PROCEEDINGS OF THE 1990 WESTERN STATES AND PROVINCES ELK WORKSHOP

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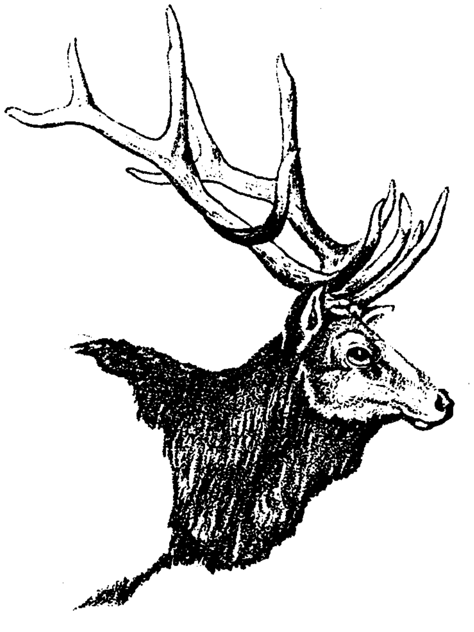

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Views represented in the *Proceedings* are those of the authors and do not represent official positions of the sponsors of the Workshop. We apologize, in advance, for any format errors that may be found in this edition, despite our efforts.

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P.S. Richard Callas spent countless hours preparing these *Proceedings.* He coordinated the review process, incorporated authors changes into the final papers and prepared the final "camera-ready" copy for printing. For this, we thank him. And to Carol, Christina, and Veronica, thanks for being so understanding about sharing your husband's and father's time with us during this process.

Donald B. Koch
Eric R. Loft

TABLE OF CONTENTS

TABLE OF CONTENTS

Elk Status Reports

APPLICATION OF A GEOGRAPHIC INFORMATION SYSTEM (GIS) TO TEST MODELS OF VANCOUVER ISLAND ROOSEVELT ELK HABITAT SUITABILITY

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

INTRODUCTION

Habitat Suitability Index (HSI) Modeling

The habitat suitability index (HSI) modeling approach as developed by the U.S. Fish and Wildlife Service is based on the assessment of the physical and biological attributes of habitat under the assumption that habitat suitability is proportional to carrying capacity (Berry 1986). HSI models generally quantify habitat quality using suitability indices that range from 0 to 1.0. The models are not intended to predict population levels, but an HSI of 0.8 should indicate better habitat quality than an HSI of 0.4 and should represent greater potential carrying capacity (Schamberger and O'Neill 1986).

Bunnell (1989) notes the proliferation of wildlife-habitat models that has occurred since their inception, but suggests that the lack of evaluation of most models is a key symptom of failure of the modeling process. Data collected in this study will document elk use or preference for areas under the assumption that animals will select and use areas that are generally best able to satisfy their life requisites. Elk habitat use then is being used as a surrogate of habitat quality to test and refine habitat suitability models which may eventually lead to predictions of population performance based on habitat conditions.

Testing HSI Models

Most wildlife HSI models have been constructed using the literature and opinions of professionals and few have been tested (Berry 1986). Irwin and Cook (1985) note that habitat evaluation models need to be field tested to ensure that they incorporate appropriate variables and to determine correlations between model outputs and indices of population dynamics that reflect habitat conditions. Lancia et al. (1982) suggest that validation of models should be carried out by testing model predictions at a different place or time than the model was developed. They consider habitat use by individual animals to be the most reliable method of validating a model. In this study, habitat use patterns of transplanted elk will form the basis for testing models that were developed in a different but similar area.

Testing provides information about model performance and reliability and also provides data that can lead to model improvement. Wildlife habitat models which have been tested have usually only examined the level of model output, which provides little information about the species' response to changing habitat variables. Testing individual model variables or assumptions provides information for determining and improving model reliability (Schamberger and O'Neill 1986). This study is designed to test model performance of both the individual assumption or variable component as well as overall model output. However, it should be noted that this test represents an unreplicated sample, and although confidence may be gained in model application if favorable results are obtained, all models - which are merely statements of hypotheses - can never truly be proven correct. Model tests serve only to either invalidate the model or strengthen belief in its usefulness (Holling 1978).

GIS Application in Wildlife Habitat Modeling

A geographic information system (GIS) can be considered as a technology to expand the use of maps in management by processing digital (rather than analog) spatial information. GIS's arose in the late 1960's as a separate concept from the more general idea of management information systems (MIS) (Devine and Field 1986). While MIS allow efficient organization, storage, and retrieval of information, a GIS allows analysis of relationships between spatial datasets as well as display of the generated information. It is the manipulation of map data stored in a GIS that is the heart of this technology.

The employment of a GIS in wildlife habitat investigations provides a number of benefits to the user because digital data allows quantitative as well as qualitative interpretations (Berry 1986). One of the major benefits is the speed at which mapped data can be analyzed, retrieved, and updated (Consoletti 1986). Multiple variable analyses also become feasible with a GIS. Single or various combinations of variables can be analyzed to determine their relative contribution to overall habitat quality (Lyon et al. 1987). This analysis of partial contributions from several variables is useful in species-specific wildlife habitat analyses because some important habitat components are often inadequately represented by land cover data alone. The influence of human activity through such measures as proximity to roads can be incorporated into conventional habitat maps using a GIS and searches for areas of specified habitat characteristics can be quickly carried out.

While a GIS provides a powerful means of quantifying the abundance of various habitat requirements of wildlife, the greatest advantage over conventional assessment procedures lies in the ability to analyze spatial relationships among habitat components. The concepts of juxtaposition and interspersion of wildlife requirements are critical factors determining habitat quality which can be easily assessed using a GIS (Stenback et al. 1987, Eng et al.

1990). While it may be possible to calculate these features manually, the process is laborious or unfeasible given the resources typically available to wildlife habitat researchers and managers.

A key feature of the models being tested in this research is the importance placed on habitat interspersion. The use of a GIS allows the assessment of spatial interspersion while retaining the spatial integrity of the habitat data. Previous attempts to incorporate habitat interspersion into the wildlife planning process have failed to adequately represent wildlife habitat because interspersion indices were added up over large areas, which fails to represent the relationships among individual habitat polygons (Eng et al. 1990).

Linking a GIS with models of wildlife habitat suitability can provide a powerful tool in determining an optimum course of management action. Verner et al. (1986) note that the ability to ask 'what if' questions in the form of maps and statistics, gives credibility to management decisions. It is this potential for gaming with numerous management options that provides a great deal of the power of a GIS in wildlife habitat assessment. Various hypothetical management options can be applied to the map, their impacts on habitat quality assessed according to the rules of the HSI model, and the most desirable option selected.

The incorporation of forest succession models in a GIS gives the time dimension needed for wildlife habitat capability models and for the assessment of future impacts of current management decisions. Stand sizes or successional stages vary in their ability to satisfy wildlife requirements and the management decision which results in the long term optimization of habitat quality may differ considerably from that which offers the best conditions for the current 'snapshot-in-time'.

The PAMAP GIS (Pamap Graphics Ltd., Victoria, B.C.) is being used in this study. The advantages of this system include its ability to easily calculate corridors around habitat features for interspersion assessments, and the fact that it is an intermediately priced local product with good support services available.

OBJECTIVES

The main objective of this study is to develop refined, tested models to quantitatively assess Roosevelt elk seasonal range habitat suitability. More specific objectives are to:

1. Apply the current models of elk habitat suitability to a watershed which was previously devoid of a breeding population of elk and predict seasonal movements and habitat use patterns;

2. Transplant a group of migratory elk into the study area and follow the general movements and seasonal habitat use patterns of radio-collared adult females through two years from March 1989 to March 1991;

3. Test individual model components and overall output by comparing predicted and actual habitat use characteristics of radio-collared elk; and

4. Refine and modify the models as required to be consistent with the results of this and previous studies of Vancouver Island elk/habitat interactions.

There were several reasons for using a transplanted group of elk to test the models. Habitat use by transplanted animals is more likely to be in response to existing habitat conditions rather than to patterns established prior to logging in the area. Also, elk densities will be much lower in the study area than in most other Vancouver Island watersheds for the first several years following the transplant. This is hoped to minimize the effects of density-dependent habitat selection patterns which may confound results obtained in areas with higher population densities. Finally, exploratory movements of the elk can be closely followed to assess which areas within the watershed the animals were or were not familiar with. This should allow more precise tests of model performance.

STUDY BACKGROUND

Approximately 3000 Roosevelt elk occur on Vancouver Island (Janz and Becker 1986). The current demand to hunt (and view) elk greatly exceeds the supply as evidenced by the fact that over 7,500 applications were received for 229 permits to hunt elk in 1989. The general management objective is to enhance elk populations on the Island through conservative harvesting and the maintenance or enhancement of habitat quality.

The Integrated Wildlife Intensive Forestry Research (IWIFR) study was initiated in 1980 to examine the effects of forestry activities on wildlife habitat. It arose mainly as a result of conflicts over the allocation of old-growth timber as deer or elk winter ranges. In addition, the 1970's saw a proliferation of intensive forestry activities including spacing and fertilization of large areas on Vancouver Island which were carried out with little consideration - or knowledge - of their impacts on wildlife habitat.

The major species of concern in the research program are black-tailed deer and Roosevelt elk. Only limited consideration has been given to other species. The main contributors to the research have been the Ministries of Environment and Forests of the Provincial government of B.C.; several of the larger forest companies including MacMillan Bloedel, Canadian Forest Products, and Fletcher Challenge Canada; and the University of British Columbia.

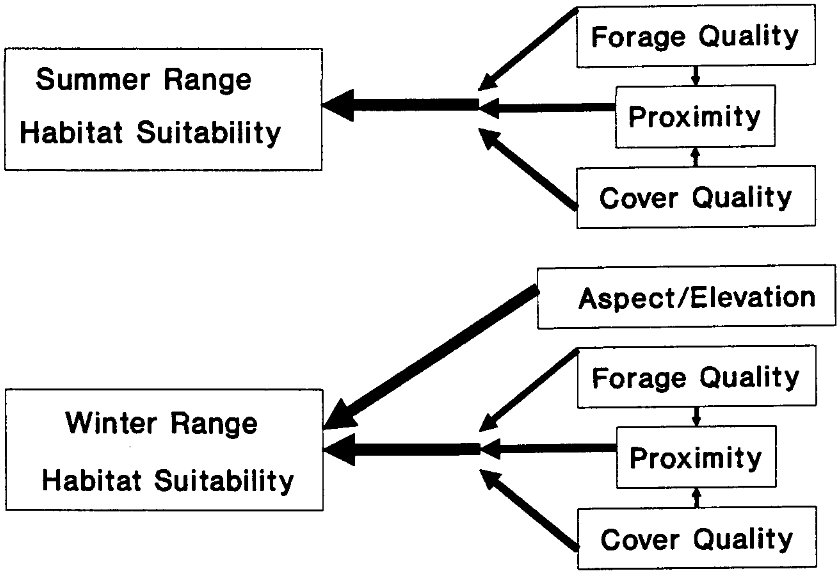

Fig. 1. Generalized relationships in the Vancouver Island elk habitat suitability models.

Field research for the elk study began in early 1981 near Campbell River on northern Vancouver Island where it was continued until 1986. This marked the end of 'Phase I' of the study. Phase I elk research examined seasonal habitat selection patterns, population performance, and other aspects of basic ecology gained from the study of 33 radio-collared elk (Brunt et al. 1989).

An important product of this first phase of elk research was a set of models of seasonal habitat suitability (Brunt and Ray 1986). The goal of the 'Phase II' portion of the elk study - which will continue through March 1991 when the research program will officially end - is to test and refine these models.

MODEL DESCRIPTIONS

Three separate models are being tested in this project for their ability to assess elk seasonal range habitat suitability on Vancouver Island. One is applicable to summer ranges while the other two model habitat suitability during mild and severe winter conditions. A spring range model is currently in development. Two different models for winter were required because winter severity varies widely across Vancouver Island and appears to have a periodicity of approximately 18 years (Page, in prep.). Therefore, the appropriate model can be applied depending on the geographic location and management objectives of the area being assessed. Generalized model relationships are outlined in Fig. 1.

Earlier versions of the models tested in this research (Brunt and Ray 1986) have undergone some revisions but the same basic habitat relationships are being modeled. The importance placed on the contribution of interspersion to habitat suitability in all 3 models is considerable - one half of the overall suitability of a site is derived from the food and cover characteristics at that location, with the other half being determined through the assessment of distances from cover and high quality foraging areas. In the two winter models, aspect and elevation combine to act as a limiting factor to habitat suitability, with the greatest influence of aspect/elevation occurring in the severe winter model. The importance of thermal and snow interception cover are also greatest in the severe

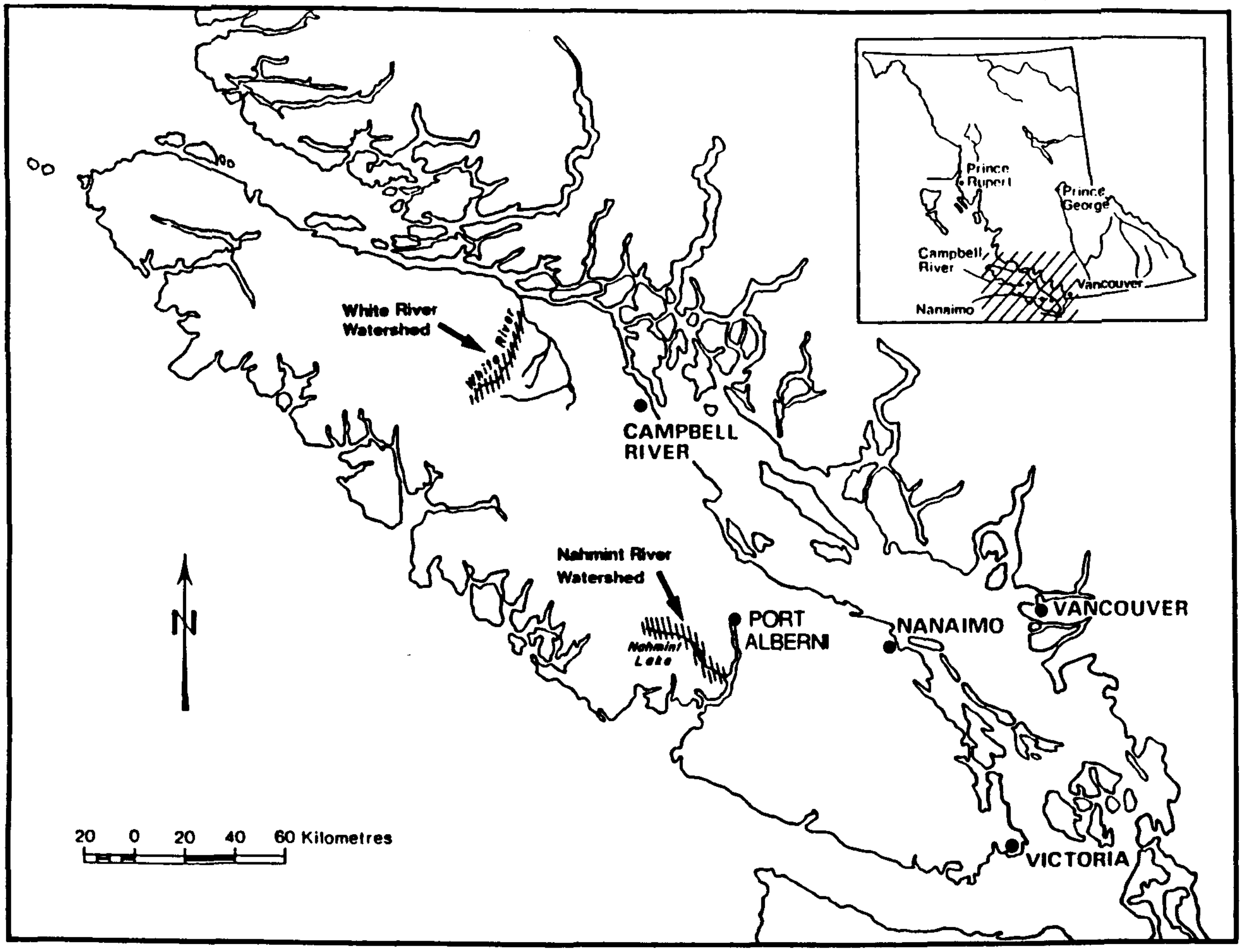

Fig. 2. Location of the Nahmint study and White River transplant source areas for the Vancouver Island elk habitat suitability model test.

winter model.

The location and density of roads - which plays an important role in determining habitat suitability in many elk models (i.e. Lyon 1979, 1983; Witmer and deCalesta 1985; Eby and Gatlin 1986; Wisdom 1986) - is not considered in these models for a number of reasons related to the area of model applicability (Vancouver Island and south-coastal British Columbia). These coastal areas do not have large non-forested natural openings, but generally have rugged topography and tend to provide security cover relatively quickly, even following clearcutting. Also, all hunting of elk on Vancouver Island is strictly regulated through a limited entry draw system and there is never more than 15 permits available to hunt elk within a hunting zone (watershed or larger area), which maintains extremely light hunting pressure. Finally, whatever negative impacts roads may impose on elk habitat suitability may be balanced by positive benefits including an abundance of preferred forage species along roadsides (e.g. willows, elderberry, etc.), and the provision of relatively easy routes of travel which are used heavily, particularly during winter. These facts have led us to believe that the number and location of roads is not a critical factor determining elk habitat suitability on Vancouver Island.

RESULTS

Field Work

In late February 1989, a group 13 elk were corral-trapped in the White River watershed near Sayward and transplanted to the Nahmint River near Port Alberni (Fig. 2). The two areas are generally similar in physiographic and vegetative characteristics, and it appears that only 2 adult bulls were in the study area prior to the transplant. The transplanted group included 8 adult cows, 2 spike bulls, 2 female calves and one male calf. All 8 adult cows were radio-collared.

Twelve hours following the transplant, one of the adult cows was found dead on the road within 200 m of the release site. Another adult cow was approximately 500 m from the release site showing a number of classic symptoms of capture myopathy (Thorne et al. 1982) and she was destroyed. Subsequent review of videotapes of the transplant procedure indicated a number of contributing factors to these mortalities and we have made changes in our methods of handling elk which we hope will eliminate similar problems in future transplants.

Radiotelemetry locations form the basis of the elk seasonal range selection dataset which will be compared with modeled predictions. Collared elk were relocated daily for the first several weeks following the transplant to examine initial exploratory movements, and since that time have been located approximately once weekly. About 500 locations have been obtained from the 6 radio-collared adult cows, but only about 175 of these are independent locations due to the fact that 5 of the radio-collared elk have remained together for most of the time since the transplant.

Access, particularly to higher elevation summer ranges, has been a major problem during the study. The watershed is only beginning to be developed for forestry use, and no road access is present in the upper portion of the study area. As a result, most summer range locations can only be efficiently obtained by helicopter and 21 flights have been taken to date. Aerial locations are being collected in a manner to allow the development of a sightability model for coastal habitats similar to that described by Samuel et al. (1987) for interior areas.

In addition to these animal location data, 3 intensive telemetry sessions with concurrent activity monitoring were held to examine winter habitat selection on a finer scale.

Habitat plots were established throughout the study area to assess the accuracy of the digital map being used as well as to provide insight to preferred habitat characteristics. To date, 110 20 x 20 m permanent plots were established. Data were collected on overstory species composition and canopy closure, understory species abundance, and the ability of the stand to provide security cover using a sighting tube (Leckenby et al. 1976). Forty-two of these plots were revisited up to 3 times during differing snow conditions to measure changes in snow depth and forage availability.

Weather data including temperature, wind speed/direction, relative humidity, solar radiation, and rainfall have been collected hourly since late July 1989 using a computerized weather station. Total snow depth at 5 snow stations on level open sites throughout accessible portions of the study area has been recorded at one to 7-day intervals throughout the winter.

Fourteen composite fecal samples have been collected at approximately monthly intervals since the beginning of the study to be analyzed for diet composition and quality, and for comparison with previous studies.

GIS Mapwork

A digital map of the study area was created from existing 1:20,000 topographic and forest cover maps and 1:15,000 (approx.) colour air photos. Features which were entered include watercourses, elevation, slope, aspect, logging history and understory type. Understory types provide the basic information used to calculate seasonal forage and cover quality for a site, and are generally analogous to ecosystem associations as described by Klinka et al. (1984). The fifteen basic understory types, along with numerous complexes that occured, resulted in 34 different habitat types in the 457 habitat polygons that comprise the study area.

Seasonal habitat suitability has been calculated for the entire study area by applying the summer, mild winter, and severe winter models. Any pixel size can be selected using the GIS, but as a compromise between computer memory, speed of model application, and precision of the map, a pixel size of 15 m by 15 m (0.02 ha) was chosen for this study. The models use forage and cover quality and interspersion as the main variables - as well as an assessment of the suitability of aspect/elevation of the site in the 2 winter models - to calculate HSI values. An overview of the methods used in combining the variables in each of the models is presented in Fig. 3.

DISCUSSION

The major task of testing the habitat suitability models in this study by overlaying elk seasonal home ranges onto suitability maps created through model application, remains to be carried out. A number of home range programs are being considered to try and accurately delineate seasonal ranges from the animal location dataset. This will prove most challenging on the higher elevation ranges where access restrictions have resulted in relatively low numbers of locations being obtained during the summer period.

In spite of a few minor bugs, preliminary examination of the results of model application are extremely encouraging. The process of 'adding up' the various components of HSI models has always been particularly troubling, but I believe we have arrived at a realistic method of assessing seasonal range habitat suitability using relatively simple models (Fig. 3). The importance of forage is greatest in the summer and mild winter models and the contribution of aspect/elevation is greatest in the severe winter model. Inverse geometric means are used to produce a relatively high suitability value when any one individual component is high, while geometric means are used when low overall habitat suitability results if any of the components being combined has a low value.

A significant problem remains which I feel could hinder broad application of the models in the forest management

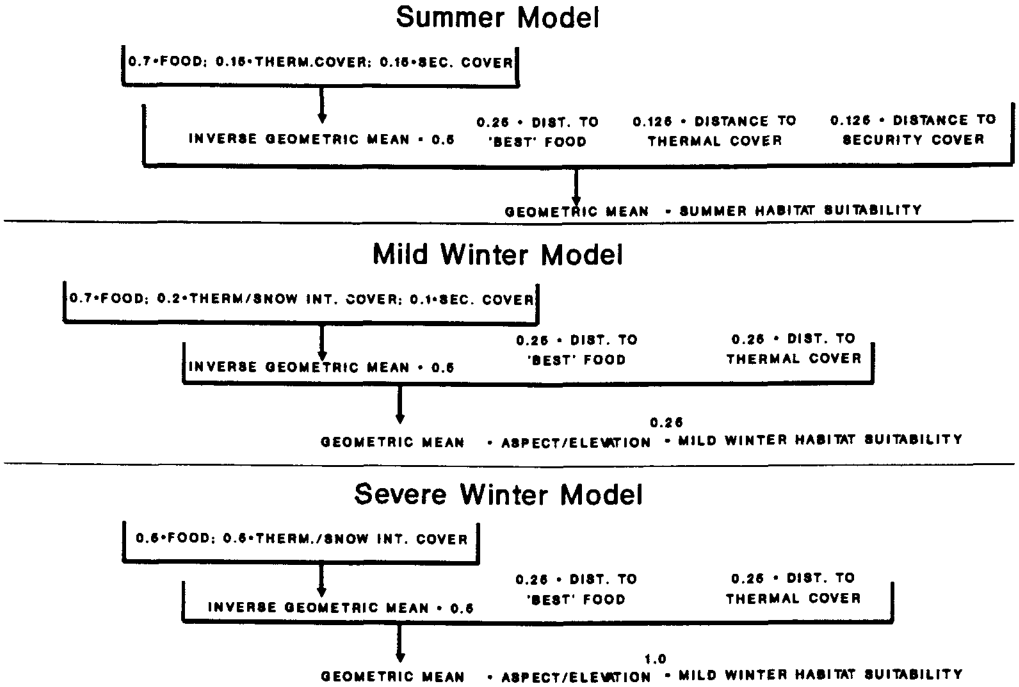

Fig. 3. How model components "add up" in the Vancouver Island elk habitat suitability models.

context for which they are being built. I refer to the relative difficulty in obtaining accurate maps of understory types - a key factor used in these models to determine both the forage and cover characteristics of a site. Forest cover maps do not accurately reflect habitat boundaries at the ecosystem association level and an outside contractor with a sound background in vegetation ecology was eventually hired to complete ecosystem mapping of the study area from colour air photos. Even so, ground truthing of habitat types and boundaries assigned through air photo interpretation is necessary - a sometimes prohibitively expensive process, especially in areas with poor accessibility and a high degree of habitat heterogeneity.

A tentative, preliminary first step has been taken to try and link the results from application of the HSI models in this study to elk population performance - the ultimate response of interest to the wildlife habitat manager. A PC based program that is driven by habitat suitability using Leslie matrices of age-specific survival and fecundity is being developed. A number of possible relationships between habitat suitability indices and population performance will be modeled.

Bunnell (1989) classifies the seasonal range HSI models being tested in this study as 'models of understanding' which represent best guesses and hypotheses brought together to increase insight into a systems connections and behavior. Taking the next step towards a 'model of (population) prediction' will require a series of further validation tests. It is hoped that long-term monitoring of elk populations in the study area will provide an opportunity to further test the ability of these models to increase understanding and to allow greater confidence in their ability to predict responses to habitat manipulations.

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HABITAT USE BY ROOSEVELT ELK IN REDWOOD NATIONAL PARK, CALIFORNIA

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: Habitat use by Roosevelt elk (*Cervus elaphus roosevelti*) in the Bald Hills of Redwood National Park was investigated using radio telemetry and visual observations (923 locations of 10 different elk). Among radio-collared elk, individuals were randomly selected for observation in a 24-hour cycle each week for 10 months (March 1987 to January 1988). Expected values for habitat use by each elk were calculated using proportions of habitat variables within the area described by a 95% confidence ellipse for each elk. Elk used grasslands, south aspects, and upper elevations more than expected ($P < 0.05$). Old-growth redwood (*Sequoia sempervirens*)/ Douglas-fir (*Pseudotsuga menziesii*), second-growth redwood/Douglas fir, and old second-growth redwood/Douglas fir stands were used less than or equal to expected ($P < 0.05$).

In the Bald Hills of Redwood National Park (RNP), Roosevelt elk numbers may be increasing. Historically, elk were reported to number in the thousand's in the Bald Hills (Wistar 1937); however, Mandel (1979) reported very few elk in 1978. In 1987 we counted 60 elk during one survey. Timber harvesting and livestock grazing ceased on these lands in 1980 and these changes may have affected elk numbers.

Elk habitat use and distribution patterns may also be influenced by changes in vegetation types in and adjacent to RNP. Historical land use practices such as livestock grazing, timber harvesting, fire suppression, and introduction of exotic plant species have altered vegetation types in the Bald Hills (Sugihara and Reed 1987). Fire suppression resulted in a 10 - 20% reduction of prairies and oak woodlands (Sugihara and Reed 1987). Clearcuts have reduced the old-growth forest in the Bald Hills by 65%; however, clearcuts will become closed-canopy forests in 20 - 50 years (Hall et al. 1985). Lastly, timber harvesting and livestock grazing continue to alter habitats adjacent to RNP.

Redwood National Park seeks to restore and maintain natural resources in the park as if they had not been altered by human technology (USDI 1980). A goal of RNP managers has been to manage the elk population in equilibrium with available resources. An understanding of how elk use habitats facilitates predicting how elk may respond to changes in habitats. Identification of areas frequently used by elk will allow managers to monitor changes in habitat quality. Our objective was to assess whether elk used habitat in proportion to availability, and if not, to identify which habitat types were used more than, equal to, or less than expected.

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STUDY AREA

Redwood National Park is located along the north coast of California in Humboldt and Del Norte counties. The Bald Hills study area of RNP is located 12 km east of Orick, California, within the Redwood Creek watershed. In the Bald Hills, temperatures can range from -5 to 35 C. Fog and low clouds were frequent in summer. Annual rainfall in the Bald Hills averages between 178 - 203 cm (Coghlan 1984) with 90% falling between October and May (Sugihara and Reed 1987).

The Bald Hills is approximately 11.2 km long and ranges in width from 2.4 - 3.2 km. The area consists of numerous ridges, drainages, and earth flows. The Bald Hills has a predominantly southwest facing aspect and slopes average 35% from ridge top (815 m above sea level) to creek bottom (46 m above sea level). Finger-like projections of prairies (grasslands) extend from ridgetops down toward Redwood Creek amongst a mixture of oak-woodlands, old-growth redwood/Douglas-fir and tree and/or shrub-dominated second-growth (see Grenier 1991 for a description of vegetation types).

MATERIALS AND METHODS

Elk Capture and Radio-Collaring

Wooden corral traps baited with alfalfa (Harper 1985) were used to capture elk. Elk were anesthetized with a combination of ketamine hydrochloride and xylazine with yohimbine used as a reversal agent (Golightly and Hofstra 1989). Captured elk were equipped with radio-collars which had motion sensors (Model 600, Telonics Inc., Mesa, Ariz.). A radio receiver and digital signal-processor (TR-2 receiver with Model TS-1 scanner/programmer, and TDP-2 Digital Data Processor, Telonics Inc., Mesa, Ariz., U.S.A.) with a two element yagi antenna were used to locate instrumented elk.

Radio-Telemetry

A systematic procedure was used to help increase efficiency and accuracy while locating radio-collared elk. The strongest signal method (Springer 1979) was used to determine bearings on instrumented elk. A minimum of three compass bearings recorded from known locations, which intersected at one point, were used to determine an elk's location.

Radio-Telemetry Error.--Radio telemetry has a number of error sources (Heezen and Tester 1967, Springer 1979). To estimate error associated with radio telemetry locations, triangulation was conducted at various times, under different weather conditions on radio transmitters placed in locations of various distances, topographies, and vegetation types. Triangulation error was the estimated distance between actual location and telemetry determined location.

Elk Monitoring.--Each week, 6 elk were randomly selected; 3 were monitored during each of 2, 24-hour cycles. Selected elk were systematically located 4 times (once every 6 hours) during a 24-hour cycle. Each 24-hour cycle was separated by a minimum of 48 hours. Females were monitored each week and males were monitored once every 2 weeks (except for 1 bull that was monitored once each week from March - June).

Habitat Use Analysis

Habitat Variables.--Four categories for slope were used: 0 - 15%, 16 - 29%, 30 - 59%, and 60 - 120%. Categories for aspect were of unequal size because SAGIS used 15° intervals (midpoints were 0°, 15°, 30°, ...,). Hence, north and south each encompassed 104° and east and west encompassed 76°. Aspect categories were defined as: North (308 - 52°), East (53 - 128°), South (129 - 232°), and West (233 - 307°).

Elevation was divided into 5 categories. Each was 154.5 m except the highest category which was 149 m. Categories were: 46 - 200.5 m, 201 - 355.5 m, 356 - 510.5 m, 511 - 665.5 m, and 666 - 815 m.

Six vegetation types were determined from aerial photographs (1:6000), ground surveys, and vegetation maps (USDI 1985, Sugihara and Reed 1987). Vegetation types were: old-growth redwood/Douglas-fir, prairie, Douglas-fir, second-growth redwood/Douglas-fir with south-west aspect (10 - 20 years post harvest), second-growth redwood/Douglas-fir with north-east aspect (10 - 20 years post harvest), and older second-growth redwood/Douglas-fir (20 - 80 years post harvest).

Observed Values.--Locations of each elk (using radio-telemetry or visual observations) defined observed use. Observed use of slope, aspect, and elevation was measured from elk locations plotted on mylar, overlaid on 7.5 minute, 1:24,000 USGS orthophotographic and topographic maps.

Expected Use.--The 95% confidence ellipse was used to delineate and define available habitat. A 95% confidence ellipse was constructed for each elk (using the program by Stuwe and Blohowiak 1985) using all locations of each elk, regardless of season. Proportions of each habitat variable within the 95% confidence ellipse (Koeppl et al. 1975) of each elk were used to generate expected values for each elk.

The proportion of each habitat type within each elk's 95% confidence ellipse was calculated using SAGIS. The geographic information system used vegetation types that were digitized from 1:24,000 vegetation maps (USDI 1985, Sugihara and Reed 1987). Slope, aspect, and elevation were digitized from 1:24,000 Digital Elevation Models (provided by USGS, Reston, VA).

Analysis.--Habitat use was estimated for individual elk. To determine if observed use was significantly different ($P < 0.05$) from expected use, the observed number of locations were compared to the known proportions of habitat (expected values; Neu et al. 1974) using a chi-square goodness-of-fit test (Zar 1984), which was consistent with recommendations by Thomas and Taylor (1990). The Bonferroni Z-statistic (Neu et al. 1974, Byers et al. 1984) was used to test whether observed use of habitat categories was significantly ($P < 0.05$) less than or greater than expected.

RESULTS

Trapping Success

Twenty-two elk were captured during 805 trap nights between April 1986 and September 1987. Ten elk with radio-collars were used for this study (5 adult cows, 1 yearling cow, 3 adult bulls, and 1 yearling bull). Four of 10 elk were monitored from initiation of data collection (3 March 1987), and 6 additional elk were captured during the following 7 months and then monitored. During the study, 2 radio-collared elk were illegally killed and radio-signals were not received from 2 other radio-collars. Thus, number of locations and time of year of monitoring each elk were dissimilar (Table 1).

Radio-Telemetry

Mean error between the actual and estimated location using radio-telemetry triangulation was ±104.3 m (SE = 11.1, $n = 22$). This mean error may be an underestimate because some locations of test collars were known to the observer (Mills and Knowlton 1989).

From March 1987 to January 1988 elk were monitored during 80, 24-hour cycles. Locations were determined using radio telemetry and visual observation, 85% and 15% of the time respectively. Number of locations per elk ranged from 34 to 170 ($n = 923$; Table 1).

Habitat Use

Sizes of areas available to elk (determined using the 95% confidence ellipse) ranged from 14.1 to 25.8 km^2 for females ($n = 6$) and from 8.4 to 31.0 km^2 for males ($n = 4$) (Table 1).

Five of 10 elk used slope significantly different than expected ($P < 0.05$, chi-square goodness-of-fit test; Table

Table 1. Sizes of available areas used to estimate habitat use by Roosevelt elk in the Bald Hills of Redwood National Park, California 1987-88. Available area was calculated using the 95% confidence ellipse (Stuwe and Blohowiak 1985).

Elk		Dates	n[a]	24-hr	Available area
#	Sex	monitored		cycles[b]	(km^2)
01	M	March 87 - Aug 87	66	17	8.4
02	F	March 87 - Jan 88	167	42	22.3
03	F	March 87 - Jan 88	169	43	18.6
04	F	March 87 - Jan 88	170	43	25.8
05	M	Apr 87 - Oct 87	64	16	24.1
06	M	Apr 87 - Jan 88	70	18	31.0
07	F	May 87 - Jan 88	96	24	14.1
08	M	May 87 - Aug 87	47	12	14.5
09	F	June 87 - Sept 88	34	8	15.5
10	F	Sept 87 - Dec 87	41	11	17.8

[a] Number of locations used to calculate available area.

[b] Numbers in this category refer to the number of times an elk was located 4 times (once every 6 hours) in 24-hours.

2), but no particular category of slope was used more or less than expected ($P < 0.05$, Bonferroni Z-statistic; Table 3). Seven of 10 elk used aspect significantly different than expected ($P < 0.05$, chi-square goodness-of-fit test; Table 2). Six of 10 elk used south aspects greater than expected ($P < 0.05$, Bonferroni Z-statistic; Table 3). Seven of 10 elk used elevation significantly different than expected ($\underline{P} < 0.05$, chi-square goodness-of-fit test; Table 2). Elk appeared to use higher elevations (356-810 m) only slightly more than lower elevations ($P < 0.05$, Bonferroni Z-statistic; Table 3). Eight of 10 elk used vegetation types significantly different than expected ($P < 0.05$, chi-square goodness-of-fit test). Six of nine elk used old growth less than expected ($P < 0.05$, Bonferroni Z-statistic; Table 3). No elk used any second-growth stands greater than expected ($P < 0.05$). Six of 10 elk used prairie greater than expected ($P < 0.05$; Table 3)

For all elk, old growth averaged 18.8% of available area, and contained 13.1% of the locations; prairies averaged 14.7% of available area with 38.3% of the locations; Douglas-fir averaged 6.6% of available area with 12.3% of the locations; second growth (SW-aspect) averaged 41.8% of the available area with 30.4% of the locations; second growth (NE-aspect) averaged 12.1% of the available area with 5.6% of the locations; and second growth (old) averaged 9.1% available area with 1.8% of the locations (Grenier 1990).

DISCUSSION

Roosevelt elk inhabit temperate coniferous rain forests along the Pacific coast between northern California and Vancouver Island, British Columbia (see Bryant and Maser 1982). Investigators of food habits (Leslie et al. 1984) and habitat use reported Roosevelt elk used old-growth forests (Graf 1955, Harper 1971, Jenkins 1980, Janz 1980, and Witmer 1982). In addition, Jenkins (1980) and Schroer (1986) reported Roosevelt elk used semi-open forests with patches of meadows or seral plant communities of deciduous trees and shrubs with grass/forb ground cover.

However, we found Roosevelt elk used old growth less than expected ($P < 0.05$). Roosevelt elk in our study used prairies more than expected and associated Douglas-fir stands equal to expected ($P < 0.05$). Roosevelt elk use of prairie is consistent with investigations of Roosevelt elk ruminoreticular characteristics (Church and Hines 1978), food habits (Harper 1961), and habitat use (Harper et al. 1967, Mandel 1979, McCoy 1986, and Schroer 1986). Also, historical range of Roosevelt elk in northern California was from the coast inland to Mount Shasta (Murie 1951, Harper et al. 1967) where numerous prairies (grasslands) occur throughout (see Barbour and Major 1977).

Lack of use of prairies by Roosevelt elk in other studies may have resulted from lack of prairie availability or small size. Lack of use of old growth in our study may indicate prairie and associated Douglas-fir stands supply sufficient forage and cover.

Use of second growth (sapling-pole stands greater than 10 - 15 years post harvest) by Roosevelt elk was reported to be less than or equal to expected (Harper 1971, Witmer 1982); we also found elk used second growth less than or equal to expected, except during the rut (Grenier 1990). Lack of use of second growth may be related to insufficient forage (Witmer 1982, Hall et al. 1985).

Table 2. Chi-square goodness-of-fit test results (X^2) for Roosevelt elk use of habitat variables in the Bald Hills of Redwood National Park, California, 1987-1988.

Habitat Variable							
#	Age	Sex	n[a]	Vegetation Type[b] X^2 (df)	Slope[c] X^2 (df)	Aspect[d] X^2 (df)	Elevation[e] X^2 (df)
1	Ad	M	66	2.8 (3) $0.25<P<0.50$	1.4 (1) $0.10<P<0.25$	5.6 (2) $0.05<P<0.10$	7.4 (3) $0.05<P<0.10$
2	Ad	F	167	237.1 (5) $P<0.001$	16.0 (2) $P<0.001$	45.8 (3) $P<0.001$	40.5 (3) $P<0.001$
3	Ad	F	169	209.6 (5) $P<0.001$	11.1 (2) $0.001<P<0.005$	47.4 (3) $P<0.001$	42.4 (3) $P<0.001$
4	Ad	F	170	238.7 (5) $P<0.001$	11.7 (2) $0.001<P<0.005$	84.4 (3) $P<0.001$	30.3 (4) $P<0.001$
5	Ad	M	64	17.7 (5) $0.001<P<0.005$	0.5 (1) $0.25<P<0.50$	8.4 (2) $0.01<P<0.025$	3.6 (3) $0.25<P<0.50$
6	Yr	M	70	140.4 (5) $P<0.001$	0.9 (1) $0.25<P<0.50$	27.6 (3) $P<0.001$	19.7 (4) $P<0.001$
7	Yr	F	96	90.3 (5) $P<0.001$	4.1 (2) $0.10<P<0.25$	11.4 (2) $0.001<P<0.005$	12.3 (3) $0.005<P<0.01$
8	Ad	M	47	4.7 (5) $0.25<P<0.50$	6.1 (1) $0.01<P<0.025$	1.6 (2) $0.25<P<0.50$	23.5 (4) $P<0.001$
9	Ad	F	34	20.9 (4) $P<0.001$	2.0 (1) $0.10<P<0.25$	12.7 (2) $0.001<P<0.005$	31.7 (3) $P<0.001$
10	Ad	F	41	37.7 (5) $P<0.001$	7.9 (1) $0.001<P<0.005$	6.0 (3) $0.10<P<0.25$	5.7 (2) $0.05<P<0.10$

[a] Number of locations (radio telemetry or visual).

[b] Vegetation types included: prairie, old-growth redwood/Douglas fir, Douglas fir, young second-growth redwood Douglas fir (S-W aspect), young second-growth redwood/Douglas fir (N-E aspect), and older second- growth redwood/Douglas fir (closed canopy).

[c] Slope categories included: 0 - 15%, 16 - 28%, 29 - 59%, and 60 - 120%.

[d] Aspect categories included: North (308 - 52°), East (53 - 128°), South (129 - 232°), and West (233 - 307°).

[e] Elevation categories included: 46 - 200.5 m, 201 - 355.5 m, 356 - 510.5 m, 511 - 665.5 m, and 666 - 815.5 m.

Elk use of south aspect was consistent with results of other studies (Jenkins 1980, Witmer 1982) and probably related to aspect of prairies. Elevation used by elk coincided with the elevation of prairies (360 - 815 m).

MANAGEMENT IMPLICATIONS

Prairies are an important component of elk habitat in the Bald Hills of RNP. However, prairies are being lost to exotic plant species invasion and Douglas-fir encroachment (Hektner et al. 1983, Sugihara and Reed 1987, Grenier 1989). It is not known how changes in species composition will affect elk use of prairies though we anticipate changes in prairies will impact the elk of RNP.

We also found old second-growth (20 + years post harvest) was used by elk less than expected. Young second-growth (10 - 20 years post harvest) will become similar to old second-growth of today in 10 - 20 years and represent 65% of the available habitat in the Bald Hills. The reduction of available habitat in the park may result

Table 3. Use of habitat variables compared to expected use by individual Roosevelt elk ($\underline{n}$ = 10) in the Bald Hills of Redwood National Park, California, 1987-88. Numbers represent numbers of individual elk.

Habitat category	Number of radio collared elk[a] Use compared to expected[b]		
	Less than	Equal to	Greater than
Slope (%)			
0 - 15	3	1	
16 - 29	2	6	2
30 - 59	1	7	2
Aspect			
North	5	2	
East	3	3	
South		4	6
West	1	8	1
Elevation (m)			
46 - 200	2	1	1
201 - 355	4	5	
356 - 510	2	7	1
511 - 665		6	4
666 - 815	1	7	
Vegetation type			
Prairie		4	6
Douglas fir	7	3	
Old growth	6	2	1
2nd growth (SW-aspect)	5	5	
2nd growth (NE-aspect)	5	3	
2nd growth (old)	5		

[a] Numbers of elk do not always total 10 because some habitat variables were not within the 95% confidence ellipse of some elk.

[b] Expected values were calculated using proportions of habitat variables within a 95% confidence ellipse for each elk. Chi-square goodness-of-fit test and Bonferroni *Z*-statistic (Byers et al. 1984) were used to test significant differences ($P < 0.05$) between observed and expected use of each habitat variable for each elk.

in increased elk use of adjacent lands, "overuse" of prairies and other resources, or changes in numbers of elk within the park. Therefore, we recommend continued monitoring of elk habitat use and restoration of native vegetation in prairies.

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NUTRITIONAL QUALITY AND TANNIN ASTRINGENCY OF BROWSE IN CLEAR-CUTS AND OLD-GROWTH FORESTS

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Recent research in the Pacific Northwest has lead to the belief that forage quality may be limiting ungulate populations. We compared nutritional quality and morphology of 4 browse forages of Roosevelt elk (*Cervus elaphus roosevelti*) and black-tailed deer (*Odocoileus hemionus columbianus*) in clear-cuts and old-growth forests to evaluate the effects of overstory removal on browse nutritional quality.

The study was conducted in the Hoh River Valley, Olympic Peninsula, Washington. Browse current annual growth was collected in 4 old-growth stands located within Olympic National Park, and 4, 5-15-year-old clear-cuts located on lands managed by the Washington Department of Natural Resources. All collection sites were on alluvial terraces along the Hoh River that were at least 400 years old. Browse species examined included vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), red huckleberry (*Vaccinium parvifolium*), and swordfern (*Polystichum munitum*). Browse was collected in July and October 1985 and January and April 1986. Nutritional and morphological attributes examined included: leaf:stem ratio, percent dry matter, fiber (cell wall constituents and lignin), in vitro digestibility, crude protein, and tannin astringency. Regression equations of Robbins et al. (1987) were used to predict the effect of astringent tannins on digestible protein.

Browse in old-growth forests had significantly greater proportion of leaves, was more succulent, and had higher percent crude protein than browse in clear-cuts. This trend was consistent for all 4 species during July, October, and January. Shrub leaves had greater proportions of cell wall constituents in old-growth than in clear-cuts in July, but shrub stems were was either higher in fiber in clear-cuts than in old-growth, or there was no difference between sites. Swordfern fiber was greater in old-growth than in clear-cuts in July, October, and January. There was no consistent pattern of difference in digestibility between forest types. Astringent tannins were present in all 4 species. Tannin astringency was greater in clear-cuts than in old growth. Because tannins decrease digestible protein (Robbins et al. 1987), digestible protein was more available in shrubs grown in old-growth than in clear-cuts; little digestible protein was available to cervids browsing in clear-cuts.

Because we did not measure forage quality of forbs and grasses, or measure biomass availability, we can not assess the nutritional adequacy of clear-cuts and old-growth overall. However browse is a major component of elk and deer diets in the Pacific Northwest, and is considered a valuable source of dietary protein. Because there appears to be a great difference in digestible protein in browse grown in these two stand types, it appears that retention of patches of old growth in the Pacific Northwest will provide optimum year-round habitat for cervid foraging.

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ELK WINTER HABITAT SELECTION AS INFLUENCED BY WINTER CONDITIONS

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Despite much research conducted on selection and use of habitat by elk, few studies have concentrated on winter habitat. Yet winter habitat may be the most limiting factor to elk productivity and survival (Skovlin 1982). The majority of winter elk studies have focused on food habits and forage utilization or seasonal movements and migrations. This study was an attempt to identify specific timber stand structures used by elk under various forms of winter stress.

We would like to thank the Montana Department of Fish, Wildlife and Parks for allowing us to monitor elk they radio-marked for other research. This project was supported by the Forest and Conservation Experiment Station, University of Montana, and the Intermountain Research Station of the U.S. Forest Service, Missoula.

STUDY AREA

The winter ranges investigated in this study are in southwest Sanders and northwest Mineral Counties, between St. Regis and Thompson Falls, in northwestern Montana. Mean temperatures range from -8 C (19 F) in January to 31 C (87 F) in July (U.S. Dept. of Commerce 1982). Mean annual precipitation is 58 cm (22.8 in.) (U.S. Dept. of Commerce 1982). Most precipitation occurs in winter as rain or snow at low elevations and snow at high elevations.

Vegetation

Habitat types (Pfister et al. 1977) are within the Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and sub-alpine fir (*Abies lasiocarpa*) series. Winter ranges are mostly forested with Douglas-fir, or Douglas-fir and western larch (*Larix occidentalis*) stands. Ponderosa pine (*Pinus ponderosa*) is a common co-dominant on drier sites.

METHODS

Habitat Description

On each of three winter ranges, timber stands were delineated on aerial photos and a portion of the stands were sampled on the ground. Stand delineations completed by local districts of the U.S. Forest Service were used when available. At each of five random plots per stand, the following parameters were measured:

Basal Area
Tree Density
Mean Tree Diameter
Shrub Density
Ground Cover (percent)
Ground Cover (relative composition)
Dead and Down Obstruction
Hiding Cover-calculated using HIDE2 (Lyon 1987)
Slope
Aspect
Elevation
Habitat Type

Extrapolations from sampled to unsampled stands were made based on their appearance on aerial photos.

Elk Locations

Elk fitted with PVC-encased 150-151 MHz transmitters by personnel of the Montana Department of Fish, Wildlife, and Parks were available for use in this study. Elk were located from the ground throughout the three winters of study. Error arcs and polygons for triangulated elk locations were determined as described by Springer (1979). Snow depth and crust hardness, precipitation, cloud cover, and wind velocity were measured at all elk locations. Both low and high temperatures, wind velocity, cloud cover, and precipitation were recorded daily at Plains, MT.

Data Analysis

Evaluation of habitats associated with elk locations included the area within a 40-ha (100-acre) circular habitat unit centered on each location (Servheen and Lyon 1989). ARC-INFO (ESRI 1987), a Geographic Information System (GIS), was used to create digitized stand maps. MAYA (Glassy and Lyon 1989), was used to compile habitat information and associate this information with elk locations plotted on the digitized habitat maps.

Analysis of the 40 ha (100 ac.) habitat units was accomplished using a stepwise discriminant function analysis (DFA). Habitat variables were used to discriminate between elk locations taken under differing environmental conditions.

RESULTS

Elk Locations

During the three winters of study, 471 elk locations were obtained. All locations were acquired between 2 December and 11 March. Error polygons for a random sample (n = 36) of triangulated elk locations averaged 7.8 ha (19.4 ac.) (SD=5.6 ha or 13.8 ac.).

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[1] Present address: P.O. Box 6249, Sheridan, WY 82801

Weather

Weather during the three winters of study was mild, with temperatures seldom falling below -18 C (0 F). However, a severe blizzard early in February 1989 caused the average high and low temperatures for that month to be 14 C (25 F) lower than historic means. Snow depths on the winter ranges for the study period were moderate, seldom exceeding 30 cm (12 in.) on middle and lower slopes.

Discriminant Analysis

Twelve variables measuring weather conditions associated with elk locations were used as grouping variables for DFA. The discriminating variables entered into analysis were those associated with the habitat surrounding winter elk locations, including variables that described features of timber stand structure: basal area, tree density, average tree diameter, hiding cover, dead and down tree obstruction, and ground cover.

DFA was used to identify variables that distinguish habitats used under different winter conditions. Three variables, wind, precipitation, and current precipitation, were removed from analysis due to small sample size. Correct classification of remaining variables from the DFA was poor, ranging from 47% to 67%.

Description of Elk Locations

Summary statistics for the habitats surrounding winter elk locations were calculated (Table 1). These data do not represent habitat selection, because they were not compared to unused areas. These summary statistics reflect the habitats where elk were found throughout the winters of study, and may be of interest to local managers.

Basal areas between 2.3-34.4 m^2/ha (10-150 ft^2/ac.) comprised the greatest portions of the 40 ha (100 ac.) plots surrounding winter elk locations. Timber stands with tree densities between 124-617 trees/ha (50-250 trees/ac.) made up most of the plots surrounding the elk locations. Tree diameters from 15.2-30.5 cm (6-12 in.) were the most common at elk locations, although all classes were well represented.

Hiding cover values for timber stands were calculated using HIDE2 (Lyon 1987). Stands offering 0 to 50% hiding cover comprised most of an average 40 ha (100 ac.) plot surrounding winter elk locations. Thick dead and down material (where one must "struggle" to travel) was the only class that was uncommon within the elk location plots. The higher vegetative ground cover classes occupied the greatest proportion of an average 40 ha (100 ac.).

Elk Movements

During all three winters of study, some elk were observed to spend a portion of each winter on the north side of Boyd Mountain. Snow depths at elk locations on this north aspect were often in excess of 61 cm (24 in.). Browse lines on the arboreal lichen (*Alectoria* spp.) were evident, as were feeding craters around beargrass (*Xerophyllum tenax*) plants. Other foods, i.e. browse species, were uncommon on this aspect.

Table 1. Stand structure variables and the mean proportion of a 40 ha (100 ac.) plot that each structure class occupies. Plots were centered on winter elk locations.

Class	Description	% of plot
<u>Basal Area</u>		
BA1	< 2.3 m^2/ha (10 ft^2/ac.)	17%
BA2	2.3-17.2 m^2/ha (10-75 ft^2/ac.)	31%
BA3	17.2-34.4 m^2/ha (75-150 ft^2/ac.)	44%
BA4	34.4-45.9 m^2/ha (150-200 ft^2/ac.)	6%
BA5	>45.9 m^2/ha (200 ft^2/ac.)	2%
<u>Stand Density</u>		
DE1	< 124 trees/ha (50 trees/ac.)	17%
DE2	124-617 trees/ha (50-250 trees/ac.)	62%
DE3	617-1,235 trees/ha (250-500 trees/ac.)	13%
DE4	1,235-2,469 trees/ha (500-1,000 trees/ac.)	6%
DE5	> 2,469 trees/ha (1,000 trees/ac.)	1%
<u>Stand Diameter</u>		
DI1	< 7.6 cm (3 in.)	12%
DI2	7.6-15.2 cm (3-6 in.)	8%
DI3	15.2-22.9 cm (6-9 in.)	30%
DI4	22.9-30.5 cm (9-12 in.)	32%
DI5	> 30.5 cm (12 in.)	18%
<u>Hiding Cover</u>		
HI1	< 10%	54%
HI2	10-25%	36%
HI3	25-50%	36%
HI4	50-75%	2%
HI5	> 75%	6%

Elk use of this north aspect did not last the entire winter. By midwinter, the snow pack developed a crust resulting from a thaw, and the elk moved to the south side of Boyd Mountain, where shallow snow depths were available throughout all winters of study.

DISCUSSION

Changes in elk habitat selection resulting from varying winter conditions were not observed in this study. The results of DFA produced poor classification rates, ranging from 47 to 67%. Timber stand characteristics at elk locations were poor predictors of winter conditions at the time of the locations.

Three possibilities may explain why no differences in elk habitat selection were observed in this study: 1) Winter conditions during the study period were not severe enough to cause shelter seeking; 2) Habitat selection may have been on a scale too fine to be detected by this study design; 3) Elk do not seek specific habitat structures to ameliorate winter weather conditions.

Mild Winters

Weather encountered during the three winters of study was mild. Temperatures rarely fell below -18 C (0 F) and snow depths across the winter ranges were relatively shallow. Because of the infrequency of high winds and the numerous shelters from wind in the steep, timbered terrain, wind is probably not an important factor in habitat selection by elk in this area. Snow crust hardness likely did not play a large role in elk habitat selection because so much area with shallow snow depths was available.

Scale of Habitat Selection

Elk may have selected specific habitat structures to ameliorate winter conditions during the study period, but on a scale too fine to be detected by this study. Timber stands, treated as units of habitat homogeneity, do exhibit variability. Elk use of "micro-sites" within defined timber stands may not have been detected by this study design.

Lack of a Winter Weather Response

Another possibility is that elk do not seek specific habitat structures to ameliorate winter conditions, but we consider this unlikely. Throughout the winters of study, elk were associated with timbered habitats. Large open drainages, even with abundant forage, were mostly avoided by elk. Leckenby (1984) reported that elk on Blue Mountain winter ranges preferred to forage in areas with at least some cover.

Elk Movements

On the Boyd Mountain winter range near St. Regis, groups of elk used the north aspect for portions of all three winters of study. These elk were found in snow depths up to 61 cm (24 in.) even though shallower snow was readily accessible. Elk use of areas not considered winter range by managers could be significant. Management actions on these sites could effect the level of use on the identified winter ranges. Actions which could effect arboreal lichen abundance or availability, possibly an important food for elk on these north slopes, should be considered as well.

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RELATING TIMBER MANAGEMENT TO COVER FOR BIG GAME ON INTERIOR NORTHWEST WINTER RANGE: SOME THOUGHTS ON REDUCING CONFLICT

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract:: Forest management plans constrain timber production to provide winter cover for big game. Constraints are based on preference data that are inferred to suggest big game derive significant energetic benefits from successionally advanced timber stands. Algorithms for predicting thermal stasis based on energy balance equations (i.e., conduction + convection + metabolism) suggest that active management of forest canopies may result in: (1) heat loss through convection; (2) decreased radiated long wave energy; and (3) enhanced forage resources, increasing metabolic heat production. Potential exists to compensate for effects of stand management on energy losses by combining understory and other forage enhancements with implementation of uneven-aged silvicultural principles. Potential benefit of forage enhancement varies with snow depth and re-distribution in managed versus adjacent unmanaged stands. The potential energetic impacts of stand management should be viewed in the context of a winter range's geoclimatic regime. Cover management plans should compare silvicultural options based on long-term sustainability. New research can clarify ungulate/forestry relations on interior northwest winter ranges, and increase options available to managers concerned with integrating timber- and cover-management goals.

Of the 3 primary factors involved in assessing habitat quality for big game (i.e., cover, forage, and disturbance), the most controversial is certainly cover. The hypothesis that some big game require coniferous forest cover, for reasons in addition to its escape value (Black et al. 1976), appears commonly accepted by biologists (Thomas et al. 1979, Thomas et al. 1988), forest planners (Edge et al. 1990), and sportsmen (Lyon 1990). Acceptance has occurred despite a lack of consensus among scientists (e.g., Peek et al. 1982, Geist 1982, Bunnell et al. 1986, Thomas et al. 1988, Edge et al. 1990).

Differences of opinion regarding the importance of cover have drawn wide attention because of the fact that cover management can affect commodity production substantially. Timber sales by National Forests in northeastern Oregon, for example, will decline as a direct consequence of cover-management goals (USFS 1987; State of Oregon 1990). Meanwhile, the perceived need for cover management has been questioned, based on data indicating that elk (*Cervus canadensis*) apparently are not dependent on coniferous cover as long as forage resources are adequate and disturbance is not excessive (McCorquodale et al. 1986,1988; Merrill et al. 1987).

Thus the economic and biological consequences of cover-related management restrictions will continue to be challenged. Wildlife biologists and foresters must clarify ungulate/cover relationships, and how these vary with timber stand structure and management. This paper addresses cover management in the context of winter range, with an emphasis on elk in the interior zone of the Pacific Northwest. We review current concepts and their relation to timber management, and present our view of how research and management can be linked to reduce controversy and enhance management effectiveness.

ASKING APPROPRIATE QUESTIONS

The current confusion involving timber production and cover management appears to revolve around perceptions of the relative value of different cover classes and relationship of these to timber management. The cover classes are "satisfactory thermal cover" and "marginal thermal cover" as defined by Thomas et al. (1988), which differ in their structural characteristics: satisfactory cover consists of trees ≥ 12 m tall, with ≥ 70% canopy closure and with a multi-storied structure, while marginal cover consists of trees ≥ 3 m tall with ≥ 40% canopy closure. In building a model of habitat effectiveness, Thomas et al. (1988) weighted these cover classes differently based on apparent preferences of elk, thus setting the stage for timber management restrictions based on the potential for various silvicultural practices to change the cover classification of timber stands. Meanwhile, Smith and Long (1987) analyzed the potential for conflict between timber- and cover-management goals, and found that even slight adjustments in the definitions could substantially alter the latitude for silvicultural management of lodgepole pine. Assuming that their findings are applicable to a broader range of timber types, it is appropriate to ask, do the current cover definitions indeed represent conditions corresponding to critical thresholds in the energy balance of wintering ungulates? Because the distinction between the 2 cover types is based on perceived preferences, rather than demonstrated bioenergetic differences (Thomas et al. 1988), a second question is, can preference data be expected to provide reliable knowledge of habitat requirements? Finally, because any cover classification can have long-term impacts on timber management, and because regimes advocated on behalf of elk should be integrated with sustainable silvicultural systems, we ask, how can we maximize habitat value of timber stands without compromising silvicultural objectives?

CONIFER COVER AND WINTER ENERGY BALANCE

Thermal cover may mediate climatic conditions sufficiently to reduce energy loss during winter, thereby enhancing winter survival and subsequent reproduction. This hypothesis is a central tenet underlying forest-management guidelines on winter ranges, has not been tested thoroughly, but was rejected in limited studies (Robinson 1960, Gilbert and Bateman 1983, Freddy 1985, 1986,). In this segment, we review evidence regarding the relationships between thermal cover and energy balance, and assess the potential of forest management to influence these relationships.

Temperate-latitude ruminants rely on various physical and physiological adaptations that facilitate concomitant tolerance to extreme cold and widely fluctuating temperatures [i.e., a relatively cold lower critical temperature (LCT) and wide thermoneutral zone TNZ)[1]]. Estimates of LCT average about -20 C to -30 C for deer (*Odocoileus* spp.) and bighorn sheep (*Ovis canadensis*) (Stevens 1972, Chappel and Hudson 1978, Parker and Robbins 1984, Mautz et al. 1985), below -30 C for moose (*Alces alces*) (Renecker and Hudson 1986), and -20 C for elk calves (Parker and Robbins 1984). We are unaware of published LCT estimates for adult elk. Long, dense pelage that is highly resistant to heat loss (Scholander et al. 1950a,b, Jacobsen 1980); autonomic regulation of vascular circulation in extremities and other tissues (Crawshaw 1980, Parker and Robbins 1984, Parker and Gillingham 1990); seasonally reduced metabolism, activity, and energy requirements; and increased reliance on endogenous energy (Silver et al. 1971, McMillin et al. 1980) facilitate tolerance to occasionally severe and variable winter climatic conditions.

Selection of thermal cover by ungulates may augment their physical/physiological adaptations and essentially extend the LCT to colder temperatures. However, the degree to which such selection actually influences the performance of big game herds depends upon the degree to which 2 primary assumptions are satisfied: (1) forest cover sufficiently moderates climatic conditions to reduce over-winter mortality or enhance subsequent reproduction; and (2) weather conditions that are severe enough to stress big game (i.e., increase metabolic demand) occur at a frequency and/or duration sufficient to affect mortality and reproduction.

Forests influence thermal balance by: (1) reducing windspeed, (2) radiating energy in the long-wave spectrum, (3) blocking solar radiation, (4) ameliorating ambient temperatures, (5) influencing forage production and availability, (6) intercepting rain, and (7) mediating snow accumulation and melt (Reifsnyder and Lull 1965, Nyberg et al. 1986). The relative importance of most of these effects can be highly dependent upon season, prevailing climatic conditions, and topography. We restrict our discussion to cold winter conditions when big game are most susceptible to energy stress.

Forced convection (Appendix 1) likely represents the greatest potential mode of heat loss for ungulates and may be the one most affected by forest management. Moen (1968c) calculated that convective loss accounted for about 33% of total heat loss under windless conditions, and 65% of total loss at wind speeds of about 6 m/s, assuming a deer standing in unobstructed winds. Parker and Gillingham (1990) calculated wind at 11.2 m/s would reduce standard operative temperature (Appendix 1) to -73 C when ambient temperature is -25 C. Chappel and Hudson (1978) observed that metabolic rates of bighorn sheep increased 40% when subjected to windspeeds of 8 m/s compared to no-wind conditions, but increases were observed only at ambient temperatures near LCT. Blaxter et al. (1963) found heat production of steers increased 6% with increases in wind from 0.2 m/s to 0.8 m/s, and heat production of domestic sheep with 50 mm fleeces rose 25% when wind increased from 0 to 4.3 m/s. Like Chappel and Hudson (1978), Blaxter et al. (1963) reported the metabolic effects of wind were most pronounced when ambient temperatures approached LCT; thus wind may be of reduced importance when temperatures are within the TNZ.

Effects of forest canopy on wind have been quantified infrequently. Bunnell et al. (1986) and Grace and Easterbee (1979) indicated forest canopies may reduce windspeeds by as much as 85% compared to more open areas. But ridges, gullies, shrubs, rock outcrops, and other obstructions moderate forced convective heat losses as well (Moen 1968a, Grace and Easterbee 1979, Parker and Gillingham 1990). Grace and Easterbee (1979) reported windspeed was reduced about 50% on lee slopes and 92% in gullies. At deer height, windspeed over vegetation averaging 1 m high was 50% of windspeeds over vegetation 0.1 m in height. Moreover, windspeed increases exponentially as a function of vertical distance from the ground; at 0.1 m, wind movement is minimal, regardless of prevailing wind

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[1] See appendix 1 for review of basic thermodynamic concepts including energy balance, standard operative temperature, and the thermoneutral zone.

conditions (Campbell 1977). Thus, elk have considerable options for avoiding wind when it can be an important influence on energy balance. Similarly, pronghorn antelope (*Antilocapra americana*) and bighorn sheep, which avoid forested communities, rely on topographic irregularities to moderate severe winter winds (Ryder and Irwin 1987, Cook 1990).

Although forest overstory and understory density are inversely correlated with wind speed, it is largely unknown how changes in forest height, canopy, composition, understory vegetation, and topography interact to affect windspeed. Without such data, it is unwise to predict how wind-related energy losses are mediated by timber stand structure and management. These relationships should be quantified given the potential effects of wind, the hypothesized value of cover, and the potential for cover management to affect commodity production.

In addition to wind, forest canopies also influence radiation balance. Dense forests can block 80% of incoming solar radiation (Bunnell et al. 1986), thereby reducing an important source of heat. For example, Parker and Gillingham (1990) calculated that sunlight could increase standard operative temperature 30 C above ambient temperature. Absorption of solar radiation by elk during the day might increase cold-tolerance at night. Thus, creating openings of sufficient size to permit sunlight to the forest floor may provide thermal benefits, on winter ranges in dense continuous forests (Nyberg et al. 1986).

Conversely, forest canopies emit long wave radiation toward the ground that might provide energetic benefits, primarily at night. Numerous authors have suggested this source of energy provides important thermoregulatory benefits to wintering big game (Moen 1968d, Beall 1974, Grace and Easterbee 1979, Leckenby 1984, Nyberg et al. 1986). Perhaps the most striking example is provided by Grace and Easterbee (1979). Using a simulation model, they calculated that night-time radiative heat loss from a standing red deer in non-forested habitats would average about 1.6 times greater than if standing in "open" coniferous woodlands. In contrast, Moen (1968d) measured long-wave radiation, and found that downward radiation averaged only 1.2 times greater in coniferous woodlands than in open pasture at -20 C. Moreover, negative thermal radiative balance will reduce standard operative temperatures only 3-4 C, on clear nights without forest cover (Parker and Gillingham 1990). The presence of forest cover reduces net thermal radiative losses, but cannot evoke positive thermal radiative balance during winter (e.g., Moen 1968d). Thus, differences in standard operative temperature, due to the effects of long wave radiation, between open areas and forested sites likely amount to about 1-2 C, assuming equal ambient temperature and wind speed.

Radiation emitted from forest canopies may result in slightly higher ambient temperatures under forest canopies (Reifsnyder and Lull 1965, Nyberg et al. 1986, Parker and Gillingham 1990). Bunnell et al. (1986) estimated temperature differences of 2 C in clearings compared to forested areas. Nyberg et al. (1986) believed forest canopies act as thermal blankets that retain warmer air masses near the ground. However the combined effects of topographic variation and cold air flow in concave sites may well eliminate such a small temperature differential (J. Cook, unpubl. data), and explain why elk tend to bed in upper-slope situations, near ridges and benches, where cold air drainage is less likely to occur (Irwin 1978).

Clouds can emit radiation toward the earth equaling that emitted from the earth's surface and that emitted by forest canopies (Riefsnyder and Lull 1965). Most studies evaluated long wave radiation only on cold clear nights, during conditions in which thermal benefits of forest canopies would be greatest. But winter nights in montane areas of the inland northwest are commonly overcast. For example, from 15 January to 15 February 1990, only on 1 night were skies completely clear during the entire nocturnal period in northeastern Oregon (J. Cook, unpubl. data). Radiation from clouds and forests to the ground's surface probably is not additive (Reifsnyder and Lull 1965:70). Therefore, big game likely derive little or no net thermal radiative benefits from forest canopies on overcast nights. Radiation from clouds also reduces rate of cooling of soil and air at ground level (Reifsnyder and Lull 1965), thereby reducing potential temperature differences between forested and nonforested sites. Finally, Moen (1968c,e) reported that long wave radiation under a single tree is as great as that within a forest. Thus timber management practices that develop and maintain small, dense patches of forest canopy probably provide ample opportunity to benefit from long wave radiation when it is possible to do so (i.e., on cold, clear nights).

In contrast to convection and radiation, the potential effects of thermal cover on evaporative and conductive heat loss appear to be inconsequential during cold, snowy conditions. Evaporative loss in respiratory tissues is greatly diminished at low ambient temperatures (Parker and Robbins 1984), and conductive losses are believed to be low when animals are bedded in snow (Jacobsen 1980, Parker and Gillingham 1990). Animals spend substantial proportions of their time bedded (Kufeld et al. 1988, Riggs et al. 1990).

The potential effects of thermal cover on energy balance should be assessed in light of how prevailing weather conditions relate to the cold-tolerance of big game. As indicated above, maximum benefits may be realized only when night-time temperatures approach the animal's LCT, or about -20 to -30 C depending on the size of the animal. To familiarize ourselves with the prevailing conditions in northeastern Oregon, we conducted a brief review of

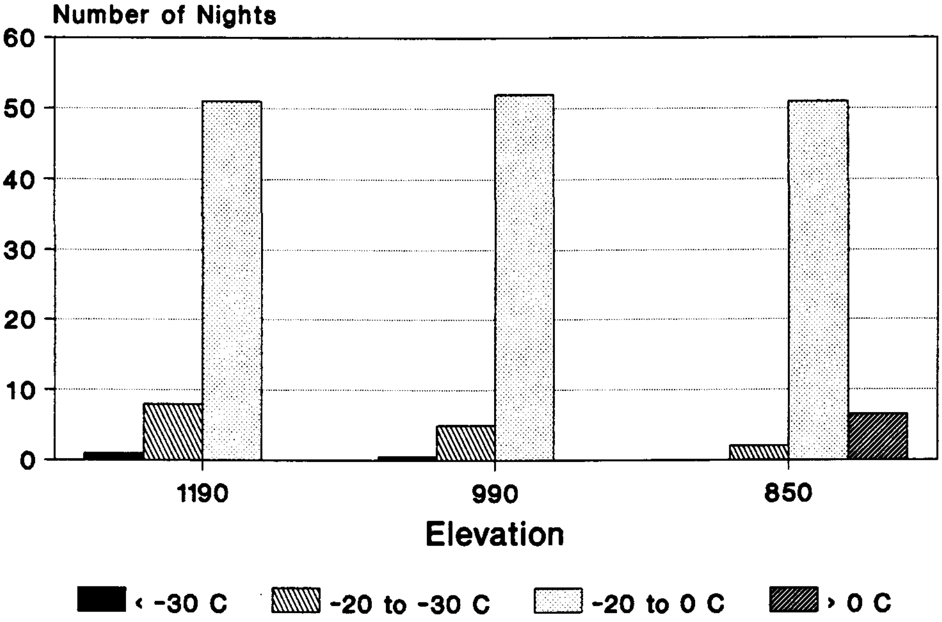

Fig. 1. Number of nights in January and February at various temperature categories in northeastern Oregon. Data are presented for low, moderate, and high elevation weather recording stations (N.O.A.A. 1987-1989).

weather data from 7 weather stations over a 3-year period (N.O.A.A. 1987-89) that included a severe winter noted for extreme temperatures (Durham 1990). Minimum nighttime temperatures in January and February averaged about -8 C (all weather stations combined), well above LCT for most big game, and the frequency of extremely warm or cold periods was low (Fig. 1). Mundinger (1984) reported that average minimum temperatures during January were -10.8 C and -11.5 C at two stations in the Swan Valley, Montana. Ambient temperatures may not be sufficiently extreme to stress elk significantly on most winter ranges. Knowledge of wind conditions during extreme cold periods is of interest, but wind data were not available for the northeast Oregon weather stations.

We are surprised that the hypothesized effects of cover on condition, survival and subsequent reproduction in ungulates rarely have been tested under controlled conditions. We are aware of only 3 attempts to do so empirically. Robinson (1960) maintained 3 groups of white-tailed deer fawns in 3 pens, 1 in sparse forest cover (34% canopy), 1 in moderate cover (55% canopy), and 1 in dense cover (73% canopy). Fawns were fed submaintenance rations to force weight loss. No differences in various condition indicators of deer among canopy treatments were found, even though ambient temperatures occasionally fell to -20 C, and wind speeds were greater in the pen with sparse cover. Gilbert and Bateman (1983) also found no significant differences in condition indices or weight between white-tailed deer fawns in pens with forest cover (72% canopy) and areas lacking forest cover. Freddy (1985, 1986) conducted similar experiments with adult mule deer maintained in pens with no cover and artificial cover (small sheds). Average minimum temperatures fell to -30 C and high winds were noted during portions of the study, but Freddy (1986) could not conclude that thermal cover provided significant survival advantage during winter.

Dietary energy levels can have substantial effects on thermal balance, in part due to the effects of the heat increment of feeding (HIF) (Moen 1968a, Webster 1983). Moen (1968a) estimated white-tailed deer could withstand -40 C, without increasing metabolic rates, when maintained on a "full" diet compared to only 0 C for deer maintained on a starvation diet. Moen (1968d) indicated free-ranging white-tailed deer were oblivious to wind and severe cold (-35 C), when forage of good quality was available. Wesley et al. (1973) indicated that the thermoneutral zone of pronghorn fed an *ad libitum* diet was 12-15 C lower than when fasted. This suggests diet can have as great an effect on energy balance as wind and solar radiation.

Modifications to the forest canopy may enhance energy intake by increasing forage quantity. The inverse relationship between forest cover and forage production is well known, and qualitatively consistent among a variety of plant communities (e.g., McConnell and Smith 1970, Regelin et al. 1974, Uresk and Severson 1989, Bojorquez

Table 1. Metabolic (fasting metabolism (FMR) and HIF) and radiative heat in clearings (Rc), hardwood (Rh), and cedar (Rce) habitats at different dietary levels during a 12-hour nocturnal period. Energetic effects of activity (standing) were excluded from these data to simplify relationships among selected variables.

		Total Available Heat		
Intake (% of maint.)	FMR+HIF (kcal/night)	Rc+FMR+HIF (kcal/night)	Rh+FMR+HIF (kcal/night)	Rce+FMR+HIF (kcal/night)
60	1,191	4,394	4,460	4,529
80	1,299	4,502	4,568	4,637
100	1,614	4,817	4,883	4,952
120	2,012	5,215	5,281	5,350

Table 2. Calculated heat losses at 3 different wind speeds.

Wind Speed	Heat loss (kcal/night)			
(m/s)	Evaporative	Radiative	Convective	Total
0	53	3,393	211	3,657
3	53	3,393	427	3,873
6	53	3,393	505	3,951

Table 3. Effects of forest cover and dietary energy on thermal balance. Data are increases in energy available from occupying forests vs. openings and increases in metabolic energy at 80 and 100% of maintenance compared to metabolic energy available at diets of 60% of maintenance.

	Increases in heat energy (kcal/night)			
Intake	Still-wind conditions		Windy conditions (6 m/s)	
(% of maint.)	Openings	Conifer forests	Openings	Conifer forests
60	0	135	0	397
80	108	243	108	505
100	423	558	423	820

et al. 1990). However, we are unaware of any experiments that have tested the hypothesis that manipulating forest canopy can result in increased energy intake by free ranging ungulates. Empirical evidence indicates that the standing crop of forage is positively correlated to intake rates and inversely correlated to energy expended in obtaining energy (Wickstrom et al. 1984). The correlation is non-linear, suggesting there is a threshold of standing crop at which increasing forage availability has little influence. Deer apparently achieve their maximum intake rates when "selected" forage biomass approaches 100 kg/ha, while elk do not achieve maximum intake rates until "selected" forage biomass approaches 1500 kg/ha (Wickstrom et al. 1984). This suggests that increasing standing crop of forage may provide direct, perhaps profound (Wickstrom et al. 1984) energetic benefits to big game, particularly elk.

Relative Importance of Factors

To identify the relative importance of components in the energy balance equation, particularly in relation to forest management, we analyzed the effects of altering forest cover on energy balance using equations and general procedures of Moen (1968a,b,c) and Grace and Easterbee

(1979). Our calculations were made for a hypothetical 70 kg deer, rather than an elk, because considerably more information is available to calculate energy balance for deer. Assumptions and equations we employed are in Appendix 2.

First, we compared the effect of changing the intake of metabolic energey (ME) to that of changing absorbed long-wave radiation emitted from cover. Our calculations indicated that increases in energy intake have substantial effects on metabolic heat production: heat output increased 108 kcal/night when ME intake was enhanced from 60% to 80% of maintenance, and 315 kcal/night when diet was enhanced from 80% to 100% of maintenance (Table 1). These effects are due primarily to the heat increment of feeding (HIF). Calculations for the effect of cover on absorbed long-wave radiation were based on Moen (1968d), who measured 3 vectors (upward, downward, and horizontal) of long-wave radiation in openings, hardwood, and cedar (*Thuja occidentalis*) forests on cloudless nights. Our hypothetical deer would absorb 3,203, 3,269, and 3,338 kcal/night (all vectors combined) in clearings, hardwood, and cedar forests, respectively. Radiative energy available under a cedar canopy exceeds that available in a clearing by 135 kcal/night, whereas available heat differs between hardwood and cedar forests by 69 kcal (Table 1).

Next we calculated heat loss as the sum of evaporative, radiative, and convective heat losses. Convective loss was calculated for winds of 0, 3, and 6 m/s. The highest of these appears to represent relatively extreme conditions for northeastern Oregon (J. Cook, unpubl. data). Evaporative and radiative heat losses were 53 and 3,393 kcal/night, respectively (Table 2). Convective losses increased from 211 to 505 kcal per night as wind speeds increased from 0 to 6 m/s.

Potential implications for forest management can be derived from comparisons of caloric balances (Table 3). In our analysis, net radiative energy losses for a deer standing in coniferous forests would be 135 kcal/night less than for a deer standing in openings, under still-wind conditions. On windy nights (i.e., 6 m/s), a deer standing in openings would potentially lose 397 more kcal/night than if it stood in a coniferous forest, due to the combined effects of radiation and convection. Energy intake has a greater potential effect; increasing energy intake from 60 to 100% of maintenance will increase heat available for thermal stasis by 423 kcal/night. These conclusions support literature reviewed above. Dietary energy potentially has far greater effects on energy balance than does long wave radiation, and equivalent or greater effects on energy balance than does convection.

These energetic savings derivable from standing in forests would only be realized under the specific (i.e., worst-case) environmental conditions assumed in our analysis: clear skies, constant 6 m/s wind with no obstructions, ambient temperatures near LCT, with the animal standing throughout a 12-hr night. It is unlikely these conditions will often occur on inland northwest winter ranges, and deviation from these conditions will reduce the thermal benefits of forest cover considerably. Benefits of forage enhancement can be available frequently, and for relatively long periods; if so, the effect of forage enhancement resulting from timber management may outweigh that of partial cover alterations substantially. Taller shrubs (>1 m) can provide forage while reducing convective loss as well (Moen 1973).

Most of this discussion has compared the energetic benefits (both potential and realized) of forest with those of open areas. This contrast of extremes was necessitated by the nature of the data available; quantitative data regarding energy balance under various forest canopy/understory/topography conditions are not available for interior northwest timber types. Yet as discussed above, the potential for conflict between timber and cover management rests on the perceived value of different cover classes and the potential for related timber management restrictions to impair silvicultural management. We propose that the thermal benefits associated with different stand structures (e.g., marginal vs. satisfactory) are certainly less than those described above, and may be inconsequential in many, if not most, circumstances. Our review and analysis support the working hypothesis that energy balance of wintering big game can be enhanced via timber management, even if overstory cover is reduced in height or closure.

CONIFER COVER AND SNOW ACCUMULATION

Although reducing overstory cover will increase the standing crop of forage, potential concomitant increases in snow accumulation may eclipse forage increases to some degree, increase the energy required to obtain forage (Parker et al. 1984, Wickstrom et al. 1984), or alter distribution (Leege and Hickey 1977, Sweeney and Sweeney 1984). Snow/cover/forage relationships are strongly influenced by the character of overstory/understory associations, topography, and precipitation patterns. Empirical data are needed to specifically define relationships among snow, forage, and foraging dynamics of big game as they relate to forest structure.

Perhaps the most significant effects of forest cover on elk stem from the relationship between snow-intercept cover and forage intake opportunities. Dense overstories preclude growth of large amounts of understory vegetation (e.g., Jameson 1967, Irwin and Peek 1979, Bojorquez et al. 1990). However, relatively more forage may be available under forest canopies than in open areas where snow buries forage (Harestad et al. 1982). Elk also eat fallen lichens and Douglas-fir (*Pseudotsuga menziesii*) foliage, and average quality may be greater for forage grown under timber cover, at least in coastal forests (Hanley et al. 1987, Hanley et al. 1989).

Forest overstory/snow/understory relationships may vary regionally due to a variety of factors. For example, Schwab et al. (1987) presented evidence for alternative conclusions for the effects of canopy cover on browse burial by snow in northcentral British Columbia. There, increasing canopy cover increased the probability that browse would be buried by snow, during both the snow-accumulation and melt periods. In that area, the wind blows dry snow from forage in openings. Also, the predominant tree species is white spruce (*Picea glauca*) which, apparently because of its recumbent branch structure, does not hold snow as well as Douglas-fir.

Further, the relationship between wind and continuity of forest cover influences snow accumulations and forage availability. Timber removal changes the aerodynamics of the canopy, resulting in attendant changes in the pattern of snow deposition. This effect is minimal in light partial cuttings and maximal in clearcuts (Troendle and Meiman 1984). Some small clearcuts can catch snow, reducing snow accumulations in downwind patches of forest (Gary 1974), which results in greater forage availability. Limited data suggest that partial cutting by marking individual trees may result in net increases in snowpack accumulation (Troendle and Meiman 1984), so the greatest potential for increasing snow re-distribution is harvesting in small clearcut patches, strips, or blocks (Gary and Troendle 1982). In northeastern Oregon, Douglas-fir often grows under canopies of Ponderosa pine (*Pinus ponderosa*); thus selective group removal of some of the pines may result in favorable snow redistribution as well as increased snow-intercept capability via growth in crown volume by the Douglas-fir. Precipitation patterns characteristic of the site, as well as the relation between snow depth and forage height will ultimately determine the importance of canopy manipulation and attendant snow redistribution on energy balance.

Our literature review revealed little information regarding effects of alternative silvicultural practices on snow dynamics, particularly in timber types common to winter ranges. New research could identify silvicultural options for creating desirable structural and successional-stage features on elk winter ranges. It may be possible, for example, to develop and maintain optimal cover in managed stands through control of snow distribution patterns, stocking, forage seeding, fertilizing, and thinnings, or implementing long rotations in selected parts of the forest (Witmer et al. 1985).

CRITICAL COVER AND HABITAT PREFERENCES

Habitat use data have been used to infer preferences and energy-balance relationships of cover. Although preference relationships may be used to identify limiting factors under some circumstances (Peek et al. 1982; Thomas et al. 1988), such studies apparently have yielded little useful information for silviculturists (Smith and Long 1987). To guide silvicultural management of cover, habitat preference studies must be designed to yield knowledge of how timber-stand structure and composition affect habitat selection. Yet relatively few habitat selection studies have embraced forest structure with such vigor. Pierce and Peek (1984) examined the habitat use patterns of moose in relation to stand characteristics that included canopy closure, height, diameter distributions, and species-specific density in both overstory and understory strata. They observed that selection for mature timber types resulted from a combination of relatively shallow snow depth and presence of understory forage, in the form of Pacific yew (*Taxus brevifolia*). Clear-cutting, which increased snow depth and reduced Pacific yew was identified as an inappropriate silvicultural option for moose habitat, whereas single-tree and group selection methods were recommended where harvest was planned. Their study did not address thermal cover, but it did illustrate the interaction between snow and the forest canopy in determining forage availability in the understory. Where thermal cover is an issue, habitat evaluations should be based on how snow and canopies interact to affect both thermal regimes and forage resources.

Beall (1974) found that 86% of 1,011 winter elk beds were associated with timber. He indicated that under normal winter conditions (i.e., -18 C to +2 C) day beds were located in "dense" timber with slight north aspect, while night beds were on "open" timbered south-facing slopes or in level open fields. Location of night-bed sites was thought to be selected for close proximity to feeding areas rather than for protection from cold (Beall 1974:92). Beall (1974:93-102) developed equations relating stand density to radiation and temperature at bed sites; correlation coefficients (r) varied from 0.65 to 0.93, with the lowest values observed for night-bed sites. However, probability of use of a stand was not related directly to its structure; this analysis would have helped to determine how changes in stand structure might affect selection. In such mensurative experiments (Hurlbert 1984), stand characteristics are likely to be strongly associated with the aspect on which the stands occur. Thus stand structure and aspect are statistically confounded, thereby precluding any meaningful analysis of the effects of silviculture on its own merits. New research is needed to quantify habitat selection as related to species composition, height, age or size distribution, canopy closure, live crown depth or ratio, available forage biomass in understories, and past management of stands. Such studies can test hypotheses regarding selection responses to forest management, and subsequently guide management.

Leckenby (1984:23-26) observed that wintering elk: (1) made proportionately greater use of cover during warm (> 13 C) periods, (2) spent proportionately more time bedding in cover at temperatures below 3 C, and (3) used bedding sites where overstory canopy cover and height were greater than at sites used for other activities. Leckenby relied on direct observations of free-ranging, wild animals. Consequently, results and subsequent interpretations may have been influenced by warmer daytime temperatures and greater need for security during the day than at night. Canopy coverage and height could be positively correlated with security value on slopes where overstory canopy is a major component of lateral hiding cover. It is difficult to explain the significance of (2) given that the thermoneutral zone of elk is likely to extend from at least -20 C to some point in excess of +13 C. In any case, the observations were not demonstrated to be statistically significant, and Leckenby (1984:25) postulated that relaxing current thermal-cover criteria might be realistic for elk. Future work should be designed to separate the effects of topography and silvicultural options on habitat selection patterns as a means of testing and/or refining habitat models. Until such work is conducted, Thomas et al. (1988) recommended weighing satisfactory cover 2 times that of marginal cover, and the State of Oregon (1990:19) has recommended that the Forest Service maintain a minimum of 15% of Northeast Oregon winter ranges in satisfactory thermal cover.

Habitat-use studies traditionally have compared use among distinctive plant community types or successional stages, rather than among structural differences within types. Structural distinctions between communities under study have often been so obvious (e.g., clearcut vs. uncut), that little or no quantification of structural variables apparently was considered necessary. Mundinger (1984), for example, primarily was concerned with the effects of extensive clearcuts, and simply classified cover types as being uncut, clearcut, or managed via overstory removal. Beall (1974) did not quantify the difference between "dense" and "open" timber stands. Dusek (1987) alluded to the presence of several managed ponderosa pine associations, but did not quantify structural differences among them or among treatments within them. Descriptions have tended to be rather general in studies concerned with fire and long-term succession as well (e.g., Singer 1979, Keay and Peek 1980). Even studies concerned with physical relationships have adopted qualitative, rather than quantitative, descriptions of forest communities (e.g., Grace and Easterbee 1979). Results of such studies have immediate utility in the area where they are conducted, but their value can be limited in other areas where silvicultural modification results in different structural characteristics. Utility may be reduced in time as well, as plant succession changes the character of the habitat mosaic (Lyon 1976, Irwin and Peek 1983). Therefore, much of the ungulate-logging literature completed to date may be of little use to silviculturists. Silviculturists will increasingly seek guidance in planning the intensity and timing of stocking controls and intermediate harvests in managed forests. Therefore, new research is needed to examine habitat selection in relation to structural differences resulting from manipulation within community types and successional stages.

Preference analyses can be of limited utility because of geographic and climatic specificity as well. Selection patterns may vary from one year to the next because of climatic fluctuations; likewise, geoclimatic differences can lead to markedly different use patterns within the same region. Owens (1981) observed that wintering white-tailed deer preferred dense stands of timber dominated by western red cedar (*Thuja plicata*), with grand fir (*Abies grandis*) and Douglas fir as codominants. In contrast, Bell (1988) observed that white-tailed deer preferred communities dominated by ponderosa pine or cottonwood (*Populus trichocarpa*). Thus, preferences are functions of the prevailing weather conditions and the options available to ungulates. One habitat model probably does not fit all range areas, even within a geographic region. This suggests there is substantial opportunity to enhance integration of big game and timber management via area-specific model refinements alone.

Some studies have crossed geographic and climatic variation in their experimental designs in attempts to identify meaningful interactions (e.g., Leckenby 1984, Lyon 1984), but with little apparent success. Failure to identify significant relationships may result from inadequate replication, inappropriate stratification of factor levels in the experimental design, or simply absence of important relationships within the range of factor levels on most ranges. Yet the frequency and duration of bioenergetically significant climatic extremes determine the potential energetic value of forest canopies, the relative use of different cover types for energetic purposes, and the energetic consequences of silvicultural alteration. Determining how topography, climate, and cover manipulation interact to affect use and value of timber stands is advisable if we hope to maximize the benefits of cover management while minimizing unnecessary restriction of wood production. Parker and Gillingham (1990) developed a response surface for operative temperatures as a function of weather variables; a similar approach might be considered for quantifying habitat-use responses and thermal value of various timber-stand canopy configurations.

Preference analyses also may be confounded by learned behavior that has little or no relation to bioenergetics. For example, behavior patterns learned early in life may not be easily altered, as in the case of foraging habits (Provenza and Balph 1987). This phenomenon also may be true of habitat-patch selection as well. If so, habitat selection experiments may require several years, and experimental animals with different histories, to adequately assess responses to habitat alteration. Likewise, interpretations of bioenergetic relationships from wild elk in winter range studies may be confounded by prior experience during hunting seasons and psychological "need" for cover. Shifts in activity patterns (day vs. night) may constitute behavioral modifications to reduce visibility and enhance psychological security, rather than modifications that enhance energy balance (Beall 1974, Green and Bear 1990). Attempts to reduce behavior bias have been made (e.g., Leckenby 1984, Riggs et al. 1990) but success has not been demonstrated. Additional effort is required to quantify the magnitude of potential confounding by learned behavior because of its potential to compromise the reliability of inferences from habitat- and diet-selection studies.

We have identified 3 potential deficiencies in typical selection studies: (1) failure to test a complete range of silvicultural regimes and structural variation; (2) limited ability to analyze geoclimatic/cover interactions; and (3) confounding of bioenergetic factors with learned behavior patterns. Nonetheless, habitat models are mostly based on selection data, and it is unlikely that this will change soon (e.g., Thomas et al. 1988). Foresters will continue to challenge the need for silvicultural restrictions in the absence of more definitive data. Thus validation experiments are clearly needed (Thomas et al. 1988, Edge et al. 1990). Much of the confusion surrounding current cover management may derive from reliance on retroduction in habitat use studies (see Romesburg 1981). Consequently, it seems appropriate to consider modifying the traditional descriptive approach in the validation process, so that the distinction between observed selection and demonstrated need can be addressed.

Validation experiments should rely more strongly on direct relationships between silvicultural treatments, attendant structural trends, and expected bioenergetic consequences when assembling experimental designs. This implies a 4-stage research process. In the first stage, quantitative data are gathered on thermal regimes, snow depth, forage availability and quality, and energy intake in different stand structures in various timber or habitat types. In the second stage, these data are used to generate testable hypotheses for habitat selection under different weather/habitat conditions based on bioenergetic relationships (e.g., Parker et al. 1984, Wickstrom et al. 1984, Stephens and Krebs 1986, Parker and Gillingham 1990). These hypotheses are tested in the third stage, via controlled experiments using free-ranging animals. More than one study area would be needed to determine geoclimatic interactions, and use of both wild and tame animals would allow estimating the potential for confounding due to learned behavior patterns. In the final stage, effects of altering cover characteristics through forest management could be modelled and validated for different winter conditions based on energetic relationships and expected use patterns (e.g., Hobbs 1989).

IDENTIFYING SILVICULTURAL OPTIONS FOR WINTER RANGE

Energy balance is a function of both energy conservation and energy acquisition, and silvicultural options should be evaluated based of how they alter both factors. Most research has focused on one or the other, rarely on both, and much work is needed to clarify how various silvicultural systems alter energy balance via effects on cover and forage resources. Arno et al. (1985) reported multiple successional pathways for some forest habitat types in western Montana. Similarly complex successions probably exist in other forest types of the interior northwest, and silvicultural options can be expected to affect successional trajectory differently. Here, we review the basic characteristics of selected systems to identify options worthy of consideration in winter-range experiments.

Throughout most of this paper silviculture has been addressed in generic terms, as if its effects were a constant. In reality, silvicultural systems are numerous, diverse, and can vary markedly in their effects on habitat. Silvicultural systems must be distinguished from reproduction methods. A reproduction method is simply a procedure by which a stand is established or renewed; a silvicultural system is a comprehensive program that plans all the management actions (e.g., regeneration, thinning, intermediate harvests, etc.) during the life of a stand. Silvicultural systems historically have been designed to maximize timber production, but these can evolve to enhance and maintain habitat quality as well, provided sufficient quantitative data are available to guide the evolution. First, one must understand the options. Most of the remainder of our discussion is condensed from Smith (1962), who broadly classified silvicultural systems as either even-aged or uneven-aged.

Even-aged systems promote stands that contain trees of essentially 1 age-class throughout most of a stand's life. The clearcut system is the purest and perhaps best known form of even-aged silviculture. Seedtree and shelterwood systems, on the other hand, are even-aged systems that retain more than 1 age class during the regeneration phase, which is usually short. The vast majority of elk/timber studies have evaluated the effects of even-aged systems, particularly those based on clearcutting, on distribution and habitat use. Clearcut and seedtree systems are particularly well suited to enhancing forage resources (e.g., Irwin and Peek 1979, Newton et al.

1989), but advanced cover classes are slow to recover following the regeneration phase in these systems. The adaptability of shelterwood systems for enhancing forage resources can vary greatly, depending on the species, density, and site potential. For example, overstory/understory relations in shelterwoods for western red cedar would differ considerably from those in a douglas-fir shelterwoods. None the less, shelterwood systems can generally be considered somewhat less effective for enhancing forage because they open stands to a lesser extent than other even-aged systems, being primarily aimed at favoring shade-tolerant species.

In contrast to even-aged systems, classical uneven-aged systems promote multiple age classes of trees throughout the life of the stand. Important modifications of uneven-aged systems include single-tree selection and group-selection. Theoretically, single-tree selection is well adapted to maintaining advanced cover classes, including multi-layered canopies, because it employs light removals of wood volume over long time periods. Single-tree selection is usually used to propagate shade-tolerant species, and it is probably the least adaptable silviculture for enhancing forage resources. Group selection involves propagating small even-aged patches within a larger uneven-aged stand and can be used to retain cover values while propagating small patches of forage. The distinction between even-aged and uneven-aged systems can be confusing because the scale at which the stand unit is defined determines the appropriate nomenclature (Fig. 2); this rather artificial differentiation is a common source of confusion. There is no set rule for determining the scale at which the stand should be delineated, but systems that are characterized as uneven-aged usually employ rather small cutting units (e.g., 1 to 2 ac. or less), within larger stands. Nonetheless, there is no particular reason (excepting operational constraints) to preclude somewhat larger or smaller stands. Where cutting units are relatively large, they can be excellent vehicles for enhancing forage resources within the larger stand. If cutting units are relatively small, they may be used to regenerate trees, or enhance growth of adjacent trees, without compromising cover value.

Uneven-aged stands also can be classified as either balanced or irregular. A balanced stand contains all the age classes addressed in the system, whereas an irregular stand is deficient in one or more age classes. Balance does not occur naturally at the scale of most practical management units, and must be developed through active management over time. The term "uneven-aged" does not mean that every single 1-year age class is represented;

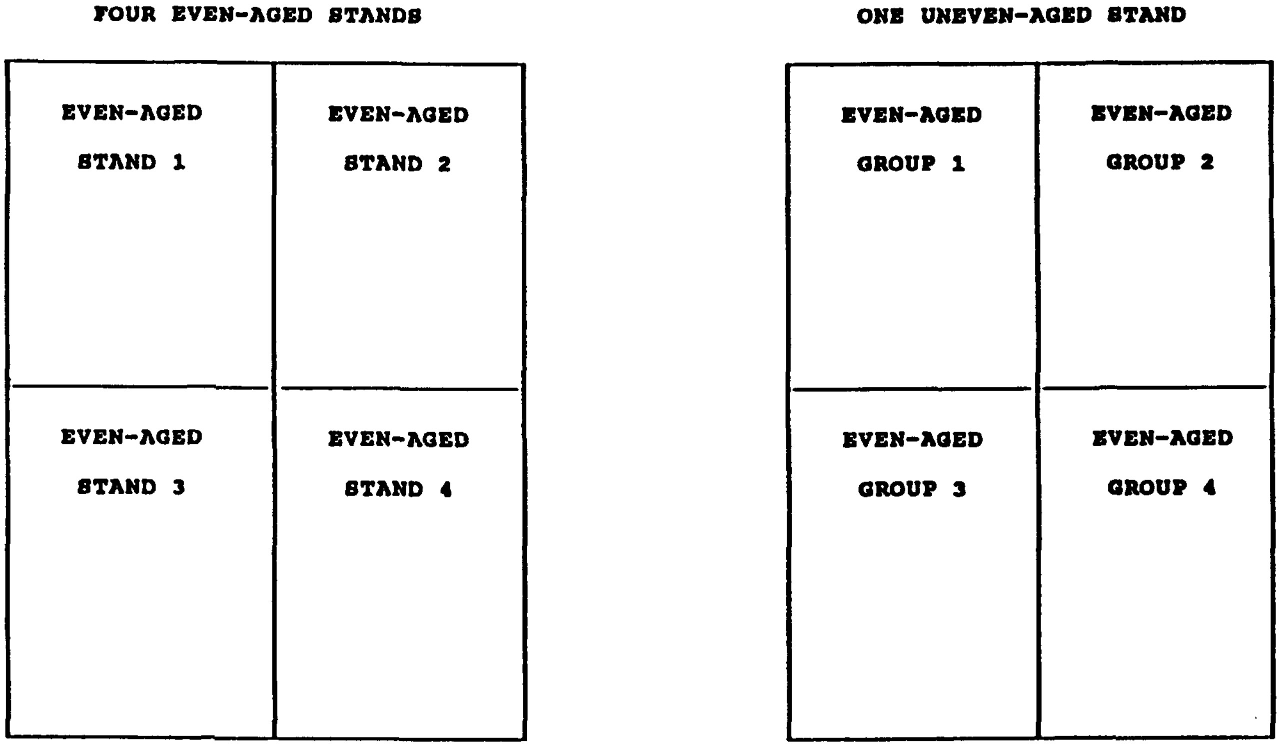

Fig. 2. Illustration of the distinction between even-aged and group-selected uneven-aged management on equal forest areas. Even-aged management of 4 stands is depicted on the left. In the right-hand diagram, the same total area is defined as a single uneven-aged stand, containing 4 even-aged groups.

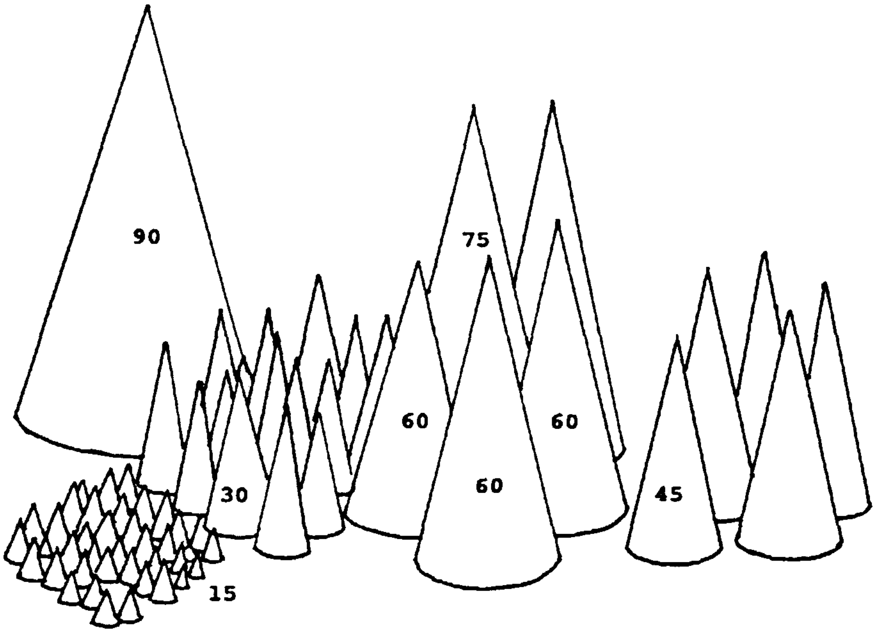

Fig. 3. Schematic oblique view of a 1/4-acre segment of a balanced uneven-aged stand being managed by the single-tree selection system on a 90-year rotation with a 15-year cutting cycle. Each tree is represented by a cone extending to the ground; the numbers indicate ages. Each group occupies about 1/24 acre. The 90-year-old tree is now ready to be replaced by numerous seedlings while the numbers of trees in the middle-aged groups are appropriately reduced by thinning (taken from Smith 1962).

more often, uneven-aged systems arrange 3, or preferably more, 20-year age classes within a stand. However, the illusion of an all-age-class stand can be approached in single-tree configurations (Fig. 3).

True uneven-aged management has not been commonly pursued in the interior northwest. These systems may be difficult to initiate, especially on small areas, because of existing stand composition and/or irregular age-class distributions. They are also more difficult to maintain, inventory, and monitor, and are frequently characterized as economically less favorable than even-aged systems. Consequently, foresters have tended to favor even-aged systems. Specific data are lacking for interior northwest types, but Lilieholm et al. (1990) reported that timber production via uneven-aged management was apparently sustainable, and comparable in terms of yield, to that under even-aged management in Sierra mixed-conifer communities. Where thermal cover is an important consideration, employment of some uneven-aged principles may enhance compatibility of habitat management and commodity production. Much remains to be learned about cover/forage/timber relations in the context of these systems.

In many cases, advanced stages of dense coniferous cover have been created artificially through the practice of economic selection, or "high-grading". This practice was driven by economic, rather than ecologic, principles. Simply put, high-grading amounted to selection of the highest quality milling stock. Over much of the interior northwest, pioneering species were initially selected for harvest. Economic selection, coupled with fire suppression and insufficient stocking control, subsequently favored shade-tolerant species on many sites (Wright and Bailey 1982, Steele 1988). Over time these residual stands regained height and developed multi-layered canopies. Thus many of the stands now considered superior thermal cover have, in fact, originated inadvertently through past management and poorly represent forest structures and composition in the era preceding white settlement. To the extent that such stands are now overstocked and composed of "off-site"[2] species, much of the current loss of cover to fire, insects, dwarf mistletoe, and various pathogens east of the Cascade Mountains in Oregon and Washington can be attributed to this phenomenon. In planning for the maintenance of cover, attempts to maintain such inherently unstable timber stands may well be self-defeating.

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[2] The term "off-site" is used here to refer to climax or subclimax species that are adapted to moisture regimes that exceed the long-term average for a given site.

Biologists should exercise caution in using cover considerations to restrict silviculture that is aimed at rehabilitating such stands.

Fire exclusion and the practice of economic selection have had profound effects on timber stand composition and vigor of many stands. In some cases, pioneer species have been so reduced by fire exclusion and/or successive entries that, due to lack of seed source, some stands cannot be naturally regenerated with anything but climax conifer species. If site class (Davis and Johnson 1987) is high enough this may be acceptable or even desirable. But in northeastern Oregon and southeastern Washington we view this to be the exception rather than the rule, especially on winter ranges where xeric conditions prevail. Where this has occurred, traditional silvicultural options may include rehabilitation via clear-cut (with planting); or where residual seed source is available, even as a minimal stand component, seedtree or shelterwood; or continued maintenance of perturbation-sensitive species through shelterwood, single-tree selection, economic selection, or harvest exclusion. These methods represent a spectrum of options that integrate long-term cover and timber goals to varying degrees, some not at all.

However, where past management has left sufficient seed stock to regenerate pioneering species, an approach known as "free-form" silviculture may provide a vehicle for integrating timber- and cover-management goals more effectively. Free-form silviculture, as practiced on industrial forests in northeastern Oregon, bears some resemblance to what Wenger (1984:419) calls "irregular shelterwood", which is essentially a formal intergradation between even-aged and uneven-aged management. Both even-aged and uneven-aged systems possess characteristics that can provide desirable levels of forage and cover. Free-form silviculture may best exploit these characteristics while minimizing less desirable aspects of both.

The free-form method has 2 simultaneous goals. The first of these is to reestablish the timber stand's original diversity to the extent possible, by retaining suitable seedtrees to regenerate pioneer species. The second goal is to maintain the highest possible periodic growth increment in the process; this involves leaving trees that exhibit favorable growth rates, even if they are large members of the shade tolerant group. In the process of balancing these 2 goals, the forester can create what amounts to a mosaic of small even- and uneven-aged units, with a multi-storied canopy, by precisely selecting for removal individuals and groups of trees as prioritized by predetermined species and vigor classifications. The forester must be expert to practice this approach successfully because it does not fit the classical precepts of either even-aged management or uneven-aged management, but rather blends the principles of both.

Effects on cover values will vary as a function of the stand composition the forester has to work with, but long-term management options may be profoundly improved for timber, forage, and cover. In many cases free-form silviculture has potential to: (1) maintain dense (e.g., 40-70% canopy closure) stands with superior heights (e.g., > 40 ft), (2) develop multi-storied canopies, (3) extend rotation of stands that would otherwise be clear-cut, (4) stimulate understory production, and (5) facilitate diversity in both the overstory and understory. Armleder et al. (1986) illustrated systems with somewhat similar attributes. To our knowledge, biologists have not documented the responses of big game to this form of silviculture. Consequently, current habitat models cannot address this potentially useful management tool.

It seems inappropriate to view cover/silviculture relationships solely on the basis of even-aged expectations. Yet current forest planning tools may force implementation of even-aged management on winter ranges. Thomas et al. (1988) presented a working hypothesis for modeling habitat quality that differentially weights marginal and satisfactory cover. The coefficient for marginal cover is 0.500 in this model and that for satisfactory cover is 1.000; the model does not have intermediate cover coefficients. Thus even slight, short-term reductions in canopy height or density, as would result from almost any silvicultural treatment, could result in a 50% reduction in the model's cover quality rating and possibly inhibit uneven-aged or free-form management. Knowledge of energy exchange under various canopy structures could be used to refine this model. Minimum standards for satisfactory cover (USDA 1987, State of Oregon 1990) may also inhibit use of uneven-aged or free-form management by requiring that a minimum proportion of winter range be maintained as satisfactory thermal cover. As a result, management of the remaining timber stands may be intensified, resulting in an unbalanced patchwork of even-aged stands.

Identifying appropriate silvicultural systems depends on several factors in addition to cover value. A stand's management history, species composition, its age, size distribution, vigor, and the site classification all contribute to determining the viability of options. Likewise, the balance between energy conservation and energy acquisition (i.e., cover/forage balance) is important. The salient point is that cover, along with other forest attributes, can become a highly predictable variable over time within a fully managed forest. It is important from the perspectives of both wildlife and timber production to balance these factors quantitatively, over extended time periods, and in relation to silvicultural plans for other timber stands on the winter range; otherwise it is impossible to defend sustained yield of either timber or cover. In an unmanaged condition, stand attributes may fluctuate wildly as climatological variables influence frequency and intensity of stand perturbing factors. Our current knowledge of how habitat attributes, bioenergetic values, and habitat use vary in silvicultural systems appears to be based almost solely on even-aged expectations. New research that identifies relationships in the context of innovative silvicultural systems can enhance integration of timber and winter range management. Our review supports the idea that well-designed and implemented timber management can favorably alter the energy balance of wintering ungulates.

CONCLUSIONS

First, more definitive information is needed regarding the relations between cover management and timber production in the timber types that predominate on interior northwest winter ranges. If confusion and conflict are to be minimized, all parties involved must have a common quantitative knowledge of the benefits and consequences associated with alternative management options. Analyses similar to that available for lodgepole pine (Smith and Long 1987) should be conducted for timber types of the inland northwest, focusing on options that go beyond traditional even-aged silviculture.

We suggest reevaluating the utility of current cover classes (i.e., marginal, satisfactory). With respect to silviculture, the current classification appears relevant to only the simplest even-aged systems, and may actually inhibit implementation of innovative systems that can be used to reduce oscillations in cover over time. Moreover, bioenergetic relationships appear so complex as to preclude meaningful use of simple classification schemes, and perceptions of the importance of cover quality appear dependent on how one interprets the literature. Basic studies that describe environmental tolerances of laboratory animals, or correlations between environmental variables within timber stands provide evidence that canopy manipulation can impact energy balance in winter. However, we found no compelling evidence that the realized effect of cover-management restrictions will be quantitatively significant, at least in the context of timber types and climatic conditions that prevail in northeastern Oregon. Empirical studies have failed to demonstrate that canopy manipulation does affect energy balance significantly. More importantly, the realized affect of cover manipulation will depend on background climatic conditions that prevail in a given area, the silvicultural prescription, its affects on wind and long-wave radiation, compensatory affects of forage responses, snow relationships, and animal selectivity. The available literature does suggest that physiological, behavioral, and environmental factors interact and may substitute for each other, such that many overstory/understory configurations have the same net effect on over-winter energy balance.

Scientists should quantify the total energetic consequences of innovative silvicultural strategies, including those that incorporate some principles of uneven-aged or free-form management. Effects of silviculture on thermal value of canopies should be analyzed in concert with effects on intake of metabolizable energy. Furthermore, comparisons should be made across timber types and geoclimatic regimes so that area-specific model modifications are possible. Efforts to quantify direct relationships between timber stand structure and energy balance should be intensified, perhaps in conjunction with preference studies that control for the confounding effect of learned behavior. Selection studies should focus on describing interactive effects of overstory and understory variables, on selection and energy balance. Modification of existing models, with appropriate validation, may help to discern the relationship between silviculture, energy balance, and productivity of wintering ungulates. Where cover is considered limiting, forest planners and managers must be able to quantitatively compare the merits of silvicultural options in terms of both ungulate production and timber production.

Finally, reducing resource management conflicts depends on integrating management of different resources. Perhaps this means identifying the most beneficial cover conditions that can be maintained within the constraints imposed by sustainable silviculture, rather than subordinating management of one resource to that of another in the short term. Research aimed at identifying modes of integration will benefit from the collective expertise of both wildlife biologists and silviculturists. We believe that implementing and monitoring management experiments in a variety of settings provides the best vehicle for such integration. Management experiments provide a basis for revealing management options that could reduce opportunity costs to wood production and improve big game habitat. Research should be expanded to include participation by the private sector as well as public agencies; doing so will result in better studies that afford opportunities to examine diverse silvicultural regimes, as well as broader acceptance and application of results.

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APPENDIX1. Definitions and descriptions of general Thermodynamic concepts

There are 3 basic concepts of thermodynamics used extensively in the literature, which we referred to frequently in this paper. The 3 are not equivalent, and it is important to understand how they differ.

The first concept is that of a thermoneutral zone (TNZ); this concept relates temperature stress to energy expenditure. Within the TNZ the animal is not temperature stressed. However, when temperatures fall below the TNZ, metabolic rates must increase in order to produce more heat to compensate for increasing heat losses. The temperature at which metabolic rates increase is the lower critical temperature (LCT); at this point, the animal can be considered cold-stressed. Metabolic rates also increase at temperatures above the TNZ, due to panting and sweating required to dissipate heat (Parker and Robbins 1984). The temperature at which this occurs is the upper critical temperature (UCT).

LCT is not fixed, but varies in relation to energy intake and, likely, animal condition. And because LCT is generally expressed in terms of ambient temperatures, other conditions such as wind and solar radiation may lower or elevate LCT even though ambient temperatures remain constant (Moen 1968c). Estimates of LCT have been derived under a variety of experimental conditions, thereby complicating comparisons among species and its use as an index to cold-stress in field situations.

Prolonged exposure to low ambient temperatures near LCT can induce an upward adjustment of metabolic rates in ruminants (Hudson and Christopherson 1985), apparently due to cold-induced non-shivering thermogenesis (Himms-Hagen 1983), resulting from moderate calorigenic effects of norepinephron and epinephron in skeletal muscle (Landsberg and Young 1983). Non-shivering and cold-induced shivering thermogenesis (Himms-Hagen 1983) elevate heat production to counter-balance elevated heat losses during short-term periods of cold stress (Parker and Robbins 1984). Physical/physiological adaptations are augmented by behavioral responses to climatological conditions; animals may vary activity, posture, and choices among habitats to maintain thermal stasis.

The second thermodynamic concept is that of standard operative temperature (Bakken 1980, 1981). This relatively new concept was developed to account for the simultaneous effects of wind, radiation, and temperature on thermal environments. It provides a means to define thermal equivalence among complex natural environments and standard laboratory conditions, based on separate effects of net radiative inputs, wind speed, ambient temperature, and thermal resistances (Bakken 1981). For example, standard operative temperature varies as wind speed or solar radiation levels vary, even though ambient temperatures remain constant. Parker and Gillingham (1990) discussed implications of standard operative temperature to management of big game habitats.

The third is the concept of energy balance itself. Although standard operative temperatures incorporate important climatological variables into a standard index, it omits important determinants of heat loss and gain, and thus incompletely assesses thermal stasis of organisms. Energy balance equations (e.g., Moen 1968a,b, McArthur 1987) provide a useful approach to evaluate the potential effects of thermal cover to evaluate cover-thermal balance relationships. Frequent discussions relying on various components of energy balance are included, so we present a basic description of these components below.

Large herbivores maintain roughly constant body temperatures by balancing heat losses with heat gains. A general form of the energy balance equation is:

$$Me + Ra + A = C + K + E + Re,$$

where Me refers to metabolic heat derived from food or stored energy reserves, Ra is heat absorbed from radiation, A is heat produced from activity, C is heat lost from conduction, K is heat lost from convection, E is heat lost from evaporation, and Re is heat emitted in the form of thermal radiation. In simplest terms, heat (i.e., energy) losses on the right side of the equation must be matched by heat gains on the left, or body temperature drops and death may occur.

Conduction involves transfer of heat due to the collisions of molecules with one another (Moen 1968b). Conductive heat losses can be important when animals are bedded, and vary considerably depending on resistance of substrata to heat flux (Gatenby 1977, Jacobsen 1980). Conductive losses are believed to be minimal when lying in snow (Jacobsen 1980, Parker and Gillingham 1990).

Convective heat losses involve 2 modes referred to as free and forced convection. Heat is first transferred to air by conduction, but air movement carries heat away (Campbell 1977). Forced convection relies on an external pressure to move air past an object, whereas free convection occurs due to density differences in the air created by heat from the animal's body (Moen 1968b). Convective heat losses are strongly affected by wind speed, and increase substantially as wind begins to penetrate the hair coat (Blaxter et al. 1963, Campbell et al. 1980, Parker and Gillingham 1990). Studies with sheep and cattle pelts suggested this windspeed is 11 m/s (Ames and Insley 1975).

Evaporative heat losses occur due to a change of physical state from a liquid to a gas, primarily in the lungs or skin of terrestrial animals. Air temperature and vapor density affect evaporative heat losses; at temperatures below freezing, cutaneous water loss essentially ceases and respiratory water loss diminishes to low levels (Parker and Robbins 1984).

Radiative heat losses stem from discrete quantum jumps in electronic energy levels in atoms or vibrational and rotational energy levels in molecules (Campbell 1977). Any object at a temperature above absolute zero gives off radiant energy, and the amount of energy emitted is dependent on temperature at the surface of the object, the emissivity of the object, and surface area, a function of posture for animals (Moen 1968a,b).

Energy available to compensate for heat losses is derived from food, radiation, and activity. Radiative energy is absorbed from the environment, the amount of which is dependent on source, temperature of radiating surfaces, and posture and absorptive characteristics of the animal (Moen 1968d). Solar radiation (short wave radiation) provides an important source of heat during the day, and thermal radiation (long wave radiation) provides heat during day and night. Long wave radiation is emitted upward from the earth's surface, downward and horizontally from vegetation, and downward from the sky. Cloud cover (vapor density), density of vegetation, temperature of radiating surfaces (Moen 1968a), and distance of the animal from radiating surfaces (due to the effects of attenuation) (Campbell 1977) mediates energy acquired from long wave radiation.

Heat from food includes the basal heat production necessary to sustain life and the heat increment of feeding (HIF) (Moen 1968b). HIF stems from heat production associated with eating and ruminating, microbial fermentation in the gut, metabolic activities of the gut, and the portion of metabolized energy dissipated as heat (i.e., is not incorporated into body tissues) (Webster 1983). Thus, forage consumption provides energetic benefits above that simply required to maintain basal metabolism.

Finally, energy resulting from activity compensates for heat loss (Moen 1968c). Energy from even moderate levels of activity can be substantial; for example, heat loss while standing averages about 1.2 times higher than when an animal is bedded (Fancy and White 1984:145). But due to increased surface area, increased convection, increased blood circulation, and changes in blood circulation, increased activity may result in substantial increases in heat loss, eclipsing energetic benefits of activity (Moen 1976, Gates and Hudson 1979).

Energy exchange with the environment through each component of the equation varies as weather, forage, and habitat conditions vary. Animals can become thermally stressed when physiological and behavioral adjustments are unable to compensate for elevated heat loss during severe ambient conditions, and/or when energy from forage is inadequate to replace heat loss (Moen 1968b,c). The animal's energy reserves can decline during these conditions, therein reducing its condition and its probability of survival or subsequent reproductive success. Death or reproductive failure usually is not the result of a single deficit at a single point in time, but depends on both the frequency and duration of multiple deficit periods, as well as their severity.

APPENDIX 2. Assumptions and equations for energy balance calculations.

ASSUMPTIONS:

1. Deer weighing 70 kg with a surface area of 2 m^2 (Moen 1968a)
2. Activity restricted to standing, to eliminate uncertainty on magnitude of conduction heat loss (Moen 1968a, Grace and Easterbee 1979)
3. Cloudless nocturnal periods lasting 12 hours
4. Ambient temperature of -20 C

ENERGY BALANCE EQUATION:

$Me + Ri + A = C + K + E + Ro$, where:
Me = metabolic energy derived from food
Ra = thermal radiation absorbed by animal
A = heat of activity
C = conductive heat loss (assumed negligible for standing deer)
K = convective heat loss
E = evaporative heat loss
Re = thermal radiation emitted from animal

METABOLIC ENERGY FROM FOOD:

$Me = (71.7\ \text{kcal/kg}^{0.75}\text{/day}) + (HIF)$, where:
the first term (in parentheses left of the +) is fasting metabolic rate (Webster 1983, Hudson and Christopherson 1985) and the second term is heat increment of feeding.
HIF = 340 kcal/Mcal of metabolizable energy (ME) consumed when intake of ME is below maintenance, 600 kcal/Mcal of ME when intake of ME exceeds maintenance (Webster 1983), and 470 kcal/Mcal of ME (by linear extrapolation) when intake of ME is equal to maintenance. ME for maintenance averages about 131 kcal/$kg^{0.75}$/day (Hudson and Christopherson 1985).

ABSORBED LONG WAVE RADIATION:

$Ra = eS_r D_d R_d + Es_r D_u R_u + Es_r D_h R_h$ (Moen 1968a), where:
e = long wave absorptivity (1.0)
S_r = radiation profile (0.7) (Moen 1968a, Grace and Easterbee 1979)
D_d = proportion of deer exposed to downward radiation flux (0.217) (calculated from Moen 1968a)
R_d = downward radiation flux at -20 C under cedar, hardwood, and open habitats (207, 188, and 170 kcal/m^2/hour, respectively) (Moen 1968d)
D_u = proportion of deer exposed to upward radiation flux (0.217) calculated from Moen 1968a)
R_u = upward radiation flux at -20 C (Moen 1968a)
D_h = proportion of deer exposed to horizontal radiation flux (0.564) (calculated from Moen 1968a)
R_h = horizontal radiation flux at -20 C (Moen 1968a)

ACTIVITY INCREMENT:

$A = I \cdot FMR$, where:
I = increment due to standing compared to lying down (1.2) (Fancy and White 1984:145)
FMR = fasting metabolic rate (see above)

CONVECTIVE HEAT LOSS:

$K = pc_p (T_s - T)/r_{Hs}$, where:
pc_p = density of air (p) · specific heat (c_p), c_p = 286.6 cal/m^3/°K (Parker and Gillingham (1990)
T_s = surface temperature of animal; averages about 4° warmer than air temperature with no wind and about 1° warmer than air temperature with winds of 4.5 m/s (Grace and Easterbee 1979). We assumed 4 C, 1.5 C, and 1 C warmer at 0, 3, and 6 m/s, respectively.
T = ambient (air) temperature
r_{Hs} = resistance to sensible heat flow; we used resistances presented by Grace and Easterby (1979:44) developed for red deer over a variety wind speeds.

EVAPORATIVE WATER LOSS:

$E = W \cdot LE$, where:
W = 0.005 g water/$kg^{0.75}$/min (respiratory water loss at -20 C, Parker and Robbins (1984))
LE = 0.6 kcal/g water evaporated (latent heat of evaporation, Campbell (1974:20))

EMITTED LONG WAVE RADIATION:

$Re = esS_r T^4$, where:
e = long wave emissivity (1.0) (Moen 1968a)
s = Stefan-Boltzman constant (4.93 · 10^{-8} kcal/m^2/hr/$K^{4)}$
S_r = radiation profile ($0.7S_t$), where S_t = total surface area (Moen 1968a)
T = surface temperature of animal (K)

BROWSE RESPONSE TO SPRING PRESCRIBED BURNING OF THE BURDETTE CREEK ELK WINTER RANGE, MONTANA

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: We used a modified twig-count method to sample current-annual-growth twigs of several important browse species on seven burn and respresentative control stands. Potential for increasing browse production in Kg/ha and g/twig appears greatest on southeast open shrubfields. Chokecherry, serviceberry, and shiny-leaf ceanothus all showed remarkable increases in mass the first growing season after spring burning. Serviceberry twigs, in particular, were about 500% heavier on burns. Mean twig weights on burns were significantly less after one-year.

Browse response to fire in the northern Rocky Mountains is well documented (Leege 1968, 1969, 1979, Leege and Hickey 1971, Asherin 1976, Merrill et al. 1982). These studies, however, involved habitat types and/or shrub species different from those characteristic of some western Montana shrub winter ranges.

The objective of this study was to assess changes in shrub production after spring prescribed burning within a mosaic of Douglas fir (*Pseudotsuga menziesii*) - mallow ninebark (*Physocarpus malvaceus*)/Douglas fir - bluebunch wheatgrass (*Agropyron spicatum*) habitat types (Pfister et al. 1977) in western Montana.

STUDY AREA

The Burdette Creek winter range encompasses nearly 6280 ha (15,700 acres) of National Forest land in the upper Fish Creek drainage, Ninemile Ranger District, Lolo National Forest. Its large size, contiguous Federal control, roadlessness and open south-facing slopes render it potentially the most important elk winter range on the Lolo National Forest (U.S. Forest Service 1988).

Elk movement and habitat-use studies have shown the primary winter range lies below 1,525 m (5,000 ft) (Bohne 1974, Zahn 1974, Lemke 1975, Lyon 1979). Habitat types on southeast to southwest facing slopes are predominantly Douglas fir-ninebark/Douglas fir-bluebunch wheatgrass mosaics; the latter is predominant on drier southwest exposures.

Shrub species used by elk include bitter cherry (*Prunus emarginata*), chokecherry (*P. virginiana*), serviceberry (*Amelanchier alnifolia*), and shiny-leaf ceanothus (*Ceanothus velutinus*) (Bohne 1974, U.S. Forest Service 1988). Mountain maple (*Acer glabrum*) and willow (*Salix scouleriana*) are also used but are not common on the areas described.

Fire scar analyses show a mean fire interval of 29.4 years (range 12-51 years) between 1731 and 1917 (Makela 1990). Lack of major fire events since 1917 have caused concern over the succession of forage areas toward conifer dominance and shrub senescence. In 1988 the U.S. Forest Service implemented a plan to burn about 500 acres per year for the ensuing decade to rejuvenate shrubs and hinder conifer encroachment (U.S. Forest Service 1988). Ideal burning conditions on 13 April 1988 enhanced efforts to aerially ignite the first acreage, providing a good opportunity to study browse response to fire.

METHODS

We selected 7 burn stands for study after an appraisal of treatment success. Stands which did not appear to burn well due to excessive gravel or moisture were not sampled. Representative unburned stands were chosen to serve as controls.

Thirty sampling points were systematically located on burn stands and 10-15 on controls. At each point, we randomly selected a compass azimuth in which to proceed while tallying current-annual-growth twigs by species and length-class in a 2m wide swath. Tallying continued until 100 total twigs were classified. Distance traveled was recorded to the nearest 0.1 m.

We also clipped twig samples of each species and length class. These were subsequently oven-dried at 100C and weighed to estimate a mean weight used in later calculations. Stands were sampled during August and September of 1988 and 1989.

To estimate total plot weight per 100 twigs (TPWT), we multiplied the number of twigs tallied for each species and length class by its respective mean weight in grams. TPWT's were then averaged across all plots in a stand to generate a stand mean TPWT.

Production per-unit-area was estimated by dividing TPWT by plot area in square m and averaging across the stand. Units were later converted to Kg/ha.

Mean weight per twig by species was estimated by dividing the species' contribution to plot weight across all length classes by the number of twigs tallied for that species. Plot means were averaged across the stand to yield a stand mean twig weight in grams.

Statistical comparison between burned and control

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Table 1. Mean weight in grams per 100 current-annual growth twigs on burned and control forage types on the Burdette Creek winter range, Lolo National Forest, Montana, 1988-89. Southeast Forested (SEF), Southwest Forested (SWF), Southwest Open Shrubfield (SWO), Southeast Open Shrubfield (SEO). Bitter cherry, chokecherry, shiny-leaf ceanothus, mountain maple, serviceberry combined.

		1988					1989				
Forage Type	Site	Burned	SE	Control	SE	Difference(%)	Burned	SE	Control	SE	Difference (%)
SEF	1	105^{ab}	6.9	27	4.5	289	60^{a}	5.7	44	10.0	36
	2	82^{ab}	4.6			204	51	7.1			16
SWF	1	125^{ab}	12.9	29^{b}	3.2	331	63^{a}	10.8	42	6.2	50
	2	48^{a}	5.3			66	25	3.4			-40
SWO	1	132^{ab}	18.6	40	7.5	230	65	17.5	65	20.4	0
SEO	1	188^{ab}	15.7	32^{b}	3.9	488	88	10.7	74	8.2	19

[a] Indicates difference between Burn and Control, same year ($P<0.1$) Student's 1-tailed t-test, assuming unequal variances.

[b] Indicates difference between years (1988-89), same treatment ($P<0.1$) Student's 2-tailed t-test, assuming unequal variances.

stands was facilitated by classifying stands by Forage Type. All stands reflected relatively similar ecological potential in terms of habitat type yet differences were obvious on the ground. Analysis, therefore, proceeded after classifying stands as Southeast Forested (SEF), Southwest Forested (SWF), Southwest Open Shrubfield (SWO), and Southeast Open Shrubfield (SEO). In this way, stands with statistically similar means could be lumped to increase sample size. From a management perspective, use of Forage Types makes practical sense as well, since stands can be easily identified in the field or on aerial photos during the planning process.

Student's t-test for samples of unequal variances was used to test differences in means between treatments. We used one-way analysis of variance to test differences between Forage Types of similar treatment and year.

RESULTS

Total Plot Weight (G/100 twigs)

Mean TPWT in grams per 100 twigs was significantly greater on burn stands in 1988 regardless of Forage Type (Table 1). The most dramatic difference occurred on the Southeast Open Shrubfield where an increase of nearly 490% was noted, compared to the control.

Burns and controls differed much less in 1989, one year after burning. TPWT on the forested burns was only 16-50% greater in most cases. On one burn stand, TPWT was less than the control. Open shrubfield burns differed from controls by 0-19% but not significantly so.

TPWT in 1988 was nearly double that of 1989 for most Burned Forage Types, and all were significantly different ($P<0.10$). Control TPWT's were heavier by at least 45% in 1989 but only significantly so for the SWF and SEO types (Table 1).

Production per Unit Area (Kg/ha)

Mean production differed significantly ($P<0.10$) between burns and controls on most Forage Types in 1988 (Table 2). SEF types exceeded the control by an average of 107%. One SWF site's production was 228% that of the control. A second SWF site, however, was 58% less than the control. The SWO burn and control did not differ significantly. The SEO burn again showed the greatest response of all types, and yielded a mean of 442 Kg/ha, compared to 91 Kg/ha for the control, a difference of 386% ($P<0.10$).

In 1989, total production did not differ significantly between any burn/control pairs. Of note is the decrease in percent difference between burns and controls as compared to 1988.

Production between 1988 and 1989 for a given treatment and Forage Type differed significantly ($P<0.10$) only on the SEO control where Kg/ha appears to have nearly tripled (Table 2). In general, production appears higher in 1989 across all controls except the SWO type, and lower on burned types. Wide variation makes interpretation tenuous, however.

Production per unit area across all Forage Types within

Table 2. Mean total browse production in Kg/ha on burned and control forage types on the Burdette Creek winter range, Lolo National Forest, Montana, 1988-89. Southeast Forested (SEF), Southwest Forested (SWF), Southwest Open Shrubfield (SWO), Southeast Open Shrubfield (SEO). Bitter Cherry Chokecherry, shiny-leaf ceanothus, mountain maple, serviceberry combined.

		1988					1989				
Forage Type	Site	Burned	SE	Control	SE	Difference (%)	Burned	SE	Control	SE	Difference (%)
SEF	1	74^a	12.4	31	8.7	139	94	21.3	64	22.1	47
	2	50^a	9.4			61	46	10.6			-28
SWF	1	118a	35.7	36	9.8	228	133	41.7	39	8.6	241
	2	15	3.0			-58	9	2.8			-77
SWO	1	190	54.8	250	104.9	-24	89	28.4	89	30.9	0
SEO	1	442^a	89.5	91^b	23.4	386	389	65.8	331	65.4	18

[a] Indicates difference between Burn and Control, same year ($P<0.1$) Student's 1-tailed t-test, assuming unequal variances.

[b] Indicates difference between years (1988-89), same treatment ($P<0.1$) Student's 2-tailed t-test, assuming unequal variances.

a given year and treatment was consistently greatest on the SEO and SWO type ($P<0.05$).

Mean Weight per Twig by Species

A major difference between burn and control sites was obvious for all Forage Types in 1988. Virtually all shrub species showed a significantly greater mean twig weight after burning ($P<0.10$). Serviceberry, in particular, generally exceeded controls by more than 500% (Table 3).

Differences were less remarkable for 1989. Twigs on burns were still significantly heavier than those on controls in most cases ($P<0.10$), but by a decidedly smaller margin than in 1988. Serviceberry mean twig weight on burns averaged only 57% heavier than controls across all Forage Types (Range 0-125). Chokecherry twig weights on burns still exceeded controls by at least a two-fold margin.

Mean weight per ceanothus twig significantly exceeded controls only on the SEO burn and SWF burn site. Interpretation of effects on this species were confounded by heavy mortality caused by a brief winter thaw immediately followed by subzero temperatures early in 1989. Mean twig weights between 1988 and 1989 for a given species, Forage Type and Treatment differed significantly ($P<0.10$) in virtually all cases (Table 3). In 1989 burn weights for deciduous species were about one-half those of 1988, whereas mean weights on controls were heavier by at least one-third. On burns, mean weights for *Ceanothus* twigs were 20-40% less in 1989; control weights were 2 to 4 times heavier, with the SWO type showing the greatest difference.

DISCUSSION

Effects of a 1988 spring prescribed burn on several key forage shrubs within a Douglas fir-ninebark, Douglas fir-bluebunch wheatgrass habitat type mosaic were impressive the first growing season. While ecological potential is generally similar across the four Forage Types considered, potential for enhancing the browse resource appears to be greater on southeast open shrubfields, both in terms of weight per-unit-area and robustness of individual twigs. Intuitively, potential should be high on southwest open shrubfields as well but radical differences in production per ha were not observed. Invariably, estimates of production by area involve large variances owing to the patchy distribution of shrubs and the difficulty in attaining desired precision and accuracy due to logistical constraints (Lyon 1968). The difficulty in locating suitable representative control sites also affects comparisons in studies such as this. Replicate sampling across many stands within a given Forage Type would be the ideal but can be impractical due to budget and manpower limits or lack of burn windows in the spring to accomplish the task.

We contend, however, that under ideal burning conditions and with use of a helitorch, browse production on this winter range can be expected to at least double the

Table 3. Mean weight per twig in grams on burned and control forage types on the Burdette Creek winter range, Lolo National Forest, Montana 1988-89. Southeast Forested (SEF), Southwest Forested (SWF) Southwest Open Shrubfield (SWO), Southeast Open Shrubfield (SEO).

			1988					1989				
Forage Type	Site	Species	Burned	SE	Control	SE	(%) Difference	Burned	SE	Control	SE	(%) Difference
SEF	1	AMAL	0.88[ac]	0.04	0.12[c]	0.01	633	0.33[b]	0.03	0.16	0.01	106
		CEVE	1.82[a]	0.28	0.52[c]	0.03	250	1.79	0.12	1.43	0.27	25
		PREM	0.84[ac]	0.09	0.09[a]	0.03	833	0.21	0.04	[d]	[d]	[d]
		PRVI	1.02[ac]	0.10	0.44	0.29	132	0.46[b]	0.05	0.17	0.04	171
	2	AMAL	0.78[ac]	0.06	0.12[c]	0.01	550	0.36[b]	0.05	0.16	0.01	125
		CEVE	1.53[a]	0.56	0.52[c]	0.03	194	1.21	0.15	1.43	0.27	-15
		PRVI	0.84[c]	0.08	0.44	0.29	91	0.50[b]	0.06	0.17	0.04	194
SWF	1	AMAL	0.80[ac]	0.06	0.11[c]	0.01	627	0.24[b]	0.02	0.18	0.01	33
		CEVE	2.85[ac]	0.28	0.58[c]	0.02	391	1.85[b]	0.19	1.44	0.12	28
		PREM	[d]	[d]	0.12[c]	[d]	[d]	0.24[d]	0.05	0.23	0.03	4
		PRVI	0.71[ac]	0.14	0.13[c]	0.02	446	0.35[b]	0.06	0.18	0.02	94
	2	AMAL	0.41[ac]	0.03	0.11[c]	0.01	273	0.18	0.01	0.18	0.01	0
		CEVE	2.01	0.96	0.58[c]	0.02	247	1.22	0.26	1.44	0.12	-15
		PREM	0.51[a]	0.13	0.12[c]	0.02	325	0.17	0.04	0.23	0.03	-26
		PRVI	0.59[a]	0.16	0.13[c]	0.02	354	0.41	0.11	0.18	0.02	128
SWO	1	AMAL	0.81[ac]	0.08	0.11[c]	0.02	636	0.32	0.05	0.24	0.01	33
		CEVE	3.44[ac]	0.46	0.61[c]	0.02	464	1.97	0.27	1.99	0.36	-1
		PRVI	1.29[d]	0.13	0.55	0.04	135	0.30	0.08	0.41	0.09	-27
SEO	1	AMAL	0.99[ac]	0.07	0.14[c]	0.01	607	0.38[b]	0.05	0.26	0.03	46
		CEVE	3.29[ac]	0.24	0.61[c]	0.02	439	1.99[b]	0.18	1.41	0.13	41
		PRVI	1.40[ac]	0.12	0.13[c]	0.02	977	0.46[b]	0.05	0.21	0.03	119

[a] Indicates difference between burn and control, same year ($P<0.1$) Students' 1-tailed t-test, assuming unequal variances.
[b] Indicates difference between burn and control, same year ($P<0.1$) Students' 2-tailed t-test, assuming unequal variances.
[c] Indicates difference between 1988-89, same treatment ($P<0.1$), Students' 2-tailed t-test, assuming unequal variances.
[d] Insufficent n to test or none in plots

first growing season after treatment, for most stands. Variation is great enough, however, that less than ideal conditions should dictate a careful reassessment of burn objectives and perhaps a postponement of burn day to capitalize on the first growing season's surge in production. Focus should be on open shrubfields having significant components of serviceberry, chokecherry and/or shinyleaf ceanothus.

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RESPONSES OF ELK TO DEVELOPMENT OF EXXON'S RILEY RIDGE GAS FIELD IN WESTERN WYOMING

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: Responses of wintering and calving elk (*Cervus elaphus*) to the development of Exxon's natural gas wellfield on public lands near La Barge, WY were measured by comparing changes in distribution patterns and numbers sighted between pre-construction, construction, post-construction, and production periods. Elk numbers and locations were determined from counts conducted from aircraft between 1979 and 1990. Differences in numbers of elk sighted in individual sections of land between the 4 periods were tested with chi-square procedures. On both winter and calving ranges elk moved out of or away from areas where construction activities were occurring and returned when these intensive activities ceased. Elk trend counts and hunter harvest data indicated that construction activities did not cause a reduction of elk numbers in the herd unit. The study exemplifies the critical value of thorough long-term planning and execution of baseline wildlife research, the need for consistent long-term data collection, and the continuing cooperation between industry and resource management agencies in siting oil and gas development to minimize impacts to wildlife.

INTRODUCTION AND HISTORY

Our study was conducted in southwest Wyoming in the Overthrust Belt (Fig. 1), which includes mountain ranges that support diverse wildlife populations. Exploration for hydrocarbon reserves occurred in the 1960s and the Riley Ridge Gas Field was discovered on the southeast side of the Wyoming Range. The gas was found at depths below 4,250 m and contained methane, carbon dioxide, and hydrogen sulfide. This field was not developed because of the high cost of construction and relatively poor quality of gas. However, the high energy prices of the 1970s and early 1980s made it economically feasible to explore for and develop this and other natural gas fields in the Overthrust Belt.

Between 1978 and 1982 exploratory wells that defined the extent of the Riley Ridge field were drilled and, in 1982, 4 companies announced plans to develop their leases within this field. An Environmental Impact Statement (USDI - BLM and USDA - FS 1984a) and Record of Decision (USDI - BLM and USDA - FS 1984b) identified issues and general mitigation measures and served as a basis for planning field development. Site-specific mitigation measures were developed for each well, road, and facility constructed. Only Exxon Company U. S. A. (Exxon) proceeded with field development. Exxon received necessary permits from the state of Wyoming through the Industrial Siting Council, and additional mitigation was identified. One measure provided funding to the Wyoming Game and Fish Department (WGFD) to monitor response of elk to construction activities. Exxon's siting permit included drilling 18 wells and constructing pipeline and manifold structures, dehydration facilities and a gas treatment plant. Exxon's LaBarge Project was developed between 1984 and 1986 over 16,400 ha, overlapping summer, winter, crucial winter, and calving ranges of elk (Fig. 2).

Based on various studies of elk response to logging (Black et al. 1976, Hearshey and Leege 1976, Lyon 1976), roads (Lyon 1979, Ward 1976, Rost and Bailey 1979), and seismic exploration (Gillin 1989), WGFD was concerned that wells drilled on crucial winter ranges and calving areas could have a negative impact on elk. In these studies, elk moved at least 0.8 km from activities or placed a physiographic barrier between themselves and the disturbance. Most of these studies were on summer ranges. Elk response to activities on winter range was less documented. Hayden-Wing (1979) found that snow depth was second only to human disturbance in controlling elk use of winter range. Sweeney and Sweeney (1984) found that elk preferred areas where snow was <40 cm deep but would forage in areas where snow was up to 70 cm deep. Knight (1980) found that elk habituated to drilling in northern Michigan where >90% of the study area was forested and provided abundant hiding and security cover. Ward (1976) found that elk habituated to constantly moving traffic along Interstate Highway 80.

We determined elk distribution on 2 segments of the wellfield, Snider Basin calving area and Graphite Hollow/Rock Creek (GH/RC) winter range, from 1979 to 1990. We compared distributions of elk during pre-construction, construction, post-construction, and production periods and evaluated effectiveness of mitigation measures implemented. Elk responses were contrasted to responses from earlier, unrelated oil and gas development on adjacent elk winter ranges where planning and coordination did not occur. No attempt was made in this study to analyze the cumulative effects of the entire project on elk distribution or numbers within the entire wellfield.

STUDY AREA

Graphite Hollow/Rock Creek Winter Range

The GH/RC winter range is administered by the BLM (Fig. 2) and includes Graphite Hollow, Long Hollow, Rock

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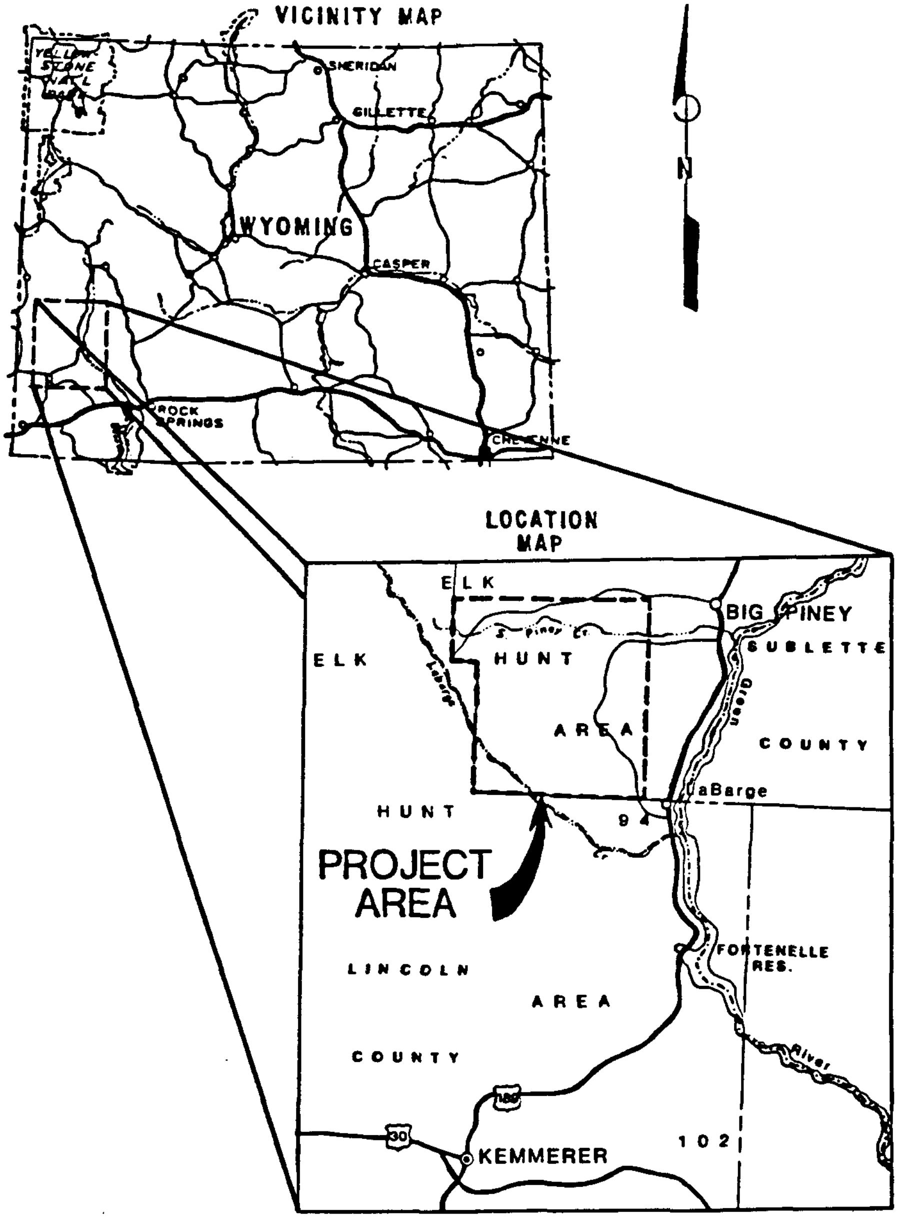


Fig. 1. Location of the Riley Ridge gas field on the east side of the Wyoming Range in southwest Wyoming.

Creek, and portions of Cedar Creek and Dry Piney Creek drainages. This winter range is located on the southern end of Deadline Ridge and varies in elevation from 2,200 to 2,900 m. Extensive oil and gas development occurred on Cedar Creek and Dry Creek drainages during the 1950s, 60s, and 70s. Foraging areas on the winter range are limited mostly to ridges or slopes with southern or southwestern aspects where wind and solar insolation reduce snow depths. Vegetation on foraging areas is a mix of shrubs and grasses, dominated by sagebrush (*Artemisia* spp.). Areas of drifted and deep snow are found on northern and western exposures within this winter range. Conifer cover, mostly lodgepole pine (*Pinus contorta*) is limited to the higher elevations and northerly aspects at lower elevations.

Exxon filed an Application for Permit to Drill (APD) a well in Graphite Hollow in 1984, 1 year earlier than originally planned. The proposed well site was on a ridge about 0.8 km from the nearest conifer cover. Negotiations were held among BLM, Exxon, and WGFD representatives over this well, and mitigation measures were identified. The well was moved into conifer cover, and Exxon used directional drilling techniques to reach the drilling target. The drill pad was constructed in summer 1984, and drilling

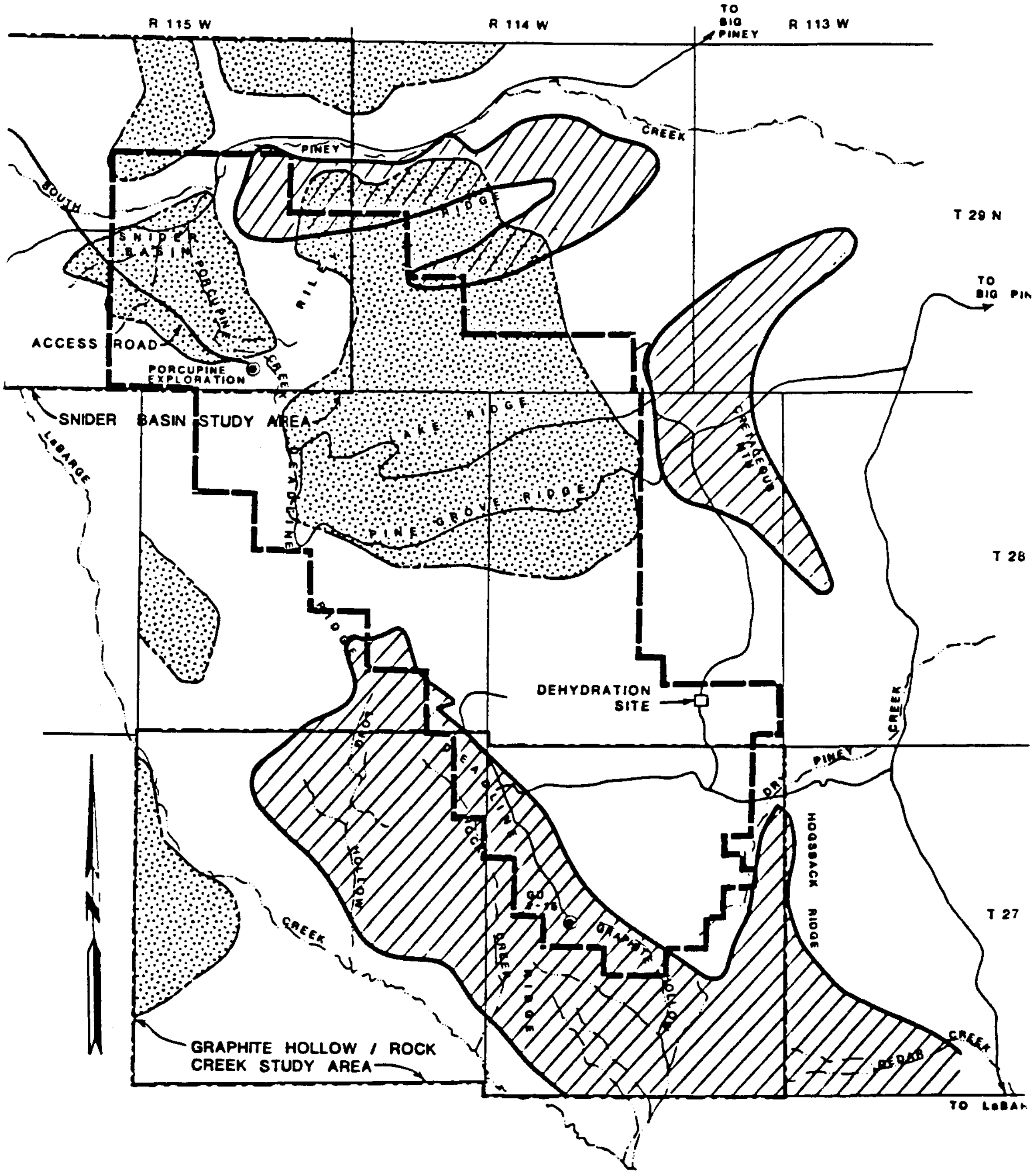
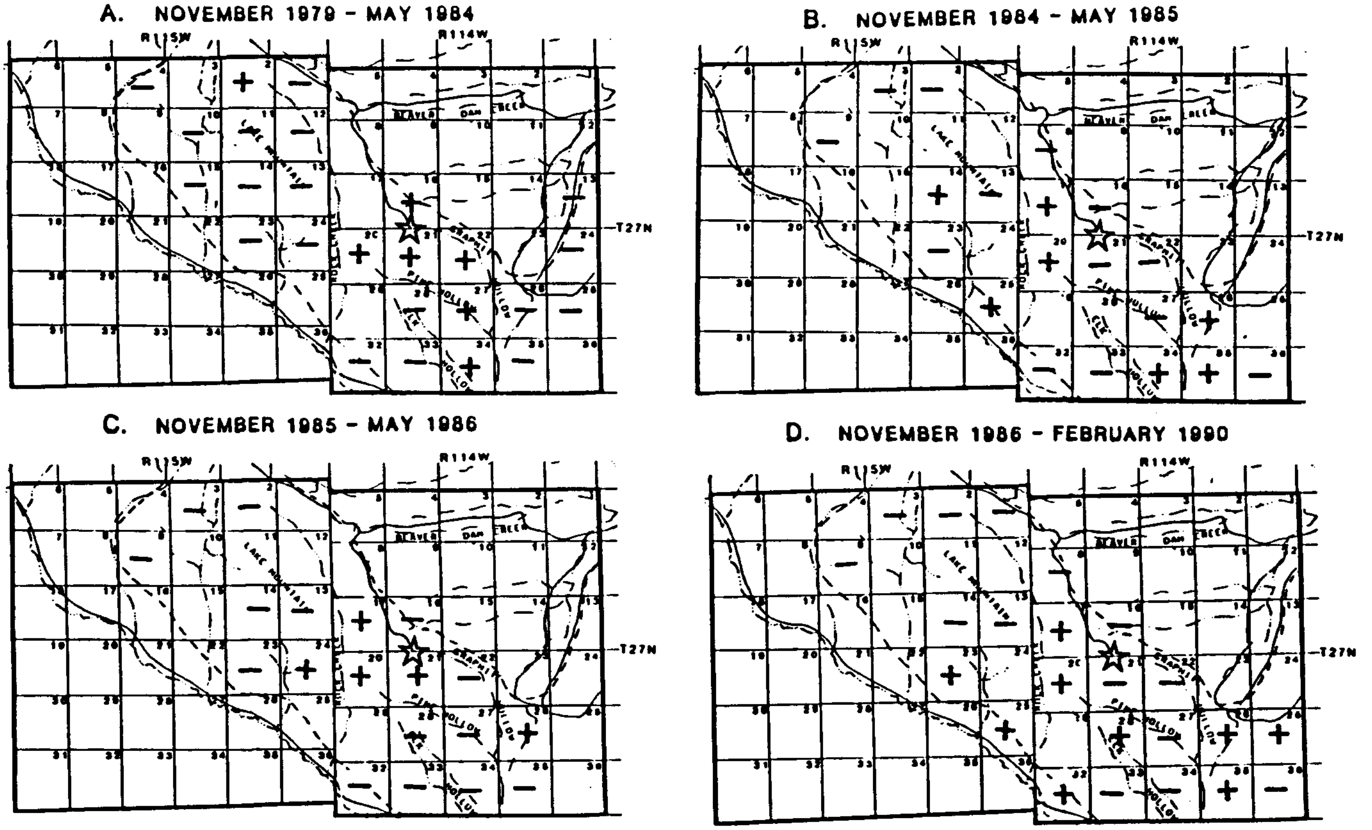


Fig. 2. Locations of wells studied in relation to elk winter and calving ranges within the wellfield of the LaBarge Project, Wyoming.

started that fall. The access road, located in conifers, was not visible from foraging areas on the winter range and approached the well from the north (Fig. 3b). Foraging areas within the winter range were closed to all motorized vehicles, including snow machines, by the BLM. Drilling was completed on 19 December 1985, and all activities at the well site ended after mid-January 1986. Pipelines were constructed in summer 1986, and the well was placed into service that summer. Since then the well has been checked at least twice weekly via over-snow vehicles, and



☆ = Well, - = Less than expected ($P < 0.05$), + = More than expected ($P < 0.05$), ----- Winter range, — = Roads.

Fig. 3. Comparisons of distribution of elk, by sections, on Graphite Hollow/Rock Creek winter range, Wyoming, during pre-construction (A), construction (B), post-construction (C), and production (D) using X^2 analysis. During the pre-construction period, expected values were based on assumed uniform distribution of elk among sections. During the other 3 periods, expected values for X^2 were based on observed distribution in pre-construction period.

by remote sensing. The well location was separated from the foraging areas on the winter range by about 30 m of aspen (*Populus tremuloides*) and lodgepole pine trees. When the well location was reclaimed in summer 1986, lodgepole pines 3-5 m tall were planted between the well head and foraging areas to provide an additional visual barrier to the winter range.

Snider Basin Calving Area

The Snider Basin calving area, on the Bridger-Teton National Forest (Fig. 4) was described by Johnson and Lockman (1980). When Exxon filed an APD, in 1978, to drill an exploratory well in Snider Basin, concerns were raised about the response of elk during calving to activities associated with drilling this well. Field inspections of the site were made, along with discussions in meetings involving Exxon, Forest Service (FS), and WGFD representatives. As a result of this planning, the well and access road were sited within conifer stands to reduce visibility and buffer noise levels. The road was closed to all public traffic during and after construction. The FS used the road occasionally for administrative use. Drilling was to be completed by May 1, prior to the elk calving season.

Drilling the well to the depth needed (>4,250 m) was more difficult than expected, and Exxon was unable to meet the calving season deadline. When Exxon was granted permission to extend drilling beyond the May 1 cutoff date, it provided an opportunity to evaluate the response of elk during calving to construction activity (Johnson and Lockman 1980). During 1984, a second well was drilled during the calving season in Snider Basin (Fig. 4c) and provided a second opportunity to evaluate elk responses. The second well site and access road were also placed in locations where they were screened from the calving range by conifer stands. Roads were closed after construction was complete. None of the wells in Snider Basin have been placed into production,

Table 1. Snow depths in Snider Basin and number of elk counted on aerial surveys of the Graphite Hollow/Rock Creek winter range, Wyoming, April 1979 - February 1990.

Period	Date			Snow Depth		Elk Counted
				Cm	% of 25[b] year mean	
Pre-construction						
	27	Apr	1979	79	86	153
	27	Apr	1980	86	94	142
	4	May	1980	74	81	70
	13	Mar	1981[a]	69	54	138
	16	Jan	1982	147	132	159
	18	Feb	1982[a]	150	118	282
	13	Jan	1983[a]	84	75	161
	15	Apr	1983	109	86	122
	5	Jan	1984[a]	102	91	209
	4	Apr	1984	117	90	248
Construction						
	3	Jan	1985	94	84	163
	10	Jan	1985[a]	94	84	203
	16	Feb	1985	107	96	80
	28	Feb	1985	124	98	171
	5	Mar	1985	124	98	226
	20	Mar	1985	127	98	124
	6	Apr	1985	119	92	140
	24	Apr	1985	71	78	153
	1	May	1985	51	56	91
Post-construction						
	26	Dec	1985	109	98	175
	4	Jan	1986[a]	109	98	197
	29	Jan	1986	109	98	114
	4	Mar	1984	190	150	162
	17	Mar	1986	142	110	117
	1	May	1986	127	139	80
Production						
	17	Feb	1987[a]	109	86	168
	28	Jan	1988	91	82	203
	20	Feb	1988[a]	96	76	249
	10	May	1988	46	50	14
	18	Jan	1989	91	82	173
	9	Feb	1989[a]	96	86	207
	13	Jan	1990	69	61	52
	31	Jan	1990[a]	107	95	186
	23	Feb	1990	104	82	135

[a] Trend Count

[b] 1961-1985 mean for February 1=112 cm; March 1=127 cm; April 1=130 cm; May 1=91 cm.

consequently, the conclusions drawn in this paper about calving areas refer only to responses of elk to drilling activities.

Piney Elk Herd

Both study areas were in elk Hunt Area 94, and the GH/RC area abuts Hunt Area 102 on LaBarge Creek (Fig. 1). Hunt Areas 94 and 92 have 518 km^2 of occupied elk habitat and comprise the Piney Elk Herd. Elk are managed by herd units by the WGFD with management objectives for population, harvest, number of hunters, recreation days, and days hunted per animal harvested. Five feedgrounds

Table 2. Total numbers of elk counted on sections of land within crucial elk winter range on Graphite Hollow/ Rock Creek winter range, Wyoming, April 1979 - February 1990 during ground and aerial surveys.

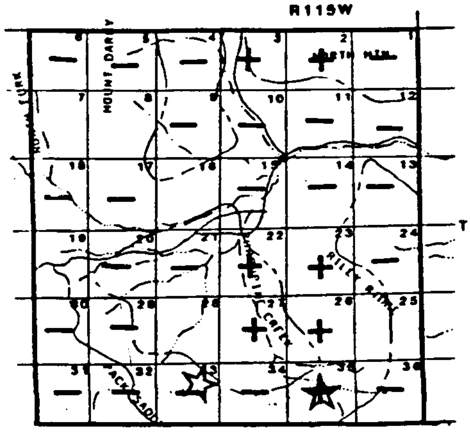
	Period											
Section	Pre-construction			Construction			Post-construction			Production		
	No.	(%)	Prob.	No.	(%)	Prob.	No.	(%)	Prob.	No.	(%)	Prob.
T27N, R114W												
8	53	(3.1)[a]	0.105-	25	(1.9)	0.012-	29	(3.4)	0.62	0	(0.0)	>0.001-
16	88	(5.1)	0.008+	0	(0.0)	>0.001-	0	(0.0)	>0.001-	22	(1.3)	>0.001-
17	55	(3.2)	0.17 -	451	(33.4)	>0.001+	105	(12.4)	>0.001+	379	(21.8)	>0.001+
20	134	(7.8)	>0.001+	245	(18.1)	>0.001+	333	(39.4)	>0.001+	246	(14.1)	>0.001+
21	117	(6.8)	>0.001+	70	(5.2)	0.023-	103	(12.2)	>0.001+	88	(5.1)	0.004-
22	307	(17.8)	>0.001+	36	(2.7)	>0.001-	92	(10.9)	>0.001-	52	(3.0)	>0.001-
25	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	151	(8.7)	NA+
26	43	(2.5)	0.004-	96	(7.1)	>0.001+	98	(11.6)	>0.001+	131	(7.5)	>0.001+
27	217	(12.6)	>0.001+	47	(3.5)	>0.001-	0	(0.0)	>0.001-	111	(6.4)	>0.001-
28	35	(2.0)	>0.001-	24	(1.8)	0.578	0	(0.0)	>0.001-	84	(4.8)	>0.001+
29	56	(3.2)	0.21 -	51	(3.8)	0.301	21	(2.5)	0.00[b]	41	(2.8)	0.312-
32	9	(0.5)	>0.001-	0	(0.0)	0.013-	0	(0.0)	0.006-	23	(1.3)	0.001+
33	17	(1.0)	>0.001-	0	(0.0)	>0.001-	0	(0.0)	>0.001-	0	(0.0)	0.001-
34	95	(5.5)	>0.001+	174	(12.9)	>0.001+	0	(0.0)	>0.001-	0	(0.0)	0.001-
35	22	(1.3)	>0.001-	28	(2.1)	0.012+	0	(0.0)	>0.001-	186	(10.7)	0.001+
36	55	(3.2)	0.17 +	0	(0.0)	>0.001-	25	(3.0)	0.070	0	(0.0)	0.001-
T27N, R115W												
1	4	(0.2)	>0.001-	0	(0.0)	0.136-	0	(0.0)	0.45	0	(0.0)	0.024-
2	166	(9.6)	>0.001+	0	(0.0)	>0.001-	0	(0.0)	>0.001-	2	(0.1)	>0.001-
3	74	(4.3)	0.377	0	(0.0)	>0.001-	0	(0.0)	>0.001-	4	(0.2)	>0.001-
5	18	(1.0)	>0.001-	0	(0.0)	>0.001-	0	(0.0)	0.005-	0	(0.0)	>0.001-
8	4	(0.2)	>0.001-	0	(0.0)	0.136-	0	(0.0)	0.45	1	(0.1)	0.078-
9	67	(3.9)	0.00[b]	0	(0.0)	>0.001-	0	(0.0)	>0.001-	0	(0.0)	>0.001-
10	3	(0.2)	>0.001-	0	(0.0)	0.227-	0	(0.0)	0.41	0	(0.0)	0.426-
11	0	(0.0)	0.00[b]	3	(0.2)	NA	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]
12	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	3	(0.2)	NA+
13	28	(1.6)	>0.001-	0	(0.0)	>0.001-	0	(0.0)	0.013-	4	(0.2)	>0.001-
14	17	(1.0)	>0.001-	71	(5.3)	>0.001+	4	(0.5)	0.007-	0	(0.0)	>0.001-
15	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	2	(0.1)	NA
16	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	12	(0.7)	NA+
23	28	(1.6)	>0.001-	0	(0.0)	>0.001-	1	(0.1)	>0.001-	40	(2.3)	0.032+
24	16	(0.9)	>0.001-	10	(0.7)	0.549	25	(3.0)	>0.001+	10	(0.6)	0.008
25	0	(0.0)	0.00[b]	20	(1.4)	NA+	8	(0.9)	NA+	149	(8.6)	NA+
26	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]
27	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	0	(0.0)	0.00[b]	1	(0.1)	NA
Totals	1728			1351			844			1742		

[a] Numbers in parentheses ( ) represent % of total count for period.

[b] Expected value = 0; could not calculate X^2 value.

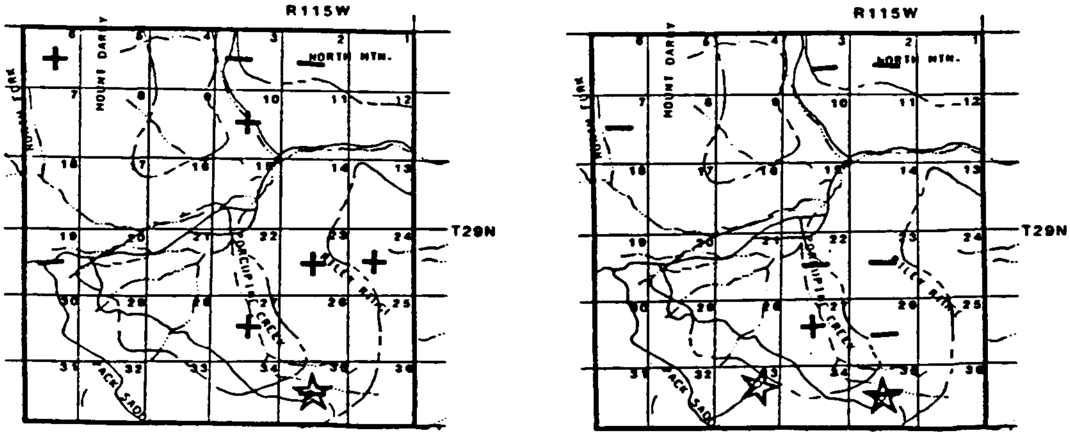
are located in this herd, and the WGFD has an objective for the number of elk at each feedground. Feedgrounds were established to minimized elk damage to stored crops. Prior to 1986, the population objective for this herd was about 1700 elk on feedgrounds and 450 elk on native winter range. In 1986, the feedground objectives were

A. NO CONSTRUCTION 1980 - 1983; 1985 - 1987



B. 1979 CONSTRUCTION PERIOD

C. 1984 CONSTRUCTION PERIOD



☆ = Well, - = Less than expected ($P < 0.05$), + = More than expected ($P < 0.05$), ----- Winter range, — = Roads.

Fig. 4. Comparisons of distribution of elk, by section, on Snider Basin calving area, Wyoming, during no-construction periods (A), and 2 construction periods (B and C) using X^2 tests. During the no-construction period, expected values were based on assumed uniform distribution of elk among sections. During the 2 other periods, expected values for X^2 were based on observed distribution in the no-construction period.

changed, increasing the objective for this herd to 2,424 elk. The closest feedground was about 29 km north of the GH/RC winter range, the largest native winter range within the herd unit. Hunt Area 102, part of the West Green River Elk Herd, contains no feedgrounds.

METHODS

Elk Numbers

Numbers of elk on the GH/RC winter range were obtained from November 16 - May 14 each winter. During the pre-construction period (April 1979 - May 1994), 10 surveys were flown, and 1728 elk were observed. During the construction period (November 1984 - May 1985), 9 flights were made, and 1351 elk were counted. Six surveys were conducted during the November 1985 - May 1986 post-construction period, and 844 elk were counted. Nine flights were made during the production period, November 1986 - February 1990, and 1742 elk were counted (Tables 1 and 2).

The number of elk counted on winter trend counts and the mean number counted on all flights among the 4 periods were compared using ANOVA. Data from flights where less than 100 elk were counted were deleted, because they generally consisted of late winter/spring counts after most elk had left winter ranges.

Aerial surveys were conducted in the Snider Basin

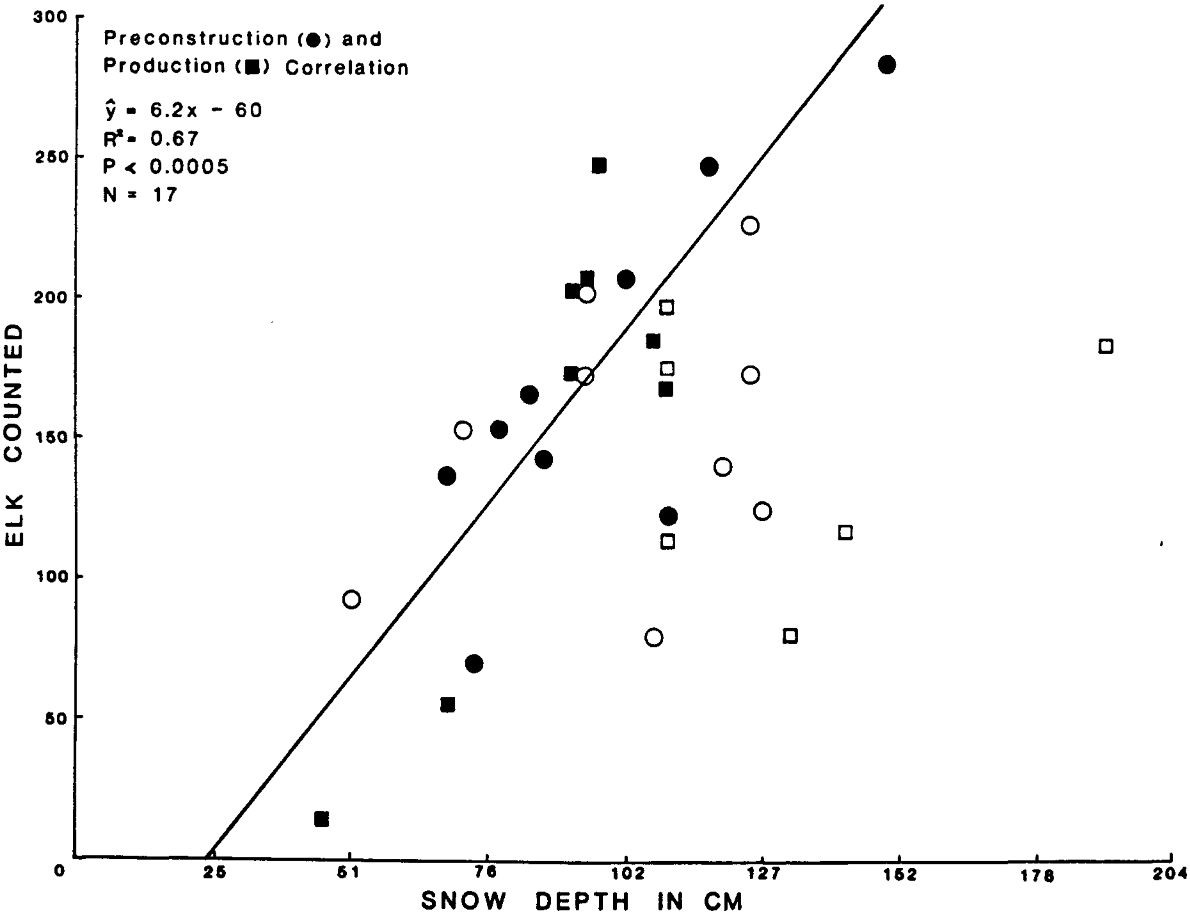


Fig. 5. Correlation between snow depths and numbers of elk counted on Graphite Hollow/Rock Creek winter range, Wyoming, during pre-construction (April 1979 - May 1984) and production (November 1986 - February 1990) periods. There was no correlation between snow depths and numbers of elk counted during construction (November 1984 - May 1985) and post-construction (November 1985 - May 1986) periods (open symobls).

area at least once each year during the calving period (May 16 - July 15), usually during late May or early June from 1979 - 1988. Elk were observed on 27 days during the 1980 calving season and on 24 other days from 1979 - 1988. A large amount of data was collected during 1979 and 1980 (Johnson and Lockman 1980). During the construction periods (1979 and 1984), 229 elk were counted; 917 were counted during the first no-construction period (1980 - 1983). A total of 56 was counted during the second no-construction period (1985 - 1988).

Most flights were made in fixed wing aircraft, except 1 winter-trend count made each year from 1981 - 1990 in a helicopter. All winter ranges were surveyed on trend counts.

Elk Distribution

Observations made during aerial surveys were pooled with all other observations of elk distribution stored in the WGFD's computerized Wildlife Observation System (WOS). These pooled data were used to analyze changes in elk distribution. No useable information existed prior to 1979 in the WOS for our study area (i.e., elk locations reported by legal description).

Chi-square goodness of fit (Zar 1974) was used to test the hypothesis that elk were uniformly distributed on winter range in the pre-construction period and to identify areas where elk concentrated, as well as areas that were unused or lightly used. Expected distribution was a uniform distribution. Significant changes in distribution during construction, post-construction and production were also determined with chi-square goodness of fit tests. Observed distributions in the pre-construction period served as expected values, and totals were adjusted to equal the sample sizes in the various periods. A separate chi-square test was preformed for each section. The same tests were performed on calving range, only observations from the no-construction period served as expected values when analyzing distribution observed during the 2 construction periods.

Snow Depths

Measurements of snow depth were obtained from a USDA Soil Conservation Service (SCS) snow survey site in Snider Basin at 2,442 m, 22 km N of the winter range. Snow depths were extrapolated for flights on days when the SCS did not measure snow depths between February 1 and May 14. Snow depths from February 1 were used for flights conducted in January. Annual snowpack was the mean of the February 1, March 1, and April 1 snow depths.

A linear regression and correlation of elk numbers counted (dependent variable) with snow depth were determined for the 4 periods. The hypothesis tested was elk numbers counted were not correlated with snow depth during the 4 periods.

Elk Harvest

Harvest statistics were estimated annually by a random mail survey of elk hunters by the University of Wyoming. Harvest was summarized by hunt area.

RESULTS

Snider Basin Calving Area

Significant differences in elk distribution patterns between construction and no-construction periods were observed and showed that elk moved away from construction activities during the 1979 and 1984 calving seasons and, following the completion of drilling, began to return the next year (Fig. 4). During the no-construction periods, elk were concentrated in 8 sections ($P < 0.05$). Five were in the south end of Snider Basin, and 3 were in north end of the township (Figure 4a). During the 1979 construction period, elk used the section where the well was drilled significantly less ($P = 0.004$). However, elk numbers in the rest of the calving area immediately north of the well (Sections 22, 23, 26, and 27) were significantly higher ($P < 0.01$) or the same as those during the no-construction period (Fig. 4b). In the 1984 construction period, elk were observed only in the NE corner of Section 27, where use was significantly higher than expected ($P< 0.001$).

Graphite Hollow/Rock Creek Winter Range

Elk Numbers.--Numbers of elk counted during the pre-construction flights were positively correlated with depth of snow ($r^2 = 0.66$, $P = 0.008$, $n = 9$) as were numbers counted on flights during the production period ($r^2 = 0.73$, $P = 0.007$, $n = 8$). When these periods were combined, numbers counted were positively correlated ($r^2 = 0.67$, $P < 0.001$, $n = 17$; Fig. 5, Table 1). During the construction period, numbers of elk counted were not correlated with snow depths ($r^2 = 0.11$, $P = .376$, $n = 9$). Similarly, numbers of elk counted on flights in the post-construction period were not correlated with snow depths ($r^2 = 0.0004$, $P = 0.97$, $n = 6$). During the construction and post-construction periods, elk numbers were highest early in winter and then declined as winter progressed. In 6 flights during these 2 periods, significantly fewer elk ($P < 0.05$) were counted than the number predicted by the linear regression developed for the pre-construction and production periods. These 6 flights occurred later in winter indicating elk left the winter range prematurely, when snow depth was still maximum.

Throughout the study there were no significant differences among the 4 periods in numbers of elk counted on: (1) trend counts ($P = .99$, $n = 10$), or (2) all aerial flights where more than 100 elk were counted ($P = 0.19$, $n = 26$). No correlation between elk harvest and field development was apparent. Harvest in this herd varied from 463 in 1983 to 891 in 1982. In 1989, 808 elk were harvested.

Elk Distribution.--In the pre-construction period, elk used 7 sections significantly more ($P < 0.05$) than expected. Five of these occurred in Graphite Hollow (Fig. 3a). Elk use in the Rock Creek drainage was similar to expected in 3 sections, and higher ($P < 0.05$) than expected in 2 sections. Within the mapped winter range 18 sections were used less than expected ($P < 0.05$). Mean annual snowpack during this period ranged from 54% - 127% of the 25-mean and averaged 94% (Table 3).

The well was drilled at the head of Graphite Hollow in NWNE Sec 21. During the construction period elk use increased west and southeast of the drill site. Significantly fewer elk were counted in the head of Graphite Hollow (Sections 16, 21, and 22) adjacent to the well site (Fig. 3b, Table 2). Significantly higher than expected numbers of elk were counted in Sections 26, 34, and 35:R114W, which were > 4 km from the well site, and in Sections 14 and 25:T115W, which were 2.4 to 4.8 km from the well site. Significantly more elk than expected were counted in the Rock Creek drainage (Sections 17 and 20). This area was 0.8 to 2.8 km from the well site and insulated from it by a stand of lodgepole pine and a ridge. Mean snowpack during this period was 94% of the 25-year mean.

During the post-construction period (Fig. 3-C), elk were concentrated in the central portion of the study area. Elk numbers were significantly higher than expected ($P < 0.02$) on Section 21 (the section the well was drilled in), Sections 17 and 20, (sections adjacent to the well), and Sections 24:R115W and 26:R114W (located between 2.4 to 3.2 km from the well). Use of the rest of the head of Graphite Hollow (Sections 16, 22, and 27) was less than expected. Mean snowpack this year was 128% of the 25-year mean.

Distribution of elk on the GH/RC winter range during the production period was much more dispersed than during any of the other 3 periods with greater than expected numbers of elk counted farther to the west, south, and southeast than had been previously observed (Fig. 3d and Table 2). Observed elk numbers in the northern portion of the winter range remained low. The greatest concentrations of elk were in 6 central and southeastern sections of the winter range. Elk use on these sections constituted 71% of all elk seen and was significantly greater than during the pre-construction period. The south end of Lake Mountain (Section 25) was also used significantly more than in the pre-construction period.

The proportion of the elk observed in the 5 sections closest to the well (16, 17, 20, 21, and 22) was higher in each of the 3 periods following the pre-construction period, with the highest occurring in the post-construction period (Table 4). Patterns of change in numbers of elk observed within these 5 sections varied considerably among sections. Numbers of elk sighted in Sections 17 and 20 were significantly higher than expected during each of the periods following pre-construction while numbers in Sections 16 and 22 remained significantly lower. Within these 5 sections, elk use increased the most in Sections 17 and 20, and declined the most in Sections 16 and 22. Twenty two elk were sighted in Section 16 in the production period. This was the first time elk were observed in this section since the pre-construction period and, although these proportions of total numbers observed were significantly lower than pre-construction levels ($P < 0.001$), (the return of elk to this section represents a noteworthy event). The number of elk sighted in the section east of the well (22) was significantly lower ($P < 0.001$) in all periods compared to the pre-construction numbers.

The proportion of the elk herd found in the 2 sections closest to the well (Sections 16 and 21) declined during the construction period (Table 4). Numbers of elk rebounded to greater than pre-construction proportions during the post-construction period, and fell to reduced levels again during the production period in Section 21. The proportion of elk found in R115W was lower during each of the 3 periods following pre-construction. The biggest decline occurred in the north end of Rock Creek (Section 2), while the greatest increase was on the south end of Lake Mountain (Section 25).

DISCUSSION

Snider Basin Calving Area

Elk responded to drilling activities during calving season by avoiding areas near drill sites and areas visible from access routes. They also moved calves at early dates, presumable away from drilling activities (Johnson and Lockman 1980). Elk returned to areas where drilling activities occurred the year after drilling. In both 1980 and 1985 there were no activities related to field development in Snider Basin, and elk were free of disturbance during the calving season. Because these wells were not placed into production, we cannot evaluate how elk respond to field production on this calving area.

Graphite Hollow/Rock Creek Winter Range

There were no significant differences among periods in number of elk counted on the GH/RC winter range. Numbers of elk counted during trend counts have shown a slight decline, but it has not been significant ($P = 0.17$), and may be related to lower snow depths the last 4 years. There was no evidence that construction activities associated with the well in the head of Graphite Hollow resulted in a decrease in elk numbers on this winter range. Similarly, there was no evidence that elk harvest was affected within the herd unit.

Snow conditions in winters during the pre-construction period ranged from very mild in 1981 - 82 to very severe in 1982 - 83 (Table 3). We assumed that elk distribution observed during this period (Fig. 3a) represented traditional preferences for habitats that provided for behavioral and physiological needs. Within the GH/RC winter range, 48% of the elk observed were found in Graphite Hollow (Sections 16, 21, 22, 27, and 34). Within the Rock Creek drainage, the highest numbers of elk were found in Section 20 (7.8%). Eighteen percent of the elk were found in Sections 2, 3, and 9 near the head of Long Hollow. These pre-construction concentration areas all contained foraging areas with adjacent cover, and were located on what were some of the most isolated portions of the winter range.

During the construction period elk moved 0.8 to 4.0 km away from the well site. Snow depth that winter was similar to the mean observed in the pre-construction period. Areas in Rock Creek where large numbers of elk were observed (Sections 17 and 20) were as close as 0.8 km from the well site. The use of this area by elk was probably enhanced by a mature stand of lodgepole pine and a ridge that were visual and auditory barriers between this area and the well site. The number of elk sighted in Section 34 was greater than expected during this period even though line-of-sight visibility to the well site was unobstructed from much of the area with no vegetative and little topographic hiding cover present. The fact that this section was > 3.2 km from the well site may have compensated for the lack of visual and auditory barriers and enhanced its acceptability to elk.

During the post-construction winter, there was no activity at the well site after mid-January, and snow depth was the highest reported during the study. Under these conditions elk appeared to forego some of their security preferences and moved closer to the well in exchange for shallower snow and greater forage availability. A higher proportion of the total elk counted that winter were observed using the head of Graphite Hollow (Sections 21, 22, and 26), compared to the construction period, and numbers observed in Sections 21 and 26 were significantly greater than observed in the preconstruction period. Elk numbers in Section 22 and 16 were still significantly lower than those observed during the pre-construction period. In this severe winter, elk use was concentrated in the central part of the winter range (Sections 20, 21, 22, and 26). Only 9% of all elk seen during the post-construction period were found in Section 17, in sharp contrast to the construction period when 33% of all elk counted were found that section. The decrease in use of Section 17 and increase in use of Sections 21, 22, and 26 between the construction and post-construction periods coincided with increased snow depth on this winter range and decreased activity at the well site.

Elk were more widely distributed during the production period than during any of the other periods. This widespread distribution appeared to be a function of lower snow depths, which were only 85-86% of the 25-year mean for each year, in combination with ongoing activities as the well site. The well was visited at least 2 times per week in this period. Elk use of the head of Graphite Hollow was greater than observed during the construction period, but less than observed during the pre-construction and post-construction periods when human activity was minimal. Observed numbers of elk were highest in the Rock Creek drainage 0.8 to >3.2 km from the well site (Sections 17, 20, and 25), and in the southeast corner of the study area >3.2 km from the well site (Sections 25, 26, and 35). Seventy one percent of the elk counted during this 4-year period were in these 6 sections. We saw increased use of the south and southwest slopes of Lake Mountain, indicating elk increased use of other portions of the winter range. During this period, elk use was dynamic among and within years. On the 1988 helicopter trend count 218 of 249 elk counted were in Graphite Hollow in close proximity (< 3.2 km) to the well, but on later and earlier flights that winter, few elk were counted in Graphite Hollow. On the helicopter trend count in 1990, all of the elk counted were found in Section 35, T114W. Elk were observed using Section 16 during this period, the first time since the well was drilled.

Even though the well was constructed in Section 21, the percent of total sightings of elk recorded for this section changed relatively little among the pre-construction, construction, and production periods (Table 2). During the post-construction winter significantly more elk than expected were found here. The relatively small change in elk sightings from pre-construction levels may be due to several factors that combined to meet behavioral and physiological needs of elk. These factors include a ridge which insulated part of this section from the well site activities, good security cover adjacent to and within the section, and a diverse mix of forage.

During the pre-construction period 17.8% of all wintering elk were in Section 22, between 0.8 and 2.4 km east of the well site. During the construction, post-construction, and production periods these proportions drop to 2.7%, 13.8%, and 3.0%, respectively. Even though Section 22 was in the opposite but same relative position to the well as Section 20, the pattern of change in elk numbers sighted in these sections was very different. As numbers of elk sighted in Section 20 increased, numbers sighted in Section 22 decreased. Numbers decreased the least in Section 22 during the deep snow winter of the post-construction period. There was good browse in this section, but security cover and visual and auditory barriers were minimal. On an elk calving range in Colorado, Brekke (1988) found that during daylight hours, elk tended to avoid line-of-sight exposure to drilling sites over distances up to 1.2 to 1.6 km.

Since only diurnal surveys were conducted, it was not possible to document the extent to which elk used foraging areas under the cover of darkness. Merrill et al. (1988) report that elk in the Mount St. Helens blast zone shifted their foraging activities to the hours of darkness in response to thermoregulatory needs. Morgantini and Hudson (1979) found that elk shifted their activity patterns to the cover of darkness to avoid hunting. This raises the possibility that some areas where elk were sighted represented places where elk were secure enough to be seen during daylight hours. Nearby areas, where elk were too insecure to be found during daylight hours, may have been used at night. Most flights were conducted early in morning or late in afternoon to minimize this potential bias. During aerial surveys of the GH/RC winter range no evidence was found (tracks and trails in the snow), to indicate that significant nocturnal movements to feeding sites occurred.

SUMMARY

Although the areas closest to the well continue to be used by elk, the proportion of the wintering elk herd found here has been lower than pre-construction levels, except during the post-construction period when snow depths were much greater than average (Table 4). However, the proportion of the herd found within approximately 2.8 km of the well site (Sections 16, 17, 20, 21, and 22) was higher in each of the periods compared to proportions observed in the pre-construction period. Although the proportion of the herd found within this 5-section area has increased, the distribution of animals within it varied considerably, apparently in response to the magnitude of human disturbance, depth of snow, and availability of forage and security.

Pre-construction planning and coordination among Exxon, the BLM, and WGFD were critical in siting the well in Graphite Hollow. In Exxon's original plan, the well was to have been drilled near the center of Section

21 in order to obtain the legally required spacing of wells and depletion of gas reserves within the lease units. The proposed site was visible for many miles on this winter range, and the human activities associated with servicing the well could have displaced elk away from this site. Had the well not been moved into conifer cover, out of sight from foraging areas on the winter range, it is likely the return of elk to the vicinity of the well site would have been much slower and levels of elk use would not have been as high as those we documented during the production period.

Proper siting of wells, roads, and other facilities is crucial to maintaining elk use of winter and calving ranges. In the 1970s oil and gas fields were developed on crucial elk winter ranges, by companies other than Exxon, on Pinegrove Ridge, Cretaceous Mountain, and Hogsback Ridge (Fig. 2). In addition, many antennas were constructed on Hogsback Ridge, and this development now serves as a major communications link for the region. None of these activities included plans to minimize or avoid impacts to wintering elk through careful placement of facilities. These were often constructed in foraging areas instead of within conifer stands. During the 1980s, no elk were observed on Pinegrove Ridge or Hogsback Ridge winter ranges, and elk were seen during only 3 winters on Cretaceous Mountain. The great reduction in elk use of these winter ranges illustrates the consequences of unplanned developments.

Pre-construction planning and communications among resource management agencies and industry are necessary to avoid and minimize impacts to elk winter ranges. If impacts cannot be avoided, habitat improvements such as burning, fertilizing, pitting, and changing grazing patterns of domestic livestock may be necessary on other portions of the winter range to maintain elk populations.

CONCLUSIONS

1.We documented no significant effect of Exxon's wellfield activities on total numbers of elk using the GH/RC winter range, or elk harvest in the Big Piney Herd.

2.Wellfield construction activities altered some of the traditional winter distribution patterns of elk in GH/RC.

3.Some elk returned to traditional winter ranges after intensive wellfield construction activities ceased even though less intensive activities continued (production) on GH/RC. Elk use was documented on 2/3 of all traditional use areas throughout the study, and some traditional use areas never showed depressed levels of utilization.

4.On the GH/RC winter range, the proportion of elk counted within 2.8 km of the well site was higher during the construction, post-construction, and production periods compared to the pre-construction period. The distribution of these animals, however, changed significantly from patterns found during the pre-construction period.

5.The proportion of the GH/RC wintering elk herd found on 1 of the sections (16) of land closest to the well decreased significantly during the construction period and remained depressed throughout the study (1990). Some return of elk to this section was recorded during the production period. Elk numbers sighted on the other section closest to the well (21) declined significantly during the construction and production periods. During the post-construction period when activities were minimal at the well and snow depth was maximum, this section contained significantly greater numbers of elk than were seen during the pre-construction period.

6.During and following the construction period, elk expanded their use of crucial winter range in R115W into areas not previously used much or at all.

7.Although they were not specifically studied, the presence of visual and auditory barriers, increased distance from the well, proximity to security cover, depth of snow cover, and the intensity level of human activities appeared to influence elk distribution. Elk remained relatively closer to human activities when barriers or security cover were available. These factors appeared less important as distance from the disturbance increased. Under deep snow conditions elk used areas closer to human activities and appeared to forego some security to obtain use of areas with less snow cover and better forage.

8.Pre-construction planning and communications among resource management agencies and industry helped to avoid and minimize impacts to elk winter and calving ranges. Had the wells not been moved into conifer cover and road management plans adopted, it is likely the return of elk to the vicinity of the well sites would have been much slower and levels of elk use would not have been as high as those we documented following the construction period.

RECOMMENDATIONS TO MINIMIZE IMPACTS OF OIL AND GAS DEVELOPMENT ON ELK HABITAT

1.Before leases or APD's are issued, identify conflicts between oil and gas development and elk habitats, and plan solutions to problems at that time.

2.Include considerations for placement of roads and wells in the pre-construction planning. Wells and roads should be screened from foraging areas on winter range by either topographic or vegetative features. In the absence of such features wells should, if possible, be located 2.4 km from crucial portions of the winter range.

3.If number 2 is not possible, and sometimes when it is, time construction activities to avoid periods of the year when elk will be in the area.

4.Develop road management plans, and close roads that are on elk winter ranges to all uses except field maintenance. Minimize trips on the road and, where feasible, utilize remote sensing equipment to monitor wells.

5.Identify all potential foraging sites within and adjacent to areas where development will occur. Where appropriate, implement habitat improvement projects on those areas at least 1 year before construction activities occur.

6.Utilize state-of-the-art drilling techniques to avoid conflicts on foraging areas of winter range. Such measures might include helicopter supported drilling activities, directional drilling, remote monitoring of completed wells, and split-season drilling.

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THE ECOLOGY OF ELK IN AN ARID ENVIRONMENT: AN OVERVIEW OF THE HANFORD ELK PROJECT

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: We studied elk (*Cervus elaphus*) in Washington's shrub-steppe region from 1982-90. The population originated from a small number of colonizers that took up residence on the Hanford Site in winter 1972-73. During 1975-1989, the population grew at a logarithmic rate of increase (r) of 0.19. During a period of intensive study (1982-86), $r = 0.30$. Rapid population growth was facilitated by high reproductive and survival rates. During 1984-89, 0.72 calves were weaned per cow ≥ 2 years of age, while 0.91 calves were weaned per cow ≥ 3 years of age. Home ranges for radio-collared cow elk averaged 156.0 km^2, and home ranges of collared bull elk averaged 166.4 km^2. Elk showed strong preferences for bedding in sagebrush (*Artemisia tridentata*) stands, the only vegetative cover available. Foraging elk typically selected previously burned habitats that no longer supported sagebrush. Elk limited their major diurnal activity, favoring dusk-to-dawn foraging with relatively high nocturnal activity levels. Elk diets were dominated by grasses from winter through early summer and by forbs during the summer drought period. High reproductive success and survival and superior antler growth relative to elk occupying more mesic environments suggested that these elk were effectively utilizing the shrub-steppe environment. Mild, short winters in the shrub-steppe environment were hypothesized to contribute to reduced winter energy deficits common in temperate herbivores, partly facilitating the observed high fitness. We also hypothesize that, in the absence of a significant overstory, the proportion of the range of these elk that would be considered foraging habitat exceeded that typical of elk occupying coniferous forests. Thus, the quantity of foraging areas may have compensated for reduced productivity typical of this region. These data suggest that elk are quite well suited for thermally extreme summer environments. These elk coped well with limited thermal and security cover, but isolation provided by the Hanford Site probably substituted for security cover.

North American elk have historically occupied a variety of habitats across the continent. Various subspecies have been associated with the vast grasslands of the Great Plains, the deciduous forests of the East, mountainous areas of the Southwest, montane forests of the western United States and Canada and the coastal and interior valleys of California. However, as Olaus Murie (1951) suggested, one notable exception to their historical widespread distribution has been the arid desert and semidesert regions of the West. Hypothetically, low forage quantity and quality, scarcity of water and thermal cover and the difficulty of maintaining thermoneutrality in a desert make these regions unacceptable elk habitat (Murie 1951, Skovlin 1982). Recently, however, several populations of elk have appeared in arid habitats of the west, bringing this hypothesis into question and creating an interesting opportunity for the study of elk and their environmental requirements.

We have studied one elk population in arid lands in the shrub-steppe region of Washington since 1982. Ideally, the application of the scientific method in wildlife studies would involve manipulating a variable of interest and examining the response of an animal or group of animals (i.e., experimentation). However, large-scale environmental manipulation is typically not feasible for wide-ranging large mammals under natural conditions. The opportunity to study a population of elk in an environment vastly different from that encountered in most previous elk research (pseudomanipulation) represents the best alternative. The opportunity to study population-level responses (e.g., growth, fecundity and survival) to environmental variation was enhanced in our study by a low-density, isolated population resulting from recent colonization. This opportunity was further facilitated by the high-visibility habitat conditions prevalent in the shrub-steppe.

Our primary objectives during this research program were twofold: first, to gather data on basic ecological strategies of elk in an arid environment (e.g., movement patterns, habitat use, forage-animal interactions, activity patterns) and, second, to assess the relative success of those strategies by examining fitness parameters such as growth, reproduction and survival.

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STUDY AREA

The primary study area was the Arid Lands Ecology (ALE) Reserve located in south-central Washington. The ALE Reserve is a 330 km^2 ecological reserve associated with the US Department of Energy's Hanford Site, a Federal nuclear technology area. The ALE Reserve, located in the shrub-steppe region of the Columbia Plateau, represents the northern limit of the Great Basin (a cold-desert biome). The essentially treeless vegetation is dominated by shrub-steppe grasses such as bluebunch wheatgrass (*Agropyron spicatum*), Sandberg's bluegrass (*Poa sandbergii*), cheatgrass brome (*Bromus tectorum*) and by big sagebrush (*Artemisia tridentata*). The sagebrush overstory has been removed from approximately 90% of the reserve by range fires. Limited riparian vegetation is

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[1] Deceased

associated with small, perennial springs in the western part of the reserve. A more detailed account of the ALE Reserve's plant communities can be found in McCorquodale et al. (1986).

The arid Hanford Site lies in the rain shadow of the Washington Cascades. During 1912-80, annual precipitation averaged 16.0 cm (Stone et al. 1983). Climatically, the region is characterized by hot, dry summers and relatively cool winters, during which light snowfalls are common. In an average year, there are 13 days when the maximum temperature exceeds 38 C (100 F) and 55 days when the maximum temperature exceeds 32 C (90 F) (Stone et al. 1983). The high ambient temperatures, high incident solar radiation and limited vegetative cover combine to produce what may be the most thermally severe summer environment experienced by a wild, free-roaming elk population in North America.

Elevations on the ALE Reserve range from 150-1,090 m. The reserve is topographically characterized by a north-to-south gradation from an extensive flat, rolling plain rising steeply to broken foothills.

The elk population inhabiting the ALE Reserve was established during winter 1972-73 by natural colonization involving approximately 5-6 individuals. Before 1972, the only large herbivores occupying the ALE Reserve were mule deer (*Odocoileus hemionus*), occurring at a low density. Livestock have been excluded from the ALE Reserve since 1968, when the site was surrounded by a standard four-strand barbed wire fence that did not restrict elk or deer movements. Technological activities associated with Hanford Site operations were limited to those areas beyond the ALE Reserve's boundaries. The elk population is not hunted within the boundaries of the reserve, but legal harvest regularly occurs on adjoining private land.

METHODS

Various aspects of this research depended heavily on the use of radiotelemetry. From 1982 through 1988, 30 elk were darted from a helicopter and fitted with radiotelemetry collars (McCorquodale et al. 1988a). These radio-collared elk were collectively located over 2,500 times. Locations of collared elk were obtained in several ways. From January 1983 through March 1986, collared elk were located with a fixed-wing aircraft weekly during spring, summer and fall, and twice monthly during winter. Mobile ground tracking also occurred approximately two times per week during this period; elk were tracked until visually located (usually) or until an exact position could be estimated from close proximity to the transmitter (rarely). During 1986-87, elk were tracked once weekly from an aircraft and for extended periods from three fixed-station tracking shelters according to the methods of Eberhardt et al. (1989). Angular error associated with fixed-station tracking was estimated to be ±1 degrees, based on blind testing. Since early 1988, collared elk have been located from fixed-wing aircraft approximately 9-12 times per year. We attempted to avoid disturbing elk at all times while radio tracking them.

Data used to analyze population phenomena were obtained from two sources. During the period of intensive study (1982-89), the regular relocation of radio-collared elk and their conspecifics formed the basis for population estimation (numerics and composition). We strongly believe that the presence of numerous radio-collared elk facilitated the locating of virtually all of the elk inhabiting the treeless ALE Reserve during this period. Numeric data from 1975 through 1981 were obtained from flight logs recorded during approximately weekly security patrol flights conducted in small, fixed-wing aircraft. Population estimates were constructed from flight logs using the bounded counts method (Seber 1982), where total abundance was estimated as $N = 2N_m - N_{m-1}$, where N_m = the maximum observed count and N_{m-1}= the next largest observed count. We believe that these early estimates were reliable, on the basis of the highly social nature of elk and the grouping patterns we observed during the early phases of the intensive study period. Rates of increase (r) were estimated by linear regression after logarithmic (ln) transformation of the population estimates.

Seasonal and annual home ranges for elk were estimated for collared elk using the minimum convex polygon (MCP) method (Odum and Kuenzler 1955) and the bivariate normal (95% ellipse) method (Jennrich and Turner 1969). These methods were selected because they had been used to analyze most data on elk home range available in the literature.

Habitat use by collared elk was evaluated by comparing actual elk use (radio locations) with habitat availabilities determined according to a modification of the methodology of Marcum and Loftsgaarden (1980) (McCorquodale et al. 1986). Use was considered statistically significant if the percentage availability of a habitat component was not included in a 95% confidence interval for elk use of the component (Neu et al. 1974).

The seasonal importance of riparian areas and water to elk was evaluated by calculating the percentage of radio locations of collared elk that fell within 4-2 km distance zones (0-2, 2-4, 4-6 and 6-8 km) radiating from all water sources on the ALE Reserve. Geographical Resources Analysis Support System software (USACE 1987) was used to construct the distance zones and to determine the proportion of radio locations falling within each zone.

Chi-square analyses and Bonferroni confidence intervals were used to evaluate the relationships between distance from water and season (Neu et al. 1974). A reduced data set consisting of a maximum of 1 relocation/marked individual/day was constructed from all aerial and ground telemetry relocations (n = 1,552). Data from all marked individuals of the same sex were combined for analysis, because data were insufficient to conduct analyses on individual animals.

Summer activity patterns of elk were determined through the use of scan sampling (Altmann 1974) conducted during sampling periods ranging from 3-18 hours. The activity of each collared elk was noted every 10 minutes during sampling periods; diurnal activity was noted visually, while nocturnal activity was noted through telemetry interpretation conducted at close range (McCorquodale et al. 1986).

Monthly elk food habits were determined through the microhistological analysis of elk fecal pellets collected within 30 hours of deposition. *In vitro* digestible dry matter (%) (IVDDM) was determined for key forage species using elk inoculum. Protein content (%) of the same forages was determined through Kjeldahl analysis. Forage-quality data were collected only for fall through spring.

RESULTS

Considering all the population estimates, the ALE Reserve elk population increased from an estimated 8 individuals in 1975 to a documented 102 individuals in 1989. For this data set, $r = 0.19$ ($r^2 = 0.97$) (Fig. 1). Considering data from the most intensive study period (1982-86), $r = 0.30$ ($r^2 = 0.99$) (Fig. 1). During 1982-89, $r = 0.19$ ($r^2 = 0.99$). Though we believe that elk harvest has occurred during most of the time elk have inhabited the ALE Reserve, harvest before 1986 appeared to be incidental. Beginning in 1986, increased public awareness of the herd led to a dramatic increase in harvest as sportsmen began to purposefully hunt elk along the ALE Reserve's boundaries. Correcting population growth for known elk kills, the 1982-89 $r = 0.26$ ($r^2 = 0.98$), while during the 1982-86 intensive study period $r = 0.31$ ($r^2 = 0.99$). The highest year-to-year r we recorded was 0.39 (1982-83). We did not document immigration or emigration during our period of study (1982-89), and all changes in elk numbers were accounted for by reproduction.

We were unable to assess early postnatal calf mortality. We began to note calves shortly after they were born in late May or early June each year. Marked animals noted with calves at this time were never seen without their calves throughout the summer and fall. Thus, any calf mortality occurring had to occur within the first few days of birth, making our estimates of calving rates in reality estimates of weaning rates. During 1984-89, the number of calves weaned per all females ≥ 2 years of age ranged from 0.58 (1989) to 0.84 (1987) and averaged 0.72. During the same period, calves weaned per all females ≥ 3 years of age (eliminates yearling breeders) ranged from 0.74 (1989) to 1.08 (1987) and averaged 0.91. Evidence of yearling breeding was mostly circumstantial; however, based upon the extremely high ratios of calves to females older than 3 years (e.g., 1987 = 1.08), we strongly suspected that yearling breeding occurs with some regularity (McCorquodale et al. 1988b). One yearling harvested in late November 1989 just off the ALE Reserve was verified to be pregnant. One 12-month-old cow captured in early June weighed 172 kg; based on Greer's (1968) data on reproductive activity relative to female body weight, this animal would likely have bred in her second fall.

We could not definitively estimate first-year survival because information relative to early postnatal mortality was lacking; however, it is clear from our weaning-rate estimates that first-year survival was probably in excess of 0.90. The annual survival of female elk ≥ 1 year averaged 0.90 during 1983-89 and appeared to be lower after the increase in harvest activity in 1986 (1983-86 = 1.0, 1986-89 = 0.80; Mann-Whitney test, $U = 9$, $P = 0.10$). During 1983-89, male elk survival (≥ 1 year) averaged 0.75 and also appeared to decrease after 1986 (1983-86 = 0.90, 1986-89 = 0.61; $U = 9$, $P = 0.10$). Human-caused mortality was clearly the major source of mortality during our entire study.

Radio-collared elk on the ALE Reserve maintained extremely large home ranges both annually and seasonally (Table 1) (McCorquodale et al. 1989a, Eberhardt et al. 1989). The sizes of seasonal home ranges of collared female elk monitored for more than 1 year did not vary between years ($P > 0.10$). However, spring home ranges were significantly larger than summer and fall ranges, and summer ranges were larger than fall ranges ($P < 0.01$). Fall home range estimates may have been conservative because a relatively small number of locations were obtained during this season. Dispersion of elk use, based on the distance between consecutive day locations, was greatest in spring (3,523 ± 586 m [1 SE], $n = 49$), smallest in summer (2,186 ± 155 m, $n = 173$) and intermediate in fall (3,011 ± 359 m, $n = 39$). Hourly movement rates from early summer through late fall obtained during intensive tracking sessions increased from June through August, declined during September and October and increased to a maximum in November (Eberhardt et al. 1989).

Elk habitat-use patterns indicated strong selection for the limited sagebrush-dominated habitats for bedding sites ($P < 0.05$ in all months but May and June) (McCorquodale et al. 1986, McCorquodale 1987). The use of sagebrush stands for bed sites was particularly pronounced during midsummer through early fall, when drought conditions prevailed (McCorquodale et al. 1986). Foraging animals typically selected previously burned areas at lower elevations that were dominated by *Poa* and *Bromus* and during summer showed a preference for riparian areas (McCorquodale 1987). During the summer, female elk

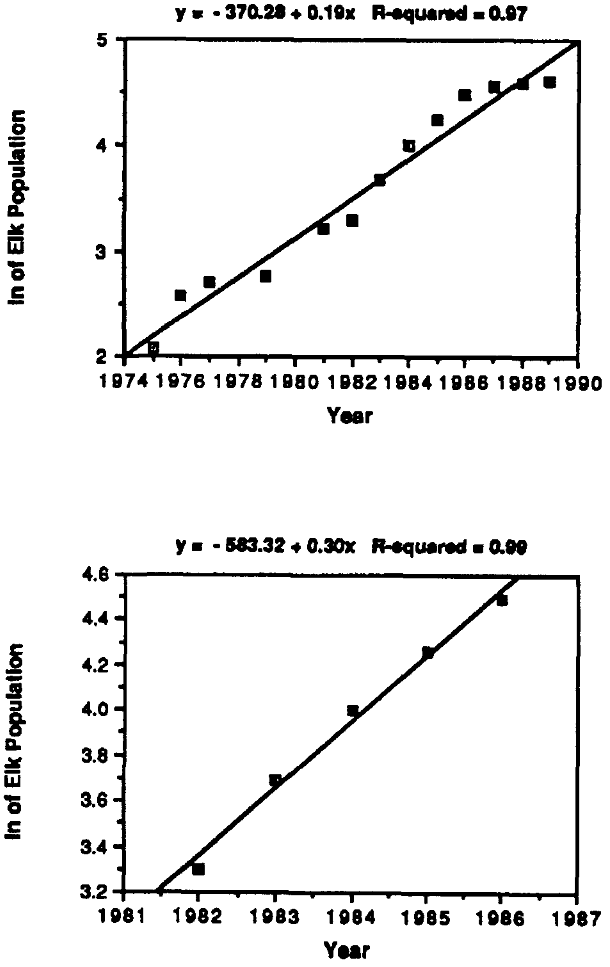

Fig. 1. Growth of the ALE Reserve elk population a) from 1975-89 and b) from 1982-86 (slope of the line = logarithmic rate of increase [*r*]).

preferred to spend a greater proportion of their time in the zone closest to water, avoiding areas distant from water (Table 2). Male elk appeared to be less dependent on riparian areas than were females. During the summer, males demonstrated a preference for areas more distant from water sources than the areas used by females (Table 2).

Summer activity patterns of elk determined from scan sampling indicated that the highest levels of activity occurred near dawn and dusk (Fig. 2). Considerable activity occurred throughout the hours of darkness, while the mid-morning through mid-afternoon hours were characterized by relative inactivity (Fig. 2). This pattern was also reflected by hourly movement data derived from intensive tracking periods (Eberhardt et al. 1989) and physiological-telemetry implant data (Petron 1987).

Elk diets were dominated by graminoids from midwinter through early summer and by forbs during summer and fall (Fig. 3). Shrubs were relatively unimportant, generally appearing in elk diets only during periods of extended snow cover and only riparian shrubs were consumed extensively. *Poa* and *Bromus* were the most important graminoids selected, while a diverse array of forbs was present in summer elk diets (McCorquodale 1985). Riparian plant species were consumed heavily during late summer (McCorquodale 1985). During midwinter, IVDDM and crude protein in forage grasses typically varied between 40-45% and between 5-7%, respectively, rising rapidly by mid-January to mid-February. For major forb forages, IVDDM and crude protein ranged from 40-50% and from 4-6%, respectively, rising rapidly by mid-February. By early March, IVDDM for major grasses and forbs ranged from 60-65% and from 65-80%, respectively, with the initiation of vegetative growth.

DISCUSSION

Until recently, conventional thought suggested that elk were poorly suited for desert-like environments; although physiologically equipped for the extremes of winter weather, it was generally thought that elk were poorly suited for the demands that high thermal loads place upon large homeotherms (Murie 1951). However, the appearance of summering elk in several arid habitats of the West during recent times suggests that elk are physiologically equipped to avoid hyperthermia in warm climates (e.g., Red Desert of Wyoming, southern Idaho, eastern Oregon). This thermoregulatory hardiness has also been confirmed by the controlled-climate work of Parker and Robbins (1984) and by the implantable-telemetry work on wild elk inhabiting Washington's shrub-steppe (Petron 1987). The data on elk reproduction, survival and antler growth from the ALE Reserve population suggest further that the thermoregulatory costs elk incur during summer in these environments may not detract appreciably from their ability to allocate energy to growth and reproduction (McCorquodale et al. 1988b, McCorquodale et al. 1989b).

The rate of increase (without immigration) displayed by the ALE population is among the highest recorded for the species (Murphy 1963, Burris and McKnight 1973, Gogan and Barrett 1987, Raedeke et al. 1986) and was obviously the result of high reproductive output coupled with high survival. The survival rates we noted (particularly first-year survival) were also among the highest recorded for this species.

It is clear that elk inhabiting Washington's shrub-steppe employ several behavioral strategies to reduce the energetic costs of summer thermoregulation in a desert-like environment. Their use of sagebrush stands, particularly as operative temperatures rise, suggest that they are seeking some microclimatic advantage offered by these stands.

Table 1. Home ranges of radio-collared elk from the Arid Ecology Reserve, Washington, 1983-1987.

	Female Elk			
	No. of Elk	Locations	MCP[a](km^2)	95% CE[b](km^2)
Annual	18	57	156.0±9.2	277.8±20.0
Spring	7	20	125.3±9.2	368.1±43.0
Summer	7	44	95.2±6.1	190.5±8.8
Fall	7	12	25.3±2.4	83.7±11.7
	Male Elk			
	No. of Elk	Locations	MCP[a](km^2)	95% CE[b](km^2)
Annual	6	42	166.4±25.2	351.7±104.9
Spring	2	12	60.7±7.3	226.8±15.5
Summer	3	25	117.7±26.6	277.2±99.8
Fall	3	11	25.0±2.4	87.4±23.7

[a] Minimum Convex Polygon.

[b] 95% Bivariate Normal Confidence Ellipse.

Table 2. Summary of elk use relative to 4,2-km-distance zones from all water sources on the Arid Lands Ecology Reserve, Washington.

					Distance zones from water (km)			
Sex	Season	N[a]	X^2 Statistic[b]	P	0-2	2-4	4-6	6-8
F	Spr	270	8.5	<0.05	NP[c]	NP	NP	NP
F	Sum	439	217.3	<0.001	Prefer	NP	Avoid	Avoid
F	Fall	252	23.1	<0.001	NP	NP	Prefer	NP
F	Win	218	131.4	<0.001	Avoid	NP	Prefer	NP
M	Spr	83	23.1	<0.001	Avoid	NP	Prefer	NP
M	Sum	105	94.5	<0.001	NP	Prefer	Avoid	Avoid
M	Fall	82	60.9	<0.001	NP	NP	NP	Avoid
M	Win	103	36.3	<0.001	Avoid	NP	Prefer	Avoid

[a] Number of locations.

[b] Test of the hypothesis that the proportion of animal relocations in a given distance zone is not significantly different than the proportional land area within that zone; degrees of freedom for the test = 3.

[c] Based on Bonferroni simultaneous confidence intervals (Neu et al. 1974). NP = no preference (i.e., avoidance or attraction) was detected.

This is further suggested by observations indicating selection for shaded bed sites within these stands (Petron 1987).

Elk also appeared to use temporal selection to reduce the costs of summer thermoregulation. Though peak activity periods still occurred near dawn and dusk, continued activity during the dark hours and limited activity during hours with appreciable incident radiation suggested that during periods of high operative temperatures elk were attempting to limit metabolic heat production from activities other than rumination. Low activity levels during the early postsunrise hours also suggested that elk were attempting to take advantage of shrub-produced shade when it was most advantageous, that is, when the sun

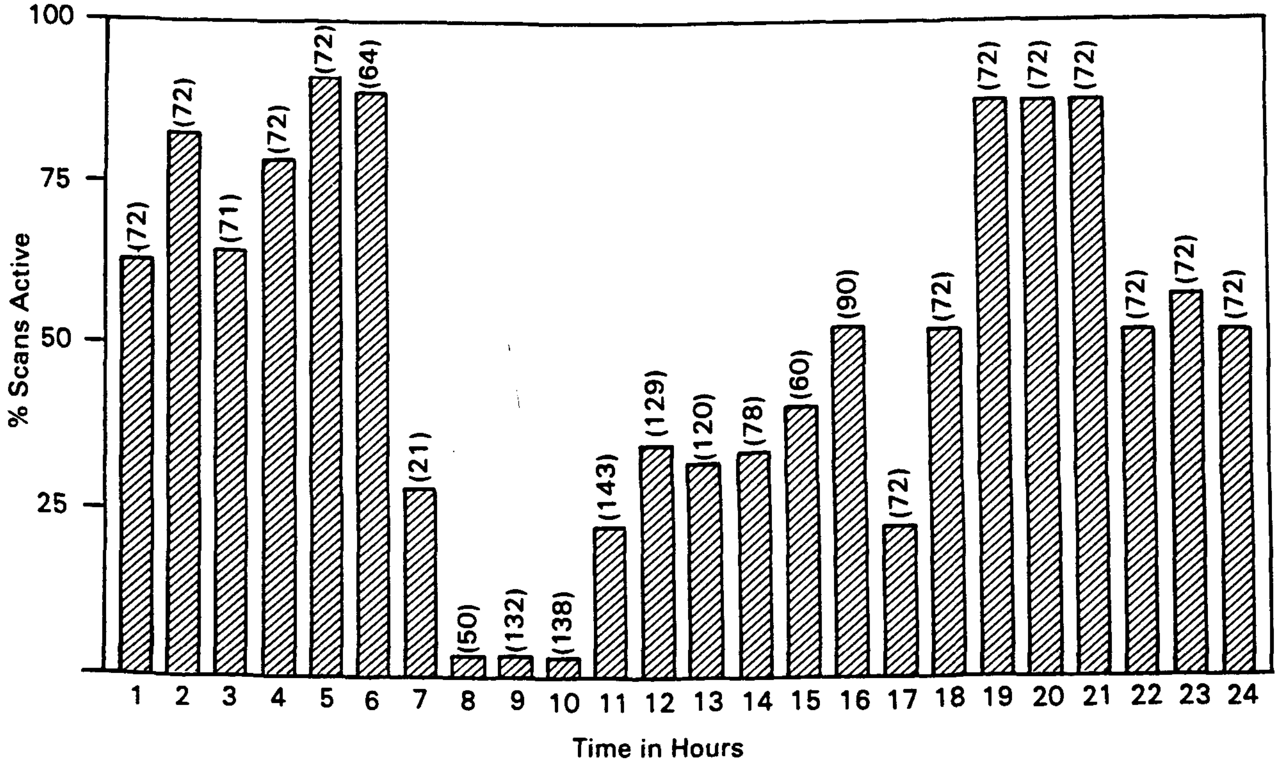

Fig. 2. Percentage of scans in which marked female elk were active during different periods of the day during summer. Numbers (1-24) representing time are 1-hour periods beginning at 0101 hours. Numbers in parentheses are sample sizes of individual scans obtained during different periods of the day.

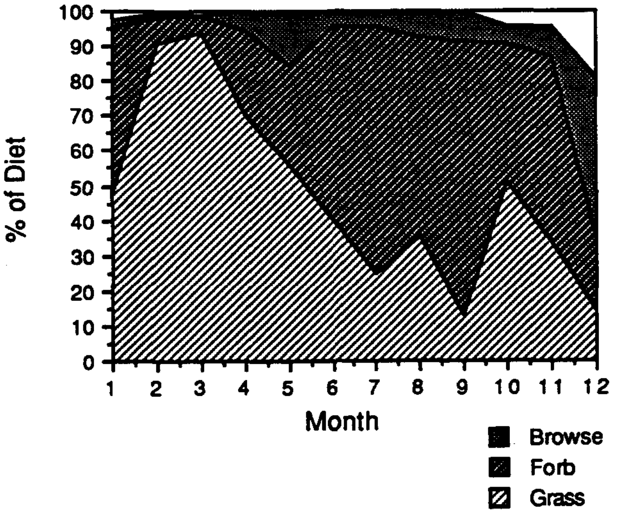

Fig. 3. Monthly diet composition (plant form) of elk on the ALE Reserve.

angle was low.

However, even considering attempted behavioral thermoregulation by elk, the summer thermal environment was still severe relative to that experienced by most summering elk populations. Further, elk were observed using habitats that were virtually without cover during severe summer weather, indicating that these animals are physiologically capable of dealing with extremely high thermal loads. This is consistent with the findings of Parker and Robbins (1984). Apparently, the primary physiological mechanism that allows elk to thermoregulate effectively in the face of high thermal loading is their capacity for cutaneous evaporation (i.e., sweating) (Parker and Robbins 1984, Petron 1987). This suggests that the most critical habitat feature for elk summering in severe climates is the availability of copious free water, which corresponds well to the constraining effects of water distribution on summer elk distribution on the ALE Reserve.

Even given that elk can successfully cope with the summer thermal environment in the shrub-steppe of Washington, the dichotomy of a remarkably successful population in a relatively unproductive biome still exists. It should be noted, however, that the bioenergetically demanding warm-season environment these elk must cope with is relatively short (June - September). During the remaining months, the environment is climatically rather favorable for large herbivores. The winter environment is particularly mild for elk. Low snowfalls and moderate temperatures reduce winter energy costs (for locomotion and thermoregulation) for these elk relative to most wintering populations. Short, mild winters also favorably affect elk through their influence on plant phenology. In late winter, IVDDM and nutrient levels rise quickly in response to favorable temperature regimes, and this rise typically occurs 60-90 days earlier than on most elk winter ranges (Ward 1971, Hobbs et al. 1981, Rowland et al. 1983). Therefore, winter energy deficits common in temperate-zone cervids would be shorter and potentially of lower magnitude in the shrub-steppe than on most elk winter ranges.

Given that the climate of the shrub-steppe can be favorable for elk during the majority of the year, the remaining question is how this large herbivore with a high nutrient demand copes with relatively low primary productivity and low biomass habitats. Although the shrub-steppe supports only a fraction of the productivity of mesic forests, nearly all production is forage in the unilayered community. That is, in the absence of a tree overstory, virtually all production in the shrub-steppe is in the herbaceous layer and, therefore, represents potential elk forage. In contrast, in forested ecosystems, productivity is high, but forage production occurs primarily in components such as meadows and in early seral stages that are of limited area over the habitat mosaic. Thus, it seems reasonable that the quantity of forage-producing habitats in the shrub-steppe has compensated for reduced productivity of any given community. The best forage-producing habitats in mesic forests are clearly more productive than the best shrub-steppe habitats; however, the least productive habitats in the shrub-steppe produce far more forage than do the least productive habitats in forested ecosystems. In fact, over large geographic areas, the shrub-steppe may rival more mesic habitats in terms of overall forage energy production (McCorquodale1991).

Elk in Washington's shrub-steppe have had to cope with a habitat tradeoff, gaining extensive foraging habitat at the expense of cover availability. Apparently, these elk have made this transition with no appreciable detriment to their fitness; in fact, it appears based on our observations, that their fitness may actually be among the highest of any western elk population. It would appear that extensive thermal cover for elk on summer range may not be a requisite of quality summer habitat. However, we believe security cover remains an important if not obligatory component of quality elk habitat. Clearly, the elk occupying the ALE Reserve have been successful without extensive security cover; however, restricted public access has greatly reduced the security needs of this population. In effect, land-use restrictions have substituted for extensive vegetative cover in meeting the security needs of elk occupying the ALE Reserve. We continue, therefore, to urge caution in applying the apparent limited thermal-cover needs of this population to other managed elk populations occupying public lands.

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EFFECT OF FEEDING LEVEL ON ELK WEIGHTS AND REPRODUCTIVE SUCCESS AT THE NATIONAL ELK REFUGE[1]

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract:: Elk (*Cervus elaphus*) on the National Elk Refuge (NER) are normally fed supplemental rations from January to April each winter. From 1976 to 1982, we measured body weights of elk offered different amounts of pelleted hay. During winter 1976, adult female elk fed 2.3 kg/day lost more ($P < 0.01$) weight (8.3%) than those fed 3.2 kg/day (4.2%). During winter 1980, weight losses of adult females fed 2.3 kg/day (10.8%) were similar ($P = 0.68$) to those of elk fed 4.5 kg on alternate days (8.5%). During winter 1982, adult females fed 2.3 kg/day lost more ($P < 0.01$) weight (6.2%) than did adult female elk fed an alternate-day ration (3.2%). Reproductive success (calves surviving until August) of brucellosis-negative adult females was 66.7% vs. 54.2% for brucellosis-positive adult females; however, reproductive success declined only 7% in a herd where 38% of the adult females had brucellosis. Calf weights were not affected by the brucellosis condition of the adult females. Calves weighing <13 kg at birth had a lower survival rate (66.7%) than heavier calves (90%). Birth weight of calves was not related to weight loss of cows.

From 1970 to 1975, the U.S. Fish and Wildlife Service evaluated pelleted (1.9 x 5.0 cm) alfalfa hay as a forage supplement for elk wintering on the National Elk Refuge (NER) at Jackson, Wyoming (Smith and Robbins 1984). The studies concluded that: (1) both confined and free-ranging elk readily accept on pelleted hay rations during winter; (2) competition does not restrict elk from feeding on the pelleted alfalfa; (3) weight changes of elk fed 2.7 and 3.6 kg daily of pelleted alfalfa during feeding trials are similar to, or less than, weight changes of elk fed 4.5 kg baled hay; and (4) mortality of elk fed pelleted hay is similar to elk fed baled hay (Smith and Robbins 1984).

Following these studies, additional feeding trials were conducted at NER from 1976 to 1982 to evaluate minimum daily ration levels that can be supplementally fed to elk. The objectives were to: (1) compare weight loss of elk fed pelleted alfalfa at different levels, (2) evaluate reproductive success of adult female elk fed at those different levels, and (3) evaluate the effect of brucellosis on newborn calf survival.

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METHODS

Supplemental feeding of elk begins on NER when forage availability is reduced by deep or crusted snow. Such snow conditions occurred in January during the 5 winters that we conducted experiments (1976, 1978-80, and 1982). Pregnant adult female (>2.5 years old) and 7-month-old calf elk were trapped in January, weighed, marked with individually identifiable neck bands, pregnancy tested by rectal palpation, and randomly assigned to a treatment. In addition, the elk were tested for brucellosis with 2-4 of the following tests: antigen rapid card, standard plate agglutination, rivanol, and complement fixation (Morton and Thorne 1981). The tests were performed by either the Wyoming State Veterinary Laboratory or the National Wildlife Health Laboratory. For this study, an elk was considered to not have brucellosis only if the brucellosis test results in both January and April were negative. If a brucellosis test was not conducted in 1 of the 2 months but the adult female was negative the 1 time she was tested, the data were not used to evaluate the effects of brucellosis on reproduction, but were used for the feeding trials study.

When the free-ranging herd on NER began to disperse from the feeding areas in the spring (early April), the study elk were again weighed and tested for pregnancy and brucellosis. In 1976, adult females were released into 3 4.0-ha pastures and held until 1 July to determine calf production. During the other 4 years, adult females and calves were released into the same 3 pastures and held until 1 August. Newborn calves were weighed and marked with color-coded tags within 2 days of birth and were matched with dams based on nursing and maternal behavior.

The feeding trials were designed to test 2 different levels of supplemental feeding (rations) each year and to duplicate, as closely as possible, the feeding program for the 5,000-9,000 elk that winter on NER. In 1976, the trials were conducted in 2, 4-ha pens. In 1977, 6, 2-ha pens were built and the subsequent trials were held in those 6 pens. Estimates of production of native vegetation within the pens ranged from 89-260 kg/ha over the period of the study, whereas they ranged from 431-1,165 kg/ha outside the pens. Smith and Robbins (1984) demonstrated

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that adult female elk weight change ranged from +1.2 to -1.2% when fed 3.6 kg of alfalfa pellets/day and that adult female elk fed 2.7 kg pellets/day lost 0.6% weight during feeding trials. Because it was not a NER objective to produce weight gains, lower amounts were offered from 1976 to 1982. In 1976, 3.2 kg pellets/day was compared to a feeding level of 2.3 kg pellets/day. During subsequent years, the objective was to compare 4.5 kg pellets fed on alternate days with 2.3 kg fed daily.

We used analysis of variance to test the hypothesis of no difference in weight loss between rations.

RESULTS

Elk moved among feeding pens during the first week of the feeding trials in 1979 and 1982 because of deep, drifted snow. In 1979, all elk were fed 4.5 kg on alternate days. In 1982, elk from 1 pen (2.3-kg/day rate) moved to another (4.5 kg on alternate days). Thus, we continued the experiment with elk in 2 pens being fed daily and elk in 3 pens being fed on alternate days.

Weight Change Related to Ration

In 1976, 7-month-old calves lost an average of 2.9% of their weight on the lower ration and 1.4% on the higher ration (*P* = 0.53) (Table 1). Adult females on the 2.3 kg level lost more (*P* < 0.01) weight (8.3%) than those on the higher level (4.2%).

Elk were fed at a rate of 4.5 kg on alternate days during the feeding periods in 1978 and 1979. During the first year, 40 adult female elk lost an average of 7.8% (Table 2) of their weight while 13, 7-month-old calves lost an average of 12% (SE = 1.25). During 1979, elk moved among pastures because of deep snow, and only 2 pastures were used. Thirty-six adult females lost an average of 6.8% (Table 2) of their weight while 20, 7-month-old calves lost an average of 10.6%

The feeding trials from January to April 1980 were conducted as designed. Weight loss of adult female elk fed 2.3 kg/day was 10.8% while those fed 4.5 kg on alternate days was 8.5% (Table 3). This difference was not significant (*P* = 0.68). During the feeding trial of 1982, female elk fed 2.3 kg/day lost more (*P* < 0.01) weight (6.2%) than those fed on the alternate-day ration (3.2%) (Table 3).

Reproductive Success and Calf Weights

Premature calves are often an effect of brucellosis (Thorne et al. 1979). In our study, birth dates for newborn calves ranged from 22 May to 8 July; the median was 7 June. Johnson (1951) reported somewhat earlier birth dates ranging from 21 May to 12 June with a peak birth date of 1 June. Twenty-five percent of the calves observed during the 4 years were born by 1 June. For 16 calves born by 1 June, we were able to identify whether the mother tested brucellosis positive or negative. Seven of those calves (43.8%) were produced by brucellosis-positive adult females. Because 38% of all calves in this study came from brucellosis-positive adult females, the percentage born by 1 June does not indicate that calves from brucellosis-positive females were born earlier than expected. Although 2 calves were born as late as July, 80% were born by 15 June. This figure is identical to that observed for Roosevelt elk (*C. e. roosevelti*) in Oregon (Hines and Lemos 1979).

During the period 1978-82, the percentage of adult

Table 1. Weight (kg) of elk prior to initiation of supplemental feeding in January and percentage weight change on 12 April 1976, after feeding trials were completed.

	Feeding rate (kg/day)	
	2.3	3.2
7-month-old calves		
n	5	5
$\bar{x}$ initial weight (SE)	112 (1.7)	119 (1.5)
$\bar{x}$ % change (SE)	-2.9 (1.3)	-1.4 (1.8)
Adult cows		
n	15	17
$\bar{x}$ initial weight (SE)	242 (4.9)	235 (4.8)
$\bar{x}$ % change (SE)	-8.3 (0.7)	-4.2 (1.1)

Table 2. Weight (kg) of cow elk prior to initiation of supplemental feeding in January and percentage weight change in April 1978 and 1979, after completion of feeding 4.5 kg pelleted alfalfa on alternate days.

	1978	1979
n	40	36
$\bar{x}$ initial weight (SE)	233 (2.7)	225 (3.2)
$\bar{x}$ % change (SE)	-7.8 (0.5)	-6.8 (0.9)

Table 3. Weight (kg) of cow elk prior to initiation of supplemental feeding in January 1980 and 1982, percentage weight change in April after completion of feeding 2.3 kg pelleted alfalfa/day or 4.5 kg pelleted alfalfa on alternate days, and newborn calf weights.

	Ration			
	2.3 kg/day		4.5 kg alternate days	
Year	1980	1982	1980	1982
Adult cows				
n	30	19	27	38
$\bar{x}$ initial weight (SE)	224 (3.2)	223 (9.7)	224 (3.7)	232 (2.8)
$\bar{x}$ % change (SE)	-10.8 (0.4)	-6.2 (2.0)	-8.5 (0.2)	-3.2 (0.4)
Newborn calves				
n	14	5	13	13
$\bar{x}$ weight (SE)	15.4 (0.8)	14.3 (2.1)	17.0 (0.5)	15.8 (0.6)

females producing calves ranged from 81.3% for females on alternate day feeding during 1982 to 100% for females on both rations in 1980. The percentage of calves surviving until release in August ranged from 69.2% for females on daily feeding in 1980 to 100% for females on alternate day feeding in 1978. Females fed daily produced significantly ($P = 0.025$) more calves (95.6%) than did females fed on alternate days (90.0%).

Brucellosis-negative adult females produced more calves (41 calves from 45 females, 91.1%) than did brucellosis-positive females (17 calves from 24 females, 70.8%) ($P = 0.073$). Of 58 calves surviving until August from 1979 to 1982, 73.2% of the calves produced by brucellosis-negative females survived, while 76.5% of the calves produced by brucellosis-positive females survived, a non-significant difference ($P > 0.25$). Thus, overall reproductive success of the 69 adult females monitored until August was 66.7% for brucellosis-negative females and 54.2% for brucellosis-positive females, again, a non-significant difference ($P > 0.25$).

Calf birth weights were not correlated with the mother's weight in January or in April or with the percentage weight change of the mother. For 70 calves, without regard to brucellosis category, the r^2 was low (<0.06). When correlated by brucellosis category, the r^2 remained low (<0.06). Thorne et al. (1976) observed positive and significant relationships between weight change and calf birth weights and we assume the difference stems from the fact that their final adult female elk weights were made in late May, whereas ours were made in April.

When newborn calf weights were combined by year and ration of the mother, those calves produced by brucellosis-positive adult females were larger, though not significantly so, than those calves produced by brucellosis-negative females. For the calves whose mothers were fed 2.3 kg/day, the difference in weight was greater between brucellosis categories (positive mean = 16.1 kg, SE = 0.54, $n = 4$; negative mean = 14.6 kg, SE = 0.83, $n = 12$; $P = 0.17$) than for the calves whose mothers were fed on alternate days (positive mean = 16.2, SE = 0.53, $n = 20$; negative mean = 15.8 kg, SE = 0.44, $n = 27$; $P > 0.50$). Thorne (pers. commun.) indicates that brucellosis should not affect newborn calf weights.

Thorne et al. (1976) reported that 90% of calves weighing >16 kg at birth survived vs. <50% of those weighing <11.4 kg. In this study, 5 calves weighed <11.4 kg and 3 survived. Thirteen kilograms appeared to be the breakpoint for the calves we weighed; survival of those weighing <13 kg was 66.7% vs. 88% for those weighing more. The average weight of those calves not surviving was 14.6 kg ($n = 14$, SE = 0.28) and was lower (P = 0.08) than the weight of those surviving ($n = 63$, mean = 15.9

kg, SE = 0.76). Clutton-Brock et al. (1982) reported similar results for red deer.

DISCUSSION

Several recommendations have been made for winter intake levels for elk. Thorne et al. (1976) recommended a minimum daily intake level of 4.2 kg based on evaluations of reproductive success of penned elk that weighed somewhat more than the average elk in our study. Regelin (pers. commun.) recommended that the NER feed 2.9 kg of pellets/day to provide the amount of metabolizable energy required for maintenance of a 204-kg elk. He based this figure on Brody's interspecific estimate of basal metabolic rate (doubled to account for cold stress and winter activity) and on Thorne and Butler's (1976) figures of gross energy (4.6 kcal/gm) and digestibility (65%) for pelleted alfalfa. Hobbs et al. (1982, Table 1) estimated that a 200-kg elk required 9,185 kcal of metabolizable energy/day, a figure 1,625 kcal higher than Regelin. At that level, and under the conditions of their study, 3.6 kg of pelleted alfalfa would be required for maintenance. According to Mould and Robbins (1981), digestible energy intake must exceed 153.3 kcal/kg$^{0.75}$ for elk to maintain a positive nitrogen balance. This would amount to 2.7 kg/day for a 200-kg elk or 3.0 kg/day for a 230-kg elk, the average elk weight in this study.

This study evaluated elk performance at 2.3 and 3.2 kg/day and at 4.5 kg on alternate days. Digestible energy is insufficient to maintain body weight at the 2.3 kg/day level (6,877 kcal) with weight loss averaging 8.9% over the 5 years. Weight loss was lower at the other 2 levels and digestible energy intake was above the level calculated from Mould and Robbins (1981). Smith and Robbins (1984) reported that about 2% of the feed was left when elk were fed 3.6 kg/day in 1973, and we observed that most of the 4.5 kg fed on 1 day was generally gone by the next; thus, elk likely fed on native vegetation on the alternate days. Although abundant on NER (431-1,165 kg/ha), availability of native vegetation is often reduced because of snow cover. Thus, to assure elk sufficient daily intake of energy and protein to meet maintenance and activity levels and to maximize calf production, we recommend a feeding level of 3.2 kg/day of pellets. We question, however, whether it is necessary to meet maintenance level in view of the normal (Price and White 1985) annual weight fluctuations of ungulates in temperate regions and the naturally occurring sub-maintenance levels of protein and energy in native vegetation during the winter.

Brucellosis-positive adult females produced fewer calves. According to Thorne et al. (1979), reduced reproductive success of brucellosis-infected females is shown in abortion, premature birth, and birth of nonviable calves. Observations of the penned elk indicated that there were 10 *in utero* losses, 8 being in brucellosis-positive adult females. Premature births did not appear to be a problem since calves produced by brucellosis-positive adult females did not occur in the early birth dates in greater proportion than their occurrence in the calf population. In an elk herd (such as at NER) where 38% of the females were brucellosis positive, only 61.9% of the females would produce a calf surviving to August. This is a 7% decrease over a herd without brucellosis.

Finally, calf birth weights were not correlated to the initial, final, or change in weight of their mother. Feed rations tested in this study affected weight dynamics of adult female elk but not calf birth weights or survival. We believe ad libitum intake of nutritious natural forage, once green-up occurs in March or April, likely permits recovery during the last trimester of pregnancy of weight losses that adult female elk experienced during winter.

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MORTALITY AND MOVEMENT OF TRANSPLANTED ROCKY MOUNTAIN AND ROOSEVELT ELK IN SOUTHEAST ALASKA

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: Elk were first introduced to Alaska on Afognak Island in 1929 and the transplant of 8 animals was successful.in establishing a huntable population of Roosevelt elk. In southeast Alaska, however, repeated introduction attempts were unsuccessful until 1987, when 50 elk were moved from Oregon to Etolin Island. In January, February, and March, 1987, 33 Roosevelt and 17 Rocky Mountain elk were released on Etolin Island. Fifteen Roosevelt and 13 Rocky Mountain elk were located on a periodic basis from January 1987 until September 1989. Known causes of mortality included losses to wolf predation, accidents, and poaching. We discuss the history of failed elk introductions in Alaska and the environmental resistance that an introduced population must overcome to be successful. After an initial period of little movement and high mortality, elk on Etolin Island have begun to disperse over the available habitat and some have moved to adjacent islands. Mortality, movement of introduced animals, reproduction and environmental resistance are discussed.

Attempts to transplant elk to southeast Alaska prior to 1987 were unsuccessful. These attempts included a total of 45 animals: 8 Roosevelt elk (*Cervus elaphus roosevelti*) were introduced to Kruzof Island near Sitka in 1926 and 1927; 27 were transplanted to Revillagigedo Island near Ketchikan in 1937, 1963, and 1964; and 10 elk were introduced to Gravina Island near Ketchikan in 1962 (Burris and McKnight 1973).

North American elk have been successfully transplanted to many locations, including Afognak Island near Kodiak, Alaska. Eight Roosevelt elk were released on Afognak Island in 1929 (Elkins and Nelson 1954, Alaska Game Commission 1931) and the first hunting season was held in 1950 (Burris and McKnight 1973). The herd spread to nearby Raspberry Island and now sustains annual hunts on both islands.

In 1987, we moved 33 Roosevelt elk and 17 Rocky Mountain elk (*C. e. nelsoni*), to Etolin Island near Wrangell in southeast Alaska. The transplant was done at the instruction of the Alaska Legislature in response to public demand for a huntable elk herd.

STUDY AREA

Etolin is a 88,839 ha (219,520 acres) island in the temperate Alexander Archipelago of southeast Alaska. Summers are cool and wet while winters are usually mild with light annual snow accumulation due to the influence of the Pacific Ocean.

The island is typified by steep-walled valleys, alluvial terraces, and rolling or steep subalpine and alpine areas showing evidence of glaciation. Landslides and avalanche paths are common on western slopes. Vegetation cover is typical of the Alaskan rainforest, often with dense understory. Treeline ends at about 610 m (2,000 ft).

Red Mountain is the island's highest point at 1195 m (3,920 ft). About 13% of the island, or 12,384 ha (30,600 acres) is alpine habitat.

METHODS

We transplanted 50 elk provided by the Oregon Division of Fish and Wildlife (ODFW) to Etolin Island by truck, ferry, and landing craft (Land et al. 1993). We released 21 Roosevelt elk on 19 January, 12 Roosevelt elk on 3 February, and 17 Rocky Mountain elk on 15 March, 1987. Release sites for the 2 subspecies were 17 airline miles apart.

Roosevelt elk were acquired from ODFW's Jewell Meadows Wildlife Management Area west of the Cascade Mountains in Oregon. Rocky Mountain elk were obtained from the Elkhorn Wildlife Management Area in eastern Oregon. Elk were fitted with colored, numbered collars. Fifteen Roosevelt elk and 13 Rocky Mountain elk also were fitted with radio collars with 6-hour mortality sensors (Telonics, Mesa AZ).

We collected 578 locations of elk from fixed wing aircraft beginning 20 January 1987, the day after the first release. We flew a total of 47 fixed wing flights through April 1990 to locate live elk and determine if mortality had occurred. All flights originated in Petersburg, Alaska, 34 miles from the closest point on Etolin Island (Fig. 1). Because of the expense and weather difficulties, we did not attempt to plot individual home ranges during routine flights. We usually investigated mortalities within 24 hours of identifying a mortality signal. Traveling by float plane or helicopter, we landed as near as possible to suspected mortality sites, then used a hand-held antenna to locate the carcass. We necropsied dead elk when feasible to determine cause of death. We searched for tracks, scat, beds and other evidence of predators.

RESULTS

Distribution and Movement

Roosevelt elk were released from landing craft on the southern end of Etolin Island at Dewey Anchorage (Fig. 1). One radio-collared cow currently ranges on 3,367 ha

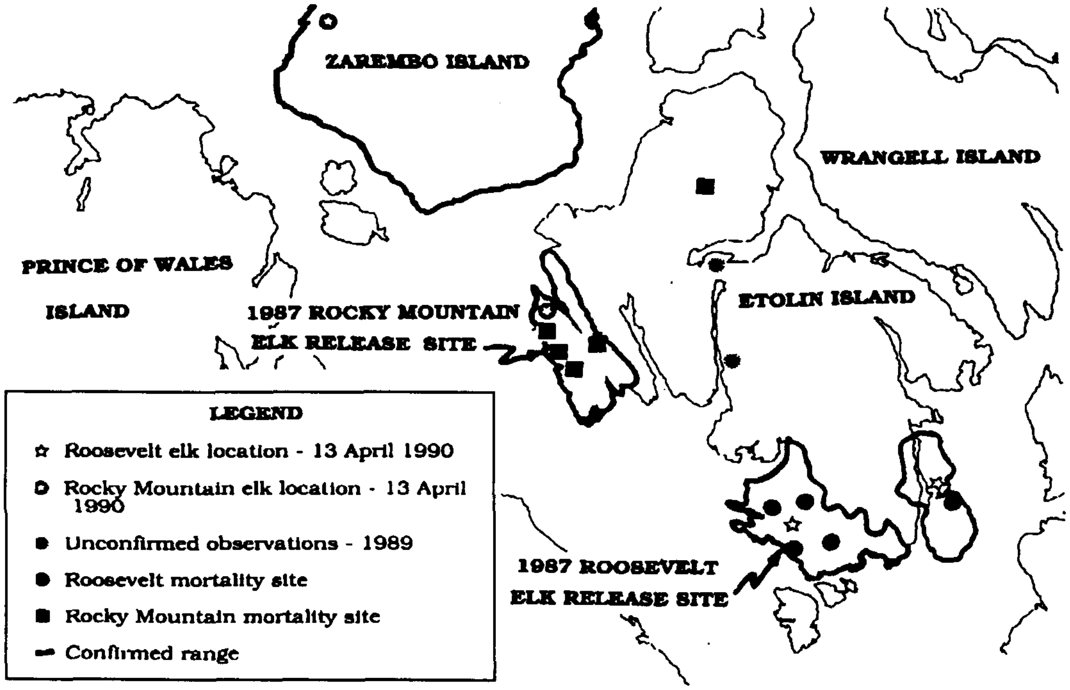

Fig. 1. Locations of sites where Rocky Mountain elk and Roosevelt elk were released in 1987 on Etolin Island, Alaska.

(8,320 acres) Brownson Island where she went soon after release. Brownson Island is 8 miles east of the release site and is separated from Etolin Island by a narrow channel (<200 m).

Most of the radio-collared Roosevelt herd moved to the area of McHenry Anchorage 4-5 miles northwest of the release site. Radio-collared Roosevelt elk remained at lower elevations (<264 m) within a mile of the shore throughout the study period.

Rocky Mountain elk were released from a landing craft near Johnson Cove on the northeast shore of Etolin Island. A mortality signal from a cow was located on Bessie Peak, 13 miles east of the release site at an altitude of >762 m (>2,500 ft). Neither the carcass nor transmitter could be located in spite of repeated searches on foot and from a helicopter. This is the only instance of an elk of either subspecies above 264 m (800 ft). Our inability to locate the transmitter may have been attributable to signal reflection from rocky cliffs.

Most Rocky Mountain elk stayed within 4 miles of the release site until the summer of 1989. In August 1989, 19 months after release, 2 cows were radio-located across Stikine Strait on adjacent 47,139 ha (116,480 acres) Zarembo Island, 2 miles north of Etolin Island and 34 miles from the release site.

We expected both subspecies of elk to disperse quickly and to utilize alpine habitat during the summer, but neither event occurred.

Population Status

Population Numbers.--Although others have demonstrated that colored neck collars can be effective in using mark-sightability to determine elk populations (Bear et al. 1989), poor sightability rendered the technique impractical for aerial surveys on Etolin Island. We rarely sighted elk from aircraft during surveys or mortality checks but we did see them during ground surveys. Fishermen occasionally reported seeing collared elk on the beach and reported the numbers or collar color.

During a June 1988 ground survey, we saw 11 Roosevelt elk: 2 marked adult males, 6 marked adult females, 2 unmarked yearling males and 1 unmarked yearling female. During the same period, we radio-located an additional adult female, and a private pilot photographed 2 marked bulls not recorded during the survey, bringing the summer 1988 count to 14 Roosevelt elk.

A total of 6 marked Rocky Mountain elk: 1 adult bull and 5 adult cows, were located during the June 1988 ground survey. No calves or yearlings were sighted. No elk were seen during a very brief ground survey in 1989 but calf tracks were seen in association with tracks of adults.

The minimum number of Rocky Mountain and Roosevelt elk surviving in June 1988 was 20 of which 17

(85%) were known to be from the original introduction.

Reproduction.-- Based on observations of animals and tracks, calves were born to Roosevelt elk in 1987, 1988, and 1989. In 1987, 1 newborn Roosevelt calf was found dead. In June 1988 we observed 3 yearling Roosevelt elk, 9 adults, and tracks of calves. In 1989 we did not see calves or yearlings, but observed calf tracks in areas frequented by both Roosevelt and Rocky Mountain elk.

Morality

Although elk transplants are common in the U. S., there is scant information in the literature on mortality of transplanted animals. Mortality of introduced elk may be fairly high, especially in areas where there are predators. We recorded 69% mortality (9 of 13) in radio-collared Rocky Mountain elk and 60% mortality (9 of 15) in radio-collared Roosevelt elk between January 1987 and May 1988.

Wolf Predation.--Wolf predation was a major factor in elk mortality on Etolin Island. Of the 9 Roosevelt elk mortalities, wolves were identified as the cause of death in 3 instances. Wolves were implicated in 3 other mortalities, having fed on the carcasses before our arrival, but there was inadequate evidence to positively identify wolf predation as the cause of the mortality. Only one of the 9 Rocky Mountain elk fatalities was a confirmed wolf kill.

When snow was on the ground, it was easier to determine if predators were involved. In one instance, a wolf pack pursued a cow for about a mile through scrub forest until she stopped, then surrounded and killed her. Wolf packs commonly bedded near kills, returning frequently to feed until all of the internal organs, meat and most of the bones were consumed. In some cases long bones were cracked and marrow consumed from the bone.

Etolin Island wolf packs are small. Tracks in the snow at kill sites indicated that packs preying on elk consisted of 3-4 wolves. Carbyn (1974, 1983) found that packs of 2-4 wolves were successful in taking elk.

Wolves were identified as major predators on Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in southeast Alaska (Smith et al. 1987, Young 1985, Wood 1982). Van Ballenberghe and Hanley (1982) concluded that wolf predation may be more of a deer management problem in southeastern Alaska than elsewhere. Wolf predation was identified as one of two predictable limiting factors on introduced elk in a transplant feasibility report (Alaska Department of Fish and Game 1985).

Elsewhere, the wolf is a known predator on elk (Weaver 1980, Atkinson 1985, Carbyn 1974, 1983). In Canada's Jasper Park, Carbyn (1974, 1983) observed that the greater occurrence of elk remains in wolf scats coincided with elk calving in late June, and stated that elk calves are vulnerable to wolf predation. In May and early June wolf predation shifted from mule deer (*O. h. hemionus*) to elk (Carbyn 1974, 1975).

In British Columbia, Roosevelt elk were second in importance only to black-tailed deer in wolf diets (Scott and Shackelton 1980). As wolves recolonized the northern half of Vancouver Island they nearly extirpated deer before significantly affecting elk numbers (Hebert 1981, Hebert et al. 1982). Wolf numbers on Vancouver subsequently declined in areas with wolf control, and predation on elk stabilized (Atkinson 1985).

Etolin Island has a high prey diversity which includes deer, beaver, mink, marten, otter, squirrels, grouse, ptarmigan, waterfowl, and salmon. Wolf predation was the primary factor limiting elk population growth in Canada in an area of high prey density and multiple prey species, including elk, moose, deer and beaver (Carbyn 1974, 1975, 1983).

Murie (1951) cited I. McT. Cowan as saying that wolves in Canada commonly prey on elk, both on calves and adults, and that a single wolf can kill an elk, which is seized by the throat or flank. He stated that elk may escape wolves by taking to water or deep, soft, snow. We have not observed this behavior in southeast Alaska although while releasing the Roosevelt elk, a number of them ran into the water and began swimming away from shore. They were turned back to shore by hazing them with a small boat. Radio-collared elk on Etolin Island spend much of their time near the shore, which may be a response to predators.

Black Bear Predation.--Evidence indicated that a black bear probably killed a Rocky Mountain elk calf. The carcass was partially consumed by a black bear. We found numerous bear tracks and scat near the carcass.

Murie (1951) found elk calves to be susceptible to predation by black bears. Moose calves in Alaska are affected by brown bear predation (Ballard et al. 1981) and in Idaho, Schlegel (1976) reported elk calf losses of around 50% from black bear predation over a period of 3 summers.

Accidents.--A Rocky Mountain elk calf fell off a cliff and sustained a broken neck. There was no evidence that the animal was running or pursued. It appeared to have lost its footing while grazing too close to an overhanging mossy edge. There was no evidence of predation or scavenging.

A Rocky Mountain cow broke her neck when she ran into a fallen tree on a trail near the beach. There was no indication of why the cow was running and no evidence of predation or scavenging. The accident occurred 22 weeks after the release.

A Roosevelt cow became wedged between drift logs in a creek and appeared to have died of stress. Upon necropsy, the cow was found to be pregnant. There was no evidence of predation or predator involvement.

Malnutrition.--A Rocky Mountain cow released on March 15 was found dead on June 30. The bone marrow was red, thin, and cloudy, and we suspected starvation. No other cause of death was indicated by necropsy.

A Rocky Mountain calf found dead on April 8 (24 days after release) appeared to have starved. Bone marrow was clear and thin, and there was no fat on mesenteries or internal organs.

Physiological.--A Roosevelt cow succumbed to what appeared to be "twisted gut syndrome". The cow had a compacted and enlarged omasum, a compacted dry bolus in mouth and gums, and red gelatinous bone marrow. A consulting veterinarian (A. Franzmann pers. comm.) said that the syndrome can occur in ruminants that suddenly change feed type and texture.

Poaching.--In July 1987, we radio-located the death site of a Rocky Mountain bull on the beach near a popular anchorage. Only the head and a few small bones were present, leading us to speculate that it may have been shot from a boat. All long bones were missing, and there was no evidence of predation. Two Roosevelt bulls with color collars but without radios were killed by a poacher on Brownson Island in December, 1988. The violation was reported by one of the people involved.

Unknown.--The cause of death could not be determined or hypothesized in one Roosevelt elk mortality and another radio-collared Roosevelt elk is no longer transmitting and presumed to be dead. Cause of death could not be determined in 2 instances of mortality in Rocky Mountain elk.

Relation of Age to Mortality.--All 4 Rocky Mountain elk calves that were radio-collared died. Three died within 24 days of release and one died 106 days after release. Calves were transplanted when it became obvious that sufficient Rocky Mountain adults could not be trapped in time for shipment. The use of calves in earlier southeastern Alaska transplants (Burris and McKnight 1973) may have doomed the transplants to failure.

Of the 4 adult and 1 yearling Rocky Mountain mortalities, the average survival rate was 130 days. A radio-collared yearling male died 133 days after release while adult Rocky Mountain cows survived an average of 129 days.

Roosevelt elk deaths occurred an average of 184 days after release. Adult cows (n=6) survived 72 days on the average, while adult and yearling bulls (n=3) survived 408 days.

Subspecific Mortality.--As of April 1990, 60% of radio-collared Roosevelt elk have died, while 69% of Rocky Mountain elk succumbed. Excluding the death of calves, adult Rocky Mountain elk mortality was 50%. We assumed that Roosevelt elk would have higher survival rates in the rainforest environment of southeast Alaska, but our findings do not indicate a clear difference.

Seasonal Mortality.--The greatest number of deaths during a given month occurred in March (Fig. 2), the month when ungulate body reserves are lowest in southeast Alaska. Snow has just melted or is melting in March, but annual plant growth has not begun.

DISCUSSION

It appeared that mortality has leveled off and that the elk herd in southeast Alaska has a good chance of survival (Fig. 2). No losses of radio-collared Rocky Mountain or Roosevelt elk occurred between May 1988 and April 1990. Geist (1982) stated that elk readily learn from experience, and surviving elk on Etolin and Zarembo islands appear to have learned to avoid predators and accidents.

Elk moved less than we expected and there was no discernible seasonal range shift. Although we expected significant use of alpine habitat, we found elk above 262 m (800 ft) in elevation in only one instance in 578 locations. Elk were occasionally sighted on the beach, but rarely seen in open areas.

Although it has not been reported, we suspect that initial mortality of introduced elk elsewhere in North America may be as high as was demonstrated in this study. Elk releases usually do not include substantial numbers of radio-collared animals so the extent of mortality may go undetected.

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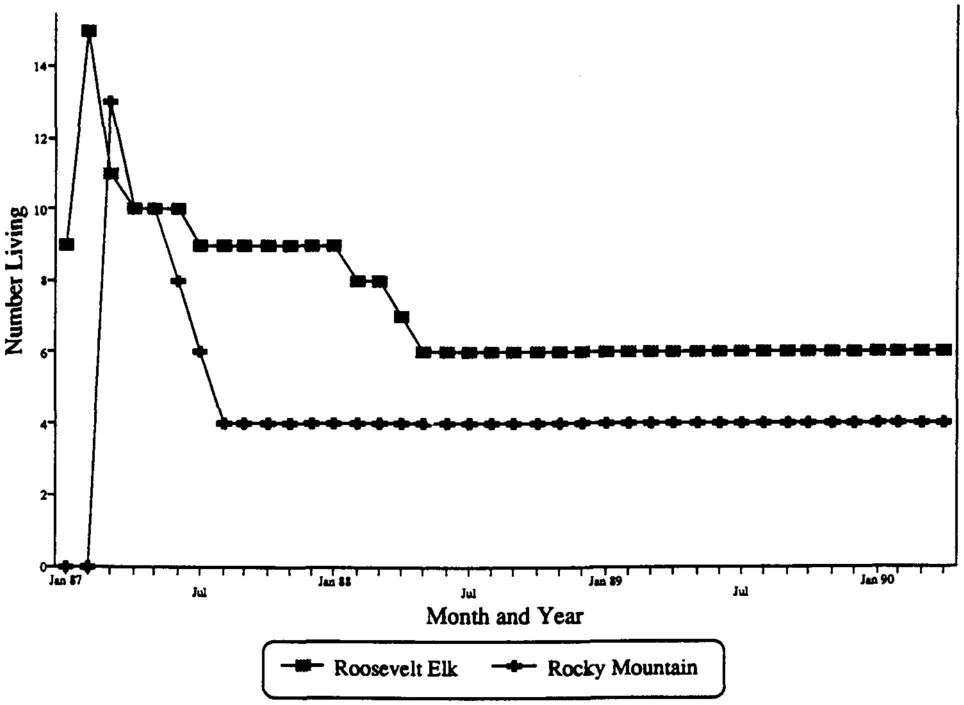

Fig. 2. Status of elk radio-collared on Etolin Island, Alaska.

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TRANSLOCATING ELK FROM OREGON TO ALASKA BY TRUCK, FERRY AND LANDING CRAFT: PROBLEMS AND TECHNIQUES

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract:: Thirty-three Roosevelt elk (*Cervus elaphus roosevelti*) from Jewell Meadows Wildlife Management Area and 17 Rocky Mountain elk (*C. e. nelsoni*) from the Elkhorn Wildlife Management Area in Oregon were captured and translocated to Etolin Island, Alaska in 1987. We used drug immobilization and/or walk-in traps. Although moving elk by vehicle is a common practice, transporting elk from Oregon to southeast Alaska by truck, commercial ferry and landing craft presented some unique problems. The ferry schedule, availability of shallow-draft landing craft, the distance involved, and weather problems which delayed boat movement, required confining elk for long periods. Two Rocky Mountain elk and one Roosevelt elk died during transport. We suggest procedures for minimizing stress and reducing the chance of injury and mortality: adjustment of light levels helps in calming and moving elk, large quantities of drinking water are essential, visual stimuli should be reduced, ad libitum feeding gave best results, spraying elk with water during transport reduces stress, and selection of the unloading site is critical.

In the past, elk have been moved long distances by wagons, rail cars, trucks, and ships. On this project we used trucks, ferries, and both private and military landing craft to transport Oregon elk to the Tongass National Forest in Alaska.

Elk were trapped in pre-baited corral traps using alfalfa hay or were captured using immobilizing drugs. Some elk were held for several days before being loaded and shipped.

We are very grateful for the outstanding cooperation and courtesy shown us by the staff of the Oregon Department of Fish and Wildlife (ODFW), the crews of the Alaska Marine Highway System, members of the Ketchikan Sports and Wildlife Club, the United States Forest Service, the Army National Guard, and also the owner and crew of the "Sea Hawk". Without this help the project would have been extremely difficult.

CAPTURE AND PROCESSING

Roosevelt elk

Roosevelt elk were captured on or near the ODFW's Jewell Meadows Wildlife Management Area located about 20 miles southeast of Astoria, Oregon. Two groups were captured; the first group consisted of 21 elk captured in corral traps and the second group of 12 elk was immobilized using Carfentanil (Janssen Pharm., Beerse, Belgium).

Trapping of surplus elk with portable corral traps at Jewell Meadows is an annual part of ODFW's operation. Normally, elk are loaded from the trap to trucks and driven to the release site within hours of capture. For this project a temporary holding area was constructed on the management area so that elk could be held until the desired number of cows and bulls were captured.

A holding pen with plywood walls 8 feet high was built inside an existing barn. Loading chutes were constructed on one side and at the end of the barn. Rubber water tubs were placed so that they could be filled from outside the pen. A cable was suspended so that a plastic sheet could be drawn across the pen to divide it to help force elk into the loading chutes. Elk were held until the day before departure when they were trucked to a corral trap. They were then driven into the handling chute where they were processed. Antlers were sawed off close to the burr. All animals were fitted with a visual collar and ear tagged. Several elk were fitted with radio collars. Blood samples were taken and elk were injected with Ivermectin (Merck & Co., Rahway, NJ), Liquamiacin (Pfizer Inc., New York, NY), and *Clostridium bacterium* (Colorado Serum, Denver, CO).

We found that elk were reluctant to move from the truck into the dark holding pen. Elk in the truck would not readily enter the chute until they could see into the barn. A floodlight operated from a portable generator solved the problem. After the elk were in the barn we kept it as dark as possible which seemed to reduce stress.

Elk at Jewell Meadows are routinely fed alfalfa hay during winter. We used alfalfa hay for bait and feeding during holding and transportation. Liberal quantities of hay were put into the holding pen daily to provide clean forage and dry bedding. Fresh water was provided twice a day. We added standard bovine electrolytes to drinking water to replace minerals that might be lost through stress.

ODFW staff at Jewell Meadows cautioned that Roosevelt elk were not hardy and could easily die from stress. Our experience tended to support this theory. One cow refused to enter the truck with the rest of the group. Attempts to induce her to load caused her to lie down in the loading chute where she died. Another Roosevelt cow was exceedingly troublesome at every stage of the operation. She appeared in good condition when loaded for the journey to Alaska but soon lay down in the truck and would not get up. It was obvious that she was not going to recover so she was euthanized.

Roosevelt elk were held for up to 10 days prior to shipment and some were held in trucks for up to 4 days prior to release, for a total of 14 days in captivity.

Rocky Mountain elk

Seventeen Rocky Mountain elk were caught in traps at the Elkhorn Wildlife Management Area in eastern Oregon.

The trapping system used at Elkhorn was similar to that used at Jewell Meadows. Portable and fixed traps were pre-baited and set when elk were routinely feeding in the traps. We did not use drugs to capture Rocky Mountain elk.

The holding pen at Elkhorn was more open than at Jewell. It was a metal hay barn enclosed with 8 foot walls and open above. A handling facility was incorporated into a corral trap near the holding pen. A chute lead from the trap to a commercially constructed cattle squeeze box and loading chute.

Elk were herded into the chute, immobilized in the squeeze section, and processed as at Jewell. The staff at the Elkhorn were not concerned about Rocky Mountain elk hardiness and we saw no serious evidence of stress; Rocky Mountain elk were nervous when disturbed but settled down quickly. The only losses during trapping, handling and shipment were from broken bones. One calf broke a leg during loading and another fell from the truck during the release and suffered a broken leg. Both were euthanized.

We held Rocky Mountain elk for 4 days or more prior to shipment and some were held in trucks for up to 4 days prior to release, making a total of 8 days or more in captivity.

TRANSPORT

Trucks

Trucks were supplied by ODFW and fitted with their standard elk transport racks consisting of a single compartment. We stapled burlap to the sideboards to provide a visual barrier. We wired rubber buckets into two corners for water. and placed shredded bark on the floor as bedding and absorbent material. We nailed cleats to the floor to help prevent slipping. We attempted to load each truck so that the standing elk braced each other.

Hay bales were lashed on top of the trucks so that we could break the bales and provide hay from the top with little disturbance to the elk.

At each rest stop we would withdraw from the trucks to allow the elk to settle. Each truck had a window to permit us to observe the elk while driving. It appeared that while the truck was in motion, the effort required to stand upright occupied most of their attention.

Departure time of the Alaska Marine Highway ferry from Seattle was a critical factor. There is one departure a week and reservations must be made well in advance to insure that space is available. We estimated driving time, loading times, rest stops, and added a margin of safety in order to arrive prior to departure time. In one instance a truck experienced engine failure and had to be replaced. Elk were successfully transferred to another truck driven from Jewell Meadows.

Ferry

One of our biggest challenges on the ferry was keeping spectators at a reasonable distance. A truck full of elk was an irresistible attraction. Burlap strips over the slatted sides of the elk racks helped screen the elk from view. Noise did not seem to bother them unless accompanied by visual stimuli. Although these elk were somewhat habituated to people, they were excited by close approach. Human activity sometimes caused elk to mill around and start to overheat. Even though it was January and the car deck was not heated, elk would still pant when excited. By spraying water on their backs we lowered body temperature (evident by the lack of exhaled moisture) and they soon settled down. The car deck was off limits while the ferry was underway but it required all of our effort to keep the passengers away from the trucks during permitted deck calls.

Elk that had been confined in the holding pens for an extended period were more docile and less affected by our activities and the activities of other people.

We fed hay twice a day at a nominal rate of 4 pounds a day per animal. We provided fresh drinking water about every 4 hours.

Landing Craft

After off-loading in Ketchikan, the trucks were driven several miles to a boat ramp for loading onto landing craft. The tidal range in southeast Alaska can be as much as 20 feet and a wait of up to four hours was often necessary to allow the landing craft to get in proper position for the trucks to board.

It is about 50 nautical miles from Ketchikan to Etolin Island which required an average 6 hours of travel by landing craft. Our departure from Ketchikan with one group of elk was delayed due to >50 knot winds, forcing us to hold the elk for an additional day. We purchased alfalfa hay locally to feed elk during the delay.

RELEASE

We had previously selected the release sitesand we preferred a remote shore free of logs and boulders adjacent to open timber and muskeg. Most of the south facing beaches on Etolin Island are littered with logs lost from logging operations. Some shores are bordered by sheer rock cliffs or ledges and were unsuitable.

It was necessary to arrive at the release site at low water so that the release could be done on a rising tide to prevent stranding the landing craft. Releasing elk at low water also helped them to avoid the hazardous jumble of drift logs that covers the area between the high tide line and the forest.

During the first release, we landed at a gradually sloping beach, but found that the landing craft grounded so that the craft's ramp was suspended at a height over 3 feet of water. In Oregon, trucks back against a cut bank to release elk, but that option was not available and we were forced to move the landing craft to a steeper beach. A wooden ramp we constructed in advance was useless. Elk were reluctant to leave the truck as long as the wood ramp was in place. We piled hay on the ground to pad rocks and with much shouting and use of a cattle prod the first shipment was released without injury. Some took to the water but a crew in a skiff turned them back.

The second group of elk was also released without incident, but during the third shipment, we failed to use hay as a padding and a Rocky Mountain calf suffered a broken leg.

CONCLUSIONS

We concluded that:

1) elk can be successfully moved long distances by most transportation means, including marine vessels;
2) elk can be confined in small areas for long periods without problem;
3) holding elk for a time prior to transport reduced stress;
4) electrolytes added to drinking water help to prevent mineral deficiencies associated with stress;
5) providing abundant hay and drinking water may have allowed elk to use displacement activity to reduce stress;
6) darkness was effective in calming elk, while artificial light was used to move elk into confined areas;
7) the use of water spray had a calming influence on elk and reduced over-heating;
8) visual screening prevented the elk from viewing human activity and had a calming influence; and
9) ramps were not necessary to unload elk, but in the absence of a cut bank, piling loose hay on the ground cushioned the elk as they exited and reduced the chance of injury.

TULE ELK MANAGEMENT IN THE CALIFORNIA STATE PARK SYSTEM: THE TUPMAN TULE ELK RESERVE TODAY

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: The original intent of establishing the Tupman Reserve in Kern County, California in 1932 was to preserve one of the last herds of tule elk (*Cervus elaphus nannodes*). The Reserve was managed by the State Fish and Game Commission and the Division of Fish and Game up until 1952 when it was transferred to the California State Park system and renamed the Tule Elk State Reserve. Today, the Reserve is managed not only for tule elk but for many other values as well. Among the more important of these values are sensitive species of wildlife which include the slough thistle (*Cirsium crassicaule*), a candidate for Federal endangered species listing and the endangered Tipton kangaroo rat (*Dipodomys nitratoides nitratoides*). The Department of Parks and Recreation must also manage the Reserve for native habitats, archaeological sites, public use and education. Natural resource management programs currently include surveys for sensitive species and their distribution, wetlands and grassland habitat improvements, a water acquisition study and, of course, elk management. Education programs at the Reserve have recently been expanded to include guided school group tours, public nature walks, junior ranger programs for children, the opening of a small visitor center and the incorporation of the nonprofit Tule Elk Natural History Association.

The Tupman Tule Elk Reserve was established in 1932 as an elk sanctuary to preserve one of the last herds of tule elk. Over the years, the Reserve has evolved into a sanctuary for many forms of wildlife. Today, the California Department of Parks and Recreation manages the Reserve not only for tule elk but for many other values as well.

Prior to the nineteenth century, as many as 500,000 tule elk roamed over the wetlands and grasslands of the coastal and central valleys of California (Koch 1989). In the 1800s, the tule elk were reduced almost to extinction by competition with herds of Spanish livestock, heavy hunting pressure during and after the gold rush and agricultural development of the land by settlers. By 1874, only a few tule elk could be found in the marshes north of Buena Vista Lake (McCullough 1969).

Pioneer rancher and conservationist Mr. Henry Miller of the Miller and Lux Cattle Empire took steps to ensure survival of the species by providing strict protection of the elk still roaming his land (Bureau of Land Management [BLM]). Through his efforts, the elk were able to survive and reproduce so that by 1914, the herd had increased to approximately 400 animals (Evermann 1915). As the number of elk grew so did the damage they did to the crops and fences on local farms.

In 1931, the State Legislature reacted to public pressure by passing a bill to establish a tule elk sanctuary. In 1932, 386 ha of land were purchased and fenced near the town of Tupman and about 140 elk were enclosed. The California Department of Fish and Game was given the responsibility to manage the new Tupman Refuge (McCullough 1969).

At the time of the purchase, the sanctuary was a fairly good example of the natural habitat of the tule elk. However, it was soon apparent that the refuge was too small to support the large number of elk. An artificial feeding program was instituted not long after the sanctuary opened. The construction of the Miller Canal split the refuge in two and cut off the Buena Vista Slough, the only natural watercourse (McCullough 1969). The range deteriorated further when the Lake Isabella Dam was constructed on the Kern River in 1952, essentially wiping out the seasonal flooding along the Buena Vista Slough. Soon after, the lush riparian habitat vanished from along the slough and from within the Reserve (McCullough 1969).

In 1954, the Tupman Refuge was turned over to the California State Park system and later renamed the Tule Elk State Reserve. At this time, there were only 3 tule elk herd locations: (1) Cache Creek in Lake County; (2) in the Owen's Valley; and (3) at the Tupman Refuge. Through the use of controlled hunts, the statewide population of tule elk was kept at about 400 animals until the early 1970s (McCullough 1969).

In 1971, the Behr Bill passed through the legislature and became law. It mandated that tule elk could not be taken until their State population surpassed 2,000 animals (Koch 1989). This prohibited the taking of excess elk and giving the meat to the State prisons as was the current practice at the Reserve. The excess elk now had to be moved out of the Reserve to supplement existing herds or to start new herds elsewhere.

Through these and other efforts, there are now 19 different herd locations in the State and over 2,500 tule elk for the first time since the 1860s (Koch 1989).

The purpose of a State reserve as defined in the Public Resources Code is "to preserve native ecological associations, unique faunal or floral characteristics, geological features and scenic qualities in a condition of undisturbed integrity." Natural resource management in

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the California State Park system is guided by a number of laws, policies and directives. The park system has three primary missions: to preserve California's natural heritage, to preserve California's cultural heritage and to provide significant recreational opportunities for Californians (California Department of Parks and Recreation 1981).

Tule elk management is and has historically been, one of the major programs at the Reserve. The Department of Parks and

Recreation works in cooperation with the Department of Fish and Game on relocation efforts at the Reserve and to ensure that the elk remain healthy. Today, the Tule Elk State Reserve is also managed for other significant values such as endangered species and the archaeological sites of the Yokut Indians.

Staffing levels have an effect on the management programs at the Reserve. There is currently a park ranger, a maintenance worker and a seasonal maintenance aid position for the Reserve. However, the Reserve has not been fully staffed over the last year because of the State budget constraints. A seasonal environmental services intern is funded by a voter approved bond act. Volunteers, convict crews and the California Conservation Corps do provide some extra labor.

Several decades ago, the Reserve's herd size objective was set at 32. However, the actual carrying capacity for the Reserve is probably much less since the Reserve is quite small (387 ha) and has fair to poor range conditions. The Tule Elk State Reserve has the second highest ratio of elk per ha in the State at 1 elk per 9 ha. Only San Luis National Wildlife Refuge has a higher ratio at 1 elk per 8 ha. However, San Luis has excellent range conditions (BLM 1989).

The Reserve lies within the southern San Joaquin Valley in an extremely arid environment where the average annual rainfall is only 14.6 cm. We are also in the fourth year of a drought in an area where all riparian water rights were reserved prior to the Reserve's creation and where overgrazing within the Reserve has been the norm for the last 50 years.

An area that the elk use heavily is the Reserve's 28-ha swamp. This wetland is a remnant of the Buena Vista Slough that meandered north from Buena Vista Lake to Tulare Lake, once the largest freshwater lake west of the Mississippi River. Today, the Reserve receives water in good rain years for its small swamp from the Buena Vista Water Storage District, specifically for ground water recharge. This water is delivered to the swamp via the outlet canal. However, in poor water years, the Buena Vista Water Storage District does not put water into the swamp and they are under no obligation to do so. Because of the lack of a regular water supply, the swamp can only function as good elk habitat on an intermittent basis.

The remainder of the Reserve is dominated by nonnative annual grassland and provides good forage, primarily in the spring. Two wells within the Reserve supply water for an 8 ha, sprinkler irrigated pasture and 1 ha of flood irrigated pasture. Occasionally small amounts of agricultural tail water are furnished by a neighboring farmer to flood irrigate an additional hectare of pasture.

A supplemental feeding program was established early in the Reserve's history (McCullough 1969) and has continued to the present. We currently feed the elk alfalfa and barley pellets during periods of overpopulation and/or poor range conditions. The feed contains copper-sulfate which was added to combat a suspected copper deficiency. Supplemental feed blocks with copper-sulfate are put out for the elk when the alfalfa and barley pellets are not being provided. The supplemental feeding program, although necessary, is undesirable because of its cost, staff time expended for feeding and the domesticating effects it has on elk. On the other hand, the feeding program has helped make it easier to bait the elk into a catch pen for relocation.

Prior to 1987, when supplemental feeding was necessary it was done every day at 2 p.m., in front of the public viewing area. Feed was also put out to lure the elk up close for guided, public tours into the Reserve. Both of these practices were discontinued in hope that the elk would not become quite so tame and would perhaps be less likely to be poached or hit by vehicles on highways when relocated into the wild. It may be quite some time before it can be determined whether or not this prohibition on feeding the elk in front of the public will actually prove to be beneficial for the elk.

Over the years, a number of relocation efforts have moved elk out of the Reserve (Fowler 1985). The most recent relocation moved 38 animals to San Luis Obispo County onto a private ranch within Los Padres National Forest in the fall of 1989. Two additional elk were shipped to the Fresno Zoo in the winter of 1989. These two moves reduced the herd to 19 elk. This is the first time since the refuge was established in 1934 that the herd's population has dropped significantly below the herd size objective of 32.

In the last 5 years, the Department has also moved tule elk into the Reserve to add to the herd's small gene pool. In 1987, 5 bulls were delivered to the Reserve from an exhibit at the Detroit Zoo that was being shut down (Koch 1989).

Habitat use at the Reserve has been monitored over the last 3 years through weekly elk surveys that have noted use by sex, age, activity and habitat type. During this same period of time, the State park system contracted with the University of California (UC) Davis to conduct a study of the Reserve and the tule elk. Vegetation plot sampling in the different seasons of the year have been used in an attempt to determine elk diet preferences. Some of this information is being used for pasture management and for habitat restoration efforts within the Reserve. A mathematical model of the range ecosystem will be developed in the next fiscal year using this data. The ecosystem simulation model will predict seasonal trends in forage quantity and quality and allow us to explore the effects of various environmental conditions and management options on the carrying capacity of the Reserve (Boyd and Martens 1988).

Part of the goal of the UC Davis study was to determine which native plants would be best suited for habitat restoration efforts and what propagation methods would be most successful. The information from this study was used when we enlarged a small elk wallow and created a larger pond by the public viewing area in the fall of 1988. We replanted the area with native trees, shrubs and grasses such as alkali sacaton (*Sporobolus airoides*), joint grass (*Paspalum distichum*), buttonwillow (*Cephalanthus occidentalis* var. *californicus*) and black willow (*Salix gooddingii*) and fenced the elk out for a year. Today the vegetation is lush and the elk are using the area heavily.

We are also experimenting with prescribed burning in an attempt to improve grassland habitats for elk forage. McCullough (1969) reported the use of alkali sacaton, a native perennial bunchgrass, by elk in the Owen's Valley. Bock and Bock (1978) found burning to be a beneficial tool in the alkali sacaton grasslands of New Mexico. In the winter of 1987, we conducted a small burn within an old stand of alkali sacaton with the goal of improving the stand and monitoring for post fire elk use. We found that the fire which was rather hot did not improve the quality of the grassland as we had hoped. However, water added to the stand the next summer produced a healthy sacaton grassland (Boyd and Martens 1988).

In May of 1990, we conducted an experimental burn in the annual grassland community. The objectives of the burn were two-fold: (1) to discourage nonnative annual grass species such as *Hordeum*; and (2) increase forb production such as *Erodium* sp. (Waldron 1989). Murie (1951) and McCullough (1969) both reported a preference for *Erodium* sp. by tule elk. Secondarily, the foxtails of *Hordeum* sp. have been known to cause abscesses in the tule elk. A fall burn will also be conducted to test for the effectiveness of a fall versus spring burn.

In the spring of 1990, the Department entered into a contract with a researcher from UC Davis to do a small water study at the Reserve. This study and others by UC Davis are being funded by State voter approved bond acts. Wetland restoration efforts at the Reserve are limited almost entirely by water. Currently, there is no reliable or inexpensive source from which to obtain water for restoration. This study will attempt to determine the annual volume of water required to maintain existing wetland habitat and restore 122 ha of former wetlands habitat within the Reserve, determine potential sources of water and which source(s) would best fit the needs of the Reserve, estimate water costs for each source and lastly identify the procedures involved in obtaining water from each source. This information will allow us to move forward to acquire the water needed for wetlands restoration and maintenance at the Reserve. Obviously wetlands restoration would greatly improve the habitat for elk and other important species of wildlife.

Sensitive species management is another important management program at the Tule Elk State Reserve. It is difficult to manage effectively for all wildlife without having information on species present, numbers, distribution and habitat requirements. Prior to 1986, information about the Reserve's wildlife, other than elk, was lacking. Although park staff kept records of some wildlife sightings and a small survey for mammals and for birds were conducted by local college students, little was known about the sensitive flora and fauna of the Reserve.

Through the contract with UC Davis and additional work by the Department of Parks and Recreation, the Reserve's plants and animals began to be systematically inventoried. Small mammal live trapping, reptile, bird and plant surveys and incidental wildlife sightings have revealed the existence of over 130 species of plants, 135 species of birds, 20 mammal species, 10 reptile species and several amphibians. Five different plant communities were identified within the Reserve including the rare alkali sink, riparian forest and alkali sacaton grassland.

This work also identified the existence of three endangered species including the Tipton kangaroo rat, the San Joaquin kit fox (*Vulpes macrotis mutica*) and the blunt-nosed leopard lizard (*Gambelia silus*), the rare San Joaquin antelope squirrel (*Ammospermophilus nelsoni*), the slough thistle, a candidate for Federal endangered species listing and 13 California Department of Fish and Game species of special concern, including the western pond turtle (*Clemmys marmorata*), the northern harrier (*Circus cyaneus*) and the burrowing owl (*Athene cunicularia*). This might seem like an extraordinarily large number of special species to occur within such a small Reserve. However, when one considers that the Reserve is surrounded by the "Bread Basket of the nation it does make more sense. In fact, only five percent of the southern San Joaquin Valley remains in a natural state and those areas contain the largest concentration of protected species anywhere in the continental United States (California Energy Commission 1986).

Additional sensitive species surveys will be conducted over the next 2 years to better identify and monitor existing populations. Surveys will also be done for several sensitive species that haven't been observed at the Reserve but could very likely occur there such as the Buena Vista Lake shrew (*Sorex ornatus inornatus*). This information will allow us to better manage the Reserve for all species of wildlife including tule elk.

Our third major program for the Reserve is visitor management which includes both recreation and education. The Department maintains a 2 ha viewing area with picnic facilities and is used by about 30,000 visitors per year.

One of the major points of focus in our public education program is the tule elk and their management. This includes school group tours which service approximately 1,000 students per year. Junior ranger programs provide more in-depth programs for children on weekends in the fall and spring.

Part of the visitor management program includes the public use area where visitors can view the elk in a natural setting. Several natural history displays help interpret the tule elk and the Reserve. Plans have been developed for the construction of a 12.2 m x 12.2 m raised viewing platform with a mounted telescope, improved natural history exhibits, benches and shade ramada. The platform would provide better opportunities for the public to view the elk, especially when the elk are lying down or are at a distance. The platform would allow programs for school groups to be offered even under inclement weather conditions. Unfortunately, financing for the platform is not currently available within the Department.

Since 1988, public nature walks have been advertised in the local Bakersfield newspaper during the rutting and calving seasons and given on weekend mornings. The walks have been quite popular and provide excellent opportunities for public education about elk.

A small visitor center was opened for the first time last spring in an old office. It is currently open on Sunday afternoons, spring through fall. It is operated by the volunteers of the Tule Elk Natural History Association. This nonprofit organization was formed in the winter of 1989 to assist the Department with its education and resource management programs at the Reserve. Currently, the association has about 40 members and about 10 are active volunteers. Some of their activities have included photo-documentation of the tule elk life cycle for educational purposes, assistance with elk surveys and wildlife sightings, insect collection and identification, revegetation, educational display panel development, operation of the visitor center and the development and implementation of junior ranger programs.

The public information and education policy of the management plan for the conservation of the tule elk developed in 1979 by the Tule Elk Interagency Task Force states that "Every opportunity must be taken to inform the public of the complexities of tule elk management and gain their input in the development and implementation of management plans and effective herd control programs". Most certainly the Reserve's public education programs are helping to achieve the goal of this policy.

Hopefully, this paper has given you an insight into the State park system's management programs at the Tule Elk State Reserve. What does the future hold for the Reserve?

The Reserve's importance as a herd site may diminish if the herd size objective is reduced to meet a more realistic carrying capacity for the Reserve. On the other hand, the Reserve will probably have greater importance as a herd site if the carrying capacity for tule elk is increased. An expansion of the carrying capacity would be dependent upon the restoration of the wetlands in the Reserve and/ or if farmlands adjacent to the Reserve are restored to wetlands as part of the California Department of Water Resources' Kern Water Bank Plan.

The Tule Elk State Reserve has very good potential as a regional center for public information and education on tule elk and wildlife management. Located 5 km west of Interstate 5 and 27 km west of Bakersfield, the Reserve is important in the story of the tule elk recovery. It includes land that was their original habitat and their last stomping ground in the southern San Joaquin Valley. Perhaps just as important, the Reserve's excess elk were used in many instances to help establish and supplement new elk herds throughout the State.

Visitor attendance at the Reserve will probably climb dramatically in the near future as Bakersfield with a population of 170,000 expands closer to the Reserve. Bakersfield is one of the fastest growing areas in California and is projected to become one of the next bedroom communities for the Los Angeles basin. Successful wetlands restoration efforts in and around the Reserve could also help draw more visitors to the area as wildlife and scenic values improve.

Originally established as a refuge for the tule elk, today the Tule Elk State Reserve is also important as a sanctuary for endangered species and as a place where the public can learn about wildlife and their management. As the demand for water grows, the Reserve's future well-being may be dependent upon public and private support for the State park system's efforts to acquire water for wetlands restoration within the Reserve. Successful habitat restoration would produce a wetlands truly representative of the vast swamp and marsh lands that once existed within the wilderness of the San Joaquin Valley; an oasis where the tule elk and other wildlife could thrive and the public could find inspiration and enjoyment for generations to come.

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ELK HABITAT USE AND HABITAT IMPACT AT THE TULE ELK STATE RESERVE, TUPMAN, CALIFORNIA

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: Located on the west side of the San Joaquin Valley, the 385 ha Tule Elk State Reserve has been preserved as a refuge for tule elk (*Cervus elaphus nannodes*) for over 60 years. This project was designed to: 1) estimate the area of major habitat types available to the elk on the Reserve and characterize the quantity and quality of forage produced, 2) provide data on the seasonal use by elk on these habitats, and 3) gauge the impact of the current herd on these habitat types by fencing experiments. Annual grassland covered 87.9% of the Reserve, with the remainder as canal and slough banks (4.9%), *Sporobolus* spp. grassland (2.4%), irrigated grassland (2.1%), mud bottoms (1.9%), and *Atriplex* spp. scrub (0.8%). Forage quantities were highest in spring, when annual grassland forage was highest in protein. Throughout the year protein levels were higher than the minimal levels suggested by McCullough (1971) for elk. Mineral levels in forage were adequate except for copper, which may be deficient. In general, annual grassland was preferred only when the plants there were actively growing. During the dry months activity shifted to irrigated areas, which had actively growing plants. Elk activity patterns differed during the two years monitored, probably due to variation in seasonal precipitation patterns. Cows spent more time in annual grassland areas than bulls. There was no detectable impact of elk or small mammals on annual grassland vegetation after caging for 9 months at current stocking rates, although there was a significant decrease in biomass and increase in bare ground after 4 years. Little impact was detected in summer-irrigated areas, where forb cover was lower on pond bottom plots to which elk had access.

Most work on elk in California has emphasized the Roosevelt elk (*Cervus elaphus roosevelti*) of the North Coast (Harper et al. 1967). However, California possesses the only subspecies endemic to any state (Bryant and Maser 1982): the tule elk (*Cervus elaphus nannodes*). Tule elk historically inhabited the perennial bunchgrass plain of the Central Valley and surrounding foothills from Cow Creek in Shasta County, south through the Sacramento and San Joaquin Valleys to the mountain barriers of southern Kern County (McCullough 1971). They also ranged to the San Fransisco Bay area and Monterey, San Luis Obispo and Ventura Counties. Prior to the mid-1800's an estimated 500,000 tule elk occupied the California valleys (McCullough 1971; Phillips 1976). Hunted almost to extinction, tule elk were restricted to the vicinity of Buena Vista Lake by 1870 (McCullough 1971).

The Tule Elk State Reserve, established in 1932 to protect this subspecies, is located in Kern County west of Bakersfield, California. The Reserve encompasses 385 fenced hectares located on flat valley bottomland. Presently 263 ha are available to the elk, most of which is annual grassland dominated by non-native species of *Bromus* spp., *Hordeum* spp., and *Erodium* spp. Elk numbers on the Reserve have fluctuated greatly in the past and at times the range has been severely overgrazed (McCullough 1971). The only green forage available during summer and fall grows in approximately 10 ha of flood or sprinkler irrigated land and a small section (less than 8 ha) of marsh/riparian forest flooded by a local canal. As a result, in some years the diet of elk has been supplemented with pelleted alfalfa after spring forage has died back.

The Reserve was administered by the Department of Fish and Game until the 1950's, at which time the Department of Parks and Recreation (DPR) assumed stewardship. Neglected both before and after the transfer, in 1984 DPR embarked on a program to upgrade the condition of the Reserve and develop recognition for other animals, plants, and habitats present (Harrison et al., in press). As part of this program, studies to assist in determining a reasonable stocking rate for the Reserve were implemented. The term 'carrying capacity' has a variety of definitions, but commonly is used to denote the number of animals which can be supported on a long-term basis without causing major changes in plant community composition (Caughley 1980). Here we report studies designed to provide information on the Reserve as habitat for elk which would aid in management decisions and help determine a stocking rate. These studies were:

1) Forage Characterization: This work described forage on the Reserve in terms of quantity and quality. We looked at what species were important during different seasons, how much forage was available, and the nutritional quality of the forage on a seasonal basis.
2) Elk Activity Patterns: Knowledge of where the elk spend most of their time during the year would allow us evaluate the importance to elk of the major habitat types on the Reserve.
3) Forage Utilization and Elk Impacts: Measuring the impact of elk on the Reserve was attempted using exclosures. This would allow us to directly measure impact of elk on the habitat types found on the Reserve and indirectly determine forage utilization in those habitats.

METHODS

Forage Characterization

Forage Grid System:--A semipermanent sampling grid system was established throughout the Reserve to: 1) assure random sampling so that results could be extrapolated to the Reserve as a whole with confidence, 2) speed data collection by minimizing the amount of time spent locating random study plots each time data were collected, and 3) provide a framework for long-term monitoring of the Reserve's forage.

Transects lines for the grid were placed in a stratified random manner, and were established relative to easily recognized borders (i.e., fencelines, etc.). The exact location of a particular transect was randomly chosen within each 126 m stretch of Reserve border (Fig. 1). Each transect was divided into 126 m lengths and the location of a plot determined randomly along each 126 meter length transect section. One hundred and fifty plots were established in the area of the Reserve currently available to elk (ca. 263 ha), with each plot representing 4.6 acres of Reserve habitat (Fig. 1). Plots were marked with a 3 foot aluminum fence post driven into the ground, numbered with a bird band, and covered with a 3 foot section of PVC pipe to protect elk. The main portion of the Reserve was marked in September 1987. In April 1988 a forage grid was established in a similar manner in the 300 acre area unavailable to elk (Fig. 1).

The main grid was 'read' during 11 September-27 October 1987 (fall), 16-18 January 1988 (winter), 7-9 April 1988 (spring), and 13-14 August 1988 (summer). Plots were 0.25 m^2 diameter circular quadrats. The actual plot used at each post was changed every season due to the need to clip plots for biomass determinations. The fall reading used the plot centered on the post which marked each plot, winter data were taken from a plot placed 2 m north of the post, spring data from a plot placed 2 m south of the post, and summer data from 1.5 m west of the post.

Data were visually-estimated covers of all identifiable plant species present. Due to time constraints, biomass was approximated by calculating the relative volume of each species in each plot. For this, the midpoint of the height (in cm) of each species in each plot was recorded. The average midpoint height for each species was multiplied by the estimated percent cover of that species to yield the relative volume. These values are not true volumes (with units of cm^3) but are numbers which express relative volumes of each species. Bare soil and litter were also estimated.

After reading, each plot was clipped to approximately 5 mm of the soil surface and the clippings placed in a paper bag. The branches of larger herbaceous and woody plants were clipped to include all plant material elk might consume (usually to 5 mm diameter stems for herbs, 3 mm diameter stems for woody plants). Bags were dried in a drying cabinet at 60 C for at least 3 days and the dry weight of the contents recorded.

Nutritional Analysis of Reserve Forage:--Plant samples were collected 'as is' from forage grid plots. Samples were dried at 60 C for at least 3 days and ground in a Wiley mill. For forage analysis, 10% of the weight of ground plant material in each bag was placed into a composite sample for each season. A second composite was made by combining all samples from non-annual grassland plots. Samples were analyzed by standard methods for mineral content, total nitrogen (N) and neutral detergent fiber. Total N was determined by a LECO CHN-600 nitrogen analyzer, with protein calculated by: %N x 6.25 = % protein. Mineral content was determined by ashing a sample and analyzing for minerals using an Inductively-Coupled Argon Plasma Spectrometer (Jarrel-Ash ICAP 9000). Sulfur (S) was determined for some samples. A LECO IR-32 sulfur analyzer was used to determine total S.

Individual species were analyzed for nutritional information regarding total N and crude protein, and for the mineral contents as described above. In spring 1987, two composite samples of 3 important annual grassland forbs (*Erodium cicutarium*, *Sysimbrium irio*, and *Amsinckia intermedia*) and 3 grasses (*Bromus rubens*, *Hordeum leporinum*, and *Festuca octoflora*) were made. In fall 1988 samples were taken of 2 of these forbs and all of the grasses, as well as samples of the grasses and forbs growing in non-annual grassland areas. Forbs included *Jussiaea repens* var. *peploides*, *Lotus corniculatus*, *Polygonum lapathifolium*, and *P. argyrocoleon*, *Sida leprosa* var. *hederacea*, *Lippia nodiflora* var. *rosea*, *Physalis angulata* var. *lanceifolia*, *Heliotropium curassavicum* var. *oculatum*, *Cressa truxillensis* var. *vallicola*, *Brassica* sp., and *Ammania coccinea*. Grasses and grass-like species included *Elymus triticoides*, *Echinochloa crusgalli*, *Eragrostis orcuttiana*, *Paspalum dilitatum*, *Distichlis spicata* var. *stricta*, *Cyperus ferax*, *Sporobolus airoides*, *Cynodon dactlyon*, *Eleocharis macrostachya*, and *Juncus balticus*. Samples consisted of plant material which elk were judged capable of consuming (ie, 5 mm diameter stems for herbs, 3 mm diameter stems for woody plants).

Elk Activity Patterns

Habitat Areas.--Approximate areas of the various habitat types were calculated by enlarging a photograph of a 1985 vegetation map of the Reserve. The area available to elk was classified as either annual grassland, *Sporobolus* sp. grassland, *Atriplex* sp. scrub, irrigated grassland, banks of canals/ponds/swamp areas, or wet areas lacking permanent emergent vegetation (called 'pond bottoms'). The areas of each habitat type were cut from the photograph and weighed to determine relative area.

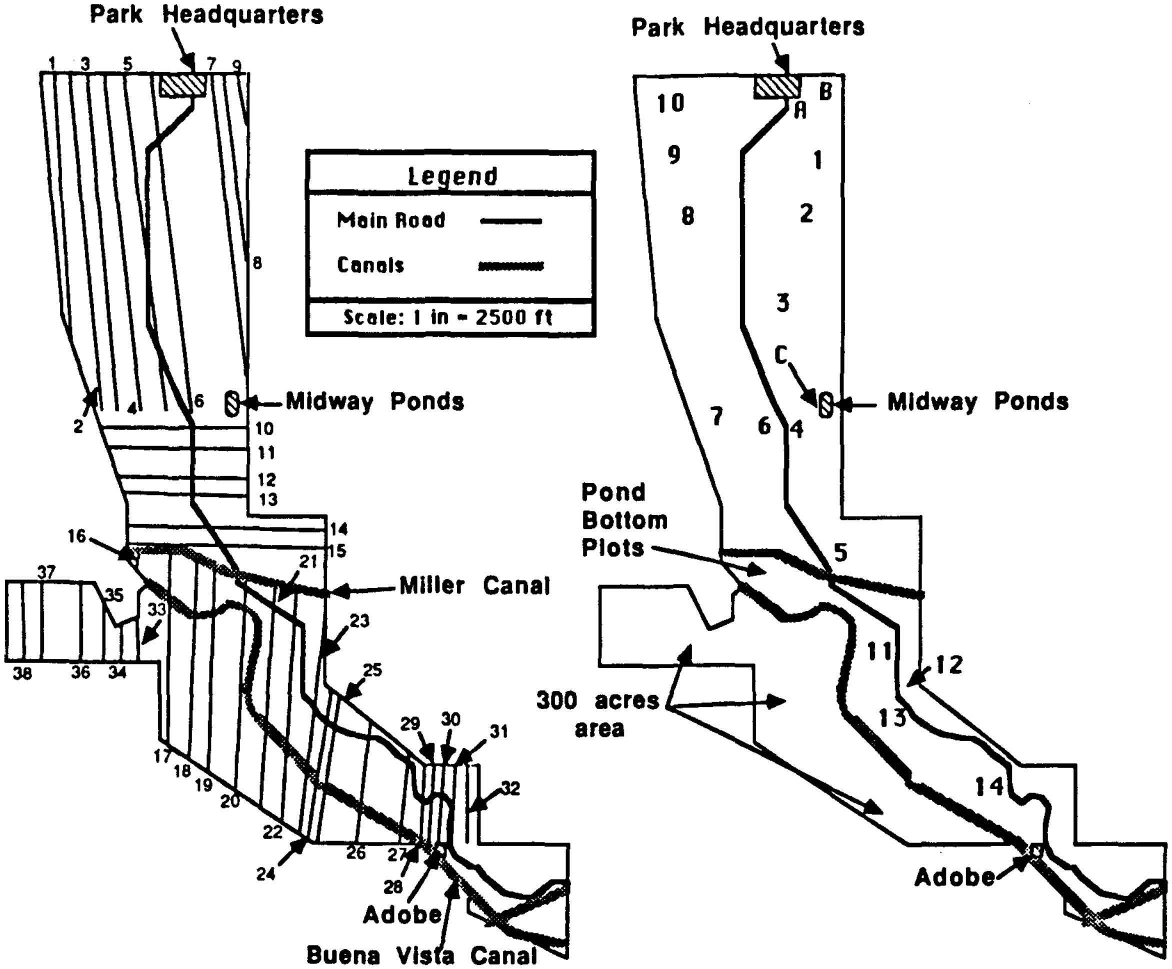

Fig. 1. Maps of the Tule Elk State Reserve. Left, the approximate locations of the 38 vegetation monitoring transects on the Reserve. Right, the locations of elk impact plots in annual grassland (numbered locations), irrigated areas (lettered locations), and pond bottoms (general area shown)

Habitat Use.--Periodic censuses of elk on the Reserve were made to assess use of the various habitat types found there. Censuses were conducted approximately every two weeks, beginning in August 1987 and ending in August 1989. Data were summarized on a monthly basis as the number of sightings of bull, cow, yearling, and calf elk in annual grassland or non-annual grassland areas. For analysis, animal counts were converted into totals in annual grassland versus other habitats by month and by sex (data for adults only). Data were analyzed by the chi-square test, in which the actual distribution of elk were compared to an expected distribution calculated from the percentage of annual grassland on the Reserve.

Forage Utilization and Elk Impacts

Three habitat types were studied to measure the impact of foraging elk on vegetation, including the annual grassland, flood-irrigated areas, and pond bottoms.

Annual Grassland.--Fourteen pairs of 7 X 7 m plots were established throughout the annual grassland areas available to elk in August 1987. Plots were located in areas with relatively uniform and dense quantities of grasses (Fig. 1) in order to minimize variability. T-posts were placed at the corners of each plot and one plot per pair was randomly selected for fencing; the other remained open to elk use. Fencing was 6 foot tall deer fence with a mesh size of 15 x 10 cm to exclude large herbivores only.

Small mammals may also have a significant impact on grasslands (Fitch and Bentley 1949). Rodents were present in all annual grassland areas of the Reserve (Boyd and Woodward 1987). Within each fenced plot, 6 transects of subplots were established, and treatments applied to these plots were: complete rodent exclosure, control exclosure, no exclosure, and no exclosure/clipped. Small mammal exclosures were 60 x 60 x 30 cm (L x W x H) made from 1.3 cm mesh hardware cloth. Exclosure controls were screened on the top and southern sides only. These treatments allowed segregation of the effects of small mammals on the grassland from those of elk. The control plot was subsampled by dividing it into 36 subplots and clipping three randomly selected subplots every time the exclosed plots were sampled. A 0.25 m^2 area centered on each plot was clipped in June 1988, after the growth of grasses had ceased and biomass was assumed to be near maximum. This experiment assessed impacts after 9 months of exclusion.

Four 3 x 3 m plots established after a fire in the annual grassland in 1984 provided longer term data to assess elk foraging impact. Two plots were located in the burned area, and two in an unburned area of the annual grassland. All 4 plots were fenced with 6 foot tall wire. Samples were taken in June 1988 both inside and outside these exclosures. A 0.25 m^2 sampling hoop was tossed three times each, inside and outside of each exclosure (at least 3 m from the fencing to minimize local influence of elk traffic around the cages). Estimated covers of plant species in each sample were recorded along with bare area, and each plot was clipped to about 5 mm height, bagged, dried at 60 C for at least 3 days, and weighed. Means of the 3 inside and outside samples for each cage were used as raw data for statistical analysis.

Flood-irrigated Areas.--Twelve pairs of 1 m diameter plots were established in three areas of the Reserve which were surface-irrigated in August 1987 (Fig. 1). One plot of each pair was randomly selected to be caged with a circular exclosure made of 6 foot tall, 15 x 10 cm mesh deer wire. The other plot in each pair was marked with a metal stake and not caged. Data were taken in January, 1988. Covers of all species present in each plot were visually estimated. A 0.25 m^2 area of each plot was clipped to about 5 mm above the soil surface, the clippings dried at 60 C for at least 3 days, and weighed.

Pond Bottoms.--Seven pairs of plots (4 x 4 m) were established in shallow water of the swamp ponds in August 1987 (Fig. 1). Plots were placed in locations where quite a bit of emergent or floating plants were growing at the time. One plot of each pair was randomly selected to be caged, using 6 foot, 15 x 10 cm mesh wire. The other plot was marked with metal T-posts at the corners and left open for elk access. In January 1988, average cover of forbs and monocots in each plot was visually estimated.

RESULTS

Forage Characterization

The list of species found in the grid plots was extensive (Boyd and Martens 1988). Only a few species were relatively abundant on a Reserve-wide basis. These were primarily grassland plants. The following species represent over 99% of the estimated cover of plant material on the Reserve over the course of a year: *Bromus rubens, Hordeum leporinum, Erodium cicutarium, Sysimbrium irio, Festuca octoflora, Lepidium dictyotum, Rumex crispus, Polygonum lapathifolium* and *P. argyrocoleon, Sida leprosa* var. *hederacea, Phaysalis angulata* var. *lanceifolia, Eleocharis macrostachya, Distichlis spicata* var. *stricta, Lippia nodiflora* var. *rosea, Frankenia grandiflora* var. *campestris, Atriplex polycarpa, Asclepias fascicularis, Artemisia douglasiana,* and *Achillea borealis* ssp. *californica.* Ranking of species was changed by considering relative volume, with relatively tall species (*Festuca, Frankenia,* etc.) becoming more important. Seasonal abundances (ie, relative volumes) of some plants varied widely. Annual grasses were always fairly abundant, but some species (notably *Erodium* and *Cynodon*) varied greatly in abundance depending on season. *Erodium* plants peaked in abundance in winter, then shattered and occupied the litter layer in summer. *Cynodon* reached peak abundance in summer and fall.

Biomass values were (mean±S.D.): fall, 44±60; winter, 48±119; spring, 50±38; and summer, 29±32 grams dry weight/0.25 m^2 plot, which converts to pounds/acre by multiplying by 7.35. Note that these values come from two different forage years. The fall value (1987) is from a better forage year when compared to the summer value of 1988. The 29 g/plot extroplates to 213 lb./acre. Data was not collected in fall 1988 due to lack of germination caused by the delay of rainfall until December. The minimum quantity of forage available to elk was therefore less than the summer value. Considering the drop between spring and summer values, it may have declined to as little as 10 g/plot before new growth began.

Nutritional Analysis of Reserve Forage.--Forage nutritional data shows some general trends (Table 1). Reserve-wide crude protein levels were much higher in winter/spring than fall/summer. This was due to fluctuations in protein contents of annual grassland species, because non-grassland plants were relatively low in protein regardless of season (Table 2). Summer-active species varied considerably in protein content (Table 2). Highest values were found in forbs, with grasses having relatively low values. Differences in various minerals were also observed (Tables 1 and 2).

The "300 acre" portion of the Reserve was also dominated by annual grassland species (*Bromus rubens, Hordeum leporinum, Lepidium dictyotum, Erodium cicutarium* were dominants), but *Atriplex polycarpa* ranked higher here than in the area of the Reserve available to elk. Biomass in this area and the main portion of the Reserve were similar (57±37 g/plot vs. 50 g/plot for the rest of the Reserve in spring), indicative of the relatively light stocking rate of elk on the Reserve vegetation.

Table 1. Forage nutritional analysis of composite samples from the grid plots as influenced by season. Data are means (S.D). N=2 for all sampling times and plot types.

Dietary Component	Plot Type	Season Sampled			
		Fall	Winter	Spring	Summer
Crude Protein (%)	All	8.8 (0.21)	15. (0.085)	18 (6.3)	8.8 (1.6)
	Non-grassland	8.2 (0.16)	7.8 (1.4)	8.3 (1.3)	7.3 (0.035)
Neutral Detergent Fiber (%)	All	53.0 (0.90)	44.0 (0.46)	54.0 (0.55)	54.0 (1.7)
	Non-grassland	53.0 (0.28)	55.0 (2.0)	54.0 (3.6)	61.0 (0.09)
Calcium (%)	All	0.55 (0.014)	0.65 (0.014)	0.49 (0.042)	0.57 (0.007)
	Non-grassland	1.4 (0.05)	1.01 (0.25)	0.69 (0.035)	0.53 (0)
Potassium (%)	All	0.62 (0.035)	1.6 (0.014)	1.1 (0.11)	0.47 (0.007)
	Non-grassland	1.5 (0.04)	0.55 (0.064)	1.02 (0.007)	0.54 (0.007)
Magnesium (%)	All	0.19 (0.007)	0.22 (0)	0.16 (0.007)	0.18 (0)
	Non-grassland	0.28 (0.007)	0.2 (0.021)	0.2 (0.021)	0.11 (0)
Phosphorus (%)	All	0.14 (0.007)	0.29 (0)	0.21 (0.021)	0.14 (0.007)
	Non-grassland	0.16 (0.007)	0.13 (0.028)	0.18 (0.007)	0.12 (0.007)
Sulfur (%)	All	0.19 (0.14)	0.24 (0.021)	0.17 (0.035)	0.23 (0.21)
	Non-grassland	0.29 (0.007)	0.21 (0)	0.22 (0.021)	0.17 (0.007)
Copper (ppm)	All	7.0 (0.71)	9.0 (0.71)	6.0 (0.71)	6.0 (0.71)
	Non-grassland	8.0 (0.71)	8.0 (0)	8.5 (1.5)	5.0 (0)
Iron (ppm)	All	1429 (153)	3551 (96.2)	1963 (245)	1653 (16.4)
	Non-grassland	908 (19.2)	3150 (192)	3510 (933)	830 (67.9)
Manganese (ppm)	All	97.5 (7.8)	130 (4.2)	99 (4.2)	93 (2.8)
	Non-grassland	98 (0)	91 (4.2)	101 (7.1)	59 (1.4)
Zinc (ppm)	All	22.5 (2.1)	34 (0.71)	23 (2.1)	19 (2.1)
	Non-grassland	33 (2.8)	33 (3.5)	35 (5.0)	17 (0)

Observations during collection of the grid data in spring indicated heavy use of some species growing on the drying mud bottoms of the swamp area. *Veronica*, *Sida*, *Eleocharis*, *Ammania*, *Cyperus*, *Paspalum*, and *Juncus* species were all grazed by elk. *Cirsium crassicaule*, a sensitive species, was often knocked over and the stems chewed out. Heavy grazing pressure was applied to *Rumex crispus*.

Elk Activity Patterns

Habitat Areas.--The percentages of habitat types available to elk were: annual grassland 87.9%, banks 4.9%, *Sporobolus* grassland 2.4%, irrigated grassland 2.1%, mud bottoms 1.9%, and *Atriplex* scrub 0.8%.

Habitat Use.--Chi-square analysis of activity patterns revealed significant deviations of elk distribution from random during most seasons. Differences between sexes and between years were also observed. Activity patterns were graphed using an 'Annual Grassland Preference Index' (Fig. 2). The Preference Index was the percentage of animals found on the annual grassland during a month, minus the percentage of the total area of the Reserve composed of annual grasslands. In general, the annual grassland was under-utilized. In 1987-88, the annual grassland was not avoided during the late fall and early winter. This coincided with the establishment of annual forbs and grasses resulting from normal seasonal precipitation. Strong avoidance was seen during the

Table 2. Nutritional analysis of plants available to elk on the Reserve in annual grassland and other habitat types. Data are means (S.D.).

Dietary Component	Plant Type	Habitat/Season Sampled Grassland/Spring	 Grassland/Fall	 Non-grassland/Fall
Crude Protein (%)	Forbs	21 (6.6)	9.3 (2.3)	17 (5.5)
	Grasses	11 (2.5)	7.7 (2.2)	9.6 (2.0)
Calcium (%)	Forbs	2.1 (0.77)	1.7 (1.3)	2.1 (1.8)
	Grasses	0.28 (0.082)	0.28 (0.11)	0.41 (0.12)
Potassium (%)	Forbs	2.9(0.23)	0.63 (1.0)	2.1 (1.0)
	Grasses	1.4 (0.66)	0.55 (0.38)	1.6 (0.64)
Magnesium (%)	Forbs	0.28 (0.026)	0.14 (0.081)	0.49 (0.23)
	Grasses	0.089 (0.018)	0.080 (0.022)	0.21 (0.10)
Phosphorus (%)	Forbs	0.40 (0.069)	0.097 (0.054)	0.28 (0.13)
	Grasses	0.18 (0.037)	0.069 (0.014)	0.16 (0.059)
Copper (ppm)	Forbs	11. (2.6)	7.1 (0.93)	14 (4.7)
	Grasses	6.0 (6.4)	4.7 (0.50)	6.6 (2.4)
Manganese (ppm)	Forbs	53 (14)	64 (39)	82 (75)
	Grasses	76 (41)	57 (19)	79 (78)
Zinc (ppm)	Forbs	45 (29)	21 (10)	50 (43)
	Grasses	14 (3.6)	12 (1.9)	26 (18)
Boron (ppm)	Forbs	280 (170)	91 (130)	90 (56)
	Grasses	52 (38)	80 (34)	35 (33)
Molybdenum (ppm)	Forbs	6.4 (5.3)	1.3 (1.0)	8.0 (5.7)
	Grasses	4.4 (1.1)	4.1 (1.6)	2.5 (1.5)
Cobalt (ppm)	Forbs	0 (0)	0.088 (0.18)	0.92 (1.3)
	Grasses	0 (0)	0.12 (0.29)	0.24 (0.44)
Chromium (ppm)	Forbs	3.0 (3.6)	2.7 (2.5)	6.2 (4.9)
	Grasses	0.032 (0.079)	0.74 (1.1)	1.2 (1.4)
Lead (ppm)	Forbs	1.8 (2.2)	6.1 (4.6)	17 (16)
	Grasses	0.19 (0.29)	2.6 (2.9)	3.7 (5.8)

summer, when animals spent much time in irrigated areas of the Reserve.

This pattern shifted in 1988-89, when the annual grassland was avoided in the fall and utilized in the spring and early summer. The reason for this may be attributed to the delay of normal seasonal precipitation until December. This caused a delay in the germination and establishment of annual grasses and forbs until late winter of that year. In late winter the elk began to make more use of the annual grassland areas.

Because drought conditions prevailed during 1988-89, supplemental feeding of elk, which had been discontinued in 1987, was resumed. Supplemental feed containing high levels of copper was provided in the annual grassland, and was continued through mid-June of 1989.

Cow use of the annual grassland increased during the summer months of 1988-89 from that of 1987-88. The reason for this may be that some of the areas were flooded. In 1989, relatively little water was provided to the major riparian and marsh areas of the Reserve, so that it was dry

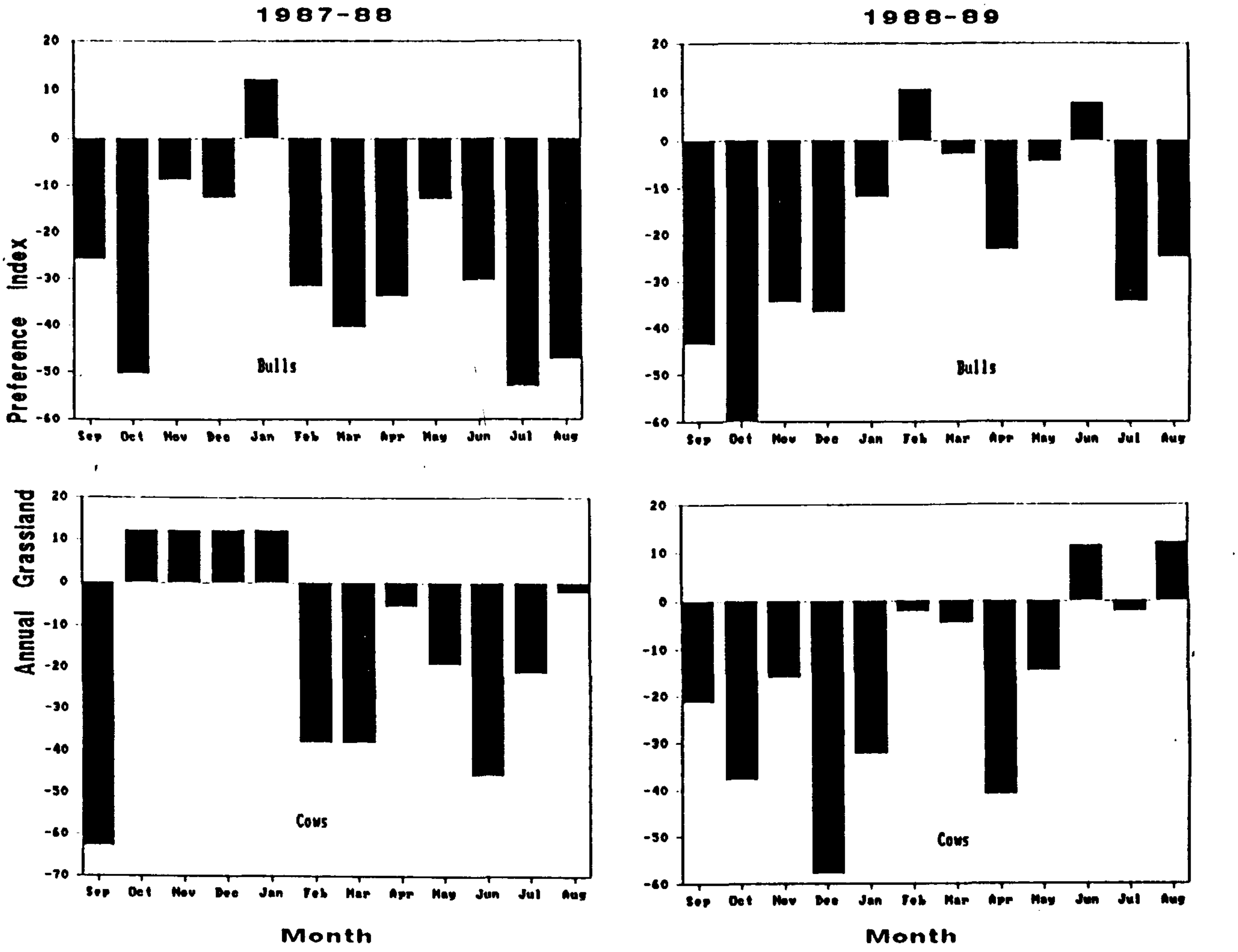

Fig. 2. Preference of cow and bull elk for annual grassland areas of the Reserve during two years. The Preference Index is the percentage of animals found on annual grassland during a month, minus the percentage of the total area of the Reserve which is composed of annual grassland (ie, 87.9%).

for most of the hot months. We suggest this caused the cows to spend more time in annual grassland areas than they might otherwise.

The above patterns in part reflect the fact elk on the Reserve usually move about in herds. Cows were almost always found together, even outside the rutting season, whereas bulls were more likely to be found singly or in small groups. The statistical test used assumes that each animal acts independently of others and therefore undoubtedly overstates the statistical significance of these patterns.

Forage Utilization and Elk Impacts

Annual Grassland.--Comparison of forage dry weight within and outside of the elk exclosures showed similar values: 58.8 g/plot (±23.0) for the caged plots and 51.4 g/plot (±14.8) for plots available to elk. Analysis of variance of these data resulted in a lack of significance ($P>0.31$). Biomass values for the small mammal exclosures inside each elk cage showed caged plots to have greater biomass (66.8±23.3 g/plot) than control (54.8±15.5g/plot) or open (58.8±23.0g/plot) plots. These differences were insignificant (ANOVA, $P>0.31$). Plants in open small plots clipped in January showed a highly significant difference in biomass (ANOVA, $P<0.001$) from those on unclipped plots (10.0±5.0g versus 59.0±23.0g).

Data from long-term cages were analyzed by paired-sample t-tests (cover data were arcsine-transformed prior to analysis to better fit statistical assumptions: Zar 1984). Biomass was significantly higher inside the exclosure ($P<0.05$) than outside (66±7.5g versus 40±9.4g). Bare ground occupied more area outside the cages ($P<0.05$) (0.92±1.6 vs. 16±5.7) than inside. No other comparisons proved significant, but these results imply that changes in grassland composition due to elk activity might develop over more than one season's time.

Flood-irrigated Areas.--Data from only 2 areas (A and C, Fig. 1) were collected, as area B failed to develop typical irrigated-area vegetation. ANOVA on dry weight data showed no significant ($P<0.05$) impact of exclosures on biomass: caged plots averaged 194±35g and open plots 188±28g. Mean estimated covers of plants on the plot types were also similar. Comparisons of species in caged versus open plots are as follows: *Cyodon dactlyon* (75% caged vs. 71% open), *Lotus corniculatus* (19% caged vs. 10% open), *Bromus* spp. (1.5% caged vs. 2.3% open), *Elymus triticoides* (9.4% caged vs. 16% open), *Lippia nodiflora* (8.8% caged vs. 7.5% open), and *Juncus balticus* (1.3% caged vs. 1.3% open).

Pond Bottoms.--Forb cover in caged plots was 56±31%, as compared to 37±25% in open plots. This difference was significant (Wilcoxen paired-sample test, $P<0.05$). Monocot cover was also higher in caged plots (15±23 vs. 4.7±5.8%), but was not statistically significant ($P<0.05$).

DISCUSSION

A major objective of our work was to address the issue of elk herd size (carrying capacity) on the Reserve. Carrying capacity has two components: an elk component and a vegetation component. The elk must have sufficient quantity and quality of forage during the year to keep them in good health, and vegetation must not be so severely impacted by their activities that it undergoes major changes in species composition.

Elk

The forage grid demonstrated that forage was available to the elk at all monitoring dates. Crude protein was measured because it is often an important limiting factor in elk diets (Nelson and Leege 1982). McCullough (1971) suggested 7% crude protein as a minimum level for elk, and this level was met overall on the Reserve at all times of the year.

We know of no studies which have examined the needs of elk for minerals in an experimental setting. McCullough (1971) discussed nutritional analysis of Owens Valley elk forage for several of the minerals for which we have data. Calcium is best examined as the ratio of calcium:phosphorus, which should be about 2 (McCullough 1971). This ratio was high for Reserve forage, being 3.9 in fall, 2.4 in winter, 2.3 in spring, and 4.1 in summer. It is apparent that when the annual grassland plants were active the ratio was acceptable, but it was high when these plants died.

Relatively high sulfur or molybdenum levels have been shown to interfere with copper metabolism of tule elk (Akeson et al. 1982). Copper levels of 5 ppm in forage appear to be an acceptable value, with copper:molybdenum ratios of 2:1 or less also viewed as hazardous (Ward 1978). Table 1 shows copper levels to be at or above the 5 ppm level on the Reserve, however, molybdenum levels for those samples were not obtained. Table 2 contains copper and molybdenum data for species groups and allows us to gain a rough idea of the copper:molydenum ratio in Reserve forage. These ratios were, in general, low in annual grassland species, and were relatively invariant with season (Table 2). Actively growing species in fall generally have adequate ratios (Table 2).

Clawson (1973) suggested 0.1-0.2% sulfur (as sulfate-sulfur) would be sufficient to induce copper deficiency. Our data reports total sulfur, and so are not directly comparable, but do fall within this range (Table 1). Sulfur was not measured for the species groups in Table 2.

Copper deficiency may be a problem for elk on the Reserve. The deaths of 3 bulls during the summer of 1988, when summer-active forage was scarce due to lack of water in the canals, the 21 acre irrigated pasture was shut down for repairs, and no dietary supplement was provided, may have been connected to copper deficiency. This problem can be alleviated by providing dietary supplements, keeping animal density very low so stress is low and opportunities to choose appropriate forage are maximized, or increasing the quantity of summer-active forage plants on the Reserve.

We do not know what levels of the other minerals listed in Table 2 may cause toxicity/deficiency symptoms in elk. In general, none of the values seemed extreme. Zinc values approached the minimum needed in plants for adequate growth, and potassium values were also relatively low (Marschner 1982). Trace metals such as cobalt, chromium, and lead were relatively low in most species (Table 2), indicating that toxicity was unlikely.

Vegetation

The stocking rate of the Reserve during these studies (ranged from 38 elk in August 1987 to 59 elk in August 1989) resulted in relatively little measurable effect on vegetation. No short-term impact was found in annual grasslands, or in irrigated areas, but a slight impact was detected in the mud bottoms. In contrast, observations during collection of the grid data showed some species (*Cirsium crassicaule, Rumex crispus*) were heavily affected by the elk. These species were summer-growing, suggesting that future efforts to quantify impact be concentrated in non-annual grassland habitats. Overall, we conclude that stocking rates experienced during this study had little measurable effect on Reserve vegetation, but can be important for some plant species in non-annual grassland habitat types.

Carrying capacity

Forage analysis and elk activity data point to an important role of irrigated areas on the Reserve in determining its ability to support a healthy elk population.

We conclude that such areas are the critical factor in determining carrying capacity of the Reserve. Even though only a small amount of the Reserve is irrigated, vegetation as a whole was little affected, indicating that an increase in elk population size could be supported. This is unwise for two reasons. First, certain plant species were affected negatively by the elk and, in the case of *Cirsium crassicaule,* this effect likely had a major negative impact on seed production of this sensitive species. Second, forage production in all areas of the Reserve is dependent upon moisture, and this factor is unpredictable. Annual grassland is affected by variations in rainfall, and irrigated areas by variations in our ability to provide water. Prudent management would keep elk population size at a level at which excess forage is available in most years. Monitoring of annual forage production should be emphasized on the irrigated areas of the Reserve where summer-active forbs and monocots provide sustenance for elk during the critical summer/early fall season.

Opening the 300 acre area to the elk has been discussed in the past. The impact of such a move on overall stocking rate is variable, depending upon how much of the summer-active forage present on the canal bank areas becomes available to the elk. Because most of the 300 acre area is annual grassland, we conclude that making it available to elk will not substantially increase the ability of the Reserve to support animals in the summer and fall.

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MONITORING HEALTH PARAMETERS IN CALIFORNIA'S ELK HERDS

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: Remnant populations of tule elk (Cervus elaphus nannodes) have been used to restock many areas of once native range in California over the past 14 years. Eighteen new herds have been established by moving approximately 1000 animals. All tule elk relocation in recent times originated from one captive herd (Tupman) and from one large free-ranging herd (Owens Valley), or their relocated offspring. Monitoring the health of parent and offspring populations has allowed us to be sure that infectious diseases and parasites of elk pose little or no unique threat to the health of livestock or other wildlife. However, some populations have had significant disease problems subsequent to relocation. Similar health monitoring has also been applied to Roosevelt elk (Cervus elaphus roosevelti) moved within California and brought in from Oregon. Elk have been treated for copper deficiency and selenium deficiency. Herd growth rates and body size appear to be habitat limited rather than strictly an inherited trait. Despite the fact that all tule elk are descended from a very small founder population, only a few anomalies that might be attributed to inbreeding have been seen.

In the late 1970's, a combination of political, financial and biological factors made it imperative that the California Department of Fish and Game (CDFG) begin large scale relocation of tule elk. The history of the tule elk and the events that made elk relocation the preferred management option have been covered elsewhere (McCullough 1969, Curtis 1974, Boll, et al. 1977a, Boll, et al., 1977b, Koch 1987). Early captures (from 1974 through 1979) were primarily by drug darting (Jessup 1983, Jessup et al. 1988). After methods for baiting and drive-trapping were perfected, it became possible to handle most cows and calves without chemical restraint. Since the mid-1980's, Roosevelt elk have also been trapped for relocation in California. Blood samples were also obtained from small numbers of privately owned Rocky Mountain elk entering California.

All elk are visually assessed for anomalies or obvious signs of disease. Since 1977, blood samples have been taken from most elk handled, and these have been used to develop a serological database. Prevalence of diseases with potential to negatively impact elk herd health and diseases of concern to livestock were monitored using standard laboratory diagnostic tests. Over 900 elk were tested for antibodies to Infectious Bovine Rhinotracheitis (IBR), Bovine Virus Diarrhea (BVD), Parainfluenza-III (PI-3), brucellosis, anaplasmosis, leptospirosis, bluetongue (BT) and Epizootic Hemorrhagic Disease (EHD). Some elk were tested for antibodies to other diseases of interest. Whole blood selenium levels were established for most major tule elk herds and for two herds of Roosevelt elk. Although records were kept on individual herds, this paper will only attempt to summarize trends.

When mortalities occurred, post mortem examination, field sampling, and more intense laboratory testing were used to reveal the causes of mortality in elk herds following relocation. Infectious diseases (paratuberculosis, clostridial myositis), nutritional deficiencies (copper deficiency), and plant intoxications (poison hemlock) were discovered. These types of herd health monitoring proved to be vital to understanding the health problems that can befall elk moved to new habitats.

MATERIALS AND METHODS

From 1977 through 1982, blood samples were obtained by jugular venipuncture from every tule elk and Roosevelt captured for transport and release (Table 1). From 1983 through 1988, blood samples were obtained from subsets (between 40 and 80%) of groups of elk captured. In 1989, 65 of 110 blood samples taken were obtained by elk hunters at the time of kill.

Most blood samples were collected via jugular venipuncture using a 60-ml syringe and a 2.5 cm 16-gauge needle. Samples were transferred to 3 red-topped

Table 1. Tule elk sampled in California.

YEAR	NUMBER
1977	27
1978	153
1979	32
Captured By Darting N=212	
YEAR	NUMBER
1980	61
1981	56
1982	6
1983	46
1984	28
1985	135
1986	64
1987	20
1988	44
Most animals sampled in Drive-Traps N=455	
YEAR	NUMBER
1989	107
1990	3
Most hunter kills	

Table 2. Roosevelt elk sampled in California.

YEAR	NUMBER
1982	17
1983	4
1984	36
1985	40 (29 from Oregon)
1990	33 (from Oregon)

10-ml clot tubes. Whole blood in EDTA was taken via jugular venipuncture from representative groups of elk and kept refrigerated until tested by fluorometric means for whole blood selenium by the methods of Wetter and Ullrey (1978).

Field and laboratory methods used to investigate mortalities in elk herds subsequent to relocation have been published elsewhere (Jessup et al. 1981, Jessup et al. 1986, Gogan et al. 1988, Gogan et al. 1989).

Table 3. Tule elk tested for antibodies to selected disease agents (percentage seropositive).

Year	IBR[a]	BVD[a]	PI-3[a]	BRUC	ANA	LEPTO[b]	BT	EHD	BRSV[a]
1978	1	18	20	0	7	5	67	55	
1979	0	6	0	0	16	0	80	nd	
1980	2	10	17	0	33	1	40	nd	
1981	0	1	27	0	16	0	63	nd	
1982	0	0	33	0	100	0	0	0[c]	
1983	0	20	0	0	-	0	87	69	
1984	0	0	36	0	-	0	46	11	
1985	0	4	4	0	-	0	7	21	3
1986	0	0	0	0	-	0	51	33	0
1987	0	0	0	0		0	81	75	-
1988	0	0	3	0		0	40	83	0
1989	nd	nd	nd	0		3	90	83	
1990[d]				0		0			

[a] Positive titers = or greater than 1:32.
[b] Positive titers = or greater than 1:64.
[c] Only 8 animals tested.
[d] Only 4 animals done so far.

Table 4. Roosevelt elk tested for antibodies to selected disease agents (percentage seropositive).

Year	IBR	BVD	PI-3	BRUC	ANA	LEPTO	BT	EHD
1982	0	5	5	0	100	nd	0	0
1983	0	0	0	0	nd	0	25	nd only 4 tested
1984	3	0	25	0	nd	0	5	0
1985	0	0	0	0	nd	0	0	16 only 6 tested
FROM OREGON								
1989	0	0	0	0	0	6*	10	nd *Lepto hadjo >1:200
1990-RESULTS PENDING								

Table 5. Whole blood selenium levels of elk herds in California.

Location	Year	Selenium ppm (Mean of 20)	Subspecies
Inyo Co.	1980	.197	tule elk
Inyo Co.	1981	.258	"
Kern Co.	1983	.151	"
Merced Co.	1985	.132	"
Solano Co.	1986	.107	"
Solano Co.	1988	.104	"
Kern Co.	1989	.161	"
Humboldt Co.	1982	.075	Roosevelt elk
Cathlamet, WA to Humboldt Co., CA	1984	.059	"

RESULTS

The number of tule elk and Roosevelt elk sampled by year for seroprevalence testing are presented in Tables 1 and 2. Yearly results are summarized in Tables 3 and 4. Two of fourteen privately owned Rocky Mountain elk sampled in Marin County, California in 1979 were suspect for brucellosis antibodies.

Mean whole blood selenium levels for selected herds of tule elk are presented by year in Table 5. Results of investigations into elk mortalities due to paratuberculosis, poison hemlock ingestion and copper deficiency have been published elsewhere (Jessup et al. 1981, Jessup et al. 1986, Gogan et al. 1988, Gogan et al. 1989).

DISCUSSION

Close visual inspection of elk captured for relocation has allowed identification of several recurrent abnormalities. Besides numerous minor traumatic injuries, injury to the cornea of the eye has been observed on a number of occasions at Tupman State Park, Grizzly Island WMA and at Concord Naval Weapons Station. These often appear to result from grass awns. Many subcutaneous and oropharyngeal abscesses have also been seen, again believed due primarily to grass awns. One totally blind calf from Tupman SP eventually died and post mortem examination revealed hydrocephalus and degeneration of many areas of the cerebral cortex.

What was diagnosed as "undershot lower jaw" in approximately 5% of elk at Tupman SP turned out to be due to elongation of the upper jaw with relatively normal lower jaw length. This was believed due to inbreeding that resulted from severe bottlenecking that occurred in the late 1800's when tule elk numbers dwindled to perhaps less than a dozen animals (McCullough 1969). Prior to 1970, affected individuals were culled. Since 1982, tule elk with this anomaly have been vasectomized (males) or given subcutaneous synthetic progesterone (MGA) implants (females). Although more expensive than culling, these methods of birth control have been acceptable to the public and appears to have successfully eliminated new cases in elk calves.

Although small and brittle antlers were reported to be common in tule elk by McCullough, they may be more a result of trace element and micronutrient imbalance than a genetic trait. Tule elk at Tupman SP and in the Owens Valley commonly have thin or broken main beams, but their progeny moved to more typical historic habitat at San Luis NWR and Grizzly Island WMA, have very thick based, heavy and normal-appearing antlers comparable to those of Rocky Mountain elk. Soils of the Owens Valley and at Tupman are alkaline and at the former contain excessive phosphorus that results in calcium/ phosphorus imbalance.

Overall nutrition of elk in the Owens Valley and at Tupman is often less than optimal due to over-grazing and poor quality browse species. Although adult male tule elk from the Owens Valley captured in the late 1970's weighed an average of 550 pounds, some of their offspring at Grizzly Island WMA and San Luis Island NWR are considerably larger, weighing up to 875 pounds. Again, typical morphology appears to be reflection of nutrition rather than a truly inherited trait.

Antler anomalies believed due to copper deficiency were identified by Gogan et al. (1988). Affected animals had corkscrew growth, waving of the main beam and/or palmate, and hollow drooping antlers. They also had extremely fragile vertebrae and long bones, and light, brittle hair coats (Gogan et al. 1988). Many of these animals were treated, apparently successfully, by supplementing their feed with copper sulfate, by reducing forage competition with cattle, and then burning off decadent browse and dispersing the herd.

As can be seen in Table 5, mean whole blood selenium levels in elk vary widely from location to location. Levels in tule elk in the Owens Valley are at least double the level considered adequate for cattle (0.1 ppm). This is well below levels suggestive of selenium excess (1.0 ppm) in livestock and supports the observations of Oliver et al. (1990), that deer utilizing browse plants on old Lahotan lakebed soils have whole blood selenium levels higher than other similar herds.

Whole blood selenium levels in tule elk herds at Tupman SP in Kern Co., San Luis Island NWR in Merced Co., and at Grizzly Island WMA in Solano Co. were adequate by livestock standards and ranged from 0.15 ppm to 0.1 ppm in declining order of the listing above. It is particularly interesting that the selenium levels in elk at San Luis Island were lower than at other locations as the infamous Kesterson NWR is less than a mile away and canal water from similar sources serve both refuges.

Roosevelt elk in Humboldt Co., and those brought to Humboldt Co. from Oregon, were below the level considered adequate for cattle. Although we routinely administer vitamin E and selenium by injection to elk captured for relocation (Jessup et al. 1988), we doubled this dosage subsequent to the findings of 1982. Heavy rainfall may leach selenium out of soils, particularly in the face of acidification of the environment and various agricultural practices (Oliver et al. 1990).

As can be seen from Table 3 and 4, there is no evidence that free-ranging elk in California have been exposed to brucellosis. *Brucella abortus* is a reportable disease in livestock and its presence in elk and bison in several Rocky Mountain states has led to a great deal of conflict. Some relocations of elk in the intermountain West have been delayed or blocked by concerns over the potential of elk to spread this disease. This has not been a problem in California.

Brucellosis surveillance is an excellent way for wildlife management agencies to show agriculture agencies that they can work together. Cooperative, well-planned efforts should not delay elk transplants and should prevent elk being blamed for this stubborn livestock disease problem. It is important to note that privately owned Rocky Mountain elk brought into California from Montana had some low titer reactors to the *Brucella* card test. These animals stayed in California only briefly and were contained on a single ranch in Marin Co. the entire time. If they were infected with or carriers of *B. abortus*, a major wildlife/livestock disease problem could have occurred as the surrounding area has many dairy cattle herds, deer and tule elk. Routine testing for *Brucella* antibodies should allow western states to establish the brucellosis-free status of most elk herds, and to pin-point infected herds. Brucellosis will cause abortion and joint infections in elk. There is no evidence that brucellosis is a natural disease process in elk. It is to everyone's advantage to cooperate in efforts aimed at eliminating brucellosis in the U.S.

Although leptospirosis is fairly common and not a reportable disease, it does cause economic loss to livestock operators, through abortion, reduced gains and some deaths. Vaccines exist, but there are many serovars. Most are transmitted between individuals via contaminated water. Tables 3 and 4 clearly show that very few elk had evidence of prior exposure and most of these were relatively low titers (>1:64, <1:200) and, as single samples, are difficult to interpret. The relatively high *leptospira hadjo* titers in two elk from Oregon brought to California in 1989, may indicate a relatively recent infection.

Between 1978 and 1988, we routinely tested elk for antibodies to IBR, BVD, and PI-3 viruses. This was done to establish baseline disease exposure data for these common cattle viruses and to help us understand the potential role of elk in their transmission. As is evident in Table 3, antibodies to these viruses are relatively uncommon in most elk herds, in most years. No disease syndrome in elk has been attributed to any of these viruses and no unusual incidence of disease potentially related to these viruses have been noted in livestock in areas where elk have been released in California. For these reasons and because blood samples collected by hunters are generally of poorer quality than those taken by CDFG biologists and veterinarians, testing elk for antibodies to IBR, BVD and PI-3 ceased in 1989. Similar results and conclusions led to cessation of testing elk serum for antibodies to BRSV.

Anaplasmosis is an important tick-transmitted red-blood cell parasite affecting a variety of wild and domestic ungulates. In cattle, it causes anemia, abortion, icterus, death and loss of condition. Although it can be treated with tetracycline, it is very difficult to eliminate. This is particularly true since black-tailed deer appear to be common carriers of this disease. Due to scarcity of reagents, we were only able to test elk periodically for antibodies to this disease. A further complicating factor are the notorious difficulties interpreting the results of *Anaplasma* card test when wild ungulate serum is used. We are currently cooperating with the USDA ARS anaplasmosis laboratory in Pullman, WA in developing genetic probes for testing elk serum for antibodies specific for *Anaplasma marginale* and *Anaplasma ovis*.

Bluetongue (BT) and Epizootic Hemorrhagic Disease (EHD) are two orbiviruses that are transmitted between cattle, sheep, goats, deer, elk and other less common ungulates via the bite of midges (*Culacoides varipennis*). These diseases may be manifest in many forms, from inapparent infections, to abortion, debilitation and lameness, and death. There is very limited information on their effects on elk. However, published reports by Stott et al. (1982) suggest that bluetongue virus infection may cause fetal deaths in elk. The hydrocephalic lesions noted in a blind elk calf at Tupman are quite similar to lesions reported from beef calves infected neonatally with

BT. Stott (1982) also noted that the virus could be recovered for some weeks from artificially infected adult elk cows. This brings up the possibility that elk may serve briefly as potentially infectious carriers of BT. For this reason, CDFG pushed elk captures back into late fall and early winter from 1979-1983. Since BT is widespread throughout California, and since cattle are known to be carriers of the BT virus for weeks to months and no precautions are taken during their relocation and transshipment, we later abandoned this practice.

As is evident from Tables 3 and 4, tule elk in eastern and central California have a high prevalence of infection with BT. Other authors have reported this situation in more detail (Jessup et al. 1984) and noted that several serotypes of BT virus were isolated from apparently normal elk. These data, when compared with seroprevalence rates for sympatric herds of deer and bighorn sheep, have led us to believe that BT and EHD transmission probably occurs in late summer and fall at altitudes of 4000 feet and below. However, Roosevelt elk herds close to the Pacific Ocean or in cooler habitats strongly influenced by marine weather, show little evidence of exposure to BT and EHD.

EHD is a cousin to BT virus and is generally thought to be less pathogenic for wildlife. However, during the 1987 outbreak of EHD in Penticton, British Columbia, Rocky Mountain elk were severely affected and some died. Several deer and bighorn species also died and bison and exotic ungulates were also infected by this EHD virus.

Because BT and EHD can also kill pronghorn antelope, white-tailed deer and mule deer, bighorn, bison and a variety of exotic wild ungulates and domestic livestock, elk serologic surveillance programs appear to be valuable and will continue. Our current panel of serologic tests run on all elk handled in California includes *Brucella*, Leptospirosis, BT and EHD. Serum is also frozen back for any future testing.

Routine veterinary prophylactic procedures have been described elsewhere (Jessup et al. 1988), but the clostridial disease situation bears some comment. Elk appear to be susceptible to a number of clostridial diseases and certainly suffer punctures and minor wounds in capture that favor the growth of many clostridial organisms. On at least one occasion, elk that did not receive a 7-way clostridial bacterin at capture died 7 to 10 days after release of apparent "black-leg", in locations where clostridial disease are common in cattle. *Clostridium sordelli* was recovered from one of these elk.

A herd of tule elk relocated onto a ranch where mycobacterium paratuberculosis infection (Johne's Diseases) had previously occurred in cattle became chronically infected (Jessup et al. 1981). Despite attempts to eliminate paratuberculosis in elk by culling infected individuals, cases are still sporadically reported in that herd. Paratuberculosis bacteria can live for several years in soil and elk should probably not be relocated onto previously infected premises for several years after they are vacant.

Hemlock (*Conium maculatum*) poisoning occurred on a wildlife area in Suisun Marsh when the elk population was allowed to exceed calculated carrying capacity (Jessup et al. 1986). That year, some previously available habitat was lost to flooding, and unique weather conditions slowed the emergence of grasses and other preferred food items. Once elk started utilizing the poison hemlock, they appeared to become habituated to it and animals that survived sublethal quantities returned to graze it and died. Some animals would paw the ground to remove roots. Hemlock patches were sprayed with diesel oil and later disked under, elk were supplementally fed and attempts were made to haze them from the area. Loco weed poisoning has been reported in Rocky Mountain elk from New Mexico when forage was quite limited.

By establishing a serologic database for infectious diseases, we have been able to be proactive in answering concerns about the potential of elk to carry diseases of concern to stockmen. No real opposition to elk relocation and management programs in California has arisen due to disease questions as has occurred elsewhere. Most disease testing of elk has been done gratis by the California Department of Food and Agriculture as it serves both their needs and ours.

Where elk disease problems have occurred after relocation, field and laboratory investigations have often revealed the cause. Alterations in medical treatment at capture and in management strategy in release areas have been designed to compensate. Elk are susceptible to a variety of infectious, nutritional, toxic and genetic health problems, but none of these have been allowed to hinder the expansion in range and increase in numbers called for in CDFG management plans. Herd health monitoring has proven to be fiscally, politically and biologically sound.

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MANAGEMENT OF MICHIGAN ELK FOR HUNTING AND VIEWING

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: The Michigan elk herd provides valuable recreational opportunities for viewing and hunting. Large antlered bulls are an important component of the herd for these activities. The herd is managed primarily through controlled harvesting. Hunting, while providing an important recreational opportunity, has the potential to reduce viewing opportunities. The objectives for this study were to model the dynamics of the Michigan elk population, to investigate the effect of varying harvest strategies on the population, especially numbers of mature bulls, and to determine the effect of hunting on elk visibility. The dynamics of Michigan's elk population were simulated with the POP-II model. The model was balanced relative to estimates of population size, recruitment rates, and herd structure. The effect of varying harvest strategies on the number of mature bulls was investigated with the simulation model. Approachability of elk was assessed by comparing their flight distances in areas open and closed to hunting. Age structure of bulls harvested in the hunts compared to the simulated population indicated that older bulls were being harvested at a rate almost 5 times higher than yearling bulls. Harvesting of bulls using non-specific bull permits could reduce numbers of older bulls and result in a decrease in the quality of viewing opportunities available from the elk herd. Alternative management strategies, such as issuing spike bull-only permits, may be an effective alternative. No differences were found between the flight distance of elk in the hunted and unhunted portions of the study area following 3 years of hunting. Management of elk in Michigan must be carefully monitored, as this relatively small herd supplies valuable but differing recreational opportunities.

Eastern elk (*Cervus elaphus canadensis*) ranged throughout the lower peninsula of Michigan until the late 1870's (Muriel951).

The present herd in Michigan is thought to have originated from a release of 7 Rocky Mountain elk (*C. e. nelsoni*) in 1918. The herd increased to an estimated 1,200 - 1,500 animals by the early 1960's (Moran 1973). During this period elk had become a significant tourist attraction. Hunting seasons were established in 1964 and 1965 in response to complaints of damage by farmers and foresters, and a total of 477 animals were harvested. These hunts eliminated the damage complaints, however, elk visibility declined resulting in unsatisfactory elk-viewing opportunities (Michigan Department of Natural Resources 1984). The herd continued to decline in the late 1960's and early 1970's. In 1975 the population was estimated to be only 200 animals (Moran 1973). Factors thought to have contributed to the decline included increased poaching, succession of brushlands and openings, and increased disturbance by human activities.

In response to the low population level and possible negative effects of hydrocarbon development within the elk range, the Michigan Department of Natural Resources (MDNR) increased law enforcement efforts and implemented an intensive habitat management program. The elk herd responded to these increased management efforts. A census in winter 1984 estimated a population of 850 animals. Although elk again had become a tourist attraction, depredation problems similar to the early 1960's were reported. In response to these damage complaints, the MDNR again proposed a controlled hunt. The first hunt was held in early December 1984. Decreased visibility following a hunt could reduce viewing opportunities for nonconsumptive users. For many tourists, sighting a large antlered bull is a highly valued experience.

The objectives of this study were to model the population dynamics of the Michigan elk herd, to investigate the effect of various harvest strategies on the number of mature bulls in the population, and to determine the effect of hunting on elk visibility.

This project was supported by the Federal Aid in Wildlife Restoration Act under Pittman - Robertson project W-127-R, and by the Michigan Agricultural Experiment Station. We thank the staff at Pigeon River Country State Forest for their assistance, and the Michigan Department of Natural Resources Wildlife Division for providing elk census and pregnancy data. We also thank R. Campa, T. Herblet, J. Brown, T. Bills, D. Luukkonen, and D. Whipple for their assistance in the field.

STUDY AREA

The elk range in Michigan occupies approximately 1,500 km^2 in the northern lower peninsula and includes parts of Otsego, Cheyboygen, Montmorency, and Presque Isle counties. The watershed is drained by the Black, Pigeon, and Sturgeon Rivers that originate in the coniferous swamps in the south and flow northward. Soil types range from low-fertility dry sandy soils on outwash plains to medium high-fertility soils on till plains and moraines (Moran 1973).

Climate alternates between continental-type and semi-marine (Moran 1973). Mean annual temperature for the area is 5.6 C. Mean annual precipitation is 74.9 cm with 59% occurring during the growing season (May - October). Annual snowfall averages 247 cm with a 90% probability of 15 cm of snow on the ground by 26 December (Michigan

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Weather Service 1974).

The diversity of vegetation types in the study area is due to differences in soils, drainage, and exposure. Diversity is further enhanced by extensive logging, repeated burning, plantations, and periodic attempts at farming (Moran 1973). Moranic uplands support sugar maple (*Acer saccharium*), basswood (*Tilia americana*), hemlock (*Tsuga canadensis*), northern red oak (*Quercus borealis*), red maple (*Acer rubrum*), white pine (*Pinus strobus*), and red pine (*Pinus resinosa*). Steep moranic slopes support aspen (*Populus* spp.), oak (*Quercus* spp.), red maple, white pine, and red pine. Plant species occurring on the outwash plain - moranic ecotone include red maple, aspen, juneberry (*Amelanchier canadensis*), and white birch (*Betula papyrifera*). The sandy outwash plains support juneberry, jack pine (*Pinus banksiana*), cherry (*Prunus* spp.), and willow (*Salix* spp.). Speckled alder (*Alnus rugosa*), dogwood (*Cornus* spp.), willow, white cedar (*Thuja occidentalis*), ash (*Fraxinus* spp.). and red elm (*Ulmus fulva*) are found on riverbanks and bottomlands. Coniferous swamps contain white cedar, balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and balsam poplar (*Populus balsamifera*) (Spiegel et al. 1963, Moran 1973).

METHODS

The dynamics of Michigan's elk population during 1975-1986 were simulated with the POP-II population model (Version 6.03; Fossil Creek Software, Ft. Collins, Co.). POP-II requires inputs of an initial age structure, age and season specific mortality rates, and age-specific recruitment rates. In a simple bookkeeping fashion, the model keeps track of the population by adding in reproduction and subtracting losses (Bartholow 1986). The model also allows different harvest rates (called relative effort values) to be applied to different sex and age classes in order to reflect hunter selectivity.

Population estimates were determined from censuses conducted by the MDNR (Table 1). The MDNR used a combined aerial and ground census in which observers attempted to count every elk within the elk range. Recruitment rates were estimated by monitoring the reproductive success of radio-collared cows in 1985 and 1986. Adult cows had natality rates of 89% (n = 19) and 85% (n = 13) in 1985 and 1986, respectively. In the model, the recruitment rate of adult cows was set at 85 calves/100 cows. Recruitment rate of yearling cows was estimated from pregnancy data collected from harvested animals (Schmitt et al. 1985, 1986). Recruitment rate of yearling cows was set at 20 calves/100 cows in the model. Sex ratio of the herd was estimated with post-rutting season counts in 1984, 1985, and 1986 (Beyer 1987). All elk observed were classified into 1 of the following categories: mature bull, yearling bull, cow, or calf (Table 2). The counts were completed within 1 week during all years except 1985, when the count took 2 weeks. An effort was made to avoid double counting of animals by systematically traversing the elk range and by monitoring movements of radio-collared animals. Confidence limits were placed on bull:cow and calf:cow ratios as described by Czaplewski et al. (1983) (Table 2).

Because rates of natural mortality for Michigan elk are unknown, the base model was balanced by manipulating the natural mortality rates (including poaching) to achieve the estimated population sizes and herd structure. The model was started in 1975 because this was the first year the MDNR conducted an elk census. The base model was balanced relative to the 1975-1986 MDNR population estimates.

After the base model was balanced relative to the population estimates, recruitment rates, and herd structure estimates, it was further refined by adjusting the relative effort values so that the age structure of the simulation harvests closely approximated the age structure of the actual harvests. The relative effort values for all age classes of cows were set equal to 1.0. When all effort values are set equal to 1.0, the model determines the harvest rate of each age class based on the proportion of animals in that age class in the population. Thus, harvest is directly proportional to availability of the animal.

In 1986, the effect of increasing bull harvest quotas on the number of mature bulls (≥ 4.5 years old) in the population was simulated for the period of 1987-1990. These simulations were made at 4 different bull:cow ratios; 55:100, 60:100, 65:100, and 70:100. A range of bull:cow ratios was used because of the relatively wide confidence intervals surrounding current sex ratio estimates. Harvest levels of cows and calves during the simulation period were set at 62 and 8, respectively. It was assumed that nonhunting mortality would remain constant. In 1990, the results of these simulations were compared to a model incorporating the actual harvest data from 1987-1989. The number of bulls harvested in 1987, 1988, and 1989 was 48, 82, and 65 animals, respectively. The number of cows harvested was 73, 119, and 89, respectively. The relatively high cow harvests were made to reduce the population to meet the MDNR's herd goal of approximately 1000 animals.

Effects of hunting on elk visibility were assessed by comparing approachability, or flight distance, of elk in the hunted and unhunted portions of the study area. Approximately 1/3 of the elk range was open to hunting in 1984 and 1985. Altmann (1958:207) defined flight distance as "the distance to which a person can approach a wild animal without causing it to flee". Flight distance was determined by slowly and steadily walking towards an elk until it ran. The distance from the observer to the place the elk was standing immediately before fleeing was measured with a range finder (Ranging Inc., East

Rochester, N.Y.). The flight behavior of each elk approached was recorded as either walking, trotting, or running.

Flight distance measurements were standardized by adhering to the following procedures: all animals were initially located with a vehicle; only animals in the open were sampled; if a group of animals was approached the measurement was taken on the closest animal; measurements were only taken during early morning and early evening hours; and measurements were not taken on days of adverse weather conditions.

Mean flight distance was determined in the designated hunted and unhunted portions of the study area during 3 seasons prior to the initiation of the December 1984 hunt. Mean flight distances were determined during 6 seasons after the hunting seasons were established. Because several data sets were non-normally distributed or had unequal variances, the data were analyzed with the Mann-Whitney U test (Siegel 1956). Chi-square analysis was used to compare flight behavior of elk in the hunted and unhunted areas. The acceptable level of statistical significance for all tests was set at $P = 0.10$.

RESULTS AND DISCUSSION

Population Model

The elk population model was developed by balancing the simulated population relative to the best available estimates of age specific recruitment rates, herd sex ratios and age structure, and population size. The simulated population tracked the MDNR population estimates reasonably well during 1975-1986 (Table 1). After the 1987-1989 harvest data were incorporated into the model, the 1989 simulated population declined below the number of animals counted by the MDNR in that year's census. These results suggest that the population estimates used to develop the model were low. Although not directly comparable to Michigan's aerial and ground census, most reports of aerial censusing suggest that the technique underestimates population size (Anderson 1954, Lovaas et al. 1966, Caughley 1974).

The model provides an estimate of natural mortality rates that must be occurring in order to keep the population at a particular level of growth and of a correct sex and age distribution (Table 3). The model estimated annual natural mortality for the entire herd to be 13%. Annual natural mortality of bulls and calves was approximately 17%, while annual natural mortality of cows was only 8%. The estimates of pre-and post-season natural mortality rates generated in the 1975-1986 simulation mimicked the herd's estimated population size (Table 1) and produced appropriate sex and age ratios for the herd through this time period. However, the simulated population from 1987-1990 decreased below the population estimates from the field censuses. The initial model was, therefore, felt to slightly underestimate herd size. With better estimates of herd size, natural mortality factors could be further refined in the model.

Table 1. Michigan Department of Natural Resources (MDNR) elk population estimates (January), 1975 - 1987 and the corresponding population level found in the POP-II simulation.

Year	MDNR population estimate	POP-II population estimate
1975	200	-
1976	-	234
1977	300	276
1978	-	326
1979	-	385
1980	500	452
1981	-	531
1982	-	623
1983	750	729
1984	850	853
1985	940	944
1986	950	961
1987	1000	994
1988	1020	999
1989	-	913
1990	980	859

Inspection of the age structure of cows harvested in the 1984, 1985, and 1986 hunts indicated that all age classes of cows appear to have been harvested in proportion to their abundance. Comparison of the age structure of bulls harvested in the 1984-1989 hunts to the age structure in the simulated population suggested that hunters were not harvesting the different age classes of bulls relative to their abundance. Hunters were selecting older bulls at a rate approximately 5 times that of yearling bulls. Relative effort values for bulls were adjusted so that the age structure of bulls in the simulation harvest reflected the age structure of the actual harvests.

Harvest Simulations

One of the goals of the MDNR's elk management program is to provide ample viewing opportunities. Many people are particularly interested in observing large bulls. To keep meeting this demand, the effect of harvest management strategies on the number of mature bulls present in the population must be known.

The main effect of differing bull:cow ratios is on the relative number of mature bulls that are present in the population. For example, there are 60 more mature bulls present in the population at the start of the 1987 year under the 70:100 simulation than under the 55:100

Table 2. Post-rutting season classification of Michigan elk in 1984, 1985, and 1986. Confidence intervals ( ) at the 90% level determined as described by Czaplewski et al. (1983).

Year	Adult bull	Yearling bull	Adult cow	calves	Total	Ratio				
						bull	:	cow	:	calf
1984	71	45	157	84	357	74(11)	:	100	:	54(9)
1985	47	56	199	91	393	52(8)	:	100	:	46(7)
1986	105	25	179	90	399	73(11)	:	100	:	50(8)
Totals	223	126	535	265	1,149	x = 66	:	100	:	50

Table 3. Natural mortality rates (%) used to balance the POP-II simulation of the Michigan elk herd, 1975-1986.

Age	Pre-season mortality		Post-season mortality	
	bull	cow	bull	cow
1[1]	8	6	10	10
2	5	3	8	5
3	7	2	8	2
4	7	2	10	2
5	7	2	12	3
6	7	2	15	3
7	8	2	20	4
8	8	3	25	4
9	8	3	30	4
10	8	3	35	5
11	12	3	40	6
12	15	5	45	10
13	20	8	50	15
14	25	8	60	25
15	25	10	100	100

[1] Age class 1 animals are calves.

simulation (Table 4). The magnitude of this difference emphasizes the need for an increased effort to collect more precise sex ratio data so that accurate estimates of bull numbers can be made. The actual number of mature bulls present in the population at any time is a function of the bull:cow ratio and the population size.

The results of the simulations (1987-1990), using the original population model, indicated that repeated annual harvests of over 50 bulls would begin to reduce the number of large mature bulls in the population regardless of the bull:cow ratio (Table 4). The number of bulls declined even though the simulated population continued to slowly increase. An annual harvest of 40 bulls allowed the number of large bulls to increase slightly in the simulation. These simulations assume that non-hunting mortality remained constant throughout the simulation, that vulnerability of bulls to hunting remained constant, and that the herd size followed that projected in the model.

If the simulation model accurately reflected the dynamics of the elk herd during the period of 1987-1989, we would expect to see an increase in the total number of bulls in the population, with a decrease in the number of mature bulls because the actual harvests exceeded those used in the simulations. Additional sex and age counts have not been conducted on the herd to check the validity of the model. However, inspection of the age structure of bulls harvested in 1987-1989 indicated that hunters were still able to select many older bulls. The fact that older bulls were still available also suggests that the population estimates used to develop the model were low. New information on current herd sex and age composition, planned to be collected in 1990, will allow for better model refinement.

Flight Distance

Flight distances and flight behavior were sampled in 3 seasons in the designated hunted and unhunted areas prior to the initiation of the hunting seasons. No significant differences ($P > 0.10$) in flight distance (Table 5) or flight behavior occurred between the 2 areas before hunting. Mean flight distances and flight behavior were determined in 6 seasons after the December hunts in 1984 and 1985. Again, no differences ($P > 0.10$) were found.

Various factors may affect flight distance. These factors include the animals reproductive status, nutritional level, and previous experiences (Altmann 1958). An important experience that could influence flight distance is whether the animal had been previously hunted. Behrend and Lubeck (1968) studied the flight distance of white-tailed deer approached by a vehicle on similar sized hunted (antlered deer only) and unhunted areas. Antlered bucks, excluding spikes, had significantly longer flight distances on the hunted area than on the unhunted area. Unhunted elk appear to develop a tolerance to human activities. Schultz and Bailey (1978) studied the effects of harassing elk observed on meadows in Rocky Mountain National Park. Neither the mean number of elk observed nor the

Table 4. Simulated numbers of mature (≥ 4.5 years) bulls under different bull : cow ratios and bull harvest quotas.

	55 bulls : 100 cows				60 bulls : 100 cows				65 bulls : 100 cows				70 bulls : 100 cows			
	Annual harvest				Annual Harvest				Annual harvest				Annual harvest			
Year	35	40	50	60	35	40	50	60	35	40	50	60	35	40	50	60
1987	84	84	84	84	100	100	100	100	117	117	117	117	144	144	144	144
1988	91	87	82	76	106	102	97	79	124	123	116	109	154	151	142	136
1989	97	91	80	69	111	108	95	84	133	128	114	103	164	156	143	130
1990	103	94	79	66	118	111	94	80	141	131	114	97	172	161	142	123

Table 5. Mean flight distance (meters) (mean ± standard error) of elk before and after the December, 1984 and 1985 hunts, in the hunted and unhunted portions of the Michigan elk range.

Season	Hunted Unit (n)[1]	Unhunted Unit (n)
Pre-hunt:		
Winter 1984	46.5 ± 4.9 (11)	60.2 ± 7.2 (15)
Summer 1984	49.0 ± 2.7 (31)	52.0 ± 2.9(28)
Autumn 1984	47.0 ± 3.0 (18)	48.3 ± 2.8(17)
Post-hunt:		
Winter 1985	47.0 ± 5.8 (8)	45.8 ± 5.2 (13)
Summer 1985	52.0 ± 2.8 (27)	47.8 ± 2.7 (21)
Autumn 1985	44.7 ± 2.9 (15)	45.0 ± 1.9 (18)
Spring 1986	44.3 ± 3.9 (15)	51.6 ± 4.1 (11)
Summer 1986	52.0 ± 2.3(25)	50.9 ± 2.8 (14)
Autumn 1986	53.0 ± 2.9(14)	50.3 ± 2.6 (17)

[1] Sample size.

mean distance of elk from roads differed between periods of harassment and periods of no disturbance. These authors suggested that the unhunted elk had learned to tolerate human activity.

Elk in Michigan have been legally hunted only 5 times since their reintroduction until 1987. It is unlikely that any of the elk present during the 1964 and 1965 hunts were alive during the 1984 hunt. Fifty hunters participated in the 1984 hunt and 49 were successful; 59% killed their elk on the first day of the season. In 1985, 119 of 120 permit holders killed elk; 61% were successful on the first day and only 13 hunters remained afield after the third day.

Although the results found in the literature suggest that hunting should reduce visibility of elk, it appears that the relatively short duration of the 1984 and 1985 hunts did not have an effect on elk visibility. However, animals with extremely long flight distances may not have been included in the samples. Measurements could not be taken on animals that ran when they saw or heard a vehicle approaching. Also, flight distance measurements would not detect an increase in hiding behavior due to hunting. However, observations of radio-collared elk in the study area suggest that an increase in cryptic behavior and/or long flight distances did not occur. An additional evaluation of flight distances of elk is planned for 1990-91. This will determine if longer exposure to hunting has caused a measurable increase in elk flight distances.

MANAGEMENT IMPLICATIONS

Elk management in Michigan is a complex problem involving consideration of population goals, herd productivity, recreational viewing, and agricultural damage. Harvest management must be carefully planned when population sizes are small and the management objective is to maintain the population at a particular level. In order to maintain the population at approximately 1000 animals, cows must be harvested. However, harvesting a disproportionate number of females increases the percentage of males in the population. Reducing the number of females in the population lowers overall herd productivity. Thus, management of cow harvests must become more fine tuned in order to avoid overharvest. To increase the number of cows in a finite population, the trend of increasing numbers of bulls must be reversed. The number of bulls in the population is also of concern because most agricultural damage is caused by bulls. Bulls have larger home ranges than cows (Beyer 1987) and tend to make exploratory movements to the agricultural areas at the periphery of the elk range. The results of our study suggest a heavy selection pressure on older bulls. Therefore, increased harvesting of bulls under the present permit system could eventually reduce numbers of older bulls and result in a decrease in the quality of viewing opportunities available from the Michigan elk herd. Other bull harvest options, such as issuing spike-bull only permits, may offer suitable alternatives to maintain the desired herd sex and age structure.

The results of the simulation modeling compared to population estimates from 1987-1990 emphasize the importance of continued field collection of information on herd dynamics. With checks on not only population estimates, but also on sex and age structure, the model can be validated for accuracy. Models generated from past data on a population should be used with caution until the accuracy of the model for predicting future events can be evaluated.

Mean flight distance and flight behavior of elk were not changed by 2 years of hunting. Other researchers have suggested that hunting should reduce elk visibility. Apparently, the relatively short duration of these hunts was not enough of an impact to change elk behavior. Elk are an important tourist attraction as well as a big game animal, and as a result, research should continue to assess their visibility. If elk become more wary of human presence, it may be necessary to manipulate viewing areas. Traditional elk viewing areas could be modified to keep observers far enough away from the elk to reduce disturbances. An opening maintenance program, including planting, fertilizing, and mowing, could be used to attract elk to these modified viewing areas. Only with careful population monitoring and planning can Michigan's elk herd provide both hunting opportunities and the quality viewing opportunities the public has come to expect.

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ZAG-POINT ELK AN ALTERNATIVE TO THE FOUR-POINT BULL ELK REGULATION

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: An investigation was conducted to determine an alternative to the four-point bull elk (*Cervus elaphus*) hunting regulation. A zag-point was defined as any point on the lower half of either main antler beam that was 5 inches (12.7 cm) long. A zag-point regulation was more selective for adult bulls (2-1/2 years or older) than the four-point regulation. For yearling bulls, 12% were legal under the zag-point regulation and 24% were legal under the four-point regulation. For adult bulls, 99.6% were legal under the zag-point regulation compared to 97.8% under the four-point regulation. Limited field testing indicated 92% of a selected group of Colorado's District Wildlife Managers (DWM's) could correctly identify zag-point opposed to 78% for a legal four-point. There appears to be 3 advantages of the zag-point regulation over the four-point regulation: determining a legal bull is easier and there will be fewer cases of hunters missing an opportunity to harvest a bull; hunters will make fewer mistakes resulting in fewer elk shot and discarded; and more four-point yearling bulls will be protected.

The Colorado Division of Wildlife (DOW) used various antler point regulations to restrict hunting to specific ages of bull elk during the 1931, 1971-2, and 1985-1989 seasons. The regulations were often limited to specific areas of the state. Since 1986, a four-point regulation has been used for most of Colorado. Some game management units (GMUs) are under the four-point regulation for some seasons (first and second rifle season) with no antler restrictions in other seasons (archery, muzzleloader, third rifle season). Other GMU's have the four-point regulation for all seasons (archery, muzzleloader, and rifle). The present regulation requires 4 points or more, ≥ 1 inch (2.5 cm) in length on at least 1 antler. Objectives of this regulation are: to increase number of branch antlered bulls, usually bulls $\geq$2-1/2 years, for harvest and breeding; and increase the chronically low post-hunt bull:cow ratios in some GMUs by protecting a portion of the bulls in the herd.

The present four-point regulation is apparently popular with most hunters in Colorado. However, there are problems with the regulation. First, determining if a bull has 4 points when observed from several hundred yards or when its head is viewed from the side is difficult. To be absolutely sure a bull is a legal four-point, a hunter should be able to count a total of at least 7 points on both antlers. Otherwise, the bull could be a 3X3 or some other illegal configuration, and the "4th point" may have actually been on the opposite antler. In Colorado, such a mistake could result in an illegal elk with a fine in excess of $1,000 or an elk that is shot and discarded. Second, hunters have passed up legal bulls because they didn't have enough time to count points. Both of these situations could contribute to low hunter satisfaction and participation.

If the basic objective of the four-point regulation is to protect yearling bull elk from harvest and concentrate harvest on elk that are $\geq$2-1/2 years old, then there may be a better way to achieve this goal. I hypothesize that nearly all adult bull elk ($\geq$2-1/2 years old) have at least one antler point $\geq$5 inches (12.7 cm) long on the lower half of at least 1 of the main beams. On the contrary, yearling bulls normally have a "spike" antler configuration (1X1), but if they have branched antlers, branching will occur mainly the tip or distal end of the antler and rarely will there be a point $\geq$5 inches long (12.7 cm) on the lower half of the main beam (Murie 1951, Boyd 1970, Peck 1982). If this hypothesis is true, I contend that determining if a bull is a yearling or $\geq$2-1/2 years old under field hunting conditions will be easier and more accurate because only 1 point will have to be ascertained. I call this point a "zag-point" (definition follows).

To avoid confusion among DOW employees and the public, I felt that this point should be named something new and completely different. A new name might cause hunters to study the regulation and find out what a "zag-point" means and avoid confusion resulting from preconceived notions. If these antler points were termed "brow tines," confusion could result because "brow tine" commonly refers only to the lowest point on an antler and it doesn't refer to the second or third point. For this manuscript the following definitions will apply (Fig. 1):

Adult Bull - a male elk $\geq$2-1/2 years old

Yearling Bull - a male elk approximately 1-1/2 years old

Zag-Point - any point on the lower half of either main beam of an elk antler that is $\geq$5 inches long (12.7 cm).

Main Beam - is measured from the lowest outside edge of the burr over the antler curve to the most distant point of what is or appears to be the main beam. (standard Boone and Crockett Club definition)

Point - a projection of an antler at least 1 inch long (2.5 cm) which is longer than the width of its base. (standard Colo. Div. of Wildl. definition)

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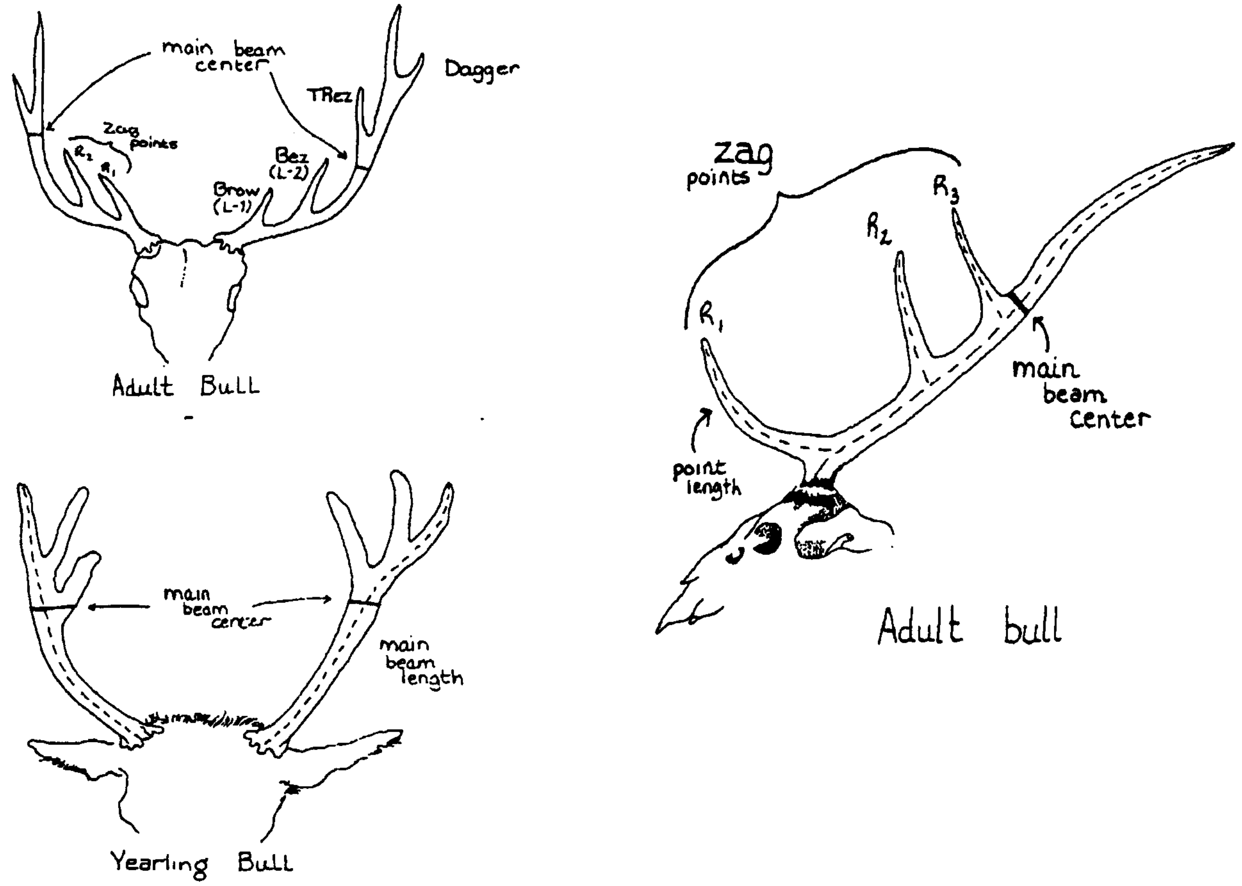

Fig. 1. Nomenclature and diagram of zag-points for yearling and adult bull elk.

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METHODS

During the 1986 and 1987 Colorado elk seasons, District Wildlife Managers (DWM's), biologists, and researchers were provided recording forms and cloth tape measures to collect data on characteristics of elk antlers from harvested bulls. The following data were collected on each bull. Age was classified as either yearling or adult and was determined by inspecting the lower incisors and canines. Yearlings typically have 2 permanent and 1 deciduous incisor and 1 deciduous canine on each side of the jaw while adults typically have all permanent incisors and canines. However, a few adult elk may have a deciduous canine (Quimby and Gaab 1957). The GMU of harvest, the total number of antler points on each antler, and the number and length of points on the lower half of the main beam (up to three points per antler) were measured and recorded by each antler.

In 1987 the data form was modified to better instruct recorders on procedures to measure all zag-points. Up to 3 zag-points per side could be measured if they were present. Zag-points were classified as R1, R2, R3, L1, L2, or L3 (R1 = lower zag-point on the right antler etc.; Fig. 1). Recorders were also asked to measure and record the length of each main beam.

All data were entered into computer files using DBASE III+. Files were then imported into LOTUS 1-2-3 for analyses and graphics.

A field test was designed using 15 sets of antlers. Antler configuration ranged from 1X1 (spikes) to 6X6

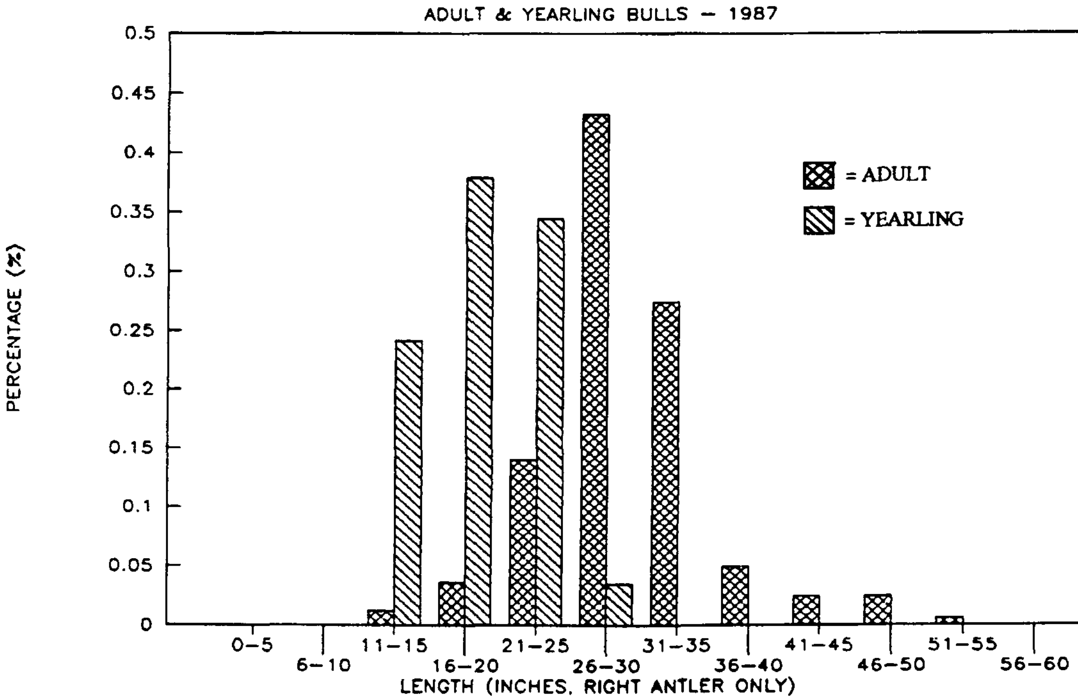

Fig. 2. Frequency of main beam length for yearling and adult bull elk collected in Colorado, 1986-87.

bulls, some had zag-points and some did not. Antler sets were nailed to a board facing to the left. Antlers were observed from 50 yards (45.7 m), the same effect as looking through a four-power rifle scope at 200 yards (182.8 m). Eight selected Colorado District Wildlife Mangers (DWM) were asked to determine which antler sets were legal under a four-point regulation and a zag-point regulation. Based upon each regulation, a definite "yes" or "no" answer was required for each antler set.

RESULTS

During 1986 and 1987, 607 elk antler sets were measured: 407 in 1986 and 200 in 1987. However, not all samples were complete and usable. The biggest omission occurred during 1986 when many recorders only measured the lowest point on the main beam (the brow tine). I estimate that only 30% of these measurements included all points. This error was mostly corrected in 1987 with a better data collection form and referring to the points as "zag-points" instead of "brow tines." Another problem with data collection was a low and biased sample of the yearling bulls. There were only 42 usable samples for yearlings opposed to 298 for adults. Considering that most yearlings probably came from seasons and GMUs where only four-point bull elk were legal, there was a serious bias in the data collection. Hunters would be expected to select only four-point yearlings and adults and pass-up, or shoot and discard, bulls with less than four-points. Yearling antler data presented here should not be considered a random and representative sample because the data are heavily skewed towards four-point yearlings.

Yearling Bull Antler Characteristics

Zag-Point Data.-- From the sample of 42 yearlings, 5 (12%) had at least one zag-point 5 inches (12.7 cm) long. However, as stated previously, I don't feel this is a valid representation of the antler characteristics of the yearling elk population in Colorado based on the obvious bias and the low sample size.

Main Beam Length.-- During the 1987 season, 29 yearling main beams were measured. Average length was 18.2 inches (46.2 cm) for the right and 19.1 inches (48.5 cm) for the left; the range was 11.3 to 28.0 inches (28.7 to 71.1 cm). The mode was 16 - 20 inches (40.6 to 50.8 cm; 43%; Fig. 2).

Antler Points.-- Twenty (48%) were spikes or 1X1 configuration; 13 (31%) had at least 2 or 3 points on at least one side, and 9 (21%) had at least 4 points on one antler (Table 1, Fig. 3). Boyd (1970) reported that 71.6% of yearlings were 1X1, 26.6% had at least 2 to 3 points on at least 1 antler and 1.8% were ≥4 points on at least 1 side (n = 1,839)

Table 1. Antler configuration for adult and yearling bull elk collected in Colorado, 1986-87.

Antler Points (RxL)	Total Yrlg.	Total Adult	Total	Yrlg. %	Adult %	Total %
1x1	20	0	20	48	0	3
1x2	3	0	3	7	0	1
1x4	1	0	1	2	0	0
2x1	1	0	1	2	0	0
2x2	3	1	4	7	0	1
2x3	4	1	5	10	0	1
2x4	0	1	1	0	0	0
3x1	1	0	1	2	0	0
3x2	0	1	1	0	0	0
3x3	0	9	9	0	2	2
3x4	2	23	25	5	4	4
3x5	0	6	6	0	1	1
3x6	0	1	1	0	0	0
4x2	2	1	3	5	0	1
4x3	3	16	19	7	3	3
4x4	0	87	87	0	16	15
4x5	1	52	53	2	9	9
4x6	0	5	5	0	1	1
5x2	0	3	3	0	1	1
5x3	1	8	9	2	1	2
5x4	0	40	40	0	7	7
5x5	0	156	156	0	28	26
5x6	0	22	22	0	4	4
6x2	0	1	1	0	0	0
6x4	0	3	3	0	1	1
6x5	0	18	18	0	3	3
6x6	0	89	89	0	16	15
6x7	0	2	2	0	0	0
7x6	0	2	2	0	0	0
7x7	0	2	2	0	0	0
Total	42	550	592	100	100	100

Adult Bull Antler Characteristics

Zag-Point Data.--Based upon a usable sample of 298 adults where all zag-points were measured (134 in 1986 and 164 in 1987), 99.6% of the bulls had $\geq$1 zag-points on at least 1 antler (Table 2, Fig. 4). The only exception was a 2-1/2 year old 2X2 bull that was branched only at the top. Zag-points ranged from 5.0 - 20.0 inches (12.7 - 50.8 cm) in length. The mode was 9 to 10 inches (22.9 to 25.4 cm, Fig. 4) for all points below the center of the main beam. When only the longest zag-point on each antler set was considered, they averaged 10.9 inches (27.7 cm) and the mode 11 and 12 inches (27.9 and 30.5 cm; Table 2; Fig. 5). Also, it was determined that 99.7% and 99.3% had points R1 and L1 respectively; 93.0% and 92.3% had points R2 and L2 respectively and 50.0% and 49.0% had points R3 and L3 (Table 2). Thus, even if several of the points were broken, which is quite common, or some points were obscured by vegetation, it would still be possible to see a zag-point because the average adult bull was found to have 4.8 zag-points.

Main Beam Length.-- During 1987, 165 adult antler sets were measured for main beam length. Mean length was 29.5 inches (74.9 cm) for both the right and left antler and ranged from 5.0 (broken main beam) to 54.0 inches (12.7 - 137.2 cm). The mode 26 to 30 inches (66.0 - 76.2 cm; 29%; Fig. 2).

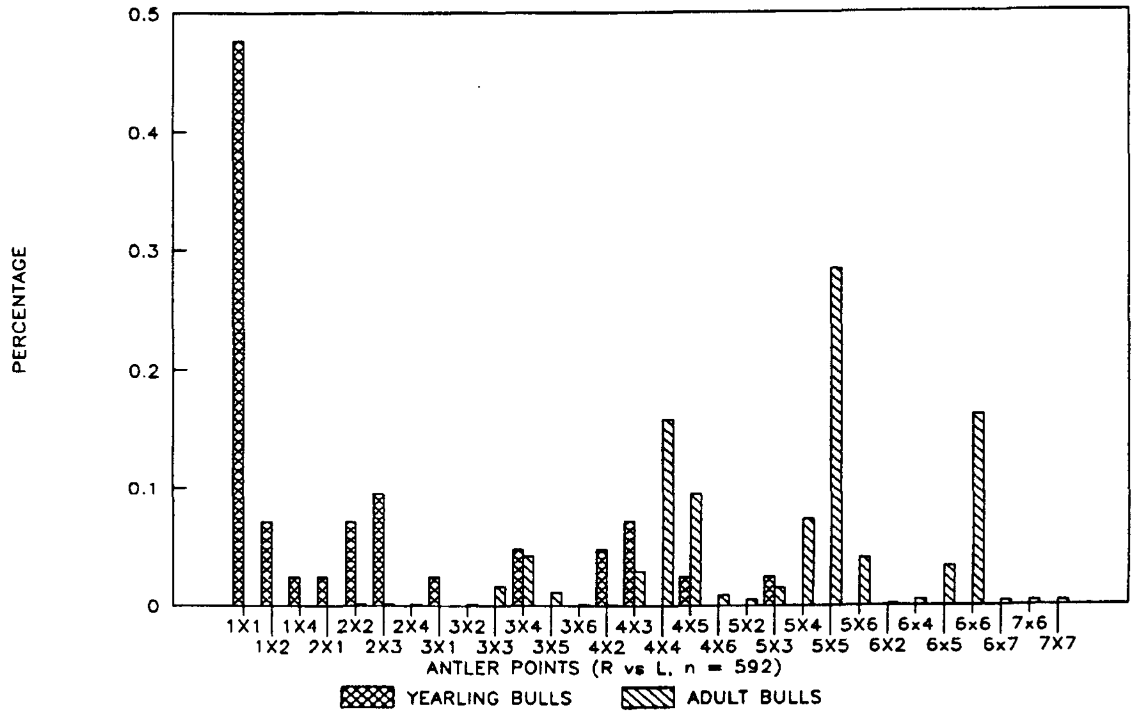

Fig. 3. Configuration of antler-points for yearling and adult bull elk collected in Colorado, 1986-87.

Antler Points.-- Based on 550 antler sets for adult bulls, 28% were 5X5, 16% were 4X4 and 16% were 6X6. Forty percent consisted of 22 different configurations, none of which exceeded more than 9% for a single category (Table 1). Bulls with 3X3 antlers, which would probably be the most difficult configuration to ascertain as a legal bull under the four-point regulation, made up only 2% of the sample. Boyd (1970) reported that 1.6% of adult bulls and 1.9% of yearlings bulls from Colorado's White River herd had the 3X3 antler configuration. However, as stated previously, most bull elk in this sample were harvested under the four-point regulation, thus the sample is strongly biased towards bull elk with antlers $\geq$ 4 points. Thirteen of the 550 adult bulls did not have at least 4 points on at least one antler (2.2%; Table 1 and Fig. 3).

Antler Point Test Results.-- DOW personnel correctly identified a legal zag-point and four-point 92% and 78% of the time, respectively.

DISCUSSION AND MANAGEMENT IMPLICATIONS

More data are needed to make definitive conclusions concerning the effects of zag or four-point regulations on the harvesting of yearling bull elk. However, $\leq$24% would likely qualify as legal bulls under the four-point regulation while $\leq$12% would qualify under the zag-point regulation. Thus, a zag-point regulation would probably protect more yearling bulls from harvest than the four-point regulation.

Under a zag-point regulation 99.6% of 298 adult bulls were legal. Under the a four-point regulation, 97.8% of 550 adults were legal. Thus, the zag-point regulation provided a slightly more accurate criteria for determining if a bull is $\geq$2-1/2 years old.

Advantages of a Zag-Point Regulation versus the Four-Point Regulation

There are several advantages to the zag-point regulation. Determining if a bull is legal is easier and more accurate. Only one antler-point needs to be observed before the hunter makes the decision to "shoot or don't shoot" as opposed to counting at least 4 points under the four-point regulation. Second, there would be greater hunter satisfaction because hunters could determine a legal bull more quickly and pass up fewer legal bulls. Third, there should be fewer illegal elk shot and discarded because determining a legal bull is easier and more accurate under the zag-point regulation. This should increase the legal bull harvest, increase hunter satisfaction, and reduce law enforcement actions.

After five years (1985-89) of four-point regulation for all seasons in Colorado's White River elk herd (Data Analysis Unit E-6), bull harvest totaled 11,222 bulls compared to the preceding five years (1980-84) when 18,122 bulls were harvested without antler-point regulations. This is a 39% (6,900) reduction in total bull

Table 2. Frequency and lengths of antler points below the center of the main beam for adult bull elk collected in Colorado, 1986-87.

Point	Point Number						Longest	Longest	Longest
Length	R1	R2	R3	L1	L2	L3	Right	Left	Both
0	1	13	89	1	11	89	1	1	1
1	0	2	0	1	2	0	0	1	0
2	3	4	2	1	5	3	0	0	0
3	1	6	0	0	8	2	0	0	0
4	3	5	1	2	7	0	1	0	0
5	7	16	5	7	19	3	1	5	1
6	10	28	4	15	14	6	9	4	2
7	36	26	10	25	25	10	21	14	10
8	37	36	23	38	36	18	22	30	19
9	42	37	20	52	52	25	42	41	41
10	46	34	26	57	37	25	46	58	47
11	42	34	24	33	20	15	48	46	49
12	31	18	14	29	19	15	47	39	49
13	15	16	9	13	10	11	28	22	32
14	10	3	3	13	7	5	10	18	20
15	9	3	2	5	7	1	10	7	13
16	3	2	3	3	3	3	4	4	3
17	1	3	1	1	1	2	4	3	6
18	1	3	1	1	2	2	2	3	3
19	0	1	0	0	0	0	1	0	1
20	0	0	1	0	1	0	1	1	1
21	0	0	0	0	0	0	0	0	0
Total >0	297	277	149	296	275	146	297	296	297
Total	298	290	238	297	286	235	298	297	298

harvest. I speculate that most of this reduction in harvest is probably a result of illegal harvest on bulls with <4 points and to a lesser degree, increased natural mortality from protecting yearlings from harvest.

Finally, there should be improved herd genetics. Antler size and development is a function of nutrition (Vogt 1947) and genetics (Harmel et al. 1988). Branch-antlered yearling bulls, especially four-point yearlings, maybe "genetically superior" and able to produce trophy size antlers when they reach optimum age for maximum antler growth. If these four-point yearlings are in fact "genetically superior", and if they are selected for harvest while more "genetically inferior" spikes are protected, there could be damage to the gene pool for producing trophy elk. However, deferring harvest to adults would allow more of these "superior genes" to express themselves in the gene pool. Because the zag-point regulation is more selective for adult bulls, less genetic damage would probably occur with this regulation than the four-point regulation.

Disadvantages of a Zag-Point Regulation versus a Four-Point Regulation

There are some disadvantages to the zag-point regulation. First, it is a new concept and considerable I & E effort will be required so the public understands and accepts the reasons for implementing the zag-point regulation. The zag-point concept would not build on the standard Boone and Crockett definitions of a "point." However, there is already considerable variance in the definition of a "point". Hunters from the Southern states traditionally call a point "anything that you can hang a ring on" and they count all the points on both sides. Thus, a four-point bull "Texas count" is actually a 2X2 bull western count. Other hunter management regulations have been introduced over the years and have been widely accepted. The "point system" in duck hunting is probably the most complicated but appears to be working well. The "3/4-curl bighorn ram" and "bearded turkey" regulations are some other harvest restrictions that are

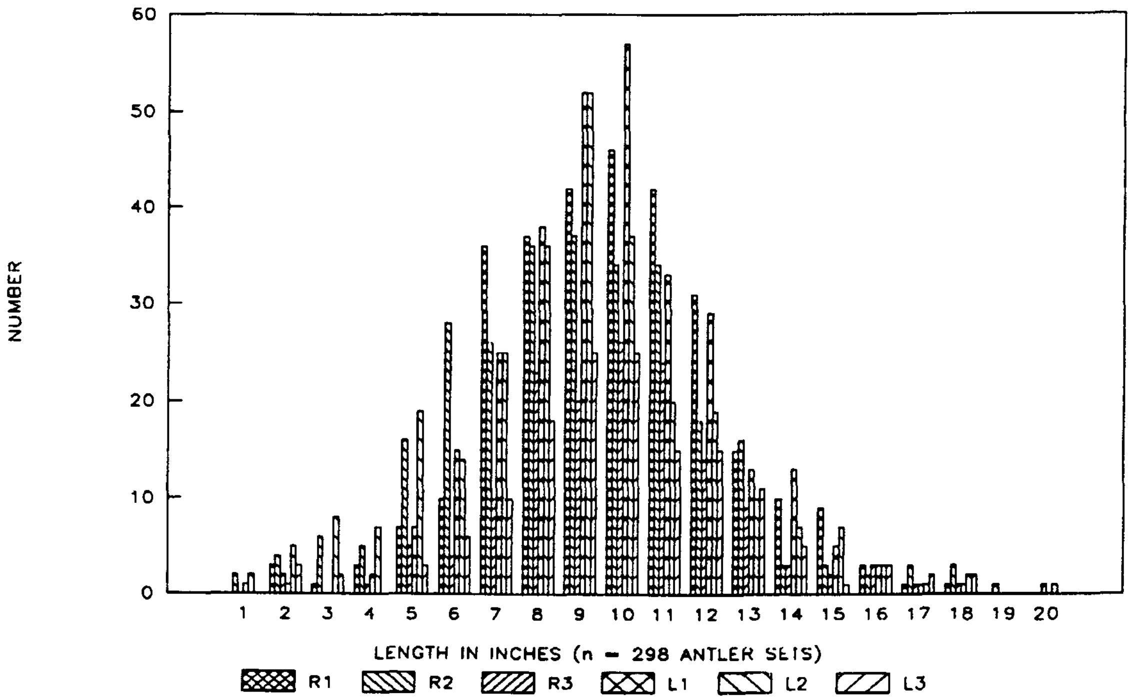

Fig. 4. Frequency of zag-point lengths for adult bull antler sets collected in Colorado, 1986-87.

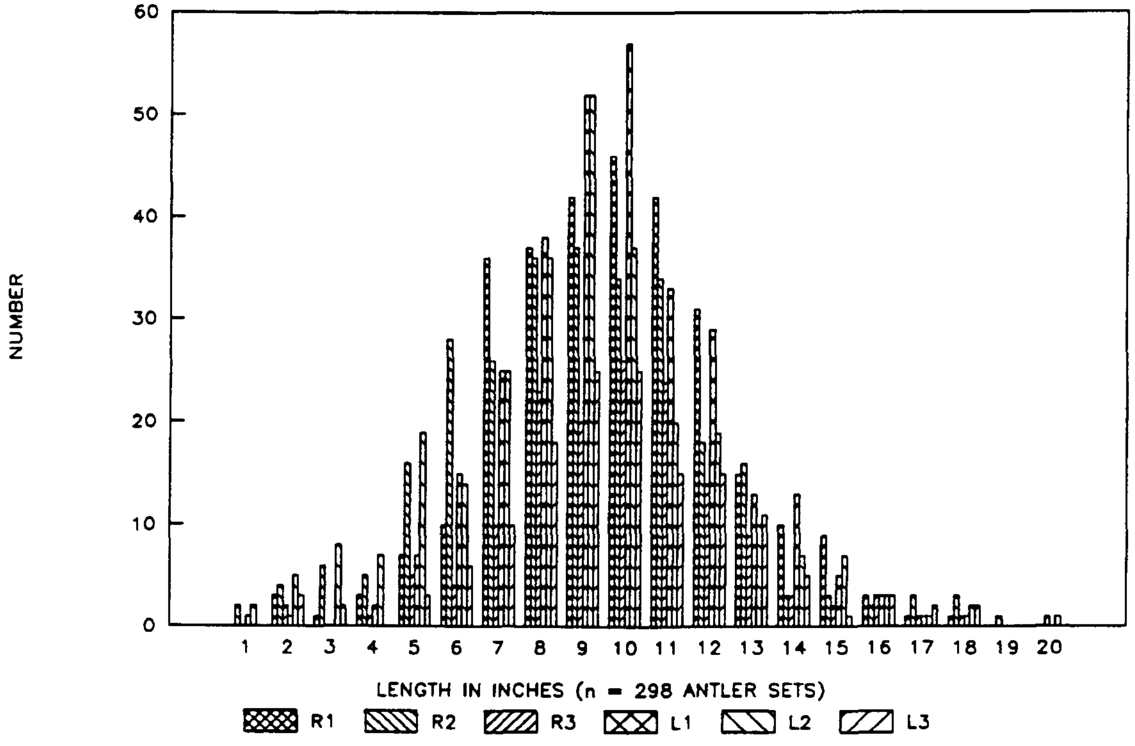

Fig. 5. Frequency for the longest zag-point from 298 bull elk antlers.

presently working well and widely accepted. Interestingly, the Colorado Wildlife Commission recently established 5 inches (12.7 cm) as the standard minimum for antler and horn length for buck deer, bull elk, bighorn ewes and buck antelope. The 5 inch (12.7 cm) zag-point regulation would conform perfectly with this standard.

Second, the regulation should increase legal adult bull harvest. Because the zag-point regulation appears to be easier for hunters to determine a legal bull, compared to the four-point regulation, more adult bulls will probably be harvested due to fewer cases of "missed opportunity." However, posthunt bull to cow ratios will probably not change much from what Colorado has experienced during the four-point regulation era, because fewer yearling bulls would be legal and presumably not harvested under a zag-point regulation.

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NO NICHE FOR NIMROD

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

"This badger proved no match for my Python and a Sierra 158-grain jacketed pistol bullet." The fellow in the picture is lofting the luckless badger in one hand, a huge revolver in the other. Dark shooting glasses hide his eyes and his thoughts.

Because you aren't a shooter you know nothing of bullets. You assume the Python is the pistol. It's like revolvers you see on TV - the kind that knock men over like bowling pins. You wonder what kind of badger would be a match for this predator with the inscrutable eyes and mammoth gun. Is this a sport hunter?

I got a call the other day from a fellow who wanted to help educate the public about hunting by giving talks at elementary schools. He said unless we tell people how much hunters do for wildlife we'll lose our right to hunt.

He sounded sincere so I was polite. I didn't tell him he was full of prunes. That we've no right to lose. That what hunters do for wildlife is of no interest to people obsessed by what hunters do to wildlife. That convincing even enlightened conservationists of hunting's merit is getting harder. Education, I agreed, is a good thing. I didn't tell him anything useful.

Telling children that the Pittman-Robertson tax has garnered 1.6 billion dollars for wildlife since 1937 is like telling new drivers how to start a Model A with a crank. You may be right, but your message has lost its utility.

We who hawk hunting have lost touch with our market. We've pushed hunter ethics to hunters and hunter dollars to people who don't hunt. We've snubbed people who rail against hunting; they picket the marshes, puncture our tires, poison our dogs. We dismiss them as lunatics, the radical fringe. What we've missed is a rumbling in the ground that threatens to put us out of business. Not only out of the hunting business but out of the business of actively managing wildlife.

A lot of hunters think people who oppose hunting either don't like what some hunters do or don't understand how hunting benefits wildlife. Not true. People who dislike hunters the most don't see hunters at all because they choose not to. A psychiatrist in this camp wrote that the hunter "is aggressive, forceful domineering ... sadistic. He likes to inflict torture." Another writer is even more graphic: "Hunters run to paunch and red faces. They are slow of foot, expensively dressed from the tips of their down booties to the knobs of their silver hip flasks. They have little desire to search for game but a great desire to kill. Hunters are noisy, belligerent and the dirtiest of all outdoor users, ... a destructive, dangerous lot who have made a mess of our wildlife." A third critic says simply: "Hunters generally shoot at anything that moves."

The writers may lack experience, honesty or both; people still read their racy reviews. To lose readers who demand facts is to lose a minority. Passion sells; hunting evokes passion.

So far hunters have countered by piously preaching about the money they generate for wildlife. Most of us in the management business have stayed above the fray, mouthing platitudes about carrying capacity and habitat. Neither response will salvage the hunt or martial support for wildlife management as we know it.

Recently I devised a short questionnaire on hunting and sent it to 15 groups whose name or stated purpose had something to do with protecting animals. Of nine respondents, five declined comment. "Our members have different opinions on that," noted one. "Some types of hunting would be much more acceptable than others," hedged a second. Other reasons: "We've no need for a position on this topic," and "We don't get involved with the gun issue."

Of the remaining four groups, only the Animal Welfare Institute and Society for Animal Protective Legislation (as one body) have "never taken a position against sport hunting by good marksmen armed with efficient firearms."

John Grandy, a vice president of the Humane Society of the United States, blasts sport hunting as "mostly macho, comraderie-based recreation that's not necessary in any sense." He says "killing for fun teaches callousness, disrespect for life and the notion that might makes right." Hunting "is no management tool at all [but] a commercial enterprise," supporting outdoor product and service companies and wildlife agencies. Grandy also claims wildlife managers who condone predator control are being used by the livestock industry to justify their own subsidies. Beyond that, however, he urges Humane Society members to join hunters in efforts to conserve habitat. He concedes some common interests.

Cleveland Amory doesn't. In a recent interview he called hunters "bloodthirsty nuts" and hunting an "antiquated expression of macho self-aggrandizement with no place in a civilized society." His Fund for Animals is "unalterably opposed to the recreational killing of wildlife," claiming that in 1988 hunters "killed dozens of bald and golden eagles, grizzly bears ... Florida panthers and whooping cranes." According to this group, the "prime function of state wildlife agencies is not to protect biological diversity but to propagate game for hunters to shoot."

Friends of Animals also attacks "hunting and the destructive methods of wildlife management." Leaving animal populations to balance themselves, it argues, "works to the benefit of all the species in an ecosystem." Hunting is "an act against nature," fueled by managers paid through game license fees. The group seeks "new legislation that will bring humane, creative and equal protection for wild animals."

What is creative protection? To what is equal protection equal? What rights are being violated and where did they come from? We're not told -- principally because we haven't bothered to ask. As wildlife professionals we've mostly ignored animal activists. These groups, however, have clearly lumped lawful hunters and wildlife managers with the slobs we so airily define as hunting's misfits. We're not score-keepers; we're the target.

People who don't like hunting have no use for hunters' money either. Many would repeal the Pittman-Robertson Act, claiming its purpose is to "artificially explode game populations", providing more targets for hunters. Habitat enhancement? "Millions of wild creatures are burned, mangled or drowned during such habitat manipulation." Conservation groups get the same barb: Ducks Unlimited "has flooded 1.4 million acres, ... transforming them into duck breeding terrain. [But] in flooding the land at least eight million mammals were drowned." The results of our tampering? "...by the year 2,000 the only native wildlife in America will be about 30 species of game animals."

The anti-hunting groups I queried admitted that hunters spend a lot of money on wildlife management. They attack management as misdirected. Tapping hunters for money they'd argue, is like releasing an ax murderer to pick up trash on the highway. Neither penance changes the lot of the victim. Biologists steeped in population dynamics can't understand this fuss over individual animals. The nonhunting public, which comprises 93% of our population, tells us it doesn't care if we understand or not.

Someone has said that no idea is so dangerous as one's only idea. That sword cuts many ways. A group so narrowly focused that it can't reason with its opponents will perish -- as will a philosophy so fierce that it repels political moderates. Doomed too, are ideas supported only by tradition, and those with no room for evolution. So far hunters have seen these flaws only in people who attack hunting. That's a myopic view.

Those who oppose hunting most vigorously do so because they see in hunting an act of violence, with perpetrator and victim. They see in each kill a brutality long outlawed elsewhere in our society. They see unfair advantage taken to extremes, a game in which the loser cannot but lose and for losing must forfeit its life.

Maybe they have a point.

It's hard to defend blood sport. Taking what you cannot restore has always been barbaric. In a society where the sanctity of human life has triggered furious debate, animal protectionism comes naturally. Hunters cause suffering. Skilled hunters cause less than unskilled, but always there's a chance for a bungled shot. Crippling losses of 50% enrage people. They should. If hunters don't wince at such waste, animal protectionists can successfully argue that hunting indeed causes callousness.

Killing is to any sensitive person a pretty grim business. Hunters accept it, many without reflection, as part of the game. This drives Cleveland Amory and company nail-eating mad. Shooting holes in animals oughtn't be fun, they scream. How can these trigger-happy maniacs look themselves in the mirror? It's easy for the uninformed to follow this reasoning. It's easy for me.

The defense, of course, is that hunting is not the same as killing; but that's hard to explain. Even President Bush had trouble when a television reporter asked him why he killed quail. Obviously frustrated at having to condense sport hunting to a sound bite, he said, "You have to eat, don't you?" For a later magazine article he said more but still couldn't define the hunt.

People who oppose hunting mark such bumblings and quickly challenge anyone claiming to cherish nature to justify killing animals for sport. It's a legitimate demand. We've not answered it well. Saying the answer is elusive won't placate people who watch video tapes of bison being shot as they wander out of Yellowstone Park. Maybe they've conceded a difference between market shooting in the 1870s and regulated shooting now. But it's still killing. Bison were all but exterminated by hunters then; shooting 569 in one barrage now hardly seems civilized.

A lot of it seems too easy too. If hunting is indeed a test of the hunter, how can outfitters advertise 100% success? If rifles, optics and bullets reach farther than an animal looks for danger, what skills can a hunter claim? Dangerous animals used to thrill and, occasionally kill, callow British officers in yesterday's Africa. But nobody courses lions anymore, and two men with modern guns allow the game slim odds. Animal activists say sport hunters are wimps. A lot of us are. Surely killing is no measure of a man, and hunters who brag of killing ought to consider Buffalo Jones.

Jones was a plainsman who became, at Yellowstone, the first US Federal Warden. He once roped an adult grizzly, and with an assistant removed a piece of metal wedged in its paw before releasing it. Another grizzly was becoming too bold around people so Jones roped it by a hind leg then strung it up on a limb, thrashed it roundly with a pole, and let it go.

I read in a recent magazine that the .338 Winchester is marginal for big bears.

While the most rabid animal protectionists denounce all hunting, moderates see some value in shooting for the table. A survey by Stephen Kellert of Yale found that 80 percent of Americans object to killing animals for their heads and 80 percent at least tolerate subsistence hunting. Alice Herrington of Friends of Animals argues that "...since the hunter is not banned from the supermarket he cannot claim hunting as a source of food." She'd join the 30% in Kellert's survey who'd ban hunting.

Government hunting and trapping programs incense people opposed to sport hunting. The Federal Animal Damage Control budget this year totals $30 million, with $15 million available from the states for cooperative work. In 1988 ADC killed nearly 4.6 million birds and animals. While 4.4 million or 96% of these were starlings and grackles, other species got more attention. Protectionists pointed out that in Arizona last year ADC killed 18 bears and 60 lions. Eleven of the cats, their heads piled in a grisly pyramid, were pictured in a *US News and World Report* cover article: The American Hunter Under Fire, February 5, 1990.

Ironically, people who have championed the esthetic values of nature are now using economics to bludgeon hunters, ranchers and others who have recognized for years the relationship of dollars to wildlife. They argue a live animal is worth more than a dead animal -- though they've not yet proven laissez-faire management will result in more live animals, or that all dead animals are equal. An African elephant shot for its tusks in 1989 before the CITES ivory ban netted a poacher about a thousand dollars. A live elephant brings Kenya over $14,000 in tourist money. Choosing between dead elephants and live elephants, then, is easy -- until you consider elephants pursued by sport hunters. Each bull shot on safari has a high price indeed, and not all hunters who spend the money for an elephant shoot one. Before native poachers used military arms to supply black markets with ivory, sportsmen dreamed of 100-pound tusks. By 1970, the mean weight of exported tusks had dropped to 22 pounds. In 1988, it was 10 pounds. The safari business doesn't thrive on 10-pound ivory.

Is a hunted animal alive or dead? Hunts that produce big dead animals command high prices for live ones not yet measured: $6,000 for a grizzly bear, $12,000 for a jaguar, $24,000 for an Argali sheep. If your ram tapes over 52.3 inches, incidentally, there's a surcharge; so a kill can up the ante. Hunters now pay $5,200 to chase the elusive snow leopard; shooting one costs them an additional $11,000. Money like that encourages management for mature animals, which in turn promises top-quality hunts and more bookings at even higher rates.

People who don't hunt also boost the value of wildlife, if only be demanding that managers do more for it. The cost of management, driven by inflation and this call for more programs, escalates. Agencies then have a choice: Ask the unlicensed public to share with hunters the cost of wildlife management, or tighten belts and boost license fees. Neither choice is appealing. Taking general fund money obligates managers to a huge, capricious group unschooled in wildlife ecology. Raising fees drives hunters away. Hunting may pay its own way but cannot yet accommodate people who want only to know the animals are there. Neither can it funnel to protected animals the amount of money used to manage game species. This bothers animal activists, who claim "hunters and their captive wildlife managers could not care less about nongame animals except for target practice."

The rancor here is predictable. Citing unequal treatment of species is a convenient way to attack the recreational killing of individuals. No matter the economic, biological or ecological justification, killing is still, to some people, inhuman. It's part of the raw material from which civilization came but has in its civility disowned.

The hunt may soon be an anachronism. In California hunting license sales have declined 20% in the last decade, while human population has increased by roughly the same amount. Wildlife programs are changing to accommodate people who not only don't hunt but don't want others to hunt. In premier western big game states license sales are still brisk, but short seasons and restricted access to private land crowd hunters. Area tag quotas maintain high_quality hunting but limit license receipts. Demand justifies higher fees but ultimately reduces the number of people able to hunt or willing to support game programs.

In 1950 a permit to hunt elk in Idaho cost nonresident hunters $50. Today the price is $372. Montana's elk license fee has tripled since 1970. Crowded coverts, complex regulations and, in many areas, a dearth of mature bulls combine to discourage hunters who remember simpler times. New hunters expect less -- but have shallower roots as well. Hunting is no longer part of an average boy's upbringing. It's becoming an easy thing to discard, a tradition with no reason to survive.

The young are reluctant to pick it up. The other night my fourth grade daughter was reading her McMillan textbook. I peeked at the story. It was about a group of children visiting a museum and talking with a zoologist. He told them about hunting:

> "Look at this. It's the skin of a baby seal. Can you see where the little seal was hit with a club?"
>
> [Youngster] "Why would anyone want to club a little seal?"
>
> Mr. Agustin explained that hunters club seals to death. Then the seal's fur is used to make coats. So many seals have been killed that now some kinds of seals are in danger of becoming extinct.
>
> "It makes me sad to think about wearing the skin of a baby seal."
>
> "Did you know that the tiger is also in danger of

> becoming extinct? People kill tigers for their skins..."
>
> "What's wrong with people anyway?"
>
> "I can see you're beginning to understand the problems," said Mr. Agustin.... "People have got to stop killing wild animals for their fur.
>
> [He continues:] "This tooth comes from another animal in danger of becoming extinct -- the Indian elephant."
>
> "But why is the elephant in danger of becoming extinct? Elephants don't have fur."
>
> "No, they don't," explained Mr. Agustin. "But some people kill elephants to get trophies or curios.... People also kill elephants for their tusks. Some people feel very proud when they kill a really big animal."
>
> "How could anyone be proud of killing an elephant?"

While youngsters can be taught to accept death, it's harder to convince them that it's okay for people to kill when they've no need. We blast terrorism but brag about shooting a deer. What;s the difference? Is animal life cheaper? Should it be? Senseless cruelty has few advocates, and what hunters do afield makes little sense to an increasing percentage of Americans. Maybe you're one who thinks hunting is outdated. Recent changes in government hiring policies have shifted agency priorities which reflect not only the will of constituents but of employees.

Schooling our youth in wildlife management, like denouncing the poacher, disowning the slob and banning the importation of ivory, is not enough. To many people, a humane, legal, biologically justified kill is still wrong if it's sport to the hunter. Killing ought not be fun, they say; death has no place in sport.

Hunters looking for agency shelter will find the roof leaky in the 1990s. Wildlife managers leaning on hunters will find the crutch shaky. Both will have to answer to people who don't want animals shot. Some of those people will be intelligent and open to reason. To ignore them is to accelerate strictures on hunting.

If hunters are sincere about the kill being secondary, they must show it. They must prove themselves civilized and sensitive, conceding that we cannot summarily dismiss an animal's life as a commodity, a perforated target or a certificate of achievement. Wildlife managers have the same mandate and one more: to meet the public's demands before they become complaints. Mobs are easier to direct from the front than from the rear. To benefit animals managers must first secure the respect of the people concerned about those animals. Until they do, all their profound mutterings about what's best for populations will be drowned by cries from people insisting that no one take what he cannot restore.

(Friends of Animals says game managers artificially boost deer numbers because 93% of all hunting is for deer. The Fund for Animals, however, says hunting to control populations is oversold because it works only for deer which comprise three percent of hunted game. The 90% discrepancy is dismissed in prose blasting hunters who slaughter, massacre, maim, cripple and destroy. Hunting is a carnage. Game is gentle, inoffensive and innocent.)

ROOSEVELT ELK DAMAGE TO AGRICULTURAL CROPS IN COASTAL WASHINGTON

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Abstract: The two most common agricultural crops in coastal Washington are cranberries and grass-hay. The Washington Department of Wildlife investigates agricultural damage claims to these crops due to elk damage. Until recently, the type of damage caused by elk to cranberry bogs was speculative and often was a major point of contention between farmers and the Department of Wildlife. It became possible to classify the damage into the following categories: berry damage, bud damage, vine damage, and grazing losses. Bogs showing high levels of elk usage were sampled. The greatest documented losses were due to berry damage caused by the trampling effect of the elk hooves. Economic loss due to elk grazing and trampling was insignificant. On the other hand, sample plots in the grass-hay fields suggest a considerably higher level of economic loss due to elk grazing. Grazing exclosure plots showed from 10-20% of the hay production was lost due to elk grazing.

The two most frequently grown agricultural crops in southwest coastal Washington are cranberries (*Vaccinium macrocarpon*), primarily the Stevens and McFarlane varieties, and grass-hay production for either green chop silage or for baled hay. Most of this production occurs in valley bottoms, diked tidelands, and wetland bogs; areas frequented by Roosevelt elk (*Cervus elaphus roosevelti*). Elk usage of these areas raises concerns about agricultural losses caused by elk grazing or trampling of the crops.

Elk recolonized much of the cranberry growing areas during the 1950's. These areas were historical elk habitat prior to logging practices and human disturbance. As elk populations grew and farming interests in cranberries expanded cranberry growers began to complain about elk damage. This has been most acute since the mid-1970's. Growers want the damage eliminated and see the elimination of elk as a necessity.

Cranberry is a low growing, woody, broadleaf, evergreen vine that produces stems or runners from one to six feet long. The vines form a thick mat that covers the entire surface of the cultivated bog. The berries themselves are the primary economic commodity. However, in some varieties, such as the Stevens, the vine prunings have a high commercial value ($2500-$3000 per ton). The means of harvesting cranberries in the study area is by flooding the bog and removing the berries using a water reel, also known as a beater. This process shakes loose the berries which float to the water surface (Shawa et al. 1984). During fruit development in August and September bog owners will minimize traffic on bogs for fear of berry and vine damage. Elk use during fruit development may break or bruise the berries making them non harvestable or unable to market. In addition, during other stages of vine development farmers fear the elk reduce future production through bud and vine destruction.

Conflicts between grass-hay production and elk follow a similar pattern as cranberries, often exacerbated by local land use practices which may convert tideland or river bottom elk feeding areas into housing or farmland. Hay production areas receive early morning and evening grazing and bedding use by elk. The main cause of damage was believed to be from elk grazing.

The evaluation of damage to these crops has been speculative and has not been quantified in Washington. This project attempted to quantify the losses and identify the types of damage caused to the cranberries and grass-hay. We attempted to find an easy to use field technique that could be used in a large number of damage areas.

STUDY AREA

The study area was located in Pacific County in southwest Washington. The cranberry bogs were located on the Long Beach Peninsula and encompassed 470 acres. These bogs represent 7% of the West Coast cranberry production. Coastal Washington produces about 4% of the total U.S. cranberry production (Washington Dept. Agriculture 1989). The soils on the cranberry bogs consist of Seastrand Series deep organic peat soils (Pringle 1986). Native plant communities consist of mosses (*Sphagnum* spp.), wild cranberry (*Vaccinium oxycoccos*), bunchberry (*Cornus canadensis*), gentian (*Gentiana* spp.), salal (*Gaultheria* spp.), and sedges (*Carex* spp.). These plant communities were removed and replaced by cranberries. The cranberry bogs are located in the deep peat bogs where water levels are controlled through a series of canals and drainage ditches. The elk utilize the adjacent Sitka spruce (*Picea stichensis*), Western red cedar (*Thuja plicata*), and hemlock (*Tsuga heterophylla*) forests described by Franklin and Dyrness (1973).

The grass-hay fields were located near Chinook, along the Columbia River, lying approximately 100 km west of Vancouver. The hay fields are typical of much of the hay production areas and pastures in this county. The fields are inside diked tidelands along smaller tributary rivers. Some of the fields are cleared forested swampland, originally cedar, spruce and alder (*Alnus rubra*) (Franklin and Dyrness 1973). The soils consist of Rennie Series soils, which are deep silty clay loam soils in flood plains (Pringle 1986). Elk utilized approximately 1250 acres of hay and pasture lands along the Chinook River. The primary grasses and forbs include fescue (*Festuca* spp.), orchard grass (*Dactylis* spp.), foxtail (*Alopecurus* spp.), ryegrass (*Elymus* spp.), buttercup (*Ranunculus* spp.), and clover (*Trifolium* spp.). Most of the Coastal pastures are not intensively managed. The hay produced is of relatively low quality averaging $40-$65 per ton.

METHODS

Cranberry Bogs

During 1987 and 1988, a 10 acre plot of cranberry bogs, receiving an estimated use of 270 elk nights per month was monitored for elk damage. The bog was partitioned into areas receiving elk use and areas without elk use. Seven sample plots measuring 1 square foot were established on the bogs in a manner consistent with cranberry sampling methodology (A. Shawa, WSU Cranberry Res. Stn., pers. commun.). All cranberries in the plots were collected and examined for bruising, crushing, or other physical damage. Three, 1 square foot control plots were located on bogs that had not received elk damage. Four, 1 square foot experimental plots were located on elk hoof depressions in areas along the elk travel routes through the cranberry bogs. This level of sampling was found to efficiently predict the overall production of a given bog based upon work by the Washington State University Cranberry Research Station (John Wayne pers. commun.). The percentage of damage was compared between the elk use area and the control plots using a paired sample t-test, and tested at the alpha=.10 level (Zar 1974).

During the fall 1987 cranberry harvest, all berries were kept separate by elk damaged and control bog. All berries were sorted and the percent of damaged berries was sampled for each of the groups by the Ocean Spray Cooperative Laboratory. Twenty-one, 2.27 kg (5 lb) random samples were made and the berries were examined for any physical damage or bruising. The berry damage in the harvest from the elk use portion of the bog was compared to the control portion of the bog with a Mann - Whitney non-parametric t-test and tested at the alpha=.10 level (Zar 1974).

During December 1987 the elk damage and control bogs were examined for dead or dying vines. This would have been an indicator of either uprooting or breakage by elk.

In spring 1988 the cranberry vines from the elk use and control bogs were examined for flower bud damage. The percent of damaged buds was compared between the elk use and control areas of the bog. Approximately 300 buds were microscopically examined for the presence of brown coloration or scarring to indicate damage to the bud. Once again bud loss or damage could result from elk travel on the bogs.

Grass - Hay Green Chop Production

During spring 1988, 4 ft square exclosures were randomly placed on six different pastures. Exclosures consisted of 5 ft steel post with 2 inch mesh chicken wire. The fields, approximately 150 acres, were grouped based on similar plant composition, age of the planting, and harvest strategy. Samples were cut bi-weekly during April, May, and June. All vegetation was clipped and removed from 1 foot square plots inside the exclosure and from random locations adjacent to the exclosure. The clipped vegetation was weighed, dried, and reweighed to attain a wet to dry weight conversion. The percentage grazing loss was calculated from a comparison between elk grazed and ungrazed areas and significance was tested using a one tailed t-test, alpha =.05 (Zar 1974). All green chop was weighed after harvest.

The following formula was used to calculate the dollar value of the grazing loss:

$$[(Y / 1.0 - PL) - Y] * CON * PRI = VALUE$$

Where:

Y = yield in tons of green chop for a field
PL = percent of grazing loss based on exclosure comparisons
CON = dry to wet weight conversion, to convert to hay equivalent
PRI = local hay price
VALUE = value of crop lost to elk grazing

RESULTS

Cranberry Bogs

The three control plots on the bogs had an average of 2.1% damaged berries. The elk hoof damage sample plots had an average of 15.9% damage (Fig.1).

This difference is significant. The percentages of damaged berries were calculated after harvest. The percentage of damaged berries from the control bogs averaged 2.1%. The percentage of damaged berries for the bogs receiving elk usage was 2.5%, with a range from 1% - 5%. There is no significant difference in berry damage between the elk use areas and the control areas of the bogs (Fig.2).

During winter examinations of vines, no dead or dying vines were found in bogs where elk usage had occurred. Microscopic spring bud examinations showed 12.27% and 12.34% bud damage in areas frequented by elk and in control areas respectively.

Grass - Hay Green Chop Production

Most of the elk grazing, as determined by direct observations and the presence of grazed grass blades, occurred along the edges of the spruce swamps. This is

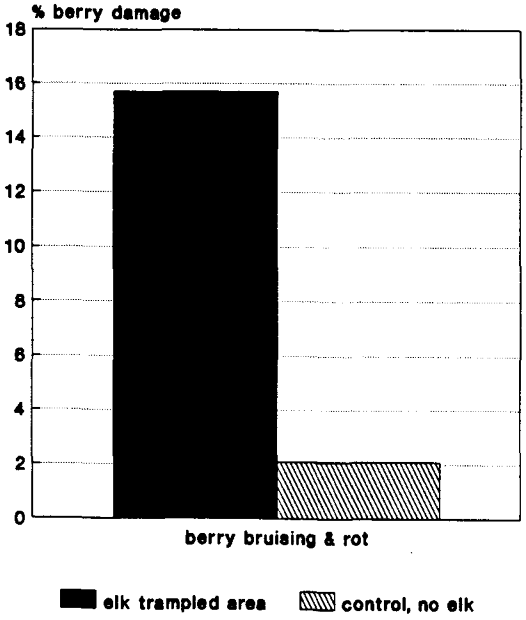

Fig. 1. Elk damage to cranberries from samples over tracks at Long Beach Peninsula, Washington.

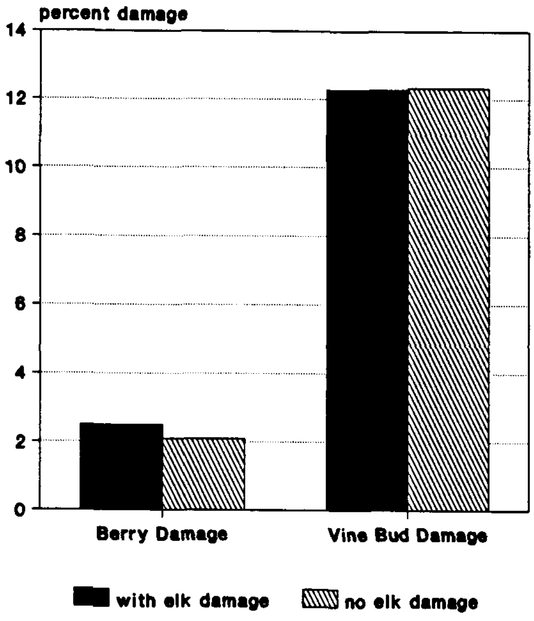

Fig. 2. Total cranberry damage by elk measured after harvest at Long Beach Peninsula, Washington.

consistent with elk behavior and feeding studies which found that elk utilize open areas closer to cover (Brown 1985, Hanley 1983, Harper and Swanson 1970, Witmer 1981). Because of this edge relationship, 26% of the fields received no elk grazing, bedding or other elk usage.

Three of the pasture types received no elk usage. The sample plots showed that 19.1% of the dry weight of grass and forbs was lost in the three fields with elk grazing. There was a significant difference between the grazed and the ungrazed plots.

The total wet weight of the green chop forage from fields receiving elk grazing was 461.5 tons. Based on the calculated dry to wet weight conversion of 0.40 and 19.1% dry weight grazing loss, 40.8 tons of dry hay was lost to elk grazing on the 150 acres.

DISCUSSION

Cranberry Bogs

Although the percentage of berry damage was high on the elk hoof depressions along the elk trails in cranberry bogs, the overall percentage of berries damaged was much lower. Elk damage occurs on a small percentage of the overall area of the cranberry bogs. Consequently, most of the berries were not effected by the elk. There was no difference in the amount of bud or vine damage in the bogs that the elk had utilized versus the control bogs.

Cranberry or vine loss to grazing was not observed on these study plots. Elk tended to travel through the bogs without stopping to browse. This observation was supported by local bog owners. However, in 1986 two elk that were killed on cranberry bogs had cranberries and cranberry leaves in their rumens. This leads one to believe that browsing does occur in some instances. The bogs in the study area, and most of the bogs with elk damage concerns use some form of hazing techniques including fuse ropes, propane cannons, and cracker shells. These techniques did not stop the elk from using the bogs. However, it may have reduced elk use on the bogs and contributed to the low amount of elk browsing.

Grass - Hay Green Chop Production

Many of the hay and pasture grazing complaints that are received from farmers occur during the late winter and early spring before elk calving and before significant pasture growth. The grazing losses of 19% represent a considerable amount of economic loss. At the local hay price of $65 per ton the 40.8 tons of lost hay represents nearly $2700. The Washington Department of Wildlife, like many other Western States, must pay agricultural losses caused by deer and elk.

MANAGEMENT IMPLICATIONS AND DAMAGE ASSESSMENT

The cranberry bogs have a high economic yield per area of production (roughly $6000 per acre). Therefore, the potential exists for large economic losses with few elk present. However, with the level of elk use observed on Long Beach Peninsula, there appears to be little economic loss and it would not be cost effective to fence bogs at this time. Wildlife managers should remain sensitive to the growers emotional stress as elk presence occurs at a time when growers are sensitive to disturbance of their crop. The damage caused by elk on cranberry bogs should be evaluated in the following ways:

1. Determine the percent of damaged berries in elk use and control areas on the same bog;
2. Vine damage should be determined during winter;
3. Microscopic evaluation of bud damage should occur the following spring; and
4. If elk are grazing in a bog then additional work and calculations will be necessary to determine total grazing losses.

Grass - Hay Green Chop Production

The method used to determine loss of grass-hay production is not statistically adequate to detect small differences. Sample sizes are restricted because of the destructive nature of the samples. It is also very time consuming and costly for field personnel, particularly when there are several landowners with damage claims in a small area. Another field method based on elk usage and consumption rates has been used by several states with satisfactory results (Austin and Urness 1987). When the Austin and Urness method, developed by Utah Fish and Wildlife, was applied to data from this study similar results were achieved.

ACKNOWLEDGMENTS

The assistance of John Wayne and the Washington State University Cranberry Research Station is greatly appreciated. I also wish to thank the many farmers who assisted in the damage assessment methodology. Also, the review of this paper by J. David Brittell, Ron Fox, Margaret Schirato, and Helmut Zahn is greatly appreciated.

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TOWARD A WORKABLE GLOSSARY OF ELK MANAGEMENT TERMS - RESULTS OF A WORKSHOP

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1990 PROCEEDINGS OF THE WESTERN STATES AND PROVINCES ELK WORKSHOP

Over the past decade we have witnessed the development and proliferation of elk habitat management guidelines throughout the North American elk range. These guidelines were primarily developed from research on the influences of timber sales and roads on elk behavior and summer/fall habitat use. However, the development of forest plans and environmental evaluations have too often resulted in inappropriate extrapolation of available information to applications on winter range, hunting seasons, and other conditions outside the scope of the original research.

In the course of this extrapolation, some commonly used terms have taken on several meanings, unusual analysis procedures have appeared, and some completely new terminology has been created. There have been applications that are confusing to managers and the public alike. The future of elk management depends on clear communication among agency personnel and the public. We believe it is essential that the terminology of elk habitat management be clarified and standardized.

This paper presents the results of an "Elk Management Terminology Workshop" held at Lubrecht Experimental Forest on April 3-4, 1990. Biologists representing State, Federal, university, and private management concerns participated in a two-day facilitated workshop where we attempted to identify the most commonly misused terms in elk management guidelines and develop a concensus for the true meaning of those terms.

Neither the workshop nor this paper could be comprehensive. Most common terminology in elk management is easily understood and used correctly. Presented here are the recommended definitions for some terms that have often been misinterpreted or used in ways that suggest two or more meanings. Workshop participants also identified some terms that have become so misused as to be virtually meaningless. We recognize that not everyone will agree with our assessments and we expect that misuse will continue despite our efforts. Maybe the best we can hope for is that we have taken a step toward making it possible for professionals to communicate with other professionals.

SELECTION OF TERMS

The Elk Management Terminology Workshop emerged from discussions among 8 to 10 concerned biologists in Montana and northern Idaho. An initial list of terms to be discussed in a workshop was generated by this group. This list was circulated to State and Federal biologists and managers actively involved in elk management and the application of guidelines and terminology. Participants were asked to indicate the most troublesome terms on the list and add additional terms if needed. Based on the responses, about 30 people were invited to a formal workshop on the terminology of elk management.

From the first mailing of the survey, we selected 42 commonly used terms in elk management for further study. Each term was sent to at least one prospective workshop participant. Some were sent to as many as three participants. Each participant was expected to determine the history and origin of their assigned term(s), to note when they were first used in the literature, and to recommend an acceptable definition. Results of this request were particularly edifying when some participants supplied their own definitions without recourse to the literature.

At the beginning of the workshop, all recommended definitions were distributed to participants who were again asked to identify those terms requiring discussion and clarification. In this process we determined that about a third of the terms are the source of most of the confusion and misuse while another third have perfectly acceptable definitions and are rarely misused. We found that troublesome terms were often interconnected so that misuse of one resulted in confusion and misuse of several others. Finally, we discovered that troublesome terms often had a good definition for either structure or function, but not both. If one definition is missing, eg. function, the term is likely to be misused or misinterpreted or both.

Participants were split into three working groups. All three groups discussed the highly controversial terms. Less difficult terms were handled by only one of the groups. At the conclusion of the workshop, participants recommended development of a new term:

Accessibility Index

This term will become an essential component of future management for elk security during the hunting season. It is needed to summarize the degree of human access facilitated by such components as roads, trails and their management, terrain and vegetation, season length, and legal restrictions. No specific definition is proposed at this time, but we recommend that research in this problem area recognize the need for broad generic applicability.

TERMS

Terms evaluated in the workshop discussions are presented here in the general order of difficulty with interrelated terms grouped together. Those terms for which misuse is rare are not discussed.

Hiding Cover

Definition

Structure: Vegetation capable of hiding 90% of a standing adult elk from the view of a human at a distance equal to or less than 200 ft. As a site-specific vegetative component of SECURITY, HIDING COVER exists across the landscape on a continuum with quality inversely proportional to SIGHT DISTANCE.

Function: HIDING COVER allows elk to utilize areas for bedding, foraging, thermal relief, wallowing, and other functions year around. HIDING COVER may contribute to SECURITY at any time, but it does not necessarily provide SECURITY during the hunting season.

Discussion

Without question, the terms causing the greatest problems and the most confusion involved multiple interpretations and cross referencing of HIDING COVER and SECURITY. The terms in this subject area often had several different meanings, and the implications, particularly with regard to the hunting season, were extremely varied.

Recommendation

Workshop participants were unanimous in concluding that HIDING COVER is a requisite of elk habitat and a component of SECURITY, but that HIDING COVER alone does not provide SECURITY during the hunting season.

Security

Definition

The protection inherent in any situation that allows elk to remain in a defined area despite an increase in stress or disturbance associated with the hunting season or other human activities.

Discussion

Note that SECURITY is a state of being or a condition. The workshop group reached a concensus that SECURITY is a functional concept and also agreed that SECURITY is most important when viewed in relation to the hunting season. The components of SECURITY may include, but are not limited to, vegetation, topography, areal extent, road density, distance from roads, size of vegetation blocks, hunter density, season timing, and land ownership.

Recommendation

Very little problem can be encountered in the use of this term if it recognized that HIDING COVER is site specific, SECURITY is area specific.

Security Area

Definition

Any area because of its geography, topography, vegetation, or a combination, that will hold elk during periods of stress.

Discussion

SECURITY AREA is the structural constituent of SECURITY. The workshop group considered this term more meaningful than SECURITY HABITAT. The concensus opinion was that SECURITY HABITAT, even if used as a synonym, can only add confusion to the concept and should be avoided.

Security Habitat

See discussion for SECURITY AREA
Recommendation: Do not use this term

Security Cover

Definition

The vegetative cover component of SECURITY.

Discussion

The literature review for this term demonstrates a tendency to equate SECURITY AREA and SECURITY COVER. Although the definition is fairly clear, the concensus of the workshop was that SECURITY AREA is entirely adequate.

Recommendation

Do not use this term

Escape Cover

Definition

Variously defined as vegetation dense enough to aid animals in escaping from potential enemies. Discussion: Although this is one of the oldest terms in game management, workshop participants considered it too imprecise for use in elk management. It appears as a synonym for SECURITY, SECURITY AREA, SECURITY COVER and HIDING COVER but fails to convey any satisfactory meaning.

Recommendation

Do not use this term

Carrying Capacity

Definition

Maximum rate of animal stocking possible without inducing damage to vegetation or related resources. Discussion: This is a well-established biological concept, but it is too imprecise for any useful application in elk management terminology.

Recommendation

Avoid using this term in relation to elk.

Habitat Capability
Elk Habitat Potential
Elk Use Potential
Habitat Use Potential
Potential Elk Use

Discussion

All of these terms strive, in one way or another, to identify the ability of a habitat to support elk. However, they are virtually always used in a context that compares current with predicted elk use in relation to change in vegetation. The terms based on "use" appear in the literature related to habitat models and are probably valid synonyms.

Recommendation

These terms should be used only as justified by the existing literature and should not be considered random synonyms. Under no circumstances should they be considered equivalent to either CARRYING CAPACITY or HABITAT EFFECTIVENESS.

Habitat Capability

Definition

The capacity of a given area to meet the needs of elk, either seasonally or year around.

Discussion

Interestingly, this term is widely used and well defined in the fisheries literature. The workshop participants, however, seemed to consider it nearly equivalent to CARRYING CAPACITY and not applicable to elk management.

Recommendation

Should not be used unless used correctly.

Elk Habitat Potential

Definition

Cannot be defined, although it has been used as a synonym for CARRYING CAPACITY, for HABITAT CAPABILITY, and for ELK USE POTENTIAL.

Discussion

This appears to be a term that tries to find some middle ground between elk use and CARRYING CAPACITY. The resulting failure also confuses accepted definitions of HABITAT EFFECTIVENESS.

Recommendation

Do not use this term.

Elk Use Potential
Habitat Use Potential
Potential Elk Use

Definition

A scaled representation of maximum possible use by elk.

Discussion

ELK USE POTENTIAL is the standard against which HABITAT EFFECTIVENESS is normally calculated. It is not, however, an acceptable expression of HABITAT CAPABILITY or CARRYING CAPACITY.

Recommendation

Should only be used correctly to indicate the level of use by elk.

Habitat Effectiveness

Definition

Percentage of available habitat that is usable by elk during the non-hunting season.

Discussion

HABITAT EFFECTIVENESS appears to have originated in the development of road density models as a means of expressing the habitat loss associated with open forest roads. It has since been used to express habitat quality, hunting season SECURITY, HABITAT CAPABILITY, CARRYING CAPACITY and several other conditions not justified by the available data. The term has been used so many different ways there was a suggestion that it simply be dropped.

Recommendation

We cannot just throw out all existing uses of the term, but biologists and managers should recognize that it has been widely abused. It is usually correct when applied to area. It is usually incorrect when substituted for SECURITY, capability, or productive capacity of habitats. Strive to limit applications to situations meeting the definition.

Elk Effective Cover

Definition

As used in several forest plans, it appears to be equivalent to HABITAT EFFECTIVENESS but including some implications of both habitat productivity and SECURITY.

Discussion

Because of the way it is used, the term appears to provide habitat information that does not, in fact, exist.

Recommendation

Should only be continued on those forests where it appears in the forest plan, and every effort should be made to clarify the usage so as not to include SECURITY or productivity.

Road Influence

Definition

The effect a road has on elk distribution, behavior, and vulnerability to hunters.

Discussion

This is sometimes interpreted as a zone of influence and is often associated with calculations involving HABITAT EFFECTIVENESS.

Recommendation

Use only as justified by existing literature and within the context of existing habitat models.

Open Road Equivalents

Definition

A measure of access that addresses all types of roads and trails used by motorized vehicles and equates these to a common standard. Frequently used in the computation of HABITAT EFFECTIVENESS.

Discussion

Commonly, miles of secondary and primitive road are converted to equivalent primary road miles. Data are available to support such conversions. Various attempts have been made to extrapolate the concept to closed roads, to trails, and to roads and trails during the hunting season. There are no data to support such conversions.

Recommendation

Confine equivalent mileage conversions to evaluation of open roads and recognize that use by any motorized vehicle creates an open road.

Hunter Opportunity

Definition

An array of options that allows hunters to choose situations that are personally rewarding.

Discussion

Components of HUNTER OPPORTUNITY are influenced by human activities, hunting regulations, access, time and space, and land management activities. The key to this concept is the ability to choose from several options and to be able to select an option that is personally rewarding. An important management decision in providing HUNTER OPPORTUNITY involves the scale of application: statewide, regionwide, forestwide.

Elk Vulnerability

Definition

A measure of elk susceptibility to being killed during the hunting season. Note that this is the antonym of SECURITY during the hunting season.

Discussion

This is primarily a functional concept that is the sum of many factors such as SECURITY, HUNTER OPPORTUNITY, hunter behavior, and elk behavior. It has often been defined in ways related to ESCAPEMENT of branch antlered bulls.

Recommendation

This term represents a complex area in which a great deal of research remains to be done.

Escapement

Definition

The number, or proportion, of elk surviving the hunting season. Frequently the emphasis is on specific age and sex classes of elk.

Discussion

In common usage there is confusion with ESCAPE COVER and with the act of escaping. Fisheries literature is clear and useful, indicating that this term can be reasonably used to describe the number of animals surviving.

Herd Home Range
Population/Habitat Unit
Elk Evaluation/Analysis Areas
Habitat Analysis Unit
Elk Management Unit
Game Management Unit

Discussion

All of these terms attempt to define a specific area within which an analysis procedure can be performed. The first two are defined by animals (by radio locations), the remainder by people. The last four all seem to be arbitrary in the sense that they are drawn to contain a general area of elk habitat rather than the specific area defined by a POPULATION/HABITAT UNIT. The last two are most often used in management of hunting seasons.

Recommendation

Use each term as defined. These are not interchangable.

Herd Home Range

Definition

The area traversed in the scope of normal activities of a social group of ungulates.

Discussion

Although this is a viable concept, we rarely have enough information to use it. It usually includes the total range for a year.

Population/Habitat Unit

Definition

A discrete association of individual elk bonded together by traditional use of a habitat.

Discussion

By definition, this appears to be identical to HERD HOME RANGE. In actual use, the unit is usually smaller and indicative of some seasonal use by a group of elk. Again, a concept for which we rarely have enough information but extremely useful when data are available.

Recommendation

Should be used when data are available.

Elk Evaluation/Analysis Areas
Habitat Analysis Unit

Definition

An area of land selected as the unit for evaluating the quality of elk habitat.

Discussion

These two terms had identical definitions and seem to be used interchangeably. Areas are commonly defined by geographic or administrative boundaries.

Recommendation

The workshop achieved no concensus on selecting one term over the other. But there was no disagreement that these terms have a different meaning than those preceding and following in this list.

Elk Management Unit
Game Managment Unit

Definition

An administrative unit established by the wildlife management agency.

Discussion

Elk management unit in Montana, Game management unit in Idaho. Other states probably use other terms.

Recommendation

These terms should not be used in reference to habitat analysis.

Cumulative Effects

Definition

The additive impacts that result when a number of unrelated, or related but discrete, management activities are completed in a given area.

Discussion

Multiple impacts on wildlife populations of simultaneous but not necessarily coordinated human activities have been recognized as extremely difficult to measure and express. Commonly included are past, present, and reasonably foreseeable future activities. We will need technologies for considering multiple effects as the implications of hunting season SECURITY become more apparent.

Cover Forage Ratios

Definition

The percentage of a HABITAT ANALYSIS UNIT in cover condition, and the percentage in forage condition, expressed as a ratio totalling 100.

Discussion

COVER:FORAGE has had general application and, when properly used, is useful in discussing the diversity of summer elk habitat. Application of the term is usually related to habitat models and habitat analysis, but COVER:FORAGE is not an evaluation of overall habitat quality. It should be recognized that COVER:FORAGE contains no inherent provision of SECURITY.

Recommendation

Use of the term should be limited to those situations described in the literature as applicable.

Optimal Cover

Definition

A forest stand with four layers, an overstory that will intercept snow, and small openings that provide forage.

Discussion

Other than the clear similarity to old-growth, this was considered a vague term, difficult to measure and define.

Recommendation

Do not use this term.

Thermal Cover

Definition

Structure: For elk a stand of coniferous trees 40 ft or more tall with average crown closure of 70% or more. In some cases, topography or vegetation less than specified may meet animal needs for thermal regulation.

Function: Situations, usually related to vegetation structure, used by animals to ameliorate effects of weather.

Discussion

THERMAL COVER, as much as any other term discussed at the workshop, seems to have developed cadres of adherents and of detractors. One reviewer suggested the substitution of "overstory cover" as a replacement. Discussion also noted that thermal relief can be supplied by topography, other animals, and different combinations of vegetation, water, and air movement.

Recommendation

Acceptable concept but should not be used loosely.

Forage Area

Definition

In habitat evaluation models, the percentage of a HABITAT ANALYSIS UNIT not considered HIDING or THERMAL COVER.

Discussion

The concensus of the workshop was that this term is intuitively apparent and will be used correctly in most instances. However, some elk habitat models define FORAGE AREA as openings, which confuses the status of forage found within timber stands.

Forested Forage

Definition

Sometimes used in habitat evaluation models to describe FORAGE AREA within forest stands that are neither HIDING nor THERMAL COVER.

Discussion

Although intended to be a solution, FORESTED FORAGE has become an additional problem. One workshop group noted that because valuable forage is often found in defined cover areas, the term might be interpreted to include all of COVER:FORAGE.

Recommendation

If used at all, this term should be carefully and specifically defined by the user.

Open Vegetation

Definition

In habitat evaluation models, clearcuts, meadows, and other openings.

Discussion

The term may be useful in verbal discussions but probably defies written definition.

Recommendation

Clarity in descriptions is probably better served by actually saying clearcuts and meadows. Do not use this term.

Migration Corridor

Definition

Situations, usually linked to topography and vegetation, that provide a completely or partially suitable habitat that animals move through during migrations.

Discussion

A term that is easy to misapply because it generally relates to specific locations and can be broadly or narrowly applied. The term usually describes a management problem rather than a definable component of habitat. Recommendation: Be cautious in application, see TRANSITIONAL RANGE.

Transitional Range

Definition

Areas on which elk concentrate during spring and/or fall. TRANSITIONAL RANGES are generally adjacent to WINTER RANGE and may provide important SECURITY during the fall.

Discussion

Important points emphasized in the workshop discussions were that TRANSITIONAL RANGE may be important for SECURITY, that transitional should not be confused with transitory, and that virtually all MIGRATION CORRIDORS are better described as TRANSITIONAL RANGE.

Recommendation

Use this term rather than MIGRATION CORRIDOR in most cases.

Transitory Range

Definition

Rangeland created to increase forage production for livestock.

Discussion

This term is sometimes confusingly substituted for TRANSITIONAL RANGE. It is not the same thing.

Recommendation

Term should be avoided in any discussion of elk management because it directly applies to livestock.

Key Components

Definition

Areas or features of the landscape of particular importance for maintaining the overall integrity of elk habitat.

Discussion

Other than the potential confusion with CRITICAL HABITAT, an acceptable term.

Critical Habitat

Discussion

A term preempted by the Endangered Species Act of 1973 and considered inappropriate in elk management since that date.

Recommendation

Do not use this term when KEY COMPONENT is intended.

Sight Distance
Bull Age Diversity
Nursery Areas
Calving Areas
Bedding Area
Winter Range

These terms are generally used correctly and commonly understood by biologists and managers. Although seemingly unrelated, they have in common a potential for misapplication in situations involving objectives other than protection of elk habitat.

Recommendation

Care should be demonstrated in using these terms correctly and in situations where they really are applicable.

Sight Distance

Definition

The distance at which 90% or more of an adult elk is hidden from view of a human.

Discussion

A measure of the effectiveness of HIDING COVER, but not a measure of SECURITY.

Bull Age Diversity

Definition

An attribute of population age structure providing a relative measure of the distribution of bull elk among age classes in a population.

Nursery Areas

Definition

Area used by a temporary elk social unit consisting of cows and young calves.

Discussion

It is not certain that the term has a specific meaning beyond normal early summer range for large elk cow/calf groups in relatively open habitat.

Calving Areas

Definition

Any area between WINTER RANGE and summer range where cows give birth to calves. Discussion: May be a specific area where a majority of calving for a herd takes place. May also be scattered locations throughout the HERD HOME RANGE.

Bedding Area

Definition

A specific site selected by big game animals to lie down and rest.

Winter Range

Definition

The area, usually at lower elevations, used by elk during the winter months.

NUMBER OF WINTERING ELK (NOTE SPECIES): 1,100-1,200 Roosevelt

BULLS/100 COWS (WINTER): 11 RANGE: —
COMMENT: August 1989 aerial composition survey; no post-hunt (winter) data available.

CALVES/100 COWS (WINTER): 26 RANGE: 21-40 for individual herds
COMMENT: August 1989

RESIDENT TAGS, RIFLE*: — BOW: — TOTAL: 467

NONRESIDENT TAGS, RIFLE*: — BOW: — TOTAL: 31
(* inc. muzzleloader)
GRAND TOTAL: 498
COMMENT: 1988 data

TAKE OF BULL, RIFLE: — BOW: — TOTAL: 86

TAKE OF ANTLERLESS, RIFLE: — BOW: — TOTAL: 33
COMMENT: 1988 data. There were also 5 additional elk of unknown sex taken.

BULL HUNTER SUCCESS: — TOTAL HUNTER SUCCESS: 25%

HOW ARE HARVEST DATA OBTAINED?: Hunter permit reports are required.

CENSUS METHODS USED (SAMPLE SIZE): Fixed-wing (PA-18) summer (July-September) composition surveys (sample size 1,048 in 1989).

PERCENT OF HUNTING BY DRAWING: 42%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Roger B. Smith, Alaska Department of Fish and Game, 211 Mission Road, Kodiak, Alaska 99615.

ONGOING RESEARCH INVESTIGATIONS: Herd identity/seasonal habitat use in relation to logging on Afognak Island is being investigated concurrently with aerial composition surveys using radio telemetry. This is not a formal research project.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: No

GENERAL ELK DEPREDATION POLICY: No problems with depredation currently.

NOTES:

Status of Elk in Southeastern Alaska

In January 1987, 50 elk were transplanted to Etolin Island south of Wrangell, Alaska. Thirty-three Roosevelt elk were released at one site, and 17 Rocky Mountain Elk were released at a second site. Reproduction and survival of a few offspring to yearling status have been verified every year since the transplant. A few elk have moved to nearby Zarembo Island. The population is estimated at 30-45 elk. Wolf and brown bear predation are limiting factors, and more than half of the original transplant animals are probably dead, based on verified losses of radio collared animals. The Roosevelt elk appear to be thriving better than the Rocky Mountain elk.

Status of Elk in the Kodiak-Afognak Area

Nearly all elk habitat on Afognak and Raspberry Islands are owned by native corporations as the result of the Alaska Native Claims Settlement Act. Intensive logging is currently underway within the home ranges of 6 of the 9 individual elk herds. Little is known about effects of logging on the Afognak elk, but large-scale removal of timber in coastal winter range is expected to be detrimental. Elk research has not been a high priority when competing with other more popular and more available big game species in Alaska.

ATTENDING REPRESENTATIVE'S NAME: Eldon Bruns

NUMBER OF WINTERING ELK (NOTE SPECIES): 13,000 *nelsoni*

COMMENT: Some *manitobensis* blood in eastern herds.

BULLS/100 COWS (WINTER): 11	**RANGE:** 6-17	

COMMENT: Aerial counts only.

CALVES/100 COWS (WINTER): —	**RANGE:** —	

COMMENT: None done

RESIDENT TAGS, RIFLE*: 24,381*	**BOW:** 2,224	**TOTAL:** 26,605 in 1988
NONRESIDENT TAGS, RIFLE*: 470 (* inc. muzzleloader)	**BOW:** 29	**TOTAL:** 499 in 1988
		GRAND TOTAL: 27,104

COMMENT: An elk license is good for both rifle and bow hunting.

TAKE OF BULL, RIFLE: 1,104	**BOW:** 46	**TOTAL:** 1,150 in 1988
TAKE OF ANTLERLESS, RIFLE: 505	**BOW:** 12	**TOTAL:** 517 in 1988
BULL HUNTER SUCCESS: 5%	**TOTAL HUNTER SUCCESS:** 6%	

HOW ARE HARVEST DATA OBTAINED?: Telephone survey.

CENSUS METHODS USED (SAMPLE SIZE): Winter (RW) counts.

PERCENT OF HUNTING BY DRAWING: Approximately 8%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Bill Glasgow/Brent Markham,
Fish and Wildlife Division, Main Floor, North Tower, Petroleum Plaza, 9945 - 108th Street, Edmonton, Alberta T5K 2G6

ONGOING RESEARCH SUBJECTS INVESTIGATIONS: Control of *Fascioloides magna* in elk by use of drugs; effects of meningeal on elk.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: Yes

GENERAL ELK DEPREDATION POLICY: Damage to destroyed crops is compensated up to $75 per acre and fencing is supplied for stacked feed.

ATTENDING REPRESENTATIVE'S NAME: Tice Supplee

NUMBER OF WINTERING ELK (NOTE SPECIES): 20,000-22,000 *nelsoni*
COMMENT: 1,500-2,000 elk winter in Arizona that summer on the Fort Apache Indian Reservation. Eighty-five percent of Arizona elk habitat is on U.S. Forest Service Land.

BULLS/100 COWS (WINTER): 31 **RANGE:** 12-75
COMMENT: Fall rather than winter bull:cow ratios are utilized for hunt recommendations.

CALVES/100 COWS (WINTER): 55 **RANGE:** 40-67
COMMENT: Fall rather than winter calf:cow ratios are utilized for hunt recommendations.

RESIDENT TAGS, RIFLE*: 7,896	**BOW:** 3,925	**TOTAL:** 11,821
NONRESIDENT TAGS, RIFLE*: 304 (* inc. muzzleloader)	**BOW:** 218	**TOTAL:** 522
		GRAND TOTAL: 12,343

COMMENT: Residents and nonresidents compete equally in the permit draw.

TAKE OF BULL, RIFLE: 2,778	**BOW:** 579	**TOTAL:** 3,357
TAKE OF ANTLERLESS, RIFLE: 1,258	**BOW:** 254	**TOTAL:** 1,512

COMMENT: 1989 tag and harvest figures. Includes harvest from Navajo Army Depot.

BULL HUNTER SUCCESS: firearms 54%
archery 24%

TOTAL HUNTER SUCCESS: firearms 55%
archery 22%

HOW ARE HARVEST DATA OBTAINED?: Mail-out hunter questionnaire (60-65% return rate). All hunters are mailed a questionnaire.

CENSUS METHODS USED (SAMPLE SIZE): Pre-hunt fall surveys (foot, horseback and vehicle). Surveys continue until 20% of the estimated population in the unit is sampled. Survey effort will sample major population concentrations and not be random. Post-hunt surveys are used to obtain an index of wintering populations.

PERCENT OF HUNTING BY DRAWING: 100%

CONTACT PERSON FOR MANAGEMENT/ RESEARCH INFORMATION: Ray Lee, Big Game Supervisor (602) 942-3000.

ONGOING RESEARCH INVESTIGATIONS: Evaluation of elk response to a Holistic Resources Management (HRM) cattle grazing cell. Identification of elk herd units and fidelity of individual elk to summer and winter ranges. (Principal Investigator: Richard Brown, Arizona Game and Fish Department)

LANDOWNER REIMBURSED FOR ELK DAMAGE?: No

GENERAL ELK DEPREDATION POLICY: Complaints are investigated, and technical advice or assistance is provided. Removal of animals may be recommended through Commission established special hunts or through a special permit to the complaining landowner. Any animals taken via a special permit must be turned over to an agent of the Department, and the edible portions must be delivered to a public or charitable institution. No special permit has been issued in Arizona.

NOTES: Elk have become a political issue over the past 3 years. The livestock industry introduced a big game ranching bill to create a study committee during the 1989 state legislative session. The bill passed, and the committee met from October-December 1989. Committee members included a sportsman, 2 game and fish commissioners, 3 livestock industry representatives and the state land department commissioner. Although the committee was legislatively directed to address all big game species, the emphasis was on elk. The committee reached no substantive agreement. Further attempts at legislation are expected.

ELK STATUS: CALIFORNIA

ATTENDING REPRESENTATIVE'S NAME: Tom Blankinship

NUMBER OF WINTERING ELK (NOTE SPECIES): 3,500 Roosevelt, 1,000 Rocky Mountain, 2,700 tule

BULLS/100 COWS (WINTER): 20-58

CALVES/100 COWS (WINTER): 14-60

RESIDENT TAGS, RIFLE*: — **BOW:** — **TOTAL:** 225**

NONRESIDENT TAGS, RIFLE*: n/a **BOW:** n/a **TOTAL:** n/a

(* inc. muzzleloader)

GRAND TOTAL: 225

COMMENT: **Either rifles or archery equipment may be used. Nonresident tags are not available. Numbers reflect 1989 hunting season.

TAKE OF BULL, RIFLE: — **BOW:** — **TOTAL:** 102

TAKE OF ANTLERLESS, RIFLE: — **BOW:** — **TOTAL:** 21

BULL HUNTER SUCCESS: 45% **TOTAL HUNTER SUCCESS:** 55%

COMMENT: Data reflect 1989 hunting season.

HOW ARE HARVEST DATA OBTAINED?: Mandatory tag return, hunter check stations.

CENSUS METHODS USED (SAMPLE SIZE): Helicopter, fixed-wing aircraft and ground counts.

PERCENT OF HUNTING BY DRAWING: 100%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Terry Mansfield, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814.

ONGOING RESEARCH INVESTIGATIONS: Currently investigating: (1) distribution and habitat use of Rocky Mountain elk in Shasta County; (2) more cost-effective means of capturing tule elk at Grizzly Island; and (3) mineral composition of tule elk antlers at Owens Valley to identify cause of unusually high incidence of broken antlers.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: No

GENERAL ELK DEPREDATION POLICY: Do not issue depredation permits. Removal of sufficient numbers of elk to alleviate damage would often involve substantial numbers of elk and is not consistent with California Fish and Game Code (Section 1801).

NOTES: No legal challenges to the Department's environmental documents regarding elk hunting were made in 1989. Environmental documents were modified to reflect current information and the Department's hunting proposals for 1990, and only minor comments were received.

In 1989, tule elk were hunted in California for the first time since 1969. Hunter success averaged 88% for tule elk hunts. However, hunters using public land in one area were frequently harassed by members of some anti-hunting organizations.

Depredation problems with tule elk continue to increase as the population expands. Since 1971, the Department has translocated over 800 tule elk to 16 sites throughout California. Currently, the statewide tule elk population has exceeded the Legislature's goal of 2,000 animals, and 12 individual herds are above herd size objectives and/or causing property damage. Actions are needed to address these conflicts. Suitable release sites in the State within historic tule elk range are scarce. Management of elk numbers through cost-effective forms of population control is the most feasible alternative.

NUMBER OF WINTERING ELK (NOTE SPECIES): 181,950 Rocky Mountain

COMMENT: 1988 post season

BULLS/100 COWS (WINTER): n/a **RANGE:** 6-83

COMMENT: 1988 post season

CALVES/100 COWS (WINTER): n/a **RANGE:** 32-64

COMMENT: 1988 post season

RESIDENT TAGS, RIFLE*: 96,092	**BOW:** 9,162	**TOTAL:** 105,254
NONRESIDENT TAGS, RIFLE*: 46,666 (* inc. muzzleloader)	**BOW:** 6,356	**TOTAL:** 53,022
		GRAND TOTAL: 158,076

COMMENT: The 1988 harvest of 32,473 was a state record. The previous record was 30,652 elk taken in 1984.

TAKE OF BULL, RIFLE: 17,576	**BOW:** 1,442	**TOTAL:** 19,018
TAKE OF ANTLERLESS, RIFLE: 12,772	**BOW:** 683	**TOTAL:** 13,455

COMMENT: 1989 harvest data not available at this time.

BULL HUNTER SUCCESS: 16% **TOTAL HUNTER SUCCESS:** 21%

HOW ARE HARVEST DATA OBTAINED?: Stratified random survey, stratified random sample telephone survey for over-the counter licenses, and mail questionnaire for limited licenses.

CENSUS METHODS USED (SAMPLE SIZE): Major elk herds are censused by helicopter each winter, primarily by total counts. Population totals are derived primarily from computer models using harvest, sex-age data and counts.

PERCENT OF HUNTING BY DRAWING: 36%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Len Carpenter (303) 291-7335

ONGOING RESEARCH INVESTIGATIONS: Livestock-Elk grazing competition study - relative to game damage; testing live transect methodology for census technique; reproductive potential versus bull:cow ratios.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: Yes

GENERAL ELK DEPREDATION POLICY: Colorado is liable for damage done to private property by elk. This includes damage to livestock forage on private property. Colorado is currently developing a new program entitled "Habitat Partnership", where emphasis will be to prevent damage by elk with habitat improvements and damage distribution hunts rather than direct payments for damage.

ATTENDING REPRESENTATIVE'S NAME: Lonn Kuck

NUMBER OF WINTERING ELK (NOTE SPECIES): 130,000-160,000 Rocky Mountain

BULLS/100 COWS (WINTER): 30-32	**RANGE:** 10-45	
CALVES/100 COWS (WINTER): 35	**RANGE:** 25-60	
RESIDENT TAGS, RIFLE*: 77,568	**BOW:** 22,805*	**TOTAL:** 77,568
NONRESIDENT TAGS, RIFLE*: 13,268 (* inc. muzzleloader)	**BOW:** 22,805*	**TOTAL:** 13,268
		GRAND TOTAL: 90,836

COMMENT: Bow hunters must have an elk tag also; includes resident and nonresident.

TAKE OF BULL, RIFLE: 13,150	**BOW:** 1,250	**TOTAL:** 14,400
TAKE OF ANTLERLESS, RIFLE: 5,750	**BOW:** 250	**TOTAL:** 6,000
BULL HUNTER SUCCESS: 19%	**TOTAL HUNTER SUCCESS:** 26%	

HOW ARE HARVEST DATA OBTAINED?: Telephone survey of stratified random sample of elk tag purchasers.

CENSUS METHODS USED (SAMPLE SIZE): Elk sightability surveys designed for helicopter surveys. The sightability model corrects each group of elk for the number of animals missed due to small group size and amount of vegetative cover.

PERCENT OF HUNTING BY DRAWING: 12%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Lonn Kuck

ONGOING RESEARCH INVESTIGATIONS: Companion research programs on Coeur d'Alene and Lochsa River drainages. Objectives: Bull elk habitat use, development of elk sightability helicopter survey techniques, and hunting season bull mortality patterns in relation to access.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: Yes

GENERAL ELK DEPREDATION POLICY: The 1990 Idaho Legislature passed legislation that authorized the Idaho Department of Fish and Game to compensate landowners for damage caused by wildlife. Two line item vetoes by the governor and a veto of a companion funding bill resulted in legislation without Department spending authority to implement it. Legislation now has triggered a revision of the Department's depredation policy, which is currently in progress.

NUMBER OF WINTERING ELK (NOTE SPECIES): 30,000-36,000 Rocky Mountain

BULLS/100 COWS (WINTER): 27 **RANGE:** 5-63

CALVES/100 COWS (WINTER): 39 **RANGE:** 29-74

TAGS, RIFLE: 7,705 **BOW:** 4,619 **MUZZLELOADER:** 2,481 **TOTAL:** 14,805

TAGS, PRIVATE HUNTS, RIFLE: — **BOW:** — **TOTAL:** 2,725

GRAND TOTAL: 17,530

COMMENT: Reflects number of public and private licenses issued in 1988-89. No quota on availability of licenses to nonresidents.

TAKE OF BULL, RIFLE: 1,462 **BOW:** 585 **MUZZLELOADER:** 257 **TOTAL:** 2,304

TAKE OF ANTLERLESS, RIFLE: 515 **BOW:** 208 **MUZZLELOADER:** 3 **TOTAL:** 726

TAKE DURING PRIVATE HUNTS, BULL: 1,455 **ANTLERLESS:** 357 **TOTAL:** 1,812

COMMENT: Projected figures.

TOTAL HUNTER SUCCESS, PUBLIC: Rifle 26.7%, archery 17.9%, muzzleloader 11%

TOTAL HUNTER SUCCESS, PRIVATE: 67.9%

HOW ARE HARVEST DATA OBTAINED?: Questionnaire survey distributed with each license (includes postage-paid return envelope).

CENSUS METHODS USED (SAMPLE SIZE): 100% sampling of license holders ± 30% return rate.

PERCENT OF HUNTING BY DRAWING: All public licenses. Private tags distributed by landowners.

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Robert S. Jenks, New Mexico Department of Game and Fish, Santa Fe, New Mexico 87501, (505) 827-7893.

ONGOING RESEARCH INVESTIGATIONS: Population, distribution and movement monitoring.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: No

GENERAL ELK DEPREDATION POLICY: Assist landowner with technical advice. Special controlled reduction hunts occasionally used.

NOTES: Information is for 1988-89. 1989-90 information is being compiled, and hopefully analyses will be completed by March 1990.

ATTENDING REPRESENTATIVE'S NAME: Rod Ingram/Chris Wheaton

NUMBER OF WINTERING ELK (NOTE SPECIES): 54,400 Rocky Mountain; 50,700 Roosevelt

BULLS/100 COWS (WINTER): Rocky Mountain: 8 **RANGE:** 3-27 in 1989
Roosevelt: 10 2-31 in 1989

CALVES/100 COWS (WINTER): Rocky Mountain: 31 **RANGE:** 17-62 in 1989
Roosevelt: 35 12-60 in 1989

RESIDENT TAGS, RIFLE*: 71,204 **BOW:** 12,851 **CONTROLLED:** 36,919** **TOTAL:** 120,974

NONRESIDENT TAGS, RIFLE*: 2,831 **BOW:** 1,175 **CONTROLLED:** 1,176 **TOTAL:** 5,182
(* inc. muzzleloader)

PIONEER ELK TAG: 6,388

GRAND TOTAL: 132,544*** in 1988

COMMENT: **Rifle or bow are legal weapons for controlled hunts. ***Grand total represents bull and antlerless tags.

TAKE OF BULL, RIFLE: 9,362* **BOW:** 754* **TOTAL:** 10,116 in 1988

TAKE OF ANTLERLESS, RIFLE: 6,965** **BOW:** 889*** **TOTAL:** 7,854 in 1988

COMMENT: *General season; **Controlled hunts, which include some hunts a "one elk" bag limit; ***Includes general season and controlled hunts.

BULL HUNTER SUCCESS: 11% for general season; 49% for controlled hunts

TOTAL HUNTER SUCCESS: 16% average; 11% for rifle, 10% for archery, 49% for controlled hunts

HOW ARE HARVEST DATA OBTAINED?: Telephone survey

CENSUS METHODS USED (SAMPLE SIZE): 15% to 50% sample size, depending on the size of the hunt (i.e., general season or controlled hunt).

PERCENT OF HUNTING BY DRAWING: 30%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Chris Wheaton, Big Game Staff Biologist, P.O. Box 59, Portland, Oregon 97207, (503) 229-5400.

ONGOING RESEARCH INVESTIGATIONS: Starkey Project - Free-ranging elk monitored inside a 40 square mile fenced enclosure to assess effects of harvest and habitat manipulation; several telemetry projects to determine movements.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: No

GENERAL ELK DEPREDATION POLICY: Cooperative cost share agreements provided on fencing, paneling, repellents and hazing materials.

ELK POPULATION: 45,000 - 55,000

HERD UNIT OBJECTIVES: Continue to expand the State's elk population. Presently, only two herd units warrant unit-wide population control. There is a need to increase the number of mature bulls in most herd units for natural herd integrity and to benefit both the hunting and viewing public. It is essential that the Division improve its ability to monitor Utah's elk resource. Helicopter surveys must become more commonly used. Additional survey efforts should be refined. Depredation is a serious problem in certain areas and must be resolved by providing suitable natural range and/or by removing the offending animals. Greater attention must be shown towards securing cooperation amongst the resource agencies, agricultural interests, sportsman, and other publics.

TRANSPLANTS: Presently, little or no effort is being expended to establish new elk populations. Few suitable habitats are available where elk may be introduced. The emphasis is to expand existing populations and address habitat needs through range projects and/or purchase of land.

POPULATION MONITORING: The following annual surveys are conducted when possible:

August Classification -- cow:calf ratios.
Mid-winter Classification and Census -- cow:calf, bull:cow, and mature bull:yearling bull ratios; population trends.
General Range Use -- ocular surveys and limited groups

HARVEST (1989): 9,313

GENERAL SEASON PERMITS (21 units):

Permits sold (any bulla)	32,251
Hunters afield	30,494
Bulls harvested	5,590
Percent hunter success	18

RESTRICTED PERMITS (22 units):

Bull permits (any bull)	633
Bull harvest	514
Percent hunter success	81
Antlerless permits	4,171
Antlerless harvest	2,866
Percent hunter success	69

ARCHERY PERMITS:

Permits sold	3,380
Bull harvest	190
Antlerless harvest	22
Total harvest	212
Percent hunter success	6

MUZZLE-LOADER PERMITS (restricted):

Permits sold	330
Hunters afield	324
Bull harvest	128
Antlerless harvest	0
Percent hunter success	40

ªOnly yearling bulls may be harvested on the Manti and Fish Lake units.

ONGOING RESEARCH INVESTIGATIONS: One major study is underway with a two-fold purpose of monitoring a newly initiated yearling bull harvest strategy and to determine elk/livestock relationships on the Fish Lake National Forest.

NOTES: Agricultural depredation and concerns from the livestock industry are the two most pressing struggles Utah is presently attempting to overcome. Drought is also a concern at present. Many areas of the State are facing serious water shortages and below normal precipitation. The 1990 harvest will reflect increased harvest in an effort to circumvent potential problems resulting from minimal vegetative growth and agricultural depredation.

ATTENDING REPRESENTATIVE'S NAME: Rolf Johnson

NUMBER OF WINTERING ELK (NOTE SPECIES): 25,600 Rocky Mountain; 27,000 Roosevelt

BULLS/100 COWS (WINTER):	Rocky Mountain: 8	**RANGE:**	3-14
	Roosevelt: 12		8-26
CALVES/100 COWS (WINTER):	Rocky Mountain: 40	**RANGE:**	33-60
	Roosevelt: 34		35-44

RESIDENT TAGS, RIFLE*: 67,502	**BOW:** 12,251	**TOTAL:** 79,753
NONRESIDENT TAGS, RIFLE*: 719 (* inc. muzzleloader)	**BOW:** 136	**TOTAL:** 855
		GRAND TOTAL: 80,608
TAKE OF BULL, RIFLE: 4,928	**BOW:** 375	**TOTAL:** 5,303
TAKE OF ANTLERLESS, RIFLE: 2,944	**BOW:** 711	**TOTAL:** 3,655
BULL HUNTER SUCCESS: 7%		**TOTAL HUNTER SUCCESS:** 11%

HOW ARE HARVEST DATA OBTAINED?: Three-wave questionnaire and game harvest report cards.

CENSUS METHODS USED (SAMPLE SIZE): Fixed-wing aircraft and helicopter (7000).

PERCENT OF HUNTING BY DRAWING: 7%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Rolf Johnson, Management; Woody Myers, Research; Jack Smith, Research

ONGOING RESEARCH INVESTIGATIONS: Habitat Development Impact Study - Colockum, Survey - Sightability Model; Blue Mountain Elk Study; Elk Mortality Study.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: Yes

GENERAL ELK DEPREDATION POLICY: Landowner notifies Department of damage problem. Agent contacts the landowner and tries to resolve the problem. If the landowner is not satisfied with the result, he can submit a damage claim against the agency. If the claim is for more than $2,000, it must be approved by the Legislature. Our Wildlife Commission approves or denies claims less than $2,000.

ATTENDING REPRESENTATIVE'S NAME: Bruce Johnson

NUMBER OF WINTERING ELK (NOTE SPECIES): 84,337 Rocky Mountain

> **COMMENT:** Elk numbers in northwestern Wyoming are currently very high due to several mild falls and winters, which reduced harvest and decreased mortality.

BULLS/100 COWS (WINTER): 21 **RANGE:** 9-54

> **COMMENT:** Bull:cow ratios are only minimum estimates, because bulls often winter in locations away from cows. However, the public loves this ratio, and management is complicated as a result.

CALVES/100 COWS (WINTER): 42 **RANGE:** 25-57

> **COMMENT:** Calf:cow ratios in herds on feeding grounds are 50% lower than those on native winter range, due to brucellosis.

RESIDENT TAGS, RIFLE*; 35,570** **BOW:** 4,700** **TOTAL:** 36,370**

NONRESIDENT TAGS, RIFLE*: 7,333** **BOW:** 716** **TOTAL:** 7,800**
(* inc. muzzleloader)

> **COMMENT:** **Since we don't have either/or hunting, license hunters can hunt with both a rifle and a bow. About 17% of our hunters only hunt with a bow.

TAKE OF BULL, RIFLE: 7,560 **BOW:** 363 **TOTAL:** 7,923

TAKE OF ANTLERLESS, RIFLE: 7,080 **BOW:** 41 **TOTAL:** 7,121

BULL HUNTER SUCCESS: 16.5% for general licenses; 41.4% for limited quota areas

TOTAL HUNTER SUCCESS: 35.2%

HOW ARE HARVEST DATA OBTAINED?: Check stations, mailed harvest questionnaire

CENSUS METHODS USED (SAMPLE SIZE): Ground and aerial counts, population modeling

PERCENT OF HUNTING BY DRAWING: 58%

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Harry Harju, Game and Fish Department, 5400 Bishop Boulevard, Cheyenne, Wyoming 82206

ONGOING RESEARCH INVESTIGATIONS: Habitat modification/improvement to change elk distribution and prevent damage to private lands; study of density-dependent regulation of elk in Jackson Hole; research on control of brucellosis through vaccination with bio-bullets.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: Yes

GENERAL ELK DEPREDATION POLICY: State is required to pay for elk damage to standing or stored crops.

NOTES: Currently, Wyoming has several elk management problems. One is lack of bulls in some areas. These areas all have 30- to 55-day hunting seasons for bulls to please outfitters, who then complain there are no bulls. Areas with good bull:cow ratios in Wyoming all have hunting seasons of 3 weeks or less.

Another problem is our inability to vary hunter numbers, especially nonresidents, to help control elk in Jackson Hole. Outfitters tried to increase the number of nonresident elk hunters a few years ago and alienated the residents, so we can't get more hunters now that we need them. Residents suspect the numbers would never be reduced once they've been raised.

Antler restrictions, or the desire for them, continue to be a problem, even though the data shows they do not produce large bulls and, in fact, have the opposite effect.

Desire to create more feeding grounds in northwestern Wyoming is an ongoing problem. The easy way out is to feed and forget about habitat. The nation's desire to rid itself of brucellosis will bring this to a head shortly (within the next 5 years). All feeding grounds checked to date have infected elk. One option proposed by U.S. Department of Agriculture is getting rid of the elk.

ELK STATUS: YUKON

ATTENDING REPRESENTATIVE'S NAME: Manfred Hoefs

NUMBER OF WINTERING ELK (NOTE SPECIES): 80 *nelsoni*

BULLS/100 COWS (WINTER): 80 **RANGE:** —

CALVES/100 COWS (WINTER): 50 **RANGE:** —

RESIDENT TAGS, RIFLE*: n/a **BOW:** n/a **TOTAL:** n/a

NONRESIDENT TAGS, RIFLE*: n/a **BOW:** n/a **TOTAL:** n/a
(* inc. muzzleloader)
GRAND TOTAL: n/a

COMMENT: Elk are not hunted at this time.

TAKE OF BULL, RIFLE: n/a **BOW:** n/a **TOTAL:** n/a

TAKE OF ANTLERLESS, RIFLE: n/a **BOW:** n/a **TOTAL:** n/a

BULL HUNTER SUCCESS: n/a **TOTAL HUNTER SUCCESS:** n/a

HOW ARE HARVEST DATA OBTAINED?: Helicopter surveys and relocation of transmitter-equiped elk.

CENSUS METHODS USED (SAMPLE SIZE): —

PERCENT OF HUNTING BY DRAWING: n/a

CONTACT PERSON FOR MANAGEMENT/RESEARCH INFORMATION: Manfred Hoefs

ONGOING RESEARCH INVESTIGATIONS: Population studies; elk calf mortality studies.

LANDOWNER REIMBURSED FOR ELK DAMAGE?: No

GENERAL ELK DEPREDATION POLICY: n/a