation changes on landscapes (Laymon and Barrett 1984, Shamberger and O'Neil 1986, O'Neil et al. 1988). The availability of geographic information systems (GIS) has made spatially explicit habitat models possible for everyday applications. The Black Hills National Forest uses a spatially explicit habitat capability (HABCAP) model in ArcInfo (Environmental Systems Research Institute 1998) GIS environment (hereafter referred to as ARC-HABCAP). ARC-HABCAP is an unpublished model that incorporates major elements of elk habitat effectiveness models developed by Wisdom et al. (1986) and Thomas et al. (1988). Our objectives were to compare the dispersion patterns of elk in Custer State Park (CSP), South Dakota with the predictions of habitat effectiveness from ARC-HABCAP in CSP.

STUDY AREA

CSP is 29,542 ha managed by the Division of Custer State Park of South Dakota Department of Game, Fish, and Parks. Elevations range from 1137m to 2,083 m. Annual precipitation averages 47 cm with approximately 80% occurring between April and July. Average monthly temperatures, during the coldest and warmest months (February and August), are - 4° C and 24° C respectively (NOAA 1994).

The predominant forest type in CSP is ponderosa pine (*Pinus ponderosa*). White spruce (*Picea glauca*) occurs on some north-facing slopes and deciduous woodlands of quaking aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), bur oak (*Quercus macrocarpa*), and green ash (*Fraxinus pennsylvanica*) are scattered throughout the park (Morgan 1987). There are about 120 km of primary roads (>35 vehicles/week), 63 km secondary roads (10-35 vehicles/week), and 432 km primitive roads (< 7 vehicles/week). The park receives over 1.7 million visitors/year, mostly during the summer. There are approximately 1,000 elk that occur in CSP along with bison (*Bison bison*), pronghorn (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*O. hemionus*). CSP is fenced and most of the elk are residents. However, some elk move in and out of the park freely in places. A limited quota elk hunt occurs each fall in CSP (Millspaugh et al. 2000).

METHODS

HABCAP models predict the relative capability (habitat capability) of vegetation communities for wildlife by assigning coefficients to vegetation communities. These coefficients may vary seasonally resulting in different models for summer and winter. Inputs into HABCAP models are land units with hierarchal vegetation descriptions based on vegetation types (dominant vegetation species) and structural stages (Buttery and Gillam 1983). In forest vegetation types, structural stages include grass-forb, shrub-seedling, sapling-pole, mature, or old growth. The sapling-pole (2.5-22.9 cm diameter at breast-height [dbh]) and mature (>22.9 cm dbh) structural stages include categories for overstory canopy closure of 0-40%, 41-70%, and >70%.

We reclassified the timber resource information for land units of 1 - 95 ha in CSP according to Buttery and Gillam (1983) and imported these data into an ArcInfo GIS geographically referenced database (coverage).

We also imported the road coverage for CSP into ArcInfo and classified roads based as primary (>35 vehicles per week), secondary (7-35 vehicles per week), or primitive (<7 vehicles per week). These coverages and the winter coefficients were the inputs for our ARC-HABCAP evaluation.

The ARC-HABCAP model for elk predicts relative effectiveness of land units as forage (FV), cover (CV), forage-cover juxaposition (HDV) and habitat effectiveness (HE) for the coverages used as inputs. ARC-HABCAP assigned coefficients to land units for FV and CV to each land unit. HDV was assigned by the model using several criteria described below. If FV for a land unit was ≥0.2, that land unit was classified as forage for the purposes of determining HDV. If CV for a land unit was ≥0.5, that land unit was classified as cover for the purposes of determining HDV. ARC-HABCAP created buffers of varying distances from the edges where forage and cover land units adjoined. Forage or cover areas <274 m from forage-cover edges were assigned HDV = 1.0, forage areas 274 – 823 m from forage-cover edges were assigned HDV = 0.54, cover areas 274 - 823 m from forage-cover edges were assigned HDV = 0.14, and forage or cover areas >823 m from forage-cover edges were assigned HDV = 0. In addition, if CV ≥0.5 and FV ≥0.2 for a land unit, it was assigned HDV = 1.0 by ARC-HABCAP because the model considers these land units as forage and cover. Habitat effectiveness (HE) for the area of consideration was computed as the geometric mean of forage, cover, and forage-cover juxtaposition ($FV*CV*HDV^{1/3}$, Wisdom et al. 1986). In effective habitat adjacent to roads was removed from the GIS coverage by the model by creating buffers 180 m wide for primary roads, 60m wide for secondary roads, 30 m wide for primitive roads.

ARC-HABCAP creates a separate coverage for each component (FV, CV, HDV) and HE that can be printed. We modified these coverages to have 3 output categories that divided the range of effectiveness values approximately into thirds. For example, for each model component and HE, we classified areas as "good" if the effectiveness value was >0.7, "fair" if the effectiveness value was >0.3 and ≤0.7, or "poor" if the effectiveness value was ≤0.3. We selected 3 categories because we believe these were meaningful categories given the simplicity of ARC-HABCAP and because the Bonferroni confidence intervals (see below) for statistical tests are increasingly large ($\alpha/2K$ for K categories) as the number of habitat categories increase. Even though ineffective habitat due to roads (road buffers) was deleted from the ARC-HABCAP outputs, we created a coverage of the road buffers.

We created a coverage of Universal Transverse Mercator coordinates of 5,413 winter (November to April) elk locations obtained from 21 female and 15 male elk with radio transmitters (Millspaugh 1999) from 1993 to 1997. Elk were captured using clover traps baited with salt (Millspaugh et al. 1994) during the summers of 1993 and 1995 and some were captured using a net-gun from a helicopter during the summer of 1993 (Millspaugh 1999). The elk location coverage was joined with FV, CV, HDV, and HE coverages and we tabulated elk use in CSP predicted to be good, fair, and poor habitat effectiveness for each model component. We also joined the road buffer coverage with the elk location coverage and tabulated elk use in areas considered by ARC-HABCAP to be ineffective habitat.

We tested hypotheses, that dispersion patterns of elk were similar to the proportional distribution of good, fair, and poor areas of FV, CV, HDV, and HE predicted by ARC-HABCAP using chi-square goodness-of-fit-tests for studies with known availability of resources (Design I, Manly et al. 1993). The term expected use throughout this paper refers to the proportion of CSP resulting from predictions of ARC-HABCAP times the number of elk locations.

We tested whether elk use differed from expected use of good, fair, and poor categories of FV, CV, HDV, and HE predicted by the model by applying a Bonferroni correction (to maintain experiment-wise error rates) to the probability of a 1df chi-square test that the estimated selection ratio was 1.0 (H_0: $w = 1.0$, Manly et al. 1993:46). We tested whether elk in CSP used areas predicted as ineffective habitat (road buffers) in proportion to availability using the chi-square goodness-of-fit test. We then tested whether elk use of predicted ineffective habitat adjacent to primary, secondary, and primitive roads was similar to expected use following the Design I methods (Manly et al. 1993) described above. Grid-cell analysis in ArcView was used develop areas of 100-m intervals from predicted forage-cover edges. We also used grid-cell analysis to develop areas of 50-m intervals from primary roads, 10-m intervals from secondary roads, and 5-m intervals from primitive roads. Elk use of 100-m interval areas from forage-cover edges was compared to expected use following the Design 1 methods (Manly et al. 1993). We compared elk use relative to expected use of distance intervals from roads by plotting these data. All tests were considered significant at $\alpha \leq 0.10$.

RESULTS AND DISCUSSION

We used 5,413 elk locations during winter for tests of the ARC-HABCAP model (Millspaugh 1999). Table 1 displays information on the sex, age, and duration of inclusion in the study of elk. All radio-marked elk were >1 yr of age. The accuracy of elk locations was estimated by placing radio transmitters at 133 locations in a variety of topographic features and vegetation types in CSP. The azimuths of the radio signal were recorded from distances 0.25 - 3.0 km from the transmitter and the estimated locations were plotted. Average distance between estimated locations and actual locations was 176.1 m (SD = ± 12.4 m, range = 13.4 - 746.6 m). Everyone that assisted with collecting location data of elk participated in this evaluation. Because ARC-HABCAP eliminates the road buffers from the coverage, elk locations in road buffers were not included in analyses of FV, CV, HDV, or HE. The resulting sample size for testing the ARC-HABCAP model during winter was 4,107 locations.

A wildfire burned 3,867 ha of the CSP in 1989. There were 5,035 ha of grasslands in the park and 121 ha of the grass-forb structural stage of ponderosa pine. Thus, 45% of CSP was considered grasslands by the model. Ponderosa pine was the next most common vegetation type in CSP with 189 ha of the shrub-seedling structural stage, 10,071 ha in forest structural stages most (75%) of which was mature timber. Other vegetation types comprised only 2.6% of CSP.

ARC-HABCAP PREDICTIONS

Forage – ARC-HABCAP predicted that 57% of CSP was good forage (FV >0.7) for elk during winter; while 20% and 23% were predicted to be fair (FV ≥0.3 and ≤0.7) or poor (FV <0.3), respectively (Table 2). Elk used areas predicted as good FV more ($P < 0.01$) than expected and areas predicted as fair ($P = 0.05$) and poor ($P < 0.01$) FV less than expected during winter.

Cover – ARC-HABCAP predicted that 15% of CSP was to be good cover (CV) for elk, 20% was predicted to be fair cover for elk and 64% was predicted to be poor cover for elk during winter. The contrast between the abundance of forage and cover in CSP for elk results from the inverse relation between forest density and herbaceous production (Uresk and Severson 1988, 1998); good forage (e.g., FV >0.7) stands are not good cover (e.g., CV >0.7) stands. Elk use of predicted cover categories differed ($P < 0.001$) from expected use. Fewer than expected

($P \leq 0.05$) elk occurred in areas predicted to be good or fair cover and more ($P < 0.01$) than expected elk occurred in areas predicted to be poor cover during winter.

Forage-cover juxtaposition – ARC-HABCAP predicted that 56% of CSP had good juxaposition of forage and cover (HDV >0.7) for elk; 20% had fair forage-cover juxtaposition, and 24% had poor forage-cover juxtaposition. Elk in CSP did not use areas of forage-cover juxtaposition similar to patterns predicted by ARC-HABCAP. More elk that expected occurred in areas predicted by ARC-HABCAP to be good or fair forage-cover juxtaposition ($P \leq 0.02$) and fewer than expected elk occurred in areas predicted to be poor forage-cover juxtaposition ($P < 0.01$). The criteria used by ARC-HABCAP for predicting stands considered forage and cover, and thus HDV=1.0, included all sapling-pole (2.5-22.5 cm dbh) and mature (>22.5 cm dbh) structural stages of ponderosa pine. This contributed the large proportion of CSP predicted to have HDV >0.7.

The ability to quantify and display the spatial relation between forage and cover on the landscape using GIS is a benefit of ARC-HABCAP. Elk in CSP used areas predicted to be forage adjacent to forage-cover edges different ($\Pi^2 = 17.4$, $P < 0.01$) from the expected patterns based on availability (Figure 1). Elk used forage areas ≤100 m from cover ($P < 0.07$) more than expected. Elk also used areas predicted to be cover adjacent to forage-cover edges different ($\Pi^2 = 103.9$, $P < 0.01$) from expected patterns. Elk used areas predicted to be cover ≤100 m from forage more than expected and used several distance intervals predicted as cover >400 m from forage less than available. General patterns of elk use relative to forage-cover edges were similar to those in Washington and Oregon (Witmer et al. 1985, Wisdom et al. 1986, Thomas et al. 1988). In these studies and ours, elk ventured further into cover than they did into openings or forage areas. The reduced use by elk of forage habitats 300 – 400 m from cover and cover habitats 200 - 300 m from forage appeared to be the result of less area available, rather than selection processes by elk. Nonetheless, the relation between elk use and forage-cover juxtaposition from research in western conifer forests (e.g., Wisdom et al. 1986, Thomas et al. 1988) were only partially included in ARC-HABCAP coefficients.

Habitat Effectiveness – ARC-HABCAP predicted that 20% of CSP had good HE for elk, 27% was fair HE, but 53% was poor HE for elk. Elk used categories of HE different ($P < 0.01$) from expected patterns. Areas predicted by ARC-HABCAP to be good or fair HE were used less than expect ($P \leq 0.05$) and areas predicted to be poor HE were used more than expected ($P < 0.01$). The geometric mean method for calculating HE resulted in a large portion of CSP predicted to be poor HE by ARC-HABCAP. If any component of the model has a value 0, the resulting HE = 0. Wisdom et al. (1986) recommended the geometric mean because it appeared to best represent their expectations of elk responses to habitat conditions and because elk appeared to compensate for low values in some components by selecting areas of high value for other parts of their model. However, Wisdom et al. (1986) and Thomas et al. (1988) also recommended very small values for coefficients rather than 0 and consequently, did not encounter this problem.

Roads – Elk in CSP used areas adjacent to roads that were predicted to be ineffective habitat similar ($P = 0.86$) to the expected use based on the proportion of CSP in these road buffers during winter. ARC-HABCAP predicted that ineffective habitat adjacent to roads comprised 24% of CSP (Table 3). Elk used road buffers adjacent to primary and secondary roads less ($P < 0.01$) than expected, but used road buffers adjacent to primitive roads more ($P < 0.01$) than expected.

We can not attribute elk dispersion patterns within road buffers to differences in habitat because the predicted HE for the areas in the road buffers and was similar to the rest of the park. While elk generally avoid roads, elk in CSP moved into areas adjacent to roads at night to take advantage the delayed phenology and green vegetation during late summer and early fall. The negative influence of primary roads on elk dispersion patterns in CSP extended to 300 m during winter (Figure 2). Although, elk selected against areas in the secondary road buffer, we could not determine how far the elk dispersion patterns were influenced by these roads. With the exception of the first 10-m interval, elk use of secondary road buffers was below expected use. Primitive roads did not have a negative effect on the dispersion patterns of elk in CSP. Although elk in CSP are hunted, the uniqueness of the park (e.g. Thompson and Henderson 1998) may have influenced how elk perceive roads. Elk in the Starkey Experimental Range exhibited increasing selection ratios further from mostly gravel roads (Rowland et al. 2000). Gravel roads would be classified as secondary roads in this study.

ARC-HABCAP MODEL ASSUMPTIONS AND RECOMMENDED CHANGES

We did not know the behavior of elk associated with locations used to test the model. Thus, we are not able to recommend modifications to coefficients relating to forage or cover. The predictions for FV and HDV generally reflected the patterns of elk use we expected in CSP. The selection ratio for predicted forage areas during winter was greater than during summer (unpubl. data, Rocky Mountain Research Station, Rapid City, SD). Because quality and quantity are more likely to limit elk during the dormancy of grasses during winter (Thomas et al. 1988), a larger selection ratio for forage areas would be expected.

ARC-HABCAP predictions of HE did not depict elk habitat effectiveness in CSP. Most of the elk in CSP are residents; the density of which (8.8 elk/mi^2) is typical of good summer ranges (M. Wisdom, USDA Forest Service, Pacific Northwest Research Station, personal communication). We believe the habitat in CSP to be good to excellent for elk. Because the ARC-HABCAP predictions of forage and forage-cover juxtaposition tended to reflect the patterns of elk that we expected, we attempted to modify the formula for calculating HE. One of the assumptions of ARC-HABCAP is that wildlife are limited by feeding habitat and that, to some extent, they can compensate for low values of forage with high values of cover and vice-versa (Modeling Philosophy: the purpose of ARC-HABCAP, unpubl. rep., Black Hills National Forest, Custer SD). We recommend a weighted average of forage, cover, and forage-cover juxtaposition for calculating HE in CSP in which predicted forage is weighted 3 time greater than cover or forage-cover juxtaposition (e.g., HE = [3FV+CV+HDV]/5). We arrived at a weighting of 3 for forage after considering that elk used areas predicted as good forage 3 – 6 times more than areas predicted as good cover (unpubl. data, Rocky Mountain Research Station, Rapid City, SD) and elk exhibited selection ratios for areas predict as good forage and against areas predicted as good cover. We believe that elk can compensate for lack of cover with good forage, but the reverse is not likely. Merrill (1991) attributed the ability of elk to handle thermal stress to abundance of high quality forage. Our modification to the HE formula allows for coefficients of 0, yet also allows for some compensation between components of the model. Elk originally occupied grassland biomes in western North American (Guthrie 1966, Bryant and Maser 1982) lending support to our contention that forage may be more important than cover to elk. The importance of cover to elk is supported by some biologists (Peek et al. 1982, Wisdom et al. 1986), but has been questioned by others (Cook et al. 1998).

Despite significant differences from predicted HE using the recommended formula (Table 4), elk use of predicted categories of HE was consistent with the theoretical prediction of a population below carrying capacity (e.g. Fretwell and Lucas 1969). CSP manages elk and other ungulates below the estimated forage capacity (G. Brundige, Wildl. Biol., CSP, pers. observ.). If the elk population in CSP was below carrying capacity, under an ideal free distribution elk should preferentially select good habitats and avoid poor habitats (Fretwell and Lucas 1969). Elk in CSP used areas predicted to be good HE using our recommended formula more ($P < 0.01$) than expected and areas predicted to be fair and poor HE less ($P < 0.01$) than expected. It is possible that our recommended formula for calculating HE captured some other variables for which selected. Tests of habitat resource selection can test an animal's selection of available resources, but cannot address the fitness of animals in relation to environmental condition. Different place or time tests of the model may provide insight into this question.

Roads – Proximity to primary roads in CSP influenced elk selection of habitats. Roads may be one of the best predictors of elk habitat use in some areas (Lyon 1984). Even though there is a limited hunting season in CSP, elk in parks may not perceive humans and vehicle traffic the same as elk other populations (e.g., Wisdom et al. 1986, Thompson and Henderson 1998). Proximity to primary roads in CSP had a negative influence on elk dispersion patterns during winter and we recommend that the distance buffer from primary roads be expanded to 300 m. Because we included elk locations during November in our analyses, it is possible that elk avoidance of roads was influenced by hunter activities. Millspaugh et al. (2000) demonstrated avoidance by elk of areas occupied by hunters during late archery hunts during November and early December. We also recommend that ARC-HABCAP be modified to include areas of reduced habitat effectiveness due to proximity to roads rather than treat these areas as ineffective habitat. The effects of primary roads in CSP on elk extended further than the buffered region in ARC-HABCAP, but did not result complete exclusion of elk as predicted in the model. It is unlikely that roads render elk habitat completely ineffective (Lyon 1979). The effect of roads on elk declined as distance from roads increased. This negative effect of roads on elk habitat should probably be modeled as a decay function.

CONCLUSIONS

Our evaluation of ARC-HABCAP indicated several deficiencies in the model. Because habitat models are tools for biologist to simplify reality (Starfield 1997), we feel the model has utility, but needs further validation and refinement. Weighting forage more than cover or forage-cover juxtaposition in the calculation of HE more closely followed the dispersion patterns for elk that we expected in CSP than when HE was calculated as the geometric mean of components in the model. Effects of primary roads on elk were greater than predicted by ARC-HABCAP, but primitive roads appeared to have a neutral or positive effect on the dispersion patterns of elk in CSP. Additional testing and modification of the model on National Forest lands should make the model a useful tool for land managers.

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Table 1. Sex, average age, and average time that radio-marked elk locations were collected for test of ARC-HABCAP model in Custer State Park from 1993-1997.

Sex	Number of animals	Average (range) of age (yrs) at capture[a]	Average yrs (range) of duration in study[b]
Male	15	2.1 (1 - 4)	1.9 (0 – 4)
Female	21	4.2 (1 – 8)	3.1 (0 – 5)

[a] All animals <1 yr of age were released without radio transmitters and are not included.
[b] Eight females captured in 1993 were alive with functioning transmitters at end of study.

Table 2. Elk use (locations) compared with expected elk use of areas predicted by ARC-HABCAP as good, fair, or poor forage (FV), cover (CV), forage-cover juxtaposition (HDV) and habitat effectiveness (HE) in Custer State Park, South Dakota during winter.[a]

Predicted effectiveness	Area[b] (ha)	Observed elk use	Expected[c] elk use	Selection ratio	Bonferroni adjusted p-value (H_0: w = 1.00)
Forage ($\Pi^2 = 258.8$, $P < 0.001$)					
Good	11,520	2,811	2,356	1.193	<0.001
Fair	4,034	764	825	0.926	0.052
Poor	4,525	532	925	0.575	<0.001
Cover ($\Pi^2 = 66.42$, $P < 0.001$)					
Good	3,096	474	633	0.748	<0.001
Fair	4,035	764	825	0.926	0.052
Poor	12,949	2,869	2,648	1.083	<0.001
Forage-cover juxtaposition ($\Pi^2 = 162.64$, $P < 0.001$)					
Good	11,256	2,391	2,302	1.038	0.016
Fair	3,963	1,028	810	1.268	<0.001
Poor	4,860	688	993	0.692	<0.001
Habitat effectiveness ($\Pi^2 = 114.28$, $P < 0.001$)					
Good	4,035	764	825	0.926	0.052
Fair	5,414	851	1,107	0.769	<0.001
Poor	10,631	2,492	2,174	1.146	<0.001

[a] Categories of good, fair, and poor represent predicted relative effectiveness (from 0-1.0) of >0.7, 0.3-0.7, and <0.3, for elk respectively, by the ARC-HABACP model.
[b] Areas predicted to be ineffective habitat for elk adjacent to roads by ARC-HABCAP were excluded.
[c] Expected elk use was calculated based on the proportion of Custer State Park predicted to be good, fair, or poor effectiveness for each model component and HE times the total number of elk locations.

Table 3. Elk use (number of locations) compared with expected elk use of areas predicted by ARC-HABCAP as ineffective habitat for elk adjacent to primary, secondary, and primitive roads during winter in Custer State Park, South Dakota.[a]

Road category (buffer width)	Area[b] (ha)	Elk observations	Expected[c] observations	Selection ratio	Bonferroni adjusted p-value (H_0: w = 1.00)
Primary (180 m)	3,780	521	626	0.720	<0.01
Secondary (60 m)	734	74	108	0.529	<0.01
Primitive (30 m)	2,317	711	571	1.606	<0.01

[a] Chi-square test for winter ($\Pi^2 = 121.13$, $P < 0.001$)
[b] Areas adjacent to roads predicted to be ineffective habitat for elk by ARC-HABCAP.
[c] Expected use was calculated based on the proportion of Custer State Park predicted to be ineffective for elk times the number of elk locations that occurred in all road buffers.

Table 4. Elk use (number of elk locations) compared to expected elk use of good, fair, and poor habitat effectiveness (HE) calculated as the weighted average of model components in Custer State Park, South Dakota predicted by ARC-HABCAP during winter[a,b].

Predicted effectiveness	Area[c] (ha)	Observed elk use	Expected[d] elk use	Selection ratio	Bonferroni adjusted p-value (H_0: w = 1.00)
Good	8,072	2,179	1,649	1.321	<0.001
Fair	7,490	1,396	1,532	0.911	<0.001
Poor	4,518	532	925	0.575	<0.001

[a] HE = (3FV+CV+HDV)/5

[b] Overall Chi-square test ($\Pi^2 = 366.84$, $P < 0.001$).

[c] Ineffective habitat for elk from road buffers was excluded.

[d] Expected elk use was calculated based on the proportion of Custer State Park predicted to be good, fair, or poor habitat effectiveness using the weighted average formula times the total number of elk locations.

Figure 1. Elk use (number of locations) compared with expected elk use of 100-m intervals from cover-forage edges, in Custer State Park, South Dakota during winter. Expected elk use was calculated based on the proportion of Custer State Park in each 100-m interval times the total number of elk locations. Pairs of bars with asterisk below them are significantly different ($P < 0.05$).

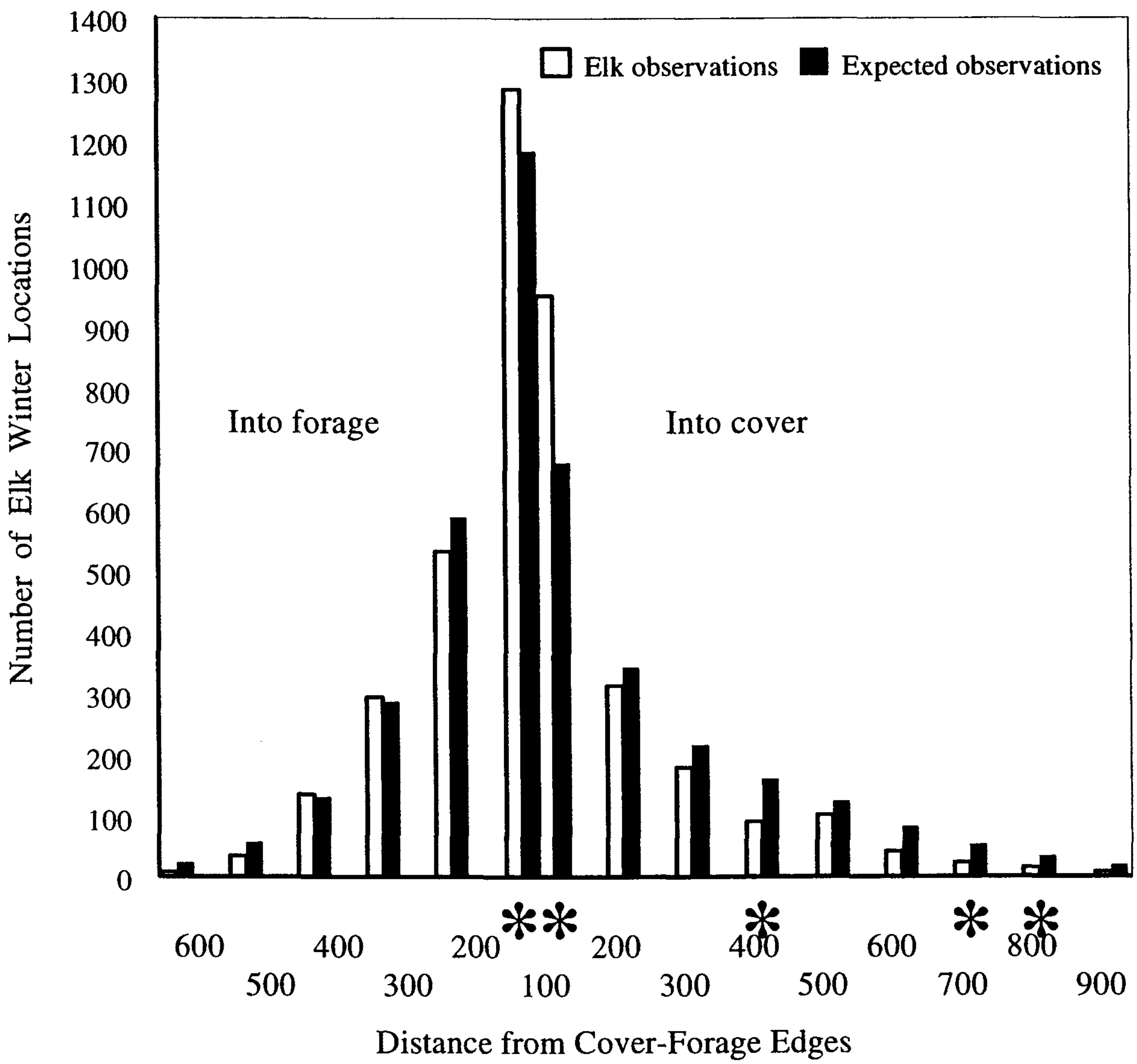
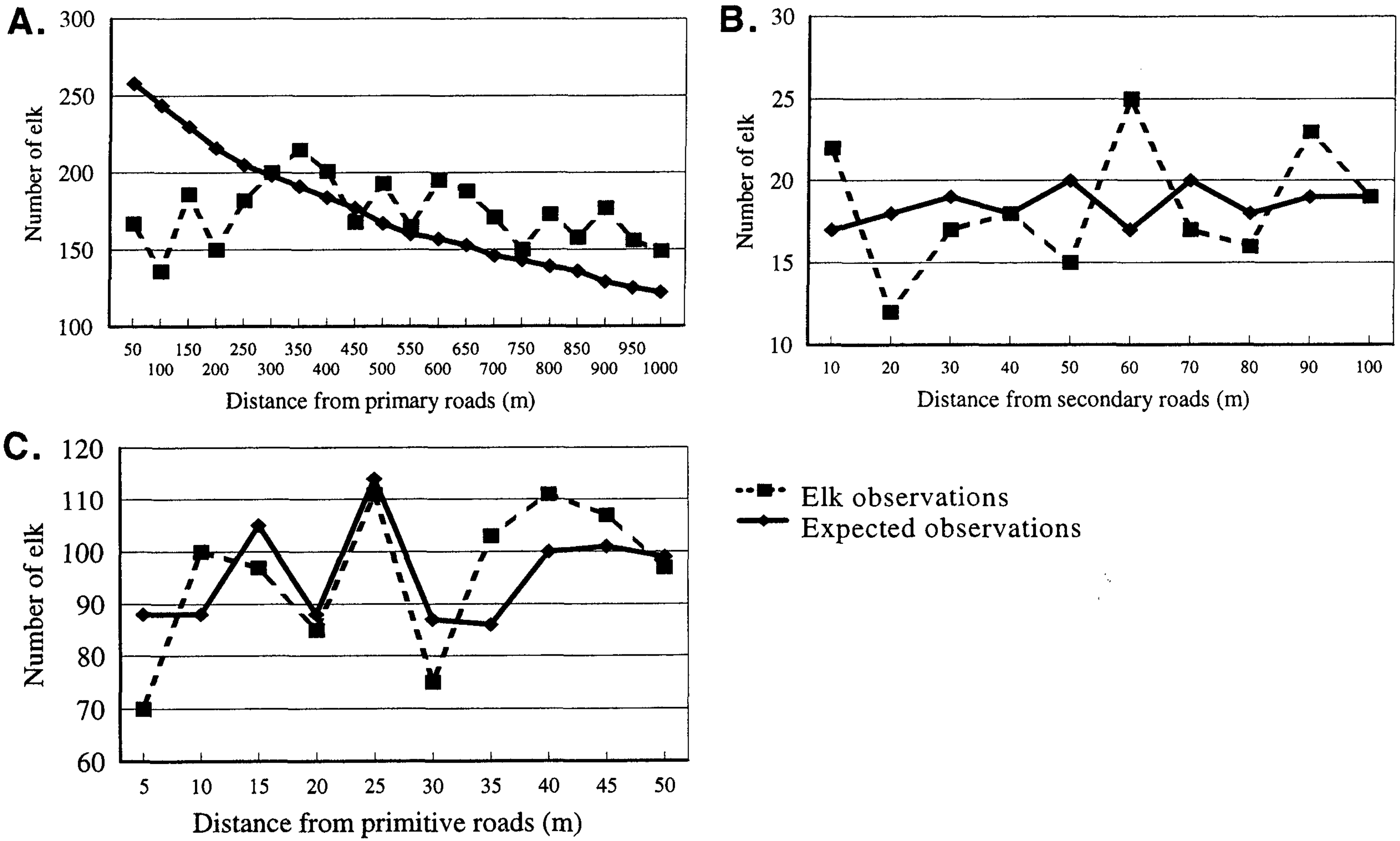


Figure 2. Elk use (number of locations) plotted with expected elk use of distance intervals from: A. primary roads, B. secondary roads, and C. primitive roads in Custer State Park, South Dakota during winter. Expected elk use was calculated based on the proportion of Custer State Park in each distance interval times the number of elk locations.



EFFECTS OF NUTRITION AND HABITAT ENHANCEMENTS ON MULE DEER FAWN RECRUITMENT: PRELIMINARY RESULTS

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We initiated a study in 2000 on the Uncompahgre Plateau in southwest Colorado to determine whether changes in habitat quality on mule deer (*Odocoileus hemionus*) winter range has been a principal cause of low December fawn recruitment. Our specific study objective was to determine whether enhancing the nutrition of adult female deer during winter and early spring increases fawn:doe ratios the following December. In November and December 2000, we placed radio collars on 73 adult female deer in 2 experimental units (treatment and control) located on winter range. Of 37 does radio-collared in the treatment unit, 32 remained in the experimental unit throughout the winter and spring. Pre-treatment December fawn:doe ratios were 52.6 (SE = 5.3) and 51.8 (SE = 5.0) fawns: 100 does for the treatment and control units, respectively. Deer occupying the treatment unit were fed a pelleted supplemental diet ad libitum from December through April. We monitored the radio-collared does in the treatment unit daily and obtained 440 visual observations of the collared does consuming the supplemental feed. We typically fed 726–816 kg of feed/day distributed throughout 22 feeding sites across the 6.0-km^2 treatment unit. Mark-resight estimates from March aerial (489 deer, SE = 62) and ground (494 deer, SE = 81) surveys, coupled with feed consumption, indicate we fed roughly 450 to 500 deer during most of the winter and spring. We also fed approximately 25 to 30 elk, but the elk did not affect deer access to the feed. Based on helicopter mark-resight surveys, the deer density in the treatment unit in December was 46 deer/km^2 (SE = 3.5), but increased shortly after and was 82 deer/km^2 (SE = 10.3) in March. Deer densities in the control unit changed little from 32 deer/km^2 (SE = 4.8) in December to 39 deer/km^2 (SE = 5.3) in March. Adult doe survival rates (15 December–24 April) were 1.000 (SE = 0.000) in the treatment unit and 0.889 (SE = 0.052) in the control unit. December 2001 fawn: doe ratios will be compared between the treatment and control units to determine whether enhanced nutrition of adult does during winter contributed to increased summer-fall fawn survival. The nutrition-enhancement segment of the study will continue for 3 additional years as part of a crossover design, followed by a habitat enhancement treatment where deer population parameters will be measured in response to habitat manipulations.

VALIDATION OF NUTRITIONAL CONDITION INDICES IN ELK

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Productivity in many northwest United States elk (*Cervus elaphus*) populations is now declining for unknown reasons. Assessment of nutritional influences, a potential cause of these declines, is difficult because many animal-based methods to determine nutritional status (e.g., serum and urine chemistry, various fat indices) are not accurate, practical, and/or adequately tested. We assessed existing and new indices of nutritional condition of both live and dead elk. Forty-three captive-raised cows of varying ages and conditions were euthanized and homogenized for chemical analysis of fat, protein, water, and ash content. Estimates of fat, gross energy, and lean muscle were compared to each of the condition indicators, with age and season as covariates. Unique to this study, we also intensely evaluated a subset of these models for bias, sensitivity, accuracy, and precision across a wide range of body condition. Results indicated that many of the most widely used indices are the most limited.

STUDIES OF NUTRITIONAL INFLUENCES ON ELK: WHAT WE HAVE LEARNED SO FAR

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We have conducted 3 years of assessing nutritional influences using captive elk under highly controlled experiments in penned settings, have initiated work using the captive elk in natural vegetation communities in western Oregon, and began monitoring body condition of wild elk in several herds across the northwest United States. The controlled experiments were used to assess influences of summer-autumn nutrition on calf growth and body mass, body fat, and breeding dynamics of cows and subsequent winter survival of calves and cows. This work indicates that summer-autumn nutritional requirements of cows and their calves are appreciably greater than previously believed and that even moderate deficiencies have pervasive negative influences on their performance. Studies with the captive elk in wild settings during summer and autumn indicate deficient nutritional conditions; these in turn suggest important limitations on elk herd productivity. Our data of body condition in wild elk is preliminary, but suggests considerable variation in nutritional status among herds and important nutritional deficiencies in several of them.

THE GENETIC CONSEQUENCES OF ELK RELOCATIONS AND SUBSEQUENT HERD GROWTH: THE PENNSYLVANIA ELK HERD

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Relocation programs have reintroduced elk (*Cervus elaphus*) to portions of its vast historical range. We investigate the genetic consequences of such relocation programs, by examining variation at ten microsatellite loci in three elk herds, a source herd (Yellowstone National Park), a large herd reintroduced from Yellowstone (Custer State Park) and a bottlenecked herd reintroduced from both Yellowstone and Custer (the Pennsylvania herd). We discuss relocation histories among these herds, and the genetic impacts of numbers of founders and rate of herd growth following relocation. Although significant differences were detected among all three herds, the Yellowstone National Park and Custer State Park herds possess similar levels of variation and heterozygosity, and the genetic distance between these two herds is small. The Pennsylvania herd, on the other hand, has experienced a 61.5% decrease in heterozygosity relative to its source herds, possesses no unique and few rare alleles, and the genetic distances between the Pennsylvania herd and its sources are large. The data confirm that the rate of population growth post relocation may have important genetic consequences and indicate that maintenance of genetic variation must be carefully considered if relocations involve only small numbers of a polygynous species. We discuss the implications of these data with reference to other historic and future elk relocation programs.

CONFLICT RESOLUTION BY ADAPTIVE MANAGEMENT: MOVING ELK WHERE THEY WANT TO GO

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Abstract: Elk conflicts in the western United States have been increasing due to several long term changes in land use. The Dry Beaver – Ladd Canyon Elk Enhancement project was designed to alleviate elk problems by using adaptive management strategies on a large scale. A combination of road closures, prescribed burning, fertilizing and salting was used to attract elk private land to public lands during the summer months. Thirty-one adult cow elk were monitored from 1993-98 to determine project effectiveness. We affected 48% of the radiocollared elk to migrate onto public land summer range for at least a portion of the time from June through September. We believe that this multi-faceted approach to land management will be useful in addressing similar conflicts in different areas.

Key Words: conflict, elk, habitat, migration, summer range

Over the past 50 years, rocky mountain elk (*Cervus elaphus nelsoni*) helped define a way of life in northeast Oregon. From the early 1900's when elk were virtually extirpated up to the mid-1990s when herds were near all-time highs, these animals have sparked controversial discussions and decisions on many levels. The controversy exists because changes occurred in land use, both on private and public land. Much of the low elevation, sagebrush/grassland elk winter range was converted to agricultural or urban uses. Summer range on public land was altered by demands for timber, road building and recreation. Elk began to spend more time on private land as security on higher elevation USFS land was being lost. Expanding elk populations also added to increasing conflicts on winter range that was privately owned and grazed by domestic livestock.

Traditional use patterns for elk in the Starkey Wildlife Management Unit (WMU) was to migrate up to high elevation summer range in early summer and return to lower elevation winter range in late fall. Between 1970 and 1990, migration patterns for elk in the Starkey WMU area changed dramatically. Van Dyke and Kemp (data on file at Oregon Dept. Fish and Wildlife office, LaGrande) found 12 of 18 of radio-collared cows never migrated from low elevation, winter range on private land to high elevation, summer range on public land from 1988 - 1990. Limited hunting on the private lands allowed the non-migratory population to increase at a faster rate than hunted populations on public lands. Also, during severe winters 6 of 18 of radio-collared cows migrated 40 km west across the Blue Mountains into lower elevations of the Ukiah WMU. In some instances, these animals caused serious agricultural damage to winter wheat fields on private ranches in the area.

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Several land management practices may have brought about this change in migration patterns. The major influence causing the shift to private lands was thought to be the security offered on private lands, where access was tightly controlled, coupled with the high level of vehicle use on the USFS lands. Effects of roads on elk distribution have been well documented (Perry and Overly 1977, Lyon and Ward 1982, Lyon 1983, Wisdom 1998, Rowland et al 2000). While most privately owned, low elevation, winter range had little or no public access, public lands had been through a period of extensive road building and, subsequently, an increase in year round forest activities. Prior to 1994, open road densities on public land were >2.2 km/km^2, while densities on private land were <0.3 km/km^2 (T. Thomas, US Forest Serv., La Grande personal communication). Logging, mushroom picking, all terrain vehicle use, woodcutting, and other recreational activities contributed to an exceptionally high activity level on public land during the critical spring and early summer calving period. From the early 1980s until 1994 open road densities on USFS and private land were similar from late October to mid November during bull elk hunting seasons when 2 cooperative road closures limited the open road density on USFS to <0.6 km/km^2.

Lack of salt could be another possible factor influencing elk to change migration patterns. Salt has long been used to attract and redistribute elk in forage areas (Skovlin 1982). We observed elk using salt sites on nearby private lands in the spring and early fall when forage was green. There was no active grazing allotment on 60% of the summer range on public land for over 20 years prior to 1990; therefore, no salt sites were available at the higher elevations. Conversely, during this same period, all private lands were grazed, and salt was routinely put out for livestock. The decrease in the number of elk following spring green up onto USFS summer range may have been influenced by the lack of salt at higher elevations. However, this was untested.

Biologists from ODFW were limited in management options to control elk populations once elk became permanent residents on private land. Hunting opportunities in the Starkey Unit were increased in an attempt to reduce the elk population to the management objective of 5,300 elk. Most private lands had little public access during hunting seasons. Many ranches were fee hunted and managed for bull elk hunting. Lack of antlerless elk harvest allowed resident elk populations on private land to increase. To maintain the Starkey elk population at management objective levels, elk hunting opportunities on public lands were increased. As a result, the number of antlerless elk harvested on private land was low, while the harvest on public land was disproportionately high. (L. Erickson, unpublished data, data on file at Oregon Dept. Fish and Wildlife office, LaGrande). This harvest imbalance heightened land use conflicts and presented a management dilemma to ODFW biologists.

These challenges prompted state wildlife managers, federal land managers and the private interests to develop unique approaches for resolving some of the land use/elk management conflicts. In 1991 the Blue Mountains Elk Initiative (BMEI) was chartered by 21 organizations. The main goal of the BMEI was to improve elk management and elk habitat in the Blue Mountains of Oregon and Washington. A common problem for the Blue Mountains was the conflict created when elk moved off public lands and took up residence on private lands. One project selected for funding was the Dry Beaver - Ladd Canyon Elk Enhancement Project (DBLC), which was a multi-year, multi-phase project done on a landscape scale.

Our primary goal was to redistribute elk during the summer. We judged our ability to affect elk distribution by whether at least 60% of elk spending the summer on private land winter range moved to summer range on public land for at least half of the summer months (June through September). Our secondary goal was to develop- adaptive management strategies to address conflict areas, which would increase the possibility of success and could be used as a template throughout the western states.

PROJECT AREA

The study area was situated in the Blue Mountains of northeast Oregon. Elevations range from 840 to 2640 m with a mean elevation of 1440 m. Approximately 60% of the area was mixed conifer stands of Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosa*), and Englemann spruce (*Picea engelmannii*). Ponderosa pine predominated at low elevations, Douglas-fir at mid-elevations, and lodgepole pine and Englemann spruce at high elevations. Approximately 40% of the area was bunchgrass rangeland.

The DBLC area lies in the center of the Starkey Wildlife Management Unit (1,194 km^2). During the early 1990s the DBLC project area was home to 3,500-4,000 of the estimated 6,500 elk in the unit. The Starkey Unit accounted for 10% of all Rocky Mountain bull elk harvested and hunter recreation days in Oregon. DBLC included a 26,305 ha low elevation, winter range (several private land ownerships) and a 22,258 ha high elevation, summer range (primarily public land managed by the LaGrande Ranger District of the Wallowa-Whitman National Forest, United States Forest Service).

METHODS

We identified several management options to meet our goal. Implementation of these strategies began in the fall 93.

Access management

We set a goal to limit the open road density at <0.62 km/km^2, comparable to the private land road density. We also requested an area closure for the project so that cross-country travel by motor vehicles was prohibited. The physical barriers were put in place starting in fall 1994. A year round, area closure prohibiting all motorized vehicle travel within USFS lands of DBLC (except on designated open roads) was implemented in spring 1995.

Roads were closed by earthen berms, locked gates, or obliteration. Portal entry signs were installed at 6 main access points providing motor vehicle entry into DBLC. Maps and brochures explaining DBLC were made available at portal signs and at ODFW and USFS offices. "Road Closure Violation" report forms were also included in the brochure. The area vehicle closure was extensively monitored by patrolling during spring, summer and fall of 1995-97 to determine closure effectiveness.

Forage enhancement

Another phase of DBLC was large--scale forage enhancement treatments. We believed that forage quantity was not likely to be a limiting factor (over half of the USFS land was not under a grazing allotment), but also felt that any forage enhancement would begin attracting elk to public land. We used prescribed burning and fertilizing (27-12-0-4 was applied at a rate of 112 kg/ha) as forage treatments, since both have been documented to improve food availability for elk (Lyon and Ward 1982).

Salt sites

We established 26 salt sites on USFS summer range, and 136 kg of mineral salt were stocked at each site during each spring and fall starting fall 1993. Sites were monitored twice each spring and once during the fall. Additional salt was provided as needed to assure continuous availability at each site. As elk began to heavily use sites adjacent to private lands, sites were relocated at higher elevations farther from the private/public land boundary fence to draw elk further onto summer range.

Monitoring elk distribution

We monitored elk migration from private land to public land during the summer (1993-97). Thirty adult cow elk were radio-collared on private land in late July 1993. We selected July because we wanted to capture elk that did not complete a typical migration to public land in the spring. We attempted to collar elk in the same proportion of the population (approximately 1%) and monitor elk with the same methods as the 1988-90 Starkey telemetry project. Using a Cessna 180 fixed-wing airplane equipped with 2 H-antennae and a II Morrow 820 GPS unit (Salem, OR), we located elk usually every 2 weeks in the spring, summer, and fall. In winter elk were located only once a month to determine if animals were migrating across the Blue Mountains to the Ukiah WMU and to check for mortality signals. Radio-collars recovered during hunting seasons were reapplied on other elk the following summer. Twelve collars were re-applied on elk captured on low elevation, private land during late summer 1994-96.

We evaluated project success by documenting radio-collared elk moving onto public land during June through September. Elk were categorized each summer as residents to private land (<25% of locations on public land), transients (>25% and <50% of locations on public land), or migrants to public lands (>50% of locations on public land). We only used animals that were monitored for ≥3 years in the analysis (n=31).

RESULTS

Overall, telemetry data indicated DBLC strategies were effective in attracting elk onto public land (Table 1). Only 19% of 31 collared elk were summer residents of private land as compared to 67% found in the earlier Starkey telemetry project (VanDyke and Kemp 1988). The percent of migrants to public lands increased between Starkey study and DBLC (22% and 29% respectively). The number of transient elk increased dramatically during DBLC to 52% of 31 collared elk spending at least some of the summer on public land, compared to only 11% of 18 found to exhibit this movement during the Starkey telemetry project.

Road closure methods were modified as needed to obtain effective closure and increase compliance. Violations dropped from 48 in 1995 to <10 in 1997. The LaGrande Ranger District also made changes to the closure, mainly for timber harvest needs throughout DBLC. Public land users were notified of these changes each year by project brochures and maps at each of the 6 portal signs.

Salt sites averaged heavy use (>136kg) in spring and moderate use (>68kg) in fall. All sites had at least some elk use in both spring and fall. A problem in assessing elk use at some sites occurred when trespass cattle were found using sites throughout the summer each year of the project.

We treated a total of 961 ha with fire. The first 2 burns were done on traditional high elk use areas. Adjacent areas were burned in later years. We fertilized 486 ha in fall 1994-95 in areas of high and moderate elk use.

DISCUSSION

DBLC had a considerable influence on elk migration patterns, although we did not meet the original objective to influence 60% of the elk to spend the majority of the summer on public land. We were optimistic to expect elk to alter their movement patterns after only 4 years of vehicle access reductions. This elk population took over 20 years to change from an annual summer migration to 67% of the population not migrating at all. DBLC attempted to reverse the change and see traditional migration patterns re-established in 5 years.

Success may have been delayed due to 2 other factors. Three major timber sales scheduled for the DBLC area resulted in a high volume of administrative traffic on closed roads. This was administered by a road use permit system and was continued throughout the summer. Secondly, although the private landowners supported DBLC, project biologists were not allowed to use any methods on private land to discourage elk from staying there. Hazing elk on private land may have affected elk movement patterns and accelerated the re-establishment of traditional migration patterns. If the amount of administrative traffic was lowered or private landowners allowed ODFW to haze resident elk, there may have been a change in elk use patterns toward the USFS land earlier or a larger change observed.

We believe we will meet our objective over the next few years considering the positive change in the number of transient elk. Only 11% of the original Starkey study elk were found on public land for short periods of time. The resident elk (67% of the population) which spent all of their time on private land never ventured to the traditional habitat the public land offered. During DBLC resident elk numbers decreased to 19% and, subsequently, transient elk numbers increased to 52%. The transient elk, moving back and forth from the private and public lands, may begin to utilize the better forage and comparable solitude found on public land. Although transient elk did not spend the entire summer on public land, they could have encountered forage improvements, salt and the increased security offered by the motor vehicle closure within the DBLC project area. These attributes may lure them to spend the majority of the summer on high elevation USFS land. As these elk re-establish a more traditional migratory pattern to summer range on public land, they may be imprinting their calves to spend more time there as well. They may influence other elk to become transient or migrate to public land. This positive change may indicate that with more time, DBLC could succeed in creating the historical migration patterns this population once exhibited.

An additional benefit was realized when more radio-collared elk began to move onto public lands during the rifle elk hunting seasons. As more elk were found to frequent public land, ODFW biologists began to increase hunting opportunity for antlerless elk. Antlerless tags were increased from 600 (4 hunt periods) in 1993 to a high of 3,100 tags (7 hunt periods) available in 1997. One new "private lands only" hunt was added to specifically target the elk herds found on private land in the DBLC area. Elk population estimates dropped from a high of 6900 in 1996 to 5700 in 1998. This was the management objective for the Starkey WMU.

From the results of DBLC, it is not unrealistic in future years to expect the DBLC project to meet the objective of redistributing 60% of the resident elk on private land to spend at least half the summer on public land. Cooperative efforts and large-scale habitat changes will continue to affect elk and their distribution throughout the area.

PROJECT GUIDELINES

The information obtained from DBLC can be used to address other elk and land use conflicts throughout the western United States. As one of the original 10 projects designated as National Demonstration Areas for the Seeking Common Ground Initiative, DBLC may be used by other agencies and private landowners as a template to solve similar problems. We believe the following guidelines will be helpful to future problem solvers.

1. *Road Closures* - Implementing the DBLC area motor vehicle closure on USFS land was the most difficult and time-consuming part of the project, but also the most essential. Three factors aided in implementation. First, the LaGrande Ranger District was simultaneously implementing their Access and Travel Management Plan. Secondly, public comments received over a 3 year period were overwhelmingly in support of the project (>95% favorable). Lastly, outside funding sources committed dollars to DBLC assuming an area vehicle closure would be implemented. The BMEI, ODFW, and Rocky Mountain Elk Foundation all made substantial monetary contributions early on in support of DBLC strategies. Also, the Seeking Common Ground Initiative chose DBLC as one of 10 National Demonstration Areas to identify methods which could help in the resolution of big game / livestock conflicts. This type of broad-based financial support enabled the LaGrande Ranger District to implement the area closure.

2. *Coordination* - The success of a large--scale project requires a major investment of agency cooperation and public education. We recommend designating one person to be responsible for project proposal deadlines, report writing, budget accountability and liaison for all cooperators. This gives all partners one main contact person who should be able to answer most questions. This is especially important when dealing with different fiscal years for agencies and organizations. Public education and involvement is best attained by each cooperator offering different venues for public contacts (i.e. newspaper articles, organizational newsletters, video productions, brochures, and field contacts with user groups).

3. *Monitoring* - Any funding source or partner willing to support a project such as this requires hard data to confirm project success. The biggest asset from our perspective was the ability to radio-collar elk and monitor their movement patterns. This data showed direct changes in elk migration patterns without having to assume improving security and forage would draw the elk onto the public land. A commitment from field personnel to make monitoring a priority in their work assignments is critical to obtain the necessary information

4. *Private landowner involvement* – We believe success would be attained much quicker with the ability to implement strategies to influence elk to move off private lands. Although our project may succeed without the private landowner support we desired, initial project development should include cooperative involvement with private landowners.

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We would like to thank Jon Paustian and Ray Guse for monitoring the road closures, conducting vegetation work, and contacting the public who used DBLC. Pilot Ken West, Oregon State Police, flew us for our telemetry monitoring surveys.

Our thanks also go to the Rocky Mountain Elk Foundation and the Seeking Common Ground Initiative. This project would not have been possible without their financial and political support.

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Table 1. Change in elk distribution (June - September) following implementation of habitat improvement projects DBLC (1993-98) compared to the Starkey study (1988-91).

	Private Land Residents	Transients	Public Land Migrants
DBLC (n=31)	6 (19%)	16 (52%)	9 (29%)
Starkey (n=18)	12 (67%)	2 (11%)	4 (22%)

CHANGING LANDSCAPES AND DEER AND ELK: HOW DO LARGE UNGULATES FIT IN?

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Landscapes in the interior western United States have undergone major ecological changes since European settlement. Livestock grazing, timber harvest and fire suppression lead an array of human related disturbance factors that have changed habitats for deer (*Odocoileus spp.*) and elk (*Cervus spp.*). Historic livestock grazing effects and fire suppression have resulted in changes in plant community composition and natural fire cycles. Forest ingrowth has initiated a cycle of insect and disease outbreaks in conifers and extreme wildfire events. In shrub-steppe landscapes, woodland expansion has resulted in simplified understories and decreased fire cycles. Federal agencies are moving toward restoration practices that will reestablish disturbance events on the landscape. As landscapes undergo these episodic disturbances, ungulate herbivory can play a role in shaping the composition of the developing plant communities. In these changing landscapes the foraging environment available to ungulates is an important consideration to the well being of ungulate herds. Recent examination of forest exclosures indicates ungulates are affecting their foraging environment. Changes in plant community composition related to herbivory have profound effects on ecosystem patterns and processes and on the ungulates themselves. Ongoing research suggests that nutrition at key times of the year is critical to reproductive success and calf/fawn survival. If herbivory is causing detrimental changes in the foraging environment, declines in ungulate productivity are possible. Confounding this premise is the increasing number of predators and their impacts on ungulate herds, and the existing ecological conditions on the landscape. Research is needed on the 3 identified factors involving ungulates, 1) herbivory effects, 2) nutrition and 3) predation; and their interactions, to provide information to managers and the public to aid in decisions regarding public policies.

MULE DEER POPULATION MONITORING IN IDAHO

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The Idaho Department of Fish and Game has traditionally monitored mule deer (*Odocoileus hemionus*) populations by obtaining estimates of population size (sightability surveys) and age and sex ratios (herd composition surveys). Improved population models can be developed by incorporating survival rate estimates into the existing framework. During the past 3 field seasons, we captured and radio-collared 667 fawns in 11 study areas across central and southern Idaho using helicopter drive nets and helicopter net guns. Over 770 volunteers were involved in capture operations. Information gathered from the radio marked fawns showed regional differences in fawn weights, survival rates, and net recruitment to the mule deer populations. Enhanced population monitoring will help wildlife managers meet specific management goals of herd size and composition by altering doe harvests according to annual changes in survival, recruitment, and population size. This program also provides real time data on fawn survival to managers, enabling them to more accurately communicate population status to hunters.

ECOLOGY OF BLACK-TAILED DEER IN GREATER VANCOUVER, WASHINGTON

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We investigated the population dynamics of black-tailed deer (*Odocoileus hemionus columbianus*) in the greater Vancouver area, Clark County, Washington. We captured and radio-tagged 19 deer by ground darting, and relocated radio-tagged deer 1-2 times per week. Doe survival rates for the period June-May were 0.73 (SD = 0.13; n = 11) and 0.70 (SD = 0.14; n = 11) for 1999-2000 and 2000-2001, respectively. Buck survival rates were 0.75 (SD = 0.19; n = 6) and 1.00 (SD = 0.00; n = 3) for 1999-2000 and 2000-2001, respectively. Eighty percent of doe mortality and all buck mortality were due to collisions with either cars or trains. Adult does produced a minimum of 1.83 fawns each in 1999 and 1.36 fawns in 2000. Fawn survival was 0.89 (SD = 0.11; n = 11) in 1999-2000 and 0.80 (SD = 0.11; n = 15) in 2000-2001. A Monte Carlo analysis indicated that the deer population had a potential rate of increase of λ = 1.39 (95% C.I. = 1.09-1.69; P [λ >1] = 1.00) in 1999-2000 and 1.24 (95% C.I. = 0.99-1.49; P [λ >1] = 0.997). Thus, the deer population in urban/suburban Vancouver is likely increasing.

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PERFORMANCE OF GLOBAL POSITIONING SYSTEM RADIO-COLLARS ON ADULT MULE DEER

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Recent advances in technology have made global positioning system (GPS) radio-collars for large ungulates more reliable, readily available, and cost effective compared to traditional very high frequency (VHF) radio-collars. We captured 167 adult mule deer in western Wyoming between 1998-2001. Of these, 17 were equipped with Telonics Generation I GPS collars, 10 with Telonics Generation II, and 140 with traditional VHF radio-collars manufactured by Advanced Telemetry Systems (ATS). The performance of GPS collars will be discussed, including; successful fix attempts, accuracy, options available (blow-off, store-on-board, programming schedules, storage capacity, etc.), cost-benefit analyses (VHF vs. GPS, GEN I vs. GEN II), and management applications.

ESTIMATING MULE DEER POPULATION SIZE USING COLORADO QUADRAT SYSTEM CORRECTED FOR IDAHO MULE DEER SIGHTABILITY: A SPORTSMEN'S ISSUE.

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Sportsmen expressed concerns about the credibility of Colorado's survey sampling methodology to estimate numbers of mule deer (*Odocoileus hemionus*) in specific populations. We therefore conducted an aerial survey in Colorado Deer Analysis Unit D-6, which was an area of concern to sportsmen. We used helicopters from 28 February to 5 March 2001 to count mule deer on randomly selected quadrats 0.65-km^2 or 2.59-km^2 in size distributed within 11 strata encompassing 943 km^2 of deer winter range composed of sagebrush (*Artemisia tridentata*) and pinyon-juniper (*Pinus edulis-Juniperous osteosperma*) habitats. From these counts, we estimated population size using standard stratified random sample estimators and the Idaho mule deer sightability model. Stratified population estimate was 6,782 $\pm$ 2,497 (90% CI) deer. Counts corrected for sightability increased the estimate to 11,052 $\pm$ 3,503 (90% CI) deer. Both aerial survey estimates buttressed population estimates of 7,000 to 7,300 deer derived from computer models and were substantially greater than sportsmen's estimate of 1,750 deer. Cost of this validation exercise exceeded 50,000 $US. We interpreted this exercise as a forerunner of the public's interest in challenging agency integrity or methods used to estimate status of ungulate populations. We caution agencies to use tested methodology that can withstand dispassionate public scrutiny.

IS MERRIAM'S ELK REALLY EXTINCT?

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Merriam's elk (*Cervus elaphus merriani*) was described as a large subspecies of the North American elk that inhabited mountain ranges in the southwestern U.S., primarily in Arizona and New Mexico until it was presumed extinct by 1906. Starting in 1913, elk from Yellowstone National Park were translocated to Arizona and the species became reestablished in the state. Arizona is known for producing large bulls and some people question whether a few small bands of Merriam's elk persisted until 1913 in the rugged and remote canyons of the White Mountains in eastern Arizona. If some of these remnants remained, they would have had the opportunity to interbreed with the small numbers of elk introduced from Yellowstone. Consequently, evidence of Merriam's elk might be detectable in Arizona's elk herd using modern genetic analysis. To evaluate this possibility, we studied the mitochondrial DNA of elk from Arizona and Yellowstone National Park. Of interest is whether there is evidence of any genetic material in current Arizona elk that can not be traced to the Yellowstone population. A total of 82 DNA samples from Arizona's present elk population were collected throughout all of northern Arizona. The last Merriam's elk were reported near Mt. Ord, which is also the location of the Merriam's elk type specimen. Many samples for this analysis were collected on winter range from the elk population that summers near Mt. Ord. In addition, 46 samples were collected from the Yellowstone North Herd, the precise source of all Arizona elk. Examining modern samples from the two areas with Single-Strand Conformation Polymorphism (SSCP), we found seven genetic variants, none of which were unique to Arizona. Two genetic variants were unique to Yellowstone, but rare. The proportion of the genetic variants in the Arizona elk herd was very similar to that in Yellowstone. These data suggested that Merriam's elk was indeed extinct before the reintroductions and did not contribute to the present-day Arizona elk herd. An alternate hypothesis questions the validity of Merriam's elk as a legitimate subspecies, as have recent genetic studies for other presumed subspecies in the Rocky Mountain region. To address this possibility, we are in the process of examining the DNA of elk collected in Arizona before the arrival of the animals from Yellowstone. There are 3 Merriam's elk specimens in existence. DNA has been successfully extracted from one such specimen housed at the University of Arizona (known as "the Jesse Burke Rack"). We used sequencing of a 111-basepair (bp) portion of the mtDNA control region to compare this sample to the analogous 111 bp segment from individuals representing all other subspecies. The sequence of this specimen differs from all other individuals (representing all extant subspecies) by an average of 3-6bp. In contrast, when sequences from animals representing all extant subspecies were compared to each other they differed by only 0-4bp. This specimen differed more (i.e., had more basepair differences) from elk representing all other extant subspecies, than the other subspecies differed from each another. This is only a small portion of DNA (111bp) and it is only one individual so these results are very preliminary, but it indicates native Arizona elk may have differed from those farther north. Analysis of the other museum specimens will shed further light on the validity of *C. e. merriami*.

THE IMPACT OF HARVEST RATE ON ANTLER CHARACTERISTICS, HARVEST AGE, AND SUBSEQUENT ECONOMIC RETURN ON PROPERTIES WITH RESTRICTED ACCESS

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We analyzed harvest rates of mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) and the subsequent impacts to average harvest age, antler characteristics (Boone and Crockett Scoring System), and economic implications on several properties with restricted access. Our results indicate that harvest rate influences antler characteristics and average age which in turn influences economic return especially in mule deer. Strong correlations were determined and predictive models have been established, which help set harvest rates designed to optimize economic return.

EFFECT OF ADULT SEX RATIO ON MULE DEER AND ELK PRODUCTIVITY IN COLORADO

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Mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) in Colorado showed a decline in post-harvest young:female ratios during 1975-1995. One hypothesized cause of this decline in productivity is a decline in male:female ratios during the breeding period. We examined Colorado Division of Wildlife (CDOW) deer and elk population composition data obtained from helicopter surveys to see if sex ratios explained variation in young:female ratios. Data for both deer and elk supported a response of young:100 females ratios to the male:100 females ratios during the previous year. The observed ratios were about 0.25 fawns:100 does per 1 buck:100 does for deer (95% CI ± 0.14) and 0.28 calves:100 cows per 1 bull:100 cows for elk (95% CI ± 0.12). However, these effects were not adequate to explain the decline in fawn:doe (1.14 fawns:100 does per year) and calf:cow ratios (0.68 calves:100 cows per year) observed during 1975-1995. Differences in the sex ratio:productivity relationship observed between populations suggested that only some areas might show an increase in young:female ratios in response to an increase in male:female ratios, and then only a small increase in young:females was predicted. We did not detect a threshold of male:female ratios for either species that precipitated a drastic decline in productivity. Based upon commonly employed population composition surveys, we conclude that increasing post-season sex ratios will have little if any impact on subsequent population productivity.

THE RESTORATION OF ELK IN ONTARIO, CANADA

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The Ontario Ministry of Natural Resources (OMNR), in partnership with 12 other organizations, has embarked on a program to restore elk (*Cervus elaphus*) to the Province of Ontario. The plan to restore elk to 6 broad geographic areas in Ontario (based on habitat suitability) was approved in 1997. The recommendation is that up to 200 animals should be released in each of the areas. As of March 2001, elk have been released in 4 areas of Ontario: Nipissing-French River (south of Sudbury); Haliburton Highlands (Bancroft/North Hastings area; Lake of the Woods (south of Kenora); and Lake Huron North Shore (east of Sault St. Marie). The elk being restored in Ontario were acquired from Elk Island National Park (EINP), Alberta. Elk were captured and processed at EINP prior to shipment to Ontario (during the winter only). Processing included testing for tuberculosis and brucellosis, treatment for liver flukes and other parasites, as well as marking the animals with ear-tags for identification. Most of the elk were fitted with radio collars. Elk were shipped using Rocky Mountain Elk Foundation (RMEF) trailers or using commercial haulers. As of March 31, 2001, 460 elk have been shipped to Ontario from Elk Island National Park, Alberta (since 1998). Once in Ontario, the elk were placed into pens (2 to 3 acres in size) and held for a variable period (usually 2-6 weeks) depending on the location and logistics of caring for them while in the pens. When the animals were released, they were monitored (using telemetry receivers) by graduate students and other personnel from the Local Implementation Committees, colleges, universities, and OMNR. Preliminary results indicate that the longer the animals are held in the pens prior to release, the lower the mortality and the closer to the release site the elk remain. The sex and age composition of the elk transported to Ontario during 1998-2001 was: 82 bulls, 247 cows, 56 male calves and 74 female calves. Total mortality for elk in all areas to date (not including those shipped in 2001) has been 26% (86/336). Causes of mortality included emaciation 21% (n = 18), wolf predation 20% (n = 17), injuries 10% (n = 9), shot 8% (n = 7), drowning 7% (n = 6), road kill 5% (n = 4), bacterial infection 10% (n = 9), and 19% (n = 16) due to other or unknown causes. Sex and age specific mortality for all areas and years was: bulls 23% (13/56); cows 24% (47/195); male calves 24% (9/38); female calves 37% (17/46). Currently there are about 500 elk in Ontario. A number of graduate research programs have been initiated at several universities in Ontario. Projects include studying the dynamics of introduced herds, determining the potential for competition between elk and white-tailed deer (*Odocoileus virginanus*), estimating elk calf survival, developing elk habitat signatures, and designing an elk dispersion model.

ESTIMATING ABUNDANCE AND COMPOSITION OF DEER AND ELK POPULATIONS

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The classic approach to assessing abundance of deer (*Odocoileus spp.*) and elk (*Cervus spp.*) populations has been to either obtain an index of relative abundance and composition from roadside surveys or from aerial counts of winter range or spring green-up areas. Treating these index counts as population estimates has never been formally justified, nor practiced by experienced biologists. Intensive studies of local herds have utilized mark-resight methods in a few cases, but the expense of this approach has prevented its broad-scale application in most management situations. The development of sightability models for aerial surveys of elk, deer, moose (*Alces alces*) and bighorn sheep (*Ovis spp.*), and their probability sampling application, has dramatically improved the value of population assessments for managing these species across the western United States. I will begin with an introduction to the methods available for assessing populations and conclude with a comparison of the relative costs and benefits of these approaches.

COYOTE CONTROL AND MULE DEER MANAGEMENT: AN EXAMPLE

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Coyotes *(Canis latrans)* have been intensively harvested on the 850,000-acre Jicarilla Apache Indian Reservation, NM since the mid 1980's as part of a comprehensive mule deer (*Odocoileus hemionus*) management program designed to increase deer numbers and provide quality hunting. Coyotes have been harvested utilizing aerial gunning, bounty payments, trapping competitions and a full-time trapper. Commercial trappers were used to harvest coyotes from 1985-1988; however, harvest records were unavailable. Harvest averaged 641 coyotes/year from 1989-2000. The majority of coyotes were harvested by the trapper or by tribal members for bounty payments. Trapping competitions have accounted for an increased proportion of the coyote harvest since 1995. The mule deer population was monitored using annual aerial counts, harvest estimates and age structure of harvest. Aerial survey counts increased steadily from 25-30 deer/hour in the mid 1980's to 126 deer/hour in 2000. Buck harvest increased from less than 100 bucks/year in 1990 to almost 300 bucks/year by 2000, while average age of bucks harvested increased from 3.3 years old to 4.7 years old. The percentage of bucks harvested 6 years old or older increased from 18% to 42% during the same time period. Post-hunt buck:doe ratio ranged from 29-38 bucks:100 does. Winter fawn:doe ratio fluctuated from 44-64 fawns:100 does from 1990-2000, and was significantly correlated with annual precipitation ($r = 0.77$, $p = 0.01$). Prior to initiation of coyote harvest fawn:doe ratio was not significantly correlated with annual precipitation. The annual coyote harvest was credited with stabilizing fawn: doe ratios and increasing mule deer numbers.

MULE DEER SURVIVAL STUDIES ON THE UNCOMPAHGRE PLATEAU, COLORADO 1997 – 2001

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Based on modeled estimates, the post hunt mule deer population on the 3,640 km^2 Uncompahgre Plateau (UP) in southwestern Colorado, has declined from approximately 60,000 deer in the early 1980's to less than 30,000 in the late 1990's with concomitant declines in buck harvest and December fawn/doe ratios. An ongoing study of mule deer survival on the UP was initiated in 1997 to more accurately model the deer population and gain insight into the reasons for these declines. Between 15 December, 1997 and 14 June 2001, a total of 529 transmitter equipped deer were monitored using fixed-wing aircraft and ground telemetry. Survival rates were calculated using the staggered-entry Kaplan-Meier procedure. Cause-specific mortality was determined whenever possible. Summer fawn survival rates $\{S \pm SE\ (n)\}$ from birth to 14 December were 0.330 ± 0.033 (89) in 1999 and 0.565 ± 0.040 (132) in 2000. Winter fawn survival rates from 15 December to 14 June were 0.513 ± .082 (39) in 1997-1998, 0.738 ± .073 (58) in 1998-1999, 0.635 ± 0.061 (92) in 1999-2000, and 0.734 ± 0.052 (97) in 2000-2001. Annual fawn survival rates from birth to 15 June were 0.209 ± 0.029 (135) in 1999, 2000 and 0.419 ± 0.044 (147) in 2000-2001. Annual doe survival rates from 15 December to 14 December were 0.805 ± 0.073 (31) in 1997-1998, 0.859 ± 0.039 (80) in 1998-1999, 0.910 ± 0.035 (67) in 1999-2000, and 0.904 ± 0.030 (97) in 2000-2001. Winter survival rate for yearling bucks from 15 December 1999 to 14 June 2000 was 1.00 ± 0.000 (26) but survival of yearling bucks from 15 June 2000 to 14 June 2001 was 0.689 ± 0.011 (34). The survival rate for two - year old bucks from 15 June 2000 to 14 June 2001 was 0.814 ± 0.090 (25) with 25% of the mortality attributed to legal harvest. Causes of cumulative winter fawn mortality (n = 90 mortalities) from 15 December 1997 to 14 June 2001 were 43% coyote predation, 13% feline predation, 8% undetermined predator, 14% non-predator related, 21% unknown. Causes of cumulative annual fawn mortality (n = 120 mortalities) from 9 June 1999 to 14 June 2001 were 29% coyote predation, 10% feline predation, 9% bear or undetermined predation, 39% non - predator related, and 13% unknown. Causes of cumulative annual doe mortality (n = 32 mortalities) from 15 December 1997 to 14 June 2001 were 16% coyote predation, 25% mountain lion predation, 9% undetermined predator, 22% non-predator related, and 28% unknown. The percentage of annual fawn mortality occurring prior to 15 December was 85% in 1999-2000 and 74% in 2000-2001. Based on a 2 age class model, a December fawn:doe ratio of approximately 40 fawns:100 does would be required to maintain the female segment of the population with the mean winter fawn (0.655 ± 0.067 (4)) and annual doe {0.869 ± 0.024 (4)} survival rates measured in this study between 1997-2001. The mean observed fawn:doe ratio in December was 44.0 ± 2.9 (4) fawns:100 does between 1997 and 2000 indicating an increase in the population during this period. Based on the 1999 and 2000 summer fawn survival rates, a measured mean fetal rate of 1.71 fetuses per adult doe, and the observed 1999 and 2000 December fawn:doe ratios, the calculated mean fetal survival rate was 0.72 for 1999 and 2000. These data indicate that the decline in the UP deer population over the last 20 years is primarily due to poor fawn survival prior to 6 months of age and possibly low fetal survival. We hypothesize that poor quality winter range conditions and possibly disease are contributing to subsequent poor survival of fetal and neonatal fawns. Survival rates derived from these studies are being used to produce a detailed model of post-hunt population structure and demography of the UP deer herd.

THE EFFECTS OF BROADSCALE PREDATOR REMOVAL ON MULE DEER POPULATIONS

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We monitored the effects of removing coyotes and mountain lions on mule deer populations in 8 game management units in southern Idaho. Wildlife Services removed coyotes from 4 management units using winter aerial gunning annually, 1997-00. Intensive ground efforts in fawning areas were added during spring and summer 1999-00. Sport harvest of mountain lions was liberalized in 1997 in 4 of the units and remained conservative in the other units. The experimental design provided 2 replicates of each possible predator removal treatment. Small mammal transects were completed each year to index alternate prey populations. We used aerial surveys in December and March to monitor changes in the composition and size of deer populations. We radio-collared 200 deer, adults, newborn fawns, and 6 month-old fawns in one removal and one non- removal area to monitor rates and causes of mortality. Changes in deer populations have varied among units. In two units with both coyote and lion removal, one increased at 13% while the other unit increased at only 3%. Other treatments have produced similar conflicting results. Average fawn/doe ratios were higher in the coyote removal units for the first time in 2000 (70 vs. 64). Mortality of radio - collared adults was lower in the removal unit in 1998 and 1999, then higher in 2000. Mortality of 6 month-old fawns was lower in the removal units for all 3 years. The difference was attributed to lower lion caused mortality in 1998 and 1999 then lower coyote caused mortality in 2000. Newborn fawn mortality was higher in the removal area in 1998 and then lower in 1999-00. Both weather and alternate prey populations appear to influence the effectiveness of predator removal.

SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF BUCK BLACK-TAILED DEER IN WASHINGTON

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We determined survival rates and causes of mortality for age 1.5 and older buck black-tailed deer (*Odocoileus hemionus columbianus*) in the Skookumchuck and Snoqualmie game management units (GMU) of western Washington. September-August survival rates were 0.494 (SD = 0.124; n = 28) in Skookumchuck and 0.385 (SD = 0.095; n = 26) in Snoqualmie for 1999-2000. Survival rates were 0.504 (SD = 0.124; n = 38) in Skookumchuck and 0.642 (SD = 0.091; n = 32) in Snoqualmie, 2000-2001. Hunting harvest was the leading cause of mortality, and accounted for 67% and 43% of all known deaths in Skookumchuck and Snoqualmie, respectively. The proportion of the age 1.5 and older buck population harvested annually was 0.31-0.35 in Skookumchuck and 0.20-0.22 in Snoqualmie.

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SUMMARY OF MULE DEER SURVIVAL STUDIES IN COLORADO 1997 – 2001

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Four sentinel deer Data Analysis Units (DAUs) are being intensively monitored in Colorado to improve modeling of deer populations across the state and enable informed decision making. These units are widely scattered and represent low to mid-elevation pinyon pine-juniper (P-J)/sagebrush/mountain shrub winter range (Uncompahgre DAU), high mountain park sagebrush steppe (Middle Park DAU), East Slope ponderosa pine/grassland/mountain shrub (Red Feather DAU), and East Slope P-J/ponderosa pine/mountain shrub (Cripple Creek DAU) habitat types. (Details of the Uncompahgre Plateau have been discussed in a separate paper). The Middle Park and Red Feather DAUs have generally been performing well while the other two have often experienced low buck ratios and poor recruitment, and have been in decline for the past 10-30 years. The Cripple Creek DAU, in particular, has experienced a proliferation of mountain subdivisions and supports an overmature shrub community; recent recruitment in this population appears insufficient to maintain the population at the desired level. The Redfeather DAU is within the endemic chronic wasting disease area in northeast Colorado. Buck hunting pressure has been significantly reduced in the Uncompahgre DAU during the last decade, and recently in Cripple Creek and Middle Park. The Red Feather DAU has not significantly restricted buck hunting opportunity, other than to eliminate unlimited license sales beginning in 1996. Components of our monitoring include overwinter survival of fawns, annual survival monitoring and radiotracking of adult females from the ground and fixed-wing aircraft, postseason helicopter herd composition monitoring and periodic population estimation using random quadrat (stratified by density) helicopter counts. Survival rates have been analyzed using the Kaplan Meier program. Fawn survival for the 4-6 month period following the hunting season has varied from a combined low of 0.65 to a combined high of 0.83 through four years of investigation (total of 758 radios). Fawn survival has been significantly higher in Red Feathers and Middle Park, averaging 0.87 and 0.81 respectively as compared to Cripple Creek with 0.57 survival and the Uncompaghre with 0.66 survival. Doe survival (with current year's results not yet finalized) has varied from a combined low of 0.84, to a high of 0.88 (n = 608). Mountain lions appear responsible for the highest portion of predation loss in adult females, while coyotes are likely the most common predators on fawns. Loss of fawns due to predation across the four areas has totaled at least 0.13 (but <0.20, if undetermined mortalities are lumped with apparent predation). These survival rates were measured during milder than normal winter conditions, and should not be considered the norm for these areas. With the exception of the Uncompahgre Plateau, we have been experiencing problems with premature release of drop-off collars, hampering the estimation of survival from the end of hunting season to fawning. Covering the latex tubing that retains the collar with aluminum foil or aluminum paint, or the use of thicker walled tubing (3/8 inch vs. 3/16 inch), appear to remedy this problem.

ELK RECRUITMENT IN NORTH CENTAL IDAHO: DOES ONE SIZE FIT ALL?

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Elk (*Cervus elaphus*) recruitment has declined markedly in several north central Idaho Game Management Units (GMUs) since 1985. As a result, the Idaho Department of Fish and Game is investigating possible causes of declining recruitment. Thus far, predation by black bears (*Ursus americanus*) and mountain lions (*Puma concolor*) is the primary proximate mortality factor, claiming about 80% of the radio-collared elk calves in the GMU 12 study area (where the elk population has declined) and about 30% of the calves in GMU 15 (where the population is approximately stable). Since black bear management became more conservative in 1992, the average age of harvested male bears has increased significantly (average age = 4.3 years vs. 5.1 years) and the survival rate has increased (S = 0.76 vs. 0.85) in GMU 12. The black bear population in GMU 15 did not change measurably during the same period. It appears that factors such as habitat quality, physical condition of the cows, and pregnancy rates also play central roles in elk recruitment. During late winter, adult cows in GMU 12 tend to have a poorer body condition score (2002 vs. 2857) and have a lower pregnancy rate (72% vs. 89%) than those in GMU 15. The current vegetation in GMU 12 is a result of the large - scale wildfires before 1935. Timber harvest and prescribed fire since 1950 dominate the GMU 15 landscape. The discussion will attempt to synthesize the preliminary research data within the context of aerial surveys, population trends, and habitat information.

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DEER–PREDATOR RELATIONSHIPS: A REVIEW OF RECENT NORTH AMERICAN STUDIES WITH EMPHASIS ON MULE AND BLACK-TAILED DEER

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In recent years mule (*Odocoileus hemionus*) and black-tailed (*O. h. columbianus*) deer appear to have declined in many areas of the western United States and Canada, causing concern for population welfare and continued uses of the deer resource. Causes of the decline have not been identified, but predation by coyotes (*Canis latrans*), mountain lions (*Puma concolor*), and wolves (*Canis lupus*) has been proposed as one of many factors. We reviewed results of published studies conducted since the mid-1970s concerning predator–deer relationships to determine if predation could be a factor in the apparent deer population declines and if there was evidence that predator control could be a viable management tool to restore deer populations. Seventeen published studies were reviewed concerning mule deer. Only 4 published studies of the effects of predation on black-tailed deer existed. A larger database existed for white-tailed deer (*O. virginianus*); with 19 studies examining effects of predation on white-tailed deer. Study results were confounded by numerous factors. A deer population's relationship to habitat carrying capacity was crucial to the impacts of predation. Deer populations at or near carrying capacity did not respond to predator removal experiments. When deer populations appeared limited by predation and such populations were well below forage carrying capacity, deer mortality was reduced significantly when predator populations were reduced. Only one study, however, demonstrated that deer population increases resulted in greater harvests, although there were considerable data that indicated that wolf (*Canis lupus*) control resulted in greater harvests of moose (*Alces alces*) and caribou (*Rangifer tarandus*). The most convincing evidence for deer population increases occurred when small enclosures (2–39 km^2) were used. Our review suggests that predation by coyotes, mountain lions, or wolves may be a significant mortality factor in some areas under certain conditions. Relation to habitat carrying capacity, weather, human use patterns, number and type of predator species, and habitat alterations all affect predator–prey relationships. Only through intensive radiotelemetry and manipulative studies can predation be identified as a major limiting factor. When identified, deer managers face crucial decisions. Reductions in predator densities have only occurred on relatively small study areas (2–180 km^2) where predators were identified as a major limiting factor and deer populations were well below forage carrying capacity (an important criterion). Thus a problem of scale, methods used to kill predators, benefit:cost ratios, results to hunters, and public acceptance are primary considerations. Methods of predator control available to deer managers have been restricted severely and current methods may not be feasible over large areas when and if predation becomes a problem. Public acceptance of predator reduction programs is essential for predator–prey management, but may not be achievable given current public attitudes towards predators. We identified several recommendations and research needs based on our review of the literature given current social and political limitations.

FINE SCALE MOVEMENTS AND HABITAT USE BY ELK AND MULE DEER IN NORTHESTERN OREGON

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We studied fine scale movements and habitat use of elk (*Cervus elaphus*) and deer (*Odocoileus spp.*) within the Starkey Experimental Forest using telemetry data collected between 1991 and 1996. We stratified telemetry data into 24 hourly time steps and seven 30-day seasons from 15 April to 15 November each year. We fitted regression models to diel and seasonal trends for 14 habitat variables as well as horizontal and vertical velocities. Elk showed major habitat transitions and velocity peaks during the periods 0600-0900 and 1600-2400 hours. The morning movements between feeding and bedding areas involved steep increases in forest canopy, northerly aspects, and distance to roads. Reciprocal changes in habitat occurred during the afternoon transition back to feeding areas. We also identified low-velocity, daytime habitat shifts in east/west aspects between 0800 and 1600 hours. We hypothesized that this change in aspects used is a thermal adaptation to the changing azimuth of solar radiation. During this daily eastern transition we also identified a trend at 1300-1800 hours consisting of downslope movements towards streams. Similar diel cycles were also observed for deer, although the patterns were weaker. String seasonal shifts in diel patterns were also noted for both elk and deer. In particular, the larger habitat amplitudes were observed for spring and fall months. We interpret these complex habitat use patterns in the context of adaptive use of heterogeneous landscapes typical of the Blue Mountains.

ECOLOGICAL RELATIONSHIPS BETWEEN COLUMBIAN WHITE-TAILED AND BLACK-TAILED DEER IN SOUTHWEST OREGON

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The co-occurrence of Columbian white-tailed (*Odocoileus virginianus leucurus*) and black-tailed deer (*Odocoileus hemionus columbianus*) in the Pacific Northwest offers the only instance of distribution overlap between these sub-species. Within this region, the sympatry of the species is rare due to the limited distribution of the endangered white-tailed deer. Few studies have investigated the ecological relationships and mechanisms of coexistence between these ecologically similar species. Our objectives were to quantify interspecific differences in spatial distribution, habitat use, and diet composition. This paper will evaluate the relative importance of resource partitioning as a mechanism for their coexistence in southwestern Oregon. Results from this study show that interspecific spatial overlap was low to moderate during most seasons. There was a high degree of interspecific overlap in habitat use and diet, though important differences existed. The results from this study suggest that there was high potential for competition, though sympatric populations of Columbian white-tailed and black-tailed deer accomplish ecological separation through differences in spatial distribution.

MULE DEER, ELK, AND LIVESTOCK INTERACTIONS ON ASPEN RANGELANDS IN THE INTERMOUNTAIN WEST: A PRELIMINARY REPORT

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Livestock producers in Utah and other western states depend heavily on forage produced on public rangelands for seasonal grazing in the annual production cycle. Of all public land uses, grazing by domestic livestock remains the most controversial. Stakeholders who oppose the use of public grazing allotments outright view them as unnecessary subsidies that also are detrimental to long-term wildlife conservation goals. In contrast, other public land stakeholders, including many wildlife biologists, are concerned that the total removal of livestock grazing practices from public rangelands would cause habitat conditions to deteriorate for many resident wildlife species. To date few replicated, large-scale experiments have been published that validate either of these contrasting viewpoints. To address these public land-use issues the Utah Legislature provides ongoing funds to support the Cedar Mountain Initiative (CMI). The goal of CMI is to conduct research to determine how aspen rangelands can be better managed to support compatible livestock and wildlife enterprises. Our objective is to describe elk and mule deer habitat-use patterns on aspen rangeland ecosystems that are used for summer livestock grazing and to assess if these patterns are driven by interactions with livestock for space and/or forage or the effects of other environmental variables. This paper summarizes results from our pilot year, the 2000 summer grazing season. The CMI study site is located in the high elevation aspen rangeland of Utah's Iron and Washington Counties. During the pilot year of the study five cow elk and five doe mule deer were captured and fitted with non-differential GPS/VHF radio-collars. Two elk and one deer died (one elk from hunter harvest and one elk and one deer of unknown causes). Data from three elk and four deer were used for descriptive analysis. Few behavioral patterns could be discerned for elk habitat use largely due to the small sample size compared to large area of use. While sample size was also low for deer during the first year, some patterns were evident. Three of four deer spatially avoided cattle during early livestock rotations, but two of four deer moved back into the area when cows were rotated out of the pastures. Two of the four deer had home ranges that included sheep pastures but neither appeared socially intolerant of sheep. Deer habitat use was probably influenced by cattle, but also by timing within the reproductive cycle. While deer shifted habitat use away from cattle, none of the deer abandoned their home ranges outright. In order to alleviate some of the problems associated with small sample sizes additional GPS collars have been purchased and deployed. The study now has seven cow elk and nine doe mule deer fitted with GPS collars. These animals will be recaptured in August 2001 to download location data, change collar batteries and re-deploy.

EVIDENCE FOR COMPETITION BETWEEN MULE AND WHITE-TAILED DEER METAPOPULATIONS IN NORTH CENTRAL WASHINGTON DURING THE PAST 19 YEARS

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The decline of mule deer (*Odocoileus hemionus*) populations in the Western United States during the past decade has rapidly become a major source of concern for biologists, managers, conservationists and hunters. Typical hypotheses to explain these declines focus on the effects of predators, weather conditions or habitat modifications. Little discussion is directed to the effects of potential competitors, yet in large portions of the mule deer range they occupy the same areas as other ungulates such as white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elaphus*). We evaluated 19 years of aerial surveys for mule and white-tailed deer conducted on the Colville Indian Reservation from 1982 to 2001 for evidence of competition between these two populations using a simple discrete time population growth and competition model. These data provide strong evidence for competition between metapopulations of these two species of deer. Our approach provides estimates of the magnitude of the negative impact of white-tailed deer on mule deer populations and vice versa. We estimate that the depressive effect of each species on its own rate of increase is 50% stronger than its effect on the competitor. A similar approach could be used to estimate the impacts on mule deer by elk and other potential competitors.

INTERACTIONS OF ELK, MULE DEER AND CATTLE IN SPRING, SUMMER AND FALL

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Mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*) and cattle share forested rangelands in spring, summer and fall throughout the western United States. But the effects of inter-specific interactions in terms of both the resources selected and animal distributions across landscapes are poorly understood. At the U.S.Forest Service Starkey Experimental Forest and Range (Starkey), located in northeast Oregon, elk and mule deer were free-ranging within a 78 km^2 study area enclosed by a 2.4 m high fence while cattle were moved among pastures in summer on a deferred rotation schedule. Elk, mule deer, and cattle were located with an automated telemetry system from 1991-1996 and locations linked to a geographic information system (GIS) of Starkey. We will summarized results of four analyses that concentrate on elk, mule deer and cattle interactions: 1) resource selection at the landscape level, 2) fine-scale animal movements on a 24-hour seasonal basis, 3) interactions among mule deer, elk and cattle as cattle were moved through pastures within Starkey, and 4) diet overlap among elk, mule deer, and cattle. At the landscape scale we produced resource selection estimates for each species on monthly time steps in spring, summer and fall. Resource selection functions predict probability of use. Results show a strong spatial separation of elk and mule deer in spring and early summer, but this pattern tended to break down as the season progressed. At the fine-scale level, elk, mule deer and cattle movements reveal daily distributional changes, for example we found crepuscular use of small mesic meadows by deer and elk. In the third analysis we compared elk and mule deer use of a pasture with cattle presence or absence in early and late summer. When cattle were introduced, elk tended to avoid cattle and to use different resources. But as the season progressed elk and cattle began to use similar resources. Strong interactions were found between elk and cattle in the ponderosa pine/Douglas fir community. From our distributional analyses we found that grand fir habitat was selected by all three species in late summer (August and September), and consequently we intensively evaluated diets in this habitat type. Cattle and elk diets in August became more similar to deer diets, as forage was removed by elk and cattle in June and July. Both the distributional and the diet overlap results suggest that competition may exist between elk and cattle, mule deer and cattle, and elk and mule deer. These species may avoid each other while forage is abundant but converge on the same habitats and consume more of the same forage species as quality and quantity of forage declines over summer and fall.

USING HERBACEOUS FORAGE DISTRIBUTION ANALYSES TO ESTABLISH ANNUAL POPULATION MANAGEMENT OBJECTIVES FOR ELK IN ARIZONA

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The Arizona Game and Fish Department (AGFD) and U.S. Forest Service (USFS), Apache-Sitgreaves National Forest, established a coordinated herbaceous forage distribution between domestic livestock and wild ungulates on National Forest System lands. Preliminary analyses indicated that existing herbaceous forage needs for permitted livestock and estimated wild ungulate populations exceeded the available herbaceous forage for ungulate grazing. Both USFS and AGFD conducted numerous interagency and public meetings to discuss the process, define the methodology, present pertinent data and information, and solicit public input on a desired forage distribution. The subsequent agreed upon forage distribution established allowable forage use rates for livestock and elk (*Cervus elaphus*) and incorporated habitat-based parameters into annual population management objectives for elk. Herbaceous forage use by elk in key areas is monitored by AGFD. Annual population management objectives for elk are based on actual forage use relative to allowable use. Based on the initial success of the forage distribution, the USFS and AGFD have initiated the public process to analyze a forage distribution in an adjoining area.

PRELIMINARY ASSESSMENT OF PATERNITY AND BIRTH DATES OF CALF ELK SIRED BY MIXED-AGE CLASSES OF BULLS

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Management objectives identified in Oregon's Elk Management Plan specify 10, 15, or 20 bulls:100 cows following hunting seasons. These objectives were established to meet public demands for increased numbers of mature bulls for aesthetics, hunting, and benefits to elk reproductive success. We report preliminary results from 6 of 8 years of breeding trials at the Starkey Experimental Forest and Range in northeast Oregon from 1993 to 2000. We assessed pregnancy rates of cows, birth dates of calves, and paternity of calves sired by various mixes of age classes of bulls. Each spring we released 40 adult cow elk, 8 bull calves (yearling bulls in the fall), and 4–8 bulls between 1 and 3 years of age into a 622–ha pasture. This pasture was grazed on an alternate spring and fall rotation by 500 cow–calf pairs. We collected ear–punch samples from each animal for DNA analyses and blood from cows for pregnancy assessment. Pregnancy rates ranged from 61% to 96% for the years 1993 and 1995–98, and do not appear to be related to adult bull:cow ratios. We dropped 1994 from the analyses because of abnormally low pregnancy rates. Preseason adult bull:cow ratios ranged from 10:100 to 22:100 during this period. Birth dates of calves sired by yearling bulls were not different from those sired by older bulls within years. When pooled across all 5 years, yearlings comprised 60% of the bulls available as breeders and sired 12% of the calves. However, during at least 1 year, yearlings were assigned as sires of 23% (n = 5) of the calves. Bulls ≥3 years old sired 81% of all calves and represented 28% of the available breeders. We will be analyzing data from the final 2 years of the study soon and will be attempting to interpret the influence of bull age and number, as well as cow condition and cattle grazing on the observed reproductive parameters.

EFFECT OF ARCHERY HUNTING SEASONS ON PREGNANCY RATES AND CONCEPTION DATES OF ELK: A PRELIMINARY VIEW

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The number of archers in some management units of northeast Oregon has increased over 400% during the 1990s. An issue identified in Oregon's Elk Management Plan is a concern that archery elk (*Cervus elaphus*) hunting during the breeding season may negatively affect elk reproduction. We present preliminary results of the effects of disturbance during an archery hunting season on conception dates and pregnancy rates of cow elk, and estimated wounding losses during the first year of a 3–year study in the Starkey Experimental Forest and Range in northeast Oregon. We estimated and compared conception dates, pregnancy rates, body condition, and age of cow elk bred by bulls ≥3 years of age that were maintained at preseason ratios of 18–24 per 100 cows during years with ($n = 1$) and without ($n = 6$) archery seasons. We estimated the minimum wounding loss of 6 bulls (29% of bull harvest) from verified hunter reports during the archery season and 2 subsequent hunting seasons in 2001. Body condition of pregnant, adult cows was lower in 2000, the year of the archery season, than condition of cows during 3 of the 6 years without archery seasons, and the same as condition of cows during the other 3 years. Conception dates during the year with archery hunting, adjusted for condition of cows, were later than 4 of the 6 years without archery seasons. The length of time from the beginning of the rut until the 90th percentile pregnant cow was bred was 43 days with an archery season, and averaged 25 days (range = 19 to 39 days) without an archery season. Pregnancy rates declined from an average of 92% (range = 86% to 96%), down to 78%, but were not significantly different. We stress the preliminary nature of our results and the importance of understanding interactions between nutritional condition of cows and disturbance during the rut prior to making management decisions regarding hunting regulations.

COLUMBIAN BLACK-TAILED DEER BIRTH SITE IDENTIFICATION AND NEONATE SURVIVAL IN WESTERN OREGON

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Columbian black-tailed deer (*Odocoileus hemionus columbianus*) have had an apparent population decline in western Oregon. Little is known about neonate survival in black-tailed deer and low fawn survival may be a factor in the population decline. Western Oregon terrain and vegetation make it logistically difficult to capture and radio collar neonates. We inserted vaginal-implant transmitters into adult does to locate parturition sites and to capture newborn fawns during spring 2000 and 2001 in the Umpqua National Forest. Data collected at birth-sites will be compared to random sites to examine habitat selection using standard regression techniques. Fawn survival will be modeled using animal traits, birth-site landscape metrics, home range size, and habitat use as covariates. These results will contribute to forest and wildlife manager's understanding of black-tailed deer fawn ecology and how fawns respond to forest structure.

CREPUSCULAR MOVEMENT PATTERNS OF ROCKY MOUNTAIN ELK IN SPRING

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We modeled the crepuscular movements of female elk (*Cervus elaphus*) in the spring at the Starkey Experimental Forest using approximately 53,000 telemetry observations collected between 1991 and 1996. We observed that elk at Starkey foraged intensively in about 25 of the 70+ meadows within the 7,600 ha study area during April and May, and made relatively rapid crepuscular movements and habitat transitions while moving to and from these areas. The reason for the attraction to these specific meadows was not evident from the extensive habitat database built for the project. We modeled movements at selected hours using nonparametric regression [SPLUS gam( ) function] and jackknifed individual animal estimates to assess uncertainty. Movement vectors showed strong landscape patterns that were consistent with distributional changes over 24-hour periods. Abrupt transitions in movement zones and movement corridors were evident from plots of movement vectors, and were qualitatively associated with topography, roads, and forest vegetation. The movement analysis illustrated the spatial link between the daytime security and nighttime foraging patches used by elk. Preliminary field visits of the foraging patches suggested that these particular sites were more mesic and support highly desirable foraging species with early phenology. We were able to differentiate the selected versus non-selected meadows using a composite of bands 4, 5, and 7 of a Landsat Thematic Mapper image.

DEVELOPMENT OF A WEB-BASED MULE DEER NEWS AND INFORMATION NETWORK

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The use of computers and the Internet has increased to almost 50% of all U.S. households. Its use as a primary resource for information and research dictates a need for dependable, quality informational websites on wildlife management and conservation issues. A topic that would benefit from such an informational resource is the decline of the mule deer (*Odocoileus hemionus*). These deer populations have been in decline since the early 1970's, which is a major concern to most state conservation agencies, special interest hunting groups and hunters, in general. There is much dispute about which factors are most important in this decline, and is fueled by misinformation, limited communication among groups, and limited access to scientific papers and data. We are developing a website, www.muledeernet.org, to determine the effectiveness of a web-based information source in addressing the needs of this wide range of audiences. The site is currently on-line and will be evaluated throughout the year to determine its effectiveness.

HABITAT USE PATTERNS AND THE EFFECTS OF HUMAN DISTURBANCE ON THE STEAMBOAT ELK HERD

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Baseline information on elk (*Cervus elaphus*) occupying sagebrush steppe habitats is needed to properly manage these unique elk herds. Due to the open nature of the country and the lack of typical security cover, desert elk may be more vulnerable to human based disturbance than their forest counterparts. We studied habitat use patterns and the effects of human disturbance on radio-collared female elk in the Red Desert of southwestern Wyoming. Treatment elk were approached and displaced by study personnel throughout the summers of 2000 and 2001. Mean daily movements of disturbed elk were significantly greater than those of control elk ($p < 0.01$). The mean 24-hour distance treatment elk moved following disturbance was 4,152 m compared to 1,114 m for control elk. The mean 95% adaptive kernel annual home range for control elk was 139.7 km^2 and 320.2 km^2 for treatment elk. Elk avoided areas within 2 km of active gas/oil wells and areas within 1.5 km of major roads and used areas greater than 3 km and 3.5 km, respectively, more than expected. Fifty-nine percent ($n = 31$) of all elk located within roadless areas in 2000, occurred during the 2 month fall hunting season. Elk preferred habitats offering security cover, including tall sage, aspen, and mountain shrub habitat types. Elk also selected riparian habitats. Maintaining habitats that provide security cover for elk or establishing disturbance free areas may be necessary to ensure viable populations of elk during periods of energy development in sagebrush steppe environments.

COMPARATIVE ECOLOGY OF COLUMBIAN WHITE-TAILED DEER IN SUBURBAN AND WILD LANDSCAPES

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Columbian white-tailed deer (*Odocoileus virginianus leucurus,* CWTD) present an interesting management scenario because they are a federally endangered species that also occupy landscapes containing different levels of human development. Similarly, there is increasing interest regarding the influence of human development on deer ecology and management. We radio-marked and monitored 41 'wild' and 23 'suburban' CWTD in Douglas County, Oregon from September 1996 to December 1998. Wild deer were captured in sites containing <10% human-interface area, suburban deer were captured in sites containing >10% human-interface area. Suburban deer consistently exhibited significantly smaller movements, home ranges and areas of concentrated use than wild deer. Conversely, there were few significant differences in habitat use between suburban and wild deer. Average annual survival was higher for wild deer (0.84) than suburban deer (0.73), but differences were not consistent between years. Just as managers often consider male and female deer separately, our results suggest that a one size fits all management strategy may not be prudent for the Douglas County sub-population of CWTD. In particular, management decisions regarding placement and size of habitat reserves, demographic modeling, and possibly translocations should not ignore the ecological differences of CWTD associated with human development. Future research should attempt to further elucidate the effects of human development on CWTD ecology.

EVALUATION OF TWO BULL ELK MANAGEMENT STRATEGIES IN NORTHEAST OREGON

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Abstract: Low post hunting season bull:cow ratios in Rocky Mountain elk (*Cervus elaphus nelsoni)* herds prompted the Oregon Department of Fish and Wildlife to change bull hunting regulations in 8 wildlife management units of northeast Oregon starting in 1996. Previous management involved 2 separate bull elk rifle seasons: a limited hunter quota season, followed by a season with unlimited hunter numbers, both with any-bull bag limit. In 3 management units elk season framework was modified to limited hunter quota seasons with concurrent any-elk and spike-only bag limits, followed by a season with unlimited hunter numbers and spike-only bag limit. In 5 units a limited hunter quota season with any-bull bag limit was employed, followed by a season with unlimited hunter numbers and spike-only bag limit. Antlerless elk rifle seasons with hunter quotas were maintained in 7 of the 8 units. Archery seasons were not altered and consisted of a 30-day season with any-elk bag limit and no restriction on hunter numbers. We evaluate and discuss the results of changes in bull elk hunting regulations with respect to bull:cow ratios, elk population management objectives, and maximizing hunter recreation.

Key Words: *Cervus elaphus,* bull:cow ratios, hunting regulations, Rocky Mountain elk

Hunting regulations play an important part in elk management, especially in areas where elk are vulnerable to harvest. Innovative hunting regulations can be useful to protect certain sex and age classes of an elk population against overharvest, and provide managers a means of obtaining desired composition within a population. Minimum bull:cow ratios are important for overall herd health and to allow hunters an opportunity to hunt older aged bulls.

In 1991 the Oregon Department of Fish and Wildlife (ODFW) developed a comprehensive elk plan that established management objectives for post hunting season bull:cow ratios and total elk numbers for each wildlife management unit (WMU) in Oregon. The Oregon Fish and Wildlife Commission adopted the Oregon Elk Plan in 1992, after considerable public involvement. The minimum bull:cow ratio was set at 10 bulls per 100 cows and the total number of elk for each WMU was set based on habitat and social carrying capacities.

Most management units in northeast Oregon remained below minimum bull:cow ratios from 1992 – 95 . In response, ODFW implemented changes in elk hunting regulations for the 21 northeast Oregon WMU in 1996. Eight of 21 WMU were selected for evaluation because their hunting season structure was similar from 1991-1995, and in 1996 these units were separated into two groups, with different hunting regulation requirements applied to each group. Previous management in the 8 WMU allowed 2 separate bull elk rifle seasons: a limited hunter number season, followed by a season with unlimited hunter numbers, both with any-bull bag limit. Elk season framework was modified in the Heppner, Ukiah, and Starkey (HUS) WMU to a 5-day limited hunter numbers first season with concurrent any elk and spike-only bag limit, followed by a 9-day unlimited hunter numbers season with spike-only bag limit. In Desolation, Catherine Creek, Imnaha, Pine Creek, and Keating (DCIPK) WMU, a 5-day limited hunter numbers season with any-bull bag limit, followed by a 9-day season with unlimited hunter numbers and spike-only bag limit was employed. Archery and rifle antlerless seasons were unchanged in all WMU, except in one where antlerless hunts were discontinued.

The objectives of this paper are to evaluate and discuss the results of 2 different bull elk hunting regulation changes in 8 WMU in terms of: 1) increasing annual bull:cow ratios to meet minimum objectives, 2) annual calf: cow ratios and maintaining objectives for WMU elk populations, and 3) providing maximum elk hunter opportunities.

STUDY AREA

The Blue and Wallowa Mountains make up the majority of occupied elk habitat within the 8 WMU. Public ownership of land varies by WMU ranging between 25 and 90 percent, most of which is administered by U.S. Forest Service. Livestock grazing and timber management are the primary land uses. Road densities vary from 0 to 5.0 km/km² and are highest in managed forests. Twelve travel management areas, restricting vehicle travel during hunting seasons, are located in 5 of the WMU and range in size from 13 to 900 km². Five of the WMU include small portions of wilderness. Habitat varies considerably and includes: mixed conifer, mountain shrub, and grassland communities occurring in relatively gentle forested plateaus and valleys to steep rugged canyons and alpine basins. Historically, HUS have higher elk densities than DCIPK , with mean elk per mile at 35.9 and 5.3, respectively in 1991-95. Mean calves:100 cows during 1991-95 was 37 in HUS and 31 in DCIPK.

METHODS

We examined data for the 8 WMU and compared the four years prior to, 1991-1995, and after, 1996-2000, hunting regulations changes went into effect. Harvest estimates were derived from telephone surveys of licensed elk hunters and designed to achieve 90% confidence limits on the estimate (White 1993). Elk population and herd composition were determined annually in March or early April from aerial and ground surveys.

RESULTS

Herd Composition

Post hunting season bull:cow ratios increased in all 8 WMU after implementation of bull elk hunt regulation changes (Table 1). Percent increase in mean bull:cow ratios for the 8 WMU ranged from 20% to 125% when comparing 1991-95 to 1996-2000. Mean bull:cow ratio for 1996-2000 was 8.3 and 8.6 for HUS and DCIPK WMU, and represents a 93% and 65% increase from the 1991 -1995 means, respectively. Calf:cow ratios declined in 6 of the 8 WMU during 1991-2000. Declines were most apparent in HUS with mean ratios of 38 and 33 calves:100 cows before and after the 1996 change in hunting regulations. A mean calf:cow ratio of 31 in DCIPK was not affected by the hunting regulation change.

Elk Populations

Population size estimates in HUS varied from 0 % to 10% above management objectives following implementation of hunting regulation change. Within DCIPK, the Desolation and Imnaha WMU remained at MO, Pine Creek WMU was 40% above MO, and both Catherine Creek and Keating WMU dropped 21% and 47% below MO, respectively.

Hunter Numbers

Bull elk rifle hunter numbers decreased in both HUS and DCIPK 9% and 31%, respectively when comparing 1991-95 to 1996-2000 (Table 2). Antlerless elk rifle hunter numbers increased 40% in HUS and decreased 9% in DCIPK. Total archery hunter numbers increased in both HUS and DCIPK 69% and 95%.

Elk Harvest

Rifle hunters harvested 29% and 40% fewer bull elk in HUS and DCIPK, respectively (Table 3). Antlerless elk rifle harvest increased (81%) in HUS, and decreased 28% in DCIPK. The number of branch antlered bulls harvested by rifle hunters decreased 68% in HUS and 57% percent in DCIPK (Table 4). However, the percent of branch antlered bulls harvested during any elk and any bull seasons increased in HUS from 24% to 34% and DCIPK from 40% to 53%. Bull elk harvested during archery season increased 35% and 69% in the HUS and DCIPK, respectively. However, the percent of branch antlered bulls among the bull elk archery harvest increased from 39% to 53% in HUS and decreased 2% in DCIPK. Antlerless elk archery harvest decreased 33% in HUS, but increased 47% in DCIPK when comparing 1991-95 to 1996-2000.

Hunter Success

Rifle hunter success for bull elk in 1996-2000 declined from 17% to 13% in HUS and from 14% to 12% in DCIPK. However, bull elk rifle hunters experienced increased success during any-elk and any-bull hunts, from 17% to 24% in HUS and 14% to 19% in DCIPK. Antlerless elk rifle hunter success decreased from 52% to 43% in HUS and 41% to 31% in DCIPK. Archery hunter success declined as well from 15% to 8% in HUS and 14% to 13% in DCIPK.

DISCUSSION

Hunting regulation changes implemented in 8 northwest Oregon WMU were selected to increase post hunting season bull:cow ratios and optimize hunter opportunity in WMU with differing elk population characteristics. For example, an any-elk bag limit was not applied to the DCIPK since hunter numbers could not be optimized without increasing antlerless harvest to undesired levels.

Increases in post hunting season bull:cow ratios were observed the first year after the season framework changed. Annual post-hunting bull elk numbers continued to improve during 1996-2000. With exception of the Catherine Creek and Pine Creek units, all other WMU evaluated in this paper were near Oregon's minimum bull management objective of 10 bulls:100 cows in 2000. Though not all WMU reached bull management objective, decreases in calf recruitment likely slowed the increase of bull:cow ratios. Variations in bull:cow ratios would be expected from unit to unit because of differences in hunting pressure, habitat conditions, and vulnerability.

Mean bull:cow ratios prior to implementing hunting regulation changes were slightly higher in the DCIPK units, but were similar to the HUS units after 5 years of hunting. Elk in northeast Oregon are vulnerable in habitat with high road density, and in managed forests with little escape cover and high hunter densities. Since hunting regulation changes were aimed at improving post hunting season bull:cow ratios, restriction in hunter numbers was coupled with antler point restrictions. Bull elk rifle hunters declined more drastically among the DCIPK and was a result of hunter reductions during limited entry seasons and hunters choosing not to hunt in the second bull season with a spike-only bag limit.

In HUS, spike-only hunting during the second season and the limited entry spike-only season were more popular among hunters. Perhaps increased elk density, greater calf recruitment resulting in more yearling bulls, and group hunting with increased hunter success provided an opportunity more popular to hunters. With the implemented hunting regulation changes, rifle hunters sacrifice their annual opportunity to potentially harvest a branch antlered bull. However, when allowed to hunt in a limited entry any-bull or any-elk season, the potential for harvesting an older bull is much greater.

It is important to recognize that elk populations at or below management objective with low calf recruitment, similar to those in DCIPK, may not benefit from concurrent limited entry any-elk or spike-only hunting followed by a unlimited spike-only hunting season. In these populations, the effects of increased spike and antlerless harvest likely would be additive.
Antlerless elk hunter numbers and harvest were significantly increased in the Ukiah and Starkey units in an attempt to lower total elk numbers and protect winter range habitat. When coupled with the any elk rifle seasons in HUS, these factors resulted in an 81% increase in antlerless harvest compared to the previous 5-year period.

During the hunting regulation public review, a proposal to limit archery hunter numbers was suggested, but not implemented. Concern was expressed that displaced rifle hunters would purchase archery tags resulting in increased pressure and harvest during archery season. The significant increase in archery hunters in both HUS and DCIPK suggests that some displaced rifle hunters did choose to archery hunt.

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Table 1. Post hunting season bull:100 cow ratios and bull:100 cow management objectives (MO) for 8 Wildlife Management Units (WMU) in northeast Oregon.

	WMU							
Year	Heppner MO=10	Ukiah MO=10	Starkey MO=10	Desolation MO=10	Catherine Cr. MO=10	Imnaha MO=15	Pine Cr. MO=15	Keating MO=10
1991	4	5	4	5	4	2	3	4
1992	4	9	4	4	5	6	3	11
1993	3	4	4	5	2	10	4	6
1994	5	6	4	6	9	13	5	7
1995	5	2	5	6	4	5	2	4
1991-95 Mean	4	5	4	5	5	7	3	6
1996	6	8	7	10	6	9	4	8
1997	5	7	8	10	6	7	7	15
1998	7	10	12	12	7	12	5	13
1999	9	8	9	9	6	9	5	7
2000	9	10	8	11	5	11	11	9
1996-00 Mean	7	9	9	10	6	10	6	10

Table 2. Elk hunter numbers in years before (1991-95) and after (1996-2000) implementation of bull hunting regulation changes for 8 Wildlife Management Units in northeast Oregon.

		Hunter Numbers		
Units	Years	Rifle Bull (%)[a]	Rifle Antlerless (%)[a]	Archery (%)[a]
HUS[b]				
	91-95	82,917	12,470	11,228
	96-00	74,616 (-9%)	17,506 (+40%)	18,931 (+69%)
DCIPK[b]				
	91-95	39,984	11,754	4,081
	96-00	27,487 (-31)	10,658 (-9%)	7,948 (+95%)

[a] Percent change in hunter numbers.
[b] HUS= Heppner, Ukiah, and Starkey; DCIPK= Desolation, Catherine Creek, Imnaha, Pine Creek, and Keating

Table 3. Elk hunter harvest in years before and after implementation of bull hunting strategies for 8 Wildlife Management Units in northeast Oregon.

		Harvest			
		Rifle		Archery	
Units	Years	Bull (%)[a]	Antlerless (%)[a]	Bull (%)[a]	Antlerless (%)[a]
HUS[b]					
	91-95	13,838	6,437	664	978
	96-00	9,834 (-29%)	11,665 (+81%)	897 (+35%)	655 (-33%)
DCIPK[b]					
	91-95	5,604	4,552	285	304
	95-00	3,335 (-40%)	3,294 (-28%)	483 (+69%)	447 (+47%)

[a] Percent change in harvest.
[b] HUS= Heppner, Ukiah, and Starkey; DCIPK= Desolation, Catherine Creek, Imnaha, Pine Creek, and Keating

Table 4. Branch antlered bulls harvested and percent of branch antlered bulls in the harvest during rifle bull and archery seasons bull harvest for 8 Wildlife Management Units in northeast Oregon.

		Harvest			
		Rifle		Archery	
Units	Years	Bulls	%	Bulls	%
HUS[a]					
	91-95	3,328	24	257	39
	96-00	1,050	34	471	53
DCIPK[a]					
	91-95	2,244	40	176	62
	95-00	1,272	53	292	60

[a] HUS= Heppner, Ukiah, and Starkey; DCIPK= Desolation, Catherine Creek, Imnaha, Pine Creek, and Keating

ANNUAL REPRODUCTIVE SUCCESS OF ELK WITH AND WITHOUT DISTURBANCE BY HUMANS DURING CALVING SEASON

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Restricting human activity in elk (*Cervus elaphus*) calving areas during calving season can be controversial because of increasing human demand for recreational access to backcountry areas, and because little evidence exists to evaluate impacts of recreational activities on elk populations. We evaluated effects of human induced disturbance on reproductive success of free-ranging elk using a control-treatment study in central Colorado. Data were collected during 1 pre-treatment year, 2 treatment years, and 2 post-treatment years for 2 naturally segregated elk herds on adjacent, ecologically similar study areas. We maintained annual samples of 71-91 marked and radio-collared adult female elk/study area/year. Throughout the study (1995-1999), we observed elk on alpine summer ranges in July and August on both areas to estimate the proportion of marked cows maintaining a calf. In 1996 and 1997, treatment elk were repeatedly approached and displaced by study personnel throughout a 3-4 week period of peak calving, while control elk did not receive treatment. We discontinued treatments in 1998 and 1999 to allow disturbance to return to ambient conditions. Pre-treatment calf/cow proportions were similar on both areas (0.644 and 0.628 calves/cow). Calf/cow proportions for the control area remained stable or increased slightly throughout the study, but those for the treatment area declined steadily in 1996 (0.524 calves/cow) and 1997 (0.397 calves/cow). In 1998 and 1999, after release from our disturbance, productivity of treatment elk rebounded to pre-treatment levels and to equality with control elk. Average depression in calf/cow proportions for the treatment group in 1996 and 1997 was 0.175 calves/cow based on treatment-control contrasts between treatment and non-treatment years. We documented treatments/individual marked cows in 1996 and 1997, and average number of disturbances/elk/year effectively modeled variation in calf/cow proportions, supporting treatment as a likely cause of declining calf/cow proportions. Population modeling using all 5 years of data indicated that estimated annual herd growth on both study areas was 8% without treatment application, given that existing human activities cause some unknown level of calving season disturbance. With an average of 10 disturbances/cow above ambient levels, our model projected no growth. Our results support maintaining disturbance free areas for elk during parturitional periods.

INTER AND INTRASPECIFIC SUMMER FORAGING DYNAMICS OF MULE DEER, ELK AND CATTLE

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Elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and cattle share rangelands throughout much of interior western North America. Much debate exists on whether competition occurs for forage among these 3 species during summer. In 1998 and 1999 we studied the inter and intraspecific grazing interactions of elk, mule deer, and cattle in 4, 2.25 ha enclosures in previously logged grand fir (*Abies grandis*) forests on the Starkey Experimental Forest and Range in northeast Oregon. Our objectives were to determine dietary overlap among the 3 species and whether grazing by either cattle or elk affected subsequent foraging dynamics of elk, mule deer, or cattle. When grazing pastures for the first time, diet overlap was 38% between cattle and elk and 67% between mule deer and elk, but only 17% between cattle and deer. In pastures previously grazed by cattle, dietary overlap among the 3 species increased by 23% to 165%. In pastures previously grazed by elk, dietary overlap between cattle and elk increased by 38%. Bite rates of cattle declined in pastures previously grazed by cattle. Total dry matter intake of all 3 species did not decline in pastures previously grazed by cattle or elk. However, cattle and less so elk, switched their diets from grasses to forbs and browse in response to prior grazing by cattle. Our results suggest that inter- and intraspecific competition for forage may exist among all 3 species during summer in grand fir forests. However, realization of competition depends on the densities of the various herbivores and annual net primary production, and on dietary overlap resulting in negative nutritional consequences. The probability of competition would be increased during years of low forage production, heavy herbivore stocking, or both.

DETERMINING HABITAT VARIABILITY BETWEEN SYMPATRIC DEER SPECIES IN WEST-CENTRAL TEXAS

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Abstract: We used Landsat 6 Thematic Mapper (TM) data to separate habitats used by mule (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus*) coexisting in Crockett County, Texas in 1999 and 2000. Mule deer and white-tailed deer utilized habitats disproportionately to availability in both supervised and unsupervised classifications. Despite an overall difference in use versus availability, supervised classifications exhibited no individual vegetation class being selected or avoided ($P > 0.05$) by mule or white-tailed deer. However, we did detect selection or avoidance for 3 vegetation classes within unsupervised classifications. Nevertheless, classes were used the same by both deer species. Increased spatial image resolution is recommended for evaluating habitat for sympatric species.

Key Words: habitat, mule deer, *Odocoileus hemionus*, *Odocoileus virginianus*, satellite imagery, Texas, white-tailed deer

Use of geographical information systems (GIS) and satellite imagery to predict habitats may assist in quantifying available habitat for ungulate species (Johnson 1990, Simmons et al. 1992, Moody and Woodcock 1995, With 1997). Use of GIS for modeling potential available habitat and interactions among different wildlife species is increasing (Mack et al. 1997, Rushton et al. 1997, Cardillo et al. 1999). Satellite imagery is considered an accurate method for classification and measurement of vegetation (Haines-Young 1992, Simmons et al. 1992) and spectral signatures from satellite images can be used to classify cover types (Iverson et al. 1989). However, variations within vegetative associations are difficult to classify and typography is not well represented as a landscape feature (Metzger and Muller 1996). Recent studies investigating effectiveness of satellite imagery to map vegetative structure indicate the broader the vegetative community the more accurate the classification. Conversely, the more finite the vegetation association the less likely classifications will be accurate (M. Kunzman, United States Geological Service, personal communicaton).

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Many studies have used GIS and satellite imagery to create predictive models of distribution and specific habitats for individual species (Buckland and Elston 1993, Andries et al. 1994, Austin et al. 1996, Hara and Seiki 1996, Bian and West 1997, Beard et al. 1999). Landscape and environmental features can be used in GIS and remote sensing models to predict potential wildlife habitat (Agee et al. 1989, Pereira and Itami 1991, Herr and Queen 1993, Roseberry et al. 1994, Verlinden and Masogo 1997). Remote sensing can be used to delineate habitat, species richness, distribution, landscape boundaries and many other landscape features (Pearce 1990, Homer et al. 1993, Metzger and Muller 1996, Cardillo et al. 1999, Estrada-Peña 1999). However, vegetation mapping and modeling using GIS is difficult and frequently inaccurate (Pearce 1990, Metzger and Muller 1996). Davis and Goetz (1990) created a model for determining habitat suitability for live oak (*Quercus agrifolia*), but found their model incorrectly classified 79% of the area where live oak occurred. Conversely, Homer et al. (1993) created a model that accurately predicted suitable habitat for sage grouse (*Centrocercus urophasianus*) in Utah. Despite difficulty creating accurate models, GIS and remote sensing models can be used to determine habitat availability for single species and possibly partitioning among species.

Supervised and unsupervised classifications are the most common methods for separating vegetation types using satellite imagery (Pearce 1990, Matthews 1991). ERDAS IMAGINE uses an ISODATA algorithm to generate unsupervised classifications (Smith and Brown 1997). Unsupervised classifications use arbitrary cluster means of available spectral signatures to generate the maximum number of classes allowed (Smith and Brown 1997). Conversely, supervised classifications represent recognized patterns from ground data that the computer can be trained to identify throughout the image (Smith and Brown 1997).

Knowledge about the distribution and habitat of animals is a basic requirement for creating effective management plans (Austin et al. 1996). In areas where species have historically been mutually exclusive it is important to understand what ecological or landscape parameters separate them. For animals that have large home ranges or occupy remote areas, it is difficult to acquire basic distribution information and species interactions (Austin et al. 1996). For these cases, remote sensing is more easily used to create predictive models for animal presence and use of areas (Austin et al. 1996).

Human influenced landscape features (i.e., water, roads, structures, and habitat destruction) can also effect habitat selection by animals (Herr and Queen 1993, Rosenstock et al. 1999). Mule deer move greater distances from permanent water (Hervert and Krausman 1986) than would be required to cross a white-tailed deer's average home range, in Texas (Marchinton and Hirth 1984). In Arizona, Coues white-tailed deer (*O. v. couesi*) avoided areas > 1.2 km from available water sources (Ockenfels et al. 1991).

Diets have been described as similar between mule and white-tailed deer (Kramer 1973, Mackie 1970, Geist 1998), but no studies have examined the influence of competition and drought on diets of sympatric deer populations. Years of low precipitation have been correlated with low productivity in white-tailed deer, while mule deer are less affected (Brown 1984, Smith 1984). We suggest years of average or above average precipitation might effect habitat use by both deer species.

Use of satellite imagery to separate habitats utilized by two sympatric species has not been conducted. Satellite imagery may improve the capability of field biologists to quantify habitat abundance and quality over larger spatial scales than previously possible (Donovan et al. 1987, Pereira and Itami 1991, Buckland and Elston 1993, Mladenoff et al. 1995, Garcia and Armbruster 1997, Knick and Dyer 1997). We evaluated the effectiveness of satellite imagery to discriminate between habitats utilized by sympatric white-tailed deer and mule deer.

We hypothesized habitats used by mule deer would possess different spectral signatures than habitats used by white-tailed deer. We examined habitat use by each deer species in relation to habitat availability based on vegetation maps generated from satellite imagery and vegetation sampling. Lastly, we hypothesized water availability was an important determinant of distribution for each deer species. We tested the prediction that desert mule deer would occur farther away from available water than white-tailed deer.

STUDY AREA

We conducted this study in the northwestern corner of Crockett County, Texas, USA on 4 ranches: Parker (4,451 ha), Andy Smith (4,618 ha), ATA (16,592 ha), and Shannon (West unit [4,856 ha] and Hershey unit [2,023 ha]). Ranches were spatially contiguous although land use patterns differed. Domestic livestock included cattle, sheep, and horses. Oil production was a major source of revenue from each ranch. Hunting was allowed throughout the study site, however, mule deer harvests were more restrictive than those of white-tailed deer (M. Humphrey, Texas Parks and Wildlife, personal communication) because mule deer are not as productive as white-tailed deer (McCullough 1987).

County road 208 north from highway 190 comprised the western boundaries of the study area. Highway 190 served as a connective southern border where the Pecos River crosses the highway. The northern boundary was the north end of the ATA and Andy Smith ranches. Elevations ranged from 700 m to 915 m with the Pecos River serving as the southern perimeter of the study site. Most topography was in the southwest portion of the study area decreasing to open flat areas to the north. The closest weather station was the National Climatic Data Center in Big Lake, Texas recording average rainfall of 48.8 cm annually. A majority of the annual rainfall was received from April through October with winter (November – March) receiving 10 cm. Year-round water was available throughout the study area from water troughs provided for domestic livestock. There were 76 known permanent water sources on the study site.

Vegetation was juniper (*Juniperus* spp.) grasslands in the highest elevations, mesquite (*Prosopis* spp.) and mixed shrub in the lower drainage areas, and tarbush (*Florencia cernua*) in the open flats of the north and south portions. We used 10 vegetation associations to classify the study area; mesquite /juniper, juniper, hackberry (*Celtis* spp.)/mixed shrubs, tarbush /mesquite, juniper/yucca (*Yucca* spp.), mesquite/mixed shrubs, juniper/mixed shrubs, mesquite/prickly pear (*Opuntia* spp.), tarbush/mixed shrubs, and mixed stand (no dominant woody plants).

METHODS

Landsat 6 Thematic Mapper (TM) data acquired in 1995 was obtained from the Texas Cooperative Fish and Wildlife Research Unit at Texas Tech University. Aforementioned imagery appeared to provide the best spatial and spectral resolution (0.09 ha/30 m pixels) of satellite data available for habitat assessment. The perimeter of each ranch was flown, < 100 m altitude over existing fence lines and roads, on 6 January 1999 and recorded with GPS to determine exact boundaries. Line files were recorded, differentially corrected and converted into

ARC/INFO coverages. Flights were contracted through Concho Aviation INC., and flown in a 2-seat Robinson helicopter. These coverages were overlaid on the TM data to delineate the entire study area.

Visual observation was the only method used for determining deer locations. During 1999 we used non-transmittered animals, while during 2000 we used transmitted animals by capturing mule deer and white-tailed deer with net-guns (Krausman et al. 1985) and fitting each with a Telonics © transmitter. Deer were selected randomly to obtain a representative sample of both the white-tailed and desert mule deer population. We located deer from horse, foot, and vehicle. Because locations of only non-startled deer were used to differentiate habitat use between species, search efforts were concentrated during crepuscular periods. During these periods animals were more active (Geist 1998) and more easily located. Because of increased activity, crepuscular periods produced more locations per unit effort. Deer activities and locations for both years were analyzed with GIS. Search routes were selected using roads or trails that appeared representative of vegetative and landscape differences occurring on each ranch. Because mule deer are more conspicuous than white-tailed deer and prefer more open vegetation (Geist 1998), distance from roads was an important environmental factor. To investigate bias in sampling procedure between mule and white-tailed deer, we compared distances from deer locations to the nearest road.

To determine if habitat used by mule deer or white-tailed deer could be identified, ARC/INFO and ERDAS IMAGINE programs were used for digital image enhancement and classification. Vegetation was recorded at each deer location by primary and secondary plant species. Thirty-eight possible vegetative classes were generated. Water, road, and location coverages were spatially joined with ARC\VIEW Geoprocessing Wizard. Distance estimates were determined from each deer location to the closest water and the closest road using ARC\VIEW Spatial Analyst.

Vegetative classes were determined based on ocular estimates of primary and secondary vegetation abundance. Each deer location (UTM) was used as a marker to delineate vegetation class for that location. All deer locations, both < 50 m from an existing road and 100 m from permanent water, were excluded from analysis because of signature variability. After the pixel was determined, the signature was expanded using Seed Properties of the ERDAS IMAGINE program. This allowed us to increase the Spectral Euclidean Distance (standardized at 5 for each location) within the signature. Increased Spectral Euclidean Distance allows a greater percentage of pixels to enter into each class, increasing statistical variation of the signature (Smith and Brown 1997). Locations were then averaged in the Signature Editor to produce a single signature representing a vegetation class. This process was duplicated for all vegetative classes represented by > 15 locations. Ten vegetation classes met these criteria, the remaining 32 vegetative classes were lumped into the aforementioned existing classes.

Once all unique vegetative class signatures were recorded, a supervised classification was conducted to separate all pixels in the image into one of the 10 vegetative classes meeting our criteria. A second model was generated with 10 additional unsupervised classes to compare to vegetation classes in the supervised model. The unsupervised classification separated the image by automatically generating signatures, using the ISODATA algorithm, (Smith and Brown 1997) and categorizing each pixel into a predetermined number of naturally occurring classes (Mathews 1991). Ten unsupervised classes were selected to compare to the 10 from ground-truthed samples. Mathews (1991) suggested the optimal number of classes for image interpretation was between 10 and 20.

Once a known vegetation class had been used to conduct a supervised classification, the image was transferred as a grid into ARC\VIEW where deer locations were overlaid onto supervised and unsupervised classifications. Study area coverages were then overlaid on the satellite image to provide area boundaries for calculating the proportion of each vegetation class within the study area.

For both supervised and unsupervised classifications, mule and white-tailed deer locations were overlaid on separate vegetation classes and the total number of deer locations within each vegetation class was determined. Chi-square analysis was conducted to determine use versus availability of vegetation for both classifications (Neu et al 1974). For each chi-square test with a significant T-statistic, a Bonferroni normal statistic was used to calculate confidence intervals (Conover 1980). Using this technique, each vegetation class selected or avoided by mule or white-tailed deer could be differentiated.

RESULTS

In 1999, we obtained 92 white-tailed deer locations and 170 mule deer locations. In 2000, 80 radiocollared individuals were monitored: 40 mule deer and 40 white-tailed deer and we recorded 75 mule deer and 42 white-tailed deer locations. An additional 254 locations were recorded of deer running (used to determine general presence/absence patterns for both species throughout the study area). Only the original 379 locations ($n = 262$ in 1999; $n = 117$ in 2000) were used for habitat analyses. There was no difference ($P = 0.89$) in average distance to water between mule deer (1,253m) locations and white-tailed (1,264m) deer locations (Fig 1a). Locations of both species were similarly distributed with respect to water sources ($X^2 = 2.53$, df = 8, $P > 0.25$). More than 100 roads were recorded and buffered to determine distances. There was no difference ($P = 0.54$) between distances mule deer (610m) and white-tailed deer (566m) were found from existing roads.

Three hundred sixty one samples were used to represent 10 vegetative classes with sufficient samples ($n \geq 15$) to enter supervised classifications. With supervised classifications, >70% of the study area juniper/yucca and juniper/mixed shrub (Table 1), while no unsupervised class exceeded 17% of the available study area (Table 2).

Mule deer and white-tailed deer utilized habitats disproportionately to availability in both supervised and unsupervised classifications (Tables 3-6). Despite an overall difference in use versus availability, using supervised classifications, no individual vegetation class was selected or avoided by mule ($\chi^2 = 19.71$; df = 9; $P = 0.0199$; Table 3) or white-tailed deer ($\chi^2 = 25.45$; df = 9; $P = 0.0025$; Table 4). Conversely, using unsupervised classifications classes 3 and 4 were avoided by white-tailed deer (($\chi^2 = 49.87$; df = 9; $P < 0.0001$; Table 5), but only class 3 was avoided by mule deer ($\chi^2 = 36.08$; df = 9; $P = 0.00004$; Table 6). Class 10 was selected by both mule deer and white-tailed deer (Tables 5 and 6).

DISCUSSION

Average distance and distribution of both deer species from water was similar. Many factors might have contributed to overlap of distance distributions between deer species. There is debate in the literature on whether deer need free-standing water. White-tailed deer appear to need water more than mule deer, but both species will use it if available (Rosenstock et al. 1999). Water was abundant on our study site and was used by both species. To determine if water influenced deer distribution and habitat use, it would have been necessary to manipulate water distribution, which was beyond the scope of this study.

Because most of our data during 1999 were collected from roads during crepuscular time periods, we were concerned that perhaps deer locations and apparent activity patterns may have been biased by our data collection methods. However, because both deer species were located similar distances from roads this was probably not a factor in this study.

Both white-tailed and mule deer did not use vegetation similar to availability for both supervised and unsupervised classifications. However, we could only determine selection or avoidance for 3 vegetation classes within unsupervised classifications. Vegetation classes selected disproportionately to availability appeared adjacent to available water (Pecos River) and in heavily vegetated riparian areas (referenced from known locations). Furthermore, the least vegetated region of the study area was avoided by both species.

Decreasing scale in which habitats are surveyed inversely impacts the accuracy of identifying specific habitat types (Herr and Queen 1993). Studies investigating the ability to accurately identify vegetation and habitat types suggested unacceptable levels of variation when identifying specific vegetation at small scales (Mayer 1984). Mayer (1984:101) defined remote sensing as "..the process of acquiring information about a subject without actually coming into contact with it." Although the ground measurements we collected at each deer location increased the amount of information about each site, they also decreased the scale which we could compare with vegetation classes.

The greatest impact to effectiveness of remote sensing to explain differences in deer habitat use between deer species appeared to be a lack of measurable structural differences in habitats used by the two species (Avey 2001). Hodgson et al. (1988) reported a similar finding for wood stork (*Mycteria americanan*) foraging sites. Broad scale, unsupervised habitat classifications coupled with ground-truthing may allow identification of potential deer habitat over large geographic areas in regions where deer species do not overlap.

Because we found limited differences in vegetation associations used by each deer species (Avey 2001) it was not surprising remote sensing did not distinguish habitat differences for each species. The next step if satellite imagery and remote sensing were to be used to separate sympatric deer species would be to include higher resolution spatial data and a wider array of secondary database attributes to more succinctly define habitat type at a landscape level. However, even this resolution may not explain spatial and temporal differences between deer species in sympatric areas.

High canyons, bluffs, and slopes with dense vegetation have been considered exclusive habitat for white-tailed deer, whereas open, rolling, desert foothills and flats were exclusive for mule deer (Krausman and Ables 1981, Geist 1998). Despite apparent differences in habitat preferences, these 2 species are sympatric throughout much of their range (Kramer 1973, Hanley and Hanley 1982, Stubblefield et al. 1986, Wiggers and Beasom 1986, Rollins 1989, Derr 1991), although little is known about their spatial and temporal interactions (Kramer 1973).

Topography and behavior were the most obvious mechanisms separating deer species in Big Bend National Park, Texas (Krausman and Ables 1981), but others (e.g., Allen 1968) ruled out competition between the species due to minimal use of common resources. However, both species actively competed for resources in the same area and competitive exclusion may eliminate white-tailed deer in the San Cayetano Mountains, Arizona (Anthony 1972). Species using the same resources cannot exist together for long without one competitively excluding the other (i.e., Gause Principle [Gause 1934, Schoener 1982]).

Environmental factors can also impact habitat use patterns of deer species (Rosenstock et al. 1999). During 1998, 1999 and 2000 the study area received, 28, 30 and 33 cm of rainfall respectively, while the average for that area was 49 cm annually. Years of low precipitation have been correlated with low productivity in white-tailed deer, while mule deer were less affected (Brown 1984, Smith 1984). Therefore, our study results may only be applicable to drought periods in this area.

MANAGEMENT IMPLICATIONS

The use of satellite imagery to differentiate habitat between sympatric species should be carefully considered before any project is started. Spatial resolution (pixel size) may have contributed to the difficulty of distinguishing individual vegetation classes between deer species. Using a higher resolution image (decreased pixel size) could provide increased information about ground differences that could then be used to delineate potential habitat variations. Nevertheless, limited habitat variability between sympatric species could render satellite imagery inadequate for separating deer habitat in this area.

For managers to effectively use TM imagery for habitat evaluations, broad scale objectives should be the focus of classification efforts. Using available resources, micro-site management using satellite imagery is not reasonable or cost effective when studying habitat for sympatric species. Investigating habitat variability across animal distributions is more likely to provide new insight into habitat selection and variability among species.

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Table 1. Area of vegetative classes based upon supervised classification of Landsat imagery in Crockett County, Texas, 1999 and 2000.

Class ID	Supervised vegetation classes	Area (ha)	Percent of total area
1	Mesquite/juniper	10.0	<1.00
2	Mesquite/prickly pear	74.9	2.27
3	Mesquite/mixed shrubs	5,739.0	1.74
4	Juniper	3,020.2	9.14
5	Juniper/yucca	11,779.6	35.66
6	Juniper/mixed shrubs	11,654.5	35.28
7	Tarbush/mesquite	4,599.9	13.93
8	Tarbush/mixed shrubs	1,102.2	3.34
9	Even stand mixed shrubs	17.9	<1.00
10	Hackberry/mixed shrubs	37.5	<1.00
TOTAL		33,030	100.00

Table 2. Area of vegetative classes based upon unsupervised classification of Landsat imagery in Crockett County, Texas, 1999 and 2000.

Class ID[a]	Area (ha)	Percent of total area
1	808.2	2
2	2,344.1	7
3	4,247.2	13
4	2,648.1	8
5	5,736.6	17
6	4,354.2	14
7	4,198.2	13
8	4,558.6	14
9	3,363.8	10
10	771.4	2
TOTAL	33,030	100

[a]Computer generated vegetation classes, no known vegetation association.

Table 3. Occurrence of mule deer relative to availability of supervised vegetation classes in Crockett County, Texas, 1999 and 2000. Selected habitats are denoted by a plus (+), avoided habitats are denoted by a minus (-), and use equal to availability by a zero (0).

Class ID	Vegetation Availability	# Mule deer per class (p_i)	% Used	# Expected	95% C.I proportion of occurrence (p_i)	Selection
1	0.00	0	0.00	0	0	0
2	0.02	0	0.00	4	0	0
3	0.02	3	0.01	4	$0.009 \leq p_i \leq 0.030$	0
4	0.09	15	0.07	19	$0.021 \leq p_i \leq 0.119$	0
5	0.35	59	0.28	75	$0.194 \leq p_i \leq 0.366$	0
6	0.34	80	0.38	73	$0.289 \leq p_i \leq 0.470$	0
7	0.14	41	0.19	30	$0.114 \leq p_i \leq 0.266$	0
8	0.03	12	0.06	6	$0.014 \leq p_i \leq 0.106$	0
9	0.01	3	0.01	2	$0.009 \leq p_i \leq 0.030$	0
10	0.00	0	0.00	0	0	0
TOTAL	1.00	213	1.00	213		0

Table 4. Occurrence of white-tailed deer relative to availability of supervised vegetation classes in Crockett County, Texas, 1999 and 2000. Selected habitats are denoted by a plus (+), avoided habitats are denoted by a minus (-), and use equal to availability by a zero (0).

Class ID	Vegetation Availability	# White-tailed deer per class (p_i)	% Used	# Expected	95% C.I proportion of occurrence (p_i)	Selection
1	0.00	0	0.00	0	0	0
2	0.02	0	0.00	2	0	0
3	0.02	5	0.04	2	$0.010 \leq p_i \leq 0.058$	0
4	0.09	10	0.08	11	$0.011 \leq p_i \leq 0.149$	0
5	0.35	26	0.22	43	$0.114 \leq p_i \leq 0.326$	0
6	0.34	42	0.35	41	$0.228 \leq p_i \leq 0.472$	0
7	0.14	28	0.23	17	$0.123 \leq p_i \leq 0.338$	0
8	0.03	8	0.06	4	$-0.001 \leq p_i \leq 0.121$	0
9	0.01	2	0.02	1	$-0.016 \leq p_i \leq 0.056$	0
10	0.00	0	0.00	0	0	0
TOTAL	1.00	121	1.00	121		0

Table 5. Occurrence of white-tailed deer relative to availability of unsupervised vegetation classes in Crockett County, Texas, 1999 and 2000. Selected habitats are denoted by a plus (+), avoided habitats are denoted by a minus (-), and use equal to availability by a zero (0).

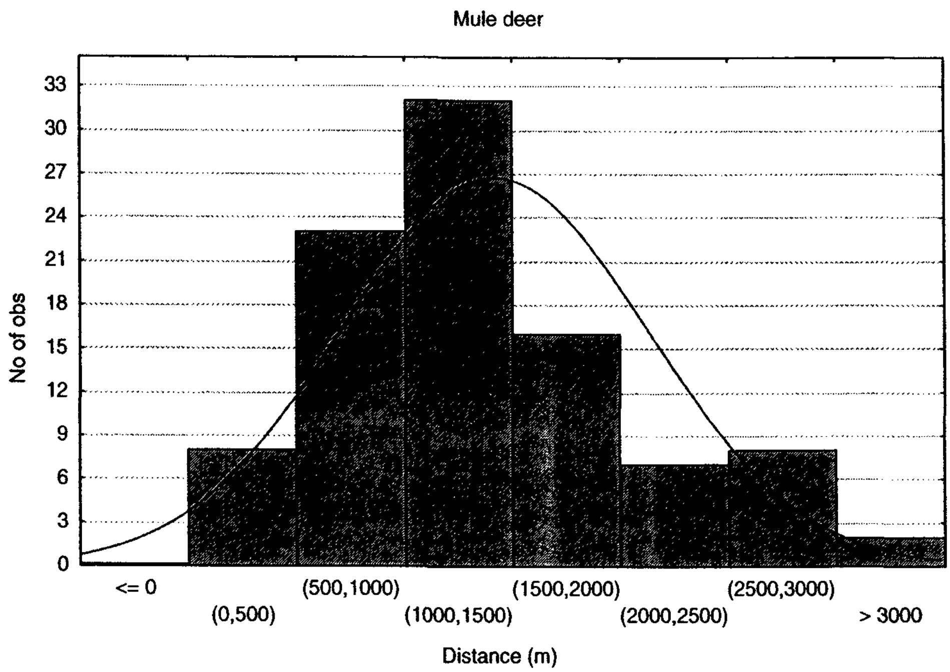
Class ID (i)	Vegetation Availability	# White-tailed deer per class (p_i)	% Used	# Expected	95% C.I proportion of occurrence (p_i)	Selection
1	0.02	5	0.04	2	$-0.010 \leq p_i \leq 0.058$	0
2	0.07	10	0.08	8	$0.011 \leq p_i \leq 0.149$	0
3	0.13	8	0.07	16	$0.047 \leq p_i \leq 0.093$	-
4	0.08	5	0.04	10	$-0.010 \leq p_i \leq 0.058$	-
5	0.17	12	0.10	21	$0.023 \leq p_i \leq 0.177$	0
6	0.14	15	0.13	17	$0.044 \leq p_i \leq 0.216$	0
7	0.13	13	0.11	16	$0.030 \leq p_i \leq 0.190$	0
8	0.14	29	0.24	17	$0.131 \leq p_i \leq 0.350$	0
9	0.10	15	0.12	12	$0.037 \leq p_i \leq 0.203$	0
10	0.02	9	0.07	2	$0.047 \leq p_i \leq 0.093$	+
TOTAL	1.00	121	1.00	121		0

Table 6. Occurrence of mule deer relative to availability of unsupervised vegetation classes in Crockett County, Texas, 1999 and 2000. Selected habitats are denoted by a plus (+), avoided habitats are denoted by a minus (-), and use equal to availability by a zero (0).

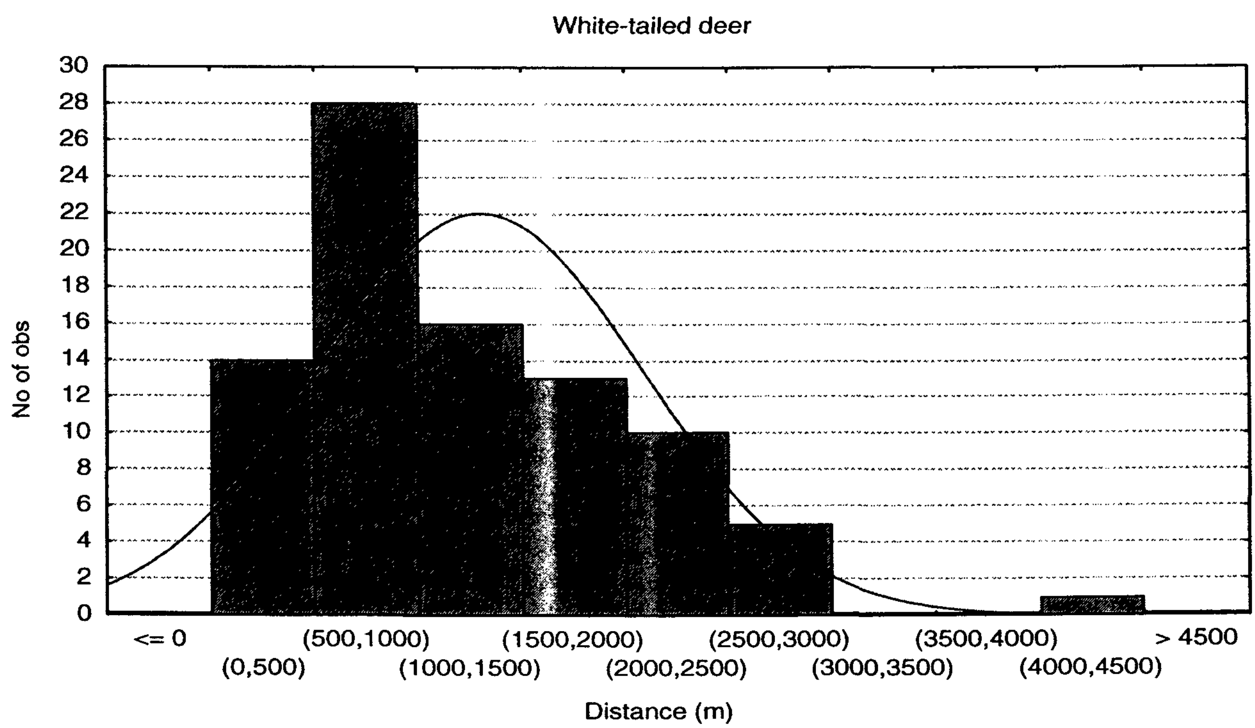
Class ID (i)	Vegetation Availability	# Mule deer per class (p_i)	% Used	# Expected	95% C.I proportion of occurrence (p_i)	Selection
1	0.02	3	0.01	4	$-0.009 \leq p_i \leq 0.030$	0
2	0.07	20	0.09	15	$0.035 \leq p_i \leq 0.145$	0
3	0.13	9	0.04	28	$0.021 \leq p_i \leq 0.059$	-
4	0.08	15	0.07	17	$0.021 \leq p_i \leq 0.119$	0
5	0.17	26	0.12	36	$0.057 \leq p_i \leq 0.186$	0
6	0.14	31	0.16	30	$0.089 \leq p_i \leq 0.231$	0
7	0.13	25	0.12	28	$0.057 \leq p_i \leq 0.186$	0
8	0.14	42	0.20	30	$0.123 \leq p_i \leq 0.277$	0
9	0.10	33	0.15	21	$0.081 \leq p_i \leq 0.219$	0
10	0.02	9	0.04	4	$0.021 \leq p_i \leq 0.059$	+
TOTAL	1.00	213	1.00	213		0

Figure 1. Distribution of mule deer (1a) and white-tailed deer (1b) locations (all activities combined) relative to distance from permanent water sources in Crocket County, Texas, 1999 and 2000.

1 a.



1 b.



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PAST DEER AND ELK WORKSHOPS

MULE DEER	ELK
1970 ~ Mule Deer Workshop Blanca, Colorado (1st)	1977 ~ Western States Elk Workshop Jan 31-Feb 2 Estes Park, Colorado
1972 ~ Mule Deer Workshop, January 11-12 Elko, Nevada (2nd)	1980 ~ Western States Elk Workshop Feb 27-28 Cranbrook, British Columbia
1974 ~ Mule Deer Workshop, January 22-23 Laramie, Wyoming (4th)	1982 ~ Western States Elk Workshop Feb 22-24 Flagstaff, Arizona
1975 ~ Mule Deer Workshop, February 18-20, Silver City, New Mexico (5th)	1984 ~ Western States and Provinces Elk Workshop, April 17-19 Edmonton, Alberta
1976 ~ Mule Deer Workshop, February 19-21 Boise, Idaho (6th)	1986 ~ Western States and Provinces Elk Workshop, March 17-19 Coos Bay, Oregon
1976 ~ Mule Deer Decline in the West Symposium, April Logan, Utah	1988 ~ Western States and Provinces Elk Workshop, July 13-15 Wenatchee, Washington
1978 ~ Mule Deer Workshop, February 21-23 Logan, Utah	1990 ~ Western States and Provinces Elk Workshop, May 15-17 Eureka, California
1980 ~ Mule Deer Workshop, March 5-6 Bend, Oregon	1993 ~ Western States and Provinces Elk Workshop, May 19-21 Bozeman, Montana
1983 ~ Western Deer Workshop, April 11-12 Spokane, Washington	
1985 ~ Western Deer Workshop, March 3-6 Bozeman, Montana	
1987 ~ Western Deer Workshop, August 4-7 Pingree Park, Colorado	
1989 ~ Western Deer Workshop, August 23-25 Albuquerque, New Mexico	
1991 ~ Western Deer Workshop, August 27-30 Monterey, California	
1993 ~ Western States and Provinces Deer Workshop, August 10-13 Vancouver, British Columbia	

DEER/ELK

1995 ~ Western States and Provinces Deer and Elk Workshop
May 23-25, 1995 Sun Valley, Idaho

1997 ~ Western States and Provinces Deer and Elk Workshop
May 21-23, 1997 Rio Rico, Arizona

1999 ~ Western States and Provinces Deer and Elk Workshop
March 3-5, 1999 Salt Lake City, Utah

2001 ~ Western States and Provinces Deer and Elk Workshop
August 1-4, 2001 Wilsonville, Oregon