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POPULATION AND HABITAT MANAGEMENT OF ELK IN MICHIGAN

By

Dean Earl Beyer Jr.

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree

DOCTOR OF PHILOSOPHY

Department of Fisheries and Wildlife

1987

ABSTRACT

POPULATION AND HABITAT MANAGEMENT OF ELK IN MICHIGAN

By

Dean Earl Beyer Jr.

The goal of elk management in Michigan is to maintain a viable elk herd in balance with the environment, and at the same time provide optimal recreational opportunities. Michigan's elk herd is managed through manipulation of the population size, structure, and distribution, and management of the habitat. This study was designed to provide information necessary for developing management strategies, specifically addressing the effect of elk hunting on elk visibility, elk habitat utilization and movements, and population management. Approachability of elk was measured to determine the effect of hunting on elk visibility. The first 2 years of elk hunting were not found to have an influence on elk approachability. Relocations of radio-collared elk were used to determine elk habitat utilization, identify elk calving areas, and determine elk home range sizes. The habitat utilization data were used to develop an elk habitat suitability model. Calving areas were found to be diverse and not limiting within the study area. Bull home range sizes were significantly larger than cows during both rut and nonrut periods of the year. These results suggest that it will be more difficult to control the distribution of bulls than cows, which is a problem because most agricultural damage problems were due to bulls rather than cows. Elk population dynamics and the effects of varying harvest strategies were investigated with a population model. Sensitivity analyses, conducted to determine the relative importance of each input, indicated that accurate estimates of population size and herd structure were the most critical. Future research should be directed towards improving estimates of these population parameters. Results from the simulation modeling also showed that hunting could be affecting the number of large bulls in the population. Bulls have a higher mortality rate than cows in terms of natural losses and poaching, and large bulls are being harvested at an effort rate 5 times that of yearling bulls. The simulation results show that a harvest of 50 bulls per year could reduce the number of older bulls in the population. Management recommendations include restricting the bull harvest to 40 or fewer animals or restricting some bull permits to spike bulls only.

ACKNOWLEDGEMENTS

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Thanks is also due to the staff at the Pigeon River Country State Forest: Ned Caveney, Arch Reeves, Rita Rennie, and Bill Sterrett for all their help in making the project run smoothly. I especially want to thank Arch Reeves for helping me fix equipment, recollar elk,

teaching me his expert woodsmanship skills, and for being a friend. His help was invaluable in keeping the project running efficiently.

Special thanks is due to my parents for all they have done for me throughout my life. This dissertation is dedicated to the memory of my mother who passed away before this work was completed and to my father.

Finally, I am indebted to my wife, Patty, for her sacrifice, patience, and encouragement throughout the study and for her expert help in preparing the figures.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

Table		Page

LIST OF FIGURES

INTRODUCTION

Eastern elk (*Cervus elaphus canadensis*) ranged throughout the lower peninsula of Michigan until approximately 1877 (Murie 1951). In the early 1900's the state made 3 unsuccessful attempts to reestablish elk. In 1918, 7 Rocky Mountain elk (*Cervus elaphus nelsoni*), including 2 bulls and 3 cows, were released in Cheboygan county (Moran 1973). The present herd is thought to originate from this release. The herd expanded in both numbers and range until an estimated population level of 1,200 - 1,500 animals was reached in the early 1960's (Moran 1973). During this same period the elk herd became a significant tourist attraction (Elk Management Plan 1984). However, at the same time the herd was blamed for depredations to farm crops, forest regeneration, and wildlife range. In addition, there were increasing demands by sportsman's groups to utilize the resource for sport hunting. Controversy over proper management of the elk herd resulted in the initiation of a Michigan Department of Natural Resources (MDNR) elk research program.

In 1964, the Michigan Department of Natural Resources (MDNR) established a controlled elk hunting season which lasted 2 years. The hunt was designed to reduce damage to farm crops and forest regeneration and to provide biological information. A total of 477 animals were harvested during the 2 hunting seasons. These hunts effectively reduced damage complaints by farmers and foresters. The hunts also resulted in lower visibility of elk which produced unsatisfactory elk viewing opportunities (Elk Management Plan 1984).

The elk herd declined in the late 1960's and early 1970's. Reduced herd size precluded additional hunting during this period. Several factors were thought to be responsible for the decline in elk numbers. These factors included increased poaching of elk, succession of forest openings and brushlands, and increased disturbance of elk by human activities (MDNR 1975).

The discovery of oil in what is now the Pigeon River Country State Forest (PRCSF) in 1970 added to the concerns of biologists managing the elk herd. MDNR wildlife biologists felt that hydrocarbon development would have a negative impact on the elk herd. In December 1973, the dedication of 376 km^2 of land as the PRCSF was approved by the Natural Resource Commission (Elk Management Plan 1984). The PRCSF makes up approximately 22% of the elk range.

In 1975, the MDNR conducted its first elk census. It was a combined aerial and ground census carried out in March of that year. The effort resulted in 159 animals being counted and an estimated herd size of 200 animals.

This low population level and concerns over possible negative impacts of hydrocarbon development prompted the development of an elk management plan by the MDNR. The goal of this management plan was to build the herd to 500 - 600 animals. This goal was to be accomplished by two actions: increasing law enforcement efforts to reduce poaching losses; and improving elk habitat quality through increased forest cuttings and development and maintenance of wildlife openings.

Concern over impacts to the elk herd from hydrocarbon development resulted in a suspension of exploration and drilling for oil in the forest during most of the period of 1975 - 1979. Strictly regulated oil development was again allowed in the PRCSF in 1980. Development was limited to the southern 1/3 of the forest and no competition between companies was allowed. These restrictions were thought to greatly reduce the impacts of oil development.

The elk herd apparently responded to the increased management efforts. Censuses in the winters of 1977 and 1980 revealed estimated populations of 300 and 500 animals, respectively.

A census in the winter of 1984 resulted in a population estimate of 850 animals. The MDNR estimated that the herd was growing at a rate of approximately 16% per year. Although the elk herd had again become a tourist attraction, depredation problems similar to the early

1960's were also present. In response to the damage complaints, the MDNR again proposed a controlled hunt to alleviate the problems. The first hunt was held in early December 1984. The public expressed concern that hunting may reduce elk visibility. Decreased visibility of elk following a hunt could reduce viewing opportunities. Consequently, local merchants dependant on the tourist trade might be negatively impacted.

The goal of the MDNR's elk management plan is "a viable elk population, in harmony with the environment, affording optimal recreational opportunities" (Elk Management Plan 1984). The degree of success in realizing this goal is dependant on the information available for use when developing management strategies. In order to effectively determine harvest quotas, MDNR managers need to know the overall herd size, the herd's composition and structure, and herd productivity. An effective harvest strategy requires knowledge of not only the correct number of animals to be removed, but also the proper kill distribution in order to remove animals that are causing damage to farm crops and forest regeneration. This requires information on the movements and relative mobility of elk between different parts of the range throughout the year.

An important part of the MDNR's goal for the elk herd is to provide recreational opportunities to the public.

Two of the most important recreational activities sought from the elk herd are sport hunting and elk viewing. These activities have been shown to be conflicting (Behrend and Lubeck 1968, Schultz and Bailey 1978), with hunting reducing the visibility of animals. It is therefore, essential for the MDNR to determine if hunting is affecting viewing opportunities.

Long term management of the elk herd also requires proper management of the habitat. Quantifying elk use of different cover types is an important step in determining elk habitat requirements. This information is also useful for developing a habitat suitability index model which can be used to evaluate the effects that management or disturbances have on elk habitat quality.

The objectives of the study were to: 1) determine elk habitat utilization and movements, 2) develop an elk habitat suitability index model, 3) determine the effect of hunting on elk visibility and movements, 4) assess the natality and rearing success of elk, 5) estimate the sex ratio and age distribution of the elk herd, and 6) compile information gathered in this study and from other sources into a population model.

The results of the study are presented as 3 separate chapters on elk response to hunting, elk habitat utilization and movements, and population analysis. These chapters are preceded by a description of the study area and a discussion of the study approach and general methods. The final chapter summaries the conclusions of the study and reports management recommendations and suggestions for further research.

STUDY APPROACH AND TELEMETRY

Introduction

Various techniques have been used to determine animal movements and habitat utilization (Hezen and Tester 1967). Radiotelemetry has become one of the most widely used techniques to determine this kind of information (Lee et al. 1985). Telemetry is favored because it avoids biases found with other techniques. For example, initial work investigating habitat utilization of elk in Michigan was based on direct observation and pellet group counts. Data determined from direct observations may be biased by differences in visibility of animals in different cover types, differences in the ability of observers to view the animal throughout various times of the day, and biases caused by preconceived ideas on the part of the researcher. Pellet group data may also be biased. Collins and Urness (1979) found that elk distributions based on pellet group counts were significantly different than the actual distribution of elk. The difference resulted from elk defecating more often while traveling than when feeding or bedding. Radiotelemetry combined with a properly designed sampling scheme can avoid these problems.

Study Area Description

The elk range in Michigan includes parts of Otsego, Cheyboygen, Montmorency, and Presque Isle counties (Fig. 1). The study area is centered over the primary elk range including the Pigeon River Country State Forest and the surrounding club lands, and that portion of the Thunder River State Forest north of Route 32 and west of Route 33. The study area is in the northern lower peninsula and lies within the Presque Isle Rolling Plain, Emmet-Alcona Hill Land, and Huron Lake-Border Plain physiographic regions (Sommers 1977). The watershed is drained by the Black, Pigeon, and Sturgeon Rivers which 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).

The climate alternates between continental-type and semi-marine (Moran 1973). The lake effect, although minimized by the area's interior location, produces increased cloud cover and prevailing westerly winds during fall and early winter which tend to moderate temperatures. The area characteristically has larger daily, monthly, and seasonal changes than areas nearer to the Great Lakes

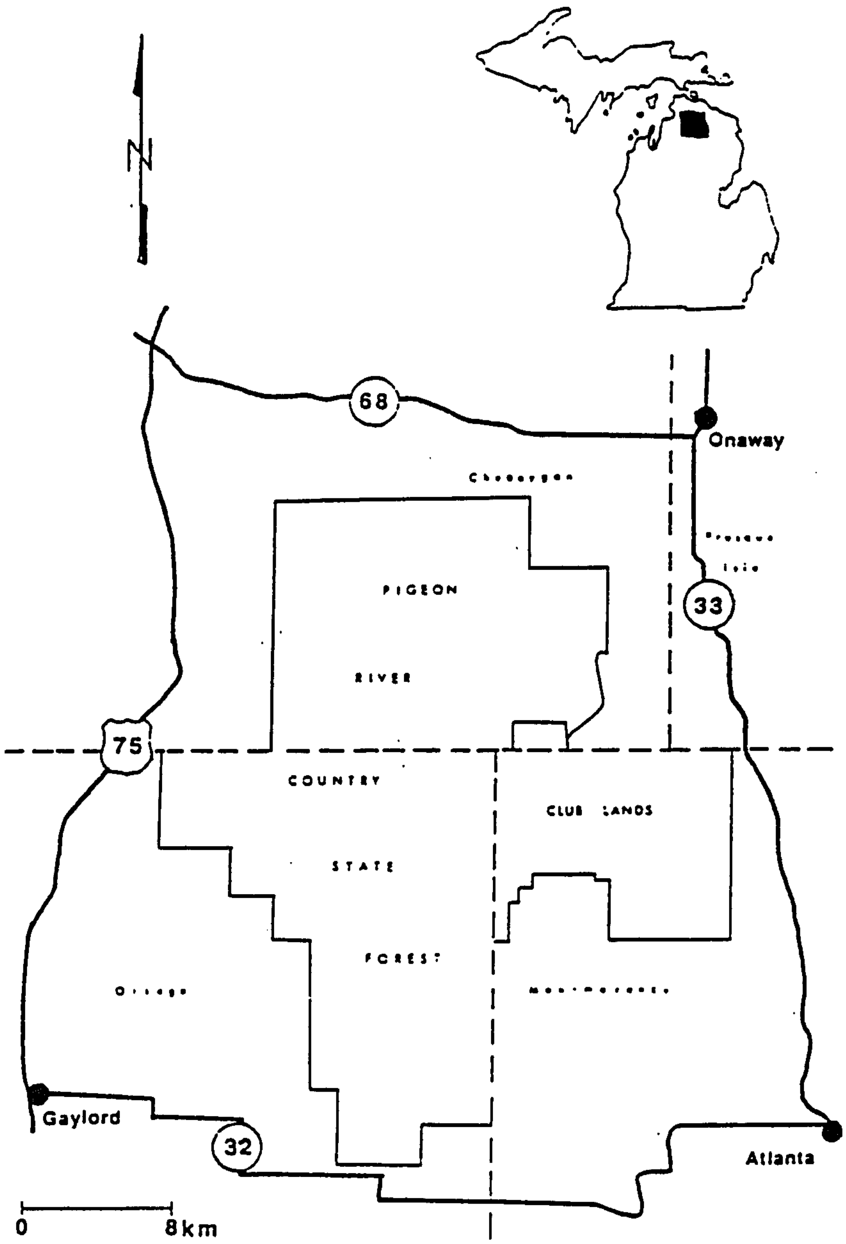

Fig. 1. Location of the elk range in Michigan.

(Michigan Weather Service 1974). Mean annual temperature for the area is 5.6 ^{o}C, ranging from a monthly low in January (-8.2 ^{o}C) to the monthly high in July (19.5 ^{o}C). The mean annual precipitation is 74.9 cm with 59% of the total received during the growing season of May - October. Mean monthly temperatures were very similiar to their respective long term averages (Fig. 2). Mean monthly precipitation was much more varied throughout the study period (Fig 3). The mean annual snowfall for Vanderbilt is 246.6 cm with a 90% probability of 15 cm of snow on the ground by 26 December (Michigan 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). Spiegel et al. (1963) classified the vegetation types of Michigan's elk range into 5 groups; morainic uplands, steep moraninic slopes, outwash plain - morainic ecotone, sandy outwash plain, and riverbanks and bottomlands. Moran (1973) added a sixth category; coniferous swamps (Fig 4).

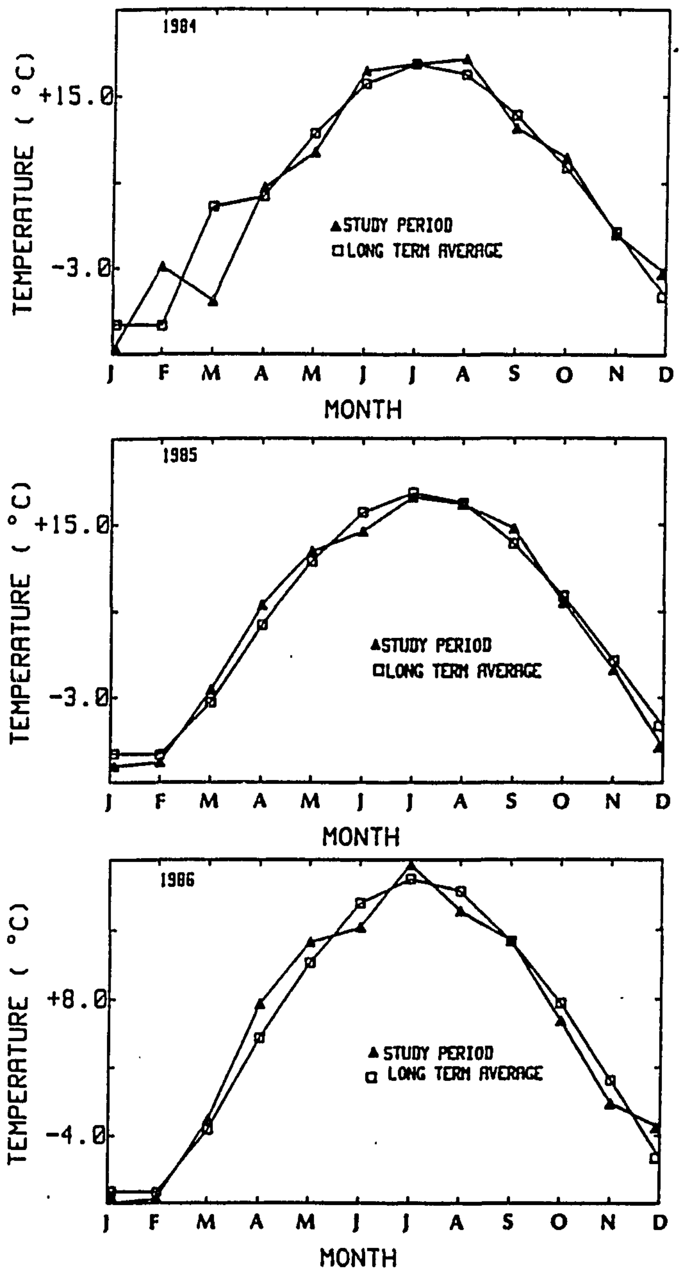

Fig. 2. Mean monthly temperatures recorded at Vanderbilt, Mi. during the study period compared with the long term average (1941-1970).

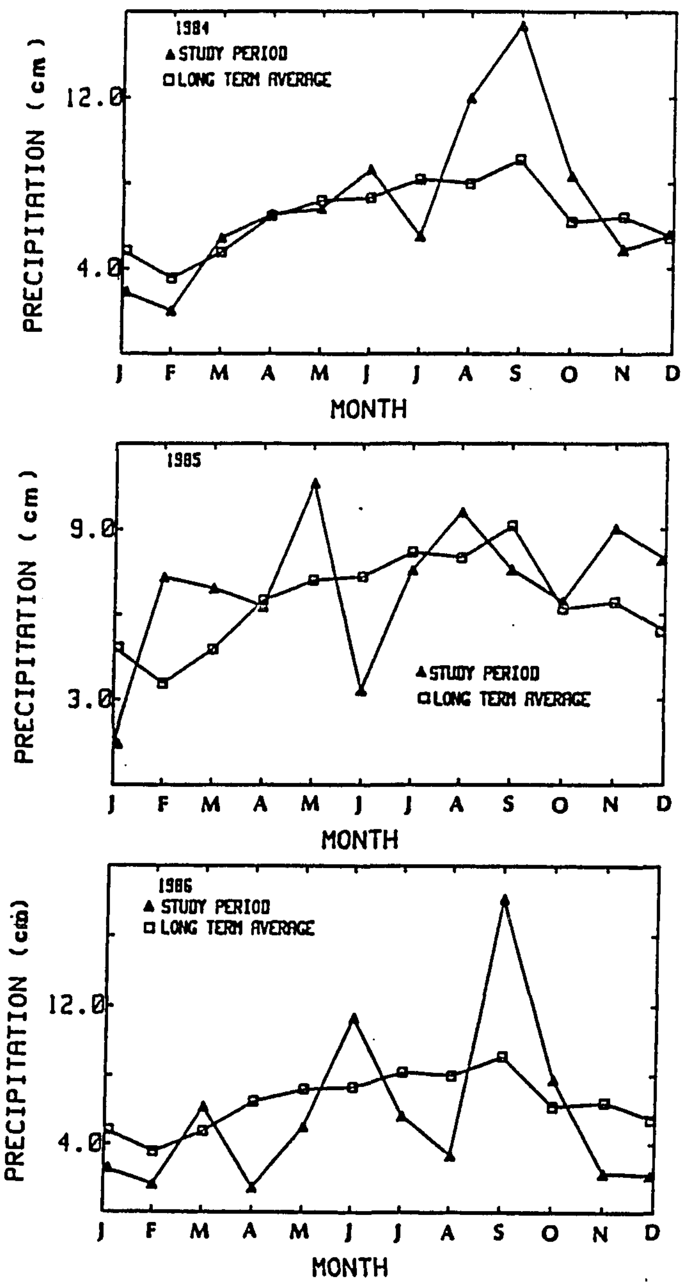

Fig. 3. Mean monthly precipitation recorded at Vanderbilt, Mi. during the study period compared with the long term average (1941-1970).

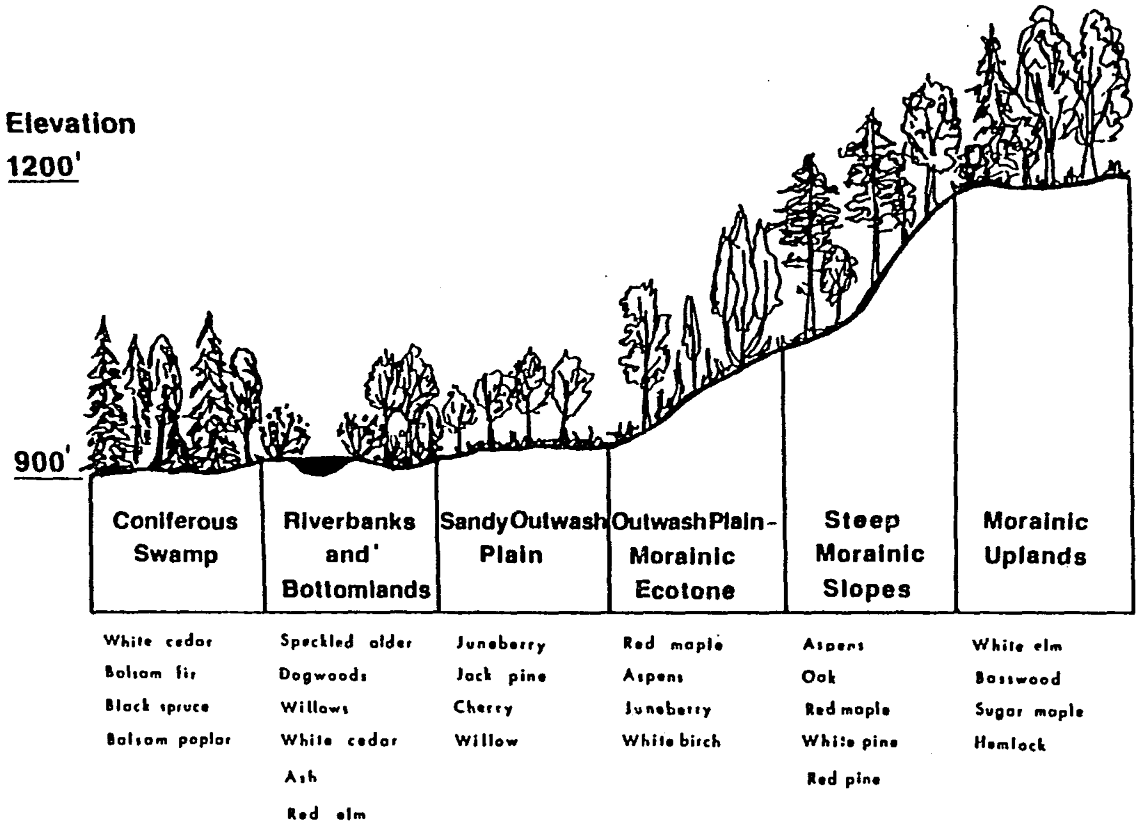

Fig. 4. Physiographic distribution of plant associations in the elk range (Moran 1973).

General Methods

Capture

Elk were captured by darting individuals with a powder charged capture gun (NASCO, Fort Atkinson, WI) which propels a dart containing succinylcholine chloride (E. R. Squibb and Sons Inc., Princeton, NJ). Dosages were determined in the field by classifying elk into 1 of 3 classes: calves (16 - 20 mg); cows (20 - 26 mg); and bulls (26 - 32 mg) (Flook et al. 1962). Captured elk were given intramuscular injections of 5 - 10 cc of Flochillan (Bristol Laboratories, Syracuse, NY) or Liquamycin (Pfizer Agricultural Division, New York, NY). Both of these drugs are long acting antibiotics. The wound caused by the dart was treated with a sulfa spray (Furazolidone) (Veterinary Products Industries, Phoenix, AZ). The eyes were treated with an ophthalmic ointment (Chloromycetin) (Pharmaderm, Melville, NY). A dosage of Dopram (A. H. Robbins Co., Richmond, VA) was administered to animals whose breathing appeared to be shallow or difficult.

Captured elk were aged by the tooth-wear method (Quimby and Gaab 1957) and classified as: less than 1 year, 1 - 2 years, 2 - 3 years, or greater than 3 years old. Elk were also ear tagged and fitted with color coded collars equipped with radio transmitters (Telonics, Meas, AZ). The transmitters were lithium powered with a rated battery life of 2-4 years. Each transmitter broadcasts on an individual frequency between 150 and 152 MHz.

In addition to animals captured by darting, newborn calves were captured by hand and ear tagged.

General location procedures

Although the procedures for sampling elk varied with the type of data that were being collected (i.e. movement or habitat utilization), the techniques for determining the location of an elk were basically the same. Radio-collared elk were located with portable TR-2 receivers and hand held yagi antennas (Telonics, Mesa, AZ). The vegetation type each elk was in - and thus its location - was determined by either walking in and actually observing the animal or by systematically moving around a minimum of 3 sides of the animal until the cover type was identified. For movement information, this location was recorded using a legal description describing the elk's location to a maximum of 16.2 ha (40 acres).

When radio-collared elk were found on inaccessible private lands, locations were determined by triangulation. Compass bearings were taken using the loudest point method described by Springer (1979). Error arcs ($\pm$ 6°) determined by Ruhl (1984) were used when mapping out triangulation readings.

Results and Discussion

Capture, mortality, and current status

Since October 1981, a total of 48 elk were radio-collared (Table 1). Nine of the 48 animals were recollared once and 2 were recollared twice. These 48 animals included 15 bulls and 33 cows. Initially, the sex ratio of radio-collared elk was nearly balanced. However, as research interests shifted from habitat utilization to population dynamics, more cows than bulls were captured. One elk died from a drug overdose during capture.

Of the 48 radio-collared elk, 50% were shot during the study. Nine elk of these elk were shot illegally. Three of the 9 were shot during the firearm deer season, 1 was part of a multiple kill case during the 1986 elk season, and 5 were poached at various times throughout the year. Fifteen radio-collared elk were legally shot during the elk hunting seasons. Seven were shot in 1985 and 8 were shot in 1986. The elk hunters were instructed at the mandatory prehunt school to avoid shooting radio-collared elk if possible. Most hunters which shot collared elk reported that they did not see the collar before they shot. In 1985, radio-collared cows made up approximately 8% of the cows in the hunt area and made up approximately 9% of

Table 1. Capture record and current status of radio-collared elk in northern Michigan 1981 - 1986.

Elk #	Date collared	Sex	Age at capture	Current status (date recovered)
1	10/29/81*	M	1 - 2	Illegally shot (12/84)
2	12/16/81	F	1 - 2	Brainworm (04/12/82)
3	12/17/81	F	> 3	Eox. Metritis (06/21/82)
4	12/18/81	F	> 3	Shot (12/12/86)
5	12/18/81	M	< 1	Malnutrition (03/17/82)
6	12/18/81	F	< 1	Unknown cause (06/22/82)
7	12/21/81*	M	1 - 2	Illegally shot (10/31/85)
8	01/25/82*	F	2 - 3	Active
9	02/21/82	M	1 - 2	Illegally shot (07/29/82)
10	05/08/82	F	1 - 2	Illegally shot (11/15/82)
11	05/09/82**	M	> 3	Shot (12/09/86)
12	06/21/82*	F	2 - 3	Shot (12/10/86)
13	06/21/82	F	2 - 3	Collar removed
14	06/23/82*	F	> 3	Active
15	07/22/82	M	1 - 2	Lost collar (12/08/85)
16	08/05/82	F	1 - 2	Shot (12/10/85)
17	09/12/82	F	2 - 3	Malnutrition (03/01/84)
18	09/13/82	M	1 - 2	Illegally shot (04/12/86)
19	09/15/82	M	> 3	Lost collar (10/09/82)
20	09/15/82*	F	> 3	Illegally shot (01/09/87)
21	09/16/82**	M	> 3	Shot (12/13/86)
22	01/08/83*	F	< 1	Shot (12/12/85)
23	09/10/84	F	2 - 3	Shot (12/12/86)
24	09/16/84	F	> 3	Shot (12/10/85)
25	09/19/85	F	1 - 2	Active
26	09/28/84	F	2 - 3	Shot (12/10/85)
27	09/30/84	F	1 - 2	Active
28	10/12/84	F	1 - 2	Malnutrition (03/24/86)
29	10/13/84	F	> 3	Active
30	10/13/84	F	1 - 2	Active
31	10/14/84	F	> 3	Shot (12/10/85)
32	10/20/84	F	> 3	Shot (12/10/85)
33	10/26/84	F	> 3	Illegally shot (11/29/85)
34	10/26/84	F	> 3	Active
35	10/27/84	F	> 3	Active
36	10/27/84	F	> 3	Shot (12/10/85)
37	11/09/84	F	> 3	Active
38	11/10/84	F	> 3	Illegally shot (11/21/85)
39	11/10/84	F	> 3	Active
40	07/21/85	F	1 - 2	Shot (12/12/86)
41	09/19/85	F	1 - 2	Active
42	08/26/86	M	> 3	Active
43	08/28/86	M	> 3	Shot (12/09/86)
44	09/17/86	M	> 3	Active

Table 1. continued.

Elk #	Date collared	Sex	Age at capture	Current status (date recovered)
45	09/18/86	M	> 3	Active
46	09/22/86	M	> 3	Shot (12/12/86)
47	09/24/86	M	> 3	Illegally shot (12/10/86)
48	10/14/86	F	1 - 2	Active

*elk was recollared once
**elk was recollared twice

the kill. Thus, if it is assumed that most hunters could not see the collars, it appears that collared elk were shot proportional to their numbers in the huntable population.

At the end of December 1986, 15 of the 48 radio-collared elk were still active and being monitored. Losses to shooting (both legal and illegal) and currently active radio-collared elk account for 39 of the 48 animals. Of the remaining 9 animals, 2 tore their collars off and 1 other collar was removed to reduce travel costs. The current status of these 3 elk is unknown. Six radio-collared elk died of natural causes. Three of the 6 died of malnutrition, 1 died from brainworm, 1 died of a uterine infection, and the other animal died of an unknown cause (Schmitt pers. comm.). The 3 animals that died of malnutrition and the animal that died from brainworm all died in late winter or early spring. This suggests that winter conditions may stress elk. Death from starvation was not restricted to calves. Two of the 3 elk which died of malnutrition were adults.

A total of 8 calves were ear-tagged, 2 in 1985 and 6 in 1986. Both calves tagged in 1985 were males. One of these calves was shot during the 1985 elk hunt and the other was poached during June 1986. Of the calves tagged in 1986, half were male and half were female. All of these calves survived the 1986 elk hunt.

RESPONSES OF MICHIGAN ELK TO HUNTING

Introduction

The growth of the Michigan elk herd following the successful reintroduction in 1918 created a new tourist attraction in northern Michigan. The herd expanded in both numbers and range until an estimated population level of 1,200-1,500 animals was reached in the early 1960's (Moran 1973).

The herd's growth also resulted in increasing reports of damage to farm crops and forest regeneration. To alleviate these problems the Michigan Department of Natural Resources (MDNR) established controlled hunting seasons in 1964 and 1965. A total of 477 animals were harvested during the 2 seasons. The MDNR established 5 hunting zones, of which 1 was restricted to antlerless only hunting. This was done to preserve antlered bulls for tourist viewing (Moran 1973).

Reduced herd size following the hunts precluded additional hunting in the 1960's and 1970's. The reduction in herd size was attributed to poaching, forest succession, and increased human disturbance of elk (MDNR 1975). The reduction in herd size reduced damage to forest and farm crops, however, it also resulted in lower visibility of elk. This reduction in visibility produced unsatisfactory elk viewing opportunities (Elk Management Plan 1984).

In 1975 the MDNR conducted an elk census which resulted in an estimated population of 200 animals. In response to this low population level and public concern over possible negative impacts of oil development in the elk range, the MDNR initiated an elk management plan. Basically this plan called for increased protection from poaching and an improvement of habitat quality. By the early 1980's the elk herd increased to a level which allowed the population to regain its status as a tourist attraction. However, depredation problems similar to the early 1960's were also present. As a result the MDNR scheduled a controlled hunt for December 1984. The public expressed concern that hunting may again reduce elk visibility. Decreased visibility of elk following the hunt would reduce viewing opportunities for nonconsumptive users. This could have a negative impact on local merchants.

The objective of this segment of the study was to determine the effect of controlled hunting seasons on elk visibility and elk movements.

Methods

Elk visibility

The impact of the elk hunts on elk visibility was assessed by comparing the flight distance of elk in the hunted and unhunted portions of the study area (Fig. 5). Flight distance was defined as "the distance to which a person can approach a wild animal without causing it to flee" (Altman 1958).

Flight distance was determined by slowly and steadily approaching 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, New York). In order to standardize the technique the following procedures were adhered to:

1. All animals were initially located from a vehicle.
2. Animals observed closer than 100 m from the vehicle were not sampled.
3. Only animals in the open were approached.
4. If a group of animals was approached, the measurement was taken on the closest animal.
5. Measurements were only taken during early morning (dawn plus 3 hours) and early evening (starting 3 hours before nightfall) hours.
6. Measurements were not taken on days of adverse weather conditions (i.e. high winds, rain, or snow).

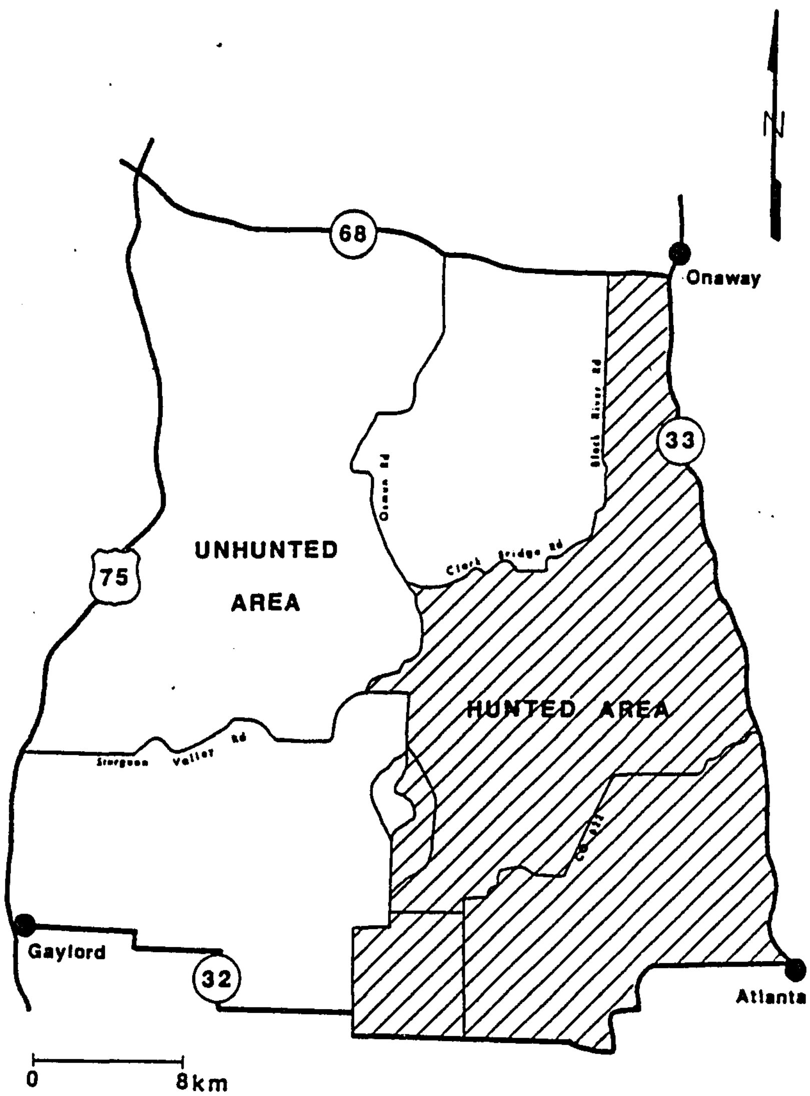

Fig. 5. Designated hunted and unhunted portions of the study area used during flight distance sampling.

7. Flight distances were not measured on radio-collared animals or groups that contained radio-collared animals.

Mean flight distance was determined in the unhunted and hunted portions of the study area 3 times prior to the initiation of the December 1984 hunt. Those sampling periods were in December 1983, July 1984, and September 1984. Mean flight distances were determined for the animals in the unhunted and the hunted portions of the study area 6 times after the hunting seasons were established. Those sampling periods were January 1985, July 1985, September 1985, April 1986, July 1986, and September 1986. When only 1 observer was working each sampling period was divided into 1 week segments. For each day within each week, the hunted and unhunted areas were randomly assigned to either a morning or evening sample. When 2 observers were working, each area was sampled each morning and evening.

Statistically adequate sample sizes for flight distance measures in the hunted and unhunted areas were determined as described by Freese (1978). Allowable error was set at 10% of the estimated mean. The hypothesis of the equality of variances was tested with an F test (Steel and Torrie 1980). The chi-square goodness of fit test was used to determine if the data were normally distributed (Sokal and Rohlf 1981). Because several data sets were non-normally distributed or had unequal variances, the data were analyzed with the Mann-Whitney U test (Siegel 1956). The acceptable level of statistical significance for all tests was set at $\alpha = 0.10$.

Elk Movements

To determine the effect of the elk hunt on daily movements each radio-collared elk in the hunted and unhunted areas was located daily, the week before, the week of, and the week after the hunt. These sampling periods will be referred to as the pre-hunt, hunt, and post-hunt samples, respectively. Elk were sampled in the same sequence to keep the amount of time between daily locations relatively constant.

Comparisons of mean daily movements of radio-collared elk in the hunted and hunted areas during each of the 3 sampling periods were made with the Mann-Whitney U test and the Kruskal-Wallis one-way analysis of variance (Siegel 1956). Significant differences found with the Kruskal-Wallis test were examined with a nonparametric multiple contrast test presented by Zar (1984). The acceptable level of statistical significance for these tests was set at $\alpha = 0.10$.

Results and Discussion

Elk visibility

Flight distances were sampled in 3 seasons in the designated hunted and unhunted areas prior to the initiation of the hunting seasons. No significant differences ($p > 0.10$) were found between the 2 areas (Table 2) before hunting. Flight distances were also sampled in 3 seasons after the December hunts in 1984 and 1985. Again no significant differences ($p > 0.10$) were found (Table 2).

Various factors can affect the flight distance of an animal. Altman (1958) concluded from her studies on elk and moose (<u>Alces alces</u>) that there were seasonal differences corresponding to different reproductive stages and nutritional levels. Other factors include the type of vegetation the animal is in and the specific experience of the animal or group.

For big game animals an important experience that would 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 during the summer. Antlered bucks,

Table 2. 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	Unhunted Unit
Pre-hunt:		
Winter 1984	46.5 ± 4.9	60.2 ± 7.2
Summer 1984	49.0 ± 2.7	52.0 ± 2.9
Fall 1984	47.0 ± 3.0	48.3 ± 2.8
Post-hunt:		
Winter 1985	47.0 ± 5.8	45.8 ± 5.2
Summer 1985	52.0 ± 2.8	47.8 ± 2.7
Fall 1985	44.7 ± 2.9	45.0 ± 1.9
Spring 1986	44.3 ± 3.9	51.6 ± 4.1
Summer 1986	52.0 ± 2.3	50.9 ± 2.8
Fall 1986	50.3 ± 2.6	53.0 ± 2.9

excluding spikes, had a significantly longer flight distances on the hunted area than on the unhunted area. Flight distances of antlerless deer did not differ between 2 areas. Elk in Rocky Mountain National park were subjected to controlled hunting by park personnel for a 13 year period (1949-1962). During this period and for some time after the herd was not very visible (Schultz and Bailey 1978). Observations in the mid 1970's suggest the elk became more visible after hunting had been stopped for over 10 years, unfortunately visibility was not quantified. Douglas (1971) reported red deer (Cervus elaphus) resuming diurnal feeding on open grassland 2 years after an intensive control hunting program was ceased. The red deer again became less visible when hunting around the boarders of the study increased. Morgantini and Hudson (1979) concluded that shelter-seeking habitat selection by elk in western Alberta during winter was a response to human activity, primarily hunting, that was presently or had previously taken place on the area rather than a response to environmental conditions.

Unhunted elk appear to develop a tolerance to human activity. 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 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. Houston (1976) reported similar tolerance of elk to humans in Yellowstone National Park after controlled hunts had been stopped.

Elk in Michigan have only been legally hunted 4 times since their reintroduction. The first 2 elk seasons were in 1964 and 1965. The high success rates for these hunts, 94% and 65% respectively, suggest that elk were not extremely wary. Almost 20 years elapsed before elk were again hunted in Michigan. It is unlikely that any of the elk present during the 1964 and 1965 hunts were alive during the 1984 hunt. Thus, none of the presnt elk had prior experience with hunting. Fifty hunters participated in the 1984 hunt. Of these 50 hunters, 49 were successful. Fifty-nine percent of the hunters killed their elk on the first day of the season. After the second day only 7 hunters remained afield. In 1985, the MDNR issued 120 elk permits. Again the elk hunters were very successful with 119 individuals tagging their elk. Sixty-one percent of the hunters were successful on the first day of the 1985 season and after the third day only 13 hunters were as yet unsuccessful.

Although the results found in the literature suggest that hunting should reduce the visibility of elk, it appears that the relatively short duration of the hunts has not yet made an impact 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 which ran when they saw or heard a vehicle approaching. Sage et al. (1983) studying the visibility and behavior of marked white-tailed deer noted that there was a difference in visibility among individuals. Highly visible individuals accounted for a majority of deer sightings along certain sections of the road. These individuals also tended to have different flight behavior than other deer, with more observed standing and walking than running or bounding. The opposite was true for less visible individuals. Sage et al. (1983) concluded that hunting reduced observation rates because the highly visible deer were more vulnerable to hunting. A similar situation may exist with elk in Michigan. A percentage of the individuals in the population may be more visible than others. This would suggest that a change in visibility as currently measured, may not occur until a majority of the highly visable animals are removed through hunting.

Maintaining a viewable population of elk is one objective of the MDNR's elk management plan. As a result, elk visibility should continue to be monitored. An increase in flight distance may have several effects. The most obvious effect would be a reduction in viewing opportunities for tourists. Altman (1956) has suggested that continued disturbance of elk by people could curtail or even suppress rutting activities. Because one of the most popular times for viewing elk is during the rut, a second possible effect would be disruption of rutting activities.

If hunting does decrease elk visibility, the results presented in the literature suggest that it will take at least 2 years and possibly up to 10 years to recover. One option to maintain elk visibility is to create an area which is not open to hunting. Because Michigan elk have relatively large home ranges (2,500-27,000 ha), the size of the unhunted area would have to be large. Another useful management practice could be the manipulation of viewing areas. Viewing areas could be created or modified to keep observers far enough away to reduce their disturbance of the elk. In addition, closing trails (to vehicle traffic) that lead to openings will also reduce the number of people that will visit these openings to observe elk, thereby reducing disturbances.

Elk movements

In 1984 in the unhunted area, mean daily movements of radio-collared elk were significantly less ($p < 0.10$) during the hunt than during the pre- or post-hunt periods (Table 3). In the hunted area, daily movements of radio-collared elk were greater during the pre-hunt and hunt periods than daily movements during the post-hunt

Table 3. Mean daily movements (mean ± standard error) in km of radio-collared elk in the hunted and unhunted portions of the Michigan elk range the week before, the week of, and the week after the December, 1984 and 1985 elk hunts.

	Sampling period		
Year	Pre-hunt	Hunt	Post-hunt
1984			
Unhunted[1]	1.23 ± 0.09^{1a}	0.64 ± 0.09^{b}	1.13 ± 0.22^{a}
Hunted	1.21 ± 0.07^{a}	1.81 ± 0.18^{a}	0.86 ± 0.06^{b}
1985			
Unhunted[2]			
Hunted	1.05 ± 0.19^{a}	1.46 ± 0.21^{a}	0.65 ± 0.23^{b}

[1]Values within a row with a different letter are significantly different ($p < 0.10$).
[2]Insufficient data.

period. During the 1984 hunt, radio-collared elk in the hunted area moved significantly ($p < 0.10$) farther each day than elk in the unhunted area. Movements of radio-collared elk before and after the 1984 hunt were similar in the hunted and unhunted areas.

In 1985, all but 2 of the radio-collared elk were found in the hunt area during all or part of the sampling periods. As a result no comparisons between elk in unhunted and hunted areas could be made. The movements of radio-collared elk in the hunted area were similar to the movements recorded in 1984. Radio-collared elk moved significantly ($p < 0.10$) farther each day during the pre-hunt and hunt periods than during the post-hunt period (Table 3). There was no difference ($p > 0.10$) in the movements of radio-collared elk in the hunt area during any sampling period between 1984 and 1985.

As expected, during the hunt radio-collared elk in the hunt area made longer daily movements than radio-collared elk in the nonhunt area. Although daily movements of radio-collared elk during the pre-hunt period did not differ significantly between the hunted and unhunted areas, pre-hunt daily movements in the hunt area were greater than movements during the post-hunt period in both years. Greater movements during the pre-hunt period may be related to an increase in human activity, primarily elk hunters and guides scouting the area for the upcoming hunt. These results suggest that elk hunting, including prehunt scouting, does have an impact on elk behavior. Currently, the impact appears to be relatively short-lived, as indicated by the decreased daily movements as soon as the hunters left the field.

ELK HABITAT UTILIZATION AND MOVEMENTS

Introduction

Michigan's elk herd is managed through manipulation of the population size and structure, and management of the habitat. In order to effectively manage elk habitat the importance of the different cover types to elk must be identified. This information is necessary to insure adequate consideration of elk habitat requirements when multiple use forest management plans are developed. This information is also needed for the development of an elk habitat suitability index model. This model will enable managers to assess the impacts of management practices and perturbations to the habitat on elk habitat quality.

Ruhl (1984) documented summer and fall habitat use and movements by northern Michigan elk. However, detailed information was not collected during winter or spring. A potentially important aspect of spring habitat utilization is the cow's choice of calving areas. Winter habitat utilization is of considerable importance because this is the time of the year when the balance of energy requirements and energy availability are the most difficult to maintain. Severe winter conditions have been shown to reduce elk population growth in 2 ways. The first is through direct mortality of animals during or immediately following periods of winter stress (Sauer and Boyce 1983). The second effect of severe winter conditions on elk population growth is decreased reproductive success the following spring (Hancock 1957, Greer 1968, Harper 1971, Thorne et al. 1976). Both Moran (1973) and Ruhl (1984) found evidence of Michigan elk concentrating in conifer swamps during deep snow conditions. Snow depths greater than 41 cm have been correlated with elk movements to areas of lesser snow depth (Beall 1974, Sweeny and Steinhoff 1976, Leege and Hickey 1977). Managers need to be able to assess the impact of varying winter weather conditions on population growth in order to effectively manage the population. An index which relates elk use of conifer swamps as thermal cover to survival or recruitment data would provide managers with the necessary information. The inital step in formulating such an index requires the documentation of winter habitat use relative to weather conditions.

The size of elk home ranges must be known so that habitat management and population management can be applied at the proper scale. Information on elk movements allows managers to direct population management programs toward those parts of the herd that inhabit areas of potential conflict with agricultural or timber products.

The objectives of this segment of the study were to determine seasonal elk habitat utilization and movements. Specifically, the objectives were: 1) to describe elk use of the various cover types; 2) to relate winter habitat utilization to environmental conditions; 3) to locate and describe calving areas; 4) to determine seasonal and yearly home range sizes of Michigan elk; and 5) to develop an elk habitat suitability index model.

Methods

Cover type definitions

The Michigan State Forest Operations Inventory (MSFOI) system classifies the vegetation on state lands into 26 categories (Table 4) (MSFOI 1982). The MSFOI also classifies stands managed for timber production by growth stage and stocking density (Table 5). Ruhl (1984) designated 14 cover type categories in 3 classes of vegetative structure in his habitat utilization study. The 3 classes of vegetative structure were open areas, regenerating stands (average stand dbh $\leq$ 12.69 cm), and forest stands (average stand dbh $\geq$ 12.70 cm).

Ruhl (1984) defined open areas as those areas which were dominated by herbaceous vegetation. These areas included natural openings, which are openings created by natural perturbations or by given site conditions such as poor soil fertility, and wildlife openings, which are openings created and maintained by the MDNR. These wildlife openings are often fertilized and planted with rye (*Secale* spp.) and clover (*Trifolium* spp.). In addition, these openings are enhanced by periodic mowing and replanting.

Table 4. Cover type classifications used by the Michigan State Forest Operations Inventory system (MSFOI 1982).

Cover type code	Cover type
A	Aspen (upland)
B	Paper birch
C	Cedar
D	Treed bog
E	Swamp hardwoods
F	Spruce-fir (upland)
G	Grass
H	Hemlock
I	Local use
J	Jack pine
K	Rock
L	Lowland brush
M	Northern hardwoods
N	Marsh
O	Oak
P	Balsam poplar
Q	Mixed swamp conifers
R	Red pine
S	Black spruce (swamp)
T	Tamarack
U	Upland brush
V	Bog and muskeg
W	White pine
X	Non-stocked, non-forested or non-productive stands
Y	Sand dunes
Z	Water

Table 5. Growth stage, mean dbh, and stocking density for forest stands as defined by the Michigan State Forest Operations Inventory system (MSFOI 1982).

Growth stage	Mean dbh (cm)	Stocking density	
Nonstocked		Less than 17%	
Seedling-sapling	0.0-12.6	Poor	17-39%
Seedling-sapling	0.0-12.6	Medium	40-69%
Seedling-sapling	0.0-12.6	Well	> 70%
Poletimber	12.7-25.3	Poor	2.3-9.1 m^2/ha
Poletimber	12.7-25.3	Medium	9.2-16.0 m^2/ha
Poletimber	12.7-25.3	Well	> 16.0 m^2/ha
Sawtimber	> 25.3	Poor	2.3-9.1 m^2/ha
Sawtimber	> 25.3	Medium	9.2-16.0 m^2/ha
Sawtimber	> 25.3	Well	> 16.0 m^2/ha

Regenerating stands were classified as either deciduous or coniferous depending on the most prevalent species. This classification included both clearcuts and plantations. Regenerating deciduous stands, primarily trembling aspen (Populus tremuloides) and bigtooth aspen (P. grandidentata), are very important as foraging areas for elk and as future timber resources. Because of the potential impact of elk browsing on these stands, regenerating deciduous stands were further broken down by age class at 5 year intervals up through age 20. This was done to investigate this potentially important pattern of elk habitat use.

Forest stands were grouped into 5 categories (Ruhl 1984). These 5 categories were: 1) jack pine (Pinus banksiana), 2) upland conifers (including red pine (Pinus resinosa, white pine (Pinus strobus), and upland spruce (Picea spp.) and fir (Abies spp.) stands, 3) swamp conifers (including white cedar (Thuja occidentalis) and mixed swamp conifer stands), 4) northern hardwoods (primarily maple (Acer spp.), and 5) upland deciduous stands (including oak (Quercus spp.) aspen, and birch (Betula spp.). Each of these forest stands were further classified into 1 of 2 groups based on their stocking density. Poorly stocked stands had stocking densities $\leq$ 9.2 m^2/ha (39 ft^2/ha) and medium to well stocked stands had stocking densities > 9.2 m^2/ha. All other stands not fitting into a previously defined category were consolidated into a group labeled "other". Cover types on private lands were not classified. Stand aspect was not considered to be an important factor affecting habitat use of elk in Michigan, unlike conditions found in the western United States.

Habitat utilization

The study area was subjectively divided into 2 areas; the north area which consisted primarily of the Pigeon River Country State Forest and the surrounding club lands; and the south area which is commonly known as the Camp 30 Hills area (Fig. 6). The starting and ending dates for the seasonal periods used were those defined by Ruhl (1984). Those periods were: winter, 22 December through 20 March; spring, 21 March through 21 June; summer, 22 June through 22 September; and fall, 23 September through 21 December. Summer and fall habitat utilization data were collected in 1983. Spring habitat utilization data were collected in 1984. Winter habitat utilization data were collected in 1984, 1985, and 1986.

Each day was divided into three 8 hour sampling periods. These sampling periods were from 8:00 am - 3:59 pm, 4:00 pm - 11:59 pm, and 12:00 am - 7:59 am. Since an elk's use of the habitat is directly dependant on its activity (feeding, bedding, traveling), and activities differ throughout the day, sampling was alternated among

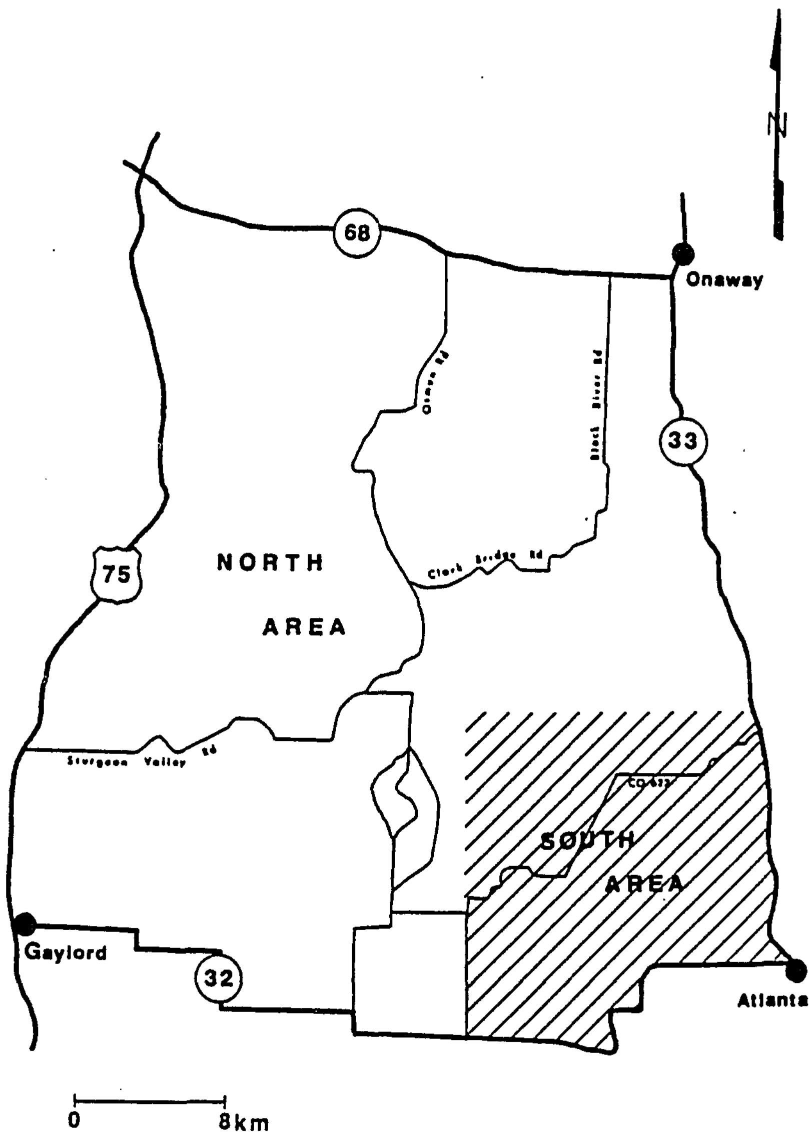

Fig. 6. Designated north and south units of the study area used during habitat utilization sampling.

sampling periods to insure equal sampling intensities. This procedure was designed to avoid any possible biases that may be created by sampling more or less during a particular time of day. Sampling was alternated between the north and south areas. For each area during every sampling period 1 radio-collared elk was randomly selected as the first animal to be located during that period. The other radio-collared elk within that area were then located by traveling the road system in a randomly chosen clockwise or counter-clockwise direction. Individual elk were located at approximately equal time intervals throughout the sampling period. The cover type each radio-collared elk was in was determined as previously described in the section on general location methods. Because elk tend to gather in larger groups during winter, it was common to find 2 or more radio-collared elk together. As a result, habitat utilization sampling was modified during winter. The sampling procedure used consisted of randomly selecting the entire order in which elk were sampled instead of just randomly selecting the starting point and the direction of travel. Habitat use of elk on inaccessible private lands could not be determined.

Concurrent with the investigation of winter habitat utilization, measurements of daily weather conditions were collected. Weather data were recorded at the Pigeon River Country State Forest headquarters which is centrally located in the study area. Temperature was recorded continuously, while snow depth and precipitation were recorded daily.

Location of calving areas

The selection of calving sites by radio-collared cows was investigated in 1984, 1985, and 1986. The procedures used to locate calves followed the methods outlined by Waldrip (1975). Beginning the third week of May in each year all radio-collared cows were located daily in order to determine a sudden preference for a particular area. An attempt was made to observe each radio-collared cow every day so that any changes in their physical characteristics would be apparent. Attempts were not made to view animals in heavy cover in order to reduce disturbances. Because of the large number of animals being monitored, daily locations were plotted on vegetation maps to aid in identifying the calving areas. When possible, newborn calves encountered were captured, aged, and eartagged. Calves were aged as described by Johnson (1951). Aging of calves aided in the location of calving sites because newborn calves move very little in their first 4 days (Waldrip 1975).

General movements

The location of each radio-collared elk was determined every other day by the methods described previously. A flexible sampling procedure was used to gather movement data. This allowed movement sampling to fit in with other data collection that required stricter sampling procedures. For example, movement data were collected concurrently with habitat utilization data. Home range sizes were calculated for rutting and nonrutting periods of the year. The rutting period is defined as 15 August to 15 November. The nonrutting period encompasses the remainder of the year outside of these dates.

Data analysis

Winter habitat utilization - winter weather

Winter habitat utilization data were reclassified into 2 groups. Each location of a radio-collared elk was classified as the elk being found in either a conifer swamp or not in a conifer swamp. The latter group was simply labeled "other". A linear discriminant function which predicts if elk would be found in a conifer swamp on a particular day based on environmental conditions was calculated. The discriminant function was calculated with the Number Cruncher Statistical System (Dr. J. L. Hintze, Kaysville, Utah). A discriminant function was calculated with the 1984 winter habitat utilization data. The 1985 and 1986 winter habitat utilization data were used to test the discriminant function for misclassifications.

Home range

Rut and nonrut home range sizes were calculated with the Telemetry Analysis Program (TAP) (Rabe 1983). This computer program determines home range size based on the minimum area method (Mohr 1947). Average rut and nonrut home range sizes were determined for each radio-collared elk from August 1982 through August 1986. The numbers of samples averaged to determine a home range varied among individuals. This variation was caused by mortality of radio-collared elk and the periodic capture and radio-tagging of additional elk throughout the study.

The Mann Whitney U test was used to compare rut and nonrut home ranges between bulls and cows. All tests were two-tailed with an alpha level of 0.10 or less used for the rejection of the null hypothesis.

Results and Discussion

Spring habitat utilization

A total of 339 observations were recorded during spring habitat utilization sampling. During this period, 6 bulls and 7 cows had radio-collars and were monitored. Openings received the highest use of any cover type by cows (Table 6). Bulls only used openings approximately 10% of the time. However, 77 additional locations of bulls were on private lands and not included in these percentages. Of these locations, 43 were known to be in hayfields. If these locations were included, bull use of openings would have been almost equal to that recorded for cows. Use of private lands was very low for the radio-collared cows. Although activity data were not specifically collected, general observations suggest that most of an elk's time in an opening is spent foraging.

Cow use of deciduous regenerating stands was relatively evenly distributed over the 4 age classes (Table 6). The majority of deciduous regenerating stands in the study area consisted primarily of aspen. Bull use of deciduous regenerating stands was more varied. Bulls used 11-15 year old stands almost 5 times as much as 0-5 year old stands. In 1984, the availability of the different age

Table 6. Cover type use (percent) by bulls and cows during spring 1984 in northern Michigan.

Cover type	Bulls (n = 6)	Cows (n = 7)
Open areas	9.4	25.8
Regenerating stands:		
Deciduous		
0-5 years	3.2	4.1
6-10 years	5.9	2.8
11-15 years	15.8	3.3
16+ years	8.4	5.4
Coniferous	3.6	1.8
Poorly stocked stands:		
Jack pine	0.0	0.0
Upland conifer	0.6	0.5
Upland deciduous	3.4	0.4
Northern hardwoods	1.8	4.0
Swamp conifers	0.0	0.0
Well stocked stands:		
Jack pine	6.3	4.9
Upland conifer	4.3	13.8
Upland deciduous	14.0	10.3
Northern hardwoods	9.9	20.2
Swamp conifers	13.3	2.7
Other stands	0.0	0.0

classes of aspen was: 18.2% 0-5 years, 20.0% 6-10 years, 33.3% 11-15 years, and 28.5% 16-20 years. Thus, the higher use of 11-15 year old stands may be related to availability. It may also be related to the availability of forage in these stands. In the later part of the spring elk are feeding on newly formed aspen leaves. Westell (1954) found increasing amounts of forage in the form of leaves and stems for bigtooth aspen as it grew from 1 to 2 meters in height. Cooper (1981) found increases in annual production for bigtooth aspen grown on poor soils until the trees were approximately 45 years old. Trees within the 11-15 years old stands have more branches and leaves than the younger trees. In addition, the trees are still small enough for bulls to reach up and break off the upper portion of the tree or ride the trees down with their chest. Thus, this age class may supply the elk with a large, readily available food supply.

Bull and cow use of poorly stocked forest stands was very low for all cover types (Table 6). Ruhl (1984) found heavy elk use of a recently thinned mature red pine stand which was growing on a relatively fertile Emmett sandy loam soil. The open canopy of the thinned stand and fertile soils allowed an extensive hardwood understory to develop. Poorly stocked stands which have developed naturally on poorer soils also have open canopies, however, the understory that develops on these sites is apparently unattractive to elk as indicated by the low use. Numerous studies have shown that ungulates will forage more heavily on vegetation that is of a higher nutritional quality (Westell 1954, Brown and Mandery 1962, Heady 1964, Gwynne and Bell 1968,, Byelich et al. 1972, Mereszczak et al. 1981). Nutritional quality of the vegetation is in part dependant on the availability of nutrients in the soil. Thus, it is likely that the lower use of these stands is due to the relatively infertile soils which produce vegetation of lower nutritional quality.

Cows showed a pattern of relatively high use of upland conifers during spring. Ruhl (1984) found high use of upland conifers by cows during summer. Ruhl also noted that the majority of locations were found in a single thinned red pine stand. This same stand was also used to a great extent during the present study. This stand was atypical of most red pine plantations. The trees were planted on a fertile soil (Emmett sandy loam), and after thinning a hardwood understory developed. As Ruhl noted, the stand was also in close juxtaposition to a large opening that was heavily used by elk.

Bulls and cows both showed moderately high use of upland deciduous and northern hardwood stands. General observations indicate that these stands were primarily used for bedding and loafing. Elk were also observed browsing as they moved through these stands.

Bulls and cows did not show similar use patterns for well stocked swamp conifer stands. Cows used swamp conifers very little during spring, while bulls were found in conifer swamps approximately 13% of the time. It has been hypothesized that bulls seek areas of high quality forage during the period of the year when body and antler growth is maximal (Geist 1982). It is possible that bulls are finding small pockets of succulent and nutritious forage along the edge and in small openings within these conifer swamps. It has also been suggested that bulls segregate from cows except during the rut. It is hypothesized that this segregation reduces competition with cows that have or may in the future bear the bull's young (Geist 1982). Spatial segregation of bulls and cows may also be related to their different predator avoidance strategies. Cows form large groups which aid in the detection of predators and reduce an individual's chance of being selected by the predator. Bulls are lighter in color and grow antlers, both of which make them the most conspicious animal in a group. It has been hypothesized that bulls do not join the large cow-calf groups for this reason. Bulls remain solitary or in small groups and try to hide from predators. The only potential predator of adult bulls in Michigan is man. Thus, the higher use of conifer swamps by bulls may be due to the bulls using the swamps as hiding cover to avoid poachers.

Summer habitat utilization

A total of 273 observations were recorded during summer habitat utilization sampling. During summer, 9 cows and 5 bulls had radio-collars and were monitored. Use of openings by both bulls and cows declined to less than 10% during summer (Table 7). As the grasses matured and dried out, elk use declined. Reduced ungulate use of herbaceous vegetation that has matured and dried out has been documented in several studies (Kirsh 1962, Stevens 1966, Edgerton and Smith 1971).

The decline in use of openings resulted from elk shifting their feeding pressure from grasses to the leaves of young deciduous trees. Overall, bull use of deciduous regenerating stands was very similar to spring use. However, the pattern of use among the age classes appeared somewhat different than spring habitat use. Bulls appeared to shift their use to younger stands, while use of stands > 11 years declined slightly. Cow use of regenerating stands was concentrated in stands > 6 years old.

As in spring, elk showed very little use of poorly stocked forest stands. Well stocked upland conifer, upland deciduous, northern hardwoods, and swamp conifers were used to a great extent during summer. Most of these stands have closed canopies which provide thermal cover for elk trying to avoid warm temperatures (Thomas et al. 1979).

Table 7. Cover type use (percent) by bulls and cows during summer 1983 in northern Michigan.

Cover type	Bulls (n = 5)	Cows (n = 9)
Open areas	8.3	6.2
Regenerating stands:		
Deciduous		
0-5 years	8.4	3.5
6-10 years	9.4	14.1
11-15 years	5.6	10.0
16+ years	6.2	7.9
Coniferous	3.0	1.8
Poorly stocked stands:		
Jack pine	1.1	0.0
Upland conifer	0.0	0.4
Upland deciduous	2.6	1.5
Northern hardwoods	1.0	0.0
Swamp conifers	0.0	0.0
Well stocked stands:		
Jack pine	1.7	2.4
Upland conifer	5.9	11.4
Upland deciduous	23.8	19.8
Northern hardwoods	13.4	17.9
Swamp conifers	8.7	2.3
Other stands	0.0	0.7

Fall habitat utilization

A total of 250 observations were recorded during fall habitat utilization sampling. During this period 9 cows and 6 bulls had radio-collars and were monitored.

Fall habitat use was similar to spring habitat use. Use of openings by both cows and bulls increased from summer use (Table 8). The radio-collared bulls again spent considerable time on hayfields on private land. The increased use of openings may be attributed to the fall green-up of vegetation and the rutting season. Fall green-up on most openings is a result of mowing and planting during late summer on both private and state lands.

Bulls and cows showed relatively uniform use of the different age classes of aspen. Poorly stocked stands were again used very little. Well stocked stands of upland conifers, upland deciduous, and northern hardwoods were used extensively by both bulls and cows.

Winter habitat utilization

A total of 1401 observations were recorded during the 3 years of winter habitat utilization sampling. In 1984, 8 cows and 5 bulls had radio-collars and were relocated 247 times. In 1985, 20 cows and 4 bulls had radio-collars with 858 observations being recorded. In 1986, 10 cows and 2 bulls had radio-collars. These particular bulls spent a majority of their time on private lands. As a result,

Table 8. Cover type use (percent) by bulls and cows during fall 1983 in northern Michigan.

Cover type	Bulls (n = 6)	Cows (n = 9)
Open areas	10.0	21.4
Regenerating stands:		
Deciduous		
0-5 years	3.3	1.9
6-10 years	4.5	6.6
11-15 years	5.7	4.9
16+ years	2.3	6.0
Coniferous	3.3	0.8
Poorly stocked stands:		
Jack pine	0.0	0.0
Upland conifer	0.0	1.3
Upland deciduous	9.5	0.6
Northern hardwoods	2.4	0.0
Swamp conifers	0.0	0.0
Well stocked stands:		
Jack pine	2.8	3.4
Upland conifer	14.8	11.6
Upland deciduous	12.4	17.1
Northern hardwoods	25.1	18.0
Swamp conifers	3.8	4.8
Other stands	0.0	1.3

very few habitat utilization observations were collected on them. The radio-collared cows were relocated 296 times.

Habitat utilization by elk differed among the 3 winters. Many of these differences appear to be related to differences in weather conditions during the 3 winters. The use of openings by elk was greatest during the winter of 1984 (Tables 9, 10, and 11). In 1984, the use of openings was primarily restricted to the period after 22 February. After this date, snow depths never exceeded 25 cm and were often much less. Snow depths were never less than 25 cm during the winter habitat utilization sampling periods in either 1985 or 1986. Thus, it appears that snow depths greater than 25 cm may prevent elk from pawing through the snow to feed on herbaceous vegetation.

Regenerating deciduous stands, primarily aspen, received a great deal of use by elk during all 3 winters (Tables 9, 10, and 11). Bulls spent approximately 40% of their time in these stands during both the 1984 and 1985 winters. Cow use of regenerating deciduous stands was more varied, with percent utilization ranging from 11.6 to 37.6%. Among the different age classes of regenerating deciduous stands bulls clearly spent the greatest amount of time in 11-15 year old stands. Cows also spent a greater amount of time in 11-15 year old stands, however, the differences were not as great as those noted for bulls. The greater use of the 11-15 year old stands may again be

Table 9. Cover type use (percent) by bulls and cows during winter 1984 in northern Michigan.

Cover type	Bulls (n = 5)	Cows (n = 8)
Open areas	8.2	8.3
Regenerating stands:		
Deciduous		
0-5 years	6.2	1.0
6-10 years	7.0	2.1
11-15 years	20.3	4.0
16+ years	5.6	4.5
Coniferous	2.0	5.5
Poorly stocked stands:		
Jack pine	0.0	0.0
Upland conifer	0.0	0.5
Upland deciduous	5.2	2.0
Northern hardwoods	0.8	0.0
Swamp conifers	0.0	2.2
Well stocked stands:		
Jack pine	1.5	3.4
Upland conifer	5.1	20.1
Upland deciduous	9.0	4.6
Northern hardwoods	4.4	13.1
Swamp conifers	21.7	27.4
Other stands	4.7	0.5

Table 10. Cover type use (percent) by bulls and cows during winter 1985 in northern Michigan.

Cover type	Bulls (n = 4)	Cows (n = 20)
Open areas	0.7	0.8
Regenerating stands:		
Deciduous		
0-5 years	3.6	8.5
6-10 years	4.0	4.7
11-15 years	29.8	12.9
16+ years	4.0	11.5
Coniferous	1.2	4.0
Poorly stocked stands:		
Jack pine	0.0	0.3
Upland conifer	0.0	0.1
Upland deciduous	9.4	1.6
Northern hardwoods	0.0	1.5
Swamp conifers	0.0	0.0
Well stocked stands:		
Jack pine	6.8	3.5
Upland conifer	13.4	6.8
Upland deciduous	13.8	15.5
Northern hardwoods	3.7	20.3
Swamp conifers	9.7	4.9
Other stands	0.0	3.7

Table 11. Cover type use (percent) by bulls and cows during winter 1986 in northern Michigan.

Cover type	Bulls[a]	Cows (n = 10)
Open areas		2.1
Regenerating stands:		
Deciduous		
0-5 years		4.5
6-10 years		9.0
11-15 years		14.2
16+ years		8.6
Coniferous		5.2
Poorly stocked stands:		
Jack pine		0.0
Upland conifer		0.3
Upland deciduous		2.3
Northern hardwoods		0.5
Swamp conifers		0.0
Well stocked stands:		
Jack pine		4.1
Upland conifer		8.4
Upland deciduous		7.3
Northern hardwoods		12.1
Swamp conifers		11.5
Other stands		14.8

[a]insufficient data

attributed to the availability of this age class and/or the availability of forage within stands of this age class.

Elk use of 0-5 year old regenerating stands was relatively low, except use by cows in 1985. Although the percent of time elk spent in these stands was low, Campa (unpubl. data) found relatively high browse utilization of young aspen stands. Campa also noted a trend of decreasing browse utilization with the age of the clearcut. These results were attributed to elk foraging more heavily on the younger vegetation which has a higher nutritional quality (Kozlowski and Keller 1968). In 1985, cows spent approximately 9% of their time in 0-5 year old aspen stands. This represented 70 relocations of radio-collared cows. Of these locations 81% were found within 3 stands. All 3 stands were 1 year old or less and were located within the homeranges of several radio-collared cows. These results suggest that elk will forage heavily on younger vegetation, but the amount of time it takes them to utilize a majority of the forage in these young stands is not great.

As in the other 3 seasons, use of poorly stocked forest stands during winter was generally low. In 1984, radio-collared bulls were found in poorly stocked upland deciduous stands 5.5% of the time. All locations were in different stands. In 1985, bull use of poorly stocked upland deciduous stands was slightly higher. All of the poorly stocked upland deciduous stands used in both years had aspen as their main component.

Elk use of well stocked forested stands varied among the 3 winters (Tables 9, 10, and 11). The greater use of upland conifers by cows in 1984 was primarily due to heavy use of 1 particular stand. This stand accounted for 63% of all observations in this cover type. This stand is similar to the red pine stand in which heavy elk use was found during spring. The stand had been thinned and was growing on fertile soil (Emmett sandy loam). This stand also developed an extensive hardwood understory. In 1984, the use of swamp conifers was the greatest, suggesting conditions were such that elk sought thermal cover periodically throughout the winter. Because the red pine stand was only partially thinned in 1984, the elk may have also used the unthinned portions of the stand for thermal cover. In addition, 3 young aspen stands are adjacent to the red pine stand. Thus, the high use of this stand is probably due to the abundance and juxtaposition of food and cover.

Elk use of well stocked swamp conifer stands also varied among the 3 winters (Tables 9, 10, and 11). Again these differences appear to be at least partially related to different weather conditions in each year. Based on winter severity index data (Verme 1968) collected at Atlanta, Michigan during the habitat utilization sampling periods, the winter of 1985 was the mildest winter with an index rating of 59.6 (T. Carlson pers. commun.). The winters of 1984 and 1986 had winter severity index ratings of 68.9 and 73.5, respectively. Verme (1968) suggested that a severity index greater than 100 would result in moderate to heavy losses of white-tailed deer. Considering that elk are larger and thus more mobile than deer during deep snow conditions, the 3 winters during the study period probably did not represent severe winter conditions for elk.

Winter habitat utilization - winter weather

An attempt was made to develop a linear discriminant function which used the winter habitat utilization data and winter weather data to predict whether or not an elk would be found in a conifer swamp on a particular day. The objective was to develop this function and correlate it with recruitment and/or survival data to formulate an elk winter severity index.

Initial attempts at constructing a discriminant function using data from all 3 winters (except 10% of the data that were saved to test the resulting function for misclassifications) failed to produce a usable model. Inspection of the data suggested that the results were confounded by differences in weather conditions in the Pigeon River Country State Forest (PRCSF) where the weather data were collected, and the Camp 30 Hills area where part of the habitat utilization data were collected. Another problem was that elk used swamp conifer stands not only during severe weather, but also when conditions indicated that thermal cover should not be necessary. As a result of these problems several assumptions were made: (1) The weather data would be applicable to habitat utilization data collected in the PRCSF; (2) Only habitat utilization data collected on cows would be used (survival and reproductive success of cows are the critical component of herd growth); (3) When snow depths are less than 38 cm elk do not seek conifer swamps for thermal cover; and (4) Locations in conifer swamps were only considered as the elk seeking thermal cover when 50% or more of the radio-collared elk were in conifer swamps on a particular day.

The initial weather variables used in the discriminant function are listed in Table 12. Because 1984 showed the highest use of conifer swamps, the habitat utilization and weather data for that year were used to construct the discriminant function. After applying the previously described assumptions, 62 usable locations remained. Of these locations, 44 were coded as non-swamp conifer and 18 were coded as swamp conifer. The resulting discriminant function correctly classified 91% of the non-swamp locations and 89% of the swamp conifer locations (Table 13). The overall Wilk's Lambda value was 0.4682. Wilk's

Table 12. Variables used in developing a discriminant function which predicts elk use of conifer swamps as thermal cover based on weather conditions.

Variable code	Variable description
V_1	Classification variable
V_2	Current temp. at time of location
V_3	Maximum temp. day of location
V_4	Mininum temp. day of location
V_5	Snow depth day of location
V_6	Maximum temp. previous day
V_7	Mininum temp. previous day
V_8	Snow depth previous day

Table 13. Classification matrix of the 1984 habitat utilization data collected on radio-collared cows in the PRCSF.

Group	Classified as non-swamp conifer	Classified as swamp conifer
non-swamp conifer	40	4
swamp conifer	2	16

Lambda is the multivariate extension of R^2 (Hintze 1986). A Wilk's Lambda of 1.0 implies low predictability while a value near 0.0 implies high predictability. The variables selected for the discriminant function were V_4, V_5, V_6, and V_7.

The method used to calculate the discriminant function is similar to multiple regression. The difference is that the dependant variable is discrete (coded 0 and 1, non-swamp and swamp conifer, respectively) rather than continuous (Hintze 1986).

Although this discriminant function performed reasonably well on the data that were used to construct it, the correct test of its accuracy would be with data not used for its development. In 1985, use of swamp conifers by radio-collared cows was very low. There was not a single day in 1985 when at least 50% of the radio-collared elk were found in a conifer swamp. As a result, all of the 280 usable locations were coded non-swamp conifer. The discriminant function correctly classified 74% of these locations. In 1986, 169 observations were selected based on the 4 assumptions. Of these locations, 156 were classified as non-swamp conifer and 13 were classified as swamp conifer. The discriminant function only correctly classified 67% of the non-swamp conifer locations and 15% of the swamp conifer locations.

The discriminant function did reasonably well in classifying the data used to construct it. However, the discriminant function did not accurately classify independent data. This suggests that there were differences among the 3 years of the study. In particular, 2 weather factors that were not measured may have contributed to the failure of the discriminant function. These 2 factors are wind chill and snow compaction. Although elk are homeotherms and do regulate their body temperatures, they cannot adequately regulate under extreme conditions of cold. As a result, elk must compensate through behavioral responses (Beall 1976), such as seeking thermal cover. Beall (1974) found that elk selected dense timber clumps and conifers when the wind chill factor approached -32° C. In addition, elk selected these same sheltered bed sites when wind velocities were greater than 30 km/h.

Snow depth appears to be the factor that is most limiting to elk distributions and movements (Banfield 1949, Anderson 1954, Knight 1970, Craighead et al. 1973, Ward 1973, Leege and Hickey 1977, Skovlin and Vara 1979, Sweeney and Sweeny 1984). Snow depths of approximately 40 cm have been correlated with elk movements to areas of lesser snow depth (Sweeney and Steinhoff 1976, Sweeney and Sweeney 1984). The condition or supportive quality of the snow is also an important factor influencing elk distributions.

Gaffney (1941) reported mature elk moving without difficulty in loose snow up to 102 cm. Verme (1968) found that weak surface crusts not only caused fatigue, but also frequent leg injuries to white-tailed deer. Parker et al. (1984), although unable to measure the supportive quality of snow (all experimental animals sank completely to the ground), found that energy expenditures of elk increased with the depth that the animal sank in the snow.

Verme (1968) developed a winter severity index for white-tailed deer in northern Michigan. The index is the sum of an air chill rating and a snow hazard rating. The snow hazard rating incorporates snow depths and a rating of its supportive characteristics. The index is computed weekly and the weekly ratings are summed for a yearly winter severity index. It is possible that the discriminant function could be improved by adding a daily rather than weekly measurement of the severity index to the list of variables used. This would allow habitat utilization to be related to wind chill and snow supportive quality.

Another factor which may have reduced the effectiveness of the discriminant function is that all 3 winters were relatively mild. Perhaps with the relatively mild weather, elk were able to select areas with favorable microclimates without seeking cover in conifer swamps. Robinson (1960) found that white-tailed deer penned in open cutover areas and densely wooded areas did not differ in physical condition at the end of winter. The author concluded that the deer in the cutover areas were able to select areas that provided a favorable microclimate. Beall (1976) concluded that elk selected their bedding sites according to the "comfort range" needed. Beall correlated this comfort range with the solar and thermal radiation conditions at each bedding site. The author found that the solar and thermal conditions vary considerably within a particular stand and the elk select different sites as weather conditions change.

Calving areas

The earliest date of parturition recorded was 25 May and the latest date was 29 June. Moran (1973) concluded that the peak of calving was approximately 1 June. The majority of newborn calves found during this study were born during the first 2 weeks of June.

The radio-collared cows chose a wide variety of cover types in which to calve. Calving sites were found in sawlog redpine stands, sawlog maple stands, a new aspen clearcut, a 1 year old aspen clearcut, a 14 year old aspen clearcut, pole sized maple, oak, and aspen stands, as well as young regenerating jackpine stands. None of the radio-collared cows which borne more than 1 calf throughout the study period showed any fidelity for calving sites.

Several studies have suggested that cow elk select hiding cover for calving areas (Altman 1952, Altman 1956). Other studies have found no apparent selection for hiding cover (Stevens 1966, Sweeney and Steinhoff 1976, Marcum 1975). For elk that migrate, the location of the calving area may be a function of where the animals are during spring migration. A common factor found in many studies is that calving and subsequent calf bedding sites generally occurred in an ecotone (Johnson 1951, Anderson 1954, Picton 1960, Harper et al. 1967, Boyd 1970, Davis 1970, Coop 1971, Reichelt 1973). Moran (1973) studying elk in Michigan found elk calving in areas of heavy cover near openings.

The diversity and interspersion of cover types in the study area apparently has created an abundance of areas suitable for calving. The results indicate that suitable calving areas are not limiting in the study area.

Home range

Both rut and nonrut home range sizes of bulls were significantly greater ($p < 0.10$) than those of cows (Table 14). Typically, larger bulls separate themselves from cows and calves during all but the rutting season (Geist 1982). As the rutting season approaches, bulls often travel great distances to reach groups of cows. A similar movement occurs at the end of the rut when bulls move back to their nonrutting range. The rut home range sampling period

Table 14. Rut and nonrut homerange sizes (ha) for cow and bull elk in northern Michigan.

	Cows			Bulls		
Season	Sample size	Mean home range	Standard error	Sample size	Mean home range	Standard error
Rut*	24	2,699	1,002	6	5,376	550
Nonrut*	26	6,444	273	6	9,363	1,359

*Mean bull home range size is significantly greater ($p < 0.10$) than cow home range size.

encompasses these pre and postrut movement periods. As a result, the bull home ranges during the rut are larger than the cow home ranges.

The larger home ranges of bulls during the nonrut period may be a function of the differences in foraging and predator avoidance of bulls and cows. Bulls require more food than cows because of their larger body size and antler growth. Bulls also hide from predators rather than forming large groups like cows. In order to meet the nutritional requirements and maintain their avoidance strategy of hiding, it has been suggested that bulls explore areas in search of small pockets of highly productive forage (Geist 1982). Thus, they can obtain the food that they need and remain hidden from predators. The larger home ranges would then result from these exploratory movements.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model applicability

Geographic area

This model has been developed from data collected on the Michigan elk herd and data found in the literature. As a result of large differences in elk habitat between Michigan and western areas the applicability of this model is restricted to the northern lower peninsula of Michigan.

Season

The model was developed to evaluate the quality of elk habitat for the entire year. The model only specifically addresses the critical winter and spring periods, however, it is assumed that habitat suitability ratings for these periods relate directly to overall yearly habitat quality.

Minimum habitat area

The smallest area that will maintain elk is unknown. The smallest winter home range observed was 413 ha. The average winter home range was 3020 ha (approximately 12 square miles). The model has been developed based on an evaluation unit of 10 square kilometers (4 square miles). The rationale behind this evaluation unit size is that an elk is assumed to be able to travel to any other portion of the unit in a short period of time. This allows the assumption that all cover types which supply an elk the necessary food and cover requirements are readily accessible.

Model description

Overview

Three potential limiting factors were identified for elk in our region: (1) winter thermal cover, (2) winter food, and (3) spring food.

This model evaluates habitat suitability based on a plan where the percentage of the selected vegetation types in an area are combined with their predicted potential to provide the first 3 limiting factors. In addition, the interspersion and juxtaposition of these cover types is considered.

Winter thermal cover

Black et al. (1976) defined thermal cover as cover used by an elk to assist that animal in maintaining homoeothermy. White-tailed deer have historically made use of cedar and other conifer swamps for winter thermal cover in northern Michigan (Verme and Johnston 1986). It has also been shown that elk in Michigan will use these swamps during severe weather conditions (Moran 1973, Ruhl 1984).

To evaluate winter thermal cover as a limiting factor for elk, cover types were separated into 3 broad categories; wooded areas, open areas, and cultivated areas.

Open and cultivated areas do not provide any thermal cover and were assigned suitability indices of 0.0 (Table 15).

Wooded areas were further broken down into 7 groups; aspen, northern hardwoods (consisting primarily of maple), oak, other hardwoods, cedar, swamp conifers, and upland conifers. Cedar and swamp conifers were assigned the optimum suitability indices of 1.0 (Table 15). These cover types provide the maximum amount of thermal cover for elk due to their lowland locations and dense cover. Thus, elk may reduce their maintenance requirements by bedding in these stands. Upland conifers were assigned a suitability value of 0.5 because they provide some thermal cover but not as much as swamp conifers because of their relatively higher elevation and different growth form. The deciduous tree cover types were assigned a suitability value of 0.3 because with certain understory characteristics they can provide some thermal cover.

Due to stand structure differences caused by differing stand age, density, and understory, the optimum suitability indices just described must be modified in order to more accurately describe the quality of thermal cover provided by a particular stand.

Table 15 . Optimum winter cover suitability values for cover types found within the Michigan elk range.

Cover type	Winter cover suitability value
Wooded areas:	
Aspen	0.3
Maple	0.3
Oak	0.3
Other hardwoods	0.3
Cedar	1.0
Swamp conifers	1.0
Upland conifers	0.5
Open areas:	
Natural	0.0
Wildlife openings	0.0
Cultivated areas:	
Winter wheat	0.0
Hay - pasture	0.0
Corn	0.0
Beans	0.0
Other	0.0

The quality of thermal cover that cedar, swamp conifers, and upland conifers provide is assumed to be a function of the size of the stand (MOD 1), the percent canopy closure (MOD 2), the height of the trees (MOD 3), and whether the stand has been managed under an evenaged or unevenaged management system (MOD 4).

Thomas et al. (1979) developed a model which described the quality of spring, summer, and fall thermal cover relative to the width of the stand. No model was developed for winter thermal cover because most western elk migrate to different winter range. Michigan elk are nonmigratory, therefore, this model was adapted as a modifier for thermal cover provided by conifer stands (Fig. 7). The relationship is based on the differences between environmental conditions at the edge of the stand and conditions in the interior of the stand as well as the size of the stand necessary to accommodate herd behavior of elk. Stands greater than 150 meters in width are considered optimum.

Thomas et al. (1979) have also shown that stands need at least 70% canopy closure to provide satisfactory thermal cover. A complete canopy closure creates an umbrella effect which helps reduce the animals radiational heat loss to the open sky. A complete canopy also reduces the snow

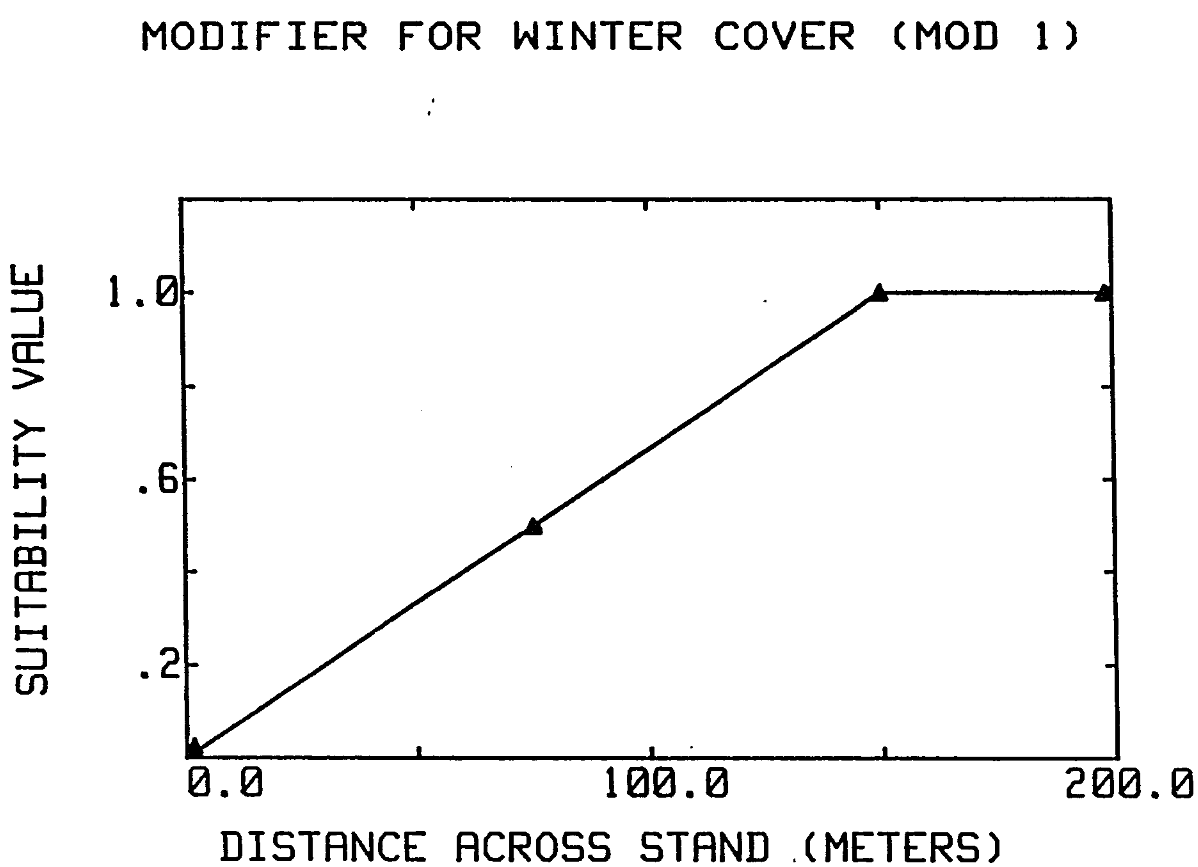

Fig. 7. The relationship between stand width and suitability of conifer stands as winter thermal cover.

depth on the ground and it increases the moisture content of the snow, both of which allow easier movements and reduced energy costs for elk (Verme 1965). Stands with canopy closures of 80% or greater are assumed to be optimum (Fig. 8).

Stands which are managed under an evenaged management system provide a great deal more thermal cover than stands which are managed under an unevenaged management system (Verme 1965). Even-aged stands modify wind currents and reduce their cooling effects on animals in those stands. As a result, even-aged stands are considered optimum while the suitability of uneven-aged stands is considered to be much lower (MOD 3) (Fig. 9).

If the stand is an even-aged stand an additional modifier is applied. Johnston (1977) reported that trees must be at least 12 meters in height to provide optimal thermal cover (Fig 10). This assumes that the taller the trees, the greater the depth of the canopy and thus the greater the ability of that stands to intercept snow and modify conditions beneath the canopy. A stand is considered optimum when the average tree height is 12 meters or greater.

An optimum stand for thermal cover would be an evenaged cedar or swamp conifer stand approximately 150 meters wide with trees $\geq$ 15 meters tall, and a canopy closure near 100%.

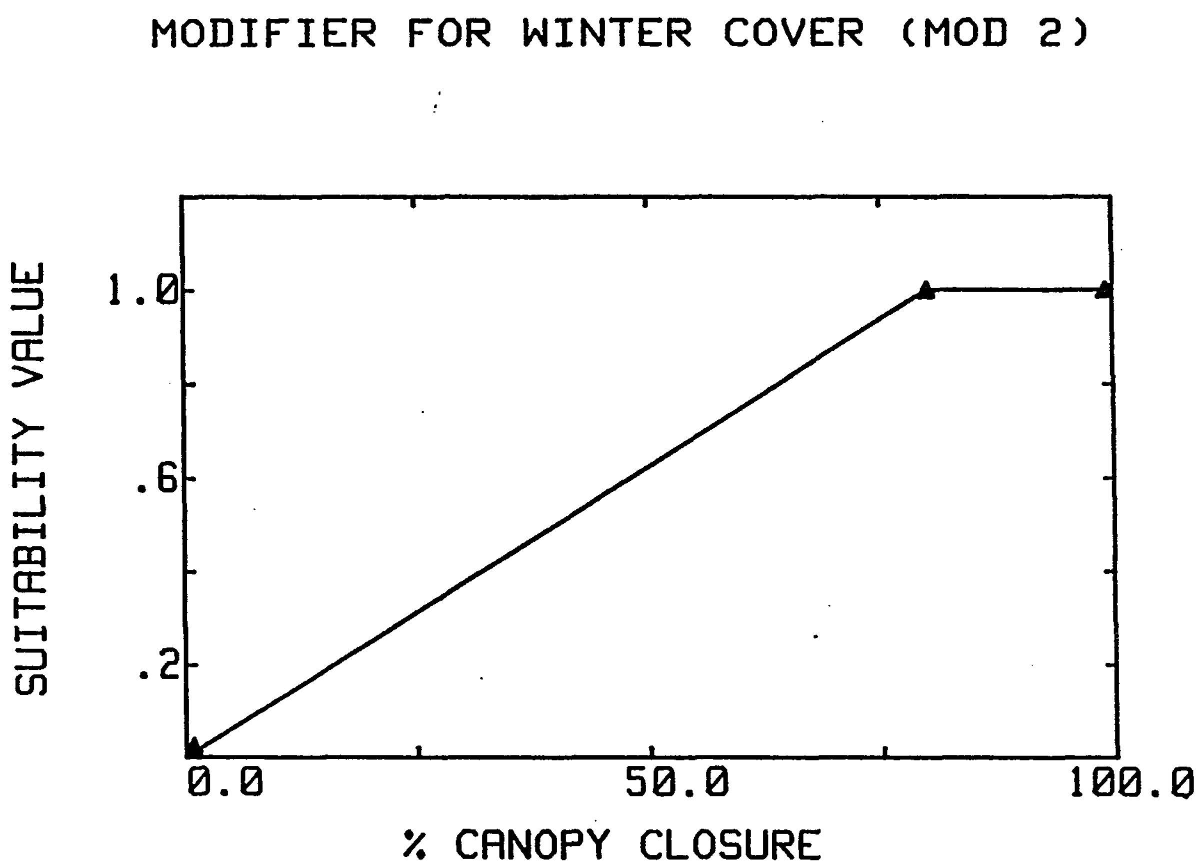

Fig. 8. The relationship between percent canopy closure and suitability of conifer stands as winter thermal cover.

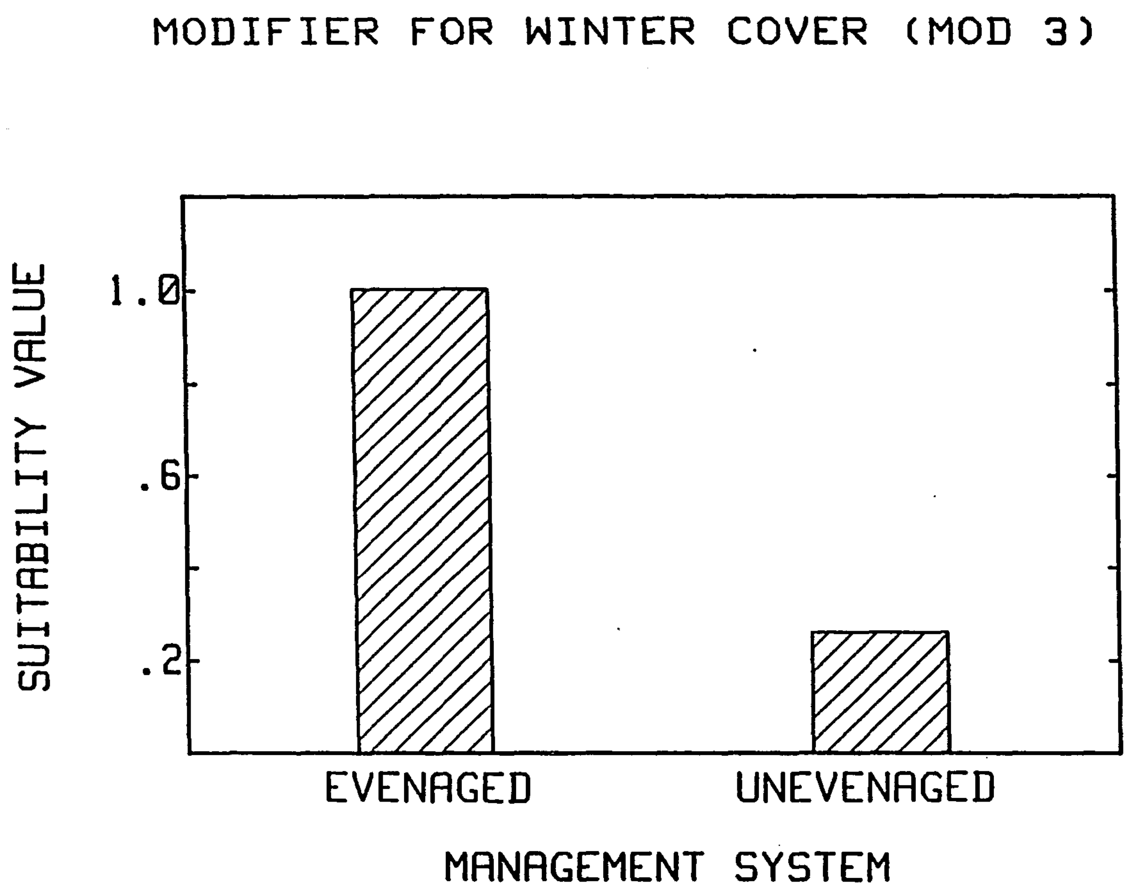

Fig. 9. The relationship between type of forest management system and suitability of conifer stands as winter thermal cover.

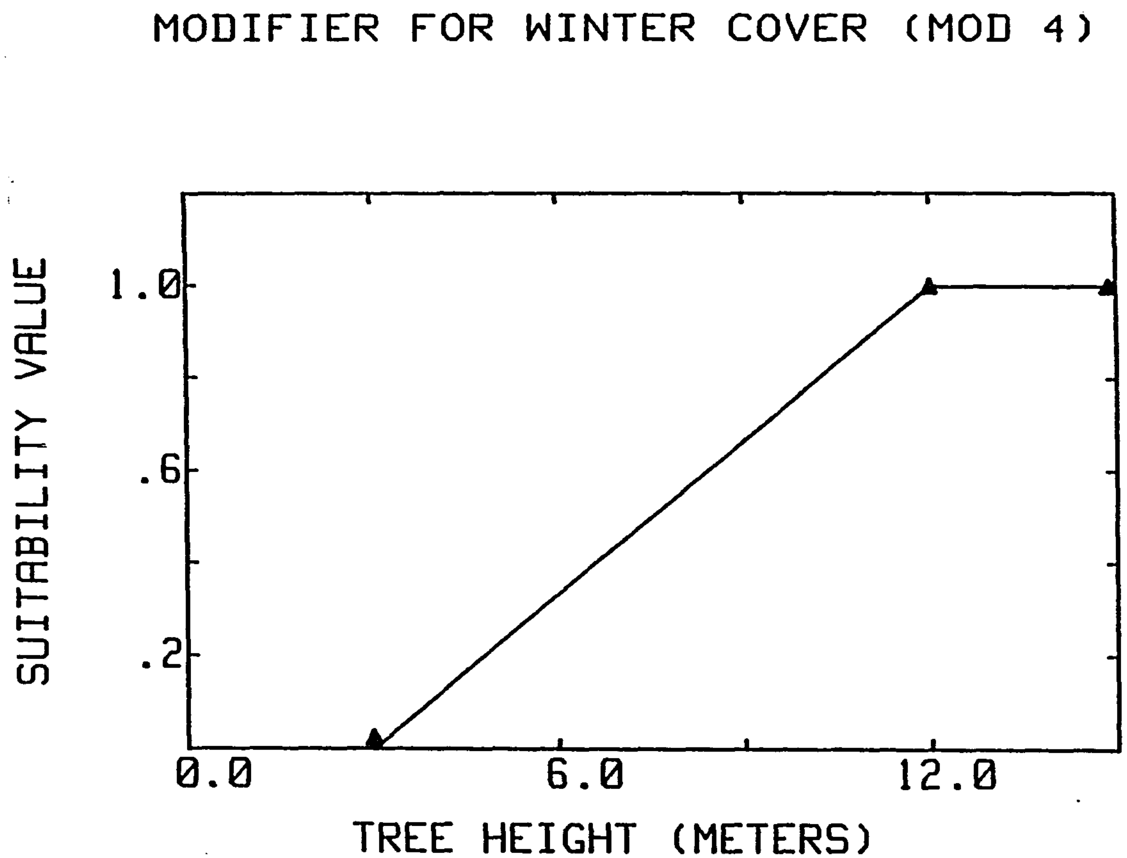

Fig. 10. The relationship between tree height and suitability of conifer stands as winter thermal cover.

The quality of thermal cover that deciduous stands provide is assumed to be partially dependant on the average basal area of the stand. Tree trunks reduce air movements which protects the animal from the chill factor associated with low temperatures and increasing wind speed (MOD 5). It is assumed that as the basal area of the stand increase, the quality of that stand as thermal cover also increases. Stands with an average basal area 16 m^2 / ha (69 ft^2/ac) or more are assigned a suitability value of 1.0 (Fig. 11). The value 16 m^2 / ha is equivalent to the MDNR's Forest Operations Inventory definition of a well stocked stand.

Stands with the same basal area can have very different structures. For example, a stand of pole sized trees can have the same basal area as a stand of sawlog sized trees. Beall (1974) found that during winter elk selected bedding sites next to the largest diameter trees in the stand. This information was used to develop another modifier for deciduous thermal cover. The quality of deciduous thermal cover is assumed to be a function of the size of the trees in the stand. Stands with trees > 35 cm dbh are assumed to be optimal (MOD 6) (Fig. 12).

An additional factor that affects the quality of deciduous thermal cover is the amount of conifer understory present. Low vegetation reduces air movements which protects the animal from wind chill. It is assumed that the greater the frequency of conifers 1 meter in height or

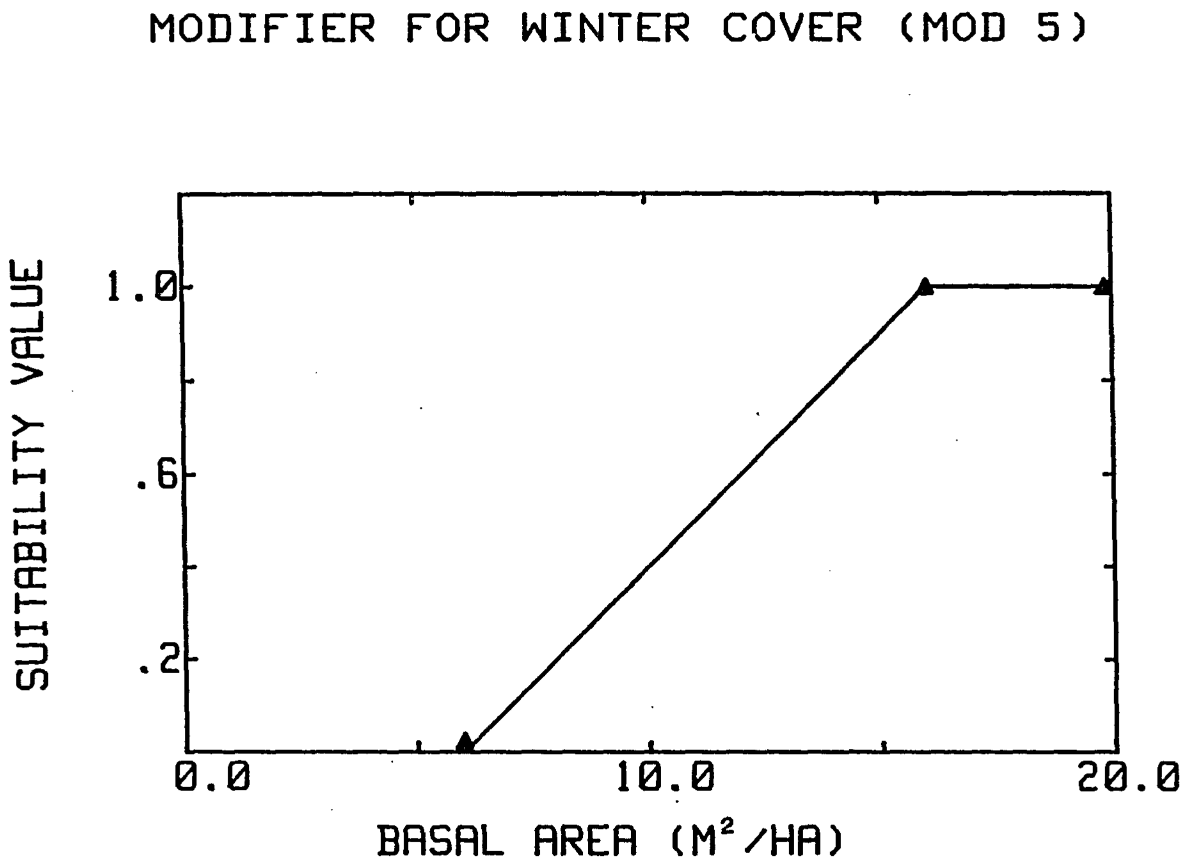

Fig. 11. The relationship between average basal area (m^2/ha) of the stand and suitability of deciduous stands as winter thermal cover.

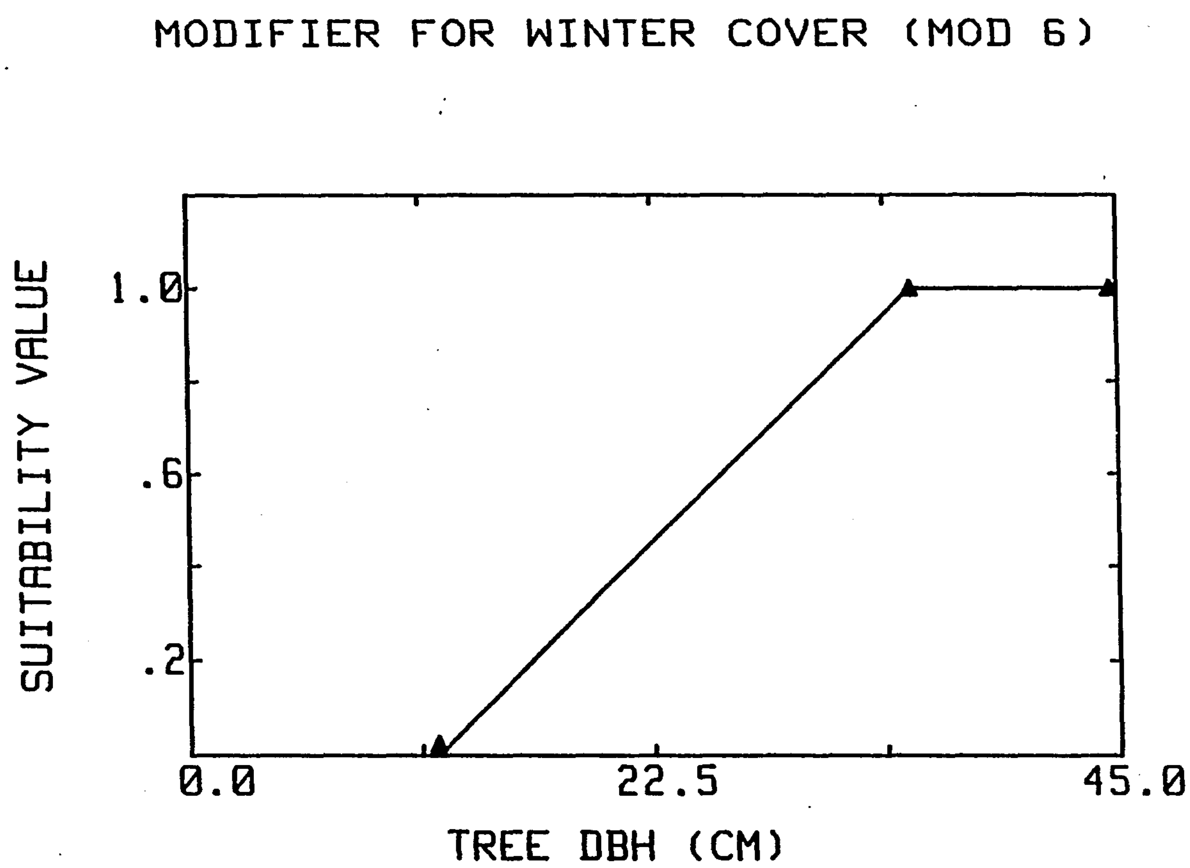

Fig. 12. The relationship between average tree diameter at breast height (dbh) (cm) and suitability of deciduous stands as winter thermal cover.

greater, measured by 5m x 5m plots, the better suited that stand is for thermal cover (MOD 7) (Fig. 13).

Optimum conditions for thermal cover in deciduous stands are found in dense mature stands with a well developed conifer understory greater than 1 m in height.

Optimum elk habitat is assumed to have 10% of the area in cover types which have a winter cover suitability rating of 1.0. To determine the overall winter cover suitability value (WCSV) for the evaluation unit, perform the following steps:

1. Identify the cover type of each stand in the evaluation unit.

2. Determine the percentage of area each stand occupies in the evaluation unit.

3. Based on the previous discussions, select those stands which appear to provide the best winter cover. The number of stands selected is limited by the area of stands. The winter cover suitability value for the area is determined on the 10% of the area that represents the best winter cover in the evaluation unit.

4. Assign each cover type its optimum suitability value (OSVWC) as winter cover based on its cover type.

5. For each stand multiply its OSV by its corresponding modifiers.

6. If conifers are present in the understory of a deciduous stand, apply the basal area (MOD 5) and tree dbh (MOD 6) modifiers. Compare the resulting value to the value of stand when modified by the frequency of conifer understory (MOD 7). The stand is assigned the highest of the 2 values.

7. Multiply the modified suitability value of each stand by the percentage of area that the stand occupies in the evaluation unit.

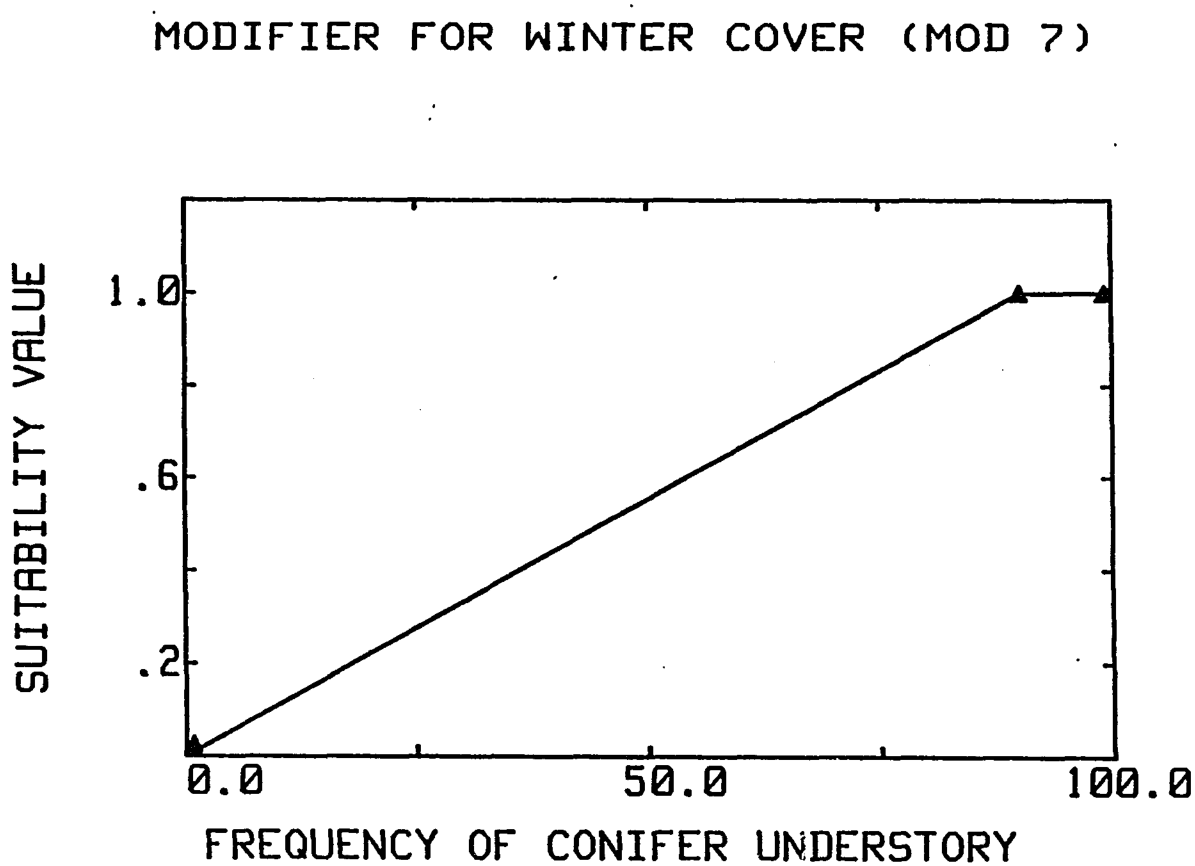

Fig. 13. The relationship between frequency of conifer understory and suitability of deciduous stands as winter thermal cover.

8. Sum the values determined in step 7 for the stands which represent the best 15% winter cover in the evaluation unit.

9. The winter cover suitability value for the evaluation unit is equal to the total determined in step 8 divided by 0.15.

Winter food

Winter food is defined as those foods, primarily browse, which are available to the elk above the snow cover. To evaluate winter food as a limiting factor for elk, the cover types were separated into the same categories that were used for evaluating winter cover.

Aspen, maple, and cedar were assigned the optimum suitability value of 1.0 because these species can provide abundant and preferred food (Table 16). Oak regeneration is lower in nutritional quality than aspen or maple so it was assigned a lower suitability value, as was the category other hardwoods (Haufler and Woodyard 1986). Upland conifers themselves have very little food value for elk, however, with certain understories they can provide a good source of winter browse. Swamp conifers can provide some winter food because there is often a small cedar component in these stands.

Open areas and cultivated areas do not have any food value in winter because most herbaceous material is dead and unavailable due to snow cover. The suitability values for crops such as corn may have to be modified if the crop is left standing.

Table 16. Optimum winter food suitability values for cover types found within the Michigan elk range.

Cover type	Winter food suitability value
Wooded areas:	
Aspen	1.0
Maple	1.0
Oak	0.7
Other hardwoods	0.5
Cedar	1.0
Swamp conifers	0.2
Upland conifers	0.7
Open areas:	
Natural	0.0
Wildlife openings	0.0
Cultivated areas:	
Winter wheat	0.0
Hay - pasture	0.0
Corn	0.0
Beans	0.0
Other	0.0

As with winter cover, the quality of food each cover type provides varies with the stand's structure. Thus, the optimal suitability values must be modified in order to accurately describe each stands potential to provide winter food.

The quality of winter food that aspen provides is a function of the height of trees within the stand (MOD 8) (Fig. 14). Campa (unpubl. data) studying 1-5 year old aspen clearcuts found a significant decline in browse utilization with increasing age of the stand. An optimum stand of aspen would be between 1 - 2.5 m tall. After aspen reaches 3 m the trees are usually large enough that elk have difficulty bending them over to reach the current annual growth.

The quality of winter food that cedar provides is assumed to be a function of the density of trees less than 7.5 meters tall (MOD 9) (Fig. 15). Verme (1965) suggested that the optimum quantity and quality of browse in Michigan's Upper Peninsula deer yards occurred when the trees were between 5 and 9 meters tall. Although elk are larger than deer and can reach higher for browse, snow depths in the Upper Peninsula are much greater than those found in the Northern Lower Peninsula. The lesser snow depths are assumed to negate the height advantage of elk, therefore Verme's results will be directly applied.

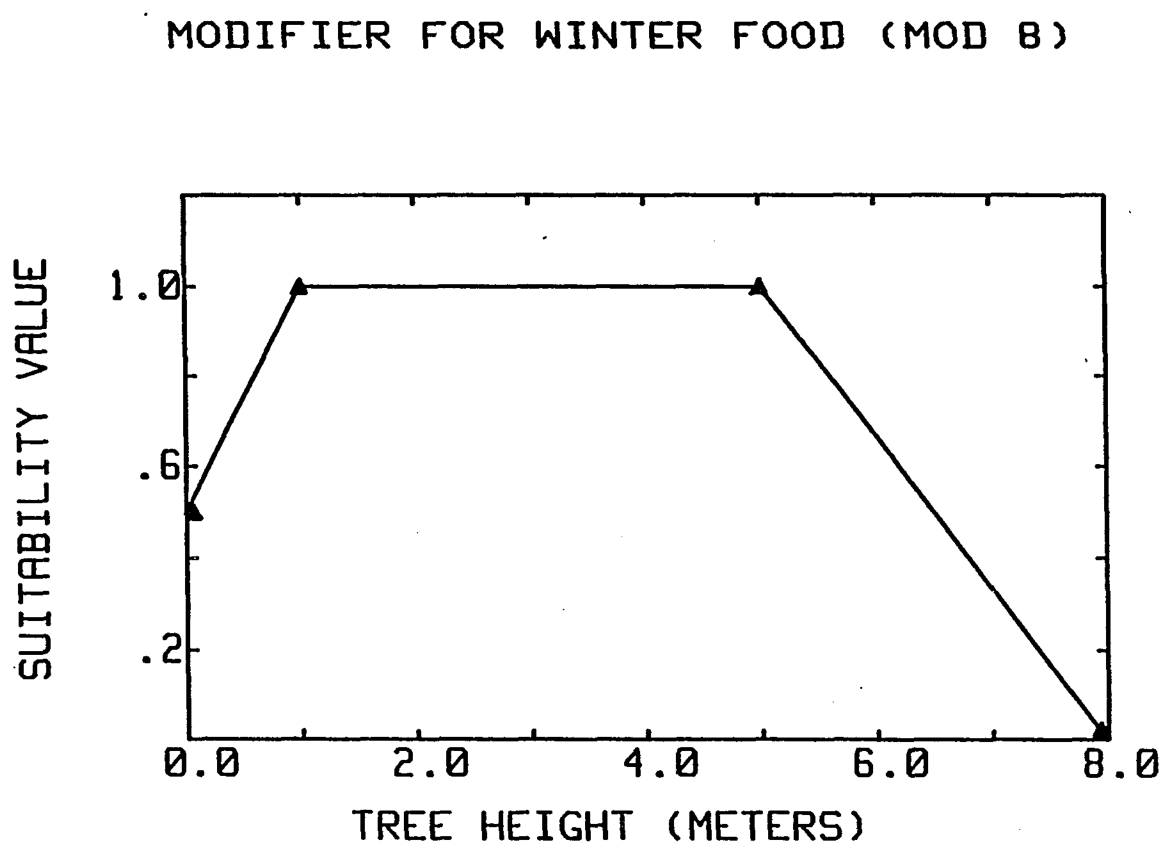

Fig. 14. The relationship between average tree height of aspen and the suitability of aspen as winter food.

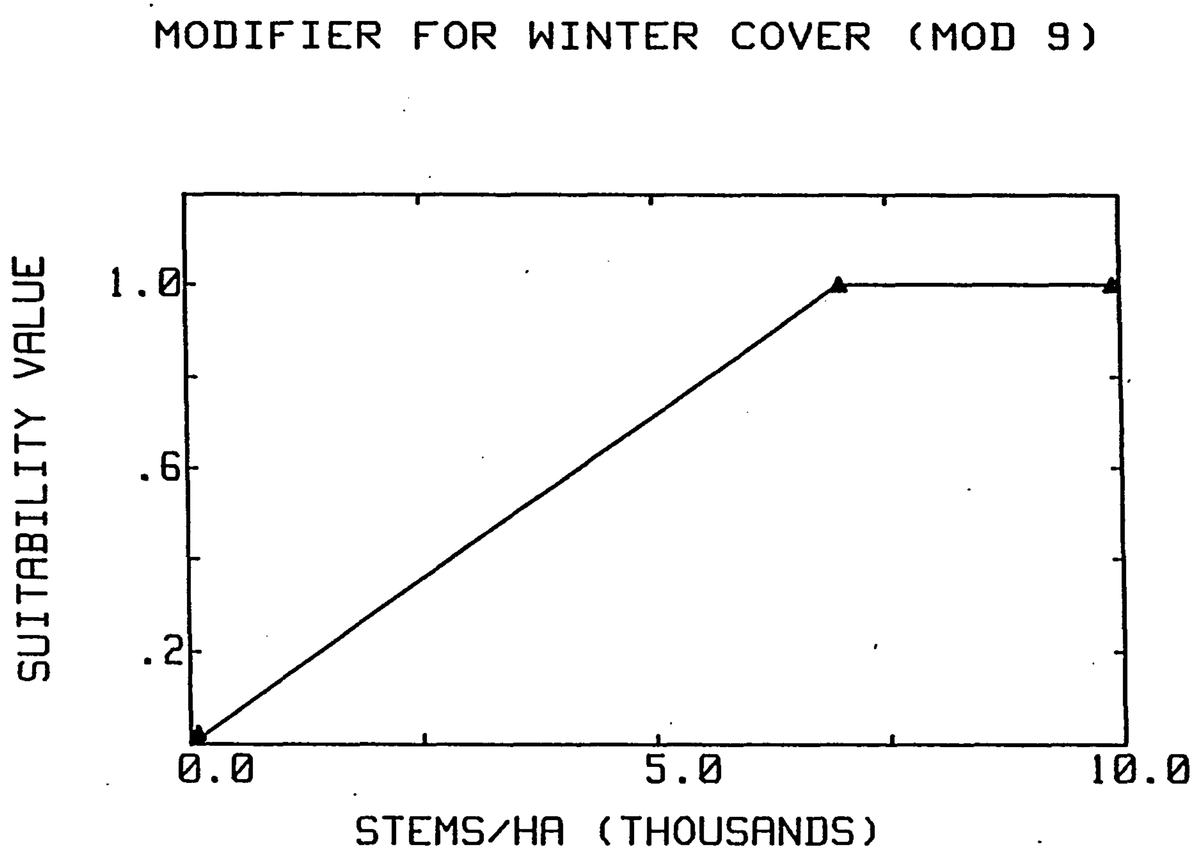

Fig. 15. The relationship between stand density and the suitability of cedar as winter food.

The amount of winter food that upland conifer stands can provide is dependant on the presence and development of a hardwood understory. Because of snow cover and the height to which elk can browse, only stems between 0.5m - 2m are considered as potential food for elk. It is assumed that upland conifer stands with hardwood stem densities greater than 10,000 stems/ha will provide optimum winter food for this cover type (MOD 10) (Fig. 16).

The quality of hardwoods as winter food is also assumed to be related to the density of trees between 0.5m - 2m in height within the stand (MOD 10)(Fig. 16).

The procedure for determining the overall winter food suitability value (WFSV) is similar to the one described for winter cover. Optimal elk habitat is assumed to have 15% of the area in cover types which have a winter food suitability rating of 1.0. Optimal suitability values for winter food and their appropriate modifiers are substituted for those used for winter cover.

Spring food

High nutritional quality forage is needed by elk in the spring to regain any loss of physical condition incurred during winter. Spring foods are defined as those foods available to elk as soon as the snow cover melts. Optimum spring foods would be the young growth of fertilized grasses and crops such as rye on wildlife

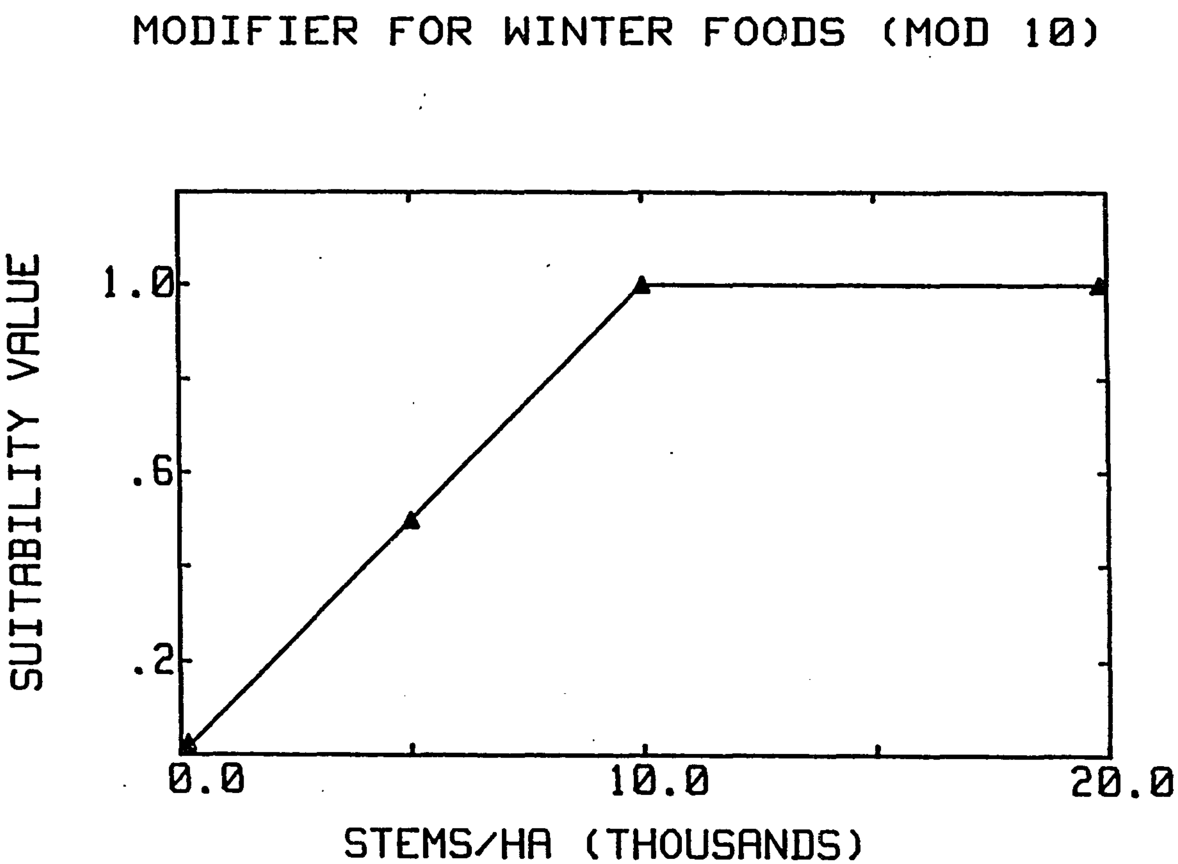

Fig. 16. The relationship between stem density of deciduous trees, except aspen, and the suitability of deciduous trees as winter food.

openings and winter wheat (Table 17). However any new growth such as hay fields, pasture, or natural openings, although typically unfertilized, will provide good forage. Corn and beans are assigned a relatively low suitability value because they will only be available at the end of the spring season.

The value of woody material decreases in the spring because of the increase in herbaceous material. Hardwoods are still available as browse and in late spring the leaves are beginning to emerge. The modifiers for the quality of spring food provided by hardwoods are the same as those described for winter foods.

The procedure for determining the overall spring food suitability value (SFSV) is similar to those described for winter cover. Optimal elk habitat is assumed to have 10% of the area in cover types which have a spring food suitability rating of 1.0. Optimal suitability values for spring food and their appropriate modifiers are substituted for those used for winter cover.

Table 17. Optimum spring food suitability values for cover types found within the Michigan elk range.

Cover type	Spring food suitability value
Wooded areas:	
Aspen	0.7
Maple	0.5
Oak	0.4
Other hardwoods	0.3
Cedar	0.7
Swamp conifers	0.5
Upland conifers	0.5
Open areas:	
Natural	0.7
Wildlife openings	1.0
Cultivated areas:	
Winter wheat	1.0
Hay - pasture	0.9
Corn	0.2
Beans	0.2
Other	0.1

Model relationships

HSI determination

The HSI value for an area is the lowest of the 3 suitability values calculated for winter cover, winter food, or spring food.

Summary of model variables

The vegetation present in the elk range was broken into 3 categories; wooded areas, open areas, and cultivated areas. Each of these categories was then subdivided into more specific cover types. These cover types were assigned optimal suitability values for each of the potential limiting factors. The actual value that each cover type provides was assumed to be influenced by some aspect of the stands structure or composition. The particular characteristic of the stands structure or composition that was assumed to affect the quality of that stand varied with each cover type and the limiting factor under consideration. The final suitability value for each limiting factor was made by comparing the modified suitability values to the assumed optimum values. The HSI for the area was lowest value determined of the 3 limiting factors.

HSI model application

The suggested measurement techniques for each modifier and variable are shown with their appropriate cover types in Table 18. If the area under evaluation is state forest land, some of the data may be obtained by examining the Michigan State Forest Operations Inventory (MSFOI) summaries.

As presented, the model represents a first draft version. The model has not yet been verified. Plans for improvement of the model include the linking of a geographic information system (GIS) with the habitat utilization data. Verification of the model will also use the GIS to generate most of the data needed to test the model.

Elk habitat management guidelines can be developed by considering timber management rotation lengths relative to optimum elk habitat conditions described by the model. Based on the model (assuming an evaluation unit size of 10 square km), optimum elk habitat at any single point in time would be provided by approximately 100 ha (256 acres) of 60 year old or older cedar, 155 ha (384 acres) of 0 - 15 year old aspen, and 100 ha (256 acres) of wildlife openings. In order to provide optimum elk habitat through time, the rotation lengths of the stands which supply the necessary food and cover requirements must be considered. For example, in order to continually provide 155 ha of aspen from 0 - 15 years old, an additional 260 ha (640 acres) of aspen must be evenly distributed in the 16 - 40 year old ages classes (assuming a 40 year rotation of aspen). If the rotation length of aspen is 60 years, then 470 ha (1150 acres) of aspen must be distributed in the 16 - 60 year old age classes. Similarly, if the rotation age of cedar is 120 years, then an additional 100 ha of cedar is needed in the 0 - 60 year old age classes. Thus, to maintain optimal elk habitat in an area where the rotation length for aspen is 40 years and the rotation length for cedar is 60 years, a total of 725 ha (1790 acres) would have to be in aspen, cedar, and wildlife opening cover types. Considering a 10 square km area, this would mean that if there was more than 310 ha (770 acres) in cover types other than those which provide optimal food and cover conditions, the area would not be able to provide optimal elk habitat. Thus, an upper limit to the amount of covertypes such as northern hardwoods, oak, and pine, which are often managed by selection cuts, can be established. However, it should be noted that because the model has not yet been verified any management guidelines developed from the model are also unverified.

Table 18 . HSI model variables and modifiers, their application to cover types and suggested measurement techniques.

Variable or modifier	Cover type(s)	Suggested technique
MOD 1 = stand size	Cedar Swamp conifers Upland conifers	Estimate from aerial photograph or MSFOI or GIS
MOD 2 = canopy closure	Cedar Swamp conifers Upland conifers	Estimate from aerial photographs or use the line intercept method or GIS
MOD 3 = management system: evenaged or unevenaged	Cedar Swamp conifers Upland conifers	Field inspection or MSFOI or GIS
MOD 4 = tree height	Cedar Swamp conifers Upland conifers	Field sampling
MOD 5 = basal area	Aspen Maple Oak Other hardwoods	Point sampling or MSFOI or GIS
MOD 6 = tree dbh	Aspen Maple Oak Other hardwoods	Field sampling
MOD 7 = frequency of conifer understory greater than 1 m in height	Aspen Maple Oak Other hardwoods	Plot sampling
MOD 8 = tree height	Aspen	Field sampling
MOD 9 = stand density	Cedar	Plot sampling or GIS
MOD 10 = stand density	Upland conifers Aspen Maple Oak Other hardwoods	Plot sampling or GIS

POPULATION ANALYSIS

Introduction

Michigan elk have been and are currently managed through the manipulation of the population size and structure, and management of the habitat. In the early 1960's the herd had grown to 1,200 - 1,500 animals and was responsible for damage to farm crops, fences, and forest regeneration (Moran 1973). The management strategy chosen in response to these problems was a population reduction program, implemented in the form of controlled hunting seasons. Controlled elk hunting seasons were conducted in 1964 and 1965. The hunting seasons were successful in reducing damage complaints by farmers and forest managers. Reduced herd size following these hunts precluded additional hunting during the remainder of the 1960's and 1970's.

Increased protection from poaching and improvements in habitat quality in the late 1970's allowed the elk herd to again increase in numbers. By the winter of 1984 the elk population was estimated to have grown to 850 animals. However, as the herd size grew so did the number of damage complaints from farmers and foresters. The MDNR's management response was to again initiate a hunting season to reduce population levels in areas where damage was occurring.

Effective harvest management is dependant on estimates of herd size, productivity, mortality, sex ratios, and age structure. In most cases accurate estimates of all these variables are not available. Recently, computer models which allow simulation of population dynamics and harvest management have been developed (Lang and Wood 1976, Bartholow 1986). These models speed calculations and allow repeated simulations of varying conditions and/or harvests in relatively short periods of time. In some cases, if there are accurate estimates of several variables (i.e. population size, natality, sex ratios), then estimates of an unknown variable (i.e. mortality) may be determined by balancing the model with respect to the known variables. Although these models can be very useful, the validity of the results is directly dependant on the accuracy of the data put into the model.

The objectives of this segment of the study were to: 1) determine the reproductive success of radio-collared cows, 2) monitor the pre-hunt survival of the calves of radio-collared cows, 3) estimate the sex ratio and age distribution of the herd, and 4) use the above information and other existing data in a simulation model to examine elk population dynamics.

Methods

Pregnancy rates, natality, and rearing success

Pregnancy rates were determined by examining the reproductive tracts of females harvested in the annual hunts (Schmitt et al. 1985, 1986). All cows harvested were aged by cementum annuli counts of an extracted incisor (Schmitt et al. 1985).

An estimate of natality was determined by recording the reproductive success of radio-collared cows during 1984, 1985, and 1986.

Rearing success was estimated by recording the survival of calves of radio-collared cows in November prior to the upcoming hunts. Repeated observations of radio-collared cows were made to insure that calves that survived were eventually sighted. Ear tagging of newborn calves aided in subsequent identification.

Sex ratio and age distribution

The sex ratio and age distribution of the elk herd was estimated during post-rutting season counts in 1984, 1985, and 1986. All observed elk were classified into 1 of the following categories: mature bull, yearling bull, cow, calf, or unknown. The counts were completed within 1 week during all years except 1985. In 1985 the count took 2 weeks. An effort was made to avoid double counting of animals.

Population modeling

The dynamics of Michigan's elk herd were simulated with a population model, POP-II (Version 6.03), developed by John Bartholow (Fossil Creek Software, Ft. Collins, CO). This model is a modified version of the ONEPOP model developed by Gross et al. (1973). ONEPOP required a mainframe computer to run, while POP-II was developed for micro computers.

POP-II requires inputs of an initial age structure, age and season specific mortality rates, and age specific recruitment rates. The model is based on a biological year beginning after all calves have been born. In a simple bookkeeping fashion, the model keeps track of the population by adding in reproduction and subtracting losses.

A simulation year in the model proceeds as follows. After the initial data inputs have been entered into the model, the first simulation step is to subtract the losses of animals during the preseason natural mortality period. This mortality period begins just after calves are born and continues until the start of the hunting season. Losses during this period include many forms of mortality such as poaching, predation, accidents, and disease. The next step in the simulation is the removal of animals killed during the hunting season. This mortality period subtracts not only those animals killed during the hunting season, but also those animals which were wounded and subsequently died, but were not recovered. Because in some cases hunters may be selectively taking certain age classes of animals (i.e. trophy bulls), the model allows the user to set relative effort values on the harvest of each sex and age class. This allows the age structure of the simulation harvest to mimic the age structure of the actual harvest. The third step is the removal of animals lost during the period of time beginning after the hunting season up until the calves are born. After this postseason natural mortality has been subtracted the model calculates the number of calves born. The number of calves born is based on yearly age specific recruitment rates. The final step in the simulation is the advancement of all age classes by 1 year and the placement of the new recruitment into the first age class. A more detailed description of POP-II can be found in Bartholow (1986).

The initial step in investigating Michigan elk population dynamics with the POP-II simulation model was to develop a base model which represented a best estimate of the population's dynamics during the period of 1975 - 1986. The model was begun in 1975 because this was the first year the MDNR conducted an elk census. The base 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 estimates. The population estimates used were determined from censuses carried out by the MDNR. Because natural mortality rates of Michigan elk are unknown, the base model was balanced by manipulating the natural mortality rates in order to achieve the estimated population sizes and herd structure. The base model was further refined by adjusting the relative effort values on males so that the age structure of the harvests in the simulation closely approximated the age structure of the actual harvests.

The base model gives us an estimate of the mortality rates that must be occurring in order to keep the population at a particular level. The accuracy of the mortality rates is relative to the accuracy of the population estimates, the estimates of natality, and the estimates of herd structure. Simulations were made to investigate the effects of varying these initial inputs (recruitment rates, population estimates, and herd structure) on mortality rates.

One of the goals of the MDNR's elk management program is to provide a viewable elk herd. For many elk watchers, an important component of that viewable herd is large antlered bulls. Typically, these larger bulls are 4.5

years or older. Because these older bulls are an important component of the population, simulations were made to determine the effect of different harvest stratigies on this segment of the herd.

Results and Discussion

Pregnancy rates, natality, and rearing success

The pregnancy rates determined from cows killed in the 1984 and 1985 hunts (Table 19) were within the range of rates reported in the literature (Green 1950, Cheatum and Gabb 1952, Kittams 1953, Flook 1970, Trainer 1971, Moran 1973, Follis and Spillett 1974). None of the 8 female elk calves shot were pregnant. Taber et al. (1982), in an extensive search of the literature, found no evidence of female calves breeding.

If the data from the 2 hunts are combined, yearlings had a pregnancy rate of 29% and adults had a pregnancy rate of 89%. These rates are slightly higher than those reported by Moran (1973) for Michigan elk harvested during the 1964 and 1965 hunts. The pregnancy rates of yearlings and adult cows killed in these earlier hunts was 23% and 77%, respectively (sample size n = 30 and n = 160, respectively). Moran (1973) reported that these rates were low relative to pregnancy rates of several western herds. It is unknown if the difference in pregnancy rates is real or a function of sampling error.

In 1984, only 6 cows were radio-collared during calving season. Five of these cows were adults. An

Table 19. Age specific pregnancy rates (%) of cow elk killed in the 1984 and 1985 hunting seasons (From Schmitt et al. 1985, 1986).

	1984		1985	
Age class	Sample size	Pregnancy rate	Sample size	Pregnancy rate
Calf	3	0	5	0
Yearling	5	40	9	22
Adult[1]	30	80	64	94

[1]an adult cow is 2.5 years old or greater when bred

additional adult cow whose transmitter had failed was sighted several times throughout the period. Of these 7 cows, only the yearling failed to produce a calf (Table 20). In the fall of 1984, 17 additional cows were radio-collared. Of these, 13 were 2.5 years or older (Adult cows) and 4 were yearlings. Ten of the 13 adult cows were observed with calves at the time of capture or during subsequent observations.

In 1985, 19 of the 23 radio-collared cows produced calves (Table 20). Adult cows had a natality rate of 89% (17 of 19 were successful) and yearling cows had a natality rate of 50% (2 of 4 were successful). It should be noted, however, that the sample size for yearlings was small. Of the 15 cows which produced calves in 1984, only 2 failed to produce calves in 1985. The natality rate of adult cows exceeded the pregnancy rate of adult cows killed in the December 1984 hunt. Due to the direction of this difference, more cows bearing calves than cows which were pregnant, it can be concluded that the difference was due to sampling error.

In 1986, 12 of the 15 radio-collared cows produced calves (Table 20). Mature cows had a natality rate of 85% (11 of 13 were successful) and 1 of the 2 yearling cows produced a calf. Thirteen radio-collared cows were alive in both 1985 and 1986. Of these, 9 produced calves in both years, 2 produced calves in 1986 but not 1985, and 2 did

Table 20. Calving success of radio-collared cows in northern Michigan during 1984, 1985, and 1986.

	Calving success		
Elk #	1984	1985	1986
8	Y	Y	Y
12	Y	Y	Y
14	Y	N	Y
16	Y	Y	-
20	Y	N	N
22	N*	Y	-
23	-	Y	Y
24	-	Y	-
25	-	N*	N
26	-	Y	-
27	-	Y*	Y
28	-	Y*	-
29	-	Y	Y
30	-	N*	Y
31	-	Y	-
32	-	Y	-
33	-	Y	-
34	-	Y	Y
35	-	Y	Y
36	-	Y	-
37	-	Y	Y
38	-	Y	-
39	-	Y	Y
40	-	-	N*
41	-	-	Y*

*Yearling age class during the breeding season.

not produce calves in either year. Of the 10 radio-collared cows which were monitored during all 3 years, 6 successfully produced a calf each year, 3 produced calves 2 of the 3 years, and 1 only produced a single calf during the 3 years.

The natality rate of adult animals in 1986 was 9% less than the pregnancy rate determined from the cows killed during the 1985 hunt. The direction of the difference might suggest prenatal losses due to winter severity. However, the differences between pregnancy rates and natality rates observed in 1984 - 1985 indicate that sampling variance is as likely a cause.

In 1985, 4 of the 19 calves observed with radio-collared cows during the summer were believed to have died by December. Although this represented a 21% loss of calves, the sample size may be too small to extrapolate to the entire population. All 12 of the calves of radio-collared cows born in 1986 survived the pre-hunt period.

Sex ratio and age distribution

The herd structure was determined in post-rutting season counts during 1984, 1985, and 1986. The number of bulls / 100 cows in the sample ranged from 74 in 1984 to 52 in 1985 (Table 21). The number of calves / 100 cows ranged from 54 in 1984 to 46 in 1985. Cows represented 44%, 51%, and 45%, respectively, of the animals counted during the 3

Table 21. Post-rutting season classification of Michigan elk in 1984, 1985, and 1986.

Year	Adult bull	Yearling bull	Adult cow	Calves	Total	Ratio Bull : Cow : Calf
1984	71	45	157	84	357	74 : 100 : 54
1985	47	56	199	91	393	52 : 100 : 46
1986	105	25	179	90	399	73 : 100 : 50
Totals	223	126	535	265	1149	

years.

Czaplewski et al. (1983) derived equations which can be used to determine required sample sizes and confidence limits for wildlife population ratios. These equations have the following underlying assumptions: 1) the population is defined, 2) individual animals are randomly sampled with no biases, 3) an upper limit to the population size is known, and 4) sampling is conducted without replacement. Based on Czaplewski et al. method's, 90% confidence intervals were placed on bull : cow and calf : cow ratios (Table 22). To increase the precision of these ratios the sample sizes would have to be increased (Czaplewski et al. 1983). For example, for a desired precision of ± 5 bulls / 100 cows with a herd size of 1000, and a bull : cow ratio of approximately 70 : 100, the number of elk, excluding calves, that must be counted is approximately 350. Similarly, if the calf : cow ratio is approximately 50 : 100, the number of elk, excluding bulls, that must be counted is approximately 340. Because cows must be counted for both ratios, the total sample size for an approximate 90% confidence interval of ± 5 bulls or calves / 100 cows is slightly over 500 animals.

The relatively wide confidence intervals on the current estimates of herd structure indicate a need for an improvement in the data collection procedure. Considering the increased number of animals which must be counted and

Table 22. Confidence intervals (90%) of bull : cow and calf : cow ratios determined as described by Czaplewski et al. (1983).

Year	Bull ± C.I. : 100 Cows	Calves ± C.I. : 100 Cows
1984	74 ± 11 : 100	54 ± 9 : 100
1985	52 ± 8 : 100	46 ± 7 : 100
1986	73 ± 11 : 100	50 ± 8 : 100

the short time span available to count the animals to avoid double counting, the need for the use of a helicopter is indicated. A helicopter could cover much more area in a shorter period of time than a person in a vehicle or on foot.

Moran (1973) estimated the bull : cow : calf ratio of the Michigan elk herd each fall during a 6 year period (1963 - 1968). The mean ratio determined from these counts was 50 : 100 : 55. The number of bulls / 100 cows ranged from a low of 30 in 1963 to a high of 113 in 1967. The number of calves / 100 cows ranged from a low of 43 in 1963 to a high of 82 in 1964.

Population modeling

The initial population and natural mortality rates used to balance the base model are shown in Table 23. The actual harvest figures from the 1984 - 1986 hunts and the projected harvest quotas for the 1987 season are shown in Table 24 . The base model assumed constant age specific recruitment rates throughout the entire simulation. Although it is unlikely that recruitment rates remained constant over the entire study period, there are no data available which would permit accurate estimates of fluctuating recruitment rates to be entered into the model. The recruitment rates used in the base model, expressed as the number of calves / 100 females, were: 0 / 100 females

Table 23. Initial population (numbers of animals) and natural mortality rates (%) used in the base run of the POP-II simulation of the Michigan elk herd.

Age	Initial pop.		Preseason mort.		Postseason mort.	
	bull	cow	bull	cow	bull	cow
1[1]	31	31	8	6	10	10
2	24	24	5	3	8	5
3	16	20	7	2	8	2
4	10	18	7	2	10	2
5	8	15	7	2	12	3
6	6	11	7	2	15	3
7	4	7	8	2	20	4
8	3	5	8	3	25	4
9	2	4	8	3	30	4
10	1	3	8	3	35	5
11	0	2	12	3	40	6
12	0	1	15	5	45	10
13	0	0	20	8	50	15
14	0	0	25	8	60	25
15	0	0	25	10	100	100

[1]age class 1 animals are calves

Table 24. Harvest quotas by sex and age category used in the POP-II simulations of the Michigan elk herd.

Year	Subadult harvest	Bull harvest	Cow harvest
1984	4	10	35
1985	10	29	80
1986	4	39	50
1987[1]	8	35	62

[1]proposed harvest

(adults). The model was balanced relative to the MDNR estimated population levels (Table 25) and a bull : cow ratio of approximately 65 : 100. Because varying annual harvests impact the bull : cow ratio, the model was balanced relative to the bull : cow ratio during the prehunt period of 1975 - 1984.

The relative effort values for all age classes of cows were set equal to 1.0. When all effort values are set 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, the harvest is directly proportional to the availability of the animal. Inspection of the age structure of cows harvested in the 1984, 1985, and 1986 hunts indicate that this is a reasonable assumption. Inspection of the age structure of bulls harvested in the 1984, 1985, and 1986 hunts indicated that hunters were not harvesting the different age classes of bulls relative to their abundance (Table 26). Hunters were apparently selecting more older and larger bulls. The relative effort values for bulls were adjusted so that the age structure of bulls in the simulation harvests was similar to the age structure of the actual harvests (Table 26).

Currently, the only completely known loss from a particular mortality form are the numbers of animals killed during the legal hunting seasons. Because nonhunting or

Table 25. MDNR estimates of population size (January) by year and the corresponding population level found in the base run of 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

Table 26. Comparisons of the actual age structure of bulls harvested in the 1984, 1985, and 1986 elk hunts with the age structure of simulated harvests using different relative (RE) values.

Model	Actual harvest			Simulated harvest				Simulated harvest			
age	1984	1985	1986	RE	1984	1985	1986	RE[3]	1984	1985	1986
2[1]	1	7	4[2]	1.0	3	9	12	1.0	1	3	5
3	1	6	10	1.0	2	6	9	2.0	2	5	7
4	2	3	4	1.0	2	5	6	2.0	1	4	5
5	2	4	5	1.0	1	3	4	4.0	2	5	7
6	0	1	5	1.0	1	2	3	5.0	2	4	6
7	2	2	7	1.0	1	2	2	5.0	1	3	4
8	1	5	1	1.0	0	1	1	5.0	1	2	2
9	1	0	2	1.0	0	1	1	5.0	0	1	1
10	0	0	0	1.0	0	0	0	5.0	0	1	1
5+[4]	6	12	20		3	9	11		6	16	21

[1]age class 2 animals are yearlings

[2]age determined by tooth wear

[3]relative effort values used in the base model

[4]age class 5+ animals are actually 4.5 years or older

natural mortality rates (including poaching losses) of Michigan elk are unknown, the model was balanced by manipulating the natural mortality rates in order to approximate the estimated population sizes and herd composition. Thus, the simulation provides an estimate of the natural mortality rates that must be occurring in order to keep the population at a particular level.

The base run simulation estimated annual natural mortality (excluding harvest mortality) for the entire herd to be 13%. Annual natural mortality of bulls and calves was approximately 17%, while cow annual natural mortality was only 8%.

The number of elk lost in a simulation year can be compared with known numbers of elk lost during that same year. During the biological year of 1985 (June 1985 through May 1986), 26 elk were found dead. These included 14 bulls, 10 cows, and 2 calves. During the same period the model predicted a loss of 151 animals (excluding losses from legal hunting). Of the projected losses, 63 were bulls, 41 were cows, and 47 were calves. These results suggest that less than 20% of all elk losses are identified. Carcasses of calves, being smaller and thus more easily consumed by predators and scavengers or carried away whole by poachers, are the least likely to be discovered.

The annual mortality rates (excluding harvest mortality) for the entire herd were not dramatically affected by changes in herd structure. Simulations of differing bull : cow ratios ranging from 55 : 100 to 70 : 100 were made. There was less than a 2% difference in annual mortality rates between the highest and lowest bull : cow ratio simulations. Cow and calf mortality rates varied less than 1% under the different bull : cow ratio simulations. Bull mortality ranged from approximately 20% in the 55 : 100 simulation to 14% in the 70 : 100 simulation.

Differences in adult recruitment rates also did not greatly affect annual mortality rates. The difference between annual mortality with adult recruitment set at 80 calves / 100 cows and adult recruitment set at 90 calves / 100 cows was only 2% (11.9 and 13.5%, respectively). Annual natural mortality rates of bulls, cows, and calves all varied less than 2% between the extremes of the recruitment simulations. Variations of yearling recruitment rates, although more likely in the real population, have even less effect because of the smaller number of animals and lower recruitment rates involved.

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. In order to keep meeting this demand, the MDNR must know how their harvest management strategies are affecting the numbers of large mature bulls (4.5 years and older).

The effects of increasing bull harvest quotas were simulated at 4 different bull : cow ratios. These bull : cow ratios were 55 : 100, 60 : 100, 65 : 100, and 70: 100. A range of bull : cow ratios were used because of the relatively wide confidence intervals surrounding current sex ratio estimates. Because hunting can have large effects on sex ratios, the simulations were balanced relative to the particular bull : cow ratio used during the nonhunting period of 1975 - 1984. All other inputs were kept constant. In addition, it was assumed that the trend of hunter selectivity for larger bulls would continue.

The results of the simulations indicate that repeated annual harvests of 50 bulls or more will begin to reduce the number of large mature bulls regardless of the bull : cow ratio (Table 27). An annual harvest of 40 bulls allows the number of large bulls to increase slightly. A harvest rate of 40 bulls per year may still be too high, especially if one considers the possibility of fluctuations in annual mortality (increased poaching losses or a severe winter). An increase in nonhunting mortality could lower the number of mature bulls below the desired level.

The simulations also show that the main effect of differing bull : cow ratios is on the relative number of mature bulls which are present in the population (Table 27). For example, there are 60 more mature bulls present

Table 27. Simulated numbers of mature (4.5 years and older) 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[1]	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

at the start of the 1987 year under the 70 : 100 simulation than under the 55 : 100 simulation. The magnitude of this difference again emphasizes the need for an increased effort to collect more precise sex ratio data so that more accurate estimates of bull numbers can be made.

A major assumption in all of the simulations and elk management is that the MDNR population estimates are accurate. The present census method is a combined aerial and ground census in which observers attempt to count every elk within the elk range. The actual counts are considered to be conservative with any possible double sightings being eliminated (Whitcomb pers. comm.). The estimates of population size are based on subjective estimates of how many elk are missed during the census. The estimates of numbers of elk missed are based on weather conditions affecting the ability of the censusers to cover the area, elk behavior, and the number of cases in which tracks were found but the animals were never sighted. Presently, there is no means with which to evaluate the accuracy of the census.

Simulations were made to investigate the effect of inaccurate census estimates on the population. The simulations were based on over and under estimates of the 1984 census. Simulations were made with an overestimate of 10% and underestimates of 10 and 20% (Table 28). The

Table 28. Population growth simulated with varying estimates of census accuracy, based on the 1984 census.

Year	MDNR estimate	Base model	Overestimate 10%	Underestimate 10%	Underestimate 20%
1984	850	853	774	939	1024
1985	940	944	851	1046	1145
1986	950	961	854	1082	1197
1987	1000	994	870	1136	1271
1988	-	1026	881	1193	1351
1989	-	1065	897	1261	1447
1990	-	1108	913	1339	1556

proposed 1987 harvest quotas used as the harvest figures for 1987 - 1990. All other model inputs were set equal to those in the base model.

It is unlikely that the 1984 population figure was overestimated by 10%. The simulation of a 10% overestimate in 1984 predicted a population size of only 870 animals in January 1987. The actual mininum number of elk counted in the January 1987 census was 914.

The base model predicts a January 1988 population size of 1026 animals. This represents a 3.2% increase over the January 1987 population of 994 animals. By January 1990, the model predicts that the population will have grown to 1108 animals. If the population estimate in 1984 was 10% low, the predicted herd size in January 1990 would be approximately 21% greater (1339 animals) than the herd size predicted in the base model. A 20% underestimate of the 1984 population would put the herd at 1556 animals in January 1990. The growth rate of the herd based on a 10% underestimate of the 1984 census increased from 5.3% in 1987 to 6.8% in 1990. The growth rate in the 20% underestimate simulation increased from 6.5% in 1987 to 8.2% in 1990. The rate of increase in the base model during the same period only increased from 4.1 to 4.5%.

The simulation results indicate that it is unlikely that the population size is being overestimated. Although not directly comparable to the Michigan ground and aerial census, most reports of aerial censusing suggest that it also underestimates population size (Anderson 1958, Lovaas et al. 1966, Caughley 1974). Thus, it is likely that future elk management problems will be the result of too many elk rather than too few. Management strategies based on population estimates that actually underestimate the population will not be as effective. If the population size is underestimated, the simulations indicate harvest quotas will not be effective in controlling the herd's rate of increase. The annual rate of increase will be higher and it will increase at a faster rate. The population model is balanced relative to the population size and harvest quotas are based on that population level. As a result, the effectiveness of harvest management is dependant on the accuracy of the population estimate. This points to the need for a census method which is statistically based so that its accuracy can be estimated.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

1) Elk hunting in 1984 and 1985 did not affect elk visibility. The results in the literature suggest 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, 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 in the elk range could be modified in order to keep observers far enough away from the elk to reduce the disturbance. Ruhl (1984) noted that elk were highly attracted to fertilized openings. An intensive opening maintenance program could be used in conjunction with the modified viewing areas. The fertilized openings would attract the elk and make them visible, yet the modified viewing areas would reduce the disturbance caused by the elk watchers. Another management alternative would be to maintain elk visibility in an area closed to hunting.

Hunting may also be affecting the number of large antlered bulls in the population. Sightings of these large bulls are especially important to tourists. Inspection of the age structure of the bulls harvested in the hunts indicated a heavy selection pressure on older bulls. Results of the simulation modeling indicate that the these larger bulls are being harvested at a rate approximately 5 times higher than yearling bulls. The simulations indicate that at the current level of hunter selectivity, a harvest of 50 bulls per year would begin to reduce the number of older bulls, even though the population would still be slowly increasing. The rate of harvest of older bulls should be monitored, especially if the harvest quotas are increased or if the regulations are changed so that a hunter knows in advance if they have drawn an either sex permit. It is conceivable that if hunters are notified in advance that they would be allowed to shoot a bull, the harvest of older bulls would increase because the hunter may spend more time scouting before the hunt. It is recommended that the annual harvest of bulls be kept below 40 animals. If the desired population level is reduced or if changes in the harvest rate become apparent, then the allowable harvest should be reexamined. An alternative management practice would be to control the number of large bulls killed by issuing a number of permits for spike bulls only.

2) Use of openings was highest during the spring and fall by both bulls and cows. Use during these periods was related to the availability of nutritious forage and the rutting season. The use of openings in the summer declined as the grasses matured and dried out. The use of openings during the winter was the greatest when snow depths were less than 25 cm. Snow depths less than 25 cm were shallow enough to allow the elk to paw through the snow to feed on herbaceous vegetation.

Use of regenerating deciduous stands by elk was high during all seasons. Ruhl (1984) reported that elk were recorded as feeding in 71% of his activity locations in regenerating stands during the summer and fall. The greater use of 11 -15 year old aspen stands by bulls during spring and both bulls and cows during winter was attributed to the greater availability of that age class and/or the greater amount of forage available in those stands. Use of 0 - 5 year old stands during winter also appeared to be related to their availability and the amount of time it takes elk to utilize a majority of the current annual growth.

3) Poorly stocked forested stands were not used extensively by elk during any season. The understory vegetation in these stands, which have developed naturally on poor soils, are unattractive to elk, possibly because

they are of lower nutritional quality. The majority of relocations of radio-collared elk in this category were in stands whose main component was aspen.

4) Elk used medium and well stocked forested stands primarily for bedding and loafing. Relatively high use of upland conifers by cows in spring was due to special characteristics of a single red pine stand. The particular stand was planted on fertile soil and had been recently thinned. An extensive hardwood understory developed after the thinning. Ruhl (1984) noted heavy elk use of this same stand. As Ruhl suggested, additional thinning of similar red pine stands grown on the same soil type could produce additional foraging areas for elk and deer.

5). An adequate discriminant function that could predict elk use of conifer swamps as thermal cover relative to winter weather conditions could not be developed. The severity of the winters during the study were considered to be relatively mild. This may have allowed elk to select areas with favorable microclimates without having to enter swamp conifer stands for thermal cover. Also, the discriminant function lacked 2 additional weather factors which may have improved the results. These 2 factors were wind chill and snow supportive quality. Both of these factors are measured in the development of the deer winter severity index used by the MDNR. A winter severity weather station should be placed at the Pigeon River Country State Forest Headquarters because of the difference in weather conditions between the western and eastern portions of the elk range. Future research should include a daily measure of the winter severity index as an additional variable in the discriminant function. This would allow habitat utilization to be related to wind chill and snow supportive quality.

6) The results of the investigation of calving areas suggest that the presence of suitable calving areas are not limiting in the study area.

7). Bull home ranges were significantly larger than cow home ranges. This suggests that it will be more difficult to control the distribution of bulls than cows. This is especially critical because most of the crop damage complaints were due to bull use of farm lands rather than cow use. In most instances the bulls that are causing the damage are not in the agricultural areas during the open season. Although a fall hunt has been suggested as a solution, many of the animals leave the agricultural areas during the rut. A fall hunt during the rut would directly conflict with tourist viewing which peaks at this time. An alternative is to radio-collar the problem animals when they are causing the damage. Knowledge of these animals movements will enable managers to effectively determine the kill distribution so that some of these problem animals are harvested.

8) The primary purpose of the habitat suitability index model is to evaluate the effect of habitat management practices or disturbances to existing elk habitat rather than evaluate unoccupied areas of land to see if they would provide suitable elk habitat. The model has not yet been verified. Therefore, the next research step is to gather data to verify the model. Improvements and verification of the model will be aided by a linking of a geographic information system with the habitat utilization data.

9) Simulation modeling serves several important purposes. One important function of modeling is that it puts all the available data into a structured format. This identifies the types of data that need to be collected. Sensitivity analysis indicates the relative importance of each input to the end result. Thus, it helps establish the priorities of future research.

The model was balanced relative to the estimates of population size, herd structure, and recruitment rates. The accuracy and effectiveness of harvest quotas based on the model is relative to the accuracy of the estimates of the initial inputs. As a result, it is extremely important to get reliable estimates of population size and herd structure. Currently the accuracy of the population estimates are unknown. The results of the simulations suggest that the current estimates of population size are reasonable. If the population size is underestimated, the harvest quotas will not be effective in controlling population growth. It is therefore, essential that a new census method be developed. The new census method should be statistically based so that its accuracy can be determined.

The confidence limits surrounding the current estimates of herd structure are too wide. The simulation results revealed a large difference in the number of large mature bulls in the population under varying bull : cow ratios. If the population is going to be managed for viewing as well as hunting, the number of large bulls in the population should be known. In this case a relatively simple solution exists. The solution is to improve the sampling procedure by using a helicopter to locate and classify animals. The helicopter could more easily locate the required number of animals and also do it in a shorter period of time which would reduce the chances of double counting any individuals.

10) The northern limit to the elk range appears to be controlled at least partially by poaching. It seems more than a coincidence that all 3 radio-collared elk which have traveled north of the Clute road have been poached. Although the habitat may not be as good as that to the south, the increase in forest cuttings in recent years should provide suitable habitat for more elk than are currently there. If additional elk are desired in the area, either through an increase in overall herd numbers or a change in elk distribution, the poaching problem will have to be corrected.

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