ELK HABITAT USE DURING CALVING SEASON WITH POSSIBLE EFFECTS ON WHITE-TAILED DEER AT THE WICHITA MOUNTAINS NATIONAL WILDLIFE REFUGE

By

GENE PAUL WALDRIP

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1975

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1977

ELK HABITAT USE DURING CALVING SEASON WITH
POSSIBLE EFFECTS ON WHITE-TAILED
DEER AT THE WICHITA MOUNTAINS
NATIONAL WILDLIFE REFUGE

Thesis Approved:

James H. Shaw
Thesis Adviser

Terry L. Bidwell

John H. Bassmith

James C. Lewis

Norman N. Durham
Dean of the Graduate College

PREFACE

The purpose of this study is to determine habitat utilization patterns of elk in summer with particular emphasis on describing the habitat used for calving activities. Home range size, diurnal habitat preferences and use were determined during May through August, 1976 and 1977. Behavioral interactions between cows and their calves, and between elk and deer are also discussed. In addition, evidence is presented supporting the hypothesis that elk may be forcing deer into marginal habitat for fawning through interspecific spatial competition, thus predisposing the fawns to predation.

Financial support was provided by the Refuge Division, U. S. Fish and Wildlife Service and Environmental Institute at Oklahoma State University (OSU). Logistical support was provided by the Wichita Mountains National Wildlife Refuge.

I wish to express my sincere appreciation to Dr. James H. Shaw, my major adviser, and to the other members of my committee, Dr. James C. Lewis, Editorial Staff, U. S. Fish and Wildlife Service, Ft. Collins, Colorado, Dr. J. J. Crockett, School of Biological Sciences, and Dr. John Bissonette, assistant Unit leader, Oklahoma Cooperative Wildlife Research Unit. Their support and advice while developing this thesis were invaluable.

Appreciation is extended to Roger Johnson, Gene Bartnicki, and Elmer Parker, U. S. Fish and Wildlife Service, Wichita Mountains National

Wildlife Refuge. The friendship and assistance extended to me by all the other refuge personnel is also greatly appreciated.

Sincere gratitude is expressed to Joe Coker, Tom Heathcock, Ron Jewell, and Steve Martin who assisted me during the summer field work, and to Gerald Garner who pioneered the field studies at the Wichita Mountains National Wildlife Refuge. I also wish to thank Bill Bartush, Deborah Holle and John Litvaitis, OSU, for their companionship during simultaneous field studies.

I wish to express my deepest appreciation to my wife, Elizabeth, and daughter, Julie Anne; without their understanding and encouragement this study would not have been possible.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The non-migratory Wichita Mountain elk herd developed from a 1907 transplant of Rocky Mountain elk (*Cervus canadensis nelsoni*) from Yellowstone National Park. The native Merriam's elk (*Cervus merriami Nelson*), an ecotypically distinct species, was extirpated from the mountains by 1881 (Hall and Kelson 1958). During the present herd's 70 yrs of existence no in-depth ecological research has been completed. Throughout the species' natural range it is regarded as an adaptable and competitive animal, traits that inevitably generate research interests. This study was designed in part to determine the ecological impact of a successfully transplanted subspecies in the Wichita Mountains ecosystem.

In recent years the refuge's white-tailed deer (*Odocoileus virginianus*) population has received considerable scientific attention. Leopold et al. (1947) included the Wichita Mountains area in their survey of over-populated deer ranges in the United States. They classified the herd as "incipient irruptive" and listed the sequence of events for an irruptive area. The refuge deer herd has generally paralleled the items Leopold et al. (1947) listed and numbers have decreased sharply since 1962 (Garner 1976). Herd numbers apparently have now stabilized, but at a significantly lower level. Steele (1969) attributed the herd's fluctuations to three possible causes, one of which was competition with elk and longhorn cattle. Garner (1976) initiated a study to identify the factors influencing fawn mortality. He found a fawn mortality of 87.9 percent, 96.6 percent of which he directly attributed to coyote (Canis latrans) and bobcat (lynx rufus) predation. Even though predation has been identified as the direct cause of fawn mortality, underlying factors may be contributing significantly. It is possible, for example, that elk-deer spacial competition is playing a key role in these fawn losses to predation. Conceivably, elk could be forcing white-tailed deer into marginal habitat for parturition and fawn-rearing, thus predisposing them to predation. Interspecific competition of this nature has not yet been investigated among North American cervids.

Odum (1971) has described interspecific competition as any interaction between populations of two or more species which adversely affects their growth and survival. Two types of such competition are recognized, direct interference and resource use (Odum 1971). Competitive interaction for resources often involves space. Interspecific competition, according to Odum, can result in equilibrium adjustments by two species, or it can result in one species replacing another or forcing it to occupy another space. Klopfer (1962) characterized space as possibly limiting populations wherever nesting, breeding or young-rearing habitat was in short supply. Although it is unlikely that space is directly limiting the refuge deer population, the lack of optimum habitat for rearing fawns may be limiting due to interspecific competition.

There have been numerous studies of use of habitat by elk, but only a few have been concerned with characteristics of calving sites (e.g., Reichelt 1973), and none have considered the possible interspecific implications with regard to coexisting cervids. Elk competition has also been intensively studied (Cliff 1939, Cowan 1947, Jones 1960, Flook 1962, Mackie 1970), but not under the unique conditions in the Wichita Mountains. In most of the previous studies forage competition was the primary concern.

Proving conclusively that elk-deer spatial competition is indirectly limiting the deer herd is outside the scope of this research. Instead, the project goal was to collect preliminary data on the elk herd that would determine whether evidence existed in support of the competition hypothesis. This project was conducted simultaneously with additional fawn mortality studies and an ecological investigation of the coyote. Hopefully, data collected from all three studies will allow a unique evaluation of the interrelated effects of competition and predation on a free-living population of a major game species. Specific objectives for the elk study were:

1. determination of biotic and abiotic characteristics of elk calving sites.
2. determination of characteristics of the habitat used by cows, before and after parturition, and calves.
3. investigation of possible competition between elk and white-tailed deer for parturition and young-rearing habitat.

CHAPTER II

THE STUDY AREA

This research was conducted exclusively on the Wichita Mountains National Wildlife Refuge (WMNWR). Located in the Central Rolling Red Plains (Gray and Galloway 1959) of southwest Oklahoma (Fig. 1) the refuge lies totally within the Wichita Mountains Biotic District (Blair 1939) and has an approximate area of 23,879 ha. Positioned along the refuge's south boundary is the 38,164 ha Ft. Sill Military Reservation, headquarters for the U. S. Army Artillery and Missile Center.

Established as a big game refuge with the original restocking of bison (*Bison bison*), the refuge has maintained its original purpose and currently supports an estimated 600 bison, 550 elk, 300 Texas longhorns (*Bos taurus*), and 500 white-tailed deer. All big game except deer are managed and maintained at desired levels either by public auction or in the case of elk by controlled hunts. Surrounding the refuge is 80 km of 2.4 m high ungulate-proof fence. Approximately 0.66 of the refuge, those lands north of the Scenic Highway (Fig. 1), are restricted from public access and maintained as a natural wildlife resource area. All research efforts were concentrated there due to the more natural conditions within this restricted region.

The climate is temperate continental of the dry subhumid type. There is a high evapotranspiration rate due to high winds and temperatures. Changes between seasons tend to be gradual, with seasonal

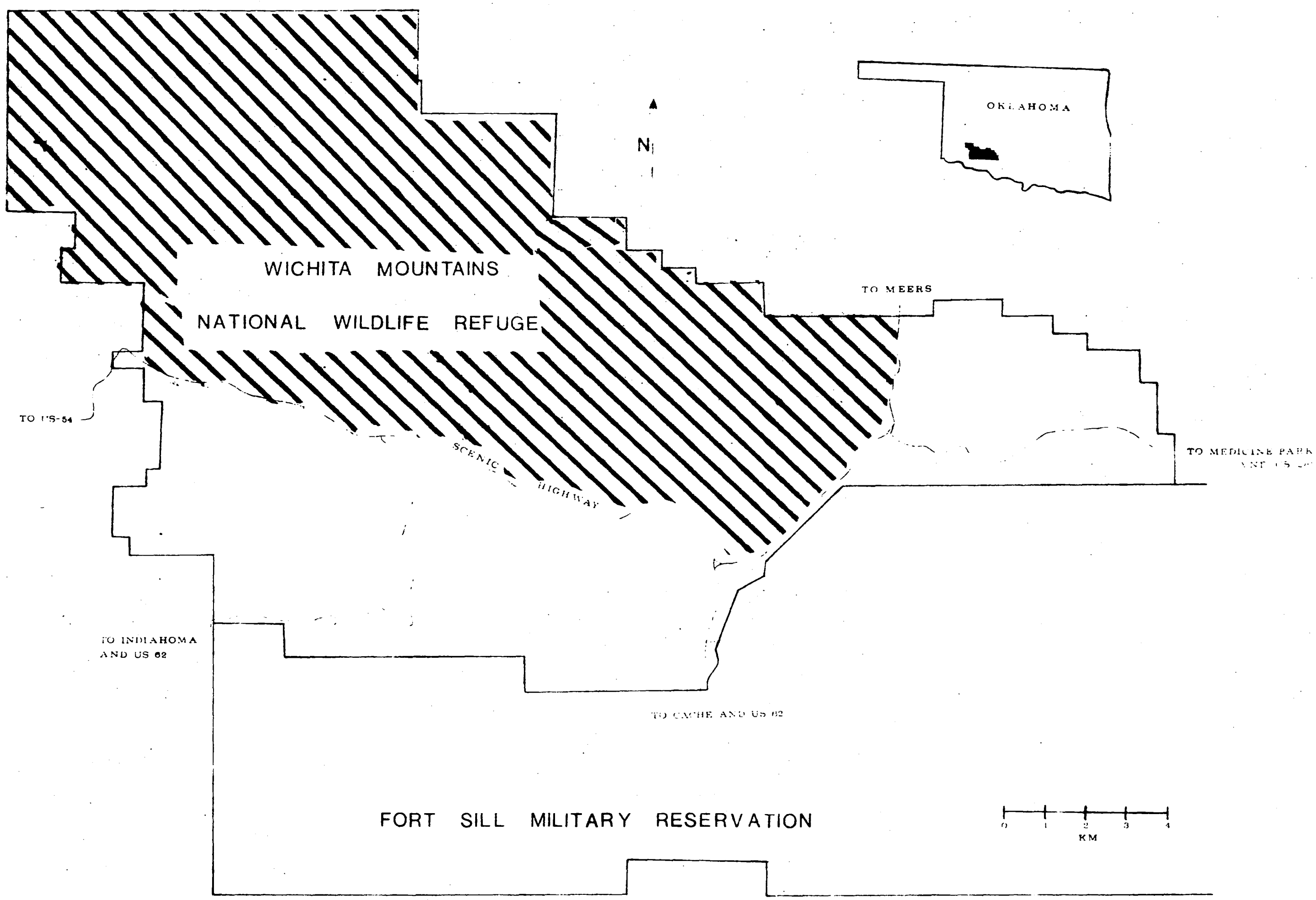

Fig. 1. The study area within the Wichita Mountains National Wildlife Refuge, Comanche County, Oklahoma

characteristics variable from year to year. Records for the period 1931 to 1960 indicate an average precipitation of 74.14 cm (Soil Conservation Service 1967). Thirty-four percent of the total precipitation falls in spring, 27 percent in summer, 24 percent in fall, and 15 percent in winter. The yearly snowfall ranges from 12.7 cm to 18.79 cm. Snows normally melt within 4 days (Soil Conservation Service 1967). The prevailing winds in the area are primarily from the south except in the winter when they become northwesterly.

Geologically, the refuge is composed chiefly of the igneous materials gabbro and granite, with limited patches of Permian sediments and recent alluvium. Buck (1964) described the mountains as monadnocks, the igneous roots of an earlier mountain system once covered by an estimated 3,353 m of sedimentary material.

The topography of the mountains has reached maturity and ranges from level to slopes exceeding 25 percent. Some sharp peaks and narrow valleys still exist, but in general the hills are rounded. The area is characterized by wide valleys and is well drained in south and southeasterly directions (Hoffman 1930). Elevations range from 152.4 m to 426.7 m above the surrounding plains. The highest point is Mt. Pinchot, 755.6 m above sea level.

The flora is extremely varied, with species composition determined by soil types and geological formations. Grasslands predominate and are categorized as short, mixed, and tall grass prairies. The tall grass species are primarily found in the deep-moist soils and include big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scopariuim*), sand bluestem (*A. halli*), switch grass (*Panicum virgatum*), and Indian grass (*Sorghastrum nutans*). Blue grama (*Bouteloua gracilis*), side-oats grama (B. curtipendula), hairy grama (B. hirsuta), and buffalo grass (Buchloe dactyloides) constitute a major portion of the short and mid grasses which dominate the more droughty soils. The more common forbs on the refuge include western ragweed (Ambrosia psilostachya), blanketflower (Gallardia pulchella), tickseed (Coreopsis tinctoria), thelesperma (Thelesperma filifolium), and sneezeweed (Helenium amarum) Crockett 1962).

Stream courses and fracture lines in igneous rock provide for the primary wooded vegetation. The fractures provide deeper soils and increased moisture. The resulting effect of fracture line growth is a mosaic of wooded areas creating a high degree of "edge" habitat (Halloran and Glass 1959). The species composition along these fractures is mostly post oak (Quercus stellata) and blackjack oak (Q. marilandica). Stream courses provide another wooded vegetative type with pecan (Carya illinoensis) and elm (Ulmus americana) common.

Examples of unique woody associations of local importance are sugar maple (Acer saccharum), western walnut (Juglans rupestris) and American elm (Buck 1962). The dominant woody species for the refuge are post oak with eastern red cedar (Juniperus virginiana) and blackjack oak respectively following (Buck 1962).

The Soil Conservation Service (1967) delineated and described seven range sites within the restricted area of the refuge (loamy prairie, loamy bottomland, hardland, slickspots, boulder ridge, hilly stony, and hilly stony savannah, Table 1). Each range site is represented by at least one mapping unit and a corresponding map symbol. Physiographic or vegetative variation within a range site classification is denoted by more than one mapping symbol and unit for that site.

Table 1. Description of range sites in the WMNWR restricted area (Soil Conservation Service 1967).

Map symbol	Range site description	Range site
Bk	breaks-alluvial land complex 0 to 20% slopes	loamy prairie and loamy bottomland
FsB	Foard-slickspots complex, 1 to 3% slopes	hardland and slickspots
Gc	granite cobbly land, 5 to 40% slopes, upland hills and ridges	boulder ridge
Go	granite outcrop, barren peaks, cliffs, escarpments, 90% exposed bedrock	boulder ridge
Ftb	Foard and Tillman soils 1 to 3% slopes	hardland
Lfc	Lawton-Foard complex 3 to 5% slopes	loamy prairie and hardland
Ro	rockland, 35 to 90% Go, 10 to 50% gently sloping to steep shallow soils	hilly stony
St	stony rockland, 15 to 50% slopes, 15 to 50% Go, 10 to 30% shallow soils, 15 to 70% deep stony soils	hilly stony and hilly stony savannah

Traditionally fire suppression has been basic refuge policy. This practice has interrupted the habitat's natural fire patterns, thus causing the prairies to be composed of over-abundant rank vegetation. A planned burning program, intended to alleviate this condition and to rejuvenate growth in selected areas was initiated in 1974. Burning has been limited primarily to the tall grass prairies located in wide mountain valleys outside the study area.

CHAPTER III

MATERIALS AND METHODS

Capturing and Marking

Capture of Adult Elk

Capture was accomplished with a 2,500 ha baited, permanent enclosure (Boyd 1970, Seidensticker et al. 1970, Harper 1977). The trap site was baited with hay during the winter months of 1976 and 1977. When sufficient numbers of elk were trapped they were driven out of the enclosure by refuge personnel on foot, in helicopters, and in vehicles into a centrally-located corral. In 1976 the animals were restrained while blood smears were taken and cows were rectally palpated to determine pregnancy (Greer and Hawkins 1967). All elk were aged by dentition (Quimby and Gaab 1957), and ear marked with button tags. The suspected gravid cows were measured (Appendix), marked with colored ear streamers for individual identification (Harper and Lightfoot 1966), and fitted with radio transmitter collars. Cows captured in 1977 were not palpated nor were physical measurements and biological samples taken because the usefulness of the techniques was outweighed by potential problems of stress to restrained cows.

Capture of Calves

Elk calves move little their first 4 days of life and cows tend to stay in the immediate vicinity of their hidden calves (Schwartz and Mitchell 1945, Johnson 1951, Altmann 1956). Thus, the daily location of cows during calving season will generally disclose calving sites. However, there are no published methods for determining when birth has occurred or for locating the calves of transmittered elk cows, consequently, a strategy had to be formulated. A combination of the following procedures worked best: (1) know each animal's individual physical characteristics. Observe animals often so that any changes in appearance, such as sudden weight loss or enlargement of the udder, will be obvious; (2) locate transmittered cows daily so that any unusual behavior patterns, such as a sudden preference for a particular area, will be noted; (3) be suspicious of cows that are skittish, alone, and never appear to be at ease. Parturient cows will continually look up while feeding, move very cautiously, and stop frequently to look around and sniff the air; (4) note any changes in activity patterns. Cows frequently decrease diurnal activities at time of parturition; (5) cows visit their calves several times during the day. In general these times are early morning, midday, and late evening. The calf usually changes its bedsite at midday and this time presents the best opportunity for capturing the calf; and (6) when a calf is seen, observe it until it leaves the cow and beds down before attempting to capture it.

Favorable vantage points were manned during early morning, midday, and late evening, to detect calves. Observation was facilitated by use of 20x spotting scopes and 8 x 40 binoculars. Calves were captured by hand using methods employed by White et al. (1972) on white-tailed deer fawns. The calf was measured (Appendix) to determine age using the technique based on physical characteristics described by Johnson (1951), ear-marked as described by Knowlton et al. (1964), and fitted with an individually-marked neck collar. The collars (Wildlife Materials, Inc., Carbondale, Illinois) consisted of a modified buck deer neck strap with a series of sewn-in folds to allow for growth. During the summer of 1977 this collar was replaced by expandable radio transmitter collars.

Radio-location Telemetry

Radio transmitters (Wildlife Materials, Inc.) were lithium-powered units with ranges of 6.4 to 9.6 km and a rated battery life of 2 to 3 yr. To aid in field recognition of cows a strip of Dayglo Saflag material (Safety Flag Company of America, Pawtucket, Rhode Island) 5 x 45 cm was sewn on the collar webbing.

Instrumented elk were located using a portable model LA12 receiver and four-element yagi antennae (AVM Instrument Company, Champaign, Illinois). The inherent error associated with long distance triangulations required that animals be monitored from within 50 to 100 m. All animal locations included either direct observation or close range triangulation from at least three points so that the specific habitat type and exact location could be determined.

Home Ranges and Habitat Use

Home Ranges

All telemetry locations were plotted on aerial photographs of the study area. Home range sizes were calculated with a compensating polar planimeter using the minimum area (Mohr 1947) and the modified-minimum area (Harvey and Barbour 1965) methods. The dot-grid method (Mosby 1971) for calculating the percentages of different habitat types from the modified-minimum area home ranges was used. Two seasonal home ranges, spring-summer (April-August) and fall-winter (September-March), were determined for the cows that were transmittered in 1976. Because of the small number of triangulations for fall-winter, these home ranges were used only to identify home range fidelity and shifts. Only the spring-summer home ranges were calculated for cows and calves in 1977.

Habitat Use

Habitat type and range site were recorded for each site where an animal was triangulated. The study area was divided into three broad habitat types, open, closed forest, and intermediate (Fig. 2). Open areas were defined as those areas $\geq$ 0.405 ha with no woody vegetation as verified on aerial photographs. Closed forest was characterized by dense, woody vegetation with virtually no canopy openings. The intermediate habitat type was also composed of woody vegetation but without the solid canopy cover and it closely resembled a savannah habitat. Soil survey maps (Soil Conservation Service 1967) were used to determine range sites and their vegetative characteristics.

Calf Bedsite Analysis

Transmittered calves were observed periodically to determine the calf's bedsite. The calf was subsequently flushed and climatic data such as temperature, cloud cover, wind speed and direction were recorded at the time of location. Vegetation and physical characteristics of the bedsite were determined using a technique that combined the line

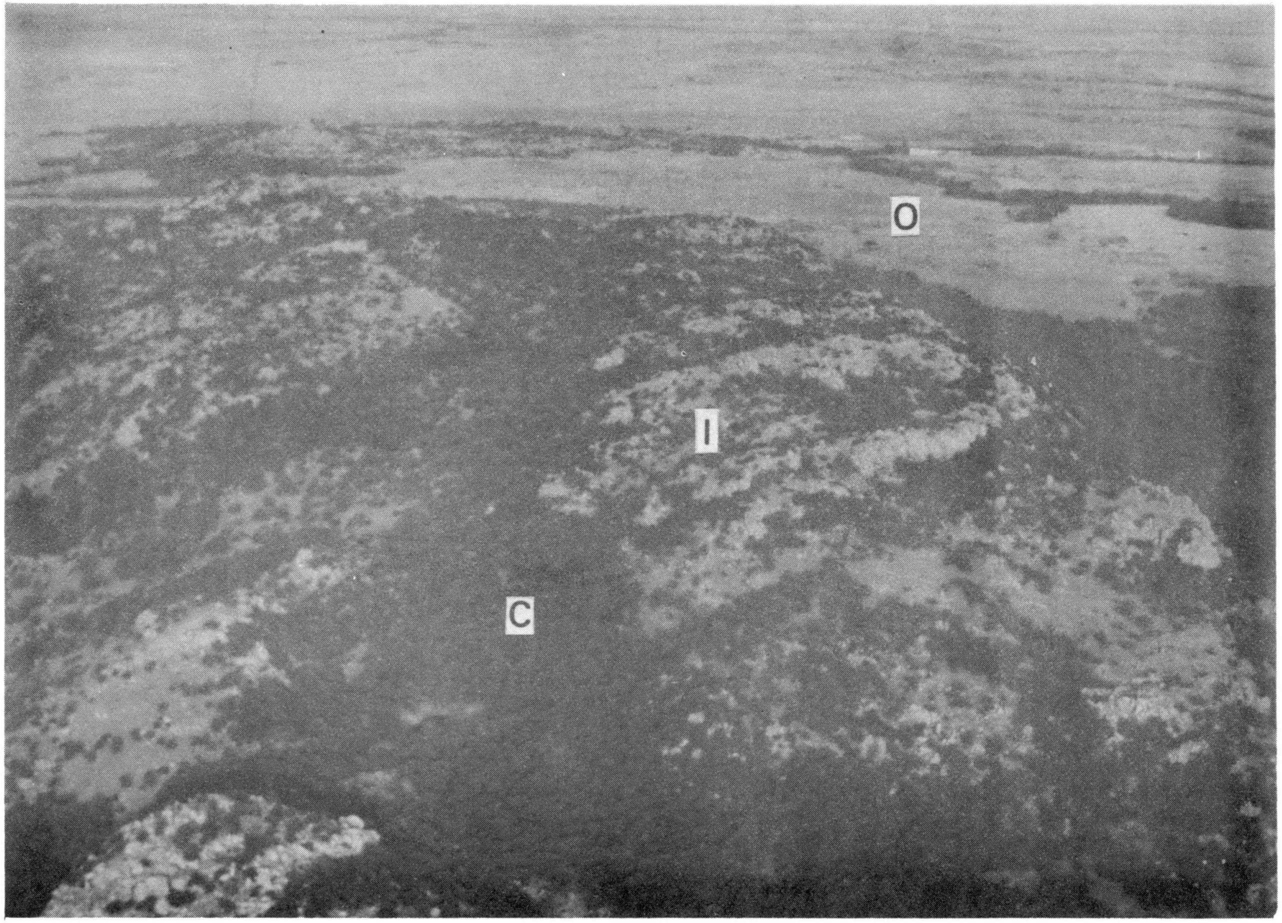

Fig. 2. The three broad habitat types, open (O), intermediate (I), and closed forest (C), WMNWR, 1977.

transect and the line intercept (Cox 1976) methods. Measurements were taken along two, 20 x 2 m, bisecting perpendicular transects which intercepted at the bedsite. Total counts were made within the transect to determine tree and boulder density. Cover was measured by the linear distance of boulder and trees intercept along the transect. Boulders were classified by height: Class I, 0-0.5 m, Class II, > 0.5-1.0 m, and Class III > 1.0 m. Randomization of transect was achieved by using the upslope and cross-slope coordinates for the transect bearings at each bedsite. Slope, aspect, elevation, range site, habitat type, and bedsite temperature at ground level were also determined. Statistical Analysis System (SAS) computer programs were used for the statistical treatment of bedsite data.

Behavioral Observations

Standardized data forms were utilized to record elk observations of behavior during the calf observation periods (morning, midday, and evening). Interspecific relationships with deer were of particular interest, but maternal care, intraspecific interactions, and unusual behavior were also noted. In addition, for all observations of elk and deer the aspect, habitat, group size and age/sex composition were recorded. Observation forms were also utilized in determining calving and activity patterns. After the calving season (15 May-1 July) observation forms were maintained as daily field records for elk and deer sightings.

Determination of Population Characteristics

Adult sex and cow:calf ratios were determined in the late summer months from aerial transects in helicopters furnished by Ft. Sill.

Flights began at dawn and lasted approximately 2 hours. Yearling females were distinguished from adult cows, whenever possible, to achieve accurate cow:calf ratios. Daily observation forms were also utilized in determining adult sex and cow:calf ratios to supplement the aerial counts. Pregnancy and fertility information were derived from ovarian analysis (Morrison 1962) and examination of elk harvested in 1975 and 1976. Data on seasonal herd sizes and composition were obtained from daily field observations.

CHAPTER IV

RESULTS

Capturing, Marking, and Biotelemetry

Twenty-five elk were captured during the winter of 1975-76; seven cows were fitted with radio-transmitters and the other 18 elk were ear-tagged and released. Three transmitters remained active through the entire first year. One transmittered cow (R-24) died in April, two transmitters (R-13 and R-20) malfunctioned by August, and another transmitter (R-19) quit in December. All transmitter malfunctions were confirmed by observing the cow. Only six cow elk were captured and transmittered in the 1976-77 trapping season; three of these were re-captures (R-13, R-20, and R-24). At the end of the 1977 field work five transmitters remained active. Transmitters remained working on only 2 cows throughout the total 20 months of research (Table 2). A total of 344 radio-locations on cows were obtained in 1976 and 434 were obtained in 1977.

Four elk calves were captured and marked in 1976; the parent cows of these three calves were also radio-equipped. Seven calves were captured in 1977 and six were fitted with transmitters (four parent cows were also transmittered cows). No malfunctions occurred among the transmitters on calves. In 1977 a total of 196 radio-locations were obtained for the 6 transmittered calves.

Table 2. Record and status of 10 marked cow elk, WMNWR, March 1976-August 1977.

Elk	Age (yrs)	Date captured	Collar color	Eartag no.		Status
				L	R	
R-2	2.5	3/9/76	Blue	24	25	Last radio location 8/10/77
R-13	2.5	3/9/76	White	27	24	Radio dead[a] 8/1/76
R-14	3.5	3/9/76	Orange	22	18	Elk dead 3/23/76
R-19	2.5	3/9/76	Yellow	21	19	Radio dead[a] 1/1/77
R-20	2.5	3/9/76	Red	21	20	Radio dead[a] 6/1/76
R-24	10.0	5/21/76	Orange	43	44	Last radio location 8/10/77
R-25	8.0	5/21/76	Black	42	45	Radio dead[a] 7/1/77
R-13	3.5	2/28/77	(recapture)			Radio dead[a] 6/20/77
R-20	3.5	2/28/77	(recapture)			Radio dead[a] 6/25/77
R-24	11.0	2/28/77	(recapture)			Last radio location 8/10/77
R-26	5.0	3/10/77	Orange	86	87	Last radio location 8/10/77
R-27	2.5	3/10/77	Red	94	97	Last radio location 8/10/77
R-28	3.5	3/10/77	Yellow	88	89	Last radio location 8/10/77

[a]Confirmed by observing the elk.

Home Ranges and Movements

The modified-minimum area and the minimum area, spring-summer home ranges were determined for four cow elk in 1976 and five in 1977 (Table 3). In all 9 home ranges approximately 98 percent of the telemetry locations occurred within the areas delineated by the modified-minimum area home range. Therefore, the modified-minimum area home range was considered the more representative of habitat utilization. Modified-minimum home ranges were less variable for cows in 1976 (range = 224-345 ha, standard deviation (S) = 45 ha) than in 1977 (range = 243-1,233 ha, S = 373 ha). The greater observed variation in the 1977 home ranges is due to cow R-24 which had a considerably larger home range in 1977 than in 1976. The 1977 mean home range size by the modified-minimum method was 344 ha (excluding R-24), 56 ha larger than in 1976. The combined 1976 and 1977 modified-minimum area home range mean was 313 $\pm$ 63 ha and the minimum area mean was 619 $\pm$ 146 ha.

Typically the modified-minimum area home ranges centered around one or two mountain complexes (Figs. 3 to 5). Individual cows demonstrated a strong preference for one particular area. Four cows (R-13, R-20, R-24, and R-25) were recaptured during the 1977 winter. Three were in the trap area for approximately 2 months and R-20 was present for 6 months. Within 24 hours after their releases from the trap site all four cows were back within the established boundaries of their 1976 spring-summer home ranges and they maintained similar home ranges in 1977. The transmitter on R-2 remained active through 1976 and 1977; her spring-summer home ranges, like the previous four cows, were very similar for the 2 yrs (Fig. 6). Home range fidelity was further demonstrated by

Table 3. The spring-summer minimum area and modified-minimum area home ranges and the number of triangulations for each of eight cow elk, WMNWR, 1976-77.

Cow	Minimum area (ha)	Modified-minimum area (ha)	Number of triangulations
1976			
R-2	764	283	57
R-13	728	275	49
R-19	477	345	44
R-24	698	224	45
R-25	657	313	39
$\bar{x}$	645	288	47
S	112	45	7
1977			
R-2	830	410	71
R-24	1595	1233	61
R-26	443	242	59
R-27	482	340	66
R-28	493	386	78
$\bar{x}$	769	522	67
S	488	373	8

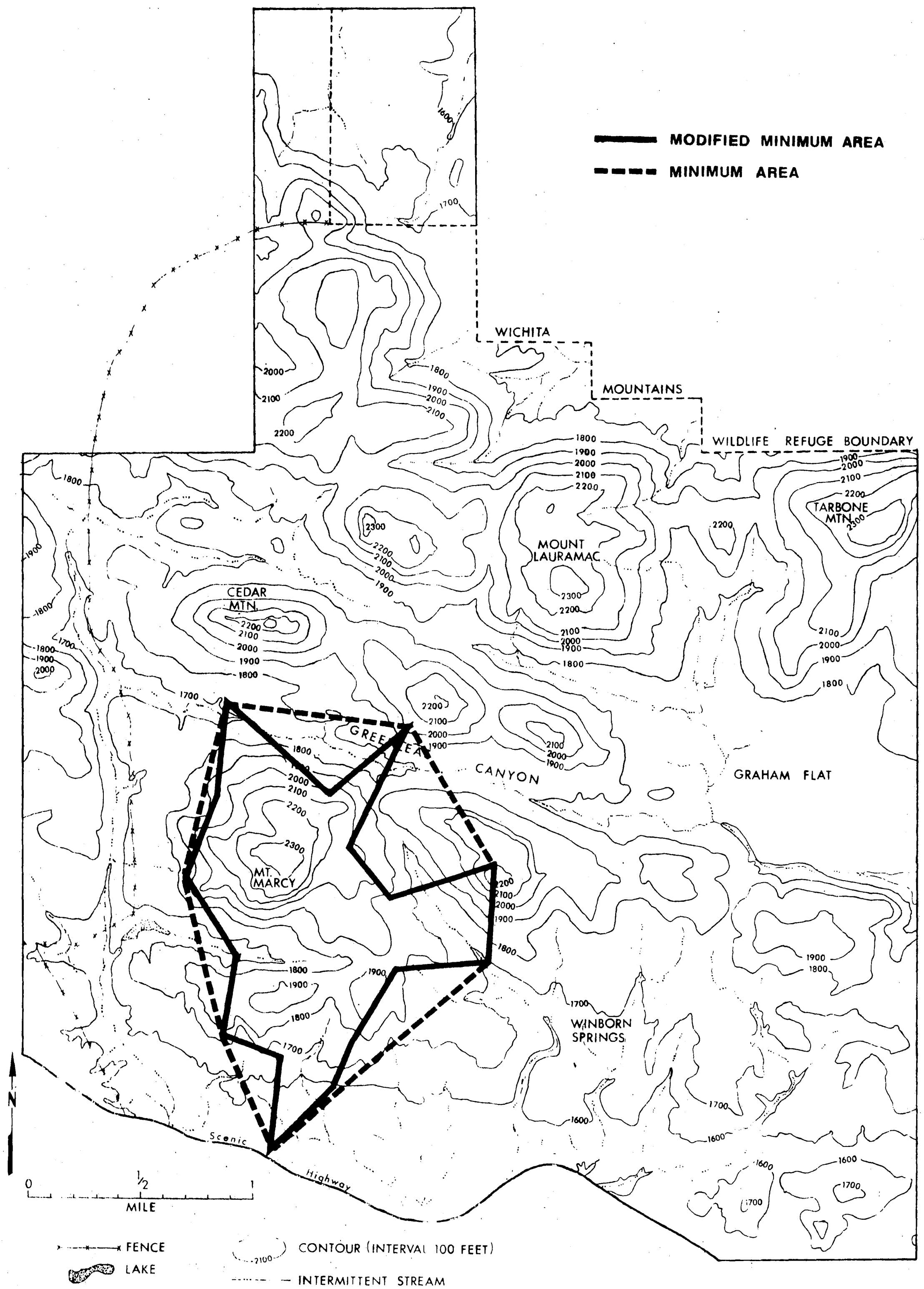

Fig. 3. The spring-summer modified-minimum area and minimum area home ranges for elk cow R-19, WMNWR, 1976.

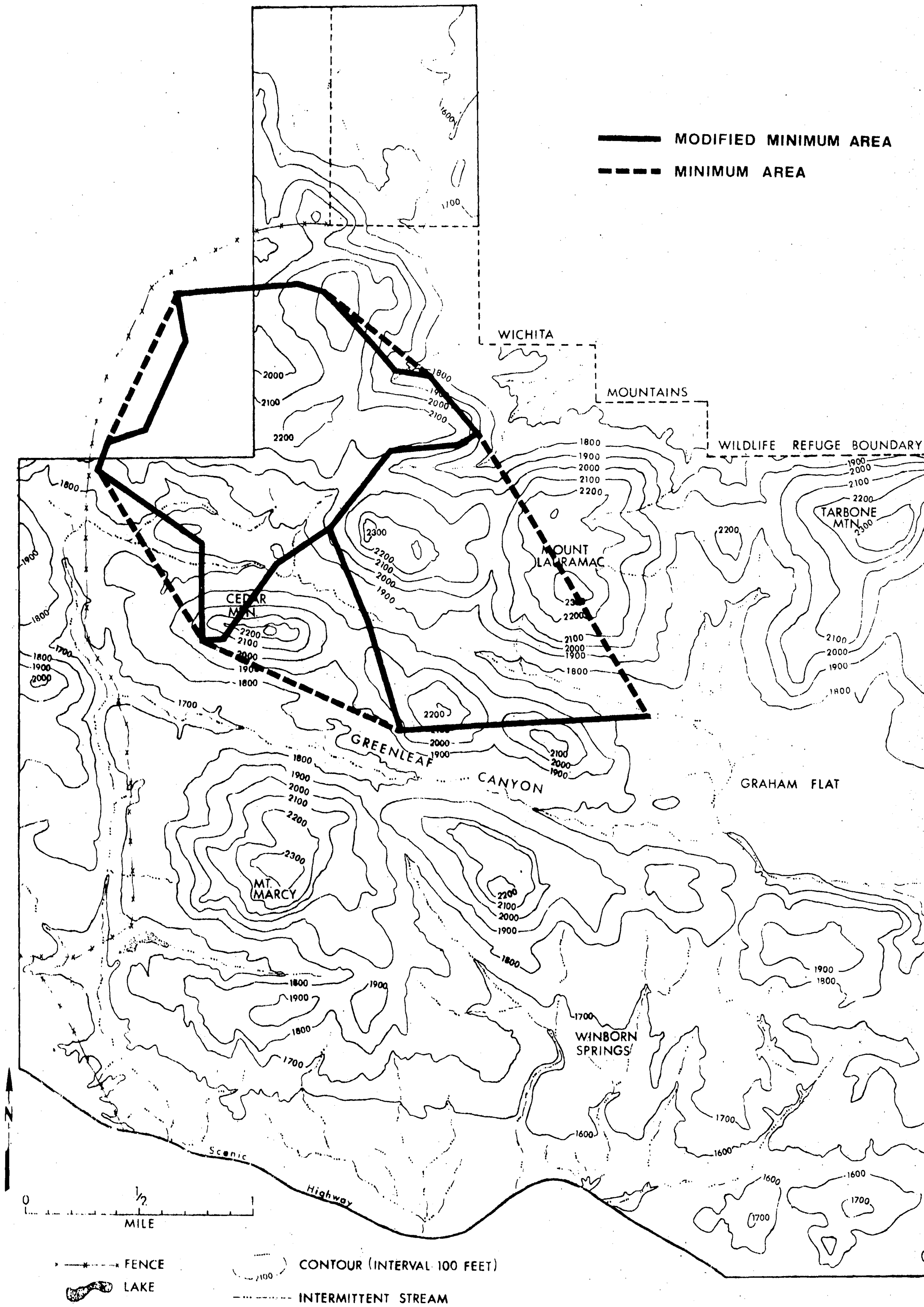

Fig. 4. The spring-summer modified-minimum area and minimum area home ranges for elk cow R-13, WMNWR, 1976.

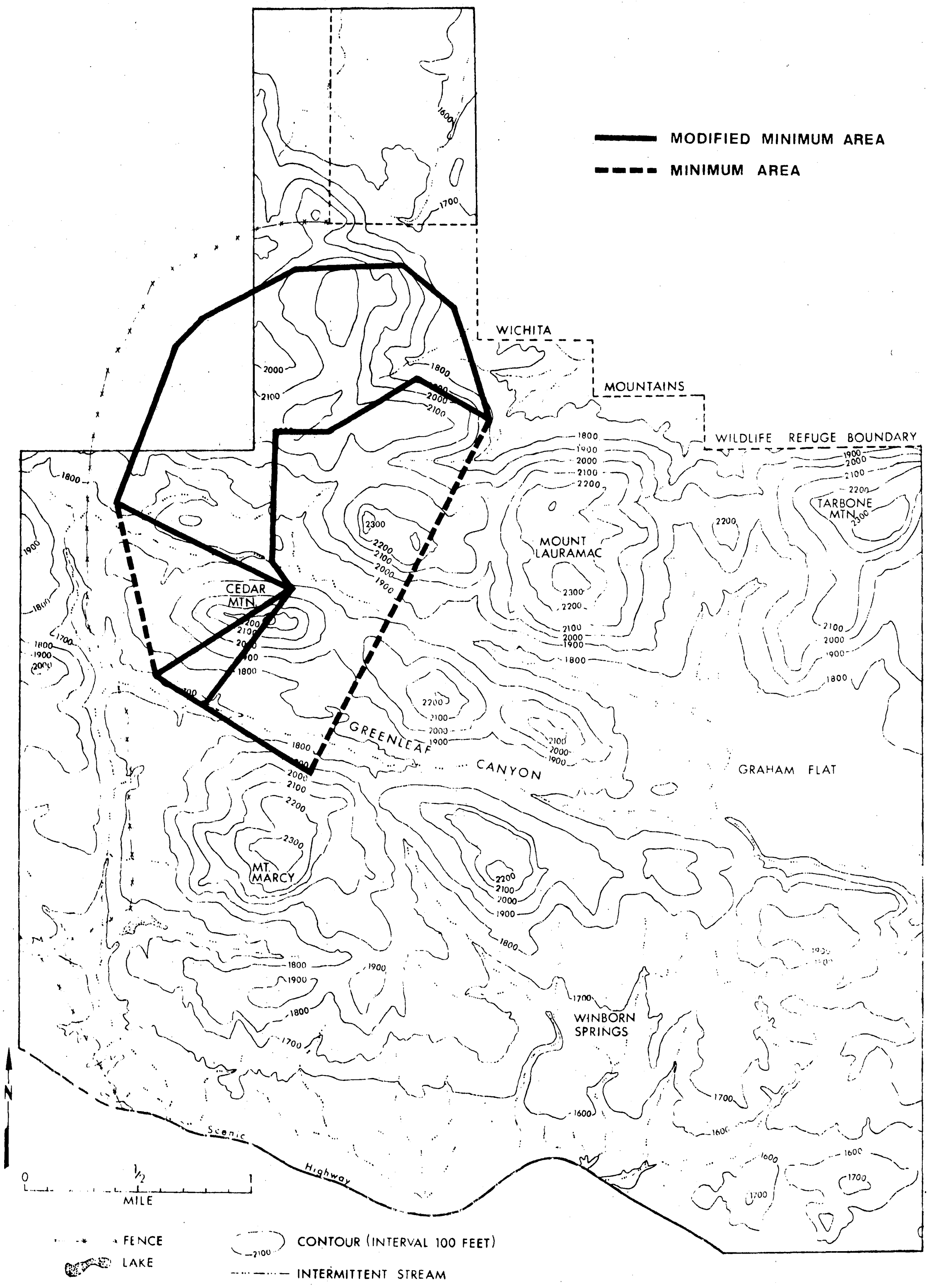

Fig. 5. The spring-summer modified-minimum area and minimum area home ranges for elk cow R-25, WMNWR, 1976.

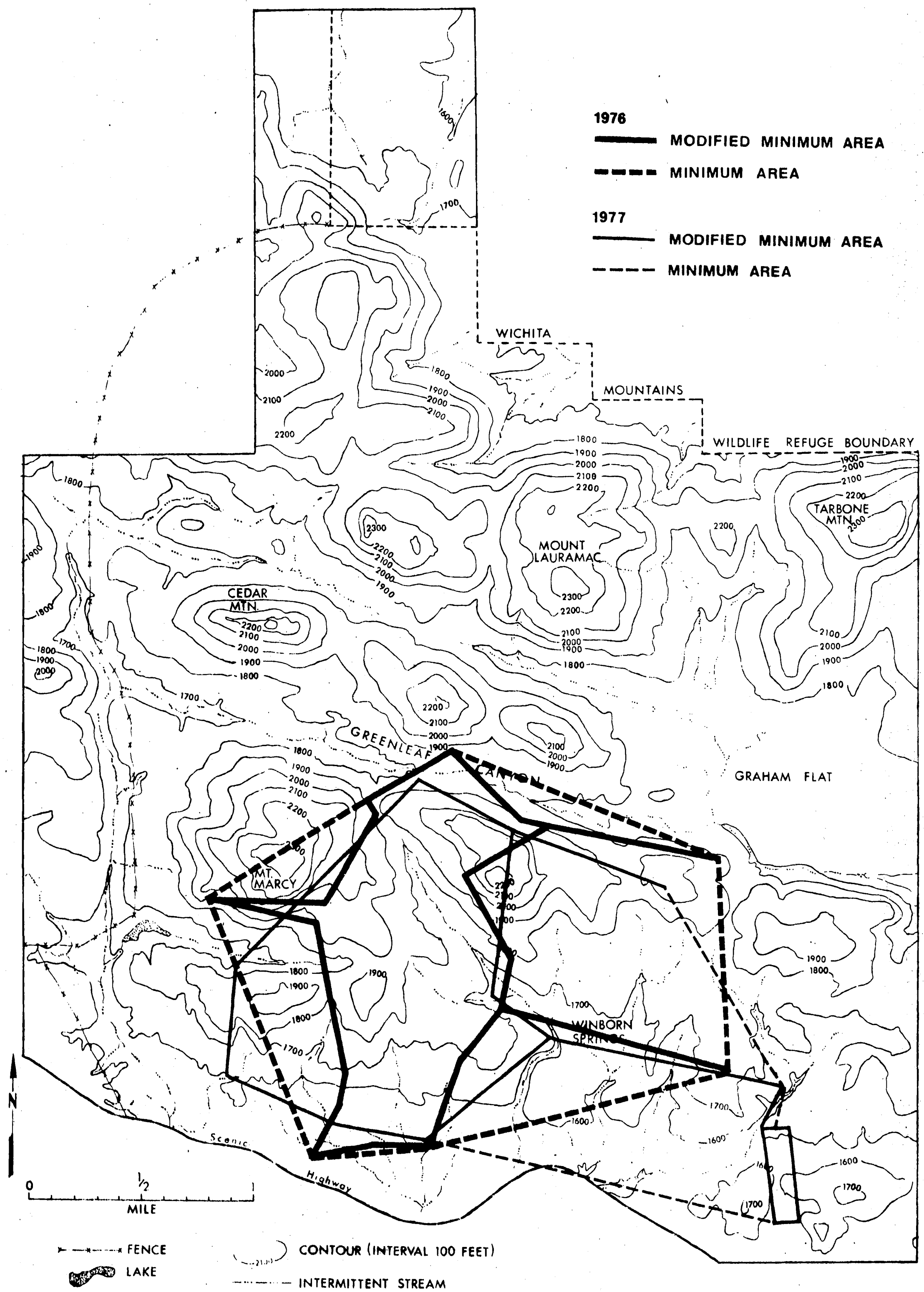

Fig. 6. Modified-minimum area and minimum area home ranges for elk cow R-2, WMNWR, in spring-summer of 1976 and 1977.

the fall-winter home ranges in 1976-77. Elk were triangulated too infrequently during this period to determine home range boundaries, but all were within the borders of their previous spring-summer home ranges.

Home ranges were determined for the six calves transmittered in 1977 (Table 4). Parent cows of four of the six calves (C-1, C-3, C-5, and C-7) also had transmitters (R-2, R-24, R-27 and R-28 respectively). As expected, the home range boundaries for those calves born in June closely approximated the home range boundaries for their cows (Figs. 7 and 8). Calf C-7 was born 25 July and its home range was within the home range boundaries of its cow but was much smaller (Fig. 9). The wide variation in dates of parturition (20 May-25 July) precluded calculations of average home range size because calf home ranges expanded with time.

Habitat Composition and Utilization of Home Range

The area and percent habitat composition for the three broad habitat types, closed forest, intermediate and open area were determined for spring-summer modified-minimum area home ranges of six cows producing calves (Table 5). The average habitat composition was 25.4 percent closed forest, 65.6 percent intermediate, and 9.1 percent open area. These habitats were considered representative of those used by calves because of the similarities between home ranges of cows and calves.

Diurnal habitat utilization by cows was determined from triangulations of summer between 0990-1730 hours (Central Daylight Time). The closed forest was the habitat most utilized by cows with the peak use (78 percent) occurring in July (Fig. 10). The intermediate habitat

Table 4. The minimum area and modified-minimum area home ranges and number of triangulations for six calf elk, WMNWR, summer, 1977.

Calf	Dates of triangulations	Minimum area (ha)	Modified-minimum area (ha)	Number of triangulations
C-1	6 June-10 Aug	561	242	50
C-3	8 June-10 Aug	1362	770	38
C-4	15 June-10 Aug	247	161	30
C-5	17 June-10 Aug	307	233	41
C-6	24 June-10 Aug	428	164	28
C-7	26 July-10 Aug	131	53	11

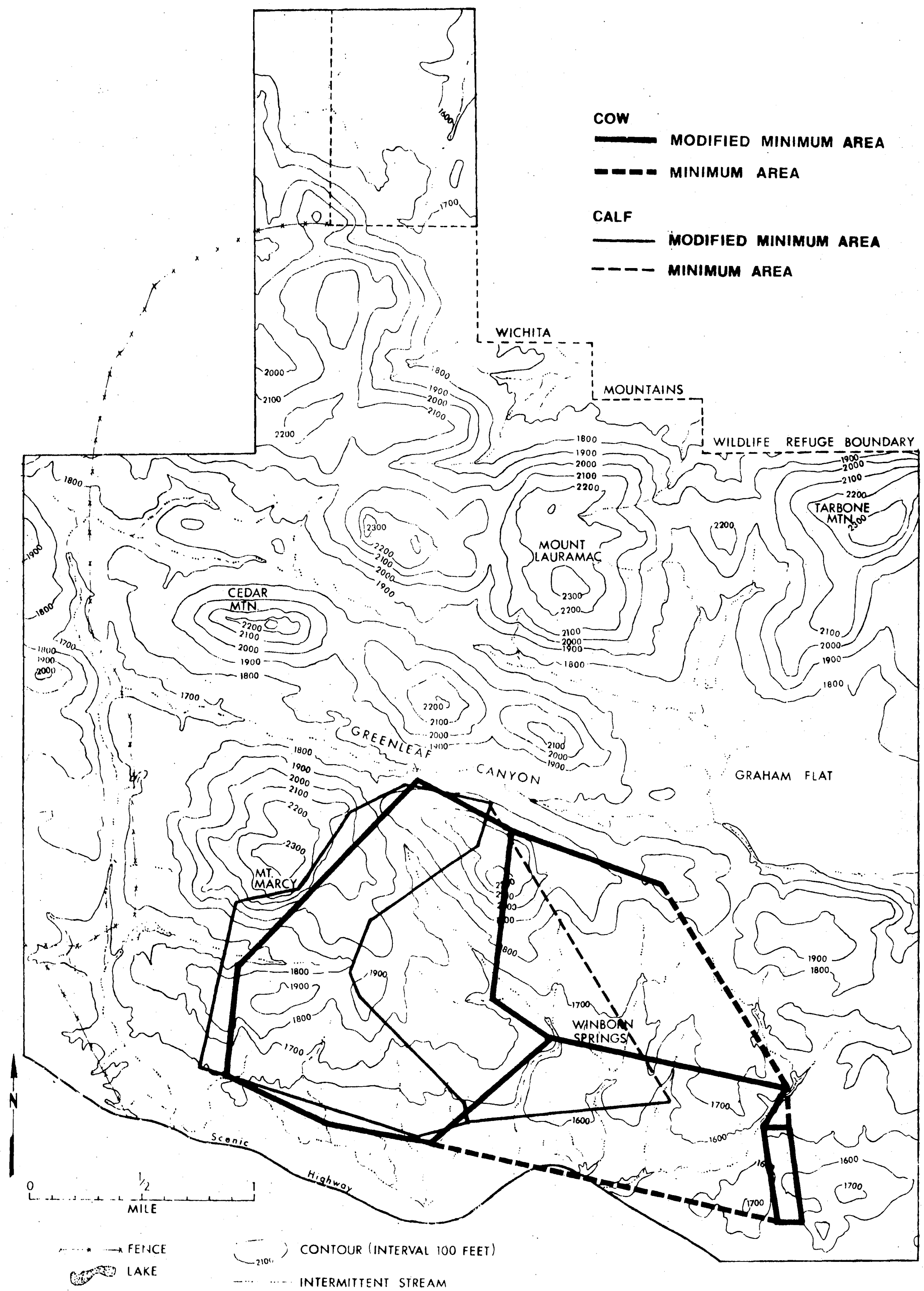

Fig. 7. Modified-minimum area and minimum area home ranges for elk cow R-2 and her calf (C-1), WMNWR, spring-summer of 1977.

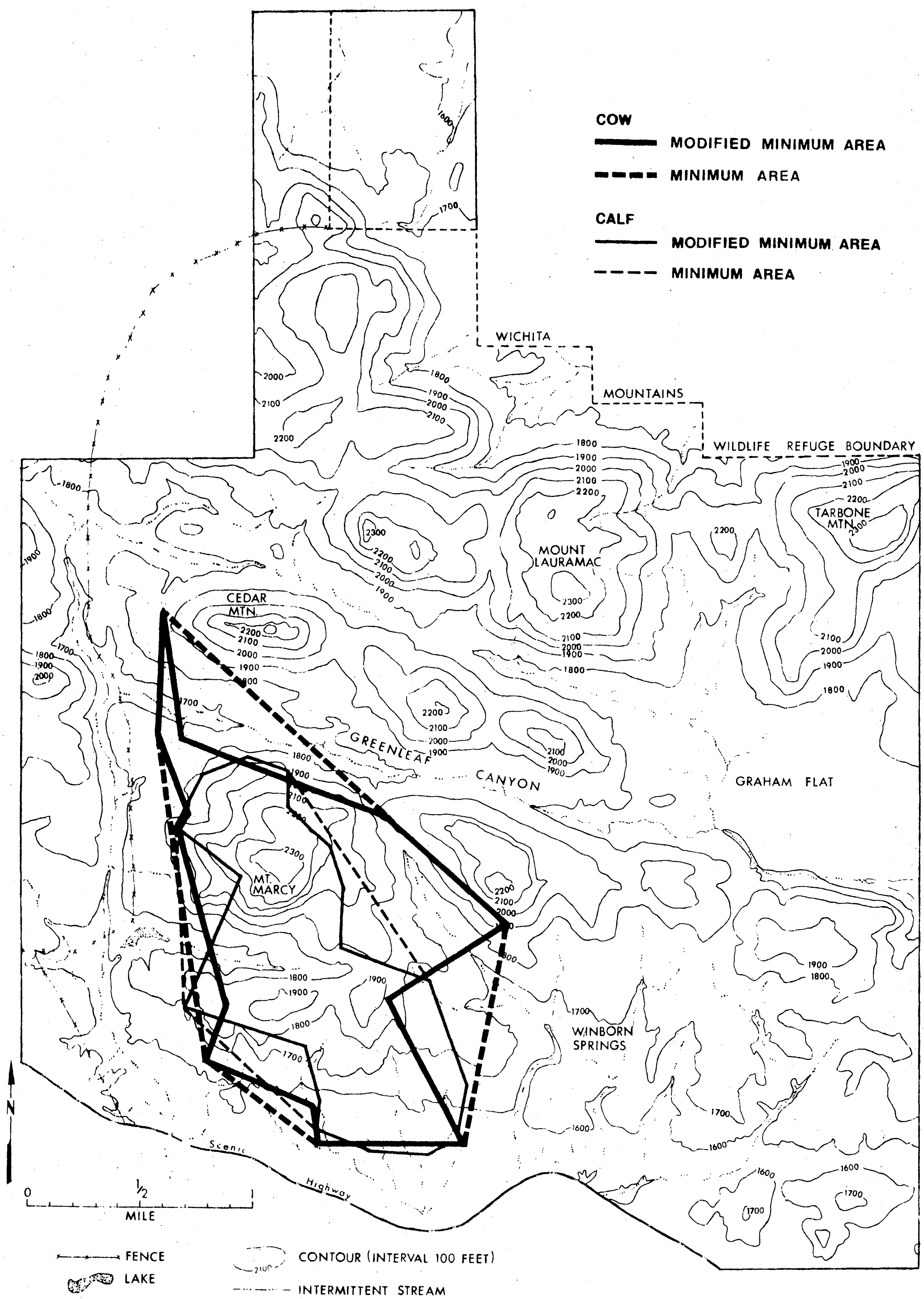

Fig. 8. Modified-minimum area and minimum area home ranges for elk cow R-28 and her calf (C-5), WMNWR, spring-summer of 1977.

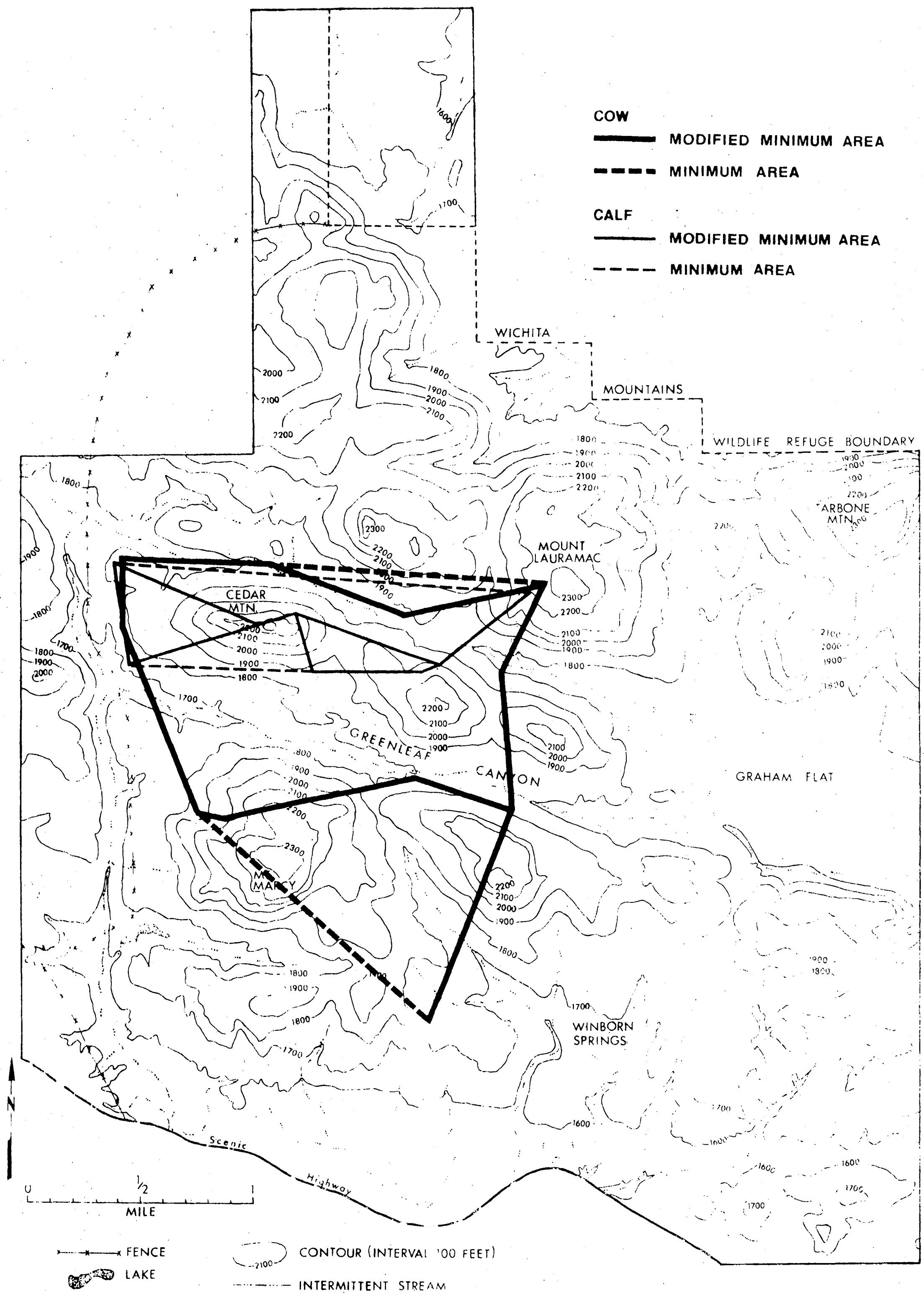

Fig. 9. Modified-minimum area and minimum area home ranges for elk cow R-27 and her calf (C-7), WMNWR, spring-summer of 1977.

Table 5. Habitat composition and locations for the modified-minimum area home ranges of six cow elk that had calves, WMNWR, in spring-summer, 1976 and 1977.

	Closed forest			Intermediate			Open area		
Cow	%	Area (ha)	Loca-tions	%	Area (ha)	Loca-tions	%	Area (ha)	Loca-tions
1976									
R-2	29.4	83.2	39[a]	59.7	169.2	10	10.8	30.8	2
R-13	16.2	44.7	27[a]	71.2	196.1	15	12.6	34.8	2
R-19	19.8	68.4	29[a]	76.2	262.9	9	3.9	13.7	2
R-25	26.6	89.4	27[a]	59.0	187.3	13	11.3	35.7	3
1977									
R-2	20.0	81.3	53[a]	65.0	267.5	18	15.0	61.4	0
R-27	24.0	116.9	42[a]	59.0	201.0	20	5.0	17.6	4
R-28	32.1	124.6	47[a]	62.7	242.2	28	5.1	19.8	4
$\bar{x}$	25.4	86.8		65.6	218.0		9.1	30.5	
S	6.8	27.2		6.6	39.0		4.3	16.0	

[a]A significant ($P<0.05$) number of locations to indicate habitat preference by X^2 test.

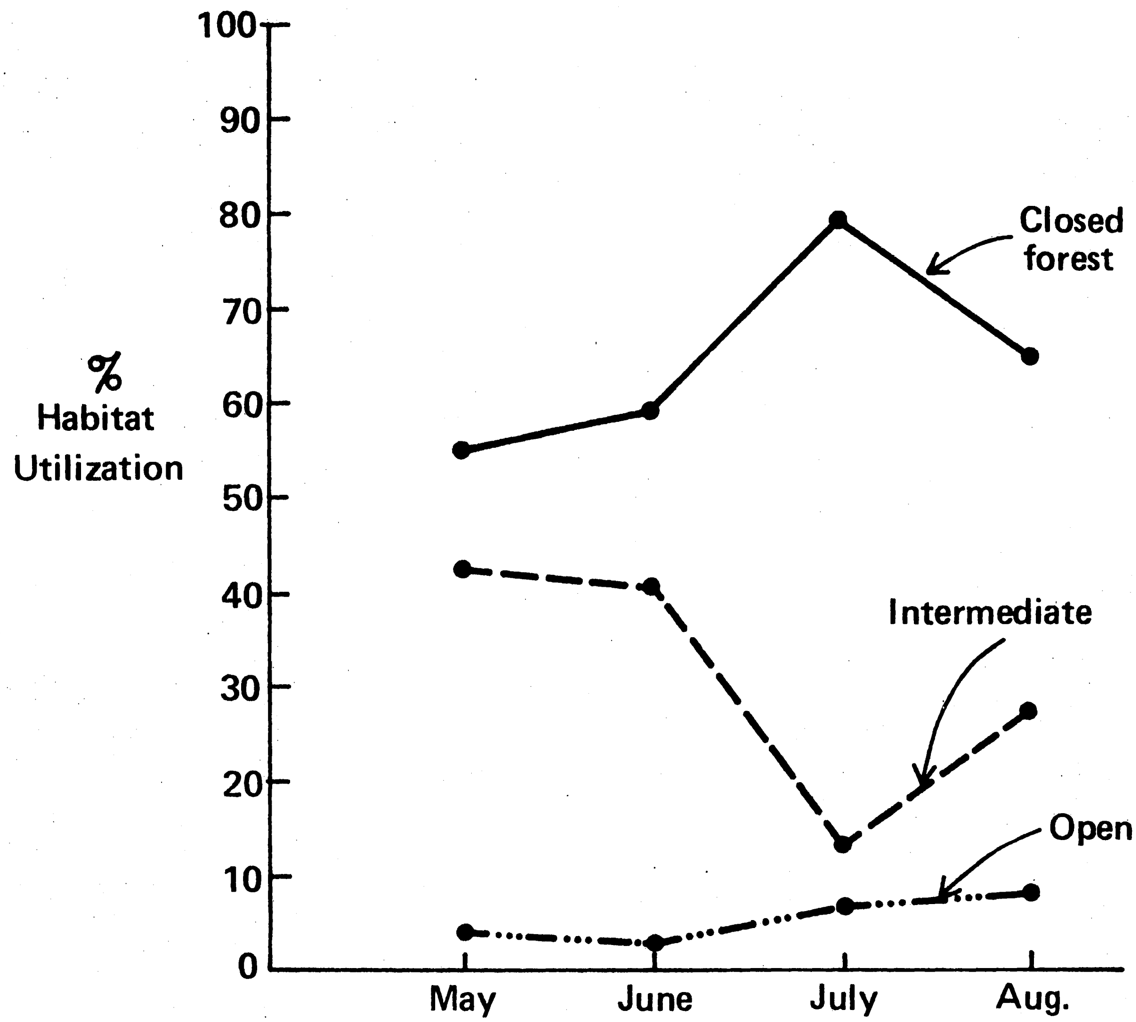

Fig. 10. Percent utilization of three habitat types (0900-1730 hours, CST) for eight cow elk, WMNWR, May-August, 1976 and 1977.

received high use until July when use decreased. Open habitat received its highest use in July (7 percent) and August (8 percent). The null hypothesis of no monthly habitat utilization difference was tested using the Chi-square test of hypothetical ratio. The hypothesis was rejected for May, June, July and August. Cows with transmitters showed a significantly greater utilization ($P \leq 0.001$) of the closed forest habitat.

Elk calves showed high diurnal use (63 percent) of the intermediate habitat (Fig. 11) in June. Elk calves and cows shifted to the closed forest habitat (64 percent) in July; open areas received little use. The null hypothesis of no preference for specific habitats shown by calves was rejected for June, July, and August. Calves showed a significant preference ($P \leq 0.05$) for the intermediate and closed forest habitat in June. The closed forest habitat was the most utilized ($P \leq 0.05$) in July and August. Cow and calf diurnal habitat use patterns were alike except in June when calves utilized more intermediate habitat than closed forest.

Habitat utilization during crepuscular feeding hours (0600-0900 and 1730-2030 hrs, Central Daylight Time) of 751 elk was determined from 545 man hours of observation between 15 May and 10 August 1977 (Fig. 12). Elk were generally observed retreating from feeding areas by approximately 0800 hours and observed returning by 1800 hours. Intermediate habitat received the highest percent utilization, peaking at 93 percent by 15 June, and steadily decreasing thereafter. Closed forest received 30 percent utilization during May, decreased to 5 percent by 15 June, increased to 12 percent by 15 July and continued to increase to 43 percent by 10 August. Open area utilization was low until the interval between 30 June and 15 July when utilization increased to 22 percent.

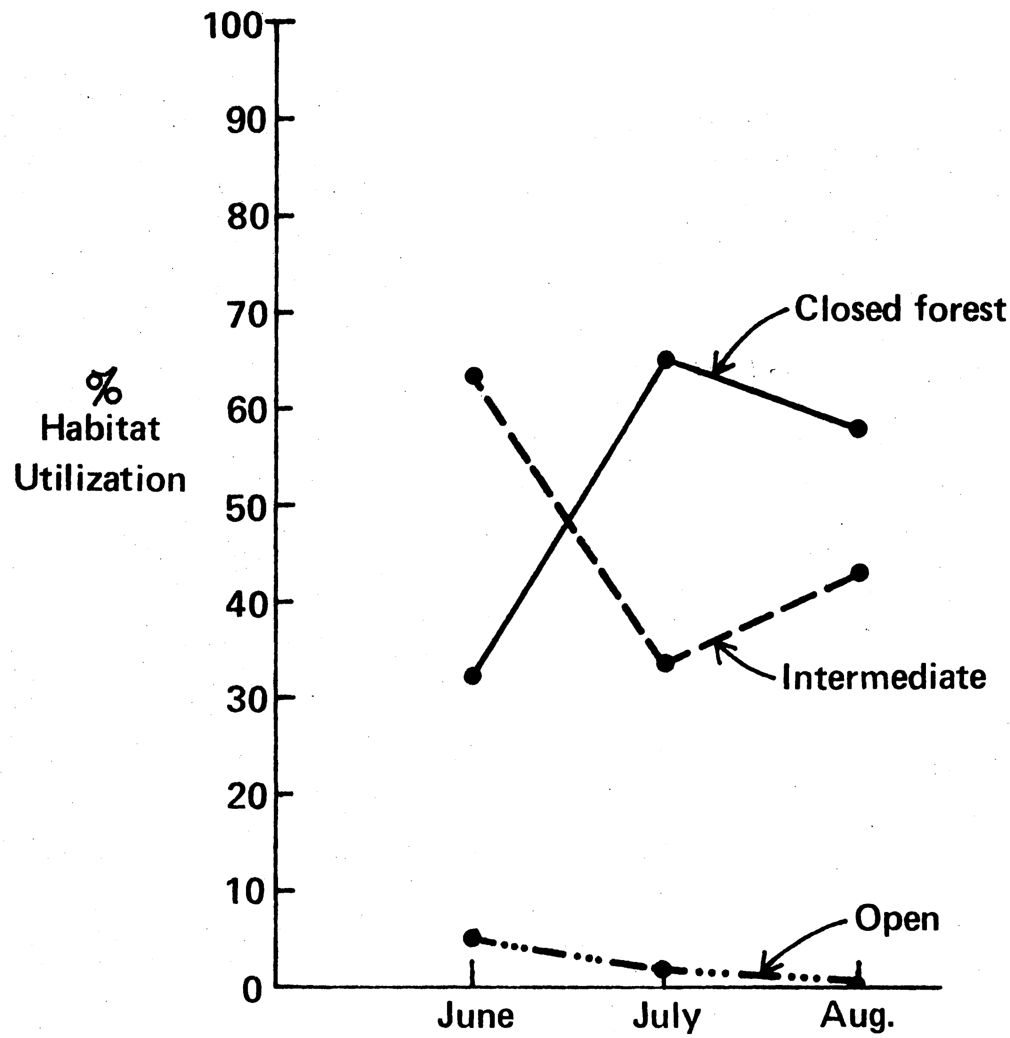

Fig. 11. Percent utilization of three habitat types (0900-1730 hours, CST) for six calf elk, WMNWR, May-August, 1977.

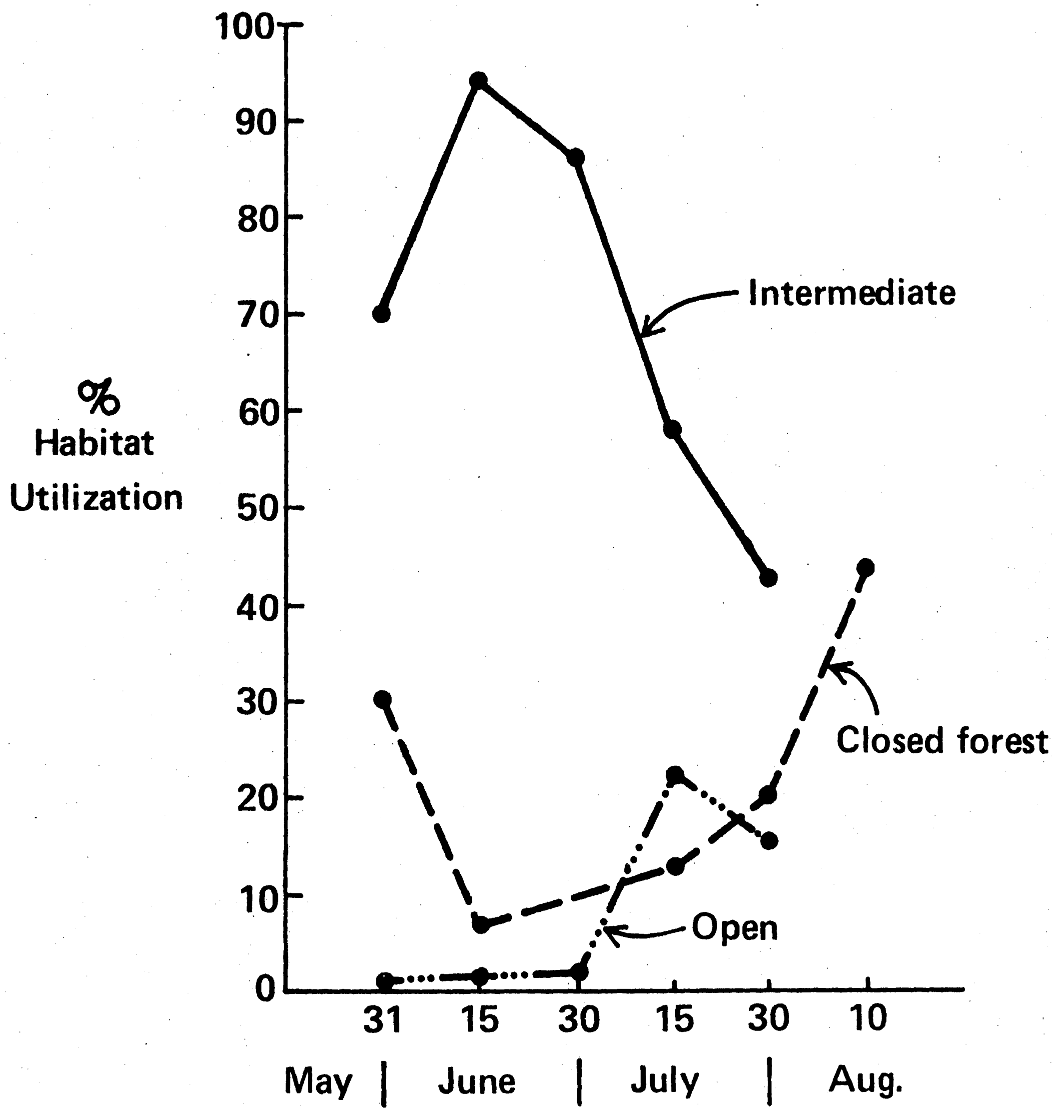

Fig. 12. Percent crepuscular feeding in three habitat types (0600-0900 and 1700-2000 hours, CST) for elk, WMNWR, May-August, 1977.

Range Site and Aspect Utilization

In May, June, and August the hilly stony savannah (St) range site received the highest percentage of diurnal utilization by transmittered cows (Fig. 13). Encompassing most all the mountainous terrain, "St" is the most abundant of the seven available range sites and is primarily composed of the intermediate habitat with the closed forest following the fracture lines and along the mountain bases. The loamy bottomland (Bk) and boulder ridge (Gc) range sites in the study area were mostly forested sites along streams. The combined "Bk-Gc" usage increased 23 percent in July as "St" utilization decreased 21 percent. In August "St" increased 12 percent and "Bk-Gc" decreased 14 percent. The monthly "Bk-Gc" and "St" utilization fluctuations corresponded to the closed forest and intermediate fluctuations observed for habitat utilization. The hilly stony (Ro) and boulder ridge (Go) are both relatively non-wooded range sites. The combined low monthly utilization of these range sites (Ro-Go) strongly resembled the depressed utilization of the open habitat.

Calves utilized habitat in patterns similar to cows, but with more acute monthly fluctuations (Fig. 14). Utilization of range site "St" sharply decreased 45 percent in July and increased 43 percent in August. The "Bk-Gc" combination increased 47 percent in July and decreased 38 percent in August. As the utilization of the intermediate habitat in the mountainous terrain (St) by calves decreased, a corresponding increase in the closed forest habitat utilization, primarily in bottomland areas (Bk-Gc), occurred.

The use of aspect by cows producing calves differed between 1976 nad 1977 (Table 6). The null hpothesis of no preference for specific aspects, based on the assumption all aspects were equally available, was

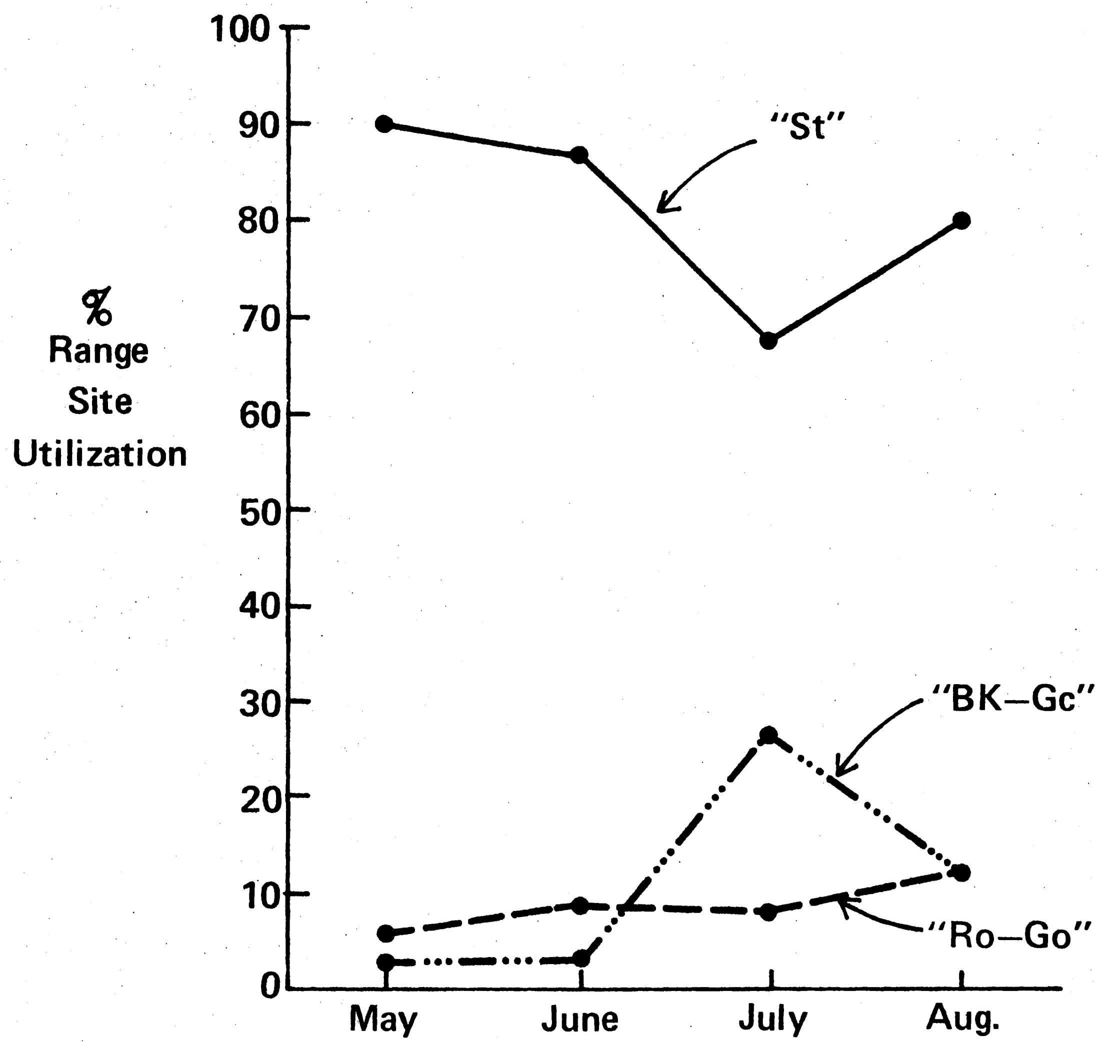

Fig. 13. Percent diurnal utilization of three range site categories for eight cow elk, WMNWR, May-August, 1976 and 1977.

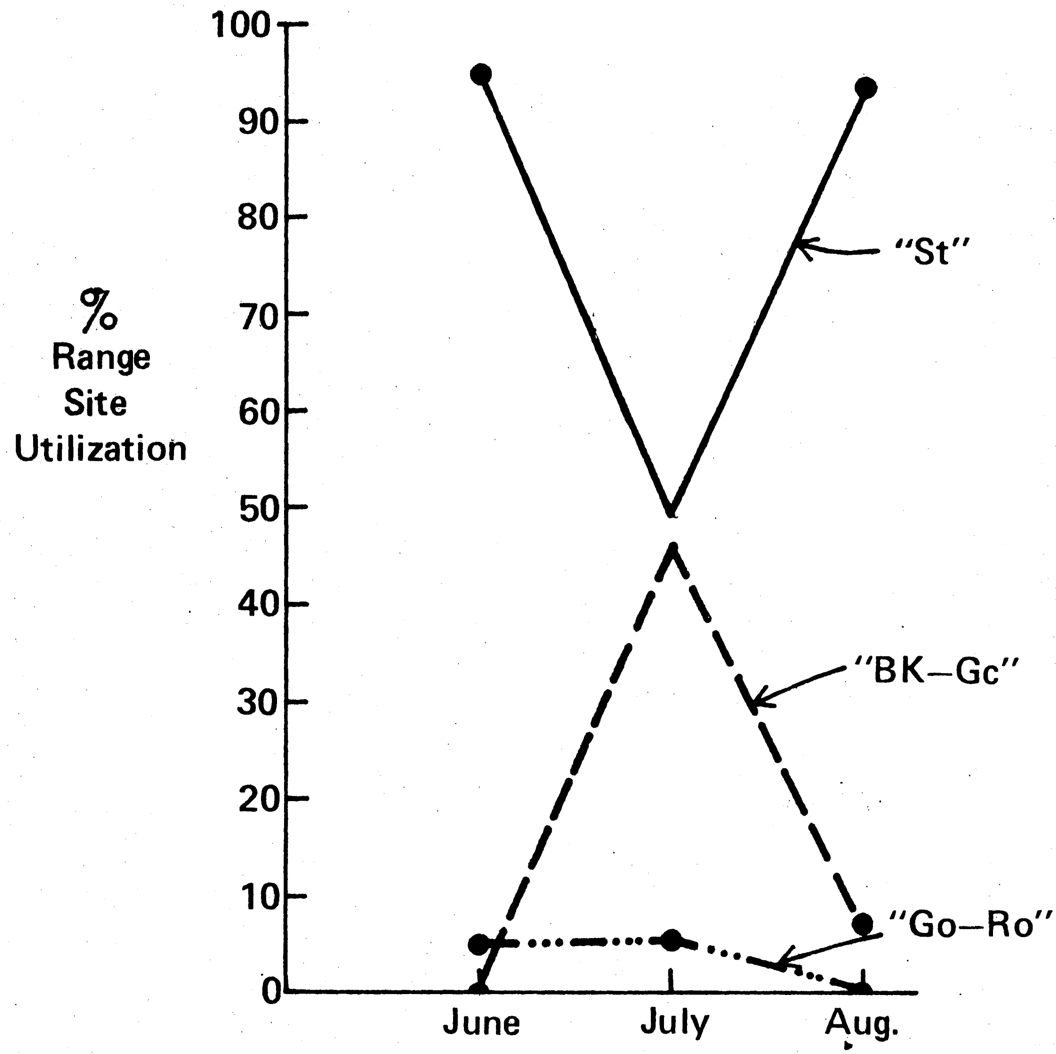

Fig. 14. Percent diurnal utilization of three range site categories for six calf elk, WMNWR, May-August, 1977.

Table 6. Preference for aspect as indicated by telemetry studies of seven cow elk that had calves, WMNWR, May-August, 1976 and 1977.

Date	Aspect and number of triangulations					Total triangulations
	East	West	North	South	Zero	
1976						
May	5 (12)[a]	4 (9)	3 (6)	20 (47)	11 (25)	43
June	9 (16)	12 (21)	10 (18)	9 (16)	16 (29)	56
July	9 (16)	3 (5)	13 (23)	13 (23)	18 (33)	56
Total	23 (15)	19 (12)	26 (17)	42 (27)	45 (29)	155
1977						
May	8 (10)	16 (19)	29 (34)	19 (22)	13 (15)	85
June	4 (4)	23 (21)	33 (30)	34 (31)	15 (14)	109
July	2 (2)	10 (11)	19 (21)	18 (20)	43 (46)	92
August	5 (22)	6 (27)	6 (27)	2 (10)	3 (14)	22
Total	19 (6)	55 (18)	87 (28)	73 (24)	74 (24)	308

[a]Percent of monthly triangulations.

tested monthly using the Chi-square test of hypothetical ratio. The null hypothesis was rejected for May and July 1976. The southern aspect was significantly ($P \leq 0.05$) utilized in May. A significant preference ($P \leq 0.05$) for the "zero" aspect, or flat terrain, was observed for July. No significant differences were observed in June. In 1977 the null hypothesis was rejected for May, June, and July. There was significant preference ($P \leq 0.05$) in May and June for the north, south, and west aspects. In July the "zero" aspect was preferred ($P \leq 0.05$); no preference was observed in August.

For calves the null hypothesis of no aspect utilization difference was rejected only for July (Table 7). In June, calves utilized all but the "zero" aspect. The "zero" aspect was significantly preferred ($P \leq 0.05$) in July. No aspect utilization differences were observed in August. Aspect utilization by calves and cows was very similar.

Reproduction and Sex:Age Ratios

Fifty-five female elk harvested in December 1975 were examined by refuge personnel for pregnancy and lactation (Table 8). All reproductive tracts were collected and analyzed for presence of corpora lutea (Table 8). Potential pregnancy rates for the sample of 44 breeding-age cows (2.5 yrs or older) was 56 percent. Cows older than age 7 showed a possible 41 percent pregnancy rate; production appeared to drop to zero in 15-year-old cows. The 1976 pregnancy rate for 21 breeding-age cows was 76 percent (G. Bartnicki, personal communication, 1977, Wichita Mountains National Wildlife Refuge).

Adult sex ratios and cow:calf ratios were determined from aerial and ground counts made during August 1976 and July and August 1977

Table 7. Preference for aspect as indicated by telemetry studies of six elk calves, WMNWR, May-August 1977.

Date	Aspect and number of triangulations					Total triangulations
	East	West	North	South	Zero	
June	13 (22)[a]	11 (19)	19 (32)	16 (27)	0 (0)	59
July	8 (7)	12 (11)	16 (15)	18 (17)	53 (50)	107
Aug	3 (14)	8 (36)	4 (18)	4 (18)	3 (14)	22

[a]Percent of total monthly triangulations.

Table 8. Age categories and reproductive status of 55 female elk, harvested December 1975, WMNWR.

Age class (yr)	Number of elk	Lactating Number	Lactating %	Pregnant Number	Pregnant %	Elk with corpora lutea
0.5	4	0	0	0	0	0
1.5	7	0	0	0	0	0
2.5	6	0	0	3	50	6
3.5	7	2	29	5	71	5
4.5	4	3	75	3	75	3
5.5	1	1	100	1	100	1
6.5	2	0	0	2	100	1
7.5	1	1	100	1	100	1
8.5	7	3	43	5	71	4
9.5	0	0	0	0	0	0
10.5	7	6	9	3	43	5
11.5	0	0	0	0	0	0
12.5	5	4	80	2	40	2
13.5	0	0	0	0	0	0
14.5	0	0	0	0	0	0
15.5	4	0	0	0	0	0
Totals	55	20	36	25	45	

(Table 9). The average bull:cow:calf ratio in 1976 was 58:100:26 compared to 73:100:55 in 1977. The increased 1977 cow:calf ratio corresponds with the increased potential pregnancy rate for 1976.

Cow-Calf Relationships

Neonatal calves invariably were visited three times daily by their cow. Transmittered cows were observed at dawn, midday, and dusk feeding intermittently while returning to the area of their hidden calf and making a soft, squealing sound closely resembling the call of a calf. The calf left its hiding place, presumably after hearing the cow's call, and promptly began nursing. No evidence was observed of cows using olfactory stimuli for locating their calves. Cows fed their calves for 5 to 30 min. Cows began slowly feeding away from the area after nursing the calf; the off spring followed closely. In all but one case calves appeared to select their own bedsites. The calf would wander off from the feeding cow in apparent search of a hiding place, often lying down several times before settling into a permanent bedsite. The cow, intently watching, would remain close by until the calf was concealed. However, one cow was observed quickly leading a calf from its midday bedsite across a mountain to a new location, where she abruptly stopped, then proceeded at a full run leaving the calf standing. The calf sought cover under the nearest tree. Apparently in this case the cow selected the area for the calf's bedsite.

Nursing times became less regular when the calves were 3 weeks old. Cows often kept their calves with them between two nursing sessions and left them the next two. Calves were not generally observed with other

Table 9. Elk sex and cow:calf ratios, WMNWR, 1976 and 1977.

Date	Survey method	Numbers of Bulls	Numbers of Cows	Numbers of Calves	Ratios Bulls	Ratios Cows	Ratios Calves
1976							
1 Aug	Air	47	92	7	51	100	8
10 Aug	Air	47	72	21	65	100	29
Aug	Ground		65	28		100	43
Total		94	229	56	58	100	26
1977							
27 Jul	Air	52	66	34	78	100	51
3 Aug	Air	59	86	52	68	100	60
Total		111	152	86	73	100	55

calves until they were 3 weeks old, then it was not uncommon to see several calves engaging in play-like behavior while the cows watched nearby. After age 3 weeks it was also not uncommon for several calves to bed together.

Neonatal hiding behavior of the elk began decreasing 5 weeks after birth (Appendix); however, it did not completely subside until approximately the sixth week. The mean distance between three transmittered cow-calf pairs was determined for four 2-week intervals beginning when the calf was captured (Fig. 15). The distances between cow-calf locations were measured on aerial photographs. The cow maintained a large distance from the calf during the second (164 m) and fourth (224 m) weeks. Not until the sixth week did the mean distance (25 m) between the pairs reflect a significant decrease in neonatal hiding behavior.

Cow elk were protective of their calves. The cows made a prompt appearance during all 11 captures of calves. Gnashing teeth and alarm calls were the common agonistic displays. One cow actually attacked but was easily censured. None of the calves were abandoned by cows after release by the investigator. Among parturient cows a close association with their calves lasted only until the next calving season. Cows R-2 and R-24 were frequently seen with their calves of 1976 until May 1977, when both calved again in June.

Mean Herd Size and Elk Group Interaction

Mean herd size was determined from 545 man hours of observation for seven 2-week intervals beginning 15 May (1976 and 1977) and ending 25 August 1976 and 15 August 1977 (Fig. 16). The mean herd sizes in 1976 and 1977 were very similar from 15 May to 15 July, oscillating between

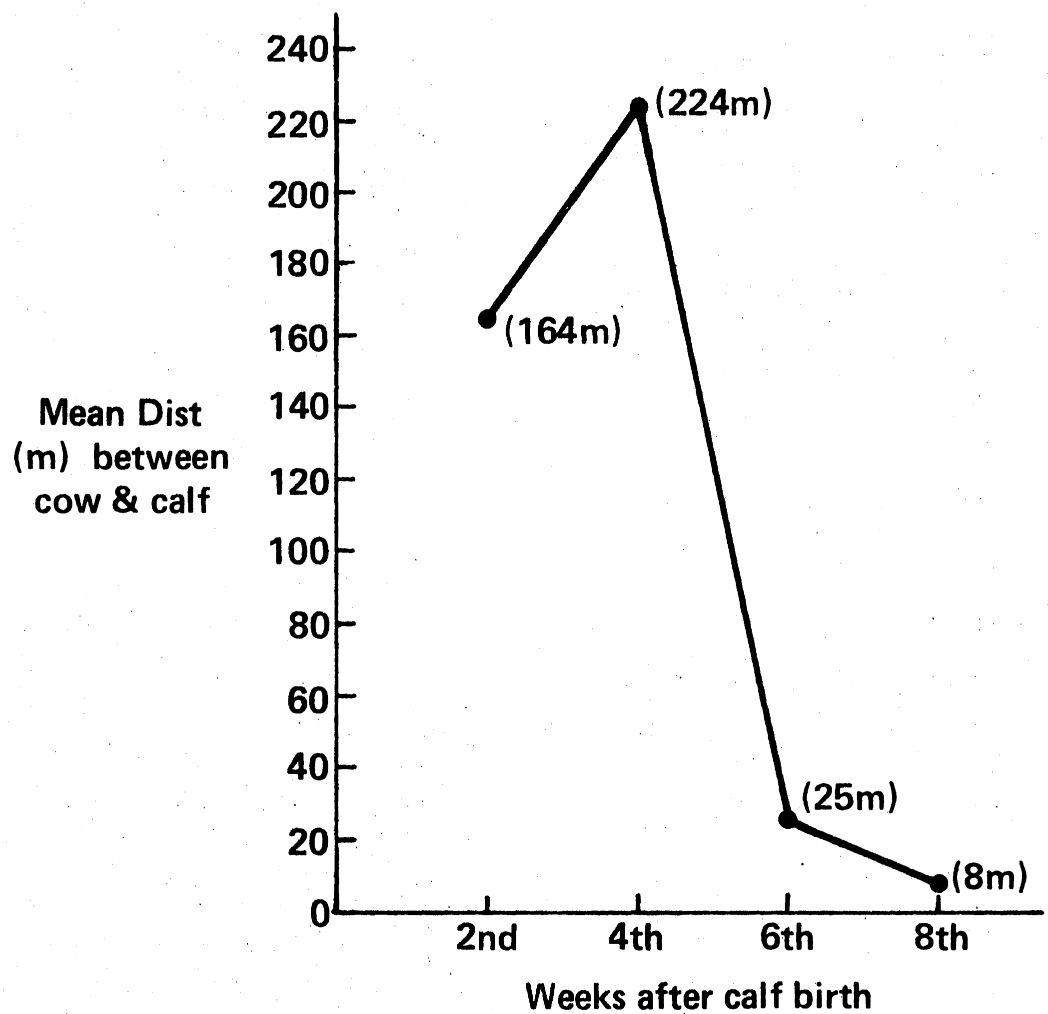

Fig. 15. Mean distance between four cow-calf pairs at four 2-week intervals after parturition, WMNWR, 1977.

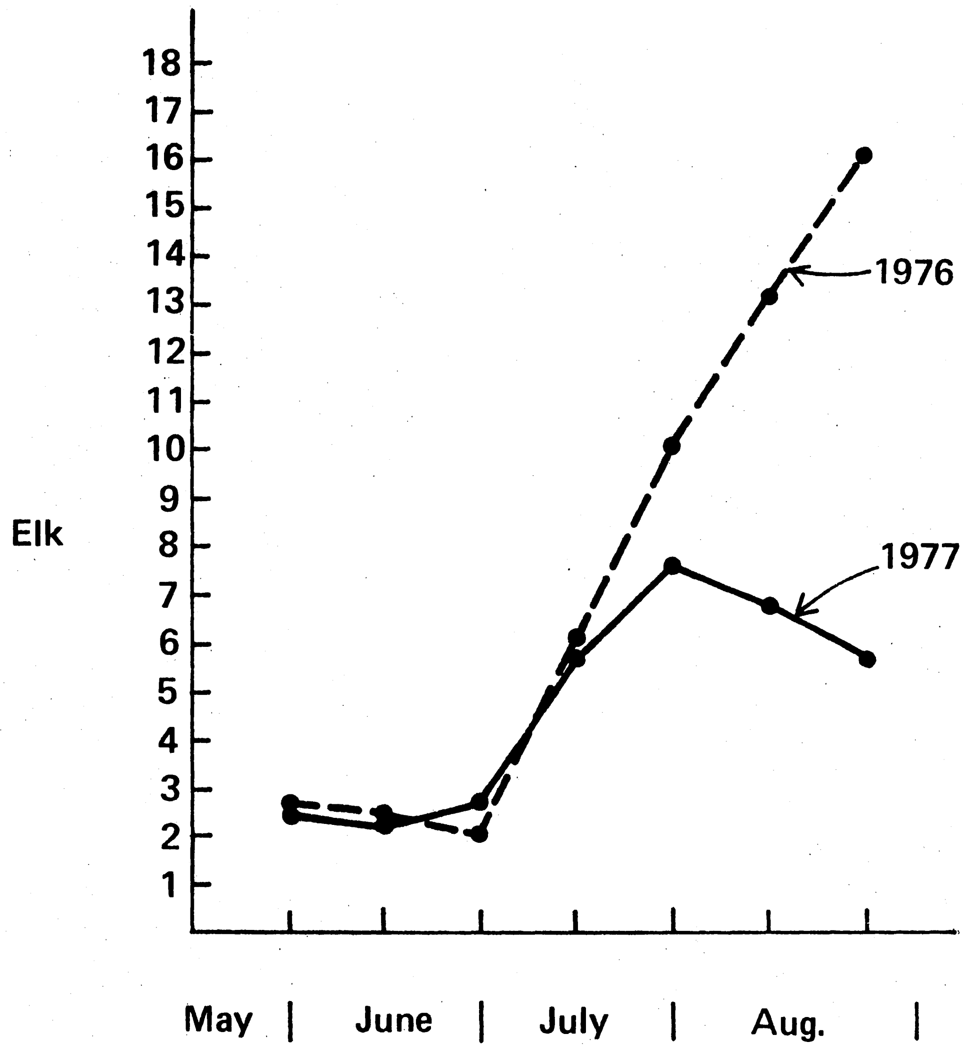

Fig. 16. Mean herd size of elk, WMNWR, May-August, 1976 and 1977.

2.0 and 3.0 elk until 30 June. Lone cows and yearlings were commonly seen during this 2-week interval. The mean herd size increased to between 5.5 and 6.0 elk by 15 July. After 15 July 1976 herd size increased to 16 elk by August. The increase in August was influenced by one herd that was repeatly observed and therefore the increase is not considered representative of the overall herding pattern for elk during August. The maximum herd size in 1977 (7.6 elk) occurred in the 2 week interval between 15 and 30 July. In both years the July increases in mean herd size were correlated with shifts in use of habitat and range sites.

Summer group constancy, the cohesiveness of a particular elk group, for aggregates associated with transmittered cows was considered minimal. Cows were often seen together in the areas where their home ranges overlapped. However, during these brief associations a transmittered cow was never observed leaving the overlap area to follow another transmittered cow into her distinctly separate home range. Cows R-20, R-26, and R-27 shared virtually the same home range in 1977; this provided an excellent opportunity to observe the degree of group association. The 3 cows were triangulated 160 times from 1 April to 10 August. Two of the three cows were observed together only 14 times and all three were never found in close association.

Interaction of Deer and Elk

Special efforts were made in 1977 to record all deer seen within the established home range boundaries of the transmittered elk. Twenty-nine deer were observed from 15 May to 10 August, 25 percent of these were seen in the extremely large home range of cow R-24. For 485 man hours of morning and evening observation (15 May-1 July), the average time needed to observe one deer in an elk's home range equalled 39 man hours, or 0.03 deer/hour. The average time spent to see one elk was 0.4 man hours (2.44 elk/hour).

No social interaction was observed between deer and elk. The two species were often observed occupying the same prairie while feeding, but never feeding together. Distances between the two species averaged an estimated 45 m. Other researchers on the study area reported similar observations (B. Bartush and J. Litvaitis, personal communication, 1977, OSU School of Biological Sciences). Elk displayed no noticeable awareness of the presence of deer, but deer were often observed standing and watching feeding elk. While feeding on the prairie, elk generally moved without showing any regard for deer. Invariably deer left an area when approached by feeding elk.

Calf Bedsite Analysis

Fifty-four daytime bedsites were sampled between 4 June and 27 July 1977. Bedsites were found on three of the seven available range sites and in all three broad habitat types (open, closed forest, and intermediate). Fifty bedsites (92 percent) occurred on the hilly stony savannah range site (St), and 2 (4 percent) each on the hilly stony (Ro) and boulder ridge (Go). Three bedsites (3 percent) were found in the open habitat type, 9 (16 percent) in the closed forest, and 42 (81 percent) in the intermediate (Table 10). Overhead woody cover occurred on 50 (93 percent) bedsites.

Bedsite temperatures averaged 0.8° C lower than the ambient temperatures. Calves generally bedded on the southern aspects of ($\bar{x}$ = 177.8 $\pm$

Table 10. Means and standard deviations for 12 variables associated with daytime calf bedsites located in three habitat types, WMNWR, 1977.

Variable	Mean ($\bar{x}$) and standard deviation (S) and (number) of bedsites by habitat type							
	Open (3)		Intermediate (42)		Closed forest (9)		Overall (54)	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Air temperature (°C)	29.9	2.5	30.8	4.1	32.2	2.3	31.0	3.8
Bed temperature (°C)	31.0	2.6	30.1	4.3	30.1	3.1	30.1	4.0
Wind direction (N=1, E=2, S=3, W=4)	3.0	0.0	2.9	0.3	3.1	0.3	2.9	0.3
Wind speed (Km/hr)	11.7	3.8	11.7	5.2	14.1	6.1	11.5	5.4
% Cloud cover	23.3	36.1	30.1	34.8	24.8	26.6	28.9	33.5
Elevation (m)	575.0	31.0	591.3	57.0	593.9	58.4	590.8	55.9
Aspect (°)	128.0	130.9	185.3	99.2	159.3	120.9	177.8	104.9
Slope (%)	11.3	1.0	16.5	6.4	17.0	5.6	16.3	6.2
Distance to woody cover (m)	5.0	4.4	0.9	1.9	0.4	0.6	1.0	2.2
Distance to nearest boulder (m)	2.1	2.9	0.4	0.9	0.7	1.0	0.6	1.1
Distance to next nearest boulder (m)	8.0	9.2	2.3	3.9	1.5	1.2	2.5	4.2

Table 10 (Continued)

Variable	Mean ($\bar{x}$) and standard deviation (S) and (number) of bedsites by habitat type							
	Open (3)		Intermediate (42)		Closed forest (9)		Overall (54)	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Canopy cover height (m)	2.0	1.7	3.1	1.2	5.5	1.9	3.4	1.7

104.0°) slopes averaging 16 ± 6.2 percent, and an average distance of 1.0 ± 2.2 m from woody cover and 0.6 ± 1.1 m from a boulder. The average canopy cover height and elevation was 3.4 ± 1.7 m and 592.3 ± 56.0 m, respectively.

The three open habitat bedsite temperatures averaged 1.6° C higher than the average ambient temperature. These bedsites were found on more gentle slopes ($\bar{x}$ = 11.3 percent) than those in the other habitats. The mean distances to woody cover (5.0 m), nearest boulder (2.1 m), and next nearest boulder (8.0 m) were the greatest in the open habitat. The relatively low mean canopy cover (x = 2.0 ± 1.7 m) height for the open habitat indicates a preponderance of small woody shrubs rather than trees. No significant differences ($P < 0.05$) for bedsite/ambient temperatures, and distances to woody cover, nearest boulder, and next nearest boulder were observed between the closed forest and intermediate habitats (97 percent of the bedsites). Calves typically selected bedsites that were cooler than the prevailing ambient temperature and in close association with boulder and woody cover.

Correlation analysis was used to identify significant relationships among the 12 variables. Bedsite temperature was significantly correlated with ambient temperature ($r = 0.69$, $P < 0.001$) which verified the selection of relatively cooler areas for bedsites. A significant correlation was also observed for nearest boulder and next nearest boulder ($r = 0.61$, $P < 0.001$), indicating that calves bed in areas where boulders are clumped. None of the remaining variables showed significant correlation.

Analysis of variance for boulder class cover (linear distance of intercept along transect) and density for variation between transects within bedsites and between bedsites produced no significant differences ($P < 0.05$). Also, no significant differences for boulder cover and density were observed between range site or habitat type. Accordingly, estimates of boulder cover and density were determined from pooled data of the two transects at each bedsite and were considered representative of all bedsites regardless of range site or habitat type. The boulder ground cover at the average bedsite equalled 25 percent. Boulder classes I, II, and III comprised 10, 4, and 11 percent, respectively. Average boulder density for class I was $0.25/m^2$, class II $0.06/m^2$, and class III $0.05/m^2$, which constitutes a $0.32m^2$ total boulder density.

Analysis of variances for woody cover and density variation between transects within bedsites and range sites revealed no significant differences ($P < 0.05$). However, significant differences were observed between habitat types. Therefore, data from the bedsite transects were pooled and analyzed by habitat type. Total woody cover and density estimates were determined from the linear distance of the transect covered by all woody cover and the total number of stems encountered. Cover and density measurements within each habitat type were combined to obtain habitat-specific woody cover and density estimates. As expected, the closed forest had the highest estimates with a density of 0.42 stems/m^2 and cover was 100 percent. The intermediate and open habitats had corresponding cover and density estimates of 59 percent, 0.28 stems/m^2 and 18 percent, 0.13 stems/m^2, respectively. The woody species encountered in the two open habitat bedsites were fruiticose, as indicated by the open habitat canopy cover height previously presented, such as smooth sumac (*Rhus glabra*), whereas, in the other two habitat types the woody vegetation was primarily arborescent and/or arborecous.

A total of nine different woody species was recorded for the 54 bedsites. Blackjack and post oak were combined because their close association in dense thickets made exact species-specific counts difficult. Frequency and number of occurrences for each species is presented in Table 11. The oaks (56.0 percent) and eastern red cedar (26.9 percent) were clearly the most frequently encountered species. The remaining seven species accounted for only 16.1 percent of the woody plants.

These bedsite data indicated that calves generally selected bedsites in the mountainous terrain closely associated with boulders and woody cover comprised primarily of oaks and cedar. This type of site maximizes concealment and affords some relief from higher summer ambient temperatures. Two calves were caught during this study within minutes after birth. In both captures the cows were still recumbent and devouring the afterbirth and the calves were still wet and unable to stand. Both birthsites had woody vegetation and physical characteristics similar to those described for the calf bedsites located in the intermediate habitat. The only apparent difference was the aspect. The birthsites were on slopes facing in a northerly direction instead of facing south like the typical calf bedsite.

Table 11. Occurrence and frequency data for eight woody species encountered at 54 elk calf bedsites, WMNWR, 1977.

Species	Occurrence		Frequency	Relative frequency
	Total encounters	Total bedsites encountered		
Sugar maple	4	2	3.7	2.2
Chittam wood (*Bumelia lanuginosa*)	4	2	3.7	2.2
Hackberry (*Celtis reticulata*)	4	2	3.7	2.2
Eastern red cedar	42	24	44.4	26.9
Oaks	92	50	92.5	56.2
Skunk bush (*Rhus aromatica*)	5	3	5.5	3.3
Smooth sumac	7	5	9.2	5.5
Currant (*Ribes sp.*)	1	1	1.8	1.0

CHAPTER V

DISCUSSION

Home Ranges and Movement

Home range determinations were used to identify the areas and habitats consistently utilized by transmittered elk. The average home range size measured the mean maximum observed distances travelled for that period. Further interpretation of the home range data requires certain assumptions. By assuming that the elk herd does not exceed the refuge's elk carrying capacity the minimum area home range mean may be viewed as an estimate of the optimum area needed by one cow to satisfy all her biological requirements.

The modified-minimum area home range, which contained 98 percent of the total triangulations, but was approximately 50 percent of the minimum area, may reflect the minimum area needed to fulfill all biological requirements. However, the refuge's carrying capacity and how many elk can utilize the same home range are not known so they must be assumed before the home range means can have any management significance.

With the exception of cow R-24 the calculated home range sizes for the cows were relatively uniform. Cow R-24 started expanding her home range 6 days prior to parturition and continued to do so for 30 days thereafter. She then suddenly returned to her previously established home range. Repeated disturbances while attempting to observe this cow prior to parturition is the expected cause for her abrupt, but temporary home range expansion.

The spring-summer cow home range sizes for the refuge are similar to home range sizes for non-migratory elk in the Rocky Mountains. Craighead et al. (1973) reported summer minimum area home ranges for cows in Yellowstone Park varied from 3.1 to 16.8 km^2, compared to 4.4 to 15.9 km^2 observed at the WMNWR. The average summer home range size for resident cow elk in the Jackson, Wyoming area is 9.3 km^2 according to Martinka (1969), only 1.8 km^2 larger than the average found for this study.

Calf summer home ranges were smaller than those of cows, but gradually increased with time. By mid-August the home range size averages for the four calves transmittered in June and their cows differed by only 1.0 km^2. The average summer home range size for calves born in June was 5.5 km^2 compared to 9.3 km^2 reported by Martinka (1969). Martinka included calf locations up to 15 September; locations in this study terminated 15 August, and probably account for his larger home range sizes.

The observed home range fidelity and absence of seasonal home range shifts or reductions by transmittered cows were most likely a response to high availability of forage. The mild, relatively snow-free Oklahoma winters do not impose quantitative food limitations or spatial restrictions on the elk. Elk in the Rocky Mountains are often forced by deep snow to restrict their winter movements, consequently reducing home range size, to stream beds and snow-free thermal areas (Craighead et al. 1973). Assuming there are no intraspecific interactions regulating elk movement, the annual forage availability remains high, and cover and water are readily available. There appears to be no ecological reasons for expecting seasonal or annual home range changes by elk on the refuge.

Herd Size and Habitat Description

Radio-equipped cows consistently utilized the closed forest habitat type for summer diurnal activities. The heavy tree cover provided concealment and probably some relief from the high summer temperatures. The high utilization of the hilly stony savannah (St) range site during the summer indicated that most of the habitat utilization occurred on mountain slopes. However, interesting fluctuations did occur in monthly habitat, aspect and range site and were related to monthly changes in mean herd size.

The average herd size in May was small and elk typically utilized the closed forest and intermediate habitats on the mountainous hilly stony savannah range site. Crepuscular feeding activities primarily occurred in intermediate habitats. The southern slopes were preferred in 1976, probably as a result of the early spring green-up on this exposure. In 1977 the northern, southern, and western aspects were the most utilized. Field observations suggested that the onset of the 1977 calving season may have occurred in late May, instead of early June as in 1976, causing cows to disperse earlier for calving. These differences in time of parturition could account for the disparity between use of aspect in 1976 and 1977.

Use of closed forest habitat increased in June, probably due to the secretive nature of cows during calving, while average herd size decreased slightly. Utilization of mountainous terrain and intermediate habitat for feeding remained high. The utilization of all aspects except the "zero" category indicates a high degree of cow dispersal in June. Calves also utilized all four cardinal directions, but unlike the cows they preferred the mountainous intermediate habitat for diurnal activities.

In July habitat utilization shifts occurred simultaneously with a significant increase in average herd size. The herds, which included calves, began utilizing more bottomland range sites with "zero" aspect and used more closed forest cover during diurnal hours. Crepuscular feeding in open areas increased during this period. These patterns reflect decreased utilization of the mountainous terrain and large herds typically feeding on the open prairies and bedding during the day in adjacent bottomland forests. This relationship began degenerating in August when the herds tended to disperse and the animals began using the closed forest and intermediate habitats on the hilly stony savannah range site.

The July increase and subsequent decrease in August in average herd size closely paralleled results from studies of Rocky Mountain elk. Martinka (1969) reported a similar monthly pattern for non-migratory elk in Jackson, Wyoming. In addition to observing similar monthly herding patterns Knight (1970) related herd size to habitat utilization patterns for the Sun River elk herd in Montana. Herd size increased with increased use of open and bottomland habitat types. The same pattern was observed in this study.

Although a definite relationship exists between the refuge's elk herd size and habitat utilization, the biological reasons for the relationship are difficult to identify. Dasmann and Taber (1956) and McCullough (1969) have suggested the relationship is an adaptation by ungulates for avoiding predators. Single individuals or small groups can more effectively conceal themselves in dense cover, an obvious advantage in critical periods such as during calving. However, in the open habitats large ungulates are quite conspicious. Large group sizes in open areas afford collective protection and presumably this reduces the individual animal's chances of falling prey, which may explain the herding behavior displayed in July when the cows and their calves increase their feeding activities in open areas.

The predator avoidance hypothesis for habitat type and group size relationships is the most accepted, but not the only possible explanation. Hirth (1977) discovered similar group size-habitat type relationships with white-tailed deer and suggested two other explanations, food location and stimulation of plant growth. Sparse vegetation in the woodlands due to limited solar energy may not be conducive to large aggregations of animals. The open areas which receive abundant solar energy produce lusher herbaceous vegetation that can support additional animals in large groups; however, this situation should be naturally selected against because of increased forage competition by members of the herd. Hirth suggested several advantages that could outweigh the competitive disadvantage. Those areas that had and had not been fed upon would be identified by the intensive grazing of large herds, thereby reducing the time spent covering areas that had been grazed earlier, but less intensively. Hirth suggested this pattern was comparable to high-intensity rotational grazing systems used in domestic livestock management which tend to maximize forage production.

Cow-Calf Relationships

Elk are classified, with regard to their post-partum mother-infant relationship, as hiders (Lent 1974). After parturition mother and offspring separate, with the mother returning to the concealed young only to nurse and defend it. Lent (1974) described the hiding behavior complex as a strategy for avoiding predation and as a means of gradually introducing the infant into a closed social group. Lent's explanation for this behavior is accepted by most wildlife scientists but the accepted species-specific mechanics associated with the hiding behavior need further research. Most of the accepted mechanics of this behavior in elk are based on outdated studies, which consisted of random observations of unmarked individuals, and have generally gone unchallenged. Therefore, various questions such as, how long does the hiding behavior last, and how does the mother find the young, deserve consideration.

Like most neonatal cervids elk calves are often considered odorless, a claim disputed by Altmann (1952) and Murie (1951). All elk calves captured for this study had a distinct musty smell, similar to, but fainter, than that of adult elk. Altmann concluded that cow elk locate their calves through olfactory senses. In this study no evidence was found to substantiate Altmann's claim.

Cows invariably were observed seeking out their hidden calves three times daily: morning, midday, and evening. Prior to locating their calves cows generally left their bedding area and began feeding in the general direction of their calf. However, they did not feed in the continuous manner typical of feeding elk. They would stop occasionally to take a few bites then resume movement towards the calf. This intermittent feeding may have been interpreted by previous researchers to represent olfactory calf detection.

On three occasions cow elk were heard emitting a soft, squealing call while approaching the general area of their hidden calf. The calf was observed coming to the cow on all three occasions, presumably in response to the cow's call. In these cases auditory responses and vocalization, not olfactory responses, appeared to be the means by which cows and their calves were reunited. In this study it was determined that elk cows were able, after being re-trapped and contained for several months, to find and return to their previous home ranges. Therefore, it is not unreasonable to assume that they can remember where they left their hidden calf.

Elk cows have been reported to hide their calves for no more than three weeks (Johnson 1951, Altmann 1952). Because cows and their calves are separated during the hiding stage the weekly mean distance between the four transmittered cow-calf pairs was considered a reliable estimate of duration of the hiding period. Unlike the previous reports, the hiding behavior did not subside until some time between 4 and 6 weeks after parturition. However, after 3 weeks the time when calves were nursed became less predictable. Cows occasionally stayed with their calves between two nursing sessions and would leave them between the next two. It is possible that other researchers regarded similar observations as the termination of the hiding stage. Also, unlike migratory elk, the Wichita Mountains elk do not leave the calving areas to continue on to higher summer range. This sedentary arrangement may account for the longer neonatal hiding period observed in this study.

Intraspecific Association

The use of radio-location telemetry, and individually marked elk provided an excellent opportunity to observe the degree of group cohesion over time (Knight 1970). Elk groups have traditionally been reported to possess a high degree of constancy, a characterization probably originating with Darling's (1937) work in Scotland with the red deer (Cervus elaphus), the European counter-part to our North American elk.

Darling described the red deer social system as a highly cohesive matriarchy based on the family unit, capable of maintaining its social identity even in large groups. Altmann (1952) implied the same tendency for group constancy in her behavior studies of Wyoming elk. She reported elk herds tended to be composed of the same individuals, but often broke up into sub-groups. However, neither Altmann nor Darling used marked animals in their studies and the ability to recognize consistently all unmarked individuals in groups and sub-groups may be questioned.

Knight (1970) was the first researcher to publish results on elk group constancy that deviated from the traditional views. He was able to demonstrate quantitatively that there are no enduring individual associations within elk groups. The groups tended to break up and reassemble with different combinations of individuals. He termed such groups as aggregations which congregated due to attractive environmental factors rather than social responses. Knight's findings were reinforced by Craighead et al. (1973) who reported similar conclusions for elk in Yellowstone Park.

The degree of group constancy was not quantified in this study but observation of marked elk did not reveal any lasting associations among these individuals. Associations between marked cows with adjacent or overlapping home ranges only occurred on the home range boundaries or in the areas of overlap and was apparently not strong enough for an individual cow to continue the association by leaving her home range to follow another cow into her home range. Also no strong associations were noted between marked cows that consistently utilized the same area. Therefore, it appears that there is no long-term group cohesiveness in elk of the Wichita Mountains. The conclusion (Craighead et al. 1973) that associations between recognizable cow elk appears to be governed by chance or factors other than sociability is supported by this study.

Reproductive Success

Calf:cow ratios have been used as indices for production and the difference between the ratio and the pregnancy rate is used as an indicator of the extent of calf mortality. The 1976 and 1977 pregnancy rates and calf:cow ratios were 56 percent, 26 calves per 100 cows, and 76 percent, 55 calves per 100 cows, respectively. However, the corresponding 30 and 21 percent calf:cow ratio-pregnancy rate differences for 1976 and 1977 are probably not accurate estimates of calf mortality. Most researchers report that sex and age ratio surveys are more reliable if conducted during the winter (Riordan 1948, Banfield 1949, Knight 1970). The July and August surveys for this study probably produced low calf:cow ratios because not all the calves have joined the herds by this time. The 1976 fall calf:cow survey, which included yearling females being counted as adults, made by refuge personnel produced a higher ratio (38:100) (G. Bartnicki, personal communication, 1977).

No mortality occurred for the 11 calves that were captured. Holle (1977) while investigating the diet and availability of the prey of the coyote on the refuge analyzed 671 coyote scats. Elk calf hair was encountered in only one scat. Based on Holle's observations and the population data previously discussed, calf mortality due to predation or any other deciminating factor was considered negligible.

The relatively low 1975 pregnancy rate (56 percent) for the refuge herd is at least partially attributable to cows aged 7 or more yrs which had a 41 percent pregnancy rate. Cows older than 15 yrs produced no calves. In 1975 the refuge conducted a cow elk-only hunt in an attempt to reduce the number of old unproductive females. This hunt may have contributed to the 20 percent increase in the pregnancy rate observed in breeding age cows in 1976. However, the probable overriding factor influencing pregnancy rates and survivorship is elk density relative to food resources. Although there are no supporting data, it seems reasonable that as elk density rises, pregnancy rates should decrease.

Bedsite Analysis

The bedsite data indicate that parturient cows and neonatal calves select a habitat type that provides a high degree of tree and boulder cover. The rocky terrain facilitates concealment of the calf while tree cover provides a cooler hiding place as well as protective cover. Tree and boulder cover probably have the most influence on elk selection of sites for parturition and the neonatal hiding, judging from the lack of correlations between combination of variables other than bedsite and ambient temperature, and distance to the nearest boulder and the next nearest boulder.

Habitat selection by ungulates for parturition and young-rearing has been described by other authors. Autenrieth (1976) found that pronghorn does (Antilocapra americana) and fawns apparently select habitat types that provide greater than average brush canopy cover, total coverage, and brush height. The use of sagebrush (Artemesia tridentata) areas by elk for calving has been reported in Montana (Johnson 1951) and Wyoming (Altmann 1952). Altmann (1952) reported that the dense sagebrush used for calving provided protection for the calves from climatic factors and from predation. In a detailed study of elk calving sites along the West Fork of the Madison River in Montana, Reichelt (1973) found that calf bedsites were closely associated with woody cover and occurred on slopes averaging 11 percent with a southerly exposure. Reichelt's results compared closely with results obtained in this study. Even though vegetative and physiographic differences exist between the Wichita Mountains and the Rocky Mountains it appears that the elk cows and calves on the WMNWR select habitats with cover and terrain characteristics similar to those utilized by elk in the Rockies.

Garner (1976) investigated the vegetative and physical factors associated with deer fawn bedsites on the WMNWR. Comparisons between Garner's bedsite data and the results reported here reveal contrasting patterns for the two species. Garner reported that 21 percent of the sampled fawn bedsites occurred on savannah range sites (boulder ridge savannah and hilly stony savannah), and the remaining 78 percent were on the relatively open range sites (hardland, boulder ridge and hilly stony). Ninety-two percent of the elk calf bedsites occurred on the hilly stony savannah and only four percent on the open range sites. The average distance to the nearest woody cover for fawn bedsites varied from 8.2 m to 14.3 m on the open range sites and 0.2 m to 1.2 m on the savannah sites, compared to the overall calf bedsite mean distance to woody cover of 1.0 m. Garner reported overhead woody cover occurred at 21.4 percent of the fawn bedsites, 71.6 percent less than for calf bedsites. He also reported a 27.3 percent rock cover on the hilly stony savannah bedsites, which is similar to the overall 25 percent mean rock cover for all calf bedsites; however, the average fawn bedsite rock cover on the open range sites, where most of the fawn bedsites occurred, varied from 0.1 to 10.0 percent. Average slope for fawn bedsites on the open range sites ranged from 6.3 to 8.8 percent and 9.5 to 13.5 percent for the bedsites on the savannah range sites, considerably less than the overall mean slope of 16 percent for calf bedsites.

Garner conducted his study from 1973-75 but the study of fawn mortality was continued by Bartush during the same period as this investigation. Bartush's (personal communication, 1977) data, reveal a continuation of the same pattern of fawn bedsite selection described by Garner. A large number of fawns consistently utilized open habitats for bedding. The selection of these relatively open areas by fawns likely contributed to the high mortality of fawns due to predation. The more wooded and rugged terrain utilized by elk calves should afford greater concealment from predators.

Interspecific Spatial Interaction

Throughout this study an attempt was made to determine if evidence existed to support the hypothesis that competitive interactions between white-tailed deer and elk could be forcing deer into marginal habitat for fawning, thus predisposing the fawns to predation. Miller (1967) termed a competitive interaction of this nature as spatial interference and defined it as the active demand by members of two or more species for a common space so that by occupying that space, one species can prevent access of a competitor to a mutally required resource. Species segregation by habitat or space must be initially identified to establish that such a situation exists.

The comparisons made between calf and fawn bedsites in the previous discussion demonstrated that the two species, for the most part, occupy different habitats during the neonatal hiding stage. The fawns typically utilize more open prairie habitats than do the elk calves. Garner (1976) reported that the fawn mortality average for 2 yrs was 87.9 percent, 96.6 percent which he directly attributed to predation. Bartush continued the fawn studies (1976-77) and also observed a similar high fawn mortality due to predation (Bartush, personal communication, 1977). Mortality of elk calves was found to be negligible. Comparison of the mortality and bedsite data for the two species suggest that the observed differential neonatal mortality may be related to habitat.

The refuge deer population presently is considered to be in a stabilized condition (Garner 1976). The population's natality and immigration must approximate its mortality and emigration if the herd size is to remain stable. If the entire refuge deer population were sustaining the fawn mortality reported by Garner and Bartush it either would be declining or stabilizing at or near carrying capacity. Consequently it may be concluded that a few fawns must be surviving to replace adult losses, presumably in habitats other than the prairie, where Garner and Bartush concentrated their research efforts. Unfortunately the rate of fawn survival for other habitats, like the wooded mountain areas, has not been determined.

In the prairie areas considered by Garner (1976) to have relatively high deer densities Bartush (personal communication, 1977) observed on the average 3.0 deer/hour and 0.8 elk per hour. Bartush suspected the elk observed represented only a few elk which repeatedly used the same areas for feeding. In this study the number of elk/hour and deer/hour observed within the home ranges of transmittered cows were 2.44 and 0.03, respectively, indicating spatial segregation among refuge elk and deer. The relatively few deer that are utilizing the more rugged terrain and heavier cover, characteristic of the areas used by elk, may be producing the annual surviving population increment needed to stabilize the deer population.

If interspecific spatial interaction between deer and elk is not forcing deer to fawn in the open habitats then it can be assumed that deer prefer the open habitats for parturition and post-partum activities. However, a thorough review of the deer habitat utilization literature revealed no such preference. White-tailed deer are usually considered to utilize fawning areas with some degree of woody cover. The Wichita Mountains National Wildlife Refuge is the only area known to this investigator where large numbers of deer are reported to utilize consistently open habitat for fawning even though abundant woody cover is present.

Published reports of spatial interference between deer and elk are few, especially for situations where increased predation is a direct result. Hornocker (1970) suggested that the observed high levels of mountain lion (Felis concolor) predation upon mule deer (Odocoileus hemionus hemionus) was attributable to elk-deer spatial interference. Large numbers of elk in the preferred summer high country displaced the mule deer, forcing them to occupy the lower elevation habitats. This less rugged terrain made the mule deer more susceptable to mountain lion predation.

The relatively few other published studies concerned with deer-elk interspecific spatial interference have generally considered such competitive situations to be unimportant. Kramer (1973) found spatial competition between white-tailed deer and elk to be minimal, but he did observe some degree of avoidance of elk by deer. A similar situation was observed in this study. Compton (1975) reported that mule deer and elk in south central Wyoming demonstrated a high degree of association, often feeding and bedding together, and concluded that no significant spatial competition existed. But during the calving season he did observe agonistic behavior towards deer by cow elk with calves. Compton attributed the lack of competitive interactions to the probability that elk and mule deer have coexisted in a "sympatric and natural situation" for a comparatively long time. However, the existence of a similar "sympatric and natural situation" on the Wichita Mountains Refuge is debatable.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The major objectives of this study were to determine biotic and abiotic characteristics of calving sites, to determine characteristics of the habitat used by cows before and after parturition, and calves, and to investigate possible competition between elk and white-tailed deer for parturition and young-rearing habitat.

Ten cows were captured and transmittered from 1975-1977. Eleven calves were captured and six were fitted with transmitters. The parent cows of four of the six transmittered calves also had transmitters. Two calves were captured at the birthsite immediately after parturition. A total of 344 cow and 196 calf radio-locations were obtained during the study.

The spring-summer (March-August) home ranges were determined by the minimum area and modified-minimum area methods. The 619 ha mean spring-summer minimum area home range for cows is similar to elk home range sizes reported for the Rocky Mountains by Craighead et al. (1973) and Martinka (1973). The modified-minimum area home ranges were approximately 0.5 less than the size of the minimum area home ranges and contained 98 percent of the locations. Therefore, the modified-minimum area home ranges were considered more representative of habitat use and were used for analysis of home range habitat. The fall-winter (September-February) home range boundaries could not be determined because the number of radio-locations for that period were too small. However, seasonal home range shifts by cows were not detected. Transmittered cows also demonstrated no yearly home range shifts. Home ranges typically centered around one or two mountain complexes. Home ranges for calves increased with time and by the second month after birth their home range sizes closely approximated the cows' movements.

The habitat utilized by cows was 25.4 percent closed forest, 65.6 percent intermediate, and 9.1 percent open areas. Closed forest was the most utilized habitat type during the summer. Calves primarily utilized the intermediate habitat during June, then shifted to closed forest in July. The intermediate habitat received most crepuscular feeding activity and the hilly stony savannah range site was the most utilized prior to July. Use of bottomland range sites increased in July.

The monthly mean herd size was correlated to monthly shifts in aspect, range site, and habitat utilization. In May and June, when most cows are calving, the mean herd size oscillated between 2.0 to 3.0 elk and utilization of the closed forest and intermediate habitats primarily occurred on all aspects of the mountainous terrain. In July the mean herd size increased and elk generally utilized the open prairies for feeding and adjacent forested creekbottoms for bedding. Elk reverted to use of mountainous terrain in August when the mean herd size began decreasing. Knight (1970) reported a similar herding-habitat relationship for the Sun River elk herd in Montana.

Group constancy for aggregates associated with transmittered cows was considered minimal. The temporary and random nature of the associations between transmittered cows suggests that elk groups were formed because of environmental, rather than social reasons. This observation agrees with the results reported in previous elk studies by Knight (1970) and Craighead et al. (1973).

There was evidence that elk cows may find their hidden calves using memory and auditory-vocalization responses, and that the neonatal hiding stage lasts for approximately 5 weeks. The hypotheses that cows locate their hidden calves by use of olfactory senses and that the hiding stage lasts no longer than 3 weeks originated with studies by Johnson (1951), Murie (1951), and Altmann (1952). The use of radio-telemetry in this study may have allowed for unique mother-infant observations that are applicable to elk in general, or the deviations noted in this study may be due to geographical and/or behavioral differences.

The differences between summer sex and age surveys and pregnancy rates of elk harvested in winter were used to estimate calf mortality. Based on these population data and previous research on the diet of the coyote on the refuge (Holle 1976) calf mortality due to predation or any other deciminating factor was considered negligible.

Deer were not regularly seen in the home ranges of transmittered elk. The average time needed to observe one deer in an elk's home range was 39 man hours, compared to 0.4 man hours to observe one elk. While working in areas of high deer densities Bartush (personal communication, 1977) reported that elk were not regularly observed. No social interactions were observed between the two species. Deer and elk were never seen closer than an estimated 45 m to each other although they often fed on the same prairie. Deer appeared to avoid feeding elk herds. Similar avoidance of elk by white-tailed deer has been reported by Kramer (1973).

These observations indicate that the majority of elk and deer are spatially segregated.

The analysis of 54 daytime calf bedsites revealed that calves generally selected bedsites cooler than the ambient temperature. The bedsites were in close association with boulders and woody cover. The high degree of protective cover provided by this arrangement may account for the negligible calf mortality due to predation. Calf bedsites were located in more rugged and wooded terrain than the fawn bedsites described by Garner (1976).

Results from Garner's (1976) deer study and from this research suggest that elk typically utilize more wooded and rugged terrain for parturition and young-rearing than do deer. The literature verified that the patterns of habitat utilization by the refuge elk are typical of most herds; however, the consistent utilization of open habitat for fawning, when abundant woody vegetation is available, contradicts published deer habitat studies. Assuming that deer typically prefer some degree of woody cover for fawning the use of open habitats by deer appears atypical. Although deer-elk interspecific competition is the suspected reason for the selection of marginal habitats for fawning by deer, it has not been proven. The evidence that deer and elk are segregated by species-specific habitat utilization patterns adds some credibility to the interspecific competition hypothesis. Additional research directed at this specific competitive interaction is needed to substantiate such an involved, conceptual theory.

This study is the first completed, in-depth ecological research on the Wichita Mountains Refuge elk herd. It appears that the re-introduced elk have successfully integrated into the Wichita Mountains ecosystem. The elk is a wonderful addition to Oklahoma's fauna and this research does not suggest their removal or reduction, or in any way criticizes the present management of the herd.

LITERATURE CITED

Altmann, Margaret. 1952. Social behavior of Rocky Mountain elk in Jackson Hole area of Wyoming. Behavior 4(2):116-143.

____________. 1956. Patterns of herd behavior in free ranging elk in Wyoming. Zoologica 41(2):65-71.

Autenrieth, Robert. 1976. A study of birth sites selected by pronghorn does and bed sites of fawns. Pages 127-134 in R. Autenrieth, ed. Proceedings of the 7th biennial pronghorn antelope workshop. Twin Falls, Idaho.

Banfield, A. W. F. 1949. An irruption of elk in Riding Mountain National Park, Manitoba. J. Wildl. Manage. 13(1):127-134.

Blair, F. W. 1939. Faunal relationships and geographic distribution of mammals in Oklahoma. Am. Midl. Nat. 22:85-133.

Boyd, R. J. 1970. Elk of the White River Plateau, Colorado. Colorado Fish and Game Comm. Tech. Bull. 25. 126 pp.

Buck, Paul. 1962. Relationships of the woody vegetation of the Wichita Mountains Wildlife Refuge to geological formations and soil types. Ph.D. Dissertation, Univ. Oklahoma, Norman. 64 pp.

____________. 1964. Relationships of the woody vegetation of the Wichita Mountains Refuge to geological formations and soil types. Ecology 45(21):336-344.

Cliff, E. P. 1939. Relationship between elk and mule deer in the Blue Mountains of Oregon. Trans. Am. Wildl. Conf. 4:560-569.

Compton, Thomas. 1975. Mule deer-elk relationships in the Western Sierra Madre Area of southcentral Wyoming. Wyoming Game and Fish Dept. Wildl. Tech. Rep. 1. 125 pp.

Cowan, I. McT. 1947. Range competition between mule deer, bighorn sheep and elk in Jasper Park, Alberta. Trans. N. Am. Wildl. Conf. 12:223-227.

Cox, G. W. 1976. Laboratory manual of general ecology, 3rd ed. Wm. C. Brown Co., Dubuque, Iowa. 232 pp.

Craighead, J. J., F. C. Craighead, R. L. Ruff, and R. O. O'Gara. 1973. Home ranges and activity patterns of non-migratory elk of the Madison Drainage Herd as determined by biotelemetry. Wildl. Monogr. 32. 50 pp.

Crockett, J. J. 1962. Grassland communities of the Wichita Mountains Wildlife Refuge. Ph.D. Dissertation, Univ. Oklahoma, Norman. 44 pp.

Darling, F. F. 1937. A herd of red deer: a study in animal behavior. Oxford, Univ. Press, London. 215 pp.

Dasmann, R. F., and R. O. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. J. Mammal. 37: 143-164.

Flook, D. R. 1962. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119-128 in D. J. Crisp, ed. Grazing in terrestrial and marine environments. British Ecol. Soc. Blackwell Publ., Inc., Oxford.

Garner, G. W. 1976. Mortality of white-tailed deer fawns in the Wichita Mountains, Comanche County, Oklahoma. Ph.D. Dissertation, Oklahoma State Univ., Stillwater. 113 pp.

Gray, F. and H. M. Galloway. 1959. Soils of Oklahoma. Oklahoma State Univ., Misc. Publ. MP-56. 65 pp.

Greer, K. R. and W. W. Hawkins. 1967. Determining pregnancy in elk by rectal palpation. J. Wildl. Manage. 31(1):145-149.

Hall, E. R. and K. R. Kelson. 1958. The mammals of North America. Vol. II. Ronald Press, N. Y.

Halloran, A. F. and B. P. Glass. 1959. The carnivores and ungulates of the Wichita Mountains Wildlife Refuge, Oklahoma. J. Mammal. 40: 360-370.

Harper, J. A. and W. C. Lightfoot. 1966. Tagging devices for Roosevelt elk and mule deer. J. Wildl. Manage. 30(3):461-466.

Harper, J. A. 1971. Ecology of the Roosevelt elk. Oregon State Comm. 44 pp.

Harvey, M. J. and R. W. Barbour. 1965. Home range of Microtus ochrogaster as determined by a modified minimum area method. J. Mammal. 46:398-402.

Hirth, D. H. 1977. Social behavior of white-tailed deer in relation to habitat. Wildl. Monogr. 53. 55 pp.

Hoffman, M. C. 1930. Geology and petrology of the Wichita Mountains. Oklahoma Geological Surv. Bull. 52. 83 pp.

Holle, D. G. 1977. Diet and general availability of prey of the coyote at the Wichita Mountains National Wildlife Refuge. M.S. Thesis. Oklahoma State Univ., Stillwater. 59 pp.

Hornocker, M. G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildl. Monogr. 21. 39 pp.

Johnson, D. E. 1951. Biology of the elk calf, *Cervus canadensis nelsoni*. J. Wildl. Manage. 15(4):396-410.

Jones, D. A. 1960. A salable approach to the elk-cattle competition problem. Trans. N. Am. Wildl. Nat. Resour. Conf. 25:387-395.

Klopfer, P. H. 1962. Behavioral aspects of ecology. Prentice Hall, Inc., New Jersey. 171 pp.

Knowlton, F. F., E. D. Michael, and W. C. Glazener. 1964. A marking technique for field recognition of individual turkeys and deer. J. Wildl. Manage. 28(1):167-170.

Knight, R. R. 1970. The Sun River elk herd. Wildl. Monogr. 23. 66 pp.

Kramer, A. 1973. Interspecific behavior and dispersion of two sympatric deer species. J. Wildl. Manage. 37(3):288-300.

Lent, P. C. 1974. Mother-infant relationships in ungulates. Pages 14-55 *in* V. Giest and F. Walter, ed. The behavior of ungulates and its relation to management. IUCN Publ. 24. IUCN, Morges, Switzerland.

Leopold, Aldo, L. K. Sowls and D. L. Spencer. 1947. A survey of over-populated deer ranges in the United States. J. Wildl. Manage. 11(2):162-177.

Makie, R. J. 1970. Range ecology and relations of mule deer, elk, and cattle in the Missouri River Breaks, Montana. Wildl. Monogr. 20. 79 pp.

Martinka, C. J. 1969. Population ecology of summer resident elk in Jackson Hole, Wyoming. J. Wildl. Manage. 33(3):465-481.

McCullough, D. R. 1969. The tule elk: its history, behavior, and ecology. Univ. Calif. Publ. Zool. 88:1-209.

Miller, R. S. 1967. Pattern and process in competition. Pages 1-74 *in* J. B. Cragg, ed. Advances in ecological research, Vol. 4. Acad. Press, London and New York. 311 pp.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Amer. Midland Nat. 37:223-249.

Morrison, J. A. 1960. Ovarian characteristics in elk of known breeding age history. J. Wildl. Manage. 24(3):297-307.

Mosby, H. S. 1971. Habitat analysis and evaluation. Pages 135-172 in R. H. Giles, ed. Wildlife management techniques, 3rd ed. The Wildl. Soc., Washington, D. C. 633 pp.

Murie, O. J. 1951. The elk of North America. The Stackpole Co., Harrisburg, Pa. 376 pp.

Odum, E. P. 1971. Fundamentals of ecology. 3rd ed. W. B. Saunders Co., Philadelphia, Pa. 574 pp.

Quimby, D. C. and J. E. Gaab. 1957. Mandibular dentition as an age indicator in Rocky Mountain elk. J. Wildl. Manage. 21(4):435-451.

Reichelt, L. R. 1973. Characteristics of elk calving sites along the West Fork of the Madison River, Montana. M.S. Thesis, Montana State Univ., Bozeman. 39 pp.

Riordan, L. E. 1948. The sexing of deer and elk by airplane in Colorado. Trans. N. Am. Wildl. Conf. 13:409-428.

Schwartz, J. E. and G. E. Mitchell. 1945. The roosevelt elk on the Olympic Peninsula, Washington. J. Wildl. Manage. 9(4):295-319.

Seidensticker, J. C., M. C. Hornocker, R. R. Knight, and S. L. Judd. 1970. Equipment and techniques for radiotracking mountain lions and elk. Idaho Coop. Wildl. Res. Unit. Forest, Wildl. and Range Exp. Stn. Bull. 6. 20 pp.

Soil Conservation Service. 1967. Soil survey, Comanche County, Oklahoma. 58 pp.

Steele, J. L. 1969. An investigation of the Comanche County deer herd. Okla. Dept. Wildl. Conserv. Fed. Aid Proj. W-87-R. Final Rep. 20 pp.

White, Marshall, F. F. Knowlton, and W. C. Glazener. 1972. Effects of dam-newborn fawn behavior on capture and mortality. J. Wildl. Manage. 36(3):897-906.

APPENDIXES

Table 12. Physical measurements (cm), including means and standard deviations, for seven adult cow elk, WMNWR, March 1976.

No.	Total length	Nose length	Hind foot		Ear		Head length	Neck circumference		
			Left	Right	Left	Right		Head	Midneck	Shoulder
R-1	223.0	27.5	56.5	55.8	21.5	21.5	48	53.3	55.8	71.2
R-2	227.9	27.9		48.2	19.8	19.8	40	53.3	54.6	66.0
R-3	202.5	23.2	49.0		18.5	18.7	45	48.0	47.0	62.5
R-13	216.0	26.5			19.0	19.0	49	57.8	63.0	73.0
R-14	212.0	27.5		48.0	20.0	19.4	45	55.5	58.0	74.2
R-19	220.0	29.0		58.0	20.0	20.0	46	55.0	57.0	72.8
R-20	221.0	28.0	57.0		21.2	20.3	45	53.5	58.5	72.5
Mean	217.5	27.0	54.2	52.5	20.0	19.8	45.3	53.8	56.3	70.3
S.D.	8.3	1.9	4.4	5.2	1.0	0.9	2.7	3.0	4.8	4.3

Table 13. Physical measurements (cm), sex and age for 11 elk calves, WMNWR, 1976-77.

No.	Sex	Age (days)	Total length	Hind leg Left	Hind leg Right	Chest girth	Neck circumference	Head length	Nose length	Head width	Ear length Left	Ear length Right
1	F	6	110.3	36.0	36.0	64.5	26.1	23.1	9.0	10.4	12.4	12.4
2	F	3	99.5	36.4	36.4	56.5	24.3	24.2	11.4	9.1	11.6	11.3
3	M	1	105.5	42.2	42.2		31.5	24.8	9.5	10.0	12.5	12.5
3[a]	-	4	105.5	42.5	42.5	68.5	33.5	22.5	10.2	10.5	12.5	12.5
4	F	3	98.2	39.0	39.0	65.0	28.5	23.0	11.0	9.9	12.9	12.5
4[a]	-	7	101.0	36.5	36.5	63.1	29.5	24.5	10.5	10.0	12.5	12.5
5	F	3	90.5	38.3	38.3	53.0	23.2	22.0	10.3	9.0	11.4	11.3
6	F	1	100.0	37.0	37.1	52.0	24.0	23.1	10.8	9.0	11.0	11.0
7	F	6	90.0	36.5	36.5	50.5	23.0	23.2	10.5	9.0	11.1	11.1
8	M	6	114.0	44.2	44.2	65.0	28.5	25.0	12.3	10.4	13.3	13.3
9	F	7	113.0	43.5	43.5	64.0	27.0	25.2	13.0	10.2	13.4	13.4
10	M	9	125.0	45.0	45.0	70.0	31.0	27.0	13.5	10.5	14.3	14.3
10[a]	-	20	133.0	45.0	45.0	64.5	29.0	29.0	13.0		15.2	15.2
11	M	6	122.5	45.5	45.5	77.5	32.0	26.5	12.0	11.0	14.0	14.0

[a]Recaptured and measured again.

VITA

Gene Paul Waldrip

Candidate for the Degree of

Master of Science

Thesis: ELK HABITAT USE DURING CALVING SEASON WITH POSSIBLE EFFECTS ON WHITE-TAILED DEER AT THE WICHITA MOUNTAINS NATIONAL WILDLIFE REFUGE

Major Field: Wildlife Ecology

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma, October 10, 1949, the son of George and Pat Bane.

Education: GED graduate of Edmond High School, Edmond, Oklahoma, November, 1968; received Bachelor of Science degree in Wildlife Ecology, Oklahoma State University, May, 1975; completed the requirements for the Master of Science degree at Oklahoma State University, December, 1977.

Professional Experience: Undergraduate Research Assistant in Wildlife, Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, summer, 1975; Research Assistantship, Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, summers, 1976 and 1977; Teaching Assistantship, School of Biological Sciences, Oklahoma State University, September-May, 1976 and September-December, 1977.

Professional Organizations: The Wildlife Society, Oklahoma Chapter of The Wildlife Society, National Wildlife Federation.