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ELK MOVEMENTS AND HABITAT UTILIZATION
IN NORTHERN MICHIGAN

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ELK MOVEMENTS AND HABITAT UTILIZATION IN NORTHERN MICHIGAN

By

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ABSTRACT

ELK MOVEMENTS AND HABITAT UTILIZATION
IN NORTHERN MICHIGAN

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Radio-collared elk were located by visual observation or by triangulation every 2 days from January to December in 1982 in the north central portion of the lower peninsula of Michigan. During June through December, intensive sampling of habitat use was conducted.

The results indicated that year-long home ranges varied from 4424 to 17628 ha. The elk were nonmigratory and seasonal home ranges had a high degree of overlap. The mean seasonal home range size of cows was significantly smaller than that of subdominant bulls during summer and fall. The mean distance between locations made every other day was not significantly different between seasons or between cows and bulls within seasons.

During winter, locations were frequently associated with swamp conifer stands. During summer, bulls used open areas and regenerating deciduous stands proportionately more than their availability. Cows used open areas and poorly stocked conifer stands proportionately more than their availability. During fall, both bulls and cows used open areas proportionately more than availability.

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INTRODUCTION

Free ranging Rocky Mountain elk (*Cervus elaphus nelsoni*) are found in the north central portion of the lower peninsula of Michigan (Baker 1983). The present herd is the result of the introduction of 7 elk in Cheboygan county in 1918 (Moran 1973). Much of the timber in this area had been removed prior to the introduction. As a result, there were large open and brushy areas available during the early years of the herd's growth. By 1939, Shapton (1940) estimated the herd size to be 300-400 animals. These animals ranged over approximately 320 to 360 square km.

By the 1960's, elk management was beset with all the problems characteristic of managing a locally abundant large herbivore. The herd had expanded to an estimated 1200-1500 animals and ranged over 1554 square km (Moran 1973). In parts of the range density was estimated at 4.44 elk/square km. Elk became a tourist attraction, but farmers and foresters complained about damage to fences, agricultural crops, and tree reproduction. Wildlife biologists investigating the range found evidence of heavy utilization of forage plants and felt that plant species composition might change as a result (Spiegel et al. 1963, Moran 1973).

In 1964 and 1965, controlled hunting was implemented in an effort to reduce pressure on the range and collect data relating to elk population dynamics and physical condition. These hunts removed 477 animals from the herd and were effective in reducing damage to crops and forest reproduction. Unfortunately, elk sightings also declined considerably. Complaints from tourists and local merchants replaced those of foresters and farmers.

In the years following the hunt, the Michigan Department of Natural Resources (MDNR) felt that the herd was not increasing at a sufficient rate and might actually be declining. The factors adversely affecting population growth were thought to be poaching, the advance of succession, and increases in disturbance of elk by human activities in the forest uplands (MDNR 1975). Poaching had apparently increased dramatically after the elk hunt. Succession was causing the continuing loss of openings and brushlands. Also, some privately owned areas that were intensively used by elk were lost because of the addition of new roads, real estate developments, ski parks, cabins and trailers (Moran 1973).

The situation became more delicate when hydrocarbon development increased dramatically on state land in what is now the Pigeon River Country State Forest (PRCSF) after the discovery of oil in 1970. Based on their observations and the existing literature on elk behavior, wildlife biologists working for the MDNR believed that the activities accompanying hydrocarbon development would drive elk out of the PRCSF (Corwith I-22 Hearing 1972), which made up approximately 22% of the elk range.

The MDNR conducted their first elk census in March of 1975. They counted 159 animals and estimated the herd size to be 200. Concerned about the viability of the herd, the Wildlife and Forestry Divisions of the MDNR cooperated in promoting commercial timber cuts in hardwood stands and created or maintained open areas in an attempt to revitalize the elk range. Law Division stationed an officer in the PRCSF in an attempt to decrease poaching.

Hydrocarbon development in the PRCSF was discontinued during most of the period between 1975 and 1979. A study of the effects of hydrocarbon development on elk movements and distribution was conducted on a 5418.5 ha area just east of the PRCSF on private land (Knight 1980). This study showed that elk movements significantly increased when seismographic crews worked within 1 km of an elk's location, partially confirming MDNR biologists' fears.

The legislature passed a law permitting hydrocarbon development to continue in the PRCSF under strict controls outlined in the revised consent agreement in 1980 (Act No. 316 of 1980). Some important controls included limiting development to the southern 1/3 of the forest and eliminating competition between companies for the hydrocarbon resource. The latter eliminated the repetition of seismographic surveys and redundant pipe lines, wells, and processing facilities.

Censuses in the winters of 1976-77 and 1979-80 showed that the herd grew to an estimated 300 and 500 animals, respectively (Boushelle, unpubl. data). The winter census of 1982-83 showed that the herd continued to grow. Presently, elk are highly visible and tourists are able to find them. However, some complaints have been made by foresters and farmers about damage to crops and regenerating trees.

Because hydrocarbon and other commercial developments have the potential to displace elk, these developments tend to increase the density of elk in the remaining range. Consequently, conflicts from local overabundance may be augmented.

While elk viewers (and potential elk hunters) would probably be pleased to see larger elk populations and range expansion, the MDNR anticipates that complaints from farmers and foresters will increase as the herd grows. Therefore, the MDNR thinks that the herd may have to undergo a reduction program. At the same time, they want to maintain a visible elk herd. It has become relatively obvious that, in order to meet human demands, an attempt should be made to manage the elk herd in both population size and in distribution.

The objectives of this study were to investigate elk movements and habitat utilization in order to identify characteristics of seasonal movements and potentially beneficial cover types. Specifically, they were to: 1) determine the home range sizes of cow and bull elk, 2) investigate the seasonal movements within these home ranges, 3) identify seasonal cover type preferences, 4) investigate activity within cover types.

STUDY AREA DESCRIPTION

The Michigan elk range includes parts of Otsego, Cheboygan, Montmorency, and Presque Isle counties (Figure 1). It lies on the northern end of the Port Huron Moraine (Kelly 1960). The topography consists of morainic uplands, steep morainic slopes, sandy outwash plains and river bottoms. The Black, Pigeon, and Sturgeon rivers originate in the coniferous swamps along the southern edge of the area and flow toward the north.

Soil types range from highly fertile organic soils in the swampy areas to dry sandy soils on the outwash plains. Medium fertility soils are found on the till plains and moraines.

The climate in the elk range is influenced by the Great Lakes to a lesser extent than much of Michigan. The most noticeable effects of the Lakes are increased cloudiness and prevailing westerly winds which moderate temperatures during the fall and early winter months (Strommen 1974). The mean annual temperature for the area is 5.8°C with mean monthly extremes in January (-8.2°C) and July 19.5°C) (NOAA 1982). Precipitation is well distributed throughout the year with 59% received between May and October (Strommen 1974). Mean annual precipitation is 74.98 cm (NOAA 1982). Average annual snowfall is 246.63 cm (Strommen 1974). During the study period the average monthly temperature was below the long term average while the average precipitation was slightly above the long term average (Figure 2).

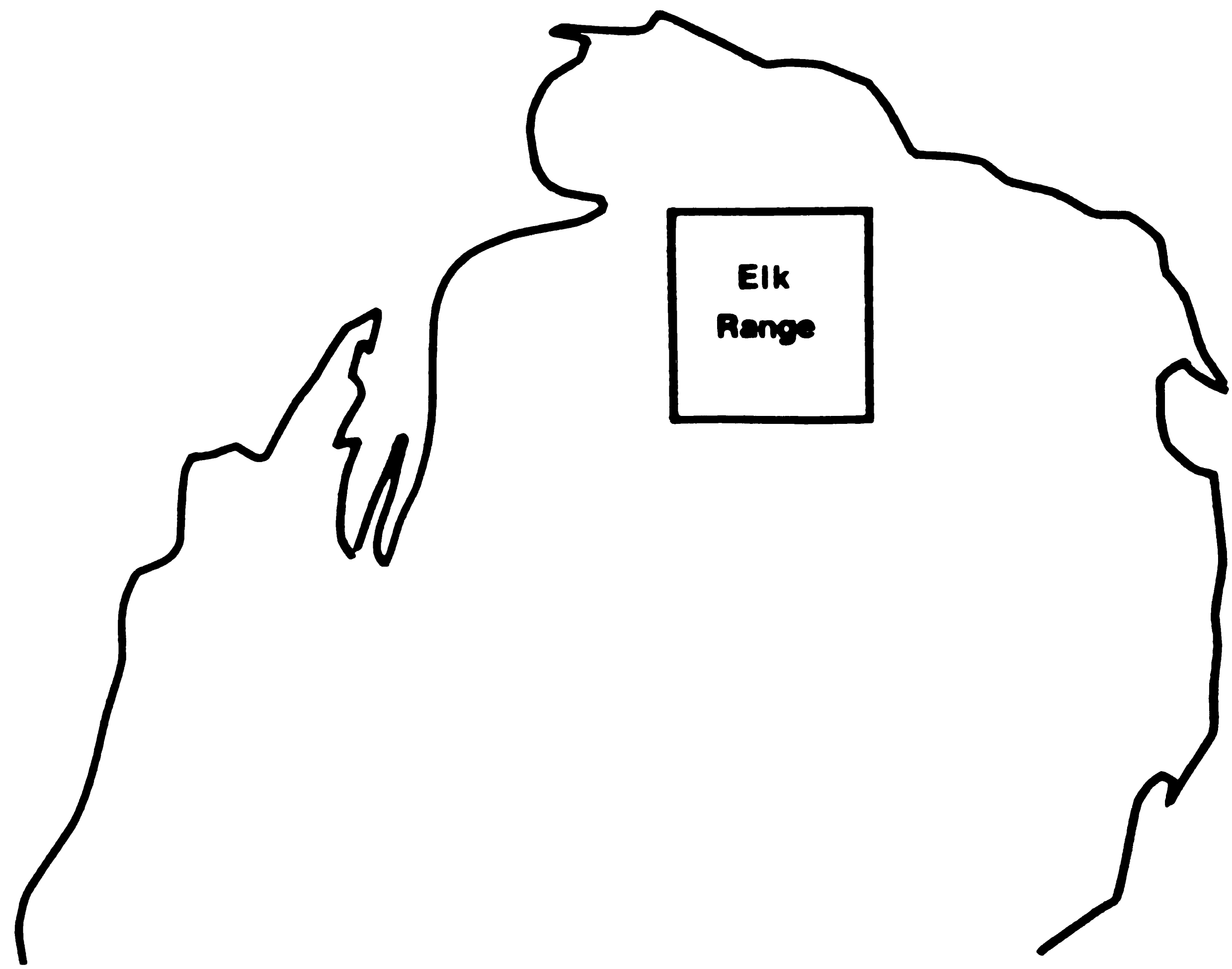

Figure 1. The location of elk range in Michigan (Moran 1973).

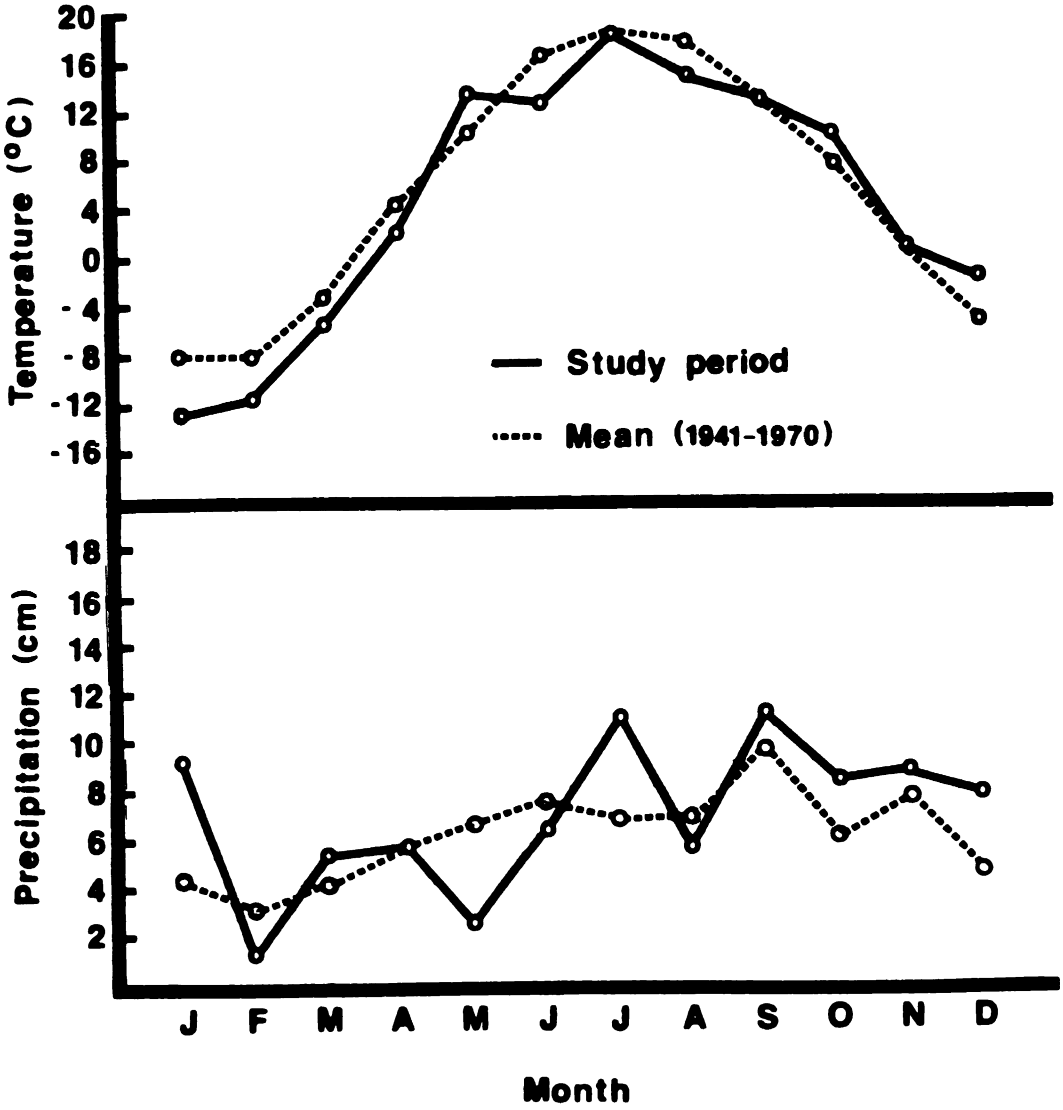

Figure 2. Mean precipitation and temperature by month during the study period, 1982.

Stands on the moraines consists of varying proportions of sugar maple (*Acer saccharum*), basswood (*Tilia americana*), hemlock (*Tsuga canadensis*), northern red oak (*Quercus borealis*), red maple (*Acer rubrum*), white pine (*Pinus strobus*), and red pine (*Pinus resinosa*). The outwash plains intergrade into the moarines and support stands containing varying proportions of red maple, juneberry (*Amelanchier canadensis*), white birch (*Betula papyrifera*), jack pine (*Pinus banksiana*), choke cherry (*Prunus virginiana*), and willow (*Salix* spp.). Riverbanks and flood plains support speckled alder (*Alnus rugosa*), dogwoods (*Cornus* spp.), willows, white cedar (*Thuja occidentalis*), ash (*Fraxinus* spp.), and red elm (*Ulmus fulva*). Coniferous swamps contain white cedar, balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and balsam poplar (*Populus balsamifera*) (Spiegel et al. 1963, Moran 1973). Scientific names are in accordance with Gray's Manual of Botany (Fernald 1970).

The diversity of vegetation caused by soil type, soil drainage, and aspect has been further complicated by extensive logging, repeated burning, tree plantation programs, and scattered attempts at farming. The Michigan State Forest Operations Inventory (MSFOI) system classifies the resulting vegetation into 26 groups (Table 1) (MSFOI 1982). Stands which are being managed for timber production are further classified by stage of growth and stocking density (Table 2).

Table 1. Cover type classifications under the Michigan State Forest Operations inventory system (MSFOI 1982).

Code	Cover designation
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 (Swamp Aspen and Birch)
Q	Mixed Swamp Conifers
R	Red Pine
S	Black Spruce (Swamp)
T	Tamarack
U	Upland Brush
V	Bog and Muskeg
W	White Pine
X	Other non-stocked, non-forest, or nonproductive stands
Y	Sand Dunes
Z	Water

Table 2. Size and stocking density designations for forest stands in the Michigan State Forest Operations inventory system (MSFOI 1982).

Size	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 sq./ha
Poletimber	12.7-25.3	Medium	9.2-16.0 m sq./ha
Poletimber	12.7-25.3	Well	> 16.1 m sq./ha
Sawtimber	> 25.3	Poor	2.3-9.1 m sq./ha
Sawtimber	> 25.3	Medium	9.2-16.0 m sq./ha
Sawtimber	> 25.3	Well	> 16.1 m sq./ha

METHODS

Capture

Elk were immobilized by using a powder-charged capture gun (NASCO, Fort Atkinson, WI) to propel a dart containing succinylcholine chloride. Dosages were determined by classifying elk in the field into 3 classes: calves, 16-20 mg; cows 20-26 mg; and bulls, 26-32 mg (Flook et al. 1962). They were given intramuscular injections of 5-10 cc of a long acting antibiotic (Flochillin) (Bristol Laboratories, Syracuse, NY). Their eyes were treated with an opthalmic ointment (choraphenicol) (Pharmaderm, Melville, NY) to prevent drying of the cornea.

Elk were aged, ear tagged, and equipped with color coded collars carrying radio transmitters. Age was estimated by the tooth-wear method (Quimby and Gaab 1957). Elk were categorized as; less than 1 year, between 1 and 2 years, between 2 and 3 years, or more than 3 years old. The radio transmitters (Telonics, Meas AZ) were lithium powered and broadcast on individual frequencies.

Triangulation

The collared elk were located by visual observation or by triangulation with a portable TR-2 receiver and 2 or 3 element hand held yagi antennas (Telonics, Mesa, AZ). Compass bearings were taken by the loudest point method (Springer 1979).

Triangulation accuracy tests were made to determine the ability of the observer to take accurate bearings on transmitters whose locations were known. During both the winter of 1982-83 and summer of 1982, transmitter locations were selected to cover a wide variety of topographic features and vegetation types. Bearings were taken from distances of 0.3 to 3.2 km from the transmitters (approximating the range of distances encountered in the field). The deviation of an observed bearing from the true bearing was determined by mapping the locations of the transmitter and the observer for each bearing. Data were recorded by observer, transmitter size (calf or adult), and antenna type (2 or 3 elements). Error arcs were calculated for each group of bearings (lumped on the basis of observer, transmitter size, and antenna type) according to the formula presented in Springer (1979).

Movements

An attempt was made to locate the radio collared elk every other day during 1982 in order to accumulate information on their general movements. These locations were found by triangulation from base points on the local road system. The mean distance between locations determined 2 days apart was calculated for each individual.

The home ranges for each individual were determined by applying the minimum area method to the error polygons found during general movement monitoring (Springer 1979). These home ranges were expanded to include locations found during sampling for habitat utilization conducted during summer and fall of 1982. Home range sizes were measured with an area planimeter.

Habitat Utilization

The MSFOI is used by both the Forestry and Wildlife Divisions in planning forest management. Therefore it was used to define 14 cover categories for evaluating elk habitat utilization. The categories used included 3 classes of vegetative structure: open areas, regenerating trees (up to 12.69 cm dbH), and forest stands (averaging greater than 12.7 cm dbH).

Open areas were dominated by herbaceous vegetation. They included areas which were left to seed naturally after disturbance, areas which were seeded with agricultural crops, and areas which have been kept open by mowing.

Regnerating stands of trees were classified as either deciduous or coniferous depending on the most prolific species. These stands included both clearcuts and plantations.

Forest stands were consolidated into 5 categories. Coniferous stands were classified as jack pine, upland conifers (including red pine, white pine, and upland spruce and fir stands), and swamp conifers (including only cedar and mixed swamp conifer stands). Deciduous stands were classified as northern hardwoods or upland deciduous trees (including oak, aspen, and birch stands). Each of these forest stand categories was further classified as either poorly stocked (< 9.2 m sq./ha) or medium to well stocked. The remaining stands identified by the MSFOI system were lumped into a single category which was labeled other.

During the summer and fall (22 June through 21 December) of 1982, individual elk were randomly assigned to 12 hour time periods. These periods were from 9 am to 9 pm and from 9 pm to 9 am. During a 12 hour period the elk was located at 7 randomly picked times (on the hour). The locations were made by triangulation over short distances (less than 1/4 km) or by visual observation. Visual observations were randomly scheduled for 1 of the 7 location times. Observers were instructed not to attempt an observation if they felt they would disturb the elk. Missed observations were rescheduled for later in the time period. The activity in which the elk was engaged during the first 30 seconds after the location time was recorded. Activities were categorized as: feeding, bedding, traveling, avoiding (nonproject) people), or disturbed by the observer.

Data Analysis

Since changes in elk movements and habitat use are generally attributed to changes in climatic and phenological conditions, seasonal periods were defined as follows: winter, 1 January through 20 March; spring, 21 March through 21 June; summer, 22 June through 22 September; and fall 23 September through 21 December. These periods did not strictly conform to climatic and phenological changes but they did allow general comparisons to be made. Because the movements of animals which later died of disease or malnutrition may not reflect the movements of healthy animals, animals which died, except the 2 that were illegally shot, were excluded from all analyses.

Home range sizes for those individuals which were monitored for approximately a year are reported. For each of these individuals, the seasonal differences in the mean distance between locations made 2 days apart were compared by a modified Tukey's test (Gill 1978: 1980).

Bartlett's test was used to check for departures from homogeneous variance (Gill 1978: 78).

Differences between cows and bull home range sizes during each season and differences between the movements of cows and bulls during each season were compared by use of a t-test designed for use with samples which have unequal variances and unequal coefficients of variation (Gill 1978: 66). Because the length of time over which an animal was monitored may have affected its home range size, animals which were monitored for less than 2 months during a season were not included in these analyses.

The Chi square test of goodness of fit was used to compare predicted use of cover types to the observed use of cover types (Gill 1978: 78). The Bonferoni Z test was used to determine the significance of differences between use and availability of each cover type (Nue 1974). Error polygons which included more than 1 cover type were not included in Chi square or Bonferoni Z analyses.

"Available" cover types were defined as those found in an individual's home range. The area of each cover type in an individual's home range was determined by use of a leaf area index analyzer (Lambda Instrument Corp., Lincoln, NE). The area of available cover type was summed across individuals to predict the use of each cover type for a group of individuals.

The type of cover in which an elk was found may have had an effect on the observer's ability to see a collared elk without disturbing it. Therefore, the data gathered on activities were evaluated within (not between) cover types. The percentage of time spent in each activity was calculated by dividing the number of times an activity was seen in a cover type by the total number of undisturbed observations made in that type.

RESULTS

Capture

Twenty-one elk were captured between October 1981 and September 1982 (Table 3). Of these, 6 died during the course of this investigation. The information gathered on mortality among collared animals is presented in Table 4. In addition, 1 elk died during capture because of drug overdose. Also, 1 large bull broke the collar off shortly after it was collared.

Because of the deaths of animals during the study and the fact that animals were collared throughout the study, the sample of animals changed in size and composition for each season. While the age structure of the collared cows may have closely represented the age structure of cows in the herd, most of the collared bulls were subdominant.

Triangulation Accuracy

The size of the error arc for each group of data (based on observer, transmitter size, and antenna type) ranged from 7.2 to 11 degrees at the 95% confidence level. Since the error arc in the worst case was less than + or - 6 degrees, a 12 degree error arc was used to map the error polygon which contained the instrumented animal with a 90% confidence level (Heezen and Tester 1967, Springer 1979).

Table 3. Capture records for Michigan elk, 1981-1982.

Date collared	Animal number	Collar colors	Sex	Age category at capture
10-29-81	1481	Blue	M	1-2
12-16-81	5011	Orange	F	1-2
12-17-81	1541	Yellow	F	> 3
12-18-81	580	Green	F	> 3
12-18-81	561	Yellow-Blue	M	< 1
12-18-81	1871	Orange-Blue	F	< 1
12-21-81	520	Orange-Yellow	M	1-2
1-25-82	1461	Black-Orange	F	2-3
2-21-82	121	Brown	M	1-2
5-8-82	1110	Yellow-Black	F	1-2
5-9-82	1571	Brown-Breen	M	> 3
6-21-82	1430	Black	F	2-3
6-21-82	1920	Yellow-Brown	F	2-3
6-23-82	1522	Brown-Black	F	2-3
7-22-82	1616	Orange-Brown	M	1-2
8-5-82	1651	Blue-Black	F	1-2
9-12-82	1590	Blue-Brown	F	2-3
9-13-82	1090	Green-Black	M	1-2
9-15-82*	1120	Green-Orange	M	> 3
9-15-82	541	Yellow-Green	F	> 3
9-16-82	5012	Orange	M	> 3

*This elk lost its collar approximately 10 days later.

Table 4. Mortality among collared elk in Michigan during 1982.

Animal number	Sex	Age at death	Date found	Cause of death
561	M	3/4	3-17-82	Malnutrition
5011	F	1 3/4	4-12-82	Brainworm
1541	F	5	6-21-82	Eoxinophilic metritus
1871	F	3/4	6-22-82	Undetermined
121	M	2	7-29-82	Shot
1110	F	2 1/2	11-15-82	Shot

Movements and Home Range

Seven animals were collared before the start of the winter season. Only 3 of them (520, 1481, and 580) lived through the entire study. There were no significant differences in the mean distance between locations during winter, spring, summer and fall for any of these animals. The seasonal home ranges of these animals had a high degree of overlap (Figure 3). During winter, locations were frequently clustered in a relatively small area of the home range (Figure 4). These activity centers were associated with swamp conifer stands.

Complete data on seasonal home ranges were available for 3 animals (520, 1481, and 580) during winter, for 5 animals (121, 520, 1481, 580, and 1461) during spring, for 9 animals (520, 1481, 1571, 580, 1110, 1431, 1461, 1522, and 1920) during summer, and for 15 animals (520, 1090, 1481, 1616, 501, 1571, 1651, 540, 580, 1110, 1431, 1461, 1522, 1590, and 1920) during fall. The mean home range size of cows were significantly smaller than that of bulls during both summer and fall (Table 5). Insufficient data were available for the analysis of cow and bull home range sizes during winter or spring. There were no significant differences in the distances between consecutive locations for these cows and bulls during any season ($P < 0.20$).

Habitat Utilization

A total of 772 usable locations of elk were made during summer and fall studies of habitat utilization. An additional 63 locations were determined but could not be used in habitat analyses because the error polygons contained more than 1 cover type. Approximately 45% of the locations were in the open areas or regenerating stands, 34% in stands classified as deciduous, and 21% in stands classified

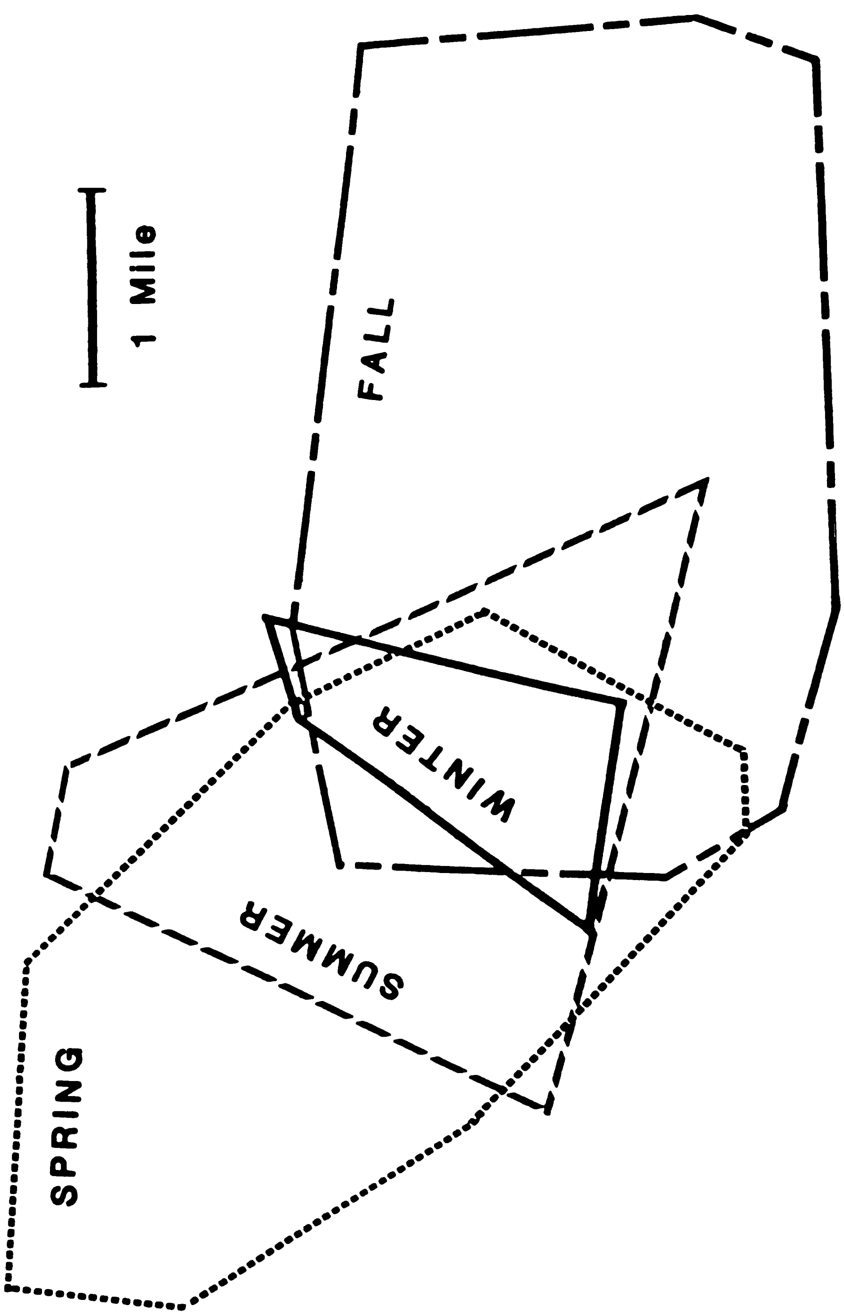

Figure 3. Seasonal home ranges of a mature cow, animal number 580, for 1982.

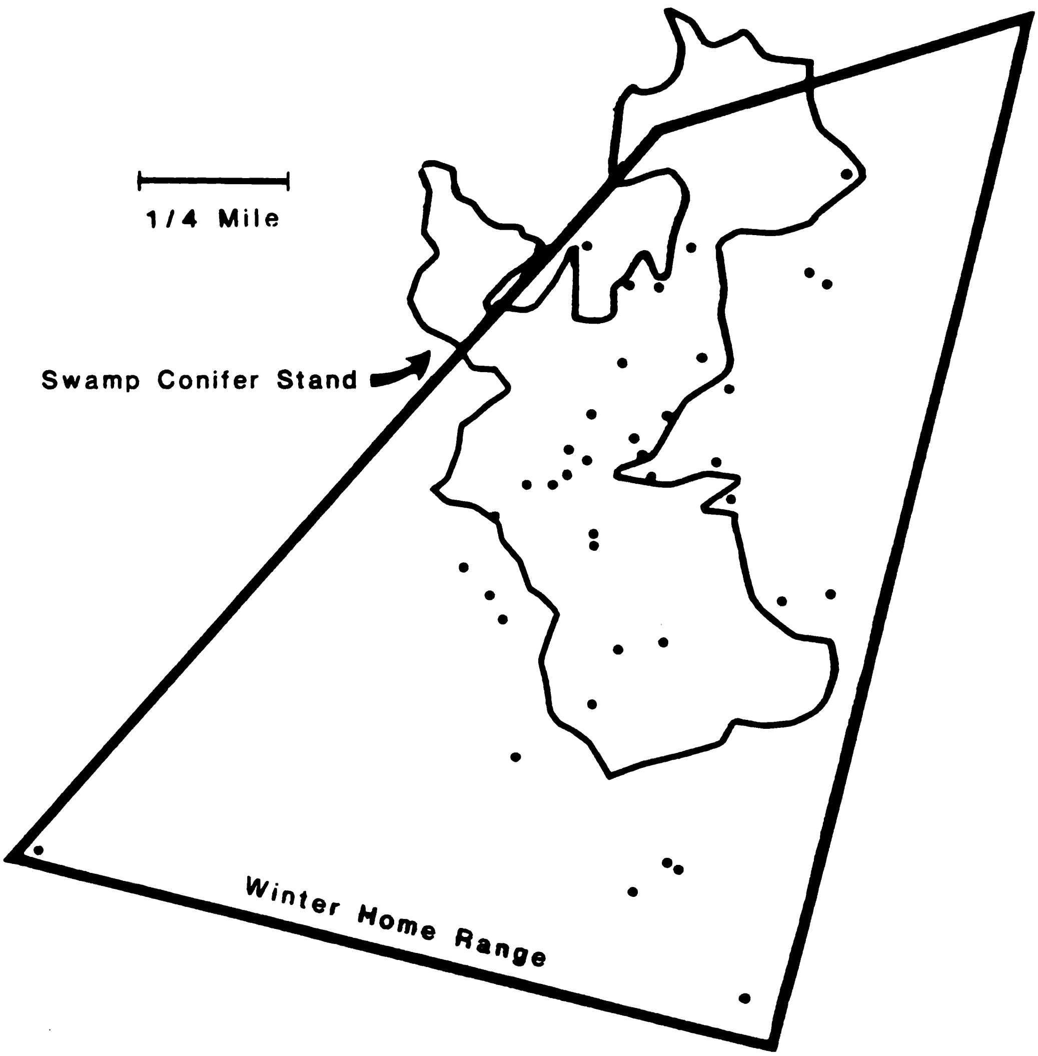

Figure 4. Winter home range and locations for a mature cow, animal number 580.

Table 5. Seasonal home range sizes (ha) for cow and bull elk in Michigan, 1982.

	Cows			Bulls		
Season	Number of elk sampled	Mean home range	Standard deviation	Number of elk sampled	Mean home range	Standard deviation
Winter	1	395	--	2	2928	1079
Spring	2	2344	134	3	3533	3754
Summer*	6	1621	638	3	3717	2331
Fall*	9	2866	927	6	4681	2832

* Mean cow home range size is significantly smaller than mean bull home range size ($P < 0.005$).

as coniferous. No locations were made in the stands lumped into the category labeled other.

A total of 109 observations of elk behavior were recorded (Table 6). During 9% of these observations, the elk were disturbed by the observer. Approximately 77% of the observations in open areas and 71% of the observations in the regenerating stands indicated that the elk were foraging. In deciduous timber stands, 67% of the observations indicated that the elk were bedded down. Observations in the coniferous stands were evenly spread among behavior categories.

Goodness-of-fit comparisons showed that the expected distribution of observations in cover types differed significantly from the actual distribution of observations in cover types for both cows and bulls in both summer and fall (bulls in summer, chi square = 155, df = 13, $P < 0.01$; bulls in fall, chi square = 151, df = 13, $P < 0.01$; cows in summer, chi square = 104, df = 13, $P < 0.01$; cows in fall, chi square = 215, df = 14, $P < 0.01$).

Bulls were located 155 times during summer (Table 7). Open areas and regenerating deciduous stands were used proportionately more than their availability. The various timber stands were used in proportion to their availability or proportionately less than their availability. No locations were made in regenerating conifer stands.

Cows were located 245 times during summer (Table 8). Open areas were preferred. Both regenerating deciduous and regenerating conifer stands were used in proportion to their availability. Most timber stands were either used in proportion to their availability or less than their availability. Poorly stocked upland conifer stands were used proportionately more than their availability.

Table 6. Elk behavior in various cover types in Michigan during summer and fall (% of observations).

Behavior	Open areas	Regenerating stands	Deciduous timber	Coniferous timber
Feeding	77	71	5	35
Bedded	5	7	67	20
Traveling	10	22	17	10
Avoiding people	0	0	0	20
Disturbed by observer	8	0	11	15

Table 7. Cover type use by bulls during summer compared to cover type availability within their summer home ranges in Michigan. (Total observations = 155).

Cover type	Proportion of total area available	Proportion of total observations	Calculated Bonferoni Z statistic*
Open areas	0.05	0.21	-4.89***
Regenerating stands:			
Deciduous	0.13	0.24	-3.21**
Coniferous	0.02	0.00	--
Poorly stocked:			
Jack pine	0.00	0.00	--
Upland conifers	0.08	0.03	3.61***
Upland deciduous	0.05	0.04	0.64
Northern hardwoods	0.02	0.04	-1.27
Swamp conifers	0.00	0.00	--
Well stocked:			
Jack pine	0.06	0.00	--
Upland conifers	0.14	0.15	-0.68
Upland deciduous	0.14	0.10	1.66
Northern hardwoods	0.17	0.17	0.00
Swamp conifers	0.09	0.02	6.22***
Other stands	0.05	0.00	--

* Negative calculated Bonferoni Z statistics indicate use is proportionately greater than availability.

** Use is significantly different than availability at the 95% confidence level.

*** Use is significantly different than availability at the 99% confidence level.

Table 8. Cover type use by cows during summer compared to cover type availability within their summer home ranges in Michigan. (Total observations = 245).

Cover type	Proportion of total area available	Proportion of total observations	Calculated Bonferoni Z statistic*
Open areas	0.08	0.19	-4.39**
Regenerating stands:			
Deciduous	0.16	0.18	-0.81
Coniferous	0.02	0.03	-0.92
Poorly stocked:			
Jack pine	0.01	0.00	--
Upland conifers	0.04	0.11	-3.50**
Upland deciduous	0.01	0.01	0.00
Northern hardwoods	0.02	0.03	-0.92
Swamp conifers	0.00	0.00	--
Well stocked:			
Jack pine	0.03	0.00	--
Upland conifers	0.15	0.20	-1.96
Upland deciduous	0.16	0.11	2.50
Northern hardwoods	0.25	0.14	4.96**
Swamp conifers	0.03	0.00	--
Other stands	0.04	0.00	--

* Negative calculated Boniferoni Z statistics indicate use is proportionately greater than availability.

** Use is significantly different than availability at the 99% confidence level.

During fall, bulls were located 152 times (Table 9). Open areas were used proportionately more than their availability. Regenerating deciduous stands were used in proportion to their availability, while regenerating conifer stands were used proportionately less than their availability. Timber stands were either used in proportion to their availability or less than their availability.

During fall, cows were located 220 times (Table 10). Again, open areas were preferred. Regenerating deciduous stands and regenerating conifer stands were both used in proportion to their availability. Timber stands were used in proportion to their availability or proportionately less than their availability.

Table 9. Cover type use by bulls during fall compared to cover type availability within their fall home ranges in Michigan. (Total observations = 152).

Cover type	Proportion of total area available	Proportion of total observations	Calculated Bonferoni Z statistic*
Open areas	0.06	0.26	-5.62**
Regenerating stands:			
Deciduous	0.19	0.16	2.48**
Coniferous	0.03	0.01	1.01
Poorly stocked:			
Jack pine	0.01	0.00	--
Upland conifers	0.05	0.05	0.00
Upland deciduous	0.04	0.00	--
Northern hardwoods	0.02	0.05	-1.70
Swamp conifers	0.00	0.00	--
Well stocked:			
Jack pine	0.04	0.00	--
Upland conifers	0.08	0.11	-1.18
Upland deciduous	0.17	0.21	-1.21
Northern hardwoods	0.17	0.15	0.69
Swamp conifers	0.10	0.00	--
Other stands	0.04	0.00	--

* Negative calculated Bonferoni Z statistics indicate use is proportionately greater than availability.

** Use is significantly different than availability at the 99% confidence level.

Table 10. Cover type use by cows during fall compared to cover type availability within their fall home ranges in Michigan (Total observations = 220).

Cover type	Proportion of total area available	Proportion of total observations	Calculated Bonferoni Z statistic*
Open areas	0.08	0.31	-7.38**
Regenerating stands:			
Deciduous	0.19	0.24	-1.74
Coniferous	0.03	0.02	1.06
Poor stocked:			
Jack pine	0.01	0.00	--
Upland conifers	0.04	0.02	2.12
Upland deciduous	0.01	0.00	--
Northern hardwoods	0.02	0.00	--
Swamp conifers	0.00	0.00	--
Well stocked:			
Jack pine	0.03	0.05	-1.36
Upland conifers	0.09	0.03	5.22**
Upland deciduous	0.20	0.09	5.70**
Northern hardwoods	0.21	0.23	-0.70
Swamp conifers	0.07	0.01	8.94**
Other stands	0.02	0.00	--

* Negative calculated Boniferoni Z statistics indicate use is proportionately greater than availability.

** Use is significantly different than availability at the 99% confidence level.

DISCUSSION

Movements and Home Range

Elk in western herds show a wide variety of seasonal movements. The existence of both migratory and nonmigratory groups of elk on wintering grounds has been reported in Wyoming, Colorado, and Washington (Martinka 1969, Boyd 1970, Taber 1976). An unusual situation was reported by Craighead et al. (1973) in which a nonmigratory group of elk remains over winter in the summer range of the migratory portion of the herd. Some herds move to higher or lower elevations in response to changes in climate and plant phenology without using well defined migratory corridors.

Elk have been reported to start migration in the west when snow depths reached only 15-25 cm (Anderson 1954). Snow depths of 46-61 cm apparently are avoided or severely restrict elk movements (Gaffney 1941, Beall 1976, Leege and Hickey 1977: 18). However, elk can move through extremely deep snow. Gaffney (1941) observed elk moving through snow up to 102 cm deep.

In Michigan, elk are unable to migrate to lower elevations in order to avoid deep snow and satisfy their nutritional demands. Moran (1973) reported that the range area used by elk in Michigan was greatly restricted when snow depths reached over 46 cm. Pellet group counts made during the severe winters of 1962 and 1965 indicated that elk made higher use of swamp conifer stands than during other years (Buss 1967). During the winter of 1981-82, snow depths reached 53 cm. The locations of collared elk during the winter of 1981-82 were frequently clustered in a relatively small proportion of the home range. These activity centers were associated with swamp conifer stands.

Similar use of conifer stands has been reported in the west. Leege and Hickey (1977) reported that elk made increasing use of coniferous stands as snow depths approached 61 cm. Skovlin and Vavra (1979) found that elk in the Blue Mountains, Oregon, shifted their diet to conifers during late winter storms.

The availability and condition of the winter ranges in the west are apparently the limiting factors on herd size. Winter mortality has frequently been reported (Schartz 1945, Craighead et al. 1973). Winter severity and weight loss by cows have also been related to lowered pregnancy rates and calf survival rates (Greer 1968, Thomas et al. 1976).

Moran (1973) cited illegal shooting, disease, and accidents as the major apparent sources of elk mortality in Michigan. Although necropsy showed a variety of causes of death among collared animals in 1982, all of the deaths (excluding animals that were illegally shot) occurred in the late winter and spring. This may be an indication that the herd was under at least some stress during winter. However, because animals that are ill may be more susceptible to capture by darting than those that are well, the proportion of collared animals that died is probably not an accurate representation of death rates for the entire herd. No information is presently available on the effect of winter severity on birth rates or survival in the Michigan herd.

The year long home range sizes of elk in Michigan were large and highly variable. Because of the migration of western elk, the sizes of home ranges over a year are rarely reported. Craighead et al. (1973) did report small home range sizes (1554, 2590, and 3056. 2 ha) for 3 nonmigratory cows in the Madison River Drainage area of the Yellowstone National Park.

Seasonal home ranges for nonmigratory cows in the Madison River Herd were also generally smaller than the home ranges of cows in Michigan during winter, spring, and summer (Craighead et al. 1973). During fall, the home ranges were of similar size. The Madison River area has extremely deep snow (127-152 cm) during winter. Migratory individuals, as well as the resident population, are present during other seasons.

Comparisons of seasonal home range sizes between elk in Michigan and elk in other western herds are directly confounded by migration. Generally, their home ranges vary from similar in size to much larger than those in Michigan. The summer home range sizes of cows in Jackson Hole, Wyoming, were similar to those of cows in Michigan (Martinka 1969). The summer home range sizes of bulls in the Blue Mountains and Jackson Hole were similar to those of bulls in Michigan (Pedersen et al. 1980: 120, Martinka 1969). Summer home ranges for cows in the Blue Mountains, Oregon, and Medicine Bow National Forest, Wyoming, averaged from 2.6 to 12.6 times the size of cow's summer home ranges in Michigan (Pedersen et al. 1980: 120, Ward 1973).

In Michigan, the degree of overlap and the distribution of the seasonal home ranges within the year varied between individuals. These individual differences are probably the result of differences in the pattern of available cover types. Craighead et al. (1973) found similar differences in seasonal home range use in the nonmigratory portion of the Madison River herd.

Moran (1973) believed that mature bulls "traveled more extensively" than cows. Similar observations have been made in studies of Roosevelt elk in California and of Rocky Mountain elk in New Mexico and Wyoming (Martinka 1969, Franklin and Lieb 1979, White 1981). In Michigan, the subdominant bulls investigated did not travel further than cows on a day to day basis. However, the bulls did have larger home ranges, at least during the summer and fall seasons. This tendency for bulls to use larger areas than cows has been attributed to spatial separation between the sexes (maintained to avoid competition) and differences in the antipredator strategies of cows and bulls (Geist 1982: 233).

Habitat Utilization

The test of availability versus use ignores the effect of interspersion and juxtaposition of cover types. If a cover type occurs in large stands or is distant from preferred cover types, the biological value of that cover type may be underrated. Therefore, the value of "neutral" and "avoided" cover types is difficult to ascertain.

Open areas in Michigan were preferred by both cows and bulls in both summer and fall. The elk in open areas spent 83% of their time foraging. Most of the locations in open areas occurred during dawn, dusk, or at night. This pattern of opening use may be the result of avoiding either summer heat or human activities during the day (Pedersen et al. 1980, Georgii 1981, Skovlin 1982: 382).

In Michigan, wildlife food plots or nonproducing oil well pads which had been fertilized and seeded with a mixture of rye and clover showed heavy use during the summer and fall. The importance of open areas as foraging sites has been well demonstrated by studies done in western states (Martinka 1969, Knight 1970, Ward 1973, Collins et al. 1978, Varland et al. 1978, Collins and Urness 1983). The consumption of grasses and forbs has been related to plant phenology and nutritional value. Brown and Mandery (1962) were temporarily successful in changing the land use patterns of Roosevelt elk in the Olympic Game Range of Washington by fertilizing and planting areas with grass and clover mixtures. This practice might change the distribution patterns of elk in Michigan during summer, fall and possibly spring.

Knight (1975) studied elk and deer use of selected open areas in Michigan. The amount of use elk made of an open area was positively related to the amount of open area in the 259.2 ha surrounding it and negatively related to its accessability by motorized vehicles. Thus, creating areas with high densities of openings and low vehicle accessability may also tend to attract elk. Thomas (1979) recommends that for maximum use by elk, foraging areas should be less than 366 m wide.

Studies of the use of clearcuts by elk are confounded by differences in the species of regenerating plants, the availability of alternative foraging areas, and the timing of the study in relation to plant phenology. Vegetation height, slash depths, and the sizes of the clearcuts may also affect the results and are frequently not recorded (Lyon and

Jensen 1980). Leege and Hickey (1977: 20) reported that there was little use of clearcuts in cedar-hemlock forests during summer but felt that this was the result of human activity in the clearcuts. Irwin and Peek (1983) found that spring-fall home ranges contained seral brush-fields and clearcuts in proportion to their occurence in the study area and that elk generally used the clearcuts in proportion to their availability during the summer. Collins and Urness (1983) found that elk preferred clearcut areas in a study area covered predominantly by lodgepole pine but used clearcuts in a study area covered predominantly by aspen at about the same level as uncut aspen stands.

In Michigan, bulls showed a preference for regenerating deciduous stands during summer. The elk in regenerating stands spent 71% of their time foraging. Most of the locations in regenerating deciduous stands were in stands that were relatively young. Spiegel et al. (1963) believed that elk in Michigan actively avoided stands with an average dbH of greater than 2.54 cm and densities of over 2470 stems per ha. Regenerating stands (seedlings and saplings) are defined in the MSFOI as those having an average dbH of less than 12.7 cm, thus including both young regenerating stands and those that may be actively avoided by elk.

Poorly stocked upland conifer stands were preferred by cows during summer. Unfortunately no observations of collared animals were made in this stand. Examination of the data showed that 73% of the locations in this cover type were made in a single stand. This stand was a 53 year old jack and red pine plantation which had been planted on relatively fertile soil (Emmett sandy loam), with a site index of 65 for red pine. In 1969, the stand was thinned to approximately 9.2 m sq. BA/ha (ranging from less than 6.9 m sq. BA/ha to over 22.9 m sq. BA/ha) leaving only the red pine. During this investigation, it averaged approximately 16.1 m sq. BA/ha and had developed an extensive hardwood understory. It was also in close juxtaposition to an open area which was heavily used by elk. The preference found for this stand probably reflected its atypical understory and particular juxtaposition. There are, however, between 1619 and 2025 ha of pine plantations of similar age on Emmett sandy loam sites in the PRCSF. It is possible that dramatic thinning of these stands may produce foraging areas for elk.

Since elk may select their seasonal home ranges on the basis of cover types (Irwin and Peek 1983), the comparison of the availability of cover types within the home ranges to the use of cover types is a conservative test of "preference." Cover types which are used proportionately more than their availability are very likely to supply physically or behaviorally important resources.

The preferred cover types found in this study of Michigan's elk were frequently used as foraging areas. Since the herd is still increasing, it is obvious that the availability of foraging areas has not yet become a limiting factor on the ultimate size of the herd. However, it is possible that the rate of growth of the herd may be effected by the availability of foraging areas and their potential impacts on elk energetics and natality.

During summer and fall in Michigan, elk spent almost half of their time in open areas (24%) or regenerating deciduous stands (21%). If it is assumed that preference indicates components of optimal habitat that are under represented, a crude estimate of optimal habitat for Michigan's elk might be a 45:55 ratio of these foraging areas to other cover types in the forest uplands. This is similar to the recommendation by Thomas et al. (1979) of a 60:40 ratio of foraging areas to hiding and thermal cover as an approximation of optimal habitat for elk in the Blue Mountains of Oregon and Washington.

In the Blue Mountains, the availability of escape cover and thermal cover (which may also be used as escape cover) is thought to be very important in determining the amount of use an area will receive from elk. In Michigan, where secondary forests are growing on relatively mesic soils and opening sizes are relatively small, the availability of escape cover is probably not limiting use (except perhaps during the calving period).

CONCLUSION AND MANAGEMENT RECOMMENDATIONS

1) The year long home range sizes of elk in Michigan were large (4424-17628 ha). This wide ranging behavior may make the control of crop damage difficult since animals that are removed may be replaced rapidly. Also, the removal of a large number of animals from a small area may affect elk visibility over a large area. During summer and fall, cows had smaller home ranges than subdominant bulls. Therefore, it is likely that cows will be more amenable to control of distribution than subdominant bulls.

2) The availability of summer and fall foraging areas may be below optimum. Obviously the continued creation or maintenance of open areas and regenerating stands is necessary because of the continuing advance of succession. An increase in the amount and quality of forage available to elk during summer and fall might have a positive effect on the rate of growth of the herd but since the herd's population dynamics have not been closely investigated, the relative effect of forage increases cannot be accurately predicted.

Open areas appeared to be the most important foraging areas for both cows and bulls during both summer and fall. The importance of regenerating deciduous stands may have been obscured by the wide range of plant sizes included in this category. Highly thinned stands on fertile soils may contribute to foraging area available to elk.

Because winter may be a period of significant physical stress, further research on wintering areas and the effect of winter severity is important if population size is to be closely regulated from year to year. The importance of conifer swamps and the possible effects of deer-elk interactions during winter have not been determined.

3) Because elk are highly attracted to fertilized wildlife openings, changing the distribution of these openings may be effective in changing the distribution of elk during the summer and fall. It may be possible to provide highly visible elk on these openings even at lower herd sizes.

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