166/D-166

ECOLOGY OF ELK AND MULE DEER IN GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

John D. Moody[1/], Leslie J. Krysl[2/], and C. David Simpson

Department of Range and Wildlife Management

Texas Tech University

Lubbock, Texas 79409

1/ Present Address: Department of Range Science, Utah State University, Logan, Utah 84322.

2/ Present Address: Department of Range Science, University of Wyoming, Laramie, Wyoming 82071.

TECHNICAL INFORMATION CENTER
DENVER SERVICE CENTER
NATIONAL PARK SERVICE

CONTENTS

INTRODUCTION .....

ACKNOWLEDGEMENTS .....

HISTORICAL BACKGROUND .....

LAND USE .....

Indian Occupation .....

European Settlement .....

ELK .....

Taxonomy .....

Dispersal and Distribution .....

Population Growth and Expansion .....

MULE DEER .....

Taxonomy .....

Dispersal and Distribution .....

Population Dynamics .....

STUDY AREA .....

PHYSIOGRAPHY .....

CLIMATE .....

VEGETATION .....

Mountain Shrub .....

Desert Shrub .....

Creosotebush .....

Coniferous Forest .....

Pinyon-Juniper .....

Four-wing Saltbush .....

Mesquite .....

Hardwood .....
Grassland .....
WATER DISTRIBUTION .....
METHODS AND PROCEDURES .....
DISTRIBUTION AND POPULATION ANALYSIS .....
HABITAT RELATIONSHIPS .....
FECAL ANALYSIS .....
VISUAL OBSERVATIONS .....
COLLECTION OF DEER .....
VEGETATION TRANSECTS .....
BROWSE EXCLOSURES .....
BROWSE UTILIZATION .....
PRESENT STATUS AND DISTRIBUTION .....
ELK .....
MULE DEER .....
POPULATION DYNAMICS .....
ELK .....
Herd Composition and Sizes .....
Sex Ratios .....
Age Ratios .....
Parturition .....
Annual Recruitment .....
Life Table Analysis .....
Predation .....
Human-Related Mortality .....
MULE DEER .....
Herd Compositions and Sizes .....
Sex Ratios .....

Age Ratios .....
Parturition .....
Annual Recruitment .....
Life Table Analysis .....
Predation .....
Human-Related Mortality .....
DISCUSSION .....
HABITAT RELATIONSHIPS .....
ELK .....
Habitat Utilization .....
Water Relations .....
Movements and Home Range .....
Dog Canyon .....
Frijole Area .....
West Dog Canyon, Blue Ridge, and Bowl Drainages .....
MULE DEER .....
Habitat Utilization .....
Water Relations .....
Movements and Home Range .....
Dog Canyon .....
Frijole Area .....
Cox Tank .....
DISCUSSION .....
FOOD HABITS AND SELECTION .....
ELK .....
Fecal Analysis .....
Annual Diet .....

Spring Season .....
Summer Season .....
Fall Season .....
Winter Season .....
Visual Analysis .....
MULE DEER .....
Fecal Analysis .....
Annual Diet .....
Spring Season .....
Summer Season .....
Fall Season .....
Winter Season .....
Rumen Analysis .....
Visual Analysis .....
ELK-MULE DEER DIETARY OVERLAP .....
IMPACT ON VEGETATION .....
BROWSE ANALYSIS .....
Dog Canyon Range .....
Front Country Range .....
High Country Range .....
West Side Range .....
BROWSE EXCLOSURES .....
BROWSE UTILIZATION .....
CONCLUSIONS .....
SUMMARY .....
MANAGEMENT ALTERNATIVES .....

LITERATURE CITED .....

APPENDICES .....

APPENDIX A .....

APPENDIX B .....

APPENDIX C .....

INTRODUCTION

It is an unfortunate fact that too often management-oriented research is initiated as high priority needs in crisis situations. While this was not the case in the Guadalupe Mountains National Park (GMNP) study reported here, the same paucity of background information encountered in crisis-solving research made this study both challenging and frustrating. A fundamental requirement for wise management decisions is an adequate background from which a viewpoint of the current status can be evaluated, and upon which future direction is determined. In this instance, the past history of elk (Cervus elaphus nelsoni) and mule deer (Odocoileus hemionus crooki) in the study area was widely scattered and fragmental, with data presented pieced together from many diverse and often conflicting sources.

The authors were fortunate in that some long-term residents of the area were still available for consultation, and that existing documentation could be cross-checked and verified through extensive interview. The end result is what we believe to be an accurate history of elk and mule deer in the Guadalupe Mountains in Texas up to initiated field work in 1976.

The present research resulted from concerns over declining elk numbers, heavy vegetation utilization in local areas, and the proposed development of the National Park for greater visitor use. Prior to making any evaluation on management of the resources or on visitor impact on wildlife, the basic status and biology of elk and mule deer in the park had to be understood. This study encompassed 3 1/2 years of field research and was primarily concentrated in the northern reaches of the park within the elk and mule deer range. Data were collected in all seasons and particular emphasis was placed on the movements of elk in and out of the park, habitat and water

requirements of elk and mule deer, and the impact of both species on browse plants. From these findings have emerged a relatively comprehensive knowledge of the status, distribution and ecological requirements of elk and mule deer in GMNP, Texas.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the U.S. Department of the Interior, National Park Service (NPS) for ~~generous~~ funding during this research. The Noxious Brush and Weed Control Research Program, and the Department of Range and Wildlife Management, Texas Tech University, Lubbock, also contributed to this study both financially and logistically and we are grateful for their support.

Various NPS personnel helped at all stages of the study and we wish to thank them for their assistance. Special mention should be made for help given by Dr. Gary M. Ahlstrand, ~~Resource~~ Ecologist; Donald A. Dayton, Park Superintendent; Bruce Fladmark, Area Manager; Roger E. Reisch, Chief Ranger; and Harry and Anne Steed of Dog Canyon Ranger Station; each and all contributed in different ways toward a successful study and a rewarding personal experience.

The historical aspects of this study would have been impossible to verify or complete without the willing help of several persons whose association with the area dates back many years. Early census data collected by the Texas Parks and Wildlife Department (TPWD) were provided by Biologist Tommy Hailey. J. C. Hunter, Jr. also provided valuable information on early elk records. Kenneth McCollaum (sp?) of the U.S. Department of Agriculture Forest Service and rancher "Spike" McGonagill were a fund of knowledge on the

Lincoln National Forest through the years, and Bob Turner of the NPS provided information on the Carlsbad Caverns National Park (CCNP) area. The history of the elk and mule deer herd in what is now GMNP would not be complete, however, without the considerable contributions made by ranchers Noel and Laurie Kincaid and Marion and "Salty" Hughes.

Texas Tech Faculty members Drs. Fred C. Bryant, Bill E. Dahl, Ernest B. Fish, Russ D. Pettit and Henry A. Wright all contributed to the planning and successful completion of this research, and were extremely helpful in reviewing drafts of theses and this manuscript.

Finally, we would like to express our appreciation to Mrs. Elouise Phillips for painstakingly typing and retyping this manuscript and for "holding the fort" on many occasions during this study.

HISTORICAL BACKGROUND

LAND USE

Indian Occupation

Flaked stone tools and other artifacts give evidence of at least intermittent Indian occupation in the Guadalupe Mountains dating back 9000 years B.C. A hunting-gathering economy characterized all these occupation periods including the recent Historic Period which encompassed use by the modern Mescalero Apache. Little evidence in this area has been documented of agriculture. These nomadic hunter-gatherers probably resided in the Guadalupe Mountains range only seasonally, although it has been hypothesized that the mild weather conditions may have allowed year-round occupation (Katz and Katz 1974). Various Agave species and other foraged food plants were cooked in small pits which are still evident today. Hunting was also

a primary component of the Indian life-style, although it is not known how extensive the hunting economy was in this area. Elk and deer have always played an important role in the material, cultural, and spiritual lives of Indian tribes inhabiting the Trans-Pecos region of Texas (Newcomb 1961). Wild ungulates are commonly found in Indian pictographs in the Trans-Pecos and both mule deer and white-tailed deer have been described from Hudspeth and Culberson counties (Jackson 1938). However, the relatively primitive hunting-gathering methods and nomadic nature of many of the Apache groups using the area probably had little effect on local environments. Hunter success undoubtedly increased with the aquisition of modern weapons in the mid- and late-1800's, and this in turn would have had an impact on the environment, especially on elk and deer populations.

European Settlement

The European occupation of the Trans-Pecos began in about 1860, and by 1890 considerable areas of this region were settled by ranchers and farmers (Simpson and Leftwich 1978). It is interesting to note that Smith (1895) claimed that all the western ranges of Texas were stocked with cattle by 1886, and that many ranges were showing signs of deterioration as early as 1890. (Smith 1895) However, the area around the Guadalupe Mountains remained a stronghold of itinerant Apache bands whose occupancy was a threat to the main trail between El Paso and Santa Fe (Leftwich 1977). It was not until military action finally ousted the Indians from the southern reaches of the Guadalupe Mountains at the turn of the century that white settlement of this area was complete (?) (Glover pers. comm.). With settlement came large numbers of livestock and intensive grazing pressures were placed on a heretofore

pristine environment.

In 1908, Willis Smith established the present day Frijole Ranch in the foothills below the eastern escarpment of the Guadalupe Mountains. Smith ran a small ranching and farming operation until 1943, when J. C. Hunter acquired the land. Hunter operated with a light stocking of cattle and goats on the area until 1949, when he leased the land to Noel Kincaid. Kincaid continued with a low stocking rate of Angora goats and cattle in the front country, and the west escarpment received little grazing pressure because rough topography made most areas inaccessible to both livestock and land operators (L. Kincaid pers. comm.). These operations did not severely deplete the range but some overgrazing occurred in the Guadalupe Spring area where a major sheep lambing ground was located (Reisch pers. comm.).

On the west side of the mountains ranching operations became established at about the same time. In 1908, H. Belcher built what is now called the William's Ranch House. He ran 1,000 head of Longhorn cattle along the west escarpment until 1913, when Dolph Williams acquired the land. In the early year, calf production was high and cattle numbers expanded rapidly, but as overgrazing became prevalent on the range, calving rates dropped drastically. Overgrazing is considered to be the causative factor which allowed creosotebush to become widespread over most of the west side rangeland (Reisch pers. comm.). Williams continued to raise cattle until 1916, when deteriorated range conditions made cattle grazing unprofitable. He then introduced 1,500 head of Angora goats and sheep to the area. Severe overgrazing of the west side continued until 1941, when J. C. Hunter bought the Williams Ranch. Hunter continued to graze sheep and goats in the area, but reduced stocking rates (Reisch pers. comm.). Hunter leased grazing rights to Noel Kincaid in 1949

along the west escarpment from Bush Mountain to Guadalupe Peak. This area was heavily grazed by goats from 1949 to 1960. The Bush Mountain area received additional grazing pressure due to a large salting station located in the vicinity (L. Kincaid pers. comm.).

No information was found on land use of the high country between the east and west escarpment prior to 1950. It seems likely that some grazing occurred in the area prior to this date, but accessability and costs of livestock management may have been prohibitive to extensive use in the early part of the century. Noel Kincaid's lease from J. C. Hunter included the high country and The Bowl area was used regularly as summer grazing for cattle, sheep,and goats from 1950 to 1960. During this time, water was pumped from Upper Pine Spring, through Bear Canyon, up to a storage tank above the escarpment. Excess water from the storage tank was then pumped into The Bowl Tank. In 1960, summer livestock grazing ceased in The Bowl area with the exception of a few cattle which grazed this area intermittantly in summer for another 10 years beginning in 1960 (Reisch pers. comm.).

Both West Dog Canyon and Upper Dog Canyon were settled in the early 1900's. The DeMoss family ran a sheep and goat operation in the Upper Dog Canyon area from 1904 to 1914. West Dog Canyon was settled by the Cox family in 1905. They also raised sheep and goats until aboug 1914. In 1914, Samual "Pappy" Hughes moved into the New Mexico part of Upper Dog Canyon, north of the present park boundary, and started a sheep and goat operation. Hughes ran some goats and sheep in West Dog and Upper Dog Canyon, north of the present park boundary, and may have grazed land within the park boundaries prior to its establishment (Reisch pers. comm.). Noel Kincaid leased the area of Upper Dog and West Dog Canyon within the park in 1949 and

ran cattle, sheep, and goats in the area until 1970, when the land was acquired by the NPS (L. Kincaid pers. comm.). Both of these areas were heavily overgrazed by the sheep and goat operations and evidence of this is still apparent in the vegetation of West Dog Canyon today.

National Park Service

Guadalupe Mountains National Park was authorized by public law 80-667, 80 Stat, 920, 1966. The park was formally established in 1972 with land donated by W. Pratt and additional land acquired from J. C. Hunter. By the end of 1970, most of the livestock had been removed from within the park except along the northwest boundary. Since that time, hiking and backpacking have been the main forms of visitor use in the park. The NPS only recently developed accessability to some areas of the park for public use. Grazing, hunting, open campfires, and collecting of natural resources are not permitted in the park. Proclamation of a wilderness covering much of the park in 1978 placed greater restriction on human activity thereby limiting land use to a minimum.

ELK

Taxonomy

It has been hypothesized that during the mesic conditions of the Pleistocene, Cervus elaphus migrated across the Bering Straits land bridge into North America from Asia where the species originated (McCullough 1969). They dispersed through most of North America as far south as northern Mexico. As mesic conditions receded northward, specialization from the generalized type C. e. nelsoni probably resulted in the development of C. e. nannodes

and C. e. roosevelti (McCullough 1969), and no doubt, the now extinct C. e. merriami. Both C. e. nannodes and C. e. merriami developed in and inhabited semiarid environments.

Merriam's elk was first described by E. W. Nelson as a separate species (Nelson 1902). Later it was given subspecific status by several workers (Murie 1951, Cockrum 1961) but, according to Anderson and Barlow (1978), without supportive evidence. Recent taxonomic comparisons between the few existing specimens of C. e. merriami and other subspecies confirm conspecificity with Cervus elaphus (Anderson and Barlow 1978).

The original range for the extinct Merriam's elk has been mapped to include the Texas portion of the Guadalupe Mountains by several authors (Bailey 1905, 1931, Davis 1940, Murie 1951, Hall and Kelson 1959). No specimens of C. e. merriami are known to have been taken from the Texas Guadalupes, but Bailey (1905) received reports of hunter kills 9.6 to 12.8 km north of the state line and he concluded they ranged into Texas. According to Bailey's (1905, 1931) records and maps, the Texas portion of the Guadalupe Mountains was probably the eastern periphery of C. e. merriami's former range. Hall and Kelson (1959) included a part of the Texas Panhandle and the Wichita Mountains of Oklahoma in their range, but as the elk they referred to as Merriam's elk from the Wichitas are not represented by any specimens, they were probably C. e. nelsoni as indicated by Bailey (1905).

During the early 1890's Merriam's elk was common in the White Mountains of Arizona, the Mogollon, Sacramento and White Mountains of New Mexico and the Guadalupe Mountains of New Mexico and Texas (Bailey 1931). However, by 1900 Merriam's elk was probably extirpated from its entire range (Bailey

1905). The disappearance of this subspecies was attributed directly to man's activities. Newly arriving settlers and market hunters in the New Mexico Territory took elk year-round for meat and hides (Lang 1958, Gates 1967), and the impact of livestock introductions into elk ranges undoubtedly contributed to the decline (Cahalane 1939, Ross 1973).

As early as 1880 the New Mexico Territorial Legislative Assembly attempted to protect the deminishing elk herds by establishing hunting seasons. However, it was not until 1903 that legislation was passed prohibiting the sale of game animals (Lang 1958, Gates 1967), by which time C. e. merriami was thought to be extinct and C. e. nelsoni were almost extirpated in the northern ranges of New Mexico. Despite restocking programs begun in 1910, only 60 head of elk were reported in New Mexico by 1912 (Lang 1958). By 1926, few elk ranged in the southern portion of New Mexico and none were found in the Guadalupe Mountains (Ligon 1927).

The herd of Rocky Mountain elk presently inhabiting the southern Guadalupes in Texas and New Mexico are descendants of 47 released in McKittrick Canyon, Texas in 1929. Forty-seven animals, 28 adult cows, 9 yearling females, 2 spike bulls, 3 female calves, 2 male calves and 3 calves of undetermined sex, were donated by Wind Cave Game Preserve (now Wind Cave National Park), South Dakota, to J. C. Hunter of Guadalupe Mountains Ranch (Anonymous 1929a). The Wind Cave herd, derived originally from 1914 to 1916 Jackson Hole-Yellowstone transplanting, was being reduced during the 1920's to alleviate overgrazing problems on the Preserve (McClanahan pers. comm.). Six of 47 elk died in transit and the remaining 40 were turned loose on 14 April 1929 at the McKittrick Canyon release site; 1 other animal was damaged during the release and was thought to have died soon thereafter (Anonymous 1929b).

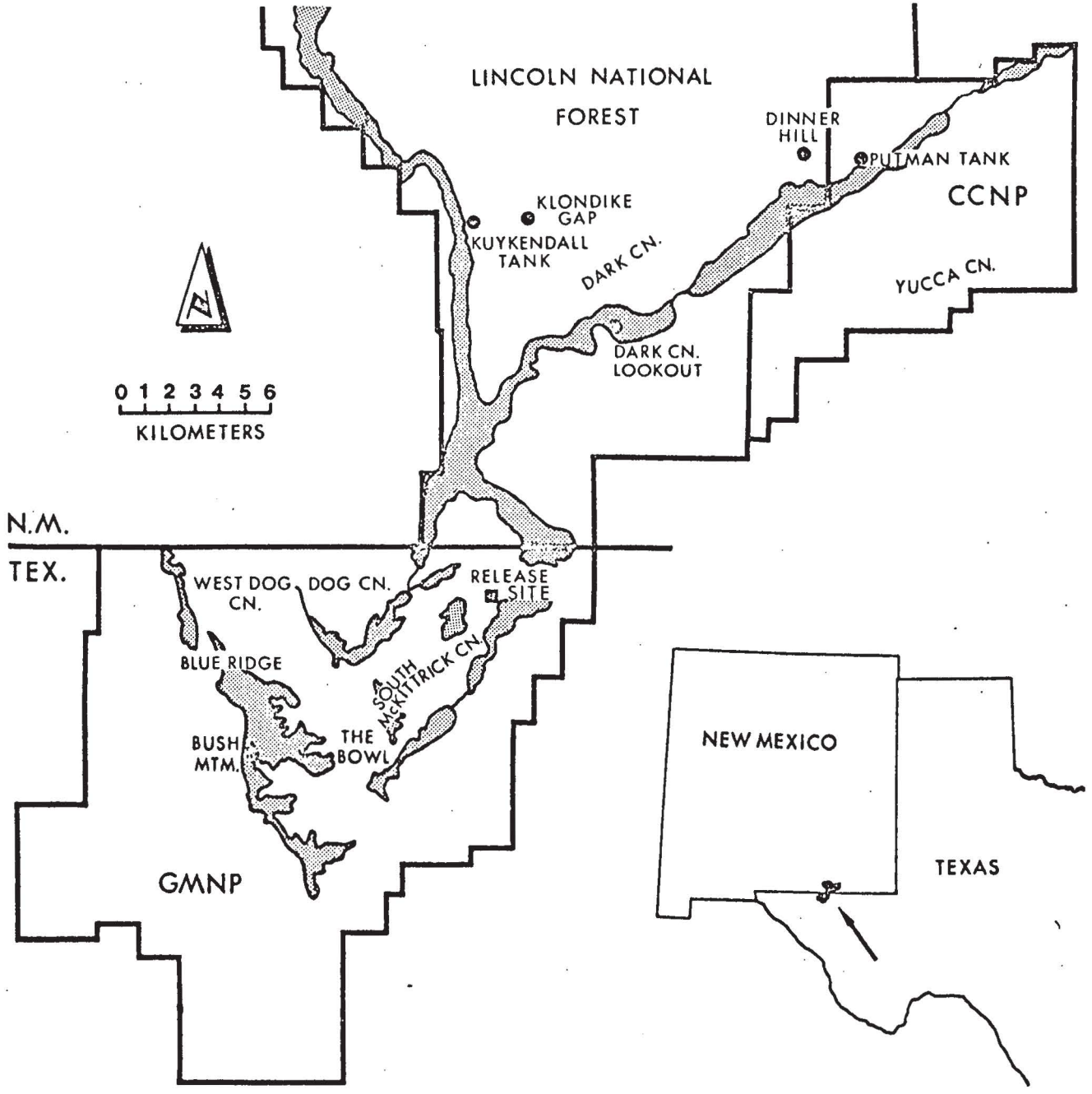
In addition, 5 adult bulls from Wyoming (probably Yellowstone National Park or the National Elk Refuge) were liberated in McKittrick Canyon on 21 April 1929 (Anonymous 1929c), thus placing the total introduction at 45 healthy animals.

Dispersal and Distribution

Much of the early information on elk dispersals and distribution was obtained from interviews with long-term residents but a few published records are available. Wright and Thompson (1934) indicated that the newly released elk were concentrated in McKittrick Canyon where they were causing severe vegetation damage along the slopes. They reported, however, that at least some elk had moved out of the release area by that time (Fig. 1). In about 1933, a bull was taken by a hunter along the west rim of Upper Dog Canyon just inside New Mexico (L. Kincaid pers. comm.). Also, elk were reported in the late 1930's around Dark Canyon Lookout in Lincoln National Forest, approximately 8.8 km north of the state line and 11.2 km north of the release site (McGonagill pers. comm.).

During his 1939 mammal survey of the Guadalupe range in Texas, Davis (1940) found the elk herd was distributed over most of the higher elevations of the mountains. He observed elk in The Bowl, on Blue Ridge, along North and South McKittirck Canyons, and along the east escarpment near the mouth of McKittrick Canyon. He found abundant elk sign in the high country and noted that elk were selecting the more forested higher range despite the scarcity of water at these elevations. Kincaid, foreman of Guadalupe Mountains Ranch, reported population increases both within what is now GMNP as well as in New Mexico, between the early 1940's and the late 1950's

Fig. 1. Map showing historic points of elk dispersal following release in Guadalupe Mountains National Park, Texas.



(N. Kincaid pers. comm.). During this same period, elk were found in New Mexico in the area south of Dark Canyon, although sightings were reported as far north as the Kuykendall Tank and Klondike Gap areas (McCollaum pers. comm.). These latter records were located approximately 16.8 km inside Lincoln National Forest from the release site and probably represent the northern most distribution achieved by the introduced elk. As they do today, elk from Dog Canyon penetrated approximately 5.64 km into New Mexico, while those in West Dog Canyon area roamed 2.4 km north across the state line (L. Kincaid pers. comm.).

When elk were first reported in the eastern portion of Lincoln National Forest and in CCNP is not known, but they probably entered the area during the 1940's when the maximum range extension apparently took place. In 1960 and 1961 elk were observed at Yucca Canyon in CCNP (Reisch pers. comm.). During the middle 1960's elk ranged in the Putman Tank-Dinner Hill areas of Lincoln National Forest and CCNP and have maintained this distribution to the present time (Fig. 1) (Turner pers. comm.)

Elk inhabiting the main portion of McKittrick Canyon near Pratt Lodge in GMNP had moved out by 1968 to 1969. The increased visitor use in this section of the canyon where the herd was originally released probably influenced their departure (Reisch pers. comm.).

The elk population began to decline in the late 1960's and by 1970 fewer elk were encountered in the high country (L. Kincaid pers. comm.). Prior to this decline, it was not uncommon to see 30 to 40 elk in the vicinity of what is now Dog Canyon Ranger Station (L. Kincaid pers. comm.), compared to the herd of 12-15 cows reported in this study. Genoway et al. (1977) reported elk still ranged through the northeastern half of the park

in 1973 to 1975, being most commonly seen in The Bowl area, West Dog, and Upper Dog Canyons and adjacent to Frijole Springs.

Population Growth and Expansion

There has been a paucity of information available to the elk population dynamics since the 1929 introduction. Only 2 published accounts address early elk numbers in the area. Wright and Thompson (1934) estimated that the herd of 45 had increased to 60 head by 1934, while Davis (1940) estimated the population to number 400 animals in 1938. This is the highest population figure recorded for Guadalupe elk and it appears to be an overestimation. Noel Kincaid, foreman of Guadalupe Mountains Ranch, reported that only about 100 elk were resident in what is now GMNP in 1942; however, by 1958 the population had increased to 240 elk on the ranch with another 75 to 100 animals occupying the New Mexico portion of the mountain range (N. Kincaid pers. comm.).

An effort to obtain population dynamics information on the Guadalupe elk herd was initiated in 1954 when the TPWD began annual censuses on the Guadalupe Mountains Ranch at the request of owner J. C. Hunter. These surveys were conducted during the breeding season as manpower and weather conditions permitted. During some years a second survey was conducted in the spring or summer. Three basic survey routes, all originating in The Bowl, were traversed on the upper elk range. One route went along the Burned Cabin Trail into South McKittrick Canyon, ending at Hunter Lodge. Another followed the present-day Guadalupe Trail into Dog Canyon to the New Mexico state line. The third and longest survey route entered West Dog Canyon via the old jeep road (Tejas Trail) and returned to The Bowl by way of Blue Ridge,

Bush Mountain and Hunter Peak. Elk sightings were recorded by sex and age along these survey routes and morning and evening counts were made at water holes. In addition, elk sign, bugling counts, and pellet transects also were used in indices to estimate the population size in most years (Hailey pers. comm.).

The first survey, conducted in 1954, yielded only a few observations and the population estimate of 100-150 elk was acknowledged as low (Uzzell 1954). This is in agreement with Kincaid's estimates quoted above. TPWD estimates during the early to mid 1960's indicated a peak population of 350 animals with high cow:calf ratios during these counts (Hailey 1963a, 1963b, 1963c, 1964, 1966a). Beginning in 1966, TPWD censuses showed a steady decline in elk numbers (Hailey 1966b, 1969a, 1969b, 1970, 1971a, 1971b, Kilpatric 1973a, 1973b). A corresponding decrease in % hunter success on New Mexico lands adjacent to the former Guadalupe Mountains Ranch was evident for the same period (Anonymous n.d.).

TPWD's last 3 censuses, conducted 1971 to 1973, all indicated a population of 225 elk in the Texas portion of the mountain range (Hailey 1971b, Kilpatric 1973a, 1973b). However, Genoways et al. (1977) spent considerable time in the field during their 1973 to 1975 mammal survey and only estimated 100 to 150 elk inhabiting GMNP at that time. The findings of this study, started in 1976, served to continue documentation of the Guadalupe Mountains elk herd through 1978.

Comparisons can be made between observed rates of increase and the theoretical maximum rate of increase (rate at which a population with a stable age distribution grows when no resource is limiting). This permits calculations to determine the relative success a population achieves under

the set of environmental conditions with which it interacts. Buechner et al. (1951) determined the theoretical maximum rate of increase for elk to be 26.0% by applying Kelker's (1947) formula to the breeding potential table presented by Leopold (1933) for species bearing first young at 3 years of age. Several elk populations have approached this maximum rate of increase (Buechner et al. 1951, Murphy 1963, Moran 1973) but they are probably exceptions.

When the historical data on the Guadalupe elk herd is examined following Kelker's (1947) formula

$$60 = 46\ r^5$$

$$\frac{\log 60 - \log 46}{5} = \log r,$$

$$\log r = 0.0230787$$

$$r = 1.0545789$$

the average annual gain for the 5 years from initial release of 45 elk to Wright and Thompson's (1934) estimate of 60 head is 5.4%. The 60.6% gain calculated from Wright and Thompson's (1934) estimate to Davis' (1940) estimate of 400 in 1938 indicates that either the former estimate was too low or the latter was extremely high.

By calculating directly from the release total of 45 head to Davis' (1940) estimate, an annual gain of 27.1% emerges. While this is within the realm of potential elk increase, it is doubtful that the introduced herd could fair so well under the harsh conditions characteristic of the xeric Guadalupe Mountains, especially during the initial adjustment period. These data, in combination with ranch foreman N. Kincaid's herd size estimates suggest that the population estimate of 400 in 1938 was much too

high. For these reasons, Davis' (1940) estimate was omitted from further calculations and discussions.

Calculation of the 1929 release of 45 animals and N. Kincaid's 1942 estimate of 100 animals using the population increase formula (Kelker 1947) produces a 6.1% annual gain. Including the 1934 estimate of 60 head (Wright and Thompson 1934) with N. Kincaid's 1942 estimate yields a 6.6% annual population gain. This further substantiates the accuracy of Wright and Thompson's (1934) estimate and indicates a steady rate of gain through these years. The overall annual gain from 1929 to 1958, at which time N. Kincaid estimated 350 elk in the Texas and New Mexico portions of the Guadalupes, is 7.2%. The 350 estimate probably represents the largest number of descendants from the 1929 release animals ever present in the Guadalupe Mountains.

A steadily decreasing trend in elk numbers was reported by TPWD personnel from 1966 through 1973. The average annual rate of decrease can be computed by applying Kelker's (1947) formula to the last high estimate of 350 animals from the 1965 TPWD survey with the 1979 estimate of 125 animals derived from this study. These calculations give a 7.1% average yearly loss of the breeding herd.

All the above data suggest that the introduced herd increased steadily at less than 10.0% per year from 1929 through 1958. During their first 30 years they did not apparently achieve the high rates of increase reported for some introduced elk herds (Murphy 1963, Moran 1973). Constraints placed on this originally northern subspecies via predation, hunting, water conditions, the xeric environment, and possibly vegetation condition,

undoubtedly contributed to keeping their population growth below the 10.0% level. The population apparently peaked at 350 animals from 1961 through 1965 in what is now GMNP. Figure 2 traces the 50-year population history of Rocky Mountain elk in the Guadalupe Mountains of Texas established above.

High numbers of elk contributed to the overbrowsed conditions prevalent in the upper ranges during the peak years (Hailey pers. comm., L. Kincaid pers. comm.). Die-offs resulting from the poor vegetation conditions were thought to have regulated population numbers in this period (Hailey pers. comm.). A steady decline in population size was recorded by TPWD from 1966 to 1973 when the surveys ceased and NPS took over management responsibility.

The average annual loss during the 14-year decline phases closely approximated the initial 30-year increase rate (Fig. 2). A corresponding decrease in % hunter success was apparent in the New Mexico section of the elk range (NMGF Dept. Rec.). Low elk numbers and hunter success in this area of New Mexico during the early 1970's resulted in a closing of the either-sex permit system between 1971 and 1975. These declining rates of hunter success in a heavily harvested mule deer area further substantiate the reported decrease in elk numbers both in the Texas and New Mexico portions of the Guadalupe Mountains.

MULE DEER

Taxonomy

Since Mearns (1907) first described the desert mule deer, Odocoileus hemionus crooki some confusion has existed as to whether or not the mule deer in the Guadalupe Mountains fall into this subspecies. The type

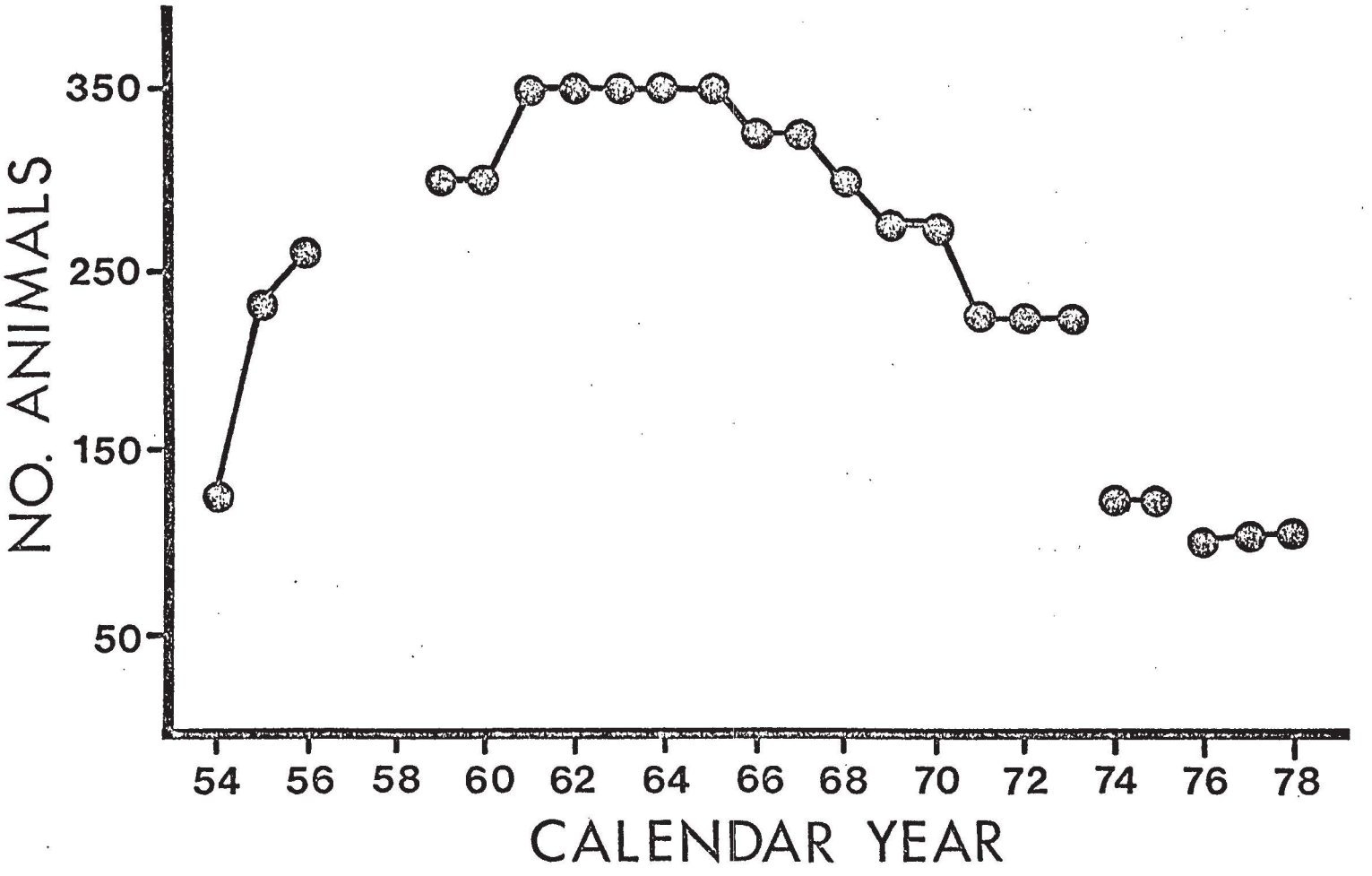


Fig. 2. Population estimates from TPWD censuses, a mammal survey (Genoways et al. 1977) and this study for elk in Guadalupe Mountains National Park, Texas.

specimen for O. h. crooki was taken in Hidalgo County in the southwest corner of New Mexico, in the Sonoran Desert. This area is marginal to the range of O. h. eremicus (Mearns), also commonly referred to as the desert mule deer. Bailey (1905) described the range of mule deer as "west of the Pecos River" and suggests that this species occurred both on the desert floor and in mountainous regions. In 1939 Davis collected 2 animals from McKittrick Canyon and a third skull from The Bowl area (Davis 1940). Based on claims that mule deer in the Guadalupe Mountains were different to those found in the Big Bend area, he tentatively assigned these 3 specimens to the subspecies O. h. canus (Merriam). However, in a later publication (Davis and Robertson 1944) the same 3 specimens were classified as O. h. crooki (Mearns). The subspecies O. h. canus was used in the mid 1940's (Texas Game, Fish and Oyster Commission 1945) but neither this subspecies nor O. h. macrotis (Say) are mentioned by Taylor (1956) in a compendium on the deer of North America. Subsequent authors generally agree that the Guadalupe Mountain subspecies of mule deer is O. h. crooki (Mearns) with all other conflicting subspecies either abandoned or with redefined ranges (Hall and Kelson 1959, Whitehead 1972, Rue 1978).

Dispersal and Distribution

Simpson and Leftwich (1981) have reviewed the history of mule deer in Texas and reported a steady decline throughout its range from first settlement until the 1940's. They attributed this decline largely to subsistence hunting by early settlers and habitat loss in some areas. With agency protection and public awareness, the mule deer herds throughout

Trans-Pecos Texas slowly increased up to their present numbers. These changes in distribution may not have had as much impact in the Guadalupe Mountains as elsewhere, however, due to lower human settlement in this area.

Early authors (Marcy 1849, Emory 1857, Reid 1935) used the generic term "deer" in many observations on distribution, thereby causing a degree of uncertainty as to the species seen (Simpson and Leftwich 1981). White-tailed deer (O. virginianus) have been reported from within or close to the Guadalupe Mountains (Bailey 1905, Davis and Robertson 1944, Taylor 1956, Davis 1974), but some doubt exists as to their occurrence within the park boundary (Genoways et al. 1979). As the Guadalupe Mountains fall well within the mule deer range in Texas there is no doubt this species has existed there since pristine times.

There is little information in the literature on distribution of mule deer within the present park boundaries. Bailey (1905) specifically mentioned the Guadalupe Mountains where "Mule deer is still more or less common in many parts", while Davis (1940) recorded animals in McKittrick Canyon and The Bowl areas. In a later report, Davis and Robertson (1944) stated "In the Guadalupes the deer occur commonly from the lowest canyons to the highest peaks. At The Bowl we found them in numbers on the surrounding ridges, particularly in places covered with dense growths of scrub oaks, buckthorn, and deer brush." They go on to mention that the presence of mescal permit ... "elk, deer and mountain sheep to remain there (on the high waterless areas) with little inconvenience."

Information from more recent time (L. Kincaid pers. comm., M. Hughes pers. comm.) indicates mule deer were found around The Bowl while the tank was kept filled, along the East Escarpment in association with the springs there, and in West Dog Canyon. The West Side always had a few mule deer, but these were never abundant.

Population Dynamics

Little is known about the reproductive dynamics of mule deer in the park area prior to this study. Bailey (1905) considered deer common in this area at the turn of the century, and Davis (1940) also recorded them as common in this area. Davis and Robertson (1944) suggested the population probably numbered more than 400 for Culberson County, Texas, which represents a relatively low population compared to later estimates. L. Kincaid (pers. comm.) felt that mule deer were abundant in the park area in the early- to mid-1960's with largest concentrations in the West Dog Canyon/PX Flats area. In 1967 he saw a single herd of 90 mule deer near Coyote Peak. By the end of the decade both L. Kincaid and M. Hughes (pers. comm.) were of the opinion that mule deer numbers were declining in the park area, and Hughes believed they continued to decline until about 1974.

STUDY AREA

Guadalupe Mountains National Park includes that portion of the Guadalupe Mountains which occurs south of latitude 32° N in Culberson and Hudspeth counties in the Trans-Pecos Region of Texas. The Park is located 176 km east of El Paso, Texas, and 82 km southwest of Carlsbad, New Mexico, by

highway (U.S. 62-180) (Fig. 3). The 309.5 km^2 Park contains flora and fauna characteristic of both the Chihuahuan Desert and, at higher elevations, of the southern Rocky Mountains (Genoways et al. 1977).

PHYSIOGRAPHY

The Guadalupe Mountains were formed from a massive up-lift of the Capitan reef during the Late Pliocene-Early Pleistocene (Gehlbach 1967). Elevations range from 1,097 m in the Salt Basin at the western periphery of the Park to 2,667 m at Guadalupe Peak, the highest point in Texas. Topography along the base of the mountains is relatively level, although well developed drainages fan out from the escarpment. Slopes along the base are usually less than 20.0% (Bunting 1978), with degree of slope and ruggedness generally increasing with elevation. The escarpment and rim are characterized by rugged out-crops of limestone rock and precipitous bluffs. Deeply incised canyons typify the upper ranges indicating the relatively young age of the complex. Loose limestone rock and thin soils comprise canyon slopes. Flat, open meadows are generally small and infrequent. Almost the entire mountain range is comprised of Permian Limestone (King 1948). Soils of this area are characterized as young, low in organic matter, and primarily of limestone origin (Bunting 1978). Detailed descriptions are available for both the geology (King 1948, Hayes 1964) and soils (Maker et al. 1974, Bunting 1978, Wilkey 1979) of this region.

CLIMATE

A semiarid-mesothermal climatic regime prevails in the Guadalupe Mountains where summer temperatures and precipitation are high (Gehlbach

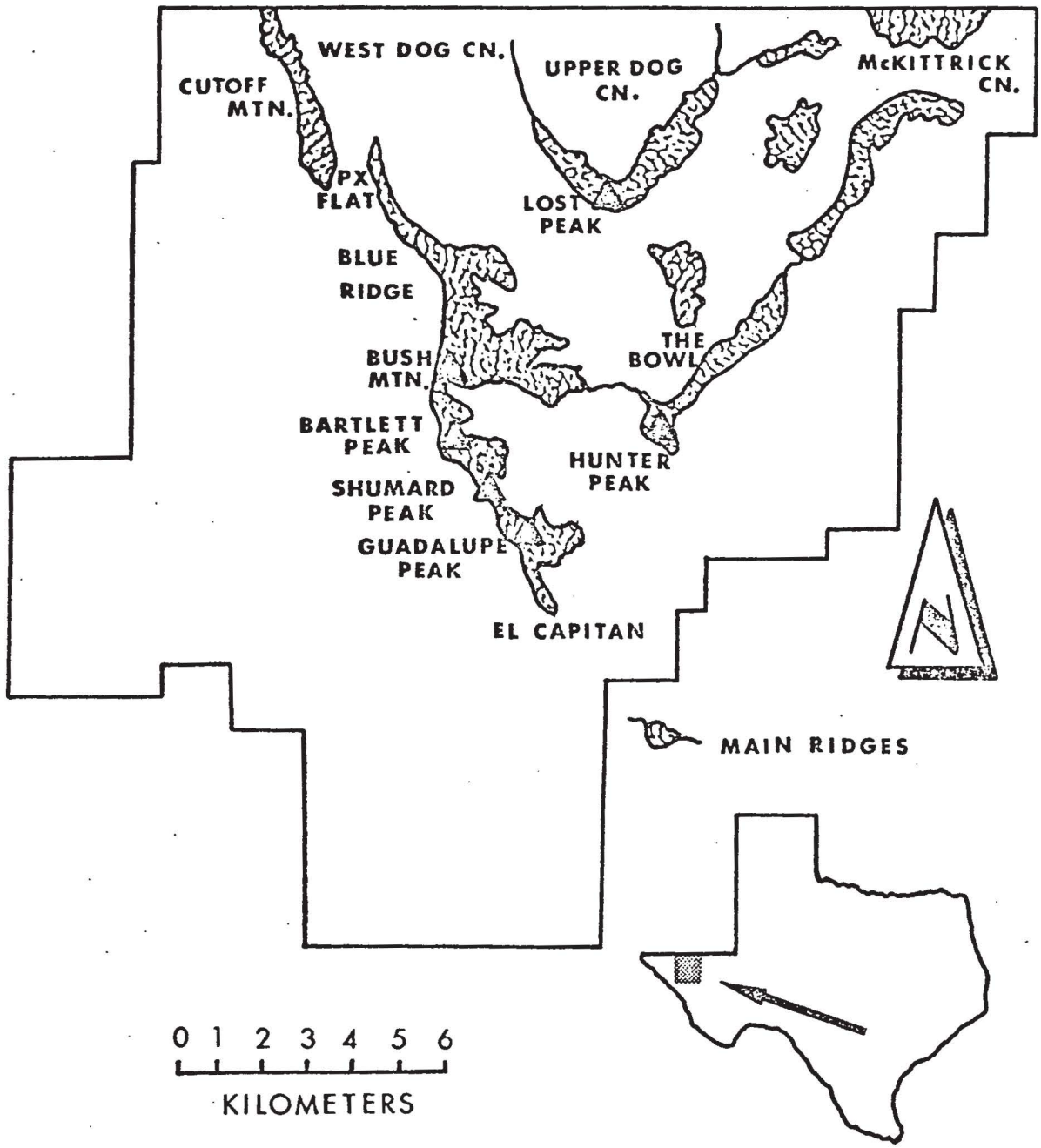


Fig. 3. Guadalupe Mountains National Park, Texas.

1967). Approximately 50.0% of the annual rainfall in the Trans-Pecos region falls during July, August, and September (Hinckley 1944) as tropical gulf air masses move northwestward into the area (Gehlbach 1967). Winter and spring are generally dry. Monthly temperature and precipitation averages taken from 25 years of data at the CCNP weather station, located approximately 56 km northeast of GMNP, ~~have been~~ are summarized in a climograph (Fig. 4). Yearly precipitation averaged 368.3 mm and the mean annual temperature was 17.1°C. January was the coldest month with an average temperature of 7.2°C and July was the warmest with a 25.7°C mean. Recorded temperature extremes during the study period were -20.5°C in December, 1978 at Dog Canyon Ranger Station and 37.7°C at Frijole Ranger Station in June, 1978 (Fish pers. comm.). Most snow falls from November through February. Snow rarely stays on the ground for long before melting, except for patches on shaded north slopes at higher elevations where it remains for much of the winter. Humidity is generally low but increases during the rainy season. Winds are mild throughout most of the year but become extremely strong during the winter and early spring seasons. Gale force winds, measured in excess of 160 kph occur in Guadalupe Pass during these seasons.

This is a personal communication now on file for citation.

VEGETATION

Eleven vegetation types inside GMNP ~~have been~~ were described by Glass et al. (1974) from aerial photographic analysis and field reconnaissance (Table 1). These are distributed in a mosaic pattern throughout the park reflecting aspect and elevational differences. A detailed discussion of the vegetation of GMNP is reported by Bunting (1978) and Krysl (1979). The major vegetation

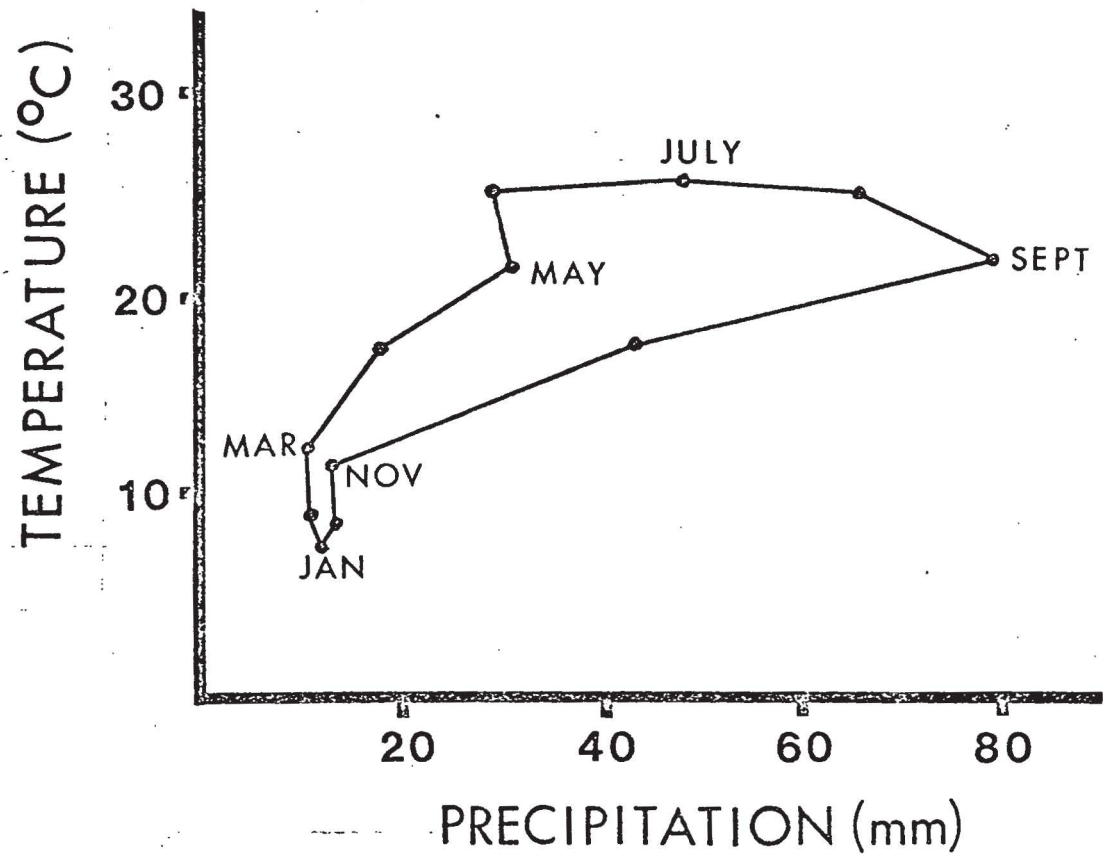


Fig. 4. Climograph representing average monthly temperature and precipitation for a 25-year period ending in 1978 at Carlsbad Caverns National Park, New Mexico.

Table 1. The 11 major vegetation types present in Guadalupe Mountains National Park, Texas (after Glass et al. 1974).

Vegetation Type	Hectares	% of total area
Mountain Shrub	10,608	35.0
Desert Shrub	7,406	24.0
Creosotebush	6,771	22.0
Coniferous Forest	3,263	11.0
Pinyon-Juniper	1,046	3.0
Four-wing Saltbush	416	1.0
Mesquite	265	1.0
Perennial Forb	197	1.0
Rock	187	1.0
Hardwood	133	0.5
Grassland	120	0.5
TOTAL PARK ACREAGE	30,416	100.0

types used in this study are discussed briefly below with plant nomenclature following Correll and Johnston (1970).

Mountain Shrub

The Mountain Shrub vegetation type usually occurs between 1,737 m and 2,286 m in elevation. It occasionally occurs above 2,286 m ~~in some places but is then restricted to~~ on south and west facing slopes. Topography in this vegetation type is highly variable but is best characterized as rough and steep, with slopes ranging from 10% to 80%. Most of the permanent water sources in the park are located within this vegetation type. The canopy is dominated by alligator juniper (Juniperus deppeana), gray oak (Quercus grisea), and pinyon pine (Pinus edulis). Mountain mahogany (Cercocarpus montanus), desert ceanothus (Ceanothus greggii), Apache plume (Fallugia paradoxa), wavyleaf oak (Quercus undulata), and skunkbush (Rhus aromatica) dominate the shrub layer, with New Mexico muhly (Muhlenbergia paciflora), curlyleaf muhly (M. setifolia), pine muhly (M. dubia), sideoats grama (Bouteloua curtipendula), blue threeawn (Aristida glauca), and littleawn needlegrass (Stipa lobata) prominant in the herbaceous layer. Forb production is variable depending on weather conditions. Dominate forbs include bladderpods (Lesquerella spp.), leatherweed croton (Croton pottsii), white sage (Artemisia ludoviciana), globemallow (Sphaeralcea spp.), and milkworts (Polygala spp.).

Desert Shrub

The Desert Shrub vegetation type usually occurs between 1,372 m and 1,737 m elevation on lower, more xeric sites than those occupied by the

Mountain Shrub vegetation type. Topography in this type is rough and steep, and slopes range from 10% to 70%. Permanent surface water is scarce, limited to earthen(?) stock tanks left over from the ranching days. The Desert Shrub type is characterized by redberry juniper (Juniperus pinchoti), skeleton goldeneye (Viguiera stenoloba), Big Bend silverleaf (Leucophyllum minus), sandpaper bush (Mortonia scabrella), and mariola (Parthenium incanum). Rosette shrubs present include sotol (Dasylirion leiophyllum), smallseed sachuista (Nolina micrantha), and various Agave species. Curlyleaf muhly, sideoats grama, wolftail (Lycurus phleoides), and hairy grama (Bouteloua hirsuta) dominate the herbaceous layer. Dominant forbs consist of puccoons (Lithospermum spp.), showy menodora (Menodora longiflora), bladderpods, crotons, and milkworts.

Creosotebush

The Creosotebush vegetation type is located below 1,372 m elevation mainly on the west side of the park, on the very shallow, rocky soils of the fans and flats. The overstory is characterized by creosotebush (Larrea tridentata), and honey mesquite (Prosopis glandulosa) throughout, while white-thorn acacia (Acacia neovernicosa) also is common in localized areas. The herbaceous layer is dominated by spike dropseed (Sporobolus contractus), mesa dropseed (S. flexuosus), fluffgrass (Erioneuron pulchellum), black grama (Bouteloua eriopoda), common dyssodia (Dyssodia pentachaeta), and mountain pepperweed (Lepidium montanum).

Coniferous Forest

This vegetation type is found predominantly above 2,286 m, but is also found at lower elevations in the heads of major drainages. No permanent water sources occur in this vegetation type. The Coniferous Forest type is usually restricted to north and east facing slopes. The canopy is dominated by Douglas-fir (Pseudotsuga menziesii), southwestern white pine (Pinus strobiformis), ponderosa pine (P. ponderosa), gambel oak (Quercus gambelii), chinkapin oak (Q. muhlenbergia), pinyon pine, and big-tooth maple (Acer grandidentatum). Utah serviceberry (Amelanchier utahensis), red mahonia (Berberis haematocarpa), skunkbush, roundleaf snowberry (Symphoricarpos rotundifolius), and smallseed sachuista form much of the understory shrub layer. The herbaceous layer is dominated by littleawn needlegrass, sideoats grama, blue threeawn, New Mexico feathergrass (Stipa neomexicana), pringle needlegrass (S. pringlei), and New Mexico muhly. Dominant forbs found in this vegetation type are orange honeysuckle (Lonicera arizonica), bedstraw (Galium microphyllum), pennycress (Thlaspi fendleri).

Pinyon-Juniper

This vegetation type occurs predominantly above the 1,737 m elevation level and locations and topographic features associated with it are highly variable. The dominant overstory consists of pinyon pine and various species of juniper. Mountain mahogany, desert ceanothus, Big Bend silverleaf, smallseed sachuista, and Guadalupe mountain laurel (Sophora gypsophilia var. guadalupensis) in a portion of West Dog Canyon, dominate the shrub layer. New Mexico muhly, curlyleaf muhly, and finestem needlegrass (Stipa tenuissima) predominate in the herbaceous layer.

Four-wing Saltbush

The Four-wing Saltbush type is located below 1,122 m elevation in association with the gypsum sand dune area on the western edge of the park. Topography of this area is generally flat except for dune formations. There is no overstory canopy; the shrub layer is comprised primarily of four-wing saltbush (Atriplex canescens), with threadleaf sartwellia (Sartwellia flaveriae) also common. The herbaceous layer is dominated by alkali sacaton (Sporobolus airoides), gypgrass (S. neallyi), and hairy bahia (Bahia ansinthifolia).

Mesquite

The Mesquite vegetation type is located on the west side of the park and is bordered by the Creosotebush and Four-wing Saltbush vegetation types. Topography is flat, permanent surface water is absent and the overstory is dominated by honey mesquite with some creosotebush occurring in localized areas. The shrub layer is sparse and is comprised mainly of four-wing saltbush, broom dalea (Dalea scoparia), with an occasional lotebush (Ziziphus obtusifolia). Giant dropseed (Sporobolus giganteus), mesa dropseed, spike dropseed, and grassland croton (Croton dioicus) dominate the herbaceous layer.

Hardwood

This vegetation type is confined to the drainage bottoms and permanent water sources at lower elevations in the park. The canopy is highly layered and is dominated by big-tooth maple, chinkapin oak, gray oak, Texas madrone

(Arbutus xalapensis), and alligator juniper. Apache plume, mountain mahogany, wavyleaf oak, Utah serviceberry, sotol, desert ceanothus, and smallseed sachuista comprise the majority of the shrub layer. The herbaceous layer is dominated by plains lovegrass (Eragrostis lugens), sideoats grama, pine muhly, wolftail, pinyon-ricegrass (Piptochaetium fimbriatum), and green sprangletop (Leptochloa dubia).

Grassland

There is no overstory canopy and the shrub layer is comprised primarily of walkingstick cholla (Opuntia imbricata). Blue grama (Bouteloua gracilis), hairy grama, black grama, wolftail, threeawns, winter fat (Eurotia lanata), plains blackfoot (Melampodium leucanthum), threadleaf groundsel (Senecio douglasii), spinyleaf zinnia (Zinnia acerosa), bladderpods, crotons, and milkworts comprise the majority of the herbaceous layer.

WATER DISTRIBUTION

Permanent surface water is extremely limited in most areas of GMNP. Exceptions are the southeastern escarpment base where springs are numerous and the intermittent streams of McKittrick Canyon (Fig. 5). Concentration of surface water along this escarpment reflects underground water resources which surface as springs in this area. These 2 well-watered areas comprise only a small portion of the Park's total land. Most of GMNP remains waterless, at least during a large portion of the year.

Temporary water sources are scattered in GMNP (Fig. 5), but are extremely important to the ecology of local wildlife. Although ephemeral pools in the drainage bottoms collect and hold rainwater for a few days, several earthen

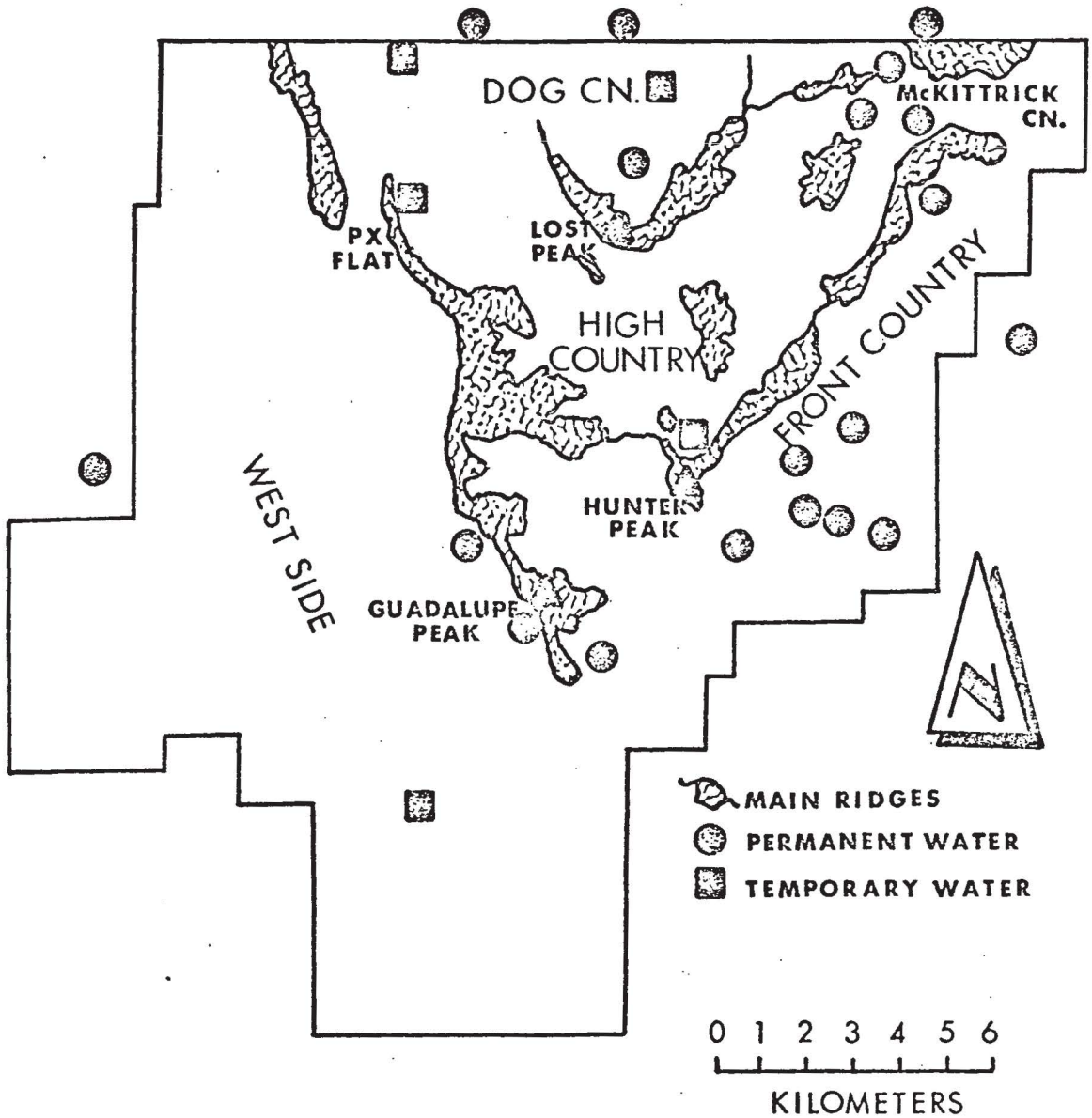


Fig. 5. Locations of permanent and temporary water sources in Guadalupe Mountains National Park, Texas.

tanks constructed during the ranching period provide the most important sources of temporary water to wildlife. These tanks have deteriorated through silting in and contain available water only a portion of the year. In certain parts of the High Country these temporary tanks provide the only surface water available to wild ungulates throughout the year.

METHODS AND PROCEDURES

The National Park was divided into 13 study units based on topographical features to facilitate complete and systematic coverage of the study area. An overlay grid system was also constructed to identify specific locations on a map. Each grid was 0.65 km^2 in area.

The study units were inventoried monthly to gather data on elk and mule deer population dynamics, to collect mandibles from mortalities, and fecal samples for food studies, to establish distribution and movement patterns, to document habitat utilization, and to obtain visual observations of forage selection by both ungulates. These inventories were conducted from foot and horseback with the aid of 8X40 binoculars and a 60X spotting scope.

To determine the present status of the elk herd in GMNP, 2 attempts were made to census the entire population within the park boundaries. These surveys were conducted at the onset (1976) and termination of field work (1978) to determine statuses of the population. Systematic coverage of the study units in specific sequences on foot (1976 and 1978) and with a helicopter (1978) aided in the counts. No attempt was made to census the mule deer population because of its large size in the National Park. Current distributions of elk and mule deer in GMNP were delineated from data on actual sightings and animal signs.

DISTRIBUTION AND POPULATION ANALYSIS

Most of the early information on elk and mule deer numbers, distribution, and general history were obtained from interviews with long time residents and newspaper articles. More concise information on the population parameters of the 2 herds from 1954 to 1973 were provided by TPWD records. Information gained from interviews also provided insight into herd histories during these intermediate years. Current status and distribution of the elk and mule deer herds were obtained from ground counts and field reconnaissance.

Mortality data were recorded when determinable. Identification of predator species involved in an elk or mule deer kill was not made unless some definite sign such as tracks, scats, or predator-specific kill characteristics were evident at the carcass. Skulls and mandibles were collected for ageing purposes. Specimens were gathered over the entire park, covering all habitat types and elevations, to evaluate possible differential mortality between seasonal ranges.

Mandibles from juvenile elk and mule deer were aged by tooth replacement criteria (Quimby and Gaab 1957, Robinette et al. 1957a) while teeth extracted from adult animals were sent to a commercial tooth analytical laboratory for sectioning and age analysis by the cementum annuli method (Laws 1952, Low and Cowan 1963, Keiss 1969). The first incisor (I_1) was found to be the tooth yielding the most accurate results with this sample and it was used whenever possible. Incisors were freqeuntly unavailable from field mortality specimens where the carcass had been scattered and the lower mandibles spearated; therefore the first molar (M_1) was collected when incisors were absent. Results from the ageing of field specimens were used in constructing life tables for both species based on ages at death (Deevey

1947, Caughley 1977). A mortality curve was developed and mortality rates were established for different age cohorts in the 2 populations.

HABITAT RELATIONSHIPS

Three adult elk cows were immobilized and fitted with radio collar transmitters to aid in determining home range boundaries and individual movements. M-99 (etorphine) and Rompun (zylazine) were used in combination to sedate the animals. The drugs were administered with a projectile syringe fired from a commercial dart gun from blinds near elk congregation areas.

Radio signals from the collars were located using a 148 Mhz frequency receiver and a yagi antennae. Once a signal was received, several location fixes were obtained to pinpoint the general area of transmission before the animal was approached to obtain a visual observation. Each visual observation was pinpointed on 15-minute map quadrangles to give home range data for the 3 marked animals. All the basic information on the animal and its band were recorded for every sighting. Differentially marked radio collars allowed individual data collection when telemetry equipment was not available, or as in the case of 1 cow, when the radio package malfunctioned. In addition, 2 physically identifiable adult cows were monitored for home range data. All locations for these cows were recorded upon encounter.

Home ranges for all 5 cows were delineated by the minimum home range method described by Mohr (1947) and utilized by Craighead and Craighead (1956) and Craighead et al. (1973) Seasonal ranges were described for 2 instrumented cows tagged in Dog Canyon.

Forty-nine mule deer were successfully marked with numbered plastic neck collars coded to sex and trap location. Animals were captured with a drop net (Ramsey 1968) or clover box trap (Clover 1954) at 3 trap sites (Dog Canyon, Cox Tank, Frijole Springs) in GMNP. Resightings provided data on distributions and home ranges in these 3 areas.

A statistical technique developed by Neu et al. (1974) was used to evaluate year round utilization by elk and mule deer of the 4 major habitats based on their availability. Total elk and mule deer ranges inside GMNP were delineated by connecting the outlying points where animals or animal sign had been encountered during the 2 years of this study. Total area of each major habitat type within the elk and mule deer range was then derived by planimeter and proportions were recorded. A null hypothesis that elk and mule deer distribution patterns over the 4 habitat types were equvalent to occurrence of the types was formulated and tested by Chi-square analysis. The Bonferroni z statistic was used to estimate if elk and mule deer distributions occurred more or less than expected in the 4 habitat types (Neu et al. 1974).

Water sources were defined as permanent or temporary water catchments exclusive of pools found in drainage bottoms. The numerous ephemeral pools along drainages important to elk and mule deer were difficult to monitor effectively. However, temporary sources (i.e., old, earthen tanks) held water longer than did drainage bottom pools and consequently were more important to wildlife. The status of temporary tanks was monitored throughout the study and elk and mule deer sightings were plotted in 1.6 km intervals from the closest known source of surface water. In addition, a watering schedule was established for the Dog Canyon elk band during 25 days spanning

the dry months of April and May, 1978. The band was monitored daily, when possible, to determine when and how often drinking occurred. Tracks, sign and actual observations of elk at the 2 available water points in Dog Canyon were used to determine elk watering habits. All tracks and signs were cleared from around the water sources following each record of use.

Three seasons were designated for analyzing elk and mule deer population and environmental parameters based on climatic influences. Winter (November - February) contained the coldest 4 months in GMNP as determined from weather station data. The driest months of the year (March, April, May) in the Trans-Pecos region of Texas occur within the Spring-summer season (March - June) (Hanks and Dick-Peddie 1974). During the Summer-fall season (July - October), half the annual precipitation received in this area occurs primarily as rain (Hickley 1944).

FECAL ANALYSIS

Approximately 30 mule deer and 30 elk fecal group samples ($\pm$ 2 samples) were collected each month from March, 1978 through February, 1979. An attempt was made to collect monthly fecal samples from all vegetation types included within the park, however, this was not always possible because of the seasonal inaccessibility of some areas. Each habitat type was visited at least once during each season of the year.

Microscopic slides were prepared of reference and fecal material as described by Free et al. (1970). Microhistological examination of fecal material followed the procedures outlined by Sparks and Malechek (1968). Twenty microscope fields were examined at 100X magnification for each sample. Results from analysis of plants identified in individual samples

were tabulated and reported as species present and % relative frequency. For seasonal analysis of food habits the 4 conventional seasons were used to correspond to plant phenology in this area. The seasons were: Winter (December - February), Spring (March - May), Summer (June - August), and Fall (September - November). A selection index was calculated for elk and mule deer for each season (Swanson et al. 1974).

COLLECTION OF DEER

A total of 36 mule deer were collected during December, 1977 through April, 1979 under scientific permits from TPWD and NPS. Six roadkills were included in this collection. Eight mule deer samples were collected during spring, 8 during summer, 8 during fall, and 12 samples during winter. Due to inaccessibility, mule deer were not collected from every habitat type. No elk were collected in this study due to their low numbers in the park.

The rumen was removed intact from the body cavity of collected animals and its contents thoroughly hand-mixed before sampling. Several samplings were taken randomly from all parts of the mixed rumen content. If there was an insufficient amount of material in the rumen, the remainder of the 1 quart sample was collected from the reticulum. Analysis of samples collected from mule deer followed those procedures described previously for fecal analysis. Rumen analysis allowed for identification and quantification of succulent forage consumed by mule deer which may have otherwise gone undetected using the fecal analysis technique.

VISUAL OBSERVATIONS

Foraging observations were made from ground, vehicle, or vantage points (e.g. trees) using the 8X40 binoculars and a tripod mounted 60X spotting scope. The species and number of plants eaten by each individual under observation was recorded. During this study 1,341 mule deer and 1,259 elk feeding observations were obtained. Only 1 observation was recorded per plant species eaten by each animal at one time, regardless of the amount consumed. If more than 1 individual was present, information was recorded separately for each animal. These data were quantified to compute a % relative frequency of plant species in the diet of elk and mule deer on a seasonal and an annual basis.

Observations on deer and elk were difficult to obtain due to their wary behavior, and determination of exactly which plant(s) were being eaten for further complicated because animals often grazed behind obstructions (e.g. large rocks and bushes). The visual observations did, however, provide information on plant species and plant parts eaten by elk and mule deer which was not determinable with either rumen or fecal analysis techniques.

VEGETATION TRANSECTS

Depending on the extent of the area, between 40 and 60 step-point transects were run in each of the 11 major vegetation types, except rock, mesquite, and perennial forb, during the spring and summer of 1978. Transects were selected to evaluate aspect, slope, and elevational differences within each vegetation type. Each transect consisted of 50 points, spaced 2 paces apart. At every sample point the status of the vegetation was recorded as either bare ground, rock, litter, grass, browse, or forb. If a non-vegetational feature was recorded on a sample point, the nearest plant to the point was

also noted.

BROWSE EXCLOSURES

In May, 1978, 10 1 m^2 exclosures were established in the Upper Dog Canyon area, on each of 5 major browse species; cliff fendlerbrush (Fendlera rupicola), desert ceanothus, hitchcock mockorange (Philadelphus hitchcockianus), mountain mahogany, and Apache plume. Paired plants of approximately the same size were selected and cages randomly placed on either plant. Current year's leader growth of plants in the exclosures and adjacent unprotected plots was clipped in November, 1978. The forage was dried and weighed on a top loading balance. Following clipping, the exclosures and controls were established in December, 1978 at a different location in Upper Dog Canyon using only desert ceanothus, mountain mahogany, and Apache plume. These shrubs were clipped in June, 1979. Statistical differences in leader production and utilization between caged and uncaged plants was determined by using a paired t-test analysis (Snedecor and Cochran 1973).

BROWSE UTILIZATION

In 1973, 49 browse transects were established and evaluated by NPS personnel in GMNP (Glass et al. 1974). The park was divided into 4 sectors: High Country; West Dog - Dog Canyon; Front Country; and West Side ranges (Fig. 5). The High Country is above 2,286 m and is dominated by a Coniferous Forest. The West Dog - Dog Canyon sector occurs below 2,286 m in the northern region of the park and is comprised of Pinyon-Juniper and Mountain Shrub types. The Front Country is found below 1,829 m and consists of Mountain

Shrub and Desert Shrub types. The West Side occurs below 1,524 m and is dominated by the Desert Shrub and Creosotebush types. As part of the present study, 37 of these 49 browse transects were selected for re-evaluation in the spring of 1979 to assess browse condition and vegetation trends over the past 6 years.

Each transect consisted of 100 points, spaced a designated number of paces apart. The status of the vegetation was recorded as either bare ground, rock, litter, grass or forb at every sample point. If a non-vegetational feature was encountered, the nearest perennial grass or forb was recorded and placed in 1 of 2 categories of distance from the sample point: 0-0.30 m or 0.30-0.91 m. If no perennial grass or forb was present within 0.91 m of the point, no information was recorded. After the understory vegetation evaluation, attention was given to determining condition of woody browse species. At every sample point, the closest browse plant within 180° arc in front of the point was recorded, regardless of distance from the sample point. Browse plants were classified into 3 categories with associated characteristics: A - good-browse species (decreasers, preferred, desirable, choice), B - fair-browse species (increasers, staple, intermediate, fair), and C - poor-browse species (invaders, low value, least desirable, unimportant). Within each category all plants were further classified according to availability and form; this was recorded as 1 of 6 categories: (1) all available, little or no hedging, (2) all available, moderately hedged, (3) all available, severely hedged, (4) partly available, little or no hedging, (5) partly available, moderately hedged, and (6) partly available, severely hedged. Shrub, tree, and rosette shrub density determinations were

made with an angle gauge at every tenth point on each transect. This browse density was used to obtain a density classification for the browse condition. Pellet groups of deer and elk were also counted at every tenth point within a 3.63 m radius circle to determine relative use in each area. After all browse was rated, the data were scored and results put into 3 categories: High, Medium, and Low, based on scoring system shown in Appendix A. Comparisons between 1973 and 1979 were made using a paired t-test (Snedecor and Cochran 1973). Data from the vegetation sampling and the browse utilization transects were used to compute availability of major forage plants consumed by elk and mule deer in GMNP.

PRESENT STATUS AND DISTRIBUTION

ELK

The present status of the resident elk population in GMNP was established through 2 attempts at total ground counts in 1976 and 1978. Residents are defined as those elk spending most of the year within the boundaries of GMNP. The 1976 count was conducted in late summer and the 1978 count was undertaken in early fall. During both these periods. Elk were more sedentary than at other times of the year. Water was available in temporary catchments and the breeding season was about to begin, making the possibility of duplicate counts or missed individuals minimal. Total population figures of 104 and 111 individuals were obtained for these 1976 and 1978 counts, respectively. It must be presumed that some elk went undetected during each count; these would probably have been lone animals or small groups (predominately bulls), which were in the more isolated and least accessible portions of the National Park during the count periods. Therefore, an adjusted population size

estimate, based on the 2 total counts, elk sign and previous sightings in isolated locations, was placed at approximately 120 to 130 resident individuals.

The distribution of elk in the park was based on elk sightings and sign recorded from 1976 to 1978 and was found to encompass 139 km^2 (Fig. 6). Elk numbers were greatest in the upper elevation ranges north of Hunter Peak. Elk commonly ranged outside the northern park boundary into New Mexico on a seasonal basis, especially in the drier seasons. The east and west boundaries of elk distribution in the upper ranges were dictated primarily by topography, suitable habitat, and possibly disturbance factors. The eastern edge of elk distribution at the upper elevations went to, but did not include, the main drainage of McKittrick Canyon. Water was available in this drainage, but intensive visitor use and, to some extent, steep-sided canyons precluded much elk use. Visitor presence was probably the main deterrant, since elk were found in the area prior to 1970. The western periphery of elk distribution in GMNP terminated along the upper western escarpment. Topography of the lower elevational gradients below the escarpment was rough down to the creosote flats. In addition, suitable elk habitat was limited below the rim, as was available surface water. These factors contributed to restricting elk distribution along the western front.

Several small elk bands inhabited the foothill ranges south and east of Hunter Peak and near the mouth of McKittrick Canyon (Fig. 6). These animals along the southeast escarpment displayed a relatively restricted distribution near the numerous water points in this portion of GMNP, but occasionally ranged south out of the National Park onto private lands. Elk occupation of these private lands was most common in winter.

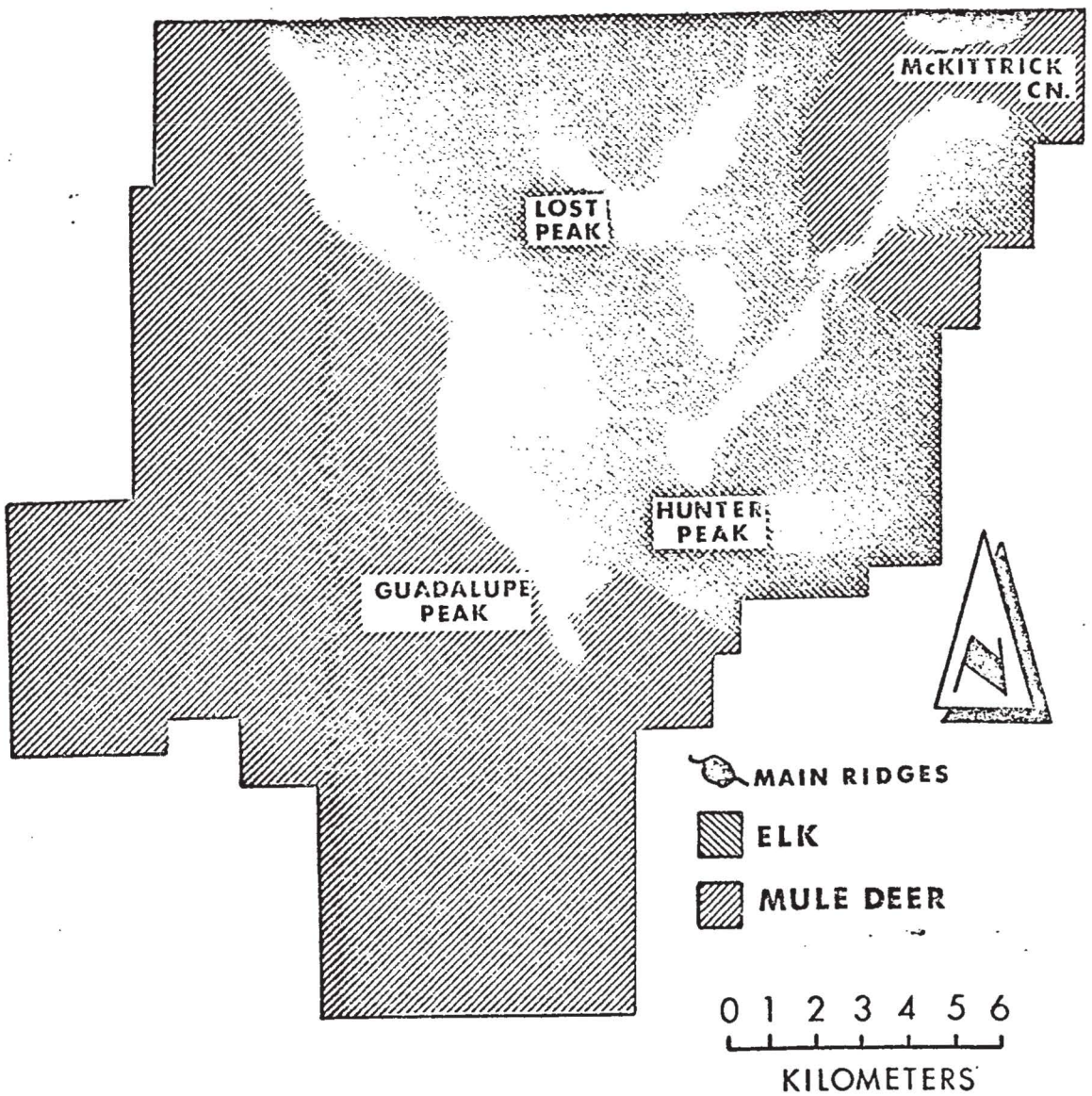


Fig. 6. Elk and mule deer range determined from sightings and sign recorded in Guadalupe Mountains National Park, Texas.

MULE DEER

Mule deer numbers were high in GMNP and surrounding areas, especially in the vicinity of permanent water sources. The total number of deer in the National Park was difficult to ascertain because of the variety of habitats and differential animal densities, but estimates place the population size at between 1,000 and 1,500 animals (TPWD Dep. Rec.). Because deer densities were high in most areas bordering the park, numbers undoubtedly fluctuated significantly on a seasonal basis.

The mule deer distribution in GMNP encompassed the entire park, but numbers were greatest in those areas also inhabited by elk (Fig. 6), indicating the suitability of the upper ranges and southeast escarpment base as wild ungulate habitat in GMNP. Generally, these areas supported the most preferred vegetal resources. Nevertheless, mule deer exhibited an ubiquitous distribution in GMNP. Intermittent animal signs were also found on the vast, poorly vegetated flats of the western boundary indicating at least some use for travel between adjacent mountain ranges.

The major deer range in GMNP mirrored the total elk range (Fig. 6) except in McKittrick Canyon and in the Guadaluple Peak-El Capitan foothills which were occupied by deer but not by elk. Determination of habitat selection by deer, however, was based only on sightings obtained within the elk range (Fig. 6) to allow for species comparisons in areas of greatest ungulate density and overlap.

POPULATION DYNAMICS

ELK

Herd Composition and Sizes

Gregarious ungulates such as elk display seasonal changes in group size and composition in response to changing physiological and behavioral processes. Herd composition and sizes were tabulated on a monthly basis in GMNP to detect these changes. Herds were defined as a collection of animals from 1 to infinity. These were classified as All Female Herds, Lone Females, All Male Herds, Lone Male, and Mixed Herds consisting of both sexes (Fig. 7). Female groups consisted of cows and juveniles. A single cow and her calf were classed in the Lone Female category.

During the first 2 months of the winter season (Nov. - Feb.) observations of Mixed Herds consisting of males and females were prevalent, indicating residual bull-cow associations following the breeding season. Sex segregation began in late winter as males became solitary or ranged in All Male groups. An increase in Lone Female observations was evident in June corresponding to parturition although few births apparently occurred among GMNP elk. Females who presumably never gave birth often were observed alone during this period. Sightings of Mixed Herds increased in July and August indicating the approach of the breeding season. Sightings obtained during September and October, at the peak of the rut, contained few All Female Herd sightings and a substantial percentage of Mixed Herds and Lone Males. Most cow groups were accompanied by a harem bull while subordinate, single males remained in the vicinity of harems throughout the rut in anticipation of breeding opportunities.

Elk group sizes in GMNP averaged 3.6 animals from June, 1977 through December, 1978. This figure was low compared to reports for other herds

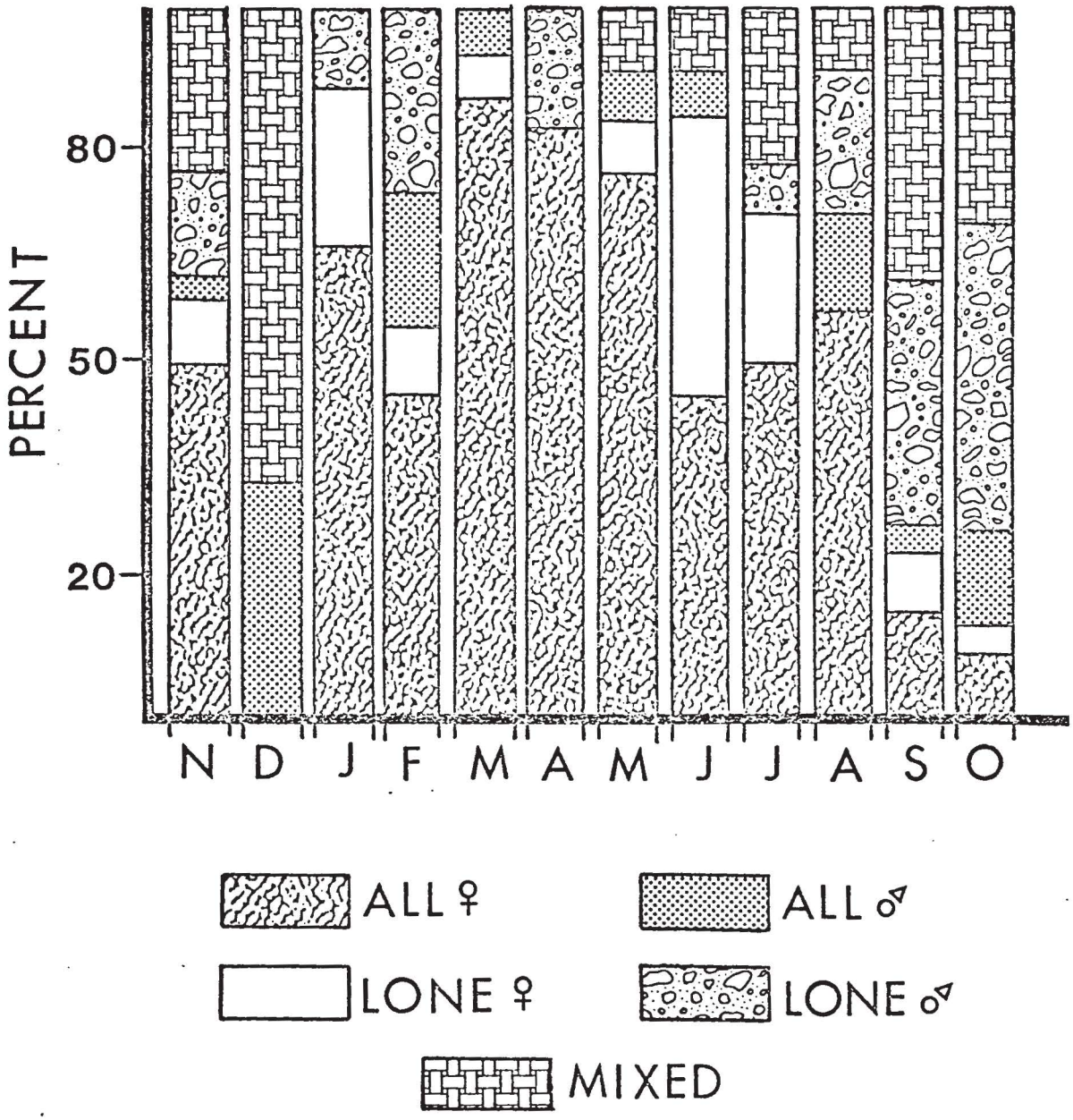


Fig. 7. Monthly percentage of herd composition of elk in Guadalupe Mountains National Park, Texas.

(Rust 1946, Mackie 1970, Boyd 1978, Varland et al. 1978), but it was probably a reflection of the small overall population since the mean group size of gregarious animals generally decreases as density decreases (Caughley 1977). The largest herd recorded during the 18-month field study was a group of 31 adults sighted by a Park Service employee in February, 1978 in PX Flat. All herd sightings obtained by research personnel (and used in data computations) contained no more than 18 animals. Average monthly herd sizes ranged from a high of 7.33 animals in December to 1.33 in January (Fig. 8), but both extremes may have been influenced by small sample sizes for these 2 months.

Herd size fluctuated throughout the year, but seasonal averages were all close to the overall annual average of 3.6 elk per herd. Highs in November and December reflected continued aggregation of large herds following the rut. The large average herd sizes reported in March and April may have been due to elk-water associations during these dry months. Herd sizes would be predictably larger as animals were concentrated in areas surrounding permanent water sources. Average herd sizes were not as high as expected during the breeding season months of August through October. The large number of single male sightings on harem peripheries undoubtedly lowered the average during this period.

Sex Ratios

Bull:cow ratios of 47.6:100 and 41.1:100 were found in this study during the 1976 and 1978 censuses, respectively (Table 2). Unequal ratios, indicating a preponderance of females, are not uncommon for a polygamous species such as elk (Murie 1951) and probably reflect differentially higher

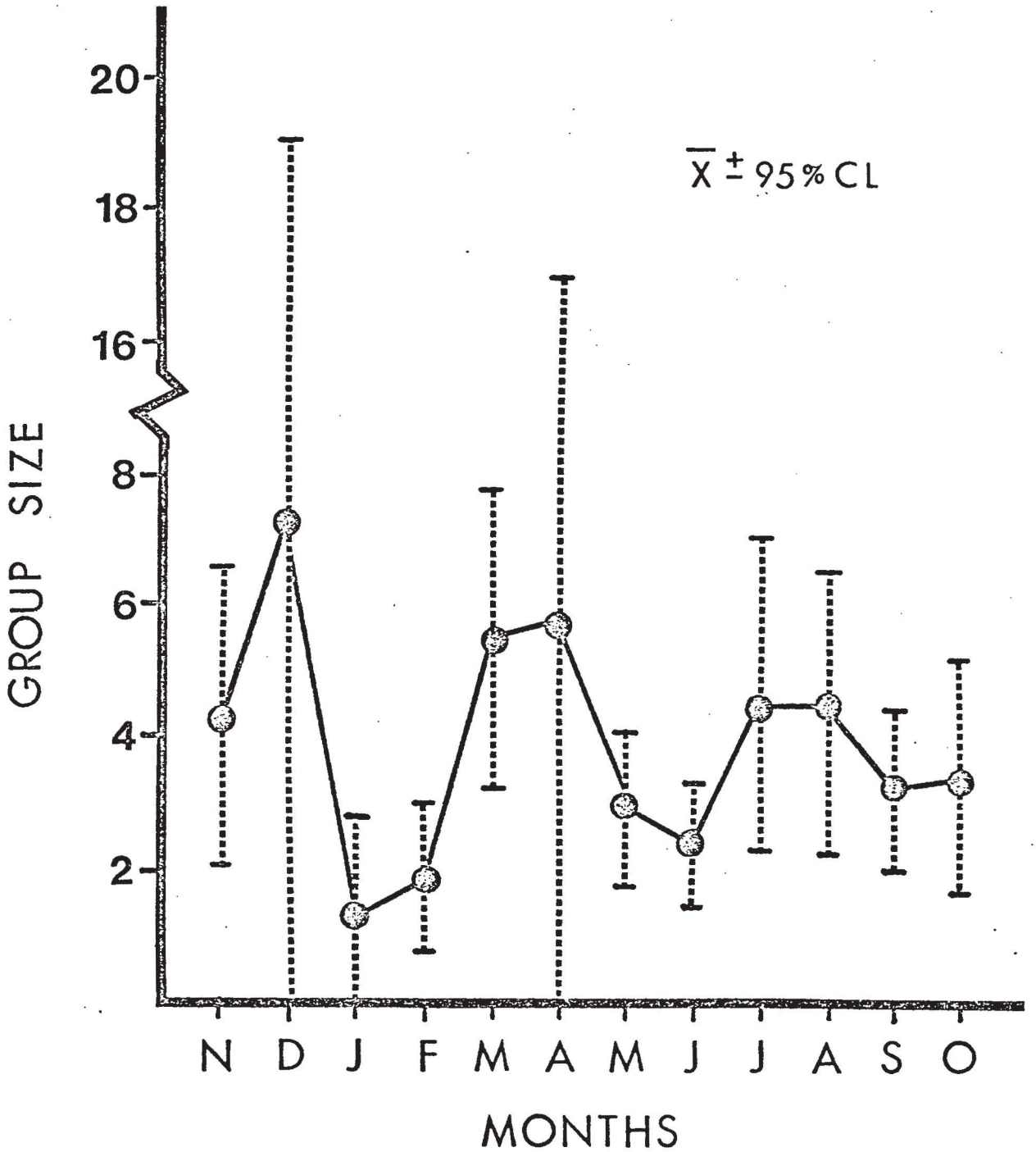


Fig. 8. Average monthly herd size for elk in Guadalupe Mountains National Park, Texas.

TABLE 2. Sex and age composition, minimum population size and bull:cow:calf ratios for elk from unduplicated counts in 1976 and 1978 in Guadalupe Mountains National Park, Texas.

	Sex and Age Composition					
	Bulls	Cows	Calves	Sex Unknown	Total	Bull:Cow:Calf Ratios
			1976			
Adult	27	57	--	4	88	
Subadult	3	6	--	--	9	
Juvenile	--	--	7	--	7	
Totals	30	63	7	4	104	47.6:100:11.1
			1978			
Adult	27	70	--	--	97	
Subadult	3	3	--	--	6	
Juvenile	--	--	8	--	8	
Totals	30	73	8	0	111	41.1:100:10.9

mortality rates among males. Murie (1951) recorded a ratio of almost 25.0:100 among adult elk over a 7-year period at the National Elk Refuge, Wyoming, while Craighead et al. (1973) documented an averaged sex ratio of 2 consecutive summers of 19.7:100 among elk of the Madison River drainage, Montana. The 80:100 ratio reported for Tule elk in California (McCullough 1969) closely parallels the situation in GMNP.

Comparisons between current ratios and those obtained from past TPWD censuses (Table 3) cannot be made. The high ratios of bulls:cows reported by TPWD personnel were probably due to greater observability of bulls during the breeding season when most of their censuses were conducted. It is also possible that bugling bulls not actually observed were included in the bull count and thus reflected disproportionate sex ratios.

Age Ratios

Cow:calf ratios were found to be low for the 2 census years (Table 2) and low ratios were also evident in 1977 when 9 calves were recorded for the birth period with 8 surviving through November, 1977. Subadult cows breed infrequently (Murie 1951, Asdell 1964), yet they have been pooled with adult females in computing cow:calf ratios in this study, resulting in slightly lower than actual ratios. This was done to allow comparisons with age ratio data from other studies since yearlings are seldom broken out of the adult female category.

The ground censuses during which sex and age structures were obtained were conducted primarily in late summer through fall. Ratios were considered summer ratios since data were collected before the winter period when some calf loss was expected. Therefore, it was important to compare the present

results with summer ratios from other herds as surveys later in the year reflect calf mortality from harsh winter conditions. Knight (1970) reported cow:calf ratios of 100:32 and 100:29 for 2 consecutive summers among Montana's Sun River elk herd. He considered a winter ratio of 100 cows:29 calves averaged over 6 years for the same herd as "below standard" in comparison with other northern herds. Craighead et al. (1973) concluded that Yellowstone National Park's Madison drainage elk cow:calf summer ratios of 100:31 and 100:38 "indicated low to normal productivity." Other herds have shown greater productivity as indicated by summer ratios of 100:59 reported by Kimball and Wolfe (1974) for a northern Utah elk herd. Clearly it is evident that cow:calf ratios of 100:11.1 and 100:10.9 for the 1976 and 1978 GMNP censuses, respectively, are much below those reported for northern elk herds and that productivity among the Guadalupe Mountains elk is quite low.

Table 3 breaks down the observed sex and age ratios reported by TPWD personnel during 10 noncontiguous years on Guadalupe Mountains Ranch (Hailey 1963a, 1963b, 1963c, 1964, 1966a, 1966b, 1969, 1970, 1971, Uzzell 1954). Relatively high cow:calf ratios were reported for almost all years. The contiguous 6-year average fall cow:calf ratio of 100:46.7 during 1961 to 1966 is compatable with Rocky Mountain elk productivity within their native distribution (Knight 1970, Mackie 1970, Follis and Spillet 1974).

Comparisons between cow:calf ratios found during this study and those reported by TPWD censuses clearly indicate a recent decline in productivity among elk of the Guadalupe Mountains. This decline was apparently fairly rapid, having begun in the early 1970's. In 1972 through 1973, calves accounted for only 8.8% of the sightings recorded by Glass et al. (1974)

TABLE 3. Annual sex and age composition and ratios for elk in Guadalupe Mountains National Park, Texas, (from Texas Parks and Wildlife Department censuses during 10 noncontiguous years).

Year	Bulls	Cows	Calves	Total Animals Seen	Bull:Cow:Calf Ratios
1956	6	17	5	28	35.2:100:29.4
1961	21	15	7	43	140.0:100:46.7
1962	24	15	7	46	160.0:100:46.7
1963	23	12	7	42	191.6:100:58.3
1964	19	10	4	33	190.0:100:40.0
1965	11	21	10	42	52.3:100:47.6
1966	10	17	7	34	58.8:100:41.1
1968	29	14	9	52	207.1:100:64.2
1969	5	14	7	26	35.7:100:50.0
1970	5	3	1	9	166.7:100:33.3
			Average (1961-1966)		132.1:100:46.7

and no subadults were recorded. In the present study, calves made up 6.7% of all elk censused in 1976 and 7.2% of the 1978 total. By contrast, during the late 1960's, calves comprised approximately 20.0% of the total elk observed by TPWD personnel (Table 3).

Because of the relatively low elk population in GMNP, no females were collected, and determination of pregnancy by external appearance of cows in the field was not possible. If conception rates were normal in the Guadalupe Mountains population then high *in utero* and/or postnatal mortalities have occurred in the past few years. Alternatively, low conception rates may have been responsible for the low calf crops observed since 1972.

Parturition

The earliest date of parturition recorded for Guadalupe Mountains elk during the 3 birth periods monitored in this study was 8 June, 1978 when a calf, judged to be newborn, and its dam were encountered near Lost Peak. Another newborn calf was observed in Dog Canyon on 10 June of the same year. During 1976 and 1977 no newborns were seen; calves first observed in these years were already running with cow bands. Estimated dates of parturition for these calves all fell within the second week of June and were obtained from subjective appraisal following Johnson's (1951) descriptions of elk calf age classes and mobility. These known and estimated birth dates fell within, although a little on the late side, of parturition periods reported for elk of northern herds (Rush 1932, Schwartz and Mitchell 1945, Rust 1946, Johnson 1951). Nevertheless, it appeared that conception and subsequent parturition times for elk in the Guadalupe Mountains were consistent with data available for Rocky Mountain elk in northern regimes.

Annual Recruitment

Annual recruitment to the GMNP elk population was extremely low. Herds outside the park were few and scattered and it appeared that little permanent immigration occurred. Hunting pressure on these peripheral herds was light and they apparently underwent little harassment that might force them into the National Park. Emmigration was also thought to be insignificant. Most, if not all, recruitment into the elk population at GMNP resulted from resident animal reproduction, which was low as shown above.

Once on the ground, calves were exposed to several sources of mortality throughout their first year, with the highest mortality rate occurring in the first 5 to 6 months of the calves' lives. An average of 28.0% of calf mortalities occurred from birth to the summer-fall count conducted when calves are approximately 5 months old, as compared to a 20.0% loss by the next count a year later (Table 4). Once calves reached 1 year of age their mortality rate declined significantly as indicated by field observations and life table analysis (Table 5).

Calves were not considered a true increment to the population until their first birthday. Therefore, the annual recruitment rate was computed from yearling animal totals obtained during the census periods and portrayed as % composition in the population size figure (Table 4). A complete herd census was not obtained in 1977 so recruitment computations for that year were based on a population size figure derived from the mean of 1976 and 1978 population numbers. Recruitment for the 3 years censused during this study was low, averaging only 6.5% annually (Table 4). These figures indicate a static to declining population when contrasted with annual mortality rates discussed below.

TABLE 4. Annual juvenile mortality in Guadalupe Mountains National Park, Texas traced from known births through age 16 months. Annual recruitment portrayed as percent composition of yearlings in the population.

Year	Known Births	Census Totals		Minimum Population	Recruitment (% of population)
		Calves	Yearlings		
1976	10	7	9		
				104.0	8.6
1977	9	8	6		
				107.5*	5.6
1978	13	8	6		
				111.0	5.4
				Average	6.5

* Mean of 1976 and 1978 Population Figures.

TABLE 5. Death based life table for elk from 50 natural mortalities between 1972-1978, Guadalupe Mountains National Park, Texas (calculations follow Caughley 1977).

Age x	Frequency fx	Mortality dx	Survival lx	Mortality Rate qx	Survival Rate px
0	11	.220	1.000	.220	.780
1	0	0.000	.780	0.000	1.000
2	0	0.000	.780	0.000	1.000
3	1	.020	.780	.026	.974
4	5	.100	.760	.132	.868
5	2	.040	.660	.061	.939
6	1	.020	.620	.032	.968
7	5	.100	.600	.167	.833
8	4	.080	.500	.160	.840
9	7	.140	.420	.333	.667
10	3	.060	.280	.214	.786
11	1	.020	.220	.091	.909
12	2	.040	.200	.200	.800
13	1	.020	.160	.125	.875
14	2	.040	.140	.286	.714
15	2	.040	.100	.400	.600
+16	3	.060	.060		

Life Tables Analysis

Fifty natural mortalities collected in the field were aged by either tooth replacement (juveniles) or tooth cementum annuli (adults). Age data from these were used to construct a life table (Table 5) based on ages at death (Deevey 1947, Caughley 1977).

The assumption was made for this life table that the rate of increase equaled zero and a stationary age distribution existed over the period in which ageable adult carcasses accumulated. This assumption was substantiated by Park Service data on elk sex and age classification (Glass et al. 1974), information from a mammal survey (Genoways et al. 1977), and specific population dynamics data from reports submitted under this study (Moody and Simpson 1977a, 1977b, 1978).

Two inherent sources of bias may have occurred through the data used for this life table. Although the tooth cementum annuli technique is one of the most accurate aging methods known (Low and Cowan 1963, Keiss 1969, Erickson and Seliger 1969), it has some shortcomings when teeth from lower latitude mammals are examined (Lockart 1972). Tooth analystical technicians indicated that the age estimates used here probably contained some error; however, all mandibles were also aged by the tooth wear method (Quimby and Gaab 1957) and the results closely approximated the cementum annuli technique findings. In comparing the 2 methods Keiss, (1969) found that the cementum annuli technique provided more reliable age estimates. Any error in aging would be consistent for the entire sample and so would not bias the results enough to alter accurate interpretation. Another realized bias exists in the portrayal of the juvenile age class. Four parturition periods (1975-1978) were represented by the 11 juvenile carcasses in Table 5, with all

births but 1 occurring after the initial elk survey began in 1976. Undoubtedly mortality in the first year of life was underestimated. This is a common bias in most life tables of this type since immature animal carcass remains decompose faster than adult carcasses and are less conspicuous (Deevey 1947, Taber and Dasmann 1957, Caughley 1966).

Table 5 records the age specific probabilities of death for elk placed in a conceptual cohort and treated as if their births were simultaneous. Of the 50 individuals comprising this imaginary cohort, 22.0% died before reaching 1 year of age while 42.0% perished after their ninth year. Six percent of the sample lived to older than 16 years. The weighted mean mortality rate per year for the elk population was calcualted at 12.4% following Caughley (1977) and indicated the proportion of animals that died annually as measured between successive birth periods.

The mortality rate (qx) curve (Fig. 9) constructed from these life table data follows a typical mammalian mortality pattern characterized by a "U" shape. This results from high juvenile mortality followed by a leveling off in mid-aged animals and a subsequent increase in mortality among the older age classes (Caughley 1966, Eberhardt 1971). This steadily increasing rate of mortality in GMNP was broken at ages 4 and 6 where higher and lower rates than expected were recorded (Fig. 9).

This basic characteristic form was reported by Caughley (1971) for red deer females from New Zealand. Mortality was high at the 0 to 1 age category, dropped quickly, and then rose steadily from age 5. A lightly hunted red deer population from Scotland, thought to have been regulated by natural mortality displayed similar trends (Lowe 1969). Similar results have been

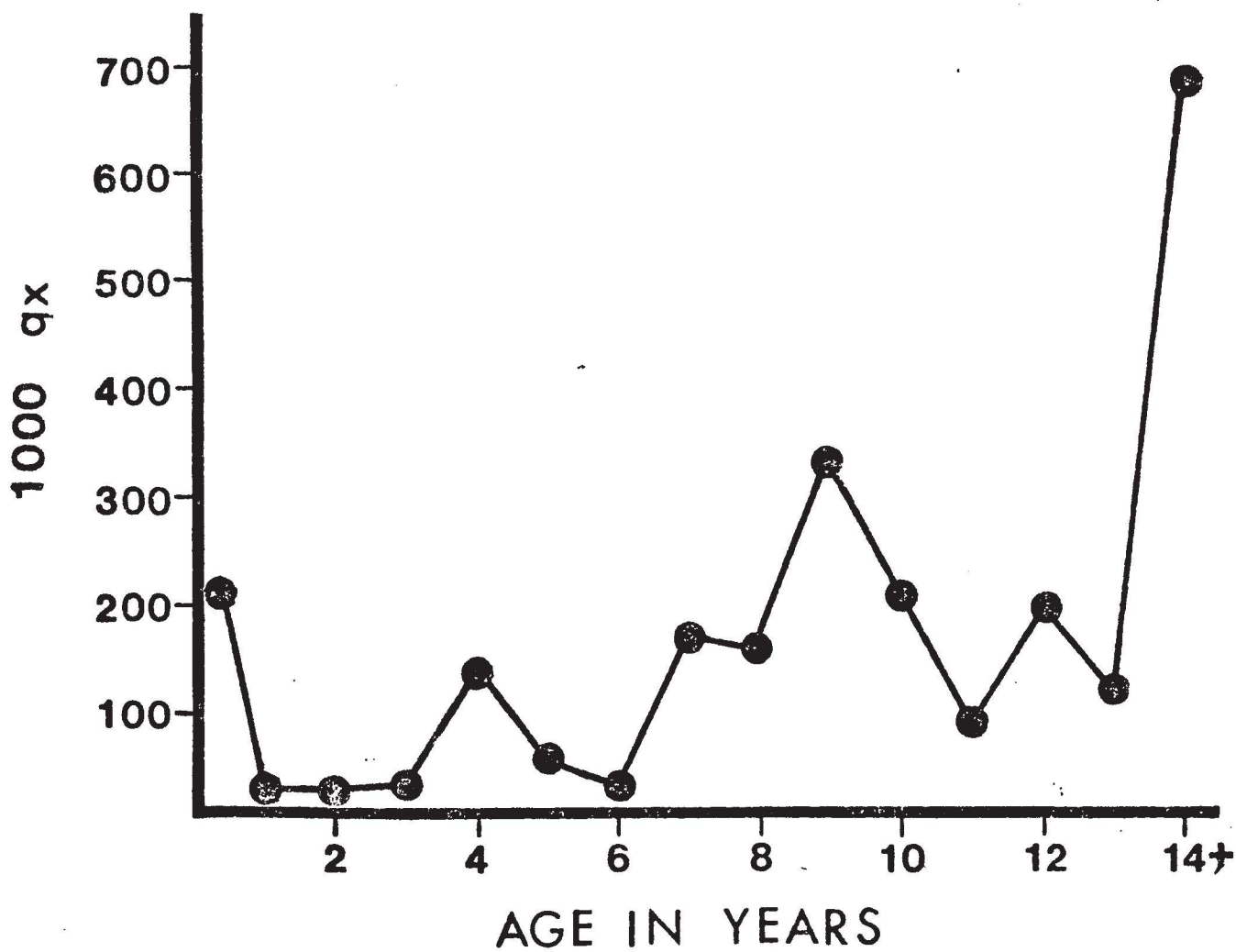


Fig. 9. Mortality rate curve (qx) for elk in Guadalupe Mountains National Park, Texas.

reported by several authors (Deevey 1947, Taber and Dasmann 1957, Caughley 1966) using Murie's (1944) mortality data from a natural, unhunted population of Dall sheep (Ovis dalli) from Mt. McKinley. Here, as in the GMNP study, skulls were collected in the field and examined to determine age at death; mortality occurred primarily in the juvenile and old age classes (Murie 1944).

Elk mortality during the first year of life in the calculated mortality curve was typically high at 22.0%. This was considerably less than the 27.0% mortality rate observed for 2 calving seasons during this study (Table 4) and probably indicates the amount of bias of juvenile underrepresentation in Table 5. The 22.0% juvenile rate was therefore considered a minimum figure. All juvenile elk mortalities investigated were aged at 6 months or less from tooth erruption patterns (Quimby and Gaab 1952) which suggested a high susceptibility of young, dependent calves. After their first half-year of life, calves faced a reduced probability of dying and low mortality continued through the third year before a drastic increase emerged at age 4 followed by 2 years of lower rates presumably attributable to a limited sample. The rate steadily increased from age 5 and reached 33.0% during the ninth year.

Senescence appeared to occur during years 9 through 16 when the greatest percentage of elk perished. The life span for elk of GMNP appeared to be in the range of age 12 through 15 with some animals reaching the upper teens. Of the 50 mortality samples, 3 were aged at 16 years or greater (16, 16.5, 20 yrs). These old ages were not extraordinary as evidenced by elk longevity data presented by several authors working with animals marked as calves (Rowan 1923, Murie 1951, Picton 1961).

The mean annual mortality rate for adult elk ($\bar{q}_{2,\infty}$) in GMNP was 12.4% (Table 9). Applying the 12.4% mortality rate to the elk population estimate of 125 animals yields a loss of 15.5 animals to the population per year. Rates were calculated within the adult category ages of 2 years to ∞ ($\bar{q}_{2,\infty}$) to demarcate the age classes where most mortality occurred. "Young" adults aged 2 through 9 ($\bar{q}_{2,9}$) exhibited a relatively low 7.7% annual mortality while the 26.6% rate for "old" adults ($\bar{q}_{9,\infty}$) fell well above the overall mean rate of 12.4%. The GMNP elk population's mortality pattern was clearly indicated by these data where high rates were prevalent at the juvenile (22.0%) and 9 to ∞ old (26.6%) age classes while younger adults displayed rates of mortality (7.7%) below the overall average (12.4%).

Comparisons between the annual recruitment rate of 6.5% (Table 4) presented earlier and the annual mortality rate of 12.4% (Table 5) indicated a declining population of elk in GMNP. Using the 125 animal population estimate with these gain and loss figures showed an annual increase of 8 animals and a decrease of 15 animals. However, because the 12.4% loss per year figure was based on calculations from a life table with inherent biases, it could not be considered absolute. The actual observed annual mortality rate, based on 5 carcasses older than age 1 found in 1978, was 4.0%. Although carcasses were diligently sought, some elk mortalities during the year were undoubtedly overlooked and the 4.0% rate would represent a minimum figure. The difference between the observed recruitment rate and calculated mortality rate indicated that the population was in a slight decline phase. Recruitment from the young age class may not have compensated for mortality losses among older elk.

A comparison of the sex ratios of adult carcasses and ratios obtained from census methods indicated a differential mortality between bull and cow elk in GMNP. The live sex ratio averaged 44:100 between the 1976 and 1978 censuses while a 62:100 bull to cow ratio emerged among the natural mortalities collected for age analysis. Mortality among bulls was therefore higher than their occurrence in the living population, indicating a greater susceptibility of bulls to mortality factors. The vulnerability of bulls was probably due to their wandering tendencies, aggressiveness, and sexual behavior (McCullough 1969). Rates of mortality are generally accepted as higher among males of the species, resulting in a population with an unequal sex ratio. Differentially higher rates of mortality have been reported for Rocky Mountain elk bulls from northern herds (Murie 1951, Craighead et al. 1973) and for Tule elk bulls (McCullough 1969).

Predation

The mountain lion (Felis concolor) was the most proficient natural predator of elk in the Guadalupe Mountains. In GMNP lions ranged over all areas where elk or elk sign were recorded and they undoubtedly encountered elk frequently. Field examination of scats indicated that mule deer were the major food item of mountain lion in the study area, but 13.0% of the analyzed scats contained elk hair. Deer were many times more abundant than elk and therefore more available to predation, which has been generally regarded as a density dependent mechanism (Nicholson 1933, Errington 1934). Nevertheless, young elk were taken by lions in GMNP, especially during the first 6 months after birth, and appeared to be an important constituent to the lion's diet.

The annual mortality rate for mature elk was low and consequently few fresh adult carcasses were encountered where cause of death could be determined accurately. Of these, only 2 adult elk, both cows, could be positively identified as mountain lion kills. Adult elk may have been taken more frequently than the field evidence indicated in this study. In the Idaho Primitive Area, Hornocker (1970) found that lions took cows indiscriminately, younger bulls in greater proportions than they occurred in the population, and only selected against mature bulls. He recorded nearly equal numbers of elk and mule deer kills despite the fact that elk were 60.0% less abundant than deer. This discrepancy was attributed by Hornocker (1970) to a greater vulnerability of elk due to their habitat selection. Clearly it was evident that lion were capable of taking a larger number of the adult elk in GMNP than the mortality data indicated. It was impossible to estimate accurately the proportion of adult elk killed by mountain lion from data obtained in this study.

Data gathered on elk calf mortality resulting from predation were more conclusive. Eleven calves were found dead on the study area and all but 2 could be classified by type of mortality. One accidental death by drowning was recorded. Of the known calf mortalities, 64.0% were the result of mountain lion predation. All these deaths occurred before the calves were 6 months old suggesting high vulnerability of young, dependent calves. The relatively high percentage of calf kills compared to adult elk kills pointed to selection for elk calves by mountain lion. Hornocker (1970) found during 4 winters that 53.0% of all elk killed by lions were calves although they comprised only 20.0% of the elk population. He concluded that mountain lion selected for calves and that the percent kill of calves increased as

elk densities increased.

The role of black bears (Ursus americanus) in predator-prey relations with GMNP elk was unresolved in this study. Bear numbers were extremely low, although a slow increase in the population has occurred under Park Service protection. At the present population level, bears were probably an infrequent predator on calves. A calf carcass was discovered in the Dog Canyon drainage with bear scats containing hair nearby, but it was not determined if a bear made the kill or just scavenged the carcass. In sufficient numbers, black bear can inflict substantial mortality among juvenile elk (Schlegel 1976).

Human-Related Mortality

Elk in GMNP were exposed to several forms of mortality resulting from human activities in the area, both past and present. Although these mortality factors were relatively few in number, they were nonetheless important and had a continuing impact on the elk population in GMNP.

Net wire fencing posed a threat to elk of all ages in the Guadalupe Mountains. This type of fence, with 2 strands of barbed wire above, was a common peripheral fencing around the park boundary. In addition, several kilometers of internal fencing, remnants of earlier ranching operations or used currently for containment of Park Service stock, were present inside GMNP. No elk were known to have died from fence entanglement during this study. However, evidence of earlier mortalities were found along the north boundary fence near Plowman Tank. Adult elk generally did not have difficulty in crossing a net wire fence, but calves as old as 4 months were

hindered by them. Several observations were recorded where calves became temporarily entangled attempting to cross fences while following their dams.

Automobile traffic represented a potential hazard to the elk in GMNP. Since the Park Service began acquiring land in 1966, no incidents of an elk-vehicle collision have been recorded near GMNP (Reisch pers. comm.). Most of the time it appeared that elk crossed U.S. 62-180 under several bridges within the park boundary. Elk-vehicle accidents would likely remain infrequent, but may rise as new NPS roads are developed and vehicular traffic increases with increased visitor use.

Sport hunting was not permitted in GMNP, but some resident elk fell prey to this mortality factor on lands immediately adjacent to the park. Most of these animals were park inhabitants which spent a portion of the year on private or U.S. Forest Service lands that border the park. The 1971 through 1975 seasons were closed to elk hunting in the New Mexico portion of the Guadalupes and only 1 animal was taken legally between 1976 and 1978 in this area. In the Texas part of the mountain range, 20 elk have been taken since 1971 on lands surrounding GMNP (Table 6).

MULE DEER

Herd Composition and Sizes

Mule deer buck and doe Mixed Herds were common throughout the year in GMNP with the majority of these associations occurring immediately before, during, and immediately following the November breeding season (Fig. 10). Buck-doe associations waned in spring, but resumed at substantial levels in the summer. Overall, sexual segregation among mule deer was not as

TABLE 6. Permits issued and elk harvested in Texas on private lands surrounding Guadalupe Mountains National Park, Texas (from Texas Parks and Wildlife Department records).

Year	Number of Permits	Harvest		Total Kill
		Males	Females	
1971	11	0	0	0
1972	11	0	0	0
1973	9	2	2	4
1974	4	2	1	3
1975	9	5	0	5
1976	7	1	0	1
1977	4	4	0	4
1978	3	3	0	3
Total	58	17	3	20

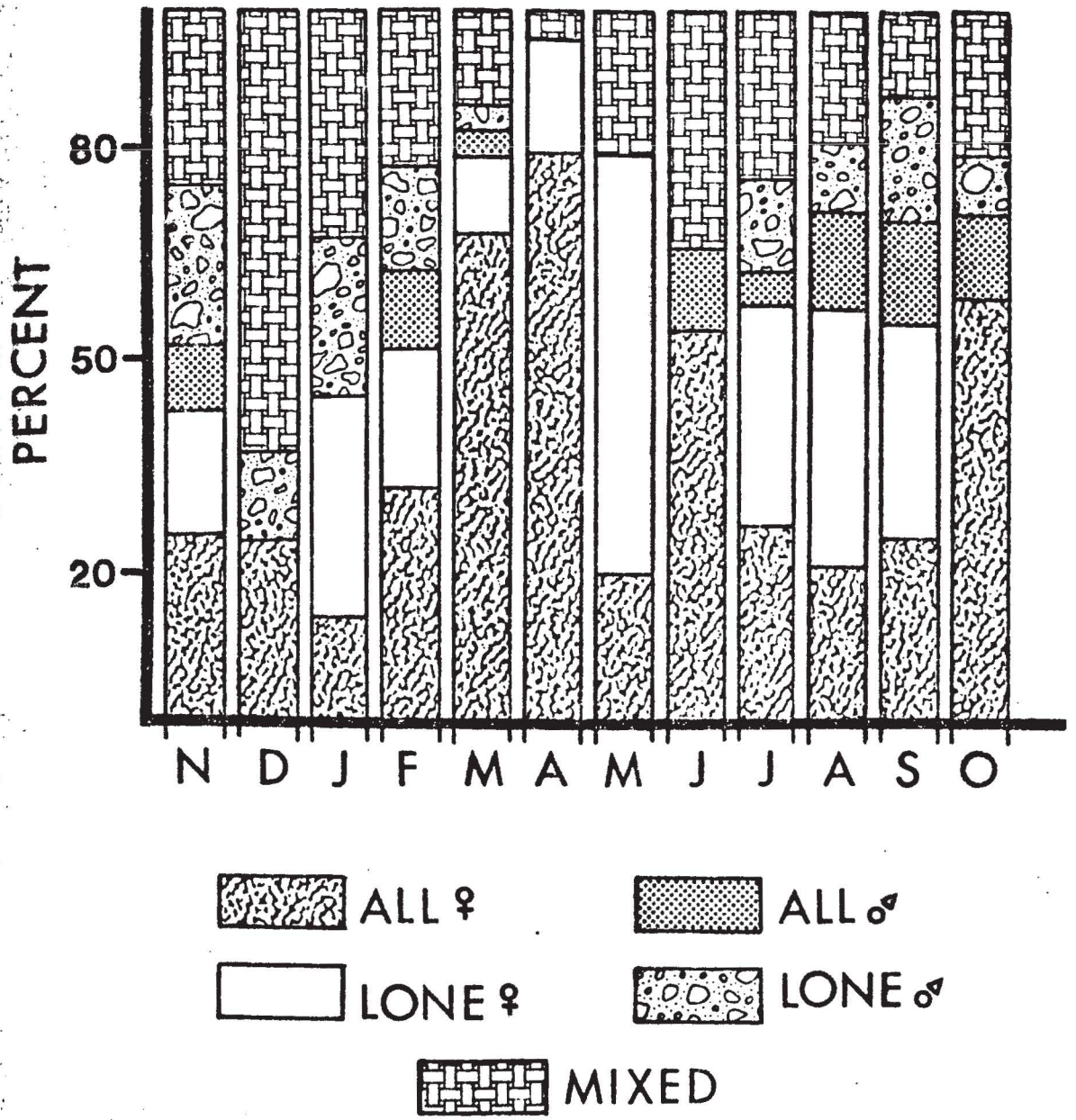


Fig. 10. Monthly percentage of herd composition of mule deer in Guadalupe Mountains National Park, Texas.

apparent or defined as with elk. There was a prevalence of Lone Males during and just after the breeding season which probably reflects sightings of sub-dominant males. High monthly percentages of Lone Female sightings which does not relect of small sample sizes (i.e., May), were concentrated around the months of July, August, and September. Fawns were born in July in the Guadalupe Mountains and the relatively high percentage of Lone Females observed at this time and the next 2 months thereafter undoubtedly reflected this reproductive behavior.

The average group size among mule deer in GMNP from June, 1977 through December, 1978 was 3.5 Group sizes remained relatively small and stable throughout the annual cycle, indicating a less gregarious social tendency in desert mule deer than was commonly observed in elk in GMNP. Lower than average monthly group sizes were observed July through September when dams and their fawns were most likely to be unassociated with other deer (Fig. 11).

Sex Ratios

A buck:doe ratio of 45.3:100 was calculated from sex and age composition data gathered from 1,356 mule deer observations collected from August, 1977 through December, 1978 in GMNP. A greater number of does in the adult population was expected among mule deer where a differentially higher natural mortality rate occurs among bucks. Other studies have shown higher ratios indicating this greater male mortality more clearly. Hornocker (1970) reported a 20:100 sex ratio over 4 years in central Idaho, while Mackie (1970) found a 4 year average ratio of 29:100 in northcentral Montana. Robinette et al. (1957b), over 14 years in central Utah, reported an average ratio of 33 bucks per 100 does. All 3 studies, however, involved hunted populations

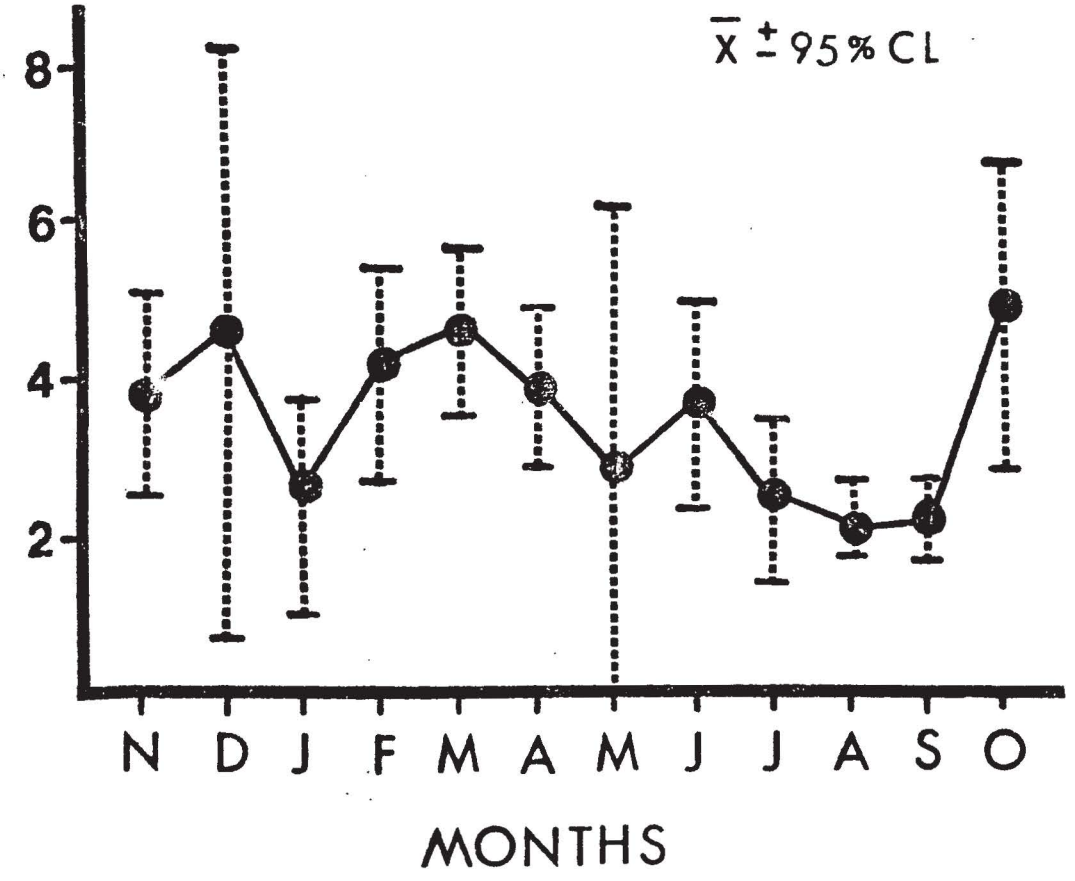


Fig. 11. Average monthly herd size for mule deer in Guadalupe Mountains National Park, Texas.

with an increased buck mortality and thus partially explained differences in ratios from those found among the unhunted GMNP population.

Age Ratios

An overall buck:doe:fawn ratio of 45.3:100:25.4 was found for 1,356 mule deer observations in GMNP during the period of August, 1977 through December, 1978, with animals calculated at less than 6 months old classified as fawns. The GMNP doe:fawn ratio was low compared to investigations in the northern states. Reports of high ratios of 100:66.2 (Mackie 1970) and 100:65.6 (Robinette et al. 1957b) are not uncommon, especially with late summer counts. Mule deer does have the capability of producing twins when nutritional planes are adequate and this often contributes to high ratios. However, lower ratios do not necessarily indicate static populations as Hornocker (1970) revealed. He found a 100:32.2 ratio in Idaho (4 year average) while deer numbers increased. His classification counts were made after early postnatal and some winter mortality had occurred. The doe:fawn ratio reported for the GMNP population also incorporated some of this mortality and thus partially explained the lower figures compared to summer counts from other areas. However, other factors were undoubtedly operative in keeping productivity low. Sightings of twin fawns during this study were very rare.

Parturition

The earliest sighting of a mule deer fawn was on 13 July 1978 and this animal was estimated to be 5-6 days old. Another young fawn thought to be 3 days old was discovered on 21 July 1978. Fawns were generally not seen until late July and did not accompany their foraging dams until middle to

late August. The birth period presumably began after the first week in July and continued through the end of the month. It was interesting to note that the birth period for mule deer corresponded to the beginning of summer precipitation, while the elk, descendants of an introduced northern subspecies, began parturition a month earlier, near the first of June.

Annual Recruitment

Recruitment to the GMNP mule deer herd was primarily from reproduction and not through immigration. Immigration was seasonal in nature, generally corresponding to hunting pressures outside the park boundary. Also, no evidence was found to suggest that a large number of resident mule deer left the park at any season.

Over 17 months and 2 parturition periods, fawns made up 14.9% of all recorded mule deer sightings. This figures provided the best estimate available for annual recruitment to the mule deer population. Fawn sightings were recorded from August, 1977 through December, 1978 and thus included observations shortly after birth as well as those later observations which occurred after most first-year mortality factors had been exerted on this segment of the population. Therefore, as nearly as possible, this 14.9% recruitment figures represents annual recruitment, although it was probably an underestimation of actual annual recruitment. One reason was the tendency for fawn classification to become difficult as the animals reached 1 year of age, the time they were considered true increments to the population. This was especially true of female fawns which reached a size close to adult does by age 1 year.

Life Table Analysis

Mule deer mortalities found in the field were aged by tooth replacement (juveniles) or tooth cementum annuli (adults) and the resultant data were used to construct a death-based life table (Deevey 1947, Caughley 1977). The 79 carcasses which compose Table 7 were all collected inside GMNP and represent natural mortality of the park's mule deer population. The assumptions surrounding this life table were equivalent to those previously outlined in the discussion of life table results for elk. In addition, the biases of aging technique and juvenile class representation were also thought to be operative here. Again, possible errors in aging would be consistent for the entire sample and would therefore not severely alter accurate interpretations.

A mule deer mortality rate (qx) curve was constructed from the life table data (Fig. 12). A relatively high mortality rate of 25.0% in the first year of life was followed by a slightly lower 15.0% rate in the yearling age category. Mortality rates dropped after the second year, then began gradually increasing until age 5, when substantial increases became evident. This configuration again followed the typical mammalian mortality rate pattern (Caughley 1966, Eberhardt 1971).

The 25.0% mortality rate in the first year age class represented a minimum figure since juvenile mortalities are commonly underrepresented (Caughley 1966). Therefore, it could be expected that more than 1 of 4 fawns would have died each year. The population weighted mean mortality rate per year, which represents the proportion of adult animals that died between successive birth periods (Caughley 1977), was calculated to be 19.8%. The greatest mortality rates among adult mule deer were in the "old" categories of age 6 though ∞ ($\bar{q}_{6,\infty} = 40.7\%$). Those animals aged 1 through

Table 7. Death based life table for mule deer from 79 natural mortalities in Guadalupe Mountains National Park, Texas (calculations follow Caughley 1977).

Age x	Frequency fx	Mortality dx	Survival lx	Mortality Rate qx	Survival Rate px
0	20	.253	1.000	.253	.747
1	9	.114	.747	.153	.847
2	3	.038	.633	.060	.940
3	7	.089	.595	.150	.850
4	5	.063	.506	.125	.875
5	8	.101	.443	.228	.772
6	5	.063	.342	.184	.816
7	11	.139	.279	.498	.502
8	7	.089	.140	.636	.364
9	2	.025	.051	.490	.510
+ 10	2	.025	.026		

MD Fig 12

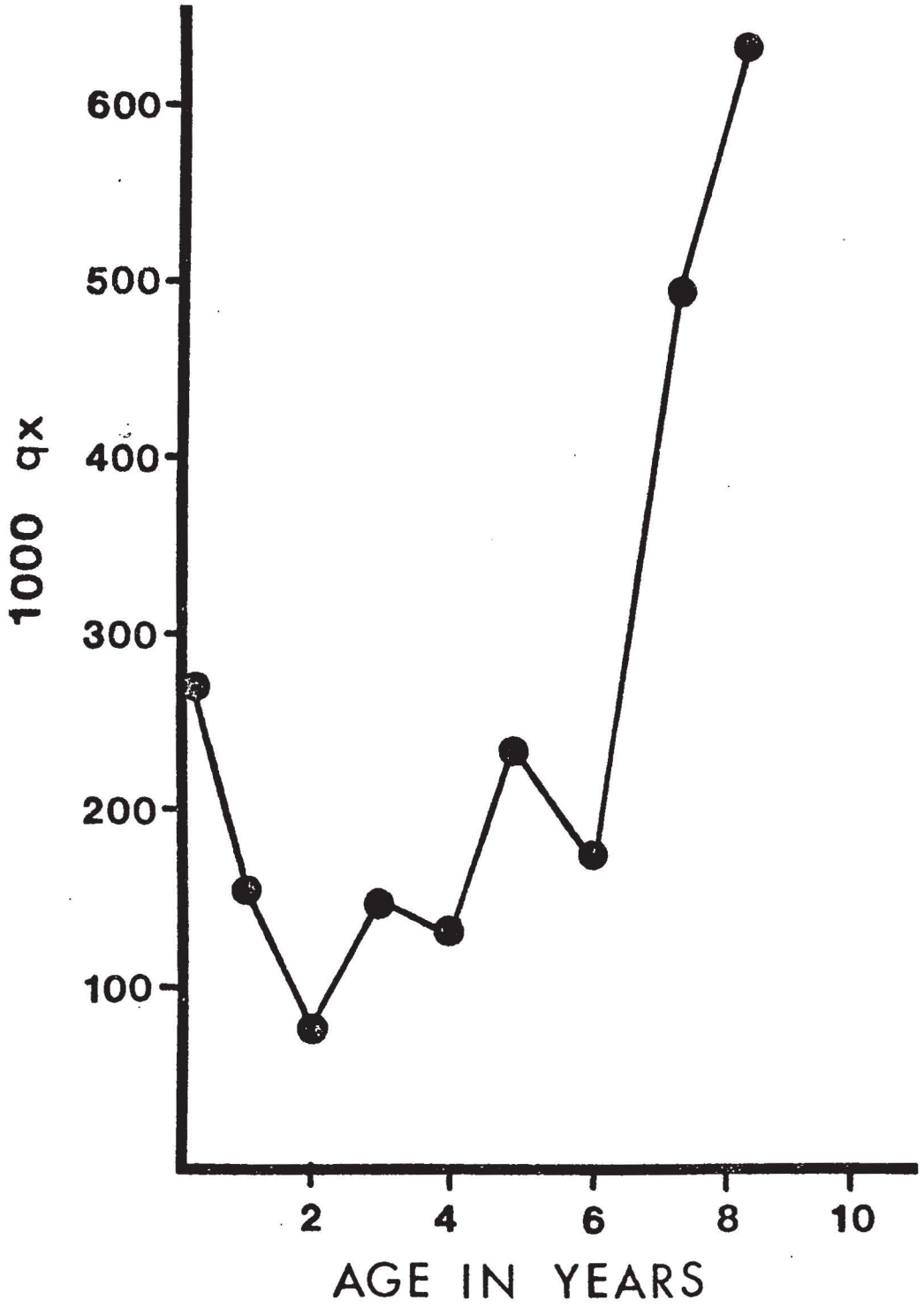


Fig. 12. Mortality rate curve (qx) for elk in Guadalupe Mountains National Park, Texas.

5 ($\bar{q}_{1,5}$) exhibited a relatively low 13.8% annual mortality rate. These values indicated that senescence began near the fifth year with most GMNP deer as mortality rates increased sharply. Few animals in the population could be expected to live beyond 9 or 10 years of age.

The estimated mean annual mortality rate for adults of 19.8% from the life table analysis, indicated that recruitment to the mule deer population must have been approximately equivalent or greater for the population to be stable or increasing. The annual recruitment rate estimated previously was 14.9% and was thought to be a minimum figure. Only a 5.0% difference existed between the annual loss of adults and the annual input of yearlings to the GMNP mule deer population. The 2 figures were too close to indicate a definite trend, given the unmeasurable variability incorporated into each estimation process. It therefore appeared safe only to tenuously project a near stable or perhaps slightly declining mule deer population.

A disparity in mortality can be expected between males and females in a population, and such a relationship was evident in the GMNP deer herd. Sex ratios at birth for most vertebrates are nearly 1:1 with a usual slight preponderance of males (Caughley 1977). Live sex ratios of adults revealed 45.5 bucks for every 100 does in the GMNP population, while the sex ratio of carcasses found in the field indicated 111 bucks for every 100 does. It was evident that adult bucks have a mortality rate about twice that for the doe segment of the population. These results were not surprising in light of buck mule deer behavior and the consequences of that behavior among large ungulates (McCullough 1969).

Predation

Predation was the primary cause of adult and juvenile mortality among mule deer in the Guadalupe Mountains. Mountain lion was considered to be the chief deer predator. Discoveries of confirmed lion kills were relatively infrequent because of carcass destruction or total consumption, however, predation on mule deer was judged to be heavy from examination of mountain lion scats. Superficial analysis revealed that 90.0% of lion scats contained some quantity of mule deer hair. Both adult and juvenile mule deer were susceptible to mountain lion predaton; Hornocker (1970) found mature bucks and fawns killed in greater proportion than their numerical availability.

Other predators in GMNP were apparently not as successful as mountain lions in taking deer. Coyote numbers were large in some areas and they were probably most successful in capturing fawns, although their impact was slight. Only 39.0% of coyote scats examined contained mule deer hair. Black bear and bobcats were capable of taking both adult deer and juveniles, but low numbers precluded their having an impact on the deer population. A golden eagle was observed attacking a fawn by a park employee; eagles were common but the magnitude of their predation on deer was most likely inconsequential.

Human-Related Mortality

As with elk, mule deer were threatened by fences around and inside the park boundary. Fences posed a greater threat to deer, however, because of their smaller stature and lowered jumping clearance. Of the mule deer carcasses evaluated for age analysis which were 1 year or older (adults), 10.0% were known to have died in a fence. Fences were an even greater threat to juvenile deer. Among the deer less than 1 year old, 30.0% were found dead

in fences. Most of these carcasses were found in fences along the New Mexico border, particularly on travel lanes to water sources.

Automobile traffic along Highway 62-180 resulted in a substantial amount of deer mortality in GMNP. Mule deer tended to feed along the highway at night and consequently most accidents occurred at that time. Automobiles are known to have accounted for 11.8% of the marked deer mortalities on the Front Side of GMNP, while the percentage of unmarked deer may have been higher.

DISCUSSION

Both ungulate species exhibited similar average group sizes (approximately 3.5 animals) throughout the year, but composition was quite different. Elk showed classical sexual segregation and aggregation in relation to breeding phenology whereas mixed deer herds were the general rule year-round.

Sex ratios were also nearly equal for both ungulates at about 455 males:100 females. The tendency for equivalence here, despite population size differences, indicated a biological inclination of both elk and mule deer towards a preponderance of females in naturally regulated populations. Age ratios for elk in GMNP were extremely low, averaging 11.0 calves for 100 cows. These represent some of the lowest ratios reported for free-ranging elk in North America. This contrasts markedly with data from the 1960's which indicated relatively high ratios for the GMNP population comparable to those reported from northern elk herds. A decline in productivity apparently began in the early 1970's and has continued through to the present. The responsible factors undoubtedly included water scarcity and vegetation conditions. The mule deer doe:fawn age ratio of 100:25.4 was also low and further substantiated the suggestion of environmental factors as causative

agents in the low productivity of both species.

As would be expected with low female:young ratios, animal recruitment for both elk and mule deer were poor at 6.5% and 14.9%, respectively. This recruitment rate for elk was only about half the mean annual mortality rate for adults, indicating a slow decline in overall population size. For deer, the recruitment and mortality rates were nearly equivalent suggesting more of a static mule deer population.

Elk lived longer (12-15 years) than did mule deer (6-9 years) in GMNP according to mortality rate curves developed from aging of specimens found dead in the field. In both species the males succumbed to mortality factors at considerably greater rates than females.

Predation was an important population regulating mechanism in both species, where regulation depended on predation equivalent to the effective birth rate (Holling 1959, Hornocker 1970). Mountain lions were the primary predators of elk calves and mule deer of all ages. Sixty-four percent of all known calf mortalities were attributed to mountain lion predation. Ninety percent of all scats examined contained deer hair. Other predators were operative, but none were as efficient as mountain lions. Predator losses restricted recruitment in both ungulate species and became more significant with elk because of their low density.

For elk, the primary human-related mortality was sport hunting outside the park, especially in Texas. Fences and automobiles were potential contributors to elk mortality. Mule deer, however, were susceptible to all 3 of these factors, especially fences and automobiles on a continuing basis.

HABITAT RELATIONSHIPS

ELK

Habitat Utilization

Utilization of the 4 major habitat types within the elk range was investigated to determine preferences using the utilization-availability technique described by Neu et al. (1974). This technique makes the assumptions that any of the habitats were available for selection by an animal and that observations were obtained randomly. All 4 habitat types were available in terms of proximity to all elk although a few bands were known to utilize only 2 or 3 types. Observations were randomly obtained as habitat data were collected from all elk encountered during monthly surveys. An important bias in the collection of these data was the relative visibility of elk in each of the 4 habitat types. The Mountain Shrub and Desert Shrub habitat types were characteristically open, whereas the Coniferous Forest and Pinyon-Juniper habitat types had taller growth forms, making sighting of elk more difficult.

The hypothesis that elk utilized each habitat type equally in proportion to its occurrence was tested by the Chi-square technique. The expected number of elk observations differed significantly from the occurrence of habitat types within the elk range, resulting in rejection of the hypothesis ($P < 0.10$).

Table 8 indicates a significant difference between the expected number of elk observations and actual occurrence in the 4 habitat types. Although 44.0% of all elk observations were in the Mountain Shrub habitat type, the expected observations exceeded the number obtained, and elk use was significantly less than hypothesized. Approximately 63.0% of the elk range in GMNP is

TABLE 8. Occurrence of elk sightings in 4 habitat types within the elk range in Guadalupe Mountains National Park, Texas (after Neu et al. 1974).

Habitat Type	Total Area (km^2)	Proportion of Total Area	Number Observed	Expected Number Observed	Proportion Observed in Each Area	Confidence interval on Proportion of Occurrence (90% family confidence coefficient)
Mountain Shrub	87.13	.627	252	357	.433	$.386 \leq p_1 \leq .479$
Coniferous Forest	30.31	.218	185	124	.325	$.281 \leq p_2 \leq .369$
Desert Shrub	11.04	.079	14	45	.025	$.010 \leq p_3 \leq .037$
Pinyon-Juniper	10.38	.075	118	43	.207	$.169 \leq p_4 \leq .245$
TOTAL	138.91		569	569		

comprised of the Mountain Shrub habitat type. The Desert Shrub habitat type was also utilized less than expected. This type was the most xeric of the 4 habitats and was least selected by elk.

Both the Coniferous Forest and Pinyon-Juniper habitat types were found to be preferred habitat for elk in all seasons. The actual number of elk observations was above the expected values despite the decreased visibility in these types. This may indicate an even greater preference for these types than Table 8 exhibits, depending on the degree of bias in animal visibility relative to cover.

A Chi-square test of independence on seasonal data in Table 9 showed that elk distributions in the 4 habitat types changed significantly over 3 seasons ($P < 0.10$). These data were calculated in Table 10 to determine preference or avoidance of habitat types by season. During winter, the Coniferous Forest and Pinyon-Juniper habitat types, both of which offered more cover than did the other 2 habitats, were preferred, while the Mountain and Desert Shrub habitat types were utilized less than their proportion of occurrence inside the elk range. However, some of the winter observations may have represented residual animals from elk concentrations in the former 2 habitat types during the fall breeding season.

During the Spring-summer, habitat selection by elk changed (Table 10). The Coniferous Forest habitat type was utilized less than expected while elk use of the Mountain Shrub habitat type increased beyond the proportion of its occurrence in the elk range. Elk continued to select against the Desert Shrub habitat type whereas Pinyon-Juniper habitat type was again a preferred habitat type. The largest area of contiguous Coniferous Forest

TABLE 9. Seasonal distribution of elk sightings in relation to 4 habitat types within the elk range in Guadalupe Mountains National Park, Texas.

Seasons	Number of Individuals				TOTAL
	Mountain Shrub	Coniferous Forest	Desert Shrub	Pinyon-Juniper	
Winter (Nov. - Feb.)	25	72	0	36	133
Spring-Summer (Mar. - June)	97	21	3	15	136
Summer-Fall (July - Oct.)	130	92	11	67	300
TOTAL	252	185	14	118	569

TABLE 10. Seasonal occurrence of elk sightings in 4 habitat types within the elk range in Guadalupe Mountains National Park, Texas (after Neu et al. 1974).

Habitat Type	Total Area (km^2)	Proportion of Total Area	Number Observed	Expected Number Observed	Properties Observed in Each Area	Confidence Interval on Proportion of occurrence (90% family confidence coefficient)
			Winter			
Mountain Shrub	87.18	.627	25	83	.188	$.112 \leq p_1 \leq .264$
Coniferous Forest	30.31	.218	72	29	.541	$.444 \leq p_2 \leq .638$
Desert Shrub	11.04	.079	0	11	.000	$.000 \leq p_3 \leq 0.00$
Pinyon-Juniper	10.38	.075	36	10	.271	$.131 \leq p_4 \leq .357$
			Spring-summer			
Mountain Shrub	87.18	.627	97	85	.713	$.626 \leq p_1 \leq .799$
Coniferous Forest	30.11	.218	21	30	.154	$.085 \leq p_2 \leq .223$
Desert Shrub	11.04	.079	3	11	.022	$.000 \leq p_3 \leq .050$
Pinyon-Juniper	10.38	.075	15	10	.110	$.049 \leq p_4 \leq .170$
			Summer-fall			
Mountain Shrub	87.18	.627	130	188	.433	$.369 \leq p_1 \leq .497$
Coniferous Forest	30.31	.218	92	65	.307	$.247 \leq p_2 \leq .366$
Desert Shrub	11.04	.079	11	24	.037	$.012 \leq p_3 \leq .061$
Pinyon-Juniper	10.38	.075	67	24	.223	$.169 \leq p_4 \leq .277$

habitat type was located in The Bowl region where the Bowl Tank was the primary water source for animals inhabiting the area. Permanent occupation of the upper elevation Coniferous Forest would be difficult during this season of water scarcity. The shift of preference in Spring-summer to Mountain Shrub habitat type may have been partially due to water availability. Permanent water points at Dog Canyon Spring and Plowman Tank where elk were distributed during the spring, were located inside extensive areas of the Mountain Shrub habitat type.

During the Summer-fall season, Coniferous Forest and Pinyon-Juniper were again the habitat types preferred by elk in GMNP. Elk could reoccupy the upper elevations, where the Coniferous Forest habitat type predominated, during this season when much of the annual precipitation had occurred and temporary tanks were filled. The Bowl Tank and Cox Tank, located in the Coniferous Forest and Pinyon-Juniper habitat types, respectively, were important congregation points during the rut, and consequently these 2 types received increased use in the Summer-fall season.

To summarize, during Summer-fall and Winter the Coniferous Forest and Pinyon-Juniper habitat types were preferred habitats while the Desert Shrub and Mountain Shrub habitat types were used proportionally less than their availability. During Spring-summer the Mountain Shrub habitat type became a preferred habitat along with Pinyon-Juniper. The Pinyon-Juniper habitat type was preferred during all seasons despite the relatively poor range condition characteristic of this type in GMNP. Therefore, it appeared that cover served an important role in habitat type selection since the more

densely covered types were preferred on a year-round basis. The availability and distribution of temporary water sources also appeared to be a significant determinant of habitat type selection by elk in GMNP.

Water Relations

Sightings of elk cows and bulls were closely associated with available surface water and steadily decreased as distance from water increased (Fig. 13). Sixty percent of all sightings of bull and cow elk occurred within 1.6 km of a surface water source. Bulls were sighted at greater distances from water more frequently than cows; 16.0% of all bull sightings were at distances greater than 4.8 km compared to only 5.0% of the cow sightings. No cow sightings were obtained greater than 6.4 km from surface water. A small percentage of bulls were seen between 6.4 km and 8.0 km from water and none were sighted beyond 8.0 km.

The seasonal differences in elk sightings related to distance from surface water were evaluated (Fig. 14). Elk were sighted at greater distances from water during the Winter in GMNP, implying a decreased water dependence during these coldest 4 months. Over half the elk sightings (55.0%) were greater than 3.2 km from a water source during November through February. Some elk water requirements were undoubtedly satisfied by eating snow when it was available and this would tend to liberate elk from surface water dependencies.

In constrast to the Winter season, there was a marked increase in the association between elk and water sources during the Spring-summer which included the 3 driest months of the year in the Guadaulpe Mountains (March,

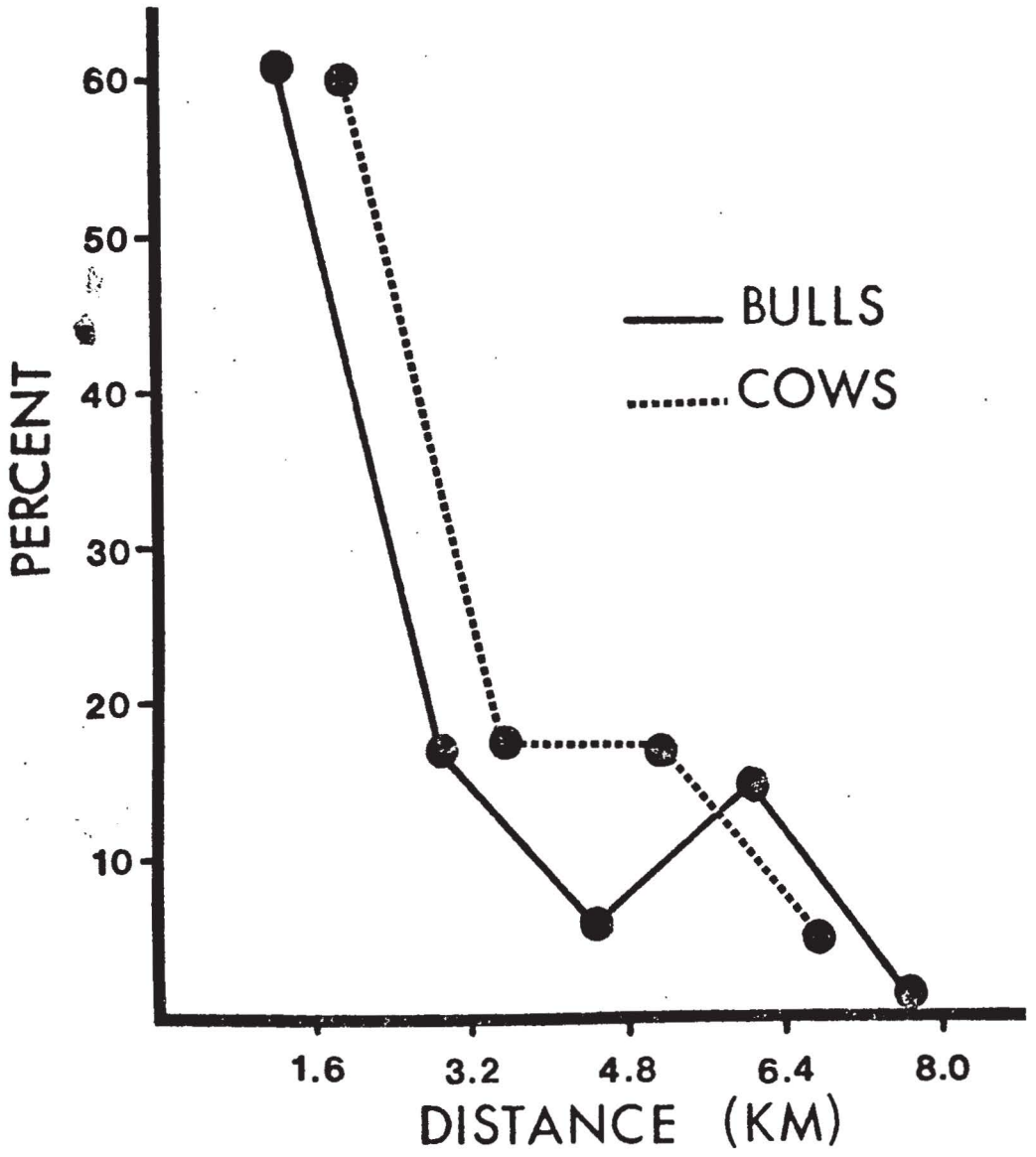


Fig. 13. Relative distances of bull and cow elk observations from known surface water as a percent of total sightings in Guadalupe Mountains National Park, Texas.

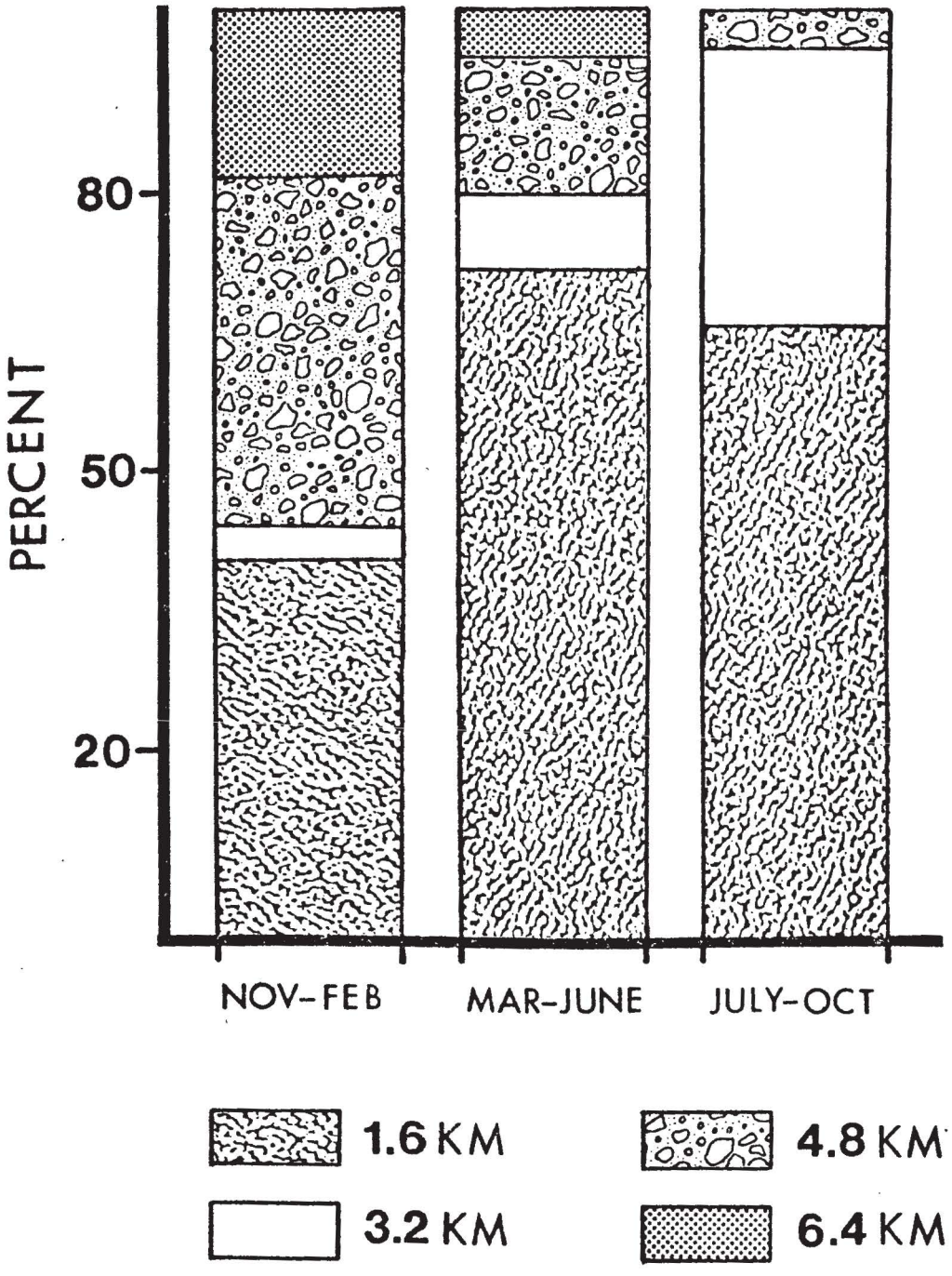


Fig. 14. Relative distances of elk observations from known surface water by season in Guadalupe Mountains National Park, Texas.

April, May). During Spring-summer 72.0% of elk sightings were within 1.6 km of a surface water source, while only 20.0% were greater than 3.2 km from water. Temporary water points were usually dry during this season (Fig. 15), and elk relied on the few permanent sources for their water requirements. These data indicate a concentration of elk near permanent water in the Spring-summer with decreased distributions in areas over 3.2 km from the nearest surface water source.

Elk ties to permanent water sources were eased during the Summer-fall season with the arrival of the rains. A reoccupation of areas abandoned due to lack of water could be expected as a response to population pressure around the limited permanent water sources during the dry Spring-summer season. This dispersal occurred where temporary water sources became increasingly important as watering points for elk during this season (Fig. 15). Data in Figure 14 indicated there was still a close association with water during the Summer-fall season despite the increased availability of water. This was due in part to a shift in elk utilization from permanent sources to temporary water sources such as Cox Tank and the Bowl Tank. In addition, the rutting activities of elk in GMNP concentrated around sources of water.

Beginning in early September, adult males were seen most often near water points where they were frequently recorded in wallowing behavior. This behavior has been suggested to serve as a form of temperature regulation among sexually active males (Murie 1951). Later in the rut, water points were important gathering places for elk breeding activities, which behaviors undoubtedly influence the close elk-water associations observed during the

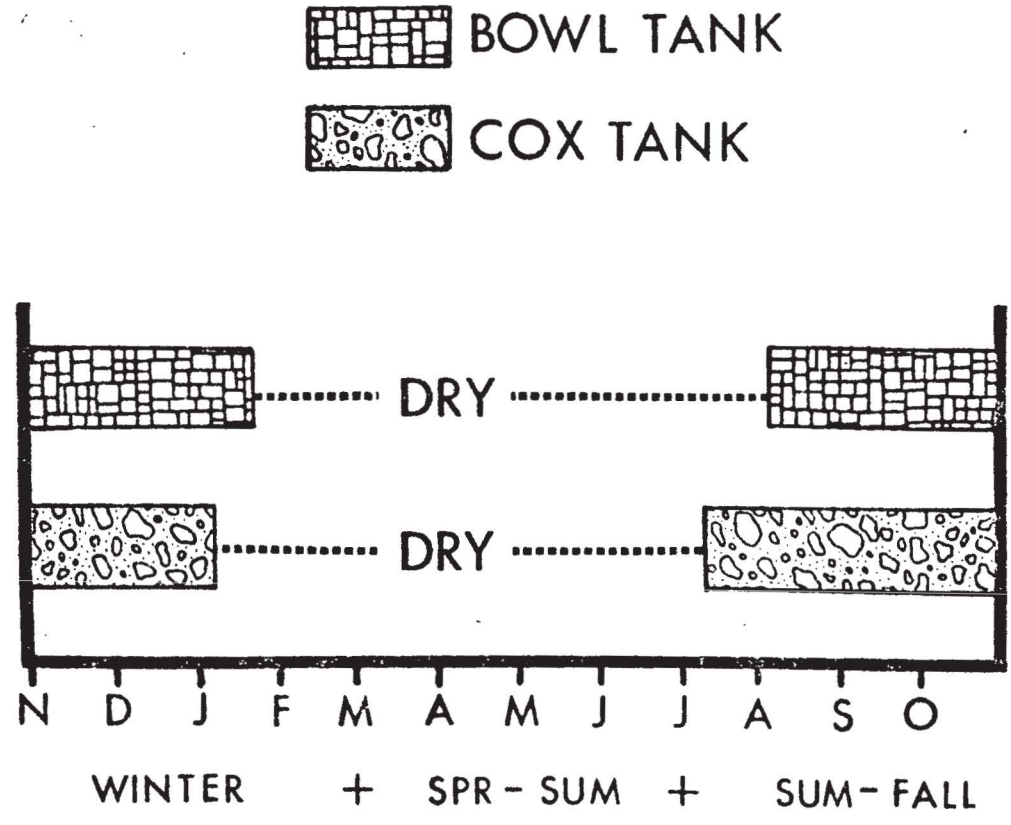


Fig. 15. Monthly water availability of the 2 most important temporary tanks during 1978 in Guadalupe Mountains National Park, Texas. Bars over the months indicate when water was available.

Summer-fall season. In the 1977 breeding season there was a dense concentration of elk around the Bowl Tank area. At least 50.8 cm of precipitation was recorded at the Bowl Tank during September, 1978. An unusually wet season allowed elk to disperse throughout the upper ranges where water was available in ephemeral drainage pools. Breeding activities were more pronounced around Cox Tank during the 1978 rut than in 1977, although the concentrations were not as great as were recorded at the Bowl Tank in 1977. Thus, the degree to which any particular water source was an important gathering place for elk breeding behavior could be dependent on water availability elsewhere in suitable habitat.

To investigate elk-water association on a daily basis, radio collared elk cows #2 and #3 from the Dog Canyon drainage were intensively monitored for 25 days in April and May, 1978. Both marked animals ranged together during this period with 10 other cows and a 10-month-old calf. These data, therefore, applied to the entire Dog Canyon band of 13 animals. The 11 April through 5 May monitoring period fell within the Spring-summer season when the Dog Canyon elk band ranged mostly within the park boundaries. Spring-summer was the driest season in the Guadalupe Mountains and no precipitation occurred during monitoring until 1 and 2 May when a total of 1.4 cm was recorded. Dog Canyon Spring and Dog Canyon Ranger Station were the only in-park water sources available to the band.

Ninety-one percent of the sightings obtained during the 25-day period were within 0.8 km of one of the 2 above mentioned water sources. No sightings were obtained beyond 1.6 km from water. Movements were distributed in a linear arrangement within Dog Canyon and appeared to be closely associated with the 2 water sources which lie approximately 1.6 km apart (Fig. 16).

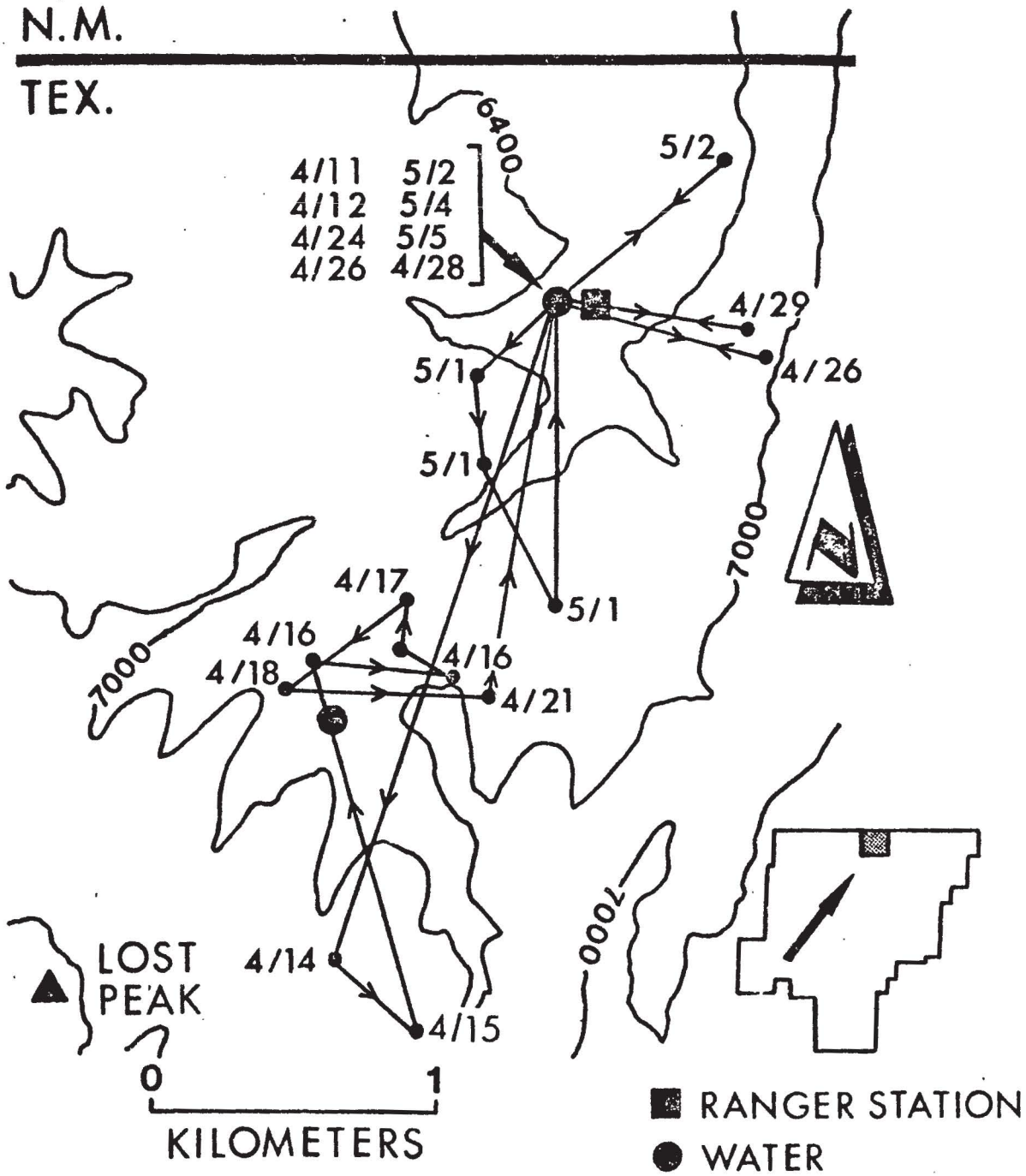


Fig. 16. Daily movements of marked cow elk #2 and #3 and their herd from April 11 to May 5, 1978 in Dog Canyon Drainage, Guadalupe Mountains National Park, Texas.

The band watered primarily at night but also during the late evening and early morning hours. No instances of water use was recorded during full daylight. Nine of the 15 observations of elk drinking at the water sources were recorded within 24 hours of the previous watering record. Elk drank every other day 3 times and every third day on 2 occasions. Once the band went approximately 96 hours without visiting a watering point. It should be noted that 1.4 cm of precipitation fell during this latter timed interval.

Elk distributions and watering schedules during the driest season of the year indicated close physical ties to available surface water. Elk in the Guadalupe Mountains watered approximately every other day during the dry months of the year, which precluded extensive ranges and therefore concentrated animals near water. Elk were observed drinking less frequently during the Winter months. The movement of the Dog Canyon elk band outside the park during Winter precluded observations of this group's water use habits, but recognizable bands from other areas indicated a schedule of approximately 96 hours (4 days) between waterings during the cold months. The availability of snow could undoubtedly extend the interval between successive waterings during winter.

Movements and Home Range

Home ranges of 5 elk cows from 3 parts of the elk range in GMNP were calculated following the minimum home range method described by Mohr (1947) and used for elk by Craighead et al. (1973). Cow elk D, ranging in the West Dog Canyon and Blue Ridge drainages, and cow elk O, along the southwest

escarpment, were both identifiable by distinctive physical characteristics. Collared elk #1 was captured and tagged at the Bowl Tank, while collared cows #2 and #3 were both instrumented near the Dog Canyon Ranger Station.

Dog Canyon

Radio instrumented cows #2 and #3 provided home range data for the Dog Canyon area. Both animals were a band of 12 to 15 cows which occupied the Dog Canyon drainage from above Dog Canyon Spring to 5.64 km north of the park, in New Mexico. Interchange with areas outside this drainage was negligible.

Annual home ranges for cows #2 and #3 were almost identical substantiating the consistency with which they were seen together. Annual ranges of cows #2 and #3 measured 19.12 km^2 (1912 ha) and 18.9 km^2 (1890 ha), respectively (Table 11). Approximately 41.0% of the land area of both minimum annual home ranges fell within the park boundary. The remainder spanned private, Bureau of Land Management, and state controlled lands north of GMNP in New Mexico.

Seasonal ranges for the 2 collared cows were again similar in size and shape (Figs. 17, 18). Winter ranges for cows #2 and #3 were distributed predominantely in the New Mexico portion of the Dog Canyon drainage and encompassed 8.74 km^2 (874 ha) and 8.09 km^2 (809 ha) respectively (Table 11). Eighty-eight percent of the winter range area for cow #2 and 94.0% for cow #3 fell outside the park boundary. Water was unavailable during most of this season at Dog Canyon Spring due to freezing temperatures in this narrow canyon during the winter and this could have influenced winter distributions of these cows and their band. Research access on to the private land where

TABLE 11. Dates with number of observations and minimum home range estimates of 5 radiocollared or recognizable elk from Guadalupe Mountains National Park, Texas. (Seasonal ranges are included for radiocollared elk #2 and #3.)

Animal	Dates of Observations	Number of Observations	Minimum Home Range Estimate		Seasonal Ranges km^2 (ha)		
			km^2	ha	Winter	Spring-summer	Summer-fall
♀ 1	10/77-10/78	7	12.79	1279	--	--	--
♀ 2	11/77-12/78	59	19.12	1912	8.74 (874)	6.52 (652)	11.96 (1196)
♀ 3	1/78-12/78	55	18.90	1890	8.08 (809)	7.24 (724)	11.96 (1196)
♀ D	7/76,11/77-11/78	13	21.68	2168	--	--	--
♀ O	8/76,9/77-12-78	27	10.59	1059	--	--	--

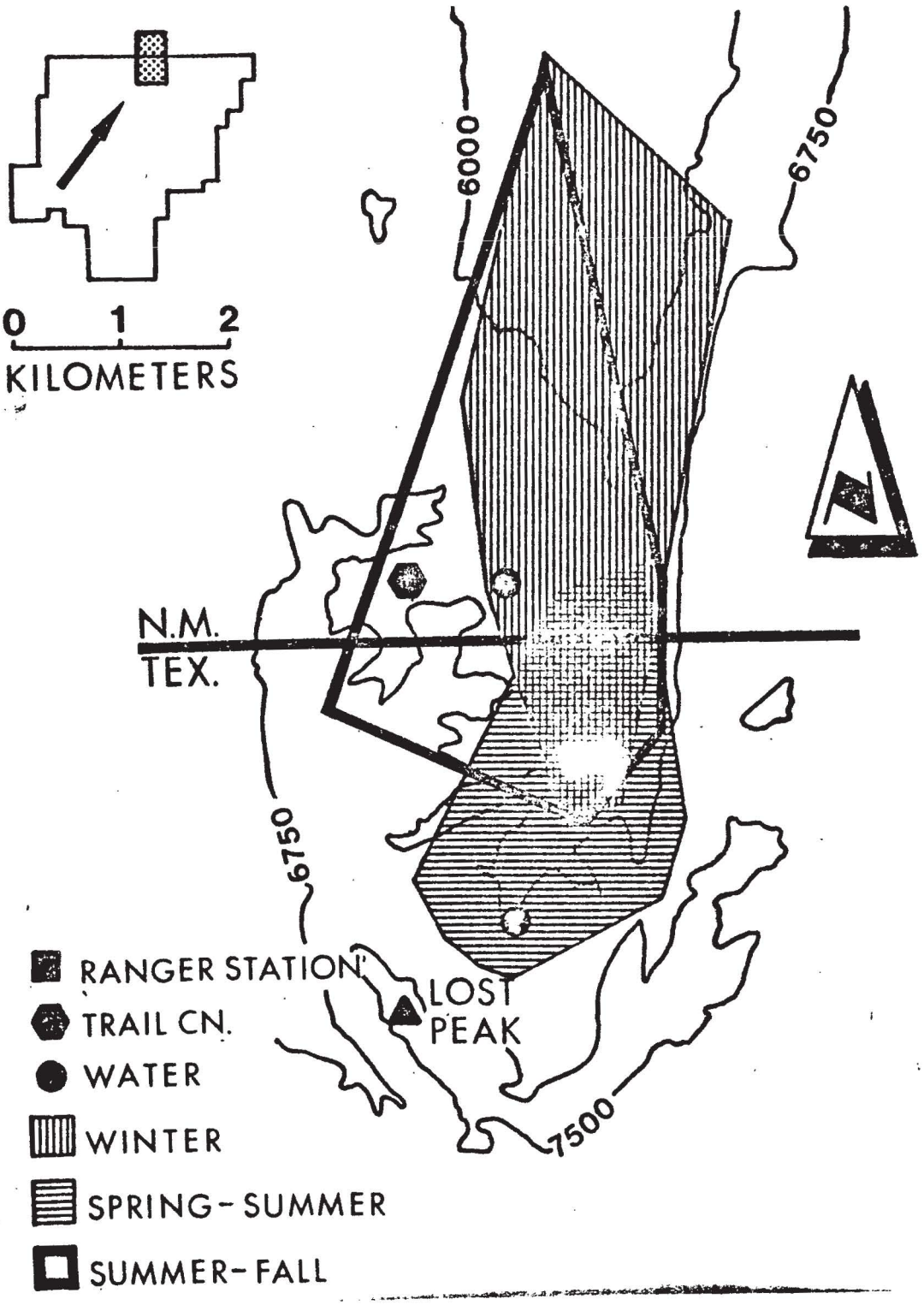


Fig. 17. Seasonal home ranges of adult cow #2 in the Dog Canyon Drainage, Guadalupe Mountains National Park, Texas.

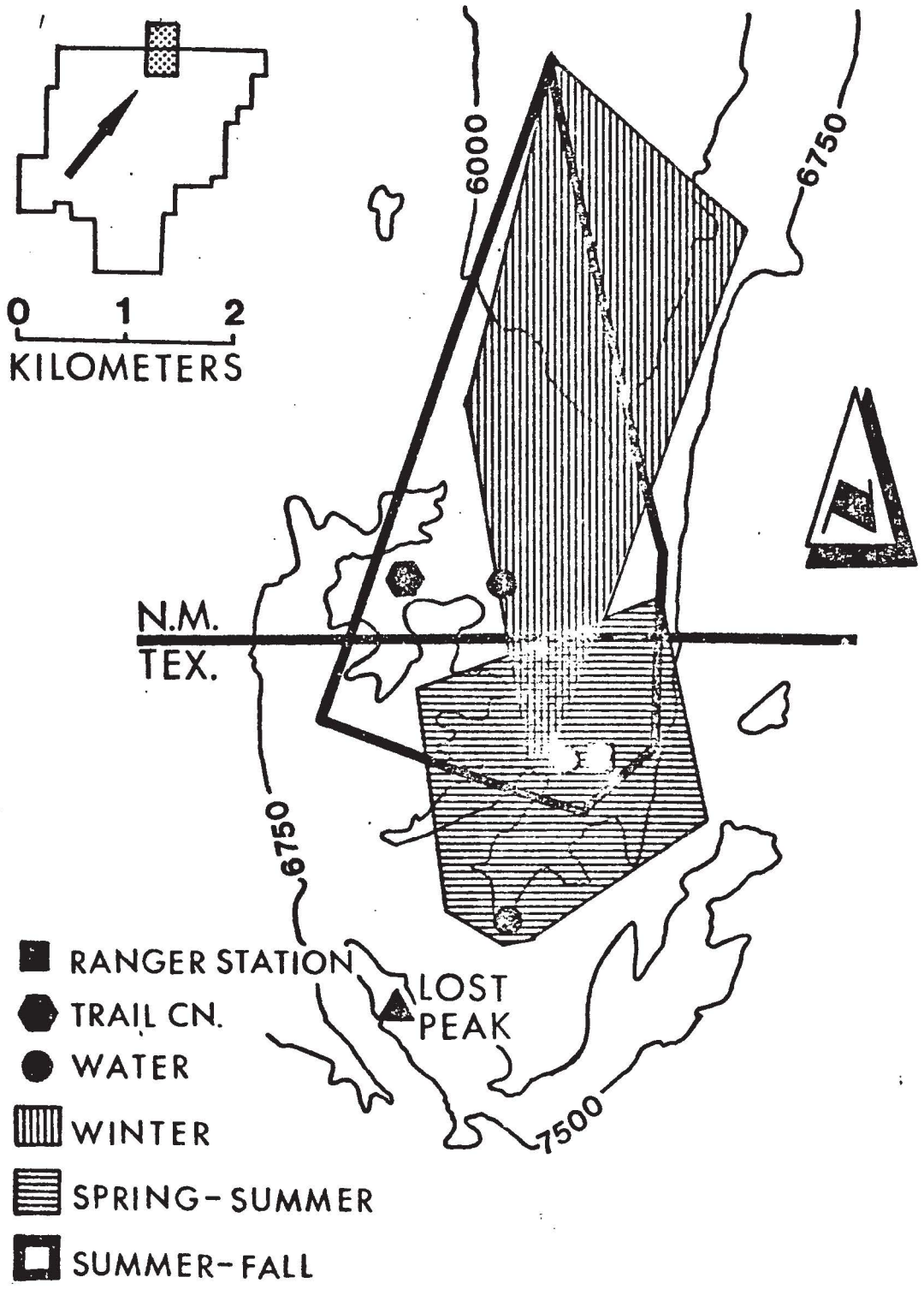


Fig. 18. Seasonal home ranges of adult cow #3 in the Dog Canyon Drainage, Guadalupe Mountains National Park, Texas.

the Dog Canyon band ranged in winter was restricted, and this precluded attempts at defining those factors that could have been attractive to elk. The 5.64 km winter movement of the Dog Canyon band into New Mexico recorded in 1977 and 1978 was consistent with winter movement patterns of previous years (M. Hughes, pers. comm.).

During November, 1978 the Dog Canyon band remained on the Hughes Ranch during New Mexico's stratified mule deer hunt. Disturbances from increased vehicular traffic and firearms discharge apparently, did not intimidate the elk enough to cause their return to sanctuary in the park. Thus the benefits obtained from ranging into the New Mexico portion of the Dog Canyon drainage during winter apparently outweighed the disturbance by hunters, increased vehicular traffic and the presence of domestic livestock in that area.

The Spring-summer (March-June) ranges of both cows were predominantly (87.0%) within the GMNP in Upper Dog Canyon (Figs. 17, 18), with range sizes for cows #2 and #3, respectively of 6.52 km^2 (652 ha) and 7.24 km^2 (724 ha) (Table 11).

During the Winter and Summer-fall seasons the home ranges inside the park boundary were all within the Mountain Shrub habitat type. During the Spring-summer season, however, elk moved farther up Dog Canyon and spent much of their time in the Dog Canyon Spring area where portions of the Coniferous Forest habitat type occur. The habitat components of each cow's Spring-summer ranges inside the park were measured. Approximately 1.22 km^2 (122 ha) of the Spring-summer ranges for both cows fell within this Coniferous Forest type (18.0%), while the remaining 5.50 km^2 (550 ha) consisted of the Mountain Shrub habitat type (82.0%).

March, April and May were the driest months in the Trans-Pecos region of Texas (Hanks and Dick-Peddie 1974) and this may have influence on seasonal range size and shape. Most sightings within the Spring-summer season in Dog Canyon were clustered within 0.8 km of 1 of the 2 permanent water sources. Parturition occurred in early June, and the water requirements of lactating cows probably increased during this season. This, coupled with the restricted mobility of young calves, may have contribued to the smaller Spring-summer ranges recorded in the study. Also, a smaller seasonal range theoretically indicated that resources during that season were more abundant and a smaller area was adequate to support the individual or group.

The onset of the calving season probably triggered movement back into the park where disturbance was less than on ranch lands to the north. Spring green-up of succulent forbs also could have influenced reoccupation of Upper Dog Canyon during March through June in the face of competition with domestic livestock in New Mexico.

All the peripheral sightings used in construction of the Summer-fall range included both marked cows and consequently their ranges were identical. This seasonal range measured 11.96 km^2 (1196 ha) in size (Table 11), of which 3.16 km^2 (316 ha) occurred within the park boundary (26.4%). The Summer-fall range of cows #2 and #3 showed features from each of the other seasonal ranges. Analysis of Summer-fall observations indicated the Dog Canyon band were mostly distributed within 1.6 km of the park boundary from Trail Canyon east to the Dog Canyon drainage bottom. All but 3 of the sightings in this season were clustered on either side of the park boundary near the Dog Canyon Ranger Station water source and Trail Canyon Tank in New Mexico (Figs. 17, 18).

Frijole Area

A missing left ear identified cow 0 from the approximately 18 other elk which utilized this portion of the elk range. A home range was constructed from sight locations of cow 0 along the southeast escarpment in the Frijole area of GMNP. She was first sighted in August, 1976 during the preliminary survey and provided home range information beginning in September, 1977 for the remaining 18 months of the study (Table 11). Her home range extended from Rader Ridge to outside the park boundary 4.8 km to the southwest (Fig. 19). The Frijole Ranger Station was the approximate midpoint of her range covering 10.59 km^2 (1059 ha). Cow 0 ranged north of Highway 62-180 most of the time, but was sighted on the south side occasionally.

The entire range of cow 0 within the park was in the Mountain Shrub habitat type which was dominate between 1585 m and 2377 m. Pockets of the Desert Shrub type occurred within this region, however, the minimum home range delimitation failed to include this type, although it was undoubtedly utilized by cow 0. The Mountain Shrub type in this area of GMNP was interspersed with tall overstory vegetation in canyon bottoms and near springs which provided escape and lounging cover. This type of cover was especially important in providing shade for temperature regulation during the summer heat. Permanent water was available along the southeast escarpment at 5 locations clustered within a 2.05 km^2 (205 ha) area of the home range of cow 0 (Fig. 19). Seventy-three percent of the sightings for this animal were 0.8 km from the nearest water source. The 10.59 km^2 (1059 ha) annual home range displayed by this animal was smaller than the other home ranges documented in this study and may reflect that abundant water and nutritional, spatial, and cover requirements are all available

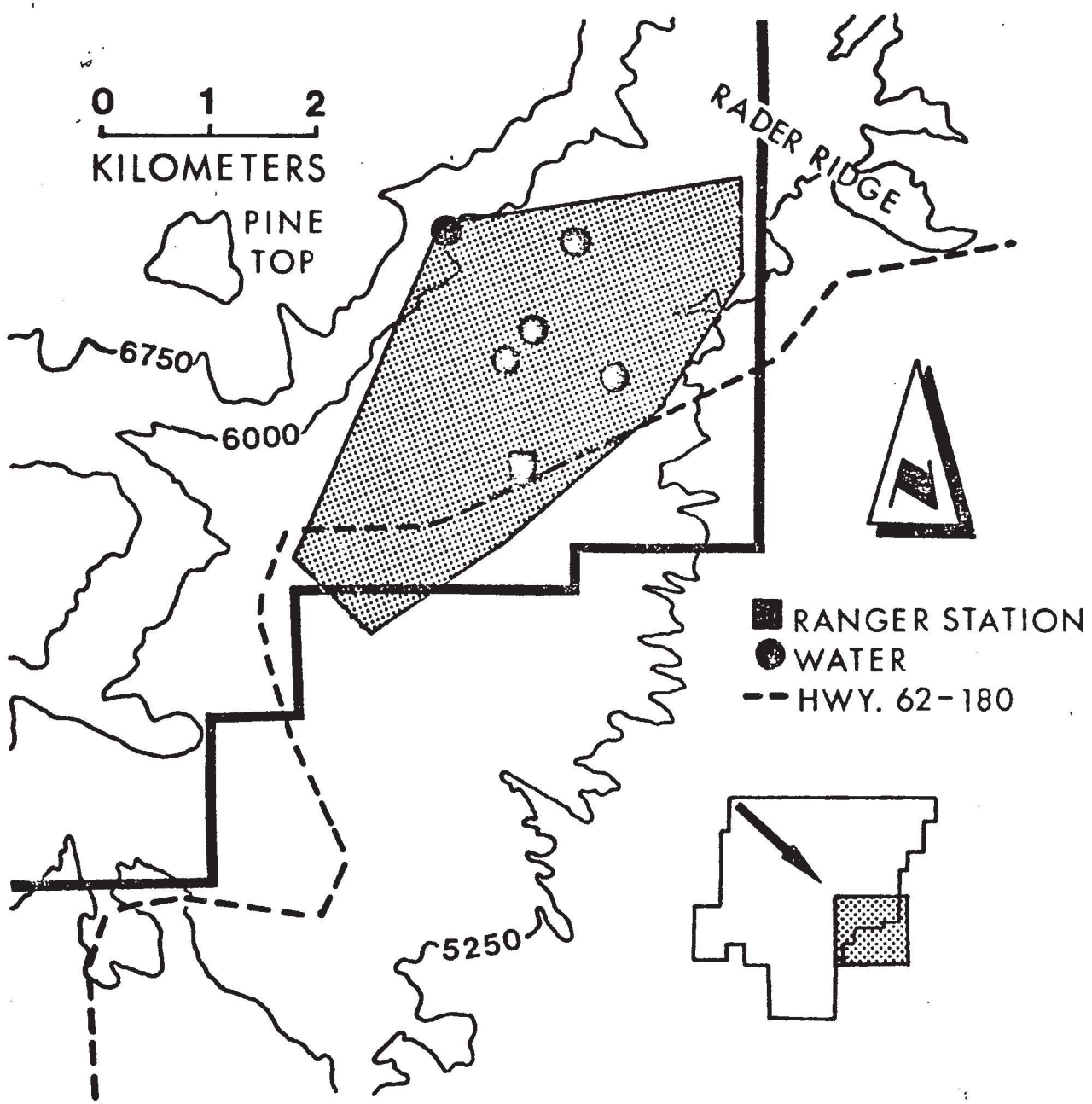


Fig. 19. Annual home range of adult cow O, southeast escarpment, Guadalupe Mountains National Park. Texas.

within a relatively small area in this part of GMNP.

Although seasonal ranges for cow O were not plotted separately, it is apparent from observation dates that those ranges would have been similar to her annual home range. No seasonal clustering of observations in a particular part of her home range were evident. Some of the Frijole elk band (which may have included cow O) ranged south of Highway 62-180 during the Winter season (Nov. - Feb.) and reports were received of elk or elk sign 4.8 km south of the Ranger Station on private lands during both the 1977 and 1978 Winters. The Frijole band was not restricted to the area included in the home range of cow O, although this group was found most frequently in this vicinity.

West Dog Canyon, Blue Ridge, and Bowl Drainages

Radio collared cow elk #1, captured in October, 1977, was monitored for only a short time before her transmitter malfunctioned in early 1978. Subsequent visual sightings were recorded and used in home range construction until the collar package fell off in late summer or fall of 1978.

Cow #1's home range, presented in Fig. 20 encompassed 12.79 km^2 (1279 ha) in a linear arrangement. Dotted lines were used to project the boundaries of her home range to include Plowman Tank in New Mexico. Although never sighted at Plowman Tank, cow #1 undoubtedly drank there when surface water was unavailable at the West Dog Canyon tanks or the Bowl Tank during dry periods of the year. This projection extended her home range size to 17.16 km^2 (1716 ha).

Fig. 20

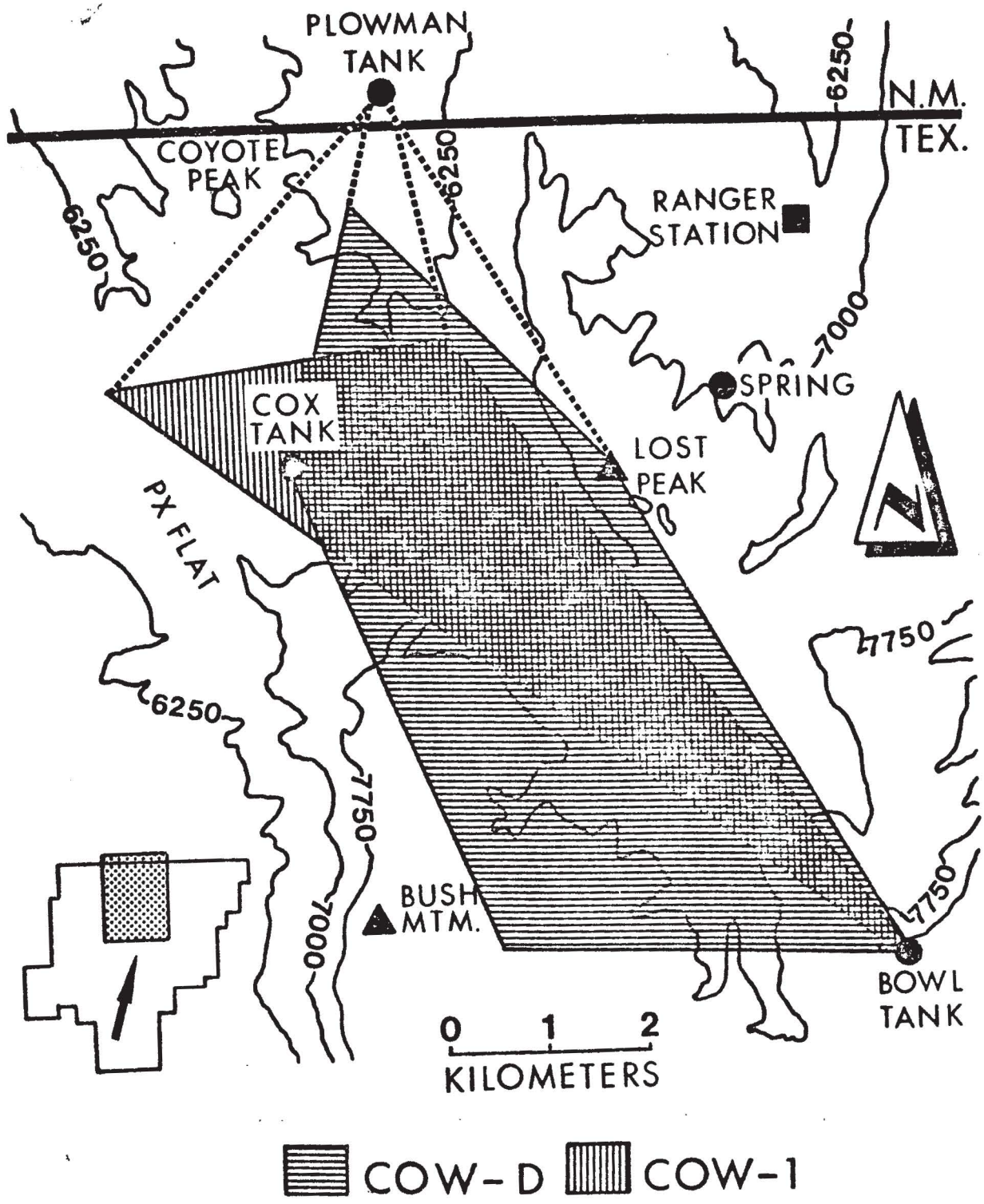


Fig. 20. Annual home ranges of adult cow D, and adult cow 1, West Dog Canyon, Blue Ridge, and Bowl drainages, Guadalupe Mountains National Park, Texas.

The major habitat component of her documented home range was the Mountain Shrub type which comprised 48.8% of the area. The Pinyon-Juniper type covered 32.2% of her range and the remaining 19.0% consisted of the Coniferous Forest type. The longest segment of her range extended 9.66 km from northern PX Flat to the Bowl Tank.

Cow D, identifiable from a hanging left ear, was first sighted during the initial elk survey in GMNP in July, 1976 and provided home range data for 12 months during the intensive study beginning in November, 1977. Her home range, measuring 21.68 km^2 (2168 ha), spanned the West Dog Canyon and Blue Ridge drainages in a northwest to southeast direction (Fig. 20). The longest portion of the home range for cow D measured 9.26 km, from the Bowl Tank to West Dog Canyon approximately 1.21 km south of Plowman Tank. Elevations varied from 1865 m in West Dog Canyon to approximately 2548 m in the southern portion of her range.

The Mountain Shrub habitat type comprised 47.5% of the home range for cow D followed by Coniferous Forest and Pinyon-Juniper types at 29.7% and 22.8%, respectively. Two major temporary water sources, Cox Tank and the Bowl Tank, were contained inside this home range (Fig. 20); when these water points were dry, she undoubtedly utilized nearby Plowman Tank as a permanent source. While no sightings were obtained of this cow watering at Plowman Tank, her range extended to within 1.21 km of it and included a much used travel lane in the floor of West Dog Canyon which led to the New Mexico water source. Water was unavailable in West Dog Canyon inside the park boundary when cow D was sighted at the northern extention of her home range near Plowman Tank. The Dog Canyon Spring was located 1.41 km east of the eastern periphery of her range and may have been utilized as a water source.

However, it did not appear that it played as important a role for elk in the juxtaposition of water in the West Dog Canyon-Blue Ridge drainages as did Plowman Tank. A steep escarpment between West Dog Canyon and Dog Canyon precluded easy access to the Dog Canyon Spring.

Home ranges of cows #1 and D and supportive evidence from observations of unmarked elk movements and distributions indicated the existence of a rectangular shaped movement corridor between the West Dog Canyon, Blue Ridge, and Bowl drainages. This overall area extended from approximately 2.41 km inside New Mexico, between the eastern and western escarpments of West Dog Canyon, south through the Bartlett and Shumard Peaks area, east to the drainages beyond The Bowl which feed South McKittrick Canyon (See Fig. 3). At least half the elk population in GMNP were resident in this 77.72 km^2 (7772 ha) area and occupied it according to water availability and seasonal needs. Elevation ranged from 1829 m in the north to over 2591 m in the southwestern corner of this corridor.

Habitat within this movement corridor was characterized by a predominance of the Mountain Shrub type and to a lesser extent, the Pinyon-Juniper type below 2073 m. These 2 types, along with the Coniferous Forest type, were interspersed throughout the range above this elevation. The Coniferous Forest was the most abundant habitat type in the southeastern portion of the corridor, in the region of The Bowl.

Permanent water within the corridor was found only at a series of springs at the bottom of the South McKittrick drainage, at the Dog Canyon Spring, and at Plowman Tank in New Mexico. Both the South McKittrick and Dog Canyon Springs were thought to be utilized by only a small number of the elk in the

corridor; elk sign and resident interviews (Reisch, pers. comm.) indicated that some elk traveled the northeast sloping ridges into South McKittrick Canyon, presumably to satisfy water needs. It appeared that the majority of elk in the corridor selected their range according to the status of water in the Bowl Tank and Cox Tank, the major temporary water sources. When these temporary sources, including ephemeral holding pools found in shaded drainage bottoms, were unavailable, elk in the corridor moved their range to permit watering at Plowman Tank in New Mexico.

No evidence was found of interchange between the Dog Canyon band and elk bands occupying the West Dog Canyon-Blue Ridge-Bowl corridor. Marked animal locations and consistent numbers of elk in the Dog Canyon drainage indicated that little movement occurred out of this area. Some immigration into the Dog Canyon drainage by corridor elk took place, especially in the upper reaches of the drainage near Dog Canyon Spring; identifiable cow elk D was sighted at Lost Peak and other elk were seen in this area when the entire Dog Canyon band were known to be in a single group near the park boundary or in New Mexico. The eastern escarpment of West Dog Canyon, as well as the South McKittrick escarpment restricted elk movement and limited significant interchange between the 2 bands. The physical barrier of the southeast escarpment above Frijole Ranger Station also hindered interchange between elk of the corridor and the Frijole band which ranged below the escarpment. Some exchange probably occurred occasionally, but was not documented during this study and would likely not represent a major interchange of individuals.

MULE DEER

Habitat Utilization

Mule deer preferences for the 4 major habitat types within GMNP were also investigated using the utilization-availability technique of Neu et al. (1974). As with elk, observations of mule deer during monthly surveys were categorized by habitat type. Generally, deer were easier observed in the characteristically open Mountain Shrub and Desert Shrub habitat types as opposed to Coniferous Forest and Pinyon-Juniper habitat types.

The hypothesis that mule deer utilized each habitat equally in proportion to that type's occurrence was tested by Chi-square analysis. The expected number of deer observations differed significantly from the occurrence of habitat types within the mule deer range, resulting in rejection of the hypothesis ($P < 0.10$). It was concluded, therefore, that mule deer observations within habitat types were not proportional to the areas covered by those habitat types (Table 12).

The proportion of observations in the Coniferous Forest and Desert Shrub habitat types was far below the proportion of area encompassed by each of these habitat types, indicating non-selectivity (or avoidance) by mule deer. The Mountain Shrub habitat type which encompassed 63.0% of the mule deer range received deer use in slightly greater proportion (58.0%) than its occurrence. More deer were observed here than expected and this indicated a slight selection for this type, even though it was the largest of the 4 types available. Overall, mule deer displayed their greatest selectivity for the Pinyon-Juniper habitat type. Approximately 24.0% of all deer observations were obtained in this type which comprised only 7.5% of the

TABLE 12. Occurrence of mule deer sightings in 4 habitat types within the deer range in Guadalupe Mountains National Park, Texas (after Neu et al. 1974).

Habitat Type	Total Area (km^2)	Proportion of Total Area	Number Observed	Expected Number Observed	Proportion Observed in Each Area	Confidence Interval on Proportion of Occurrence (90% family confidence coefficient)
Mountain Shrub	87.18	.627	607	559	.681	$.646 \leq p_1 \leq .716$
Coniferour Forest	30.31	.218	53	194	.059	$.041 \leq p_2 \leq .077$
Desert Shrub	11.04	.079	18	71	.020	$.009 \leq p_3 \leq .031$
Pinyon-Juniper	10.38	.075	213	67	.239	$.207 \leq p_4 \leq .271$
TOTAL	138.91		891	891		

mule deer range in GMNP. These data supported causal observations of deer numbers in the Pinyon-Juniper habitat type, especially in West Dog Canyon where the type predominated.

A seasonal evaluation of mule deer habitat selection through Chi-square analysis (Table 13) led to the rejection of the hypothesis ($P < 0.10$) that mule deer were distributed proportionately to habitat availability within each season. As a result, Table 14 was constructed to evaluate mule deer preference or avoidance of habitat types by season.

During all seasons the Pinyon-Juniper habitat type was used in greater proportion than its availability on the mule deer range, although the magnitude of the use changed between seasons. The greatest selectivity towards the Pinyon-Juniper type was during the Spring-summer season (Table 14) when available surface water was most limiting. This was reciprocal to the seasonal low of deer sightings in the Coniferous Forest habitat type which made up a substantial portion of mule deer range in the high elevation areas of The Bowl and Blue Ridge drainages. These latter areas supported no permanent water during the dry Spring-summer season and therefore deer apparently did not use them at this time. The high incidence of deer use in the Pinyon-Juniper type at lower elevations to the north substantiated the belief that deer in the high and seasonally dry elevations migrated to West Dog Canyon and relied on Plowman Tank and other water sources just outside the National Park during this period of water scarcity.

Mule deer selectivity of the Mountain Shrub habitat type fluctuated between seasons but was at least equivalent to the occurrence of the type on the deer range (Table 14). During the Winter and Spring-summer seasons, use was greater than expected indicating a selectivity for this type. Winter was the season of greatest selectivity for this type and the lowest for the

TABLE 13. Seasonal distribution of mule deer sightings in relation to 4 habitat types within the deer range in Guadalupe Mountains National Park, Texas.

Seasons	Number of Individuals				TOTAL
	Mountain Shrub	Coniferous Forest	Desert Shrub	Pinyon-Juniper	
Winter (Nov. - Feb.)	231	21	18	58	328
Spring-Summer (Mar. - June)	237	10	0	106	353
Summer-Fall (July - Oct.)	131	22	0	57	210
TOTAL	599	53	18	221	891

TABLE 14. Seasonal occurrence of mule deer sightings in 4 habitat types within the deer range in Guadalupe Mountains National Park, Texas (after Neu et al. 1974).

Habitat Type	Total Area (km^2)	Proportion of Total Area	Number Observed	Expected Number Observed	Proportion Observed in Each Area	Confidence Interval on Proportion of Occurrence (90% family confidence coefficient)
				Winter		
Mountain Shrub	87.18	.627	231	206	.704	$.647 \leq p_1 \leq .760$
Coniferous Forest	30.31	.218	21	71	.064	$.034 \leq p_2 \leq .094$
Desert Shrub	11.04	.079	18	26	.055	$.027 \leq p_3 \leq .083$
Pinyon-Juniper	10.38	.075	58	25	.177	$.129 \leq p_4 \leq .224$
				Spring-summer		
Mountain Shrub	87.18	.627	237	221	.671	$.614 \leq p_1 \leq .727$
Coniferous Forest	30.31	.218	10	77	.028	$.008 \leq p_2 \leq .048$
Desert Shrub	11.04	.079	0	28	.000	$.000 \leq p_3 \leq .000$
Pinyon-Juniper	10.38	.075	106	27	.300	$.245 \leq p_4 \leq .355$
				Summer-fall		
Mountain Shrub	87.18	.627	131	132	.624	$.549 \leq p_1 \leq .698$
Coniferous Forest	30.31	.218	22	46	.105	$.058 \leq p_2 \leq .152$
Desert Shrub	11.04	.079	0	16	.000	$.000 \leq p_3 \leq .000$
Pinyon-Juniper	10.38	.075	57	16	.271	$.202 \leq p_4 \leq .339$

Pinyon-Juniper habitat type. Among many influences, the occurrence of preferred browse species in the Mountain Shrub habitat to carry animals through the Winter season probably contributed to higher selectivity among deer for this habitat type.

In summary, the Pinyon-Juniper habitat type was overwhelmingly preferred by deer during all seasons. The Mountain Shrub habitat type was used by deer in greater proportion than its occurrence during Winter and Spring-summer, and in equal proportion to occurrence during Summer-fall. Both the Coniferous Forest and Desert Shrub types were selected against during all seasons by deer in GMNP. As with elk, the seasonal availability of temporary water influenced mule deer habitat selection.

Water Relations

Mule deer sightings were closely associated with the intermittent water sources in GMNP (Fig. 21). Seventy-three % of all buck sightings were within 1.6 km of a water source while 66.0% of doe sightings were also inside this distance. Only 9.0% of all deer sightings obtained from August, 1977 through December, 1978 were made beyond 3.2 km from available surface water. No deer were observed further than 6.4 km from known water. There was little overall difference between the sexes regarding their association with water sources.

Mule deer were generally found in close proximity to water during all seasons although somewhat less so during Winter when routine water consumption was not as critical (Fig. 22). Nonetheless, 77.0% were observed within 3.2 km of water during the Winter season. This may have been a function of deer mobility or concentrations of deer breeding groups near water sources during the November rut.

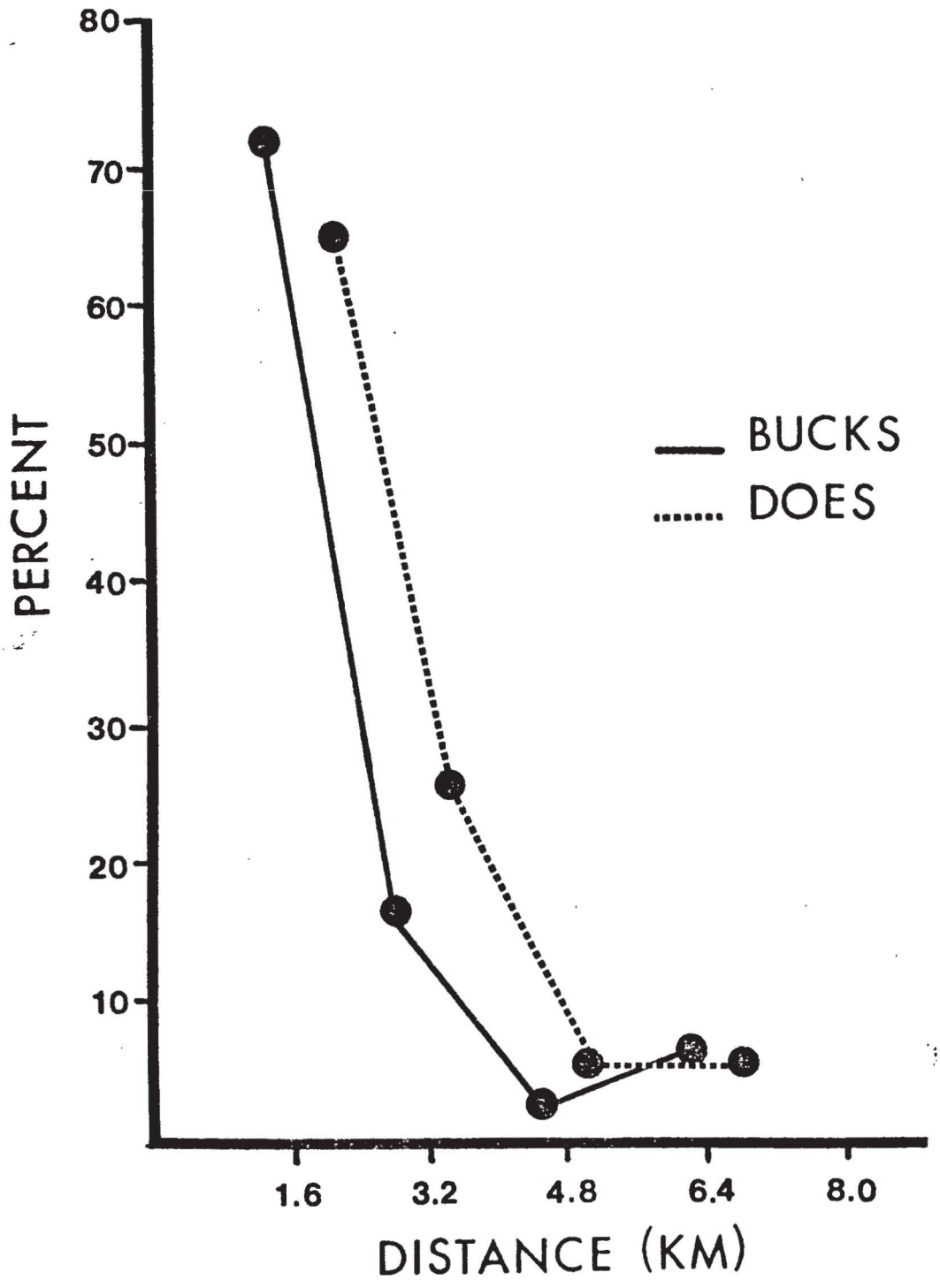


Fig. 21. Relative distances of buck and doe mule deer observations from known surface water as a percent of total sightings in Guadalupe Mountains National Park, Texas.

The 3 driest months, March, April, and May, were included in the Spring-summer season. Ephemeral pools were dry during this season and wild ungulates in GMNP were necessarily concentrated near the few permanent water sources inside and immediately outside the park boundary. Despite this dependence on limited water, only 45.0% of deer sightings were within 1.6 km, with a further 45.0% between 1.6 and 3.2 km. Therefore, during the period when surface water was most limiting, 90.0% of all deer sightings were obtained within 3.2 km of water.

The arrival of the rains during the Summer-fall season eased the dependence of mule deer on permanent water sources. Concomitantly, mule deer observations increased near previously abandoned ephemeral water holes. Therefore, deer remained in close proximity to water (Fig. 22) during the Summer-fall seasons, but range expansion occurred as water availability increased in areas which were waterless during the dry months.

Movements and Home Range

During June through August, 1977, 49 mule deer (15 bucks and 34 does) were captured and successfully marked with individual identifying plastic neck collars, coded to trap locations. Resighting locations obtained on each deer until December, 1978 were recorded on topographical maps. Minimum home ranges (Mohr 1947) were delimited for several does in 2 areas. However, due to a low number of observations during this study, mule deer home ranges were undoubtedly underestimated (Severson and Carter 1978).

Dog Canyon

Seven bucks and 13 does were collared near Dog Canyon Ranger Station; a doe was known to have died during the study. Only 16 total observations

MD Fig 22

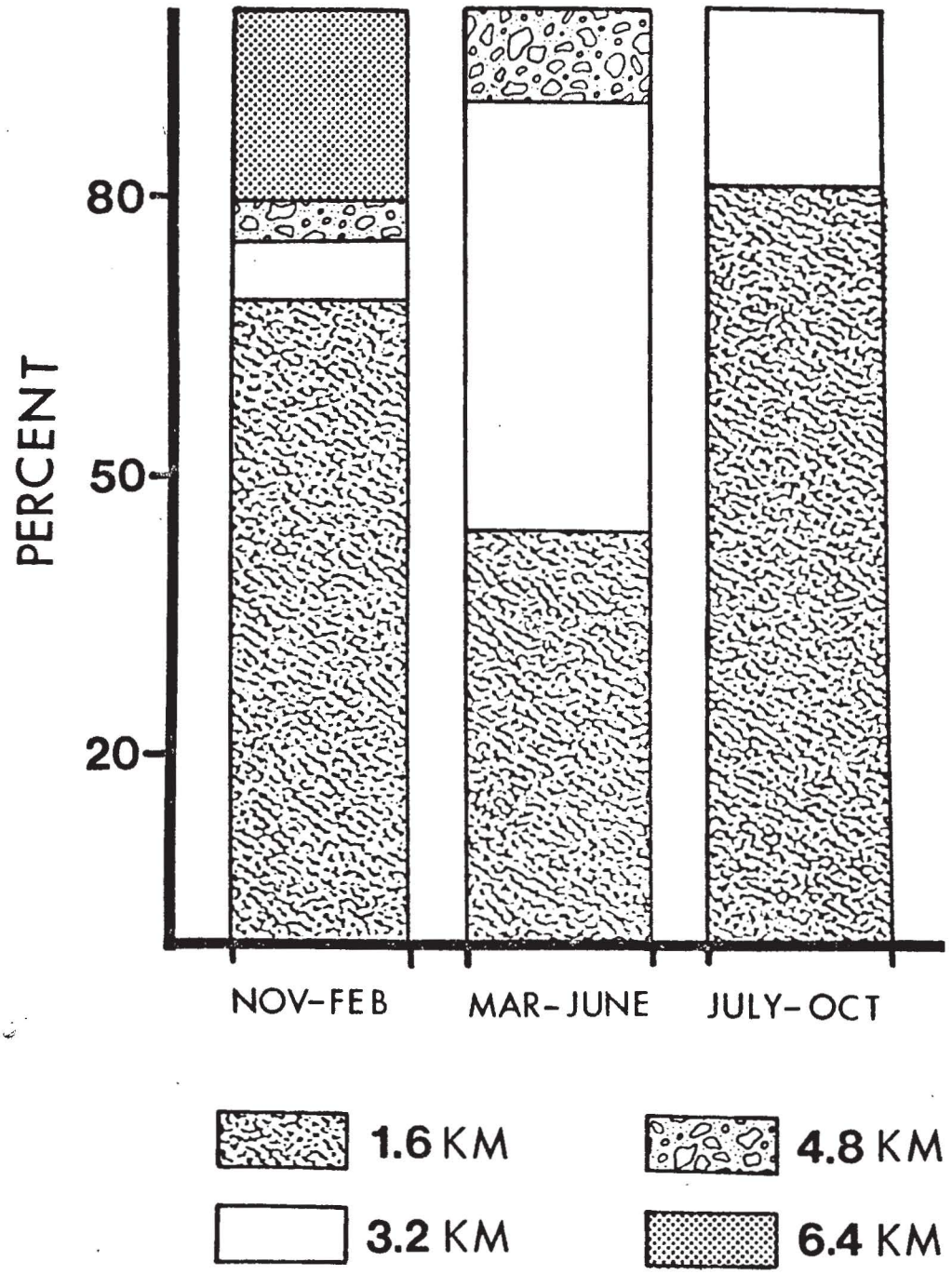


Fig. 22. Relative distances of mule deer observations from known surface water by season in Guadalupe Mountains National Park, Texas.

of bucks were obtained over the 18 month study period while 86 total observations were obtained for does. This same trend was evident in the number of resightings for individuals (Fig. 23a). No bucks were resighted over 3 times while some does were resighted more than 10 times. The lower frequency of marked buck resightings indicated that they either ranged outside the park boundary most of the time or that they were lost at a greater rate than does through mortality.

Observations obtained for marked bucks were at greater distances from the release site than marked does. Ranges for does were more restricted and concentrated near the release site where water was available, and 1.6 km up the canyon, at the only other water source in Dog Canyon area (Dog Canyon Spring). All sightings of does in this area were within 1.6 km of surface water and 2.4 km of the release location. More resightings were obtained in the large meadow where the original trapping took place.

Three of the 13 does monitored in the Dog Canyon area were chosen for minimum home range estimates based on the number of observations for each individual (Table 15). No attempt was made to construct home ranges for bucks due to limited sample sizes. All 3 does displayed restricted ranges which concentrated around Dog Canyon Range Station (release site) and in the canyon containing Dog Canyon Spring (Fig. 24). Home range size for the 3 averaged 1.00 km^2 (100 ha) based on minimum estimates since only visual data points were available from home range plotting. Nonetheless, these ranges typified the distribution pattern for does in this area showing heavy concentration near the release site and occasional ventures up canyon in the vicinity of Dog Canyon Spring. Most resightings of does were in the Mountain

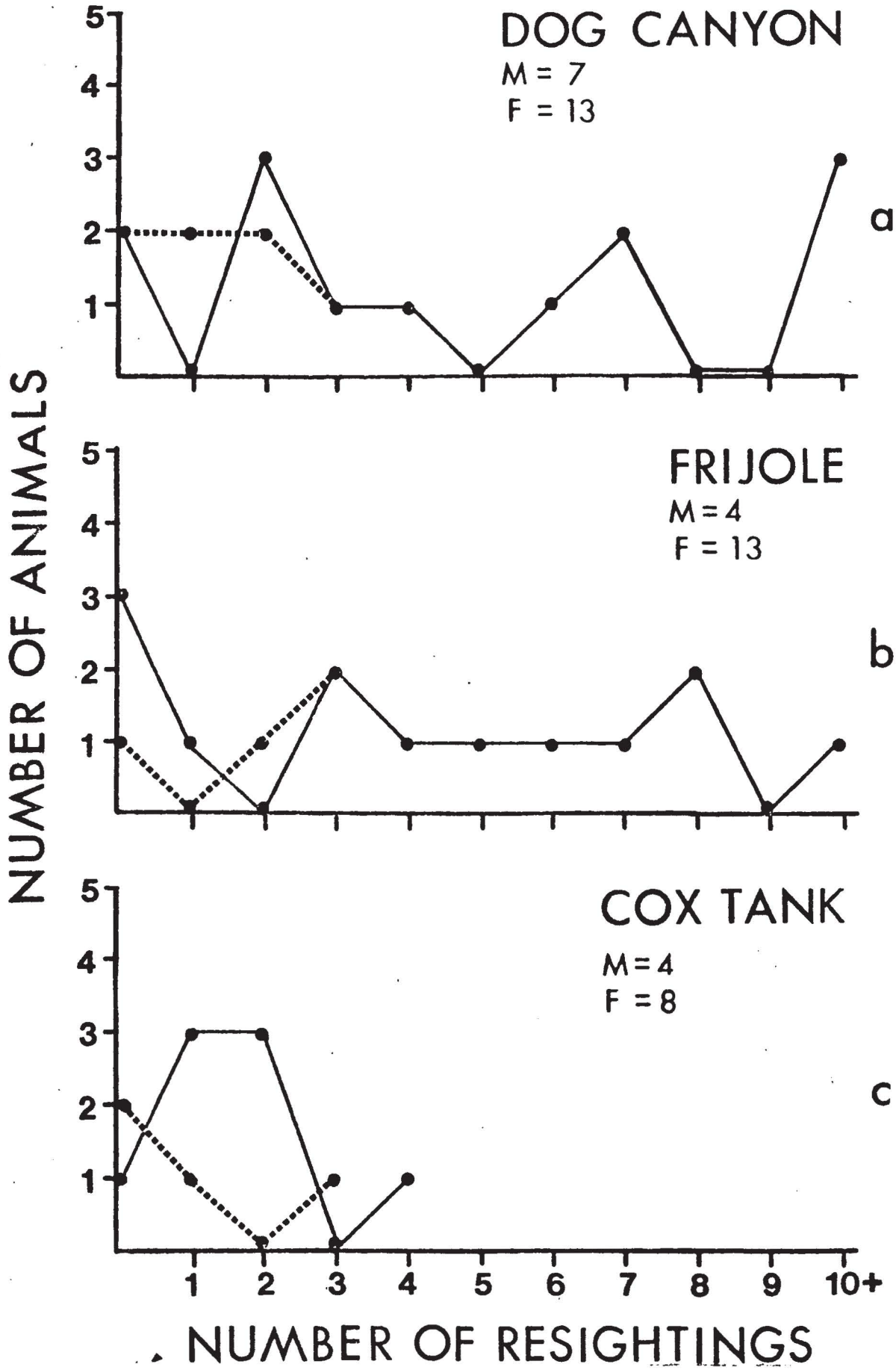


Fig. 23. Incidence of resightings on males (---) and females(——) captured and collared at 3 locations in Guadalupe Mountains National Park, Texas.

TABLE 15. Dates and number of observations and minimum home range estimates of 6 marked deer from Guadalupe Mountains National Park, Texas.

Animal	Dates of Observations	Number of Observations	Minimum Home Range Estimate (km^2)	Hectares (ha)
Dog Canyon				
♀ M	6/77-12/78	18	0.49	49
♀ A	6/77-12/78	15	1.21	121
♀ F	6/77-8/78	7	1.27	127
Frijole				
♀ O	7/77-12/78	13	1.84	184
♀ K	7/77-8/78	8	0.38	38
♀ P	7/77-11/78	6	0.91	91

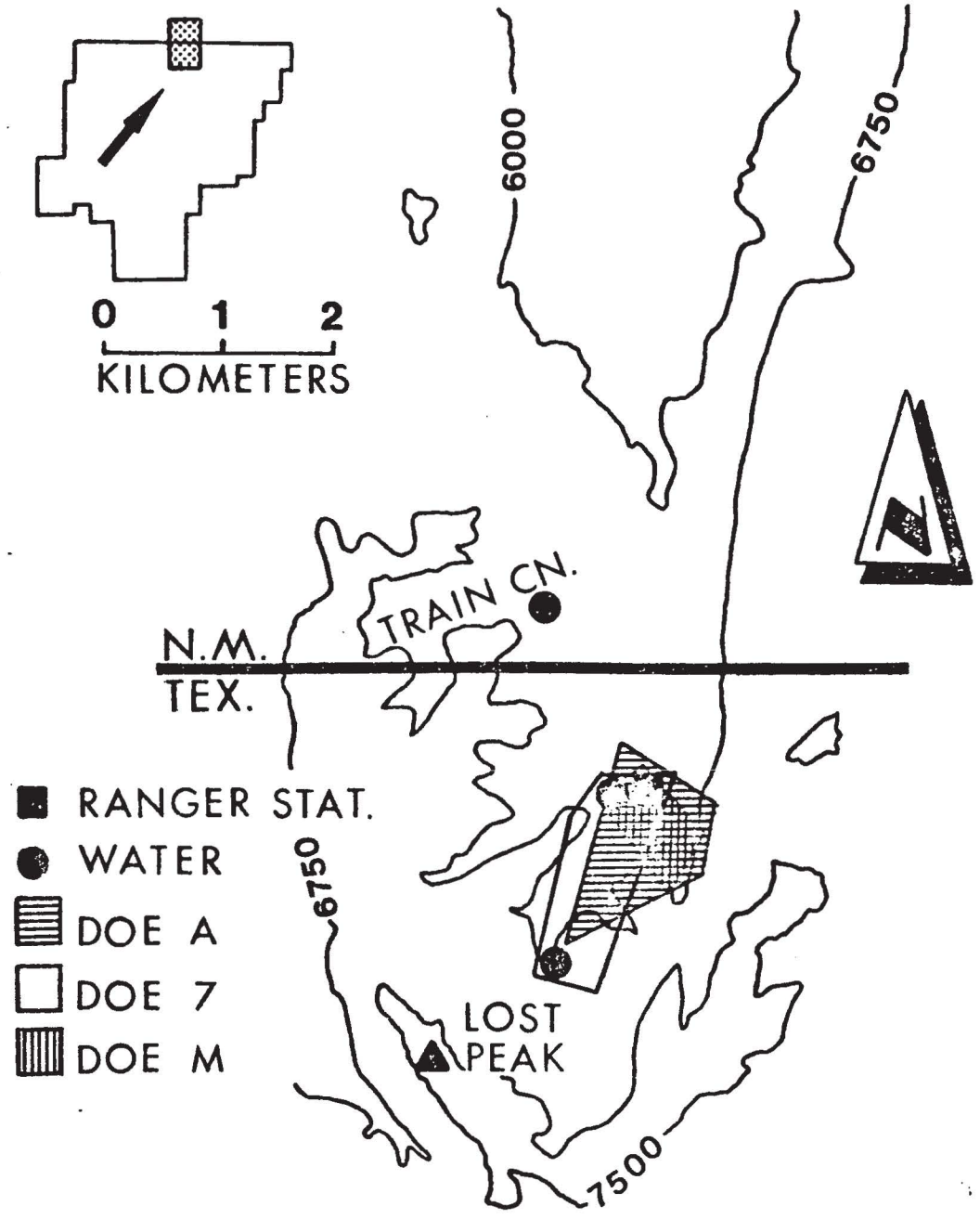


Fig. 24. Annual home ranges of 3 doe mule deer in the Dog Canyon Drainage, Guadalupe Mountains National Park, Texas.

Shrub habitat type with only a few obtained in the Coniferous Forest type at higher elevations.

Frijole Area

Trapping operations near Frijole Ranger Station resulted in 4 bucks and 13 does collared, of which 3 died (1 buck, 2 does) during the study. As found with marked deer elsewhere, bucks were observed less often (10 observations) than does (66 observations). Number of resightings of individual bucks and does were similar to that recorded for Dog Canyon (Fig. 23b). The same conclusions were also drawn regarding ranges of bucks and differential mortality rates. Here, too, bucks were found to be more wide ranging than does, the latter restricting their distributions to the vicinity of the release site and nearby water points.

Three home ranges of does in this area were plotted (Fig. 25). The home ranges, based on visual data points collected throughout the study, averaged 1.04 km^2 (104 ha) (Table 15). Again, most data points were concentrated near the release site where water was available. Other nearby water sources either fell within the plotted ranges or came close to them. These trends, as well as the tendency to range close to the escarpment base, typified the distributons of marked does in this area. All sightings were obtained within the Mountain Shrub habitat type which predominated in this portion of the National Park.

Cox Tank

Resightings of the 4 bucks and 8 does collared at Cox Tank were relatively infrequent (Fig. 23c). Of the 12 marked deer, bucks were observed a total of

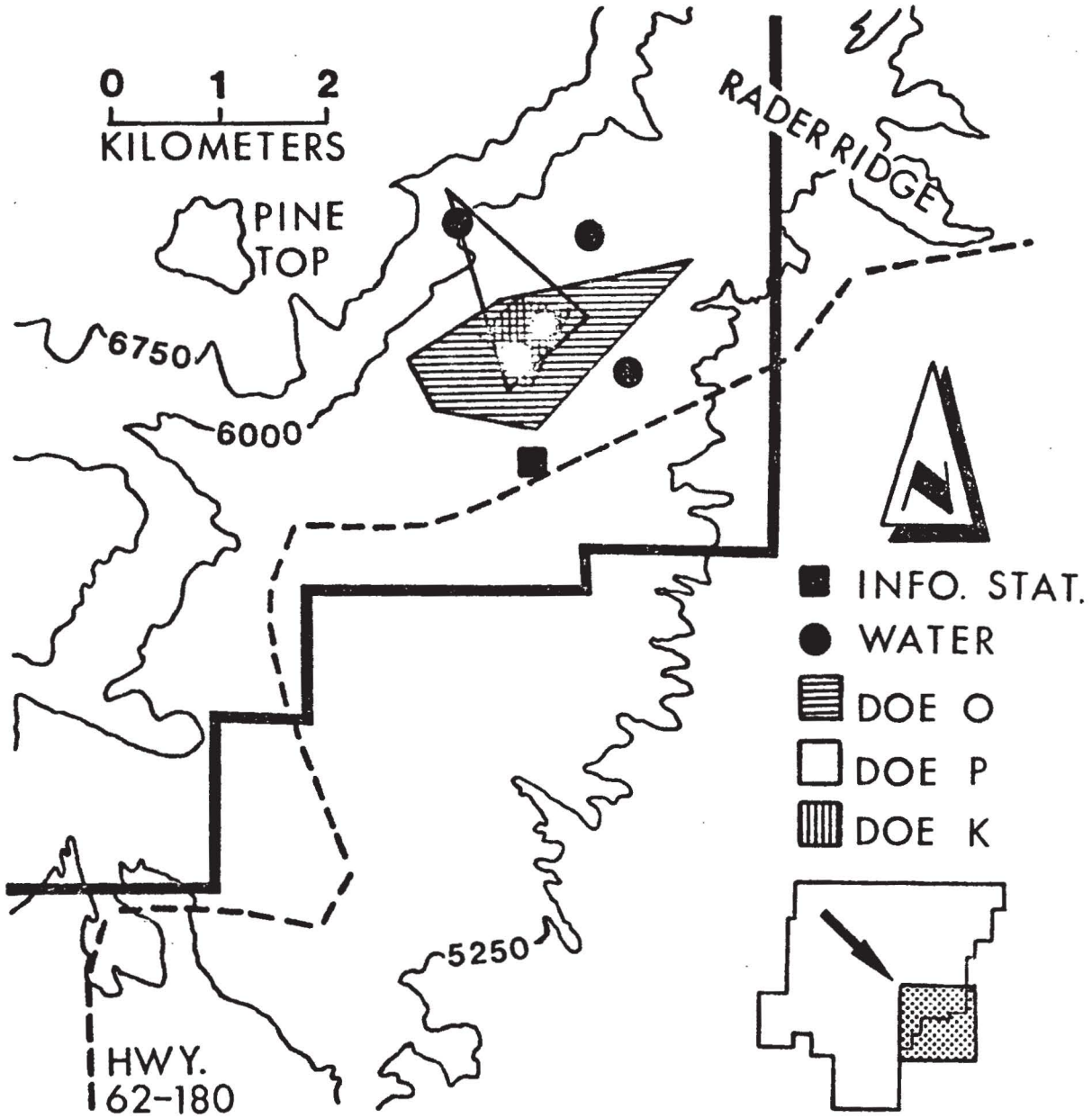


Fig. 25. Annual home ranges of 3 doe mule deer, southeast escarpment, Guadalupe Mountains National Park, Texas.

8 times and does 23 times, with a maximum of 4 resightings for single individual, a doe. One doe was the only known mortality among collared animals in this area. Because of the infreqeuncy of sightings of either sex, no attempt was made to construct deer home ranges for this area. Most resightings of marked animals occurred very near the release site when water was available at this ephemeral source. Marked deer were never observed at Plowman Tank in New Mexico, the only permanent water in West Dog Canyon, although they were seen on a major travel lane to that water source on several occasions.

The infrequent resightings of the Cox Tank collared deer indicated they were absent from the release area a great deal of the time during the study. Mule deer undoubtedly relied heavily on Plowman Tank and possibly other water points outside the National Park during those periods when Cox Tank was dry, thus partially explaining the few resightings in this area.

Data gathered on all marked mule deer in GMNP revealed several aspects of their range and distribution. Deer, especially does, in areas of year-round water availability exhibited relatively restricted ranges around these water sources. Also, no seasonal movements were evident among these groups. However, deer occupying the Bowl, West Dog Canyon, and Blue Ridge were influenced by seasonal water availability and adjusted their ranges and distributions accordingly. Some of their movements were relatively extensive and took place in the dry season when water was available primarily outside GMNP, and in the period following mid-summer rains when range expansion back into areas with temporary water entrapments was possible.

In all 3 areas where deer were trapped and marked, bucks displayed ranges greater than does and were relocated less often. Overall, an average of 2.3

sightings per marked buck and 5.2 sightings per marked doe was obtained during the 18 month monitoring period.

The annual home ranges for adult female mule deer in both areas of the park differ substantially from those reported for other nonmigratory herds in the Southwest which range from 2.85 km^2 (285 ha) to 8.03 km^2 (803 ha) (Hanson and McCulloch 1955, Dickinson 1979, Koerth 1981).

DISCUSSION

Comparison of data on elk and mule deer responses to their environment in GMNP showed species-specific differences. These included habitat selection, water relations, movements, and home ranges.

Neither species utilized the available habitat types in proportion to the availability of these types. This indicated a selective response towards those habitat types which were most beneficial to the species at a given time of year. Overall, elk exhibited preference towards the Pinyon-Juniper and Coniferous Forest habitat types. Both of these types more closely typified elk habitat in the typical elk ranges of western states. Mule deer selected towards the Pinyon-Juniper habitat type overwhelmingly and, to a lesser degree, the Mountain Shrub hatiat type. The implications of both ungulates selecting the Pinyon-Juniper type must be considered. This habitat comprised only 7.5% of the overlap range of elk and mule deer yet on an annual basis it received 24.0% of the mule deer use and 21.0% of the elk use. These levels of range use by both ungualtes indicated an area of potential competition which could lead to deterioration of the range plant resource in the Pinyon-Juniper type.

Finally, in discussing habitat use, the influence of water availability on ungulate distributions must be reiterated. Water availability played an important role in the responses of elk and mule deer to their environment. Generally, elk were observed at greater distances from surface water than mule deer which may have been due to the greater mobility elk displayed in utilizing their environment. Overall evaluation of distances from water showed 60.0% of elk within 1.6 km, 17.0% between 1.6 km and 3.2 km, and 23.0% more than 3.2 km from known surface water sources. Similar evaluation of the total mule deer data collected during this study indicated 70.0%, 22.0%, and 8.0% respectively for the above 3 categories.

During the dry Spring-summer season both species were concentrated near available surface water. However, some inter-sepcific interaction apparently kept mule deer at slightly greater distance from water than elk during these dry periods. Most elk (72.0% of sightings) were concentrated within 1.6 km water while only about half the mule deer sightings (45.0%) were within this distance. Nonetheless, 80.0% of all elk and 90.0% of all mule deer sighted were within 3.2 km of water during the dry season. This posed a serious threat to range condition and placed severe utilization and trampling pressure on the vegetation near these watering points. Thus abnormal concentrations of elk and mule deer around a limited number of water sources during the dry season, have resulted in deterioration of range condition in these areas.

Due to the different behavioral strategies adopted by elk and mule deer, little can be gained in comparison of home ranges for these species. The average home range sizes found for elk were somewhat smaller than those recorded elsewhere in the species' range. However, this was not surprising

in that water strongly influenced elk distribution in GMNP whereas seasonal climatic factors were relatively unimportant; elsewhere in the elk range seasonal changes often necessitate substantial changes between summer and winter home ranges. The small sample sizes for calculation of mule deer home ranges sizes undoubtedly limited the veracity of results obtained in this study. While the average home range size for mule deer in GMNP may have been somewhat larger than documented here, we believe that home ranges are generally smaller than reported for mule deer elsewhere in its range.

FOOD HABITS AND SELECTION

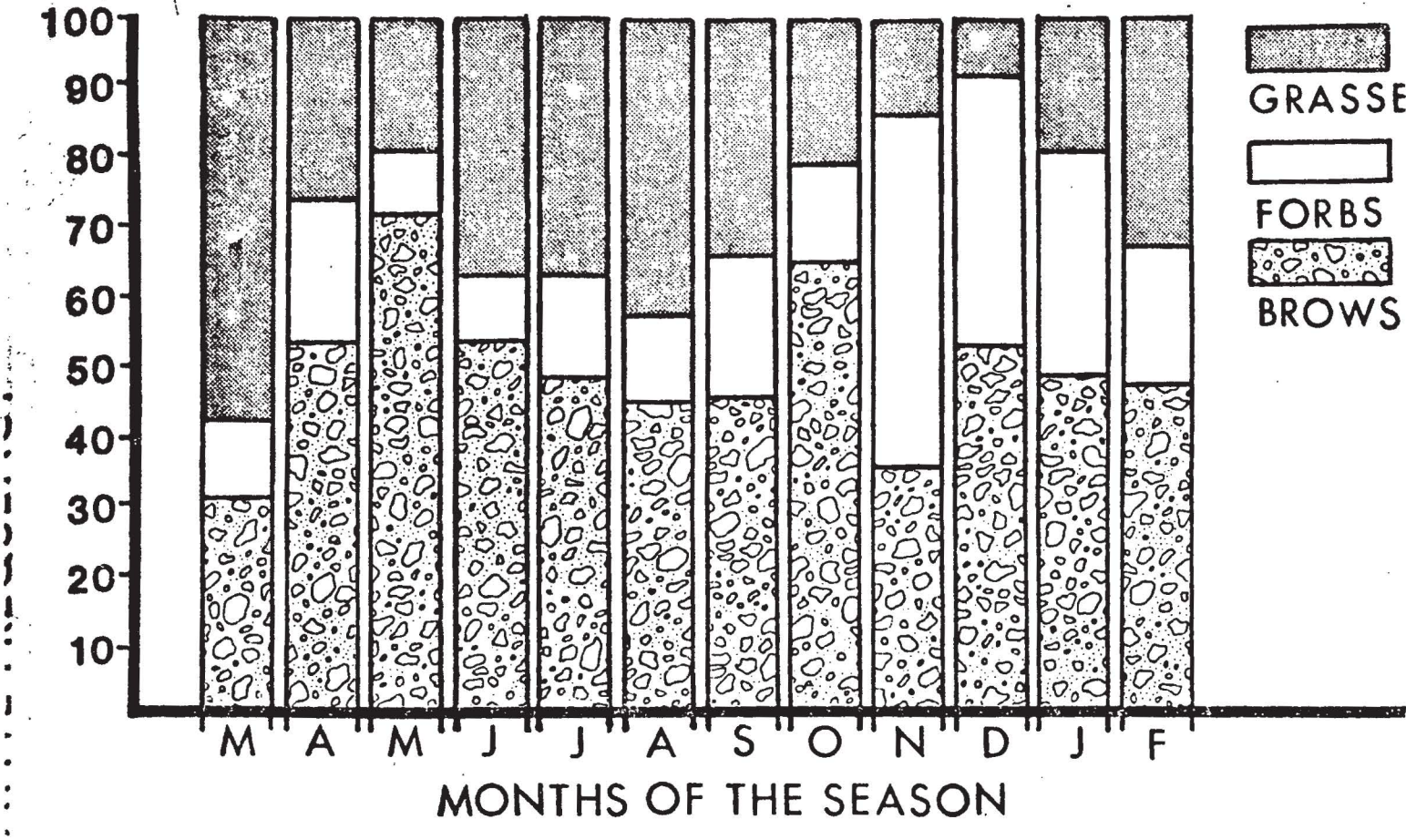
ELK

Fecal Analysis

Annual Diet

Analysis of 332 fecal samples revealed 132 different plant species in the elk diet from March, 1978 through February, 1979 (Appendix B). The average annual diet for elk in GMNP consisted of 32.0% grasses, 20.0% forbs, and 48.0% browse (woody plants and cacti) (Fig. 26). Sixteen major food plants were taken by elk in amounts of 1.0% or more and accounted for 78.0% of the annual diet (Table 17).

Threeawns (2.0%) includes Aristida pansa, A. glauca and A. wrightii and the bladderpods (1.0%) consisted of Lesquerella vallida and L. fendleri. Oaks (31.0%) consisted of Quercus grisea, Q. undulata, Q. pungens, Q. gambelii, and Q. muhlenbergia, and juniper (2.0%) included Juniperus pinchoti and J. deppeana. Monthly utilization of the top 6 forage plants consumed by elk is shown in Figure 27.



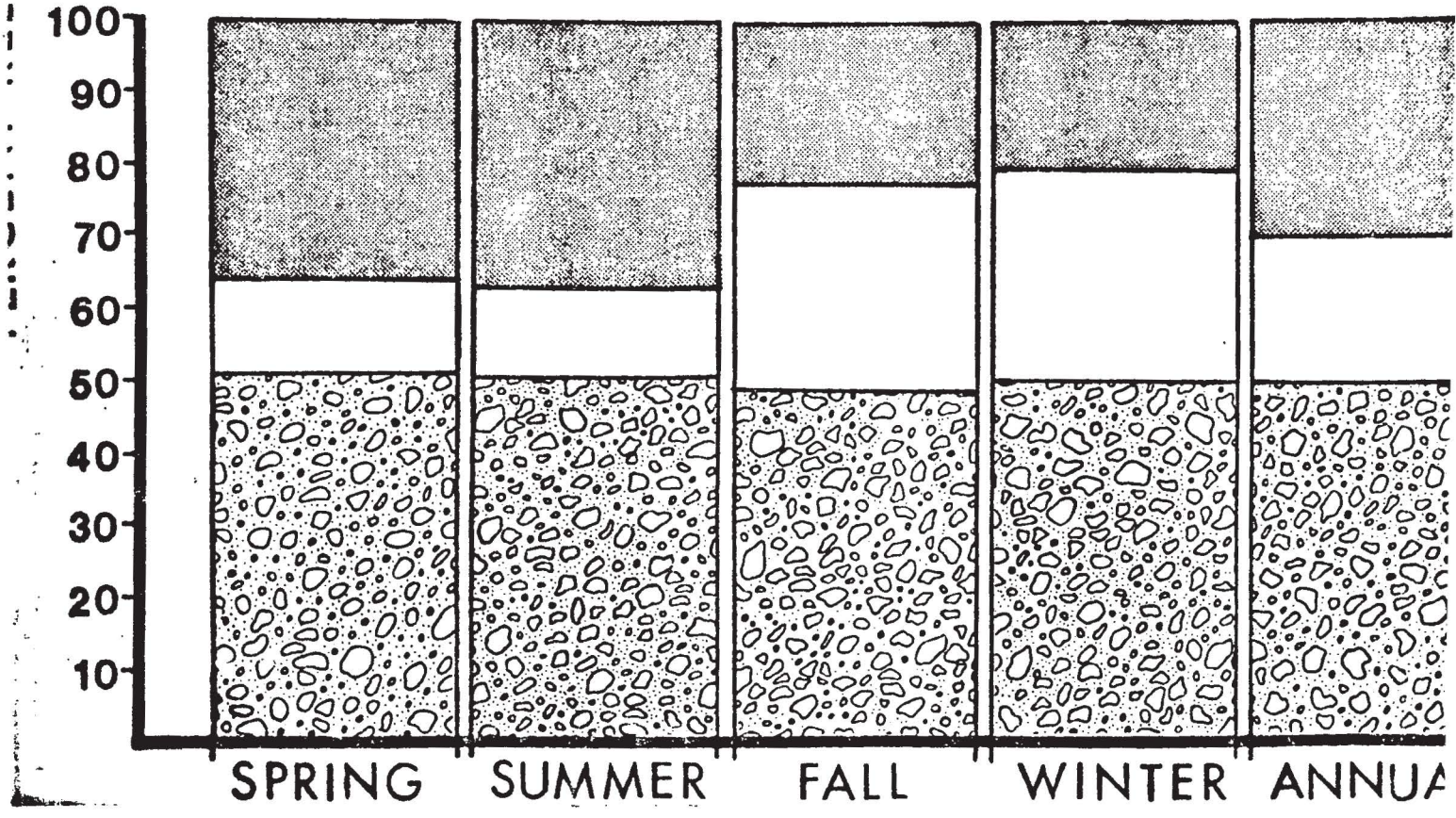


Fig. 26. Monthly and seasonal use of the major forage classes by elk in Guadalupe Mountains National Park, Texas.

TABLE 17. Sixteen major food plants in the annual diet of elk in Guadalupe Mountains National Park, Texas.

Food Plant		Relative Frequency	Percent [1/] Occurrence (N = 332)
GRASSES:			
Blue grama	Bouteloua gracilis	9.0	72.0
Curlyleaf muhly	Muhlenbergia setifolia	4.0	39.0
Littleawn needlegrass	Stipa lobata	3.0	39.0
Wolftail	Lycurus phleoides	2.0	33.0
Indiangrass	Sorghastrum avenaceum	2.0	33.0
Threeawns	Aristida spp.	2.0	20.0
Western wheatgrass	Agropyron smithii	1.0	16.0
Sideoats grama	Bouteloua curtipendula	1.0	17.0
FORBS:			
Common horehound	Marrubium vulgare	9.0	48.0
Leatherweed croton	Croton pottsii	7.0	32.0
Narrowleaf globemallow	Sphaeralcea angustifolia	2.0	16.0
Bladderpods	Lesquerella spp.	1.0	5.0
BROWSE:			
Oaks	Quercus spp.	31.0	94.0
Desert ceanothus	Ceanothus greggii	5.0	38.0
Junipers	Juniperus spp.	2.0	18.0
Mountain mahogany	Cercocarpus montanus	1.0	12.0

[1/] Occurrence refers to the % of samples/year (N) in which the plant species occurred.

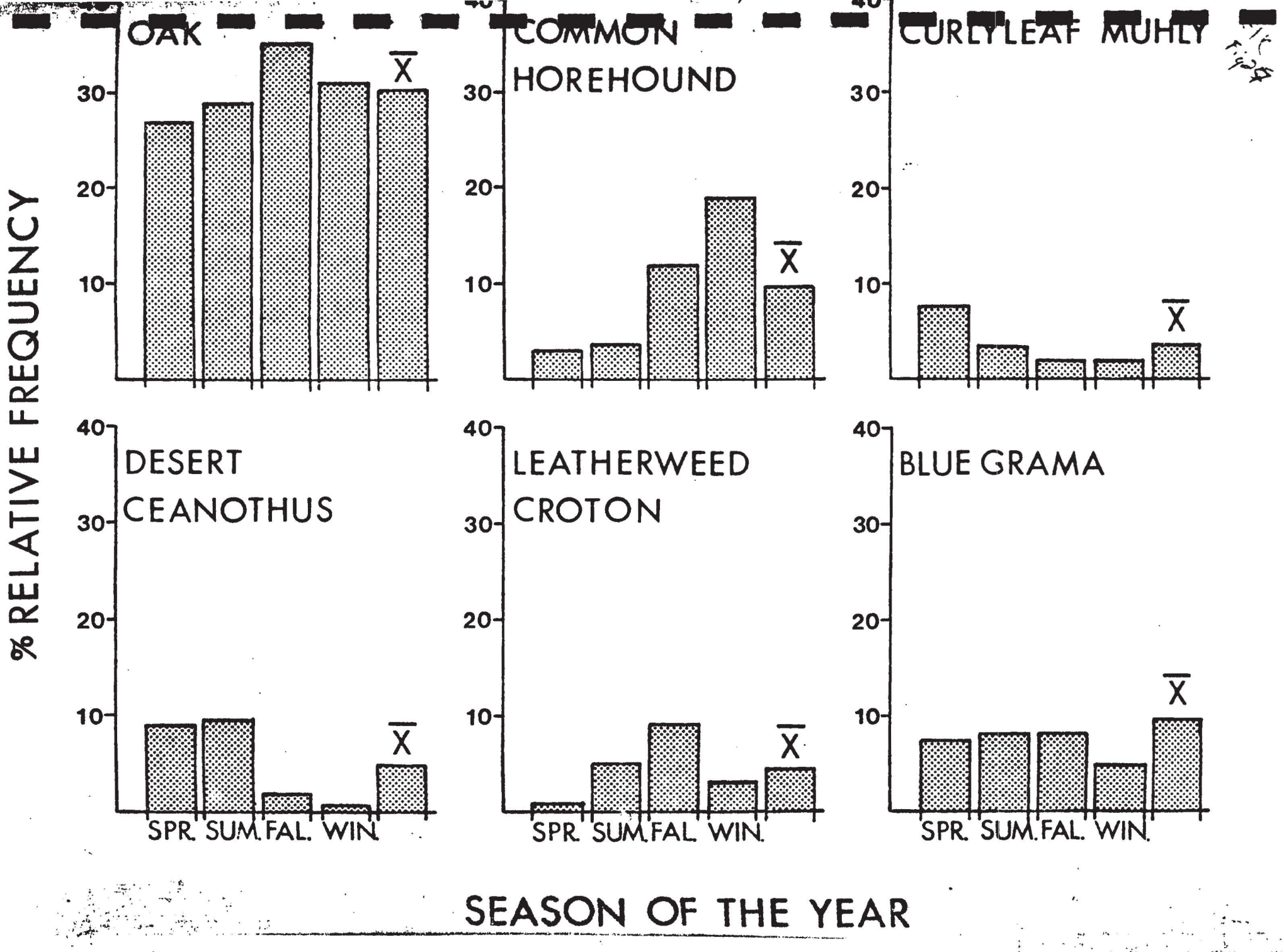


Fig. 27. Seasonal utilization of the top 6 plants consumed by elk in Guadalupe

Browse was heavily utilized year-round. Oaks were the dominant browse utilized comprising 31.0% of the annual diet. Heavy utilization of oaks has been attributed to their maintaining a high protein level throughout the year (Swank 1958). Forbs were consumed predominantly during the fall and winter seasons while grasses were utilized principally during the spring and summer seasons. Littleawn needlegrass and western wheatgrass, both cool season grasses, were the heaviest utilized grasses during the spring season. Blue grama, a warm season grass was the major grass component during the summer season.

The relative availability of major grass and browse plants consumed by elk was used to determine a selection index (Table 18). Results indicated that elk were selective feeders during all seasons of the year. The 2 exceptions were mountain mahogany and sideoats grama which were never recorded as being selected for by elk during the study. Dietary analysis revealed that mahogany and sideoats only accounted for 2.0% of the total annual diet and were of minor importance to elk. The low selection of sideoats grama was due in part to a low percentage of sideoats occurring in areas of heavy elk use. Elk showed the highest selectivity for oaks and blue grama throughout the year. As previously stated these 2 plants were the major forage components consumed by elk on an annual basis.

The high percentage of browse recorded in annual elk diet during this study (48.0%) was considerably higher than reported from elsewhere in the species distribution (DeNio 1938, Morris and Schwarts 1957, Mackie 1970, Anthony and Smith 1974). Harper (1962) reported the average annual diet for Roosevelt elk in California consisted of 63.0% grasses, 12.0% forbs, and 25.0% browse. The average annual diet for elk in southern Colorado was

TABLE 18. Selection Index for the 7 grass and 4 browse plants forming the bulk of the annual diet for elk in Guadalupe Mountains National Park, Texas.

Common name	Scientific name	Dietary Use (Selection Index) Annual	Spring	Summer	Fall	Winter	Availability (%)
GRASSES:							
Blue grama	Bouteloua gracilis	27 (24)	18 (15)	43 (40)	24 (21)	18 (15)	3.0
Western wheatgrass	Agropyron smithii	5 (5)	11 (11)	---	1 (1)	4 (4)	.4
Indiangrass	Sorghastrum avenaceum	7 (6)	T[1/] (-1)	9 (8)	13 (12)	6 (5)	1.0
Wolftail	Lycurus phleoides	8 (6)	T (-2)	11 (9)	10 (8)	11 (9)	2.0
Curlyleaf muhly	Muhlenbergia setifolia	11 (3)	20 (12)	9 (1)	7 (-1)	8 (0)	8.0
Littleawn needlegrass	Stipa lobata	11 (1)	13 (3)	4 (-6)	9 (-1)	20 (10)	10.0
Threeawns	Aristida spp.	6 (-1)	10 (3)	4 (-3)	7 (0)	4 (-3)	7.0
Siedoats grama	Bouteloua curtipendula	4 (-8)	8 (-4)	2 (-10)	2 (-10)	T (-12)	12.0
BROWSE:							
Oaks	Quercus spp.	70 (42)	57 (29)	66 (38)	85 (57)	72 (44)	28.0
Junipers	Juniperus spp.	7 (6)	7 (6)	T (1)	2 (1)	12 (11)	1.0
Desert ceanothus	Ceanothus greggii	12 (5)	19 (12)	22 (15)	5 (-2)	T (-7)	7.0
Mountain mahogany	Cercocarpus montanus	4 (-16)	8 (-12)	5 (-15)	1 (-19)	1 (-19)	20.0

1/ T = trace (< 1.0%)

Selection Index (< 0) shows non-selection

Selection Index (> 0) shows selection

comprised of 73.0% grasses, 8.0% forbs, and 19.0% browse (Hansen and Reid 1974). Kufeld (1973) combined various studies conducted in Montana and determined the year long elk diet consisted of 68.0% grasses, 25.0% forbs, and 7.0% browse. Forbs were predominantly used during the summer season in Montana accounting for 64.0% of the total seasonal diet in that area. The high preponderance of browse in the elk diet in this study was probably related to browse abundance throughout the year rather than a preference for woody species. But the abundance of browse in the elk diet could have been related to nutritional levels in browse plants.

Spring Season

Fecal analysis showed that 77 plant species were consumed by elk during the spring season (see Appendix B). The diet consisted of 37.0% grasses, 12.0% forbs, and 51.0% browse (Fig. 26). Fourteen major food plants were consumed by elk in amounts of 1.0% or more of the spring sample (Table 19). Threeawns (5.0%) were comprised of Aristida glauca, A. pansa, and A. wrightii and the bladderpods (5.0%) consisted of Lesquerella vallida and L. fendleri. Included in the oak (27.0%) category were Quercus grisea, Q. undulata, Q. pungens, and Q. muhlenbergia. The top 14 rankings accounted for 87.0% of the spring diet.

Analysis of these plants revealed differences between months within the spring season. Oaks only accounted for 11.0% of the sample in early spring due to winter dormancy, but with the advent of leaf formation, increased to 60.0% of the late spring diet. Concomitant with increased use of oaks, desert ceanothus showed a reverse trend, with the 11.0% consumed in early spring declining to 3.0% by the end of the season. Bladderpods comprised

TABLE 19. Fourteen major food plants in the spring diet of elk in Guadalupe Mountains National Park, Texas.

Food plant		Relative Frequency	Percent [1] Occurrence (N = 83)
GRASSES:			
Curlyleaf muhly	Muhlenbergia setifolia	8.0	55.0
Blue grama	Bouteloua gracilis	7.0	69.0
Littleawn needlegrass	Stipa lobata	5.0	38.0
Threeawns	Aristida spp.	5.0	45.0
Western wheatgrass	Agropyron smithii	4.0	43.0
Sideoats grama	Bouteloua curtipendula	3.0	42.0
New Mexico needlegrass	Stipa neomexicana	3.0	12.0
Mountain brome	Bromus anomalus	1.0	28.0
FORBS:			
Bladderpods	Lesquerella spp.	5.0	22.0
Common horehound	Marrubium vulgare	3.0	27.0
BROWSE:			
Oaks	Quercus spp.	27.0	81.0
Desert ceanothus	Ceanothus greggii	9.0	2.0
Mountain mahogany	Cercocarpus montanus	4.0	30.0
Alligator juniper	Juniperus deppeana	3.0	43.0

[1] Occurrence refers to the % of diet samples/season (N) in which the plant species occurred.

9.0% of the early spring sample. They are cool season forbs which were abundant on the study area in late winter and early spring. As the season progressed, availability of bladderpods decreased and they only accounted for a negligible amount of the late spring diet. A similar trend was observed for littleawn needlegrass and curlyleaf muhly, both cool seasons grasses. Littleawn needlegrass accounted for 11.0% of the early spring diet, but declined to 3.0% by season's end. Similarly, curlyleaf muhly accounted for 12.0% of the early spring diet, but as the season progressed, it declined to 2.0% of the late spring diet. This decline in utilization was probably related to cool season grasses becoming coarse and decadent as the season progressed.

Kufeld (1973) combined various works and reported the diet for elk in Montana during the spring season consisted of 87.0% grasses, 6.0% forbs, and 7.0% browse. Similarly, Harper (1962) concluded that the spring diet for Roosevelt elk in California included 61.1% grasses, 4.2% forbs, and 33.6% browse. Burt and Gates (1949), working on elk in Pecos Basin of New Mexico, found the spring diet consisted of 97.0% grasses, no forbs, and 3.0% browse. Fecal analysis for elk in southern Colorado revealed that the spring diet consisted of 71.0% grasses, 10.0% forbs, and 19.0% browse (Hansen and Reid 1974). These last authors also found that needlegrasses were the most important component and contributed 16.0% of the spring diet. Results from this study indicated that elk in the Southwest utilized greater amounts of browse during the spring season than has been reported for elk in other regions of the United States.

Summer Season

Analysis of fecal samples showed 87 plant species were ingested by elk during the summer season (see Appendix B). The diet consisted of 39.0% grasses, 12.0% forbs, and 49.0% browse (Fig. 26). Fourteen major food plants were taken by elk in amounts of 1.0% or more of the summer sample (Table 20) and accounted for 81.0% of summer diet. Included in the oaks (29.0%) category were Quercus grisea, Q. pungens, Q. undulata, Q. gambelli, and Q. muhlenbergia.

Detailed examination of the occurrence of these plant species revealed differences between months within the summer season. Blue grama, a warm season grass, had only accounted for 7.0% of the spring diet. With the onset of new growth, utilization increased to 23.0% of the early summer diet. As summer progressed, blue grama became coarse and decadent, and utilization dropped to 13.0% by late summer. During the same period of time, Indiangrass (Sorghastrum avenaceum) rose from less than 1.0% to 3.0% of the late summer diet. In early summer, elk consumed 6.0% algerita (Berberis trifoliata), but use declined to a negligible amount by the season's end. Field observations showed that this utilization trend coincided with the algerita berry production cycle. Oaks in the diet declined almost 50.0% from early to late summer.

In Montana during the summer season, diets of elk consisted of 30.0% grasses, 64.0% forbs, and 6.0% browse (Kufeld 1973). The high proportion of forbs in the diet reflected a high composition of weedy vegetation in some areas of that state. Hansen and Reid (1974) reported, summer elk diets in southern Colorado consisting of 83.0% grasses, 6.0% forbs, and 11.0% browse. They also stated that oaks were utilized heaviest during the summer season

TABLE 20. Fourteen major food plants in the summer diet of elk in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1] Occurrence (N = 85)
GRASSES:			
Blue grama	Bouteloua gracilis	8.0	88.0
Wolftail	Lycurus phleoides	4.0	40.0
Indiangrass	Sorghastrum avenaceum	3.0	46.0
Curlyleaf muhly	Muhlenbergia setifolia	3.0	44.0
Littleawn needlegrass	Stipa lobata	1.0	22.0
Halls panicum	Panicum hallii	1.0	19.0
Spike dropseed	Sporobolus contractus	1.0	11.0
FORBS:			
Leatherweed croton	Croton pottsii	6.0	30.0
Common horehound	Marrubium vulgare	3.0	43.0
Narrowleaf globemallow	Sphaeralcea angustifolia	2.0	31.0
Multiflower puccoon	Lithospermum multiflorum	1.0	15.0
BROWSE:			
Oaks	Quercus spp.	29.0	98.0
Desert ceanothus	Ceanothus greggii	9.0	54.0
Mountain Mahogany	Cercocarpus montanus	2.0	17.0

[1] Occurrence refers to the % of samples/season (N) in which the plant species occurred.

and accounted for 6.0% of the diet. Using rumen analysis, Stevens (1966) reported that elk in Montana utilized browse heavily in July and August, accounting for 43.0% and 17.0% of the summer diet, respectively.

Fall Season

Fecal analysis revealed that 72 plant species were consumed by elk during the fall season (see Appendix B). The diet consisted of 25.0% grasses, 28.0% forbs, and 47.0% browse (Fig. 26). Thirteen major food plants were consumed by elk in amounts of 1.0% or more of the fall sample (Table 21). Oaks (35.0%) consisted of Quercus grisea, Q. undulata, Q. pungens, Q. gambelli, and Q. muhlenbergia. The top ranking 13 plants accounted for 78.0% of the fall diet.

Analysis of these plant species also revealed differences between months within the fall season. Blue grama comprised 13.0% of the late summer diet. As the fall season progressed, utilization of blue grama dropped to 5.0% of the late fall diet. This downward trend may have been due to blue grama curing out and becoming coarse, which decreased its palatability. This trend toward decreased utilization as the season progressed was manifested by all grass species eaten by elk. Forbs, on the other hand, showed a reverse trend in utilization. Common horehound (Marrubium vulgare) increased from 3.0% to 26.0% over the fall season. Plains blackfoot, for the same period, increased from less than 1.0% to 3.0%.

Burt and Gates (1959) described the fall diet of elk in Pecos Basin, New Mexico as 74.0% grasses, 5.4% forbs, and 20.2% browse. Elk diets in southern Colorado were composed of 63.0% grasses, 8.0% forbs, and 29.0% browse (Hansen and Reid 1974). Western wheatgrass was the primary plant

TABLE 21. Thirteen major food plants in the fall diet of elk in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1/] Occurrence (N = 81)
GRASSES:			
Blue grama	Bouteloua gracilis	6.0	63.0
Indiangrass	Sorghastrum avenaceum	3.0	56.0
Wolftail	Lycurus phleoides	3.0	36.0
Littleawn needlegrass	Stipa lobata	2.0	32.0
Curlyleaf muhly	Muhlenbergia setifolia	2.0	27.0
Fowl mannagrass	Glyceria stricta	2.0	13.0
Spike dropseed	Sporobolus contractus	1.0	19.0
FORBS:			
Common horehound	Marrubium vulgare	12.0	51.0
Leatherweed croton	Croton pottsii	9.0	63.0
Narrowleaf globemallow	Sphaeralcea angustifolia	4.0	33.0
Plains blackfoot	Melampodium leucanthum	2.0	30.0
BROWSE:			
Oaks	Quercus spp.	35.0	99.0
Desert ceanothus	Ceanothus greggii	2.0	25.0

[1/] Occurrence refers to the % of samples/season (N) in which the plant species occurred.

consumed during the fall season, accounting for 25.0% of the diet. Harper (1962) reported that the fall diet of Roosevelt elk in California consisted of 56.5% grasses, 22.5% forbs, and 20.9% browse.

Winter Season

Fecal analysis showed that 92 plant species were utilized by elk during the winter season (see Appendix B). The diet consisted of 24.0% grasses, 29.0% forbs, and 48.0% browse (Fig. 26). Fourteen major food plants were consumed by elk in amounts of 1.0% or more of the winter season (Table 22) and accounted for 80.0% of the winter diet. Threeawns (3.0%) comprised of Aristida glauca, A. adscensionis, A. wrightii, and A. pansa. Included in the oaks (31.0%) category were Quercus undulata, Q. grisea, Q. pungens, and Q. gambelli. Junipers (5.0%) consisted of Juniperus deppeana and J. pinchoti.

Analysis of these plants also revealed differences between months within the winter season. Littleawn needlegrass, a cool season species, increased from 1.0% to 8.0% of the diet by the end of the winter season. Concomitant with a decrease in oak utilization due to winter dormancy, junipers showed a marked increase throughout the season. Junipers comprised only 1.0% of the early winter diet but by the season's end accounted for 8.0% of the diet. As winter progressed, common horehound became rank and coarse and its utilization declined accordingly. Common horehound accounted for 27.0% of the early winter diet but had declined to 10.0% by late winter.

Harper (1962) reported that the winter diet for Roosevelt elk in California consisted of 75.9% grasses, 1.4% forbs, and 21.8% browse. Rumen analysis by Burt and Gates (1959) showed that the diet of elk in the Pecos Basin, New Mexico included 70.0% grasses, a trace of forbs, and 30.0% browse. Kufeld

TABLE 22. Fourteen major food plants in the winter diet of elk in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1/] Occurrence (N = 83)
GRASSES:			
Littleawn needlegrass	Stipa lobata	5.0	64.0
Blue grama	Bouteloua gracilis	4.0	70.0
Threeawns	Aristida spp.	3.0	36.0
Wolftail	Lycurus phleoides	2.0	55.0
Curlyleaf muhly	Muhlenbergia setifolia	2.0	29.0
Indiangrass	Sorghastrum avenaceum	1.0	31.0
Western wheatgrass	Agropyron smithii	1.0	22.0
Squirreltail	Sitanion longifolium	1.0	15.0
FORBS:			
Common horehound	Marrubium vulgare	19.0	72.0
Leatherweed croton	Croton pottsii	6.0	35.0
Narrowleaf globemallow	Sphaeralcea angustifolia	3.0	17.0
BROWSE:			
Oaks	Quercus spp.	31.0	97.0
Junipers	Juniperus spp.	5.0	29.0
Rabbitbrush	Chrysothamnus spathulatus	2.0	35.0

[1/] Occurrence refers to the % of samples/season (N) in which the plant species occurred.

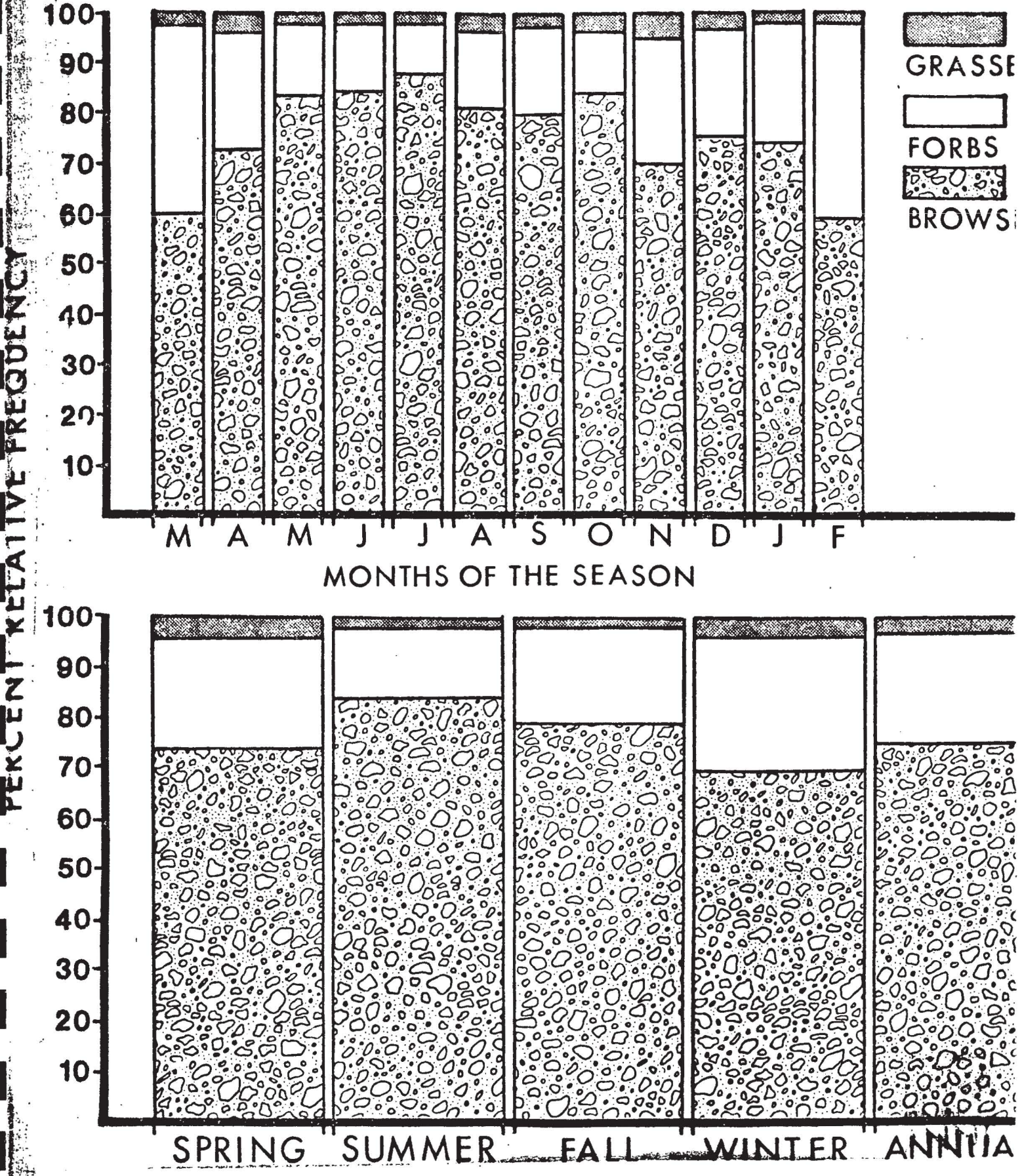


Fig. 28. Monthly and seasonal use of the major forage classes by mule deer in Guadalupe Mountains National Park, Texas.

TABLE 23. Fourteen major food plants in the annual diet of mule deer in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1] Occurrence (N = 353)
FORBS:			
Bladderpods	*Lesquerella* spp.	6.0	22.0
Leatherweed croton	*Croton pottsii*	2.0	21.0
Globemallows	*Sphaeralcea* spp.	2.0	21.0
Flannel mullein	*Verbascum thapsus*	1.0	9.0
Common horehound	*Marrubium vulgare*	1.0	8.0
BROWSE:			
Oaks	*Quercus* spp.	31.0	84.0
Mountain mahogany	*Cercocarpus montanus*	13.0	74.0
Desert ceanothus	*Ceanothus greggii*	10.0	54.0
Junipers	*Juniperus* spp.	7.0	50.0
Apache plume	*Fallugia paradoxa*	4.0	53.0
Skunkbush	*Rhus aromatica*	2.0	9.0
Plume brickellbush	*Brickellia brachyphylla*	1.0	14.0
Littleleaf sumac	*Rhus microphylla*	1.0	16.0
Sandpaper bush	*Mortonia scabrella*	1.0	11.0

[1] Occurrence refers to the proportion of diet samples/year (N) in which the plant species occurred.

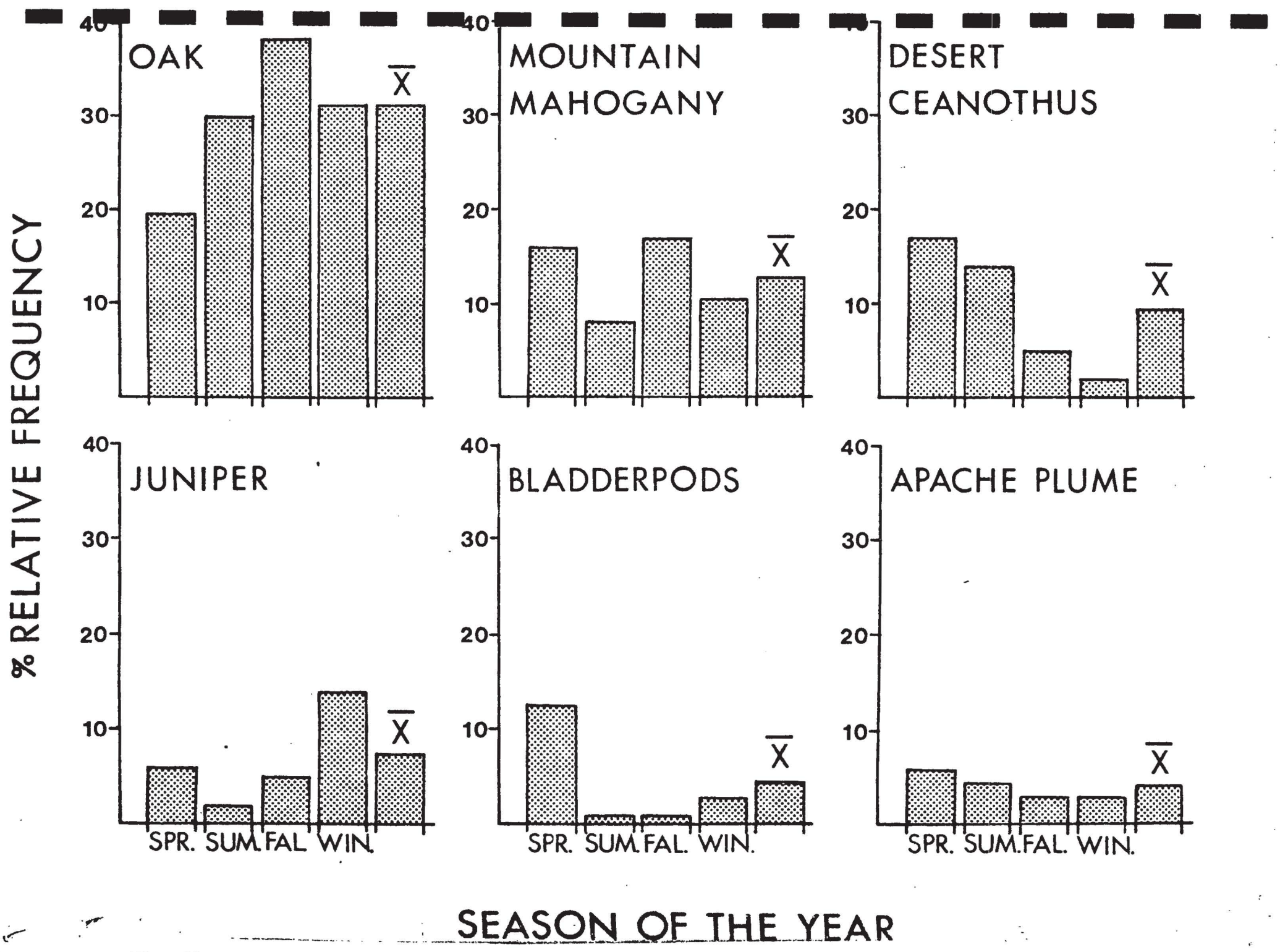


Fig 29 Seasonal utilization of [illegible]

(1973) found the average winter diet of elk in Montana to be composed of 84.0% grasses, 8.0% forbs, and 9.0% browse. Hansen and Reid (1974) reported the winter diet of elk in southern Colorado consisted of 74.0% grasses, 8.0% forbs, and 18.0% browse. They also found that western wheatgrass, needlegrasses, and bromes (Bromus spp.) were the heaviest used forage plants and accounted for 63.0% of the winter diet. Whereas, Trout and Leege (1971) reported that elk in Idaho utilized 82.0% browse, 22.0% of which was conifer species. Similarly, Lang (1958) found that elk in New Mexico consumed 95.0% browse in the winter months. He also found that mountain mahogany and oak were the primary plants eaten during this season comprising 32.8% and 16.0%, respectively.

Visual Analysis

Of the 1259 feeding observations made in GMNP over the study period, 61 plant species were identified as being consumed by elk. Grass comprised 48.0% of the annual diet and were used heaviest during the summer and fall seasons. Blue grama, western wheatgrass, wolftail, threeawns, sideoats grama, and littleawn needlegrass comprised the majority of the dietary grass component. Forbs were predominantly consumed during the winter season and accounted for 16.0% of the annual diet. Common horehound, leatherweed croton, and globemallows were the most abundant forb species consumed. Browse accounted for 36.0% of the annual diet and was used heaviest during the spring season. Oak, desert ceanothus, mountain mahogany, juniper, and skunkbush were the predominant browse species utilized by elk during the study period. Agave spp. flower stalks were taken readily during the spring and summer seasons when available. Murie (1951) also reported that elk in

Guadalupe Mountains, Texas utilized Agave flower stalks. These results were similar to those obtained by fecal analysis.

MULE DEER

Fecal Analysis

Annual Diet

Analysis of 353 fecal samples showed 156 plant species in the mule deer diet from March, 1978 through February, 1979 (Appendix C). The average annual diet for mule deer in GMNP consisted of 2.0% grasses, 21.0% forbs, and 77.0% browse (Fig. 28). Fourteen major food plants, consumed by mule deer in amounts of 1.0% or more, accounted for 81.0% of the annual diet (Table 23). The 6.0% bladderpod component was composed of Lesquerella fendleri, L. vallida, and L. gordoni, and the 1.0% globemallows category consisted of Sphaeralcea coccinea, and S. angustifolia. The 31.0% oaks included Quercus grisea, Q. pungens, Q. undulata, Q. gambelli, and Q. muhlenbergia, with the 6.0% junipers consisting of Juniperus deppeana, J. pinchoti, J. monosperma, and J. scopulorum. Monthly utilization of the top 6 forage plants consumed by mule deer is shown in Figure 29.

Browse was the major forage type taken by mule deer in all seasons. Oaks, mountain mahogany, and desert ceanothus were the dominant browse plants utilized throughout the year comprising 54.0% of the annual diet. Heavy usage of oaks has been attributed to their maintaining a high protein level throughout the year (Swank 1958). Forbs were consumed by mule deer predominantly during winter and spring seasons with cool season species forming the majority of the forb component. Mule deer utilized grasses

primarily during the summer season. Littleawn needlegrass and Muhlenbergia spp. were the only species of an appreciable amount in the grass component of the annual diet of mule deer.

The relative availability of major browse plants consumed by mule deer was used to calculate a selection index (Table 24). Results indicated that mule deer were selective feeders throughout the year. Mule deer showed extreme selectivity for oaks during all seasons except the spring. As previously stated, oaks were the major forage component consumed by mule deer throughout the year. Mountain mahogany showed the highest non-selection of any of the plants during the summer season. Snyder (1961) has shown that crude protein is lowest in mahogany during the summer. The high selection for junipers during the winter season was considered to be a response to decreased foliage availability among other forage plants. The selection index showed a general non-selection trend toward browse during the spring and winter seasons. Dietary results also showed a similar trend for browse plants during these same seasons. This was due in part to defoliation and dormancy of some browse plants, along with increased cool season forb production.

The average annual diet for Rocky Mountain mule deer calculated over its entire range has been broken down into 15.0% grasses, 28.0% forbs, and 57.0% browse (Kufeld et al. 1973). Mule deer diets in GMNP contained substantially more browse and less grass. However, Anderson et al. (1965) found mule deer in the Guadalupe Mountains of New Mexico utilized 4.0% grasses, 26.0% forbs, and 70.0% browse. Rumen analysis conducted on the Fort Bayard Administrative site, located in southwestern New Mexico, also showed mule deer diets consisted of approximately 2.2% grasses, 1.0% forbs, and 75.0% browse (Boeker et al.

TABLE 24. Selecting Index for the 6 browse plants forming bulk of the annual diet for mule deer in Guadalupe Mountains National Park, Texas.

Common name	Scientific name	Dietary Use (Selective Index)					Availability (%)
		Annual	Spring	Summer	Fall	Winter	
Junipers	*Juniperus* spp.	9 (8)	8 (7)	2 (1)	5 (4)	20 (19)	1.0
Apache plume	*Fallugia paradoxa*	6 (5)	8 (7)	5 (4)	4 (3)	4 (3)	1.0
Desert ceanothus	*Ceanothus greggii*	13 (6)	22 (15)	16 (9)	7 (1)	3 (-4)	7.0
Oaks	*Quercus* spp.	42 (14)	27 (-1)	43 (15)	48 (20)	46 (18)	28.0
Mountain mahogany	*Cercocarpus montanus*	17 (-3)	21 (1)	10 (-10)	21 (1)	15 (-5)	20.0
Skunkbush	*Rhus aromatica*	3 (0)	T[1/] (-2)	7 (4)	4 (1)	1 (-2)	3.0

[1/] T = trace (< 1.0%)

Selection Index (< 0) shows non-selection

Selection Index (> 0) shows selection

1972). Keller (1975) described the annual diets of mule deer occupying the desert shrub areas in Pecos County, Texas as consisting of 3.4% grasses, 42.3% forbs, and 45.1% browse.

Boeker et al. (1972) determined that oaks and mountain mahogany comprised 56.0% of the annual diet in mule deer in southwestern New Mexico. Anderson et al. (1965) reported that wavyleaf oak, junipers, hairy cercocarpus (Cercocarpus montanus) and yucca species contributed 54.0% to the annual diet. Stewart (1959) determined that oaks, junipers, mountain mahogany, and ceanothus comprised 42.49% of the year long diet for mule deer in the Capitan Mountains, New Mexico. He reported that oaks accounted for 27.42% of the annual diet and was the primary browse plant consumed.

Spring Season

Fecal analysis revealed that 72 plant species were consumed by mule deer during the spring season (see Appendix C). The diet consisted of 3.0% grasses, 23.0% forbs, and 74.0% browse (Fig. 28). Ten major food plants taken by mule deer in amounts of 1.0% or more (Table 25), accounted for 85.0% of the total sample from the spring diet. Bladderpods (12.0%) consisted of Lesquerella fendleri, L. vallida, and L. gordoni. Oaks (20.0%) recorded in the diet were Quercus grisea, Q. undulata, Q. gambelli, Q. pungens, and Q. muhlenbergia, and the junipers (6.0%) comprised Juniperus deppeana, J. pinchoti, and J. monosperma.

Analysis of the occurrence of these plants also revealed differences between months within the spring season. Oaks only accounted for 1.0% of the sample in early spring due to winter dormancy, but increased to 47.0% of the diet

TABLE 25. Ten major food plants in the spring diet of mule deer in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1/] Occurrence (N = 88)
FORBS:			
Bladderpods	Lesquerella spp.	12.0	37.0
Grandleaf milkwort	Polygala macradenia	3.0	28.0
BROWSE:			
Oaks	Quercus spp.	20.0	66.0
Desert ceanothus	Ceanothus greggii	17.0	72.0
Mountain mahogany	Cercocarpus montanus	16.0	83.0
Apache plume	Fallugia paradoxa	6.0	61.0
Junipers	Juniperus spp.	6.0	48.0
Sandpaper bush	Mortonia scabrella	2.0	15.0
Littleleaf sumac	Rhus microphylla	2.0	37.0
Pinyon pine	Pinus edulis	2.0	27.0

[1/] Occurrence refers to the % of diet samples/season (N) in which the plant species occurred.

by late spring due to leaf development as the season progressed. Concomitant with the increase of oaks, desert ceanothus showed a reverse trend, with the 28.0% consumed in early spring declining to 6.0% by the end of this season. Bladderpods and grandleaf milkwort (Polygala macradenia) made up 21.0% and 5.0%, respectively of the early spring sample. These cool season forbs were most abundant on the study area in late winter and early spring. With the advent of warmer temperatures, availability decreased and mule deer fecal samples taken in late spring showed only 4.0% bladderpods and less than 1.0% grandleaf milkworts in the diet.

Boeker et al. (1972) found that browse contributed 50.0% to the spring diet of mule deer in southwestern New Mexico. They also found that oaks and birchleaf mountain mahogany (Cercocarpus breviflorus) were the predominant plants eaten. Anderson et al. (1965) concluded that junipers, birchleaf mountain mahogany, and yuccas were the important plants eaten by mule deer in the Guadalupe Mountains of New Mexico and comprised 57.0% of the spring diet. Stewart (1959), working on mule deer in the Capitan Mountains of New Mexico, found that oaks comprised 5.0% of the early spring diet and steadily increased to 65.0% by late spring.

Kittams et al. (1975) reported that during a drought period in late spring 1969, mule deer ate an excessive amount of leaves and bark from madrone trees in McKittrick Canyon, GMNP. Texas Parks and Wildlife Department harvested 4 mule deer in McKittrick Canyon on June 16, 1969. Analysis of paunches revealed that madrone comprised 7.0% of the total sample. The present study was conducted during an exceptionally wet year and madrone was not recorded in fecal or rumen samples. However, mule deer were visually recorded eating tender madrone sprouts during the summer season.

Summer Season

Analysis of fecal samples showed that 99 plant species were ingested by mule deer during the summer season (see Appendix C). The diet consisted of 1.0% grasses, 14.0% forbs, and 85.0% browse (Fig. 28). Table 26 shows the 13 major food plants taken by mule deer in amounts of 1.0% or more of the samples; these accounted for 84.0% of the summer diet. Globemallows (2.0%) recorded were Sphaeralcea coccinea, and S. angustifolia. Oaks (40.0%) recorded in the diet were Quercus grisea, Q. undulata, Q. pungens, and Q. muhlenbergia, and the junipers (2.0%) consisted of Juniperus deppeana, and J. pinchoti. Viguiera spp. (1.0%) recorded were V. stenoloba and V. dentata.

Detailed examination of plant occurrence revealed differences between months within the summer season. The warm summer temperatures and increased photoperiod stimulated browse species to develop succulent new shoots. Desert ceanothus, which had declined to 6.0% of the diet by late spring, showed an upward trend and by late summer accounted for 22.0% of the diet. Skunkbush accounted for less than 1.0% of the late spring diet because leaf material was unavailable. However, by early summer the proportion of skunkbush in the diet had increased to 9.0% due to increased availability of leafy growth. As summer progressed, the amount of skunkbush in the diet decreased again to 2.0%. Mountain mahogany was consumed throughout the spring season averaging 16.0% of the diet, but by the end of the summer season this species had dropped to 4.0% of the diet.

Boeker et al. (1972) stated that the summer diet of mule deer in southwestern New Mexico consisted of 2.0% grasses, 44.0% forbs, and 54.0% browse. They reported oaks and birchleaf mountain mahogany were the predominant plants consumed and accounted for 31.0% of the summer diet. They

TABLE 26. Thirteen major food plants in the summer diet of mule deer in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1/] Occurrence (N = 85)
FORBS:			
Globemallows	Sphaeralcea spp.	2.0	24.0
Leatherweed croton	Croton pottsii	1.0	17.0
BROWSE:			
Oaks	Quercus spp.	38.0	93.0
Desert ceanothus	Ceanothus greggii	15.0	72.0
Mountain mahogany	Cercocarpus montanus	8.0	65.0
Skunkbush	Rhus aromatica	6.0	43.0
Apache plume	Fallugia paradoxa	4.0	67.0
Junipers	Juniperus spp.	2.0	37.0
Littleleaf sumac	Rhus microphylla	2.0	34.0
Big Bend silverleaf	Leucophyllum minus	1.0	10.0
Sandpaper bush	Mortonia scabrella	1.0	11.0
Plume brickellbush	Brickellia brachyphylla	1.0	11.0
	Viguiera sp.	1.0	20.0

[1/] Occurrence refers to the proportion of diet samples/season (N) in which the plant species occurred in the diet.

also described trends similar to those found in this study for utilization of skunkbush by mule deer. Keller (1975) reported that honey mesquite, littleleaf sumac, and Dalea spp. comprised the bulk of the summer diet for mule deer in Pecos County, Texas. Anderson et al. (1965) found that oaks, curlyleaf mountain mahogany, and yuccas accounted for 55.0% of the summer diet of mule deer in the Guadalupe Mountains of New Mexico.

Fall Season

Fecal analysis showed that 100 plant species were consumed by mule deer during the fall season (see Appendix C). The diet consisted of 2.0% grasses, 19.0% forbs, and 79.0% browse (Fig. 28). Thirteen major food plants were taken by mule deer in amounts of 1.0% or more of the sample (Table 27). Globemallows (2.0%) consisted of Sphaeralcea coccinea, and S. angustifolia, and zinnias (1.0%) included Zinnia acerosa, and Z. grandiflora. Oak species (43.0%) represented were Quercus grisea, Q. undulata, Q. pungens, Q. gambelli, and Q. muhlenbergia, and junipers (4.0%) recorded were Juniperus deppeana, J. pinchoti, J. monosperma, and J. scopulorum. The top 13 plants accounted for 87.0% of the fall diet.

Analysis of these plant species again revealed differences between months within the fall season. Utilization of skunkbush increased from 2.0% in late summer to 5.0% in early fall, but cooler temperatures caused defoliation and dietary use dropped to less than 1.0% by the end of the season. Viguiera spp. showed a similar trend; it accounted for 2.0% of the early fall diet but was negligible in the diet by the season's end. With the advent of cooler temperatures, many browse species entered winter dormancy. As a

TABLE 27. Thirteen major food plants in the fall diet of mule deer in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1] Occurrence (N = 91)
FORBS:			
Leatherweed croton	Croton pottsii	3.0	35.0
Flannel mullein	Verbascum thapsus	3.0	17.0
Globemallows	Sphaeralcea spp.	2.0	32.0
Zinnias	Zinnia spp.	1.0	24.0
Wavey cloakfern	Notholaena sinuata	1.0	15.0
Common horehound	Marrubium vulgare	1.0	18.0
BROWSE:			
Oaks	Quercus spp.	38.0	96.0
Mountain mahogany	Cercocarpus montanus	17.0	74.0
Desert ceanothus	Ceanothus greggii	5.0	46.0
Junipers	Juniperus spp.	4.0	49.0
Skunkbush	Rhus aromatica	3.0	36.0
Apache plume	Fallugia paradoxa	3.0	51.0
Plume brickellbush	Brickellia brachyphylla	2.0	19.0

[1] Occurrence refers to the proportion of diet samples/season (N) in which the plant species occurred.

result, junipers increased from less than 1.0% to 9.0% of the diet by the end of this season. Flannel mullein was not recorded as eaten in early fall but comprised 6.0% of the late fall diet. This probably occurred because flannel mullein was one of the few green forb species available to mule deer during the late fall season.

Anderson et al. (1965) reported that wavyleaf oak and mountain mahogany accounted for 44.6% of the fall diet consumed by mule deer in the Guadalupe Mountains of New Mexico. Similarly, Boeker et al. (1972) found that oaks and birchleaf mountain mahogany comprised 72.2% of the fall diet for mule deer in southwestern New Mexico. Emory oak (Quercus emoryi) and Dalea spp. were the primary food plants in the diet of mule deer in Pecos County, Texas (Keller 1975).

Winter Season

Fecal analysis showed 85 species of plants in mule deer diets during the winter season (see Appendix C). The diet contained 2.0% grasses, 28.0% forbs, and 70.0% browse (Fig. 28). Fourteen major food plants were selected by mule deer in amounts of 1.0% or more of the sample (Table 28). Bladderpods (10.0%) recorded were Lesquerella fendleri, and L. vallida, and the globemallows (1.0%) consisted of Sphaeralcea angustifolia, and S. coccinea. The zinnias (1.0%) consisted of Zinnia acerosa and Z. grandiflora. Oaks (34.0%) consisted of Quercus grisea, Q. undulata, Q. pungens, and Q. muhlenbergia, and junipers (13.0%) included Juniperus deppeana, J. pinchoti, and J. monosperma. The top 14 plants accounted for 84.0% of the winter diet.

Examination of the data indicated differences between months within the winter season. Oaks were heavily utilized at first, accounting for 57.0% of the early winter diet, but due to defoliation by late winter had declined to 8.0%. Concomitantly, junipers during this period rose from 8.0% in December to 20.0% in February. Mountain mahogany increased from 4.0% to 16.0% of the diet throughout this sampling period. Bladderpods, which are late winter-early spring forbs, also increased from 7.0% to 21.0% of the diet by the end of the winter season.

Anderson et al. (1965) reported junipers were utilized most heavily by mule deer in the Guadalupe Mountains of New Mexico during the winter season, contributing 20.7% of the diet. Similar results were reported from CCNP (Kittams et al. 1975). Stewart (1959) found mule deer in the Capitan Mountains, New Mexico, utilized whitesage (Artemisia ludoviciana) heaviest during the winter months when it comprised 3.8% of the diet, and this species made up 2.35% of the annual diet in that area. Whitesage accounted for only 1.0% of the winter diet in this study.

Rumen Analysis

A total of 84 food plants were identified in 36 paunches of mule deer collected in GMNP during all seasons. Grasses made up 2.0%, forbs 28.0%, and browse 75.0% of the annual diet for mule deer in the park with this technique. Littleawn needlegrass and western wheatgrass were the only grass species that comprised more than 1.0% of the grass component in the diet. Rumen analysis reflected that forbs were utilized predominantly during the winter and spring season. Bladderpods, globemallows, leatherweed croton,

flannel mullein, and multiflower puccoon (Lithospermum multiflorum) were forbs that comprised 1.0% or more of the annual diet. These results are similar to those determined by fecal analysis, with the single exception of multiflower puccoon which only contributed a trace to the annual diet in the latter analysis. Browse was again the major constituent of the mule deer diet and rumen analysis revealed that oak, mountain mahogany, desert ceanothus, and juniper were the dominant browse plants consumed by mule deer on an annual basis (Table 29). These rumen analyses also in agreement with the food habits determined from fecal analysis. Selection for certain plant parts was evident, with the bulk of food material consisting of leaves. Nutritional analysis ahs shown that leaves of most plants contain a higher percentage of crude protein than either stems or flowers (Aldous 1945).

Visual Analysis

Of the 1341 feeding observations made in GMNP over the study period, 67 plant species were identified as eaten by mule deer. Grasses comprised 5.0% of the annual diet. Blue grama, western wheatgrass, Muhlenbergia spp. and littleawn needlegrass comprised the majority of the grass component. Forbs accounted for 22.0% of the annual diet, with globemallow, leatherweed croton, and flannel mullein being the major species consumed. These results were similar to those determined by fecal and rumen analysis. Browse species dominated the diets of mule deer in all seasons, accounting for 73.0% of the annual diet. Oak, mountain mahogany, desert ceanothus, juniper, and apache plume were the predominant browse plants utilized by mule deer during the

TABLE 28. Fourteen major food plants in the winter diet of mule deer in Guadalupe Mountains National Park, Texas.

Food plants		Relative Frequency	Percent [1/] Occurrence (N = 89)
FORBS:			
Bladderpods	Lesquerella spp.	10.0	51.0
Leatherweed croton	Croton pottsii	3.0	40.0
Common horehound	Marrubium vulgare	2.0	16.0
Flannel mullein	Verbascum thapsus	1.0	18.0
Globemallows	Sphaeralcea spp.	1.0	28.0
Zinnias	Zinnia spp.	1.0	26.0
Whitesage	Artemisia ludoviciana	1.0	18.0
BROWSE:			
Oaks	Quercus spp.	31.0	81.0
Junipers	Juniperus spp.	13.0	66.0
Mountain mahogany	Cercocarpus montanus	10.0	73.0
Apache plume	Fallugia paradoxa	3.0	34.0
Desert ceanothus	Ceanothus greggii	2.0	25.0
Plume brickellbush	Brickellia brachyphylla	1.0	25.0
Sandpaper bush	Mortonia scabrella	1.0	17.0

[1/] Occurrence refers to the proportion of diet samples/season (N) in which the plant species occurred.

TABLE 29. Seasonal and annual relative frequencies of plants identified from 36 mule deer rumens collected in Guadalupe Mountains National Park, Texas.

Food plants		Spring (N=8)	Summer (N=8)	Fall (N=8)	Winter (N=12)	Annual (N=36)
GRASSES:						
Littleawn needlegrass	*Stipa lobata*	1.4	T	T	2.1	T
Western wheatgrass	*Agropyron smithii*	1.1	---	---	T	T
FORBS:						
Bladderpods	*Lesquerella* spp.	10.8	T	---	5.0	4.0
Flannel mullein	*Verbascum thapsus*	2.5	---	3.7	1.9	2.2
Leatherweed croton	*Croton pottsii*	2.3	2.3	1.7	1.6	2.0
Spinyleaf zinnia	*Zinnia acerosa*	1.8	1.1	1.2	1.3	1.4
Grandleaf milkwort	*Polygala macradenia*	1.4	---	---	T	T
Narrowleaf globemallow	*Sphaeralcea angustifolia*	1.4	4.0	2.0	1.9	2.3
Multiflower puccoon	*Lithospermum multiflorum*	1.1	2.1	1.2	T	1.2
Scarlet globemallow	*Sphaeralcea coccinea*	1.1	T	---	---	T
Spreading sida	*Sida filacaulis*	---	1.1	---	---	T
White sage	*Artemisia ludoviciana*	---	---	3.8	---	T
Wavey cloakfern	*Notholaena sinuata*	---	---	2.3	1.3	T

TABLE 29. Seasonal and annual relative frequencies of plants identified from 36 mule deer rumens collected in Guadalupe Mountains National Park, Texas (continued).

Food plants		Spring (N=8)	Summer (N=8)	Fall (N=8)	Winter (N=12)	Annual (N=36)
Common horehound	Marrubium vulgare	---	---	---	1.9	T
Hawkweed wildbuckwheat	Eriogonum hieracifolium	---	---	---	1.3	T
BROWSE:						
Oaks	Quercus spp.	27.7	40.5	45.7	29.3	36.3
Mountain mahogany	Cercocarpus montanus	9.2	12.2	13.1	8.4	10.7
Desert ceanothus	Cenothus greggii	7.2	9.3	4.9	2.9	6.1
Junipers	Juniperus spp.	9.7	1.5	4.0	19.2	8.7
Littleleaf sumac	Rhus microphylla	4.5	2.1	1.4	T	2.1
Apache plume	Fallugia paradoxa	2.9	2.7	2.9	2.3	2.7
Sotol	Dasylirion leiophyllum	1.4	---	---	---	T
Skunkbush	Rhus aromatica	1.1	3.2	3.2	---	1.9
Feather dalea	Dalea formosa	1.1	---	---	T	T
Sandpaper bush	Mortonia scabrella	---	3.0	---	T	T
Skeleton goldeneye	Viguiera stenoloba	---	1.0	---	T	T

1/ N = No. of rumens in sample

2/ T = traces accounted for (< 1.0%) of the diet

study period. Observations also showed a preference for leaf material, and flower parts of some species during certain seasons of the year. There were no appreciable differences between the results of the various techniques used when data were compared on a forage class and individual basis (Table 30).

ELK-MULE DEER DIETARY OVERLAP

The overall dietary similarity indices suggest that generally the overlap between elk and mule deer was non-competitive for all seasons (Table 31). However, more detailed analysis showed a high degree of overlap in the browse component during all seasons except in summer. Elk and mule deer relied heavily on browse forages throughout the year. Among the browse, oaks were predominant, accounting for 31.0% of the annual diets for both elk and mule deer. Mountain mahogany, desert ceanothus, and junipers comprised the majority of the remaining dietary browse component for both ungulates. Our data produced a browse similarity index of 78.0% on all annual basis, with the highest seasonal overlap occurring in the spring diet (similarity index = 91.0%). This was a response by both species to new browse growth in spring, prior to initial growth of the grasses. With growth and foliation of the grasses in late spring and early summer, the elk diet changed toward grasses, hence the observed drop in the summer browse similarity index (Table 31).

Annual diet similarity indices for forbs and grasses were low, averaging 37.0% and 13.0% respectively. Forbs in the diets of elk and mule deer overlapped primarily in the summer and winter season, while the overlap for grasses was greatest during the fall and winter season (Table 31).

TABLE 30. Comparison of the annual diet relative frequencies between 3 food habit techniques for the 14 major food plants utilized by mule deer in Guadalupe Mountains National Park, Texas.

Common name		Fecal (N=353) (%)	Rumen (N=36) (%)	Visual (N=1341) (%)
FORBS:				
Bladderpods	*Lesquerella* spp.	6.00	4.00	3.00
Leatherweed croton	*Croton pottsii*	2.00	2.00	1.00
Globemallows	*Sphaeralcea* spp.	2.00	2.00	2.00
Flannel mullein	*Verbascum thapsus*	1.00	2.00	1.00
Zinnias	*Zinnia* spp.	0.65	1.40	----
Multiflower puccoon	*Lithospermum multiflorum*	0.12	1.20	----
BROWSE:				
Oaks	*Quercus* spp.	31.00	36.00	23.00
Mountain mahogany	*Cercocarpus montanus*	13.00	12.00	14.00
Desert ceanothus	*Ceanothus greggii*	9.00	6.00	10.00
Junipers	*Juniperus* spp.	7.00	9.00	7.00
Apache plume	*Fallugia paradoxa*	4.00	3.00	4.00
Skunkbush	*Rhus aromatica*	2.00	2.00	2.00
Plume brickellbush	*Brickellia brachyphylla*	1.00	0.22	0.57
Sandpaper bush	*Mortonia scabrella*	1.00	0.88	0.52

Table 31. Weighted similarity indices between mule deer and elk on a seasonal basis, following Kulcynski's formula (plant species < .05% in the diet were not included in calculations).

	Spring	Summer	Fall	Winter	Annual
Browse	91.0	65.0	75.0	75.0	78.0
Forb	24.0	59.0	25.0	35.0	37.0
Grass	8.0	5.0	16.0	13.0	13.0
OVERALL INDEX VALUE	60.0	55.0	57.0	60.0	67.0

Hansen and Reid (1974) found the overall dietary overlap between mule deer and elk in southern Colorado ranged from 3.0% in winter to 48.0% during the summer season. Data from the present study suggest a greater dietary overlapping during winter than did the work of Hansen and Reid (1974). This would indicate that in GMNP there may be a greater potential for competition between mule deer and elk during this season than recorded for southern Colorado. At the present time browse quantity does not appear to be a limiting factor to either ungulate population size. However, should the browse resource continue its present downward trend, competition between mule deer and elk may increase. This will inevitably result in further downgrading of the range condition and a gradual reduction of the preferred browse species.

In other regions of the country, elk diets consisted primarily of grass species (DeNio 1938, Morris and Schwartz 1957, Harper 1962, Hansen and Reid 1974). Thus, elk have the potential to undergo a dietary shift and utilize a higher percentage of the available grass component should interspecific competition for browse become severe, but at this time browse was preferred to grasses by elk in GMNP.

IMPACT ON VEGETATION

One of the significant features of GMNP is that it contains relic species of plants from the Rocky Mountain flora as well as from the Chihuahuan desert, and as such, forms a vegetation complex found nowhere else in the United States. A large number of these relics are browse species considered important forage plants for the elk and mule deer which occupy the area.

Because of the uniqueness of this ecosystem, the interrelationship of these herbivores with the vegetation is of major importance to managers charged with preservation in GMNP.

To this end, the availability of the vegetation and % utilization of selected major browse plants consumed by mule deer and elk in GMNP were assessed during this study. Trends in browse condition, understory vegetation and soil stability were also evaluated (see Appendix A); comparison with data from a previous study (Glass et al. 1974) permitted measurement of the impact of animals on the vegetation over the past 6 years.

BROWSE ANALYSIS

Dog Canyon Range

Eleven permanent transects, established in 1973, in the Mountain Shrub and Pinyon-Juniper habitat types were re-evaluated during the study. Browse composition remained in the same medium condition as was measured in 1973, but the percentage of good-browse species decreased slightly. Browse density ratings also remained unchanged, but showed a significant ($P < 0.05$) downward trend when compared to 1973 data. Browse vigor continued to have a low rating but did show a significant ($P < 0.05$) upward trend over the same period. Although the understory rating was high, it showed a slight downward trend from 1973. Browse availability and soil stability remained in high condition, but soil stability showed a slight downward trend when compared to earlier evaluations.

Observations taken during sampling indicated an upward trend in browse vigor. Young good-browse species were frequent in the transect areas and

the severe hedging on good-browse species reported in 1973 appeared to have decreased. Fair-browse species showed moderate use while poor-browse species exhibited little or no signs of utilization. Soil erosion was apparent only in localized sites.

Front Country Range

Thirteen permanent transects in this sector, most of which were in the Mountain Shrub and Desert Shrub communities, were re-examined to evaluate vegetation trends. Browse composition for the area remained in low condition with a significant ($P < 0.05$) downward trend since 1973 for the whole area. Browse vigor remained in the same low condition as recorded in 1973. Availability and soil stability both received high rating and showed a slight upward trend.

General examination of the areas surrounding the transects indicated a slight overall downward trend. Young, good-browse species were frequent in the sample area, but showed signs of moderate to heavy utilization. Established good-browse species were usually heavily utilized, although some mature specimens of mountain mahogany seemed to be unused by wildlife. This situation may be related to phenotypic differences exhibited by individual plants. Fair-browse species were also showing signs of moderate to heavy hedging but poor-browse species showed only light utilization. Soil movement and erosion again was apparent only in localized areas.

High Country Range

Seven permanent transects were re-evaluated in the spring of 1979. Browse composition remained in high condition, but showed a downward trend from 1973,

particularly for good-browse species. Browse density continued with a medium rating, but also showed a significant ($P < 0.05$) downward trend. Browse vigor for the area was in low condition, and revealed only a slight downward trend from 1973. Browse availability and soil stability continued to be rated high, but a significant ($P < 0.05$) downward trend was noted for soil stability. Understory vegetation again received a high rating, although a definite downward trend was also indicated.

General observations taken during the sampling period also indicated an overall downward trend. Young good-browse species were scarce in the transect areas and those present were heavily utilized. There were also numerous decadent plants in the sampling area. Use on fair-browse species was moderate to heavy while poor-browse species only showed light utilization.

West Side Range

Five permanent transects were re-examined in the Desert Shrub vegetation type and results compared to 1973 data. Browse composition remained low and showed a slight downward trend, with good-browse species also declining in % composition. Browse density continued to have a low rating and showed a significant ($P < 0.05$) downward trend. Browse vigor for the area also remained low and revealed a slight downward trend. Understory vegetation was rated low and showed a definite downward trend. Browse availability and soil stability again received high ratings, but a slight downward trend was noted for soil stability.

General observations made during the re-evaluation period indicated an overall downward trend. There were few young good-browse species present in the transect area. Also, most of the good-browse plants in the area were heavily utilized. Furthermore, some poor-browse species were showing signs of moderate utilization. Soil movement and erosion were apparent in the area and little restoration was noted.

BROWSE EXCLOSURES

Results obtained from analyses of the clipping data indicated a strong potential for overuse of major browse species by herbivores in the National Park. Utilization of major browse species was heavy and, when compounded with the constant threat of drought common in the Southwest, many browse plants may have vanished from the vegetation complex.

Only a limited amount of work has been conducted in the Southwest on the relationships between herbivore utilization and it's impact on browse production and vigor, so little is known of the long-term effects of browse over-utilization. However, the findings of this study clearly indicated that future management planning should be cognizant of the potential disastrous effects of overuse.

Comparison of the average leader production for caged and uncaged mountain mahogany plants revealed that utilization on this species was heavy, averaging 74.20 $\pm$ 8.10% (Table 32). Garrison (1953) speculated that the safe level of use for curlyleaf mountain mahogany (Cercocarpus ledifolius) in the Pacific Northwest was between 50.0 and 60.0%, and that a high degree of use may be necessary to keep browse available to grazing herbivores. He

Table 32. Summary of annual leader production (g/plant) in caged and uncaged specimens and utilization (%) of 5 browse plants utilized by mule deer and elk in Guadalupe Mountains National Park, Texas.

Plant species	Number of pairs	Annual leader Production (g/plant)		Utilization
		Caged	Uncaged	%
Mountain mahogany	20	29.12	7.17 **	74.20 ± 8.10
Desert ceanothus	20	18.85	5.67 **	66.75 ± 8.74
Apache plume	20	11.30	2.43 **	66.75 ± 1.70
Cliff fendlerbrush	10	5.20	2.80 *	17.00 ± 9.39
Hitchcock's mockorange	10	2.35	1.13 *	12.30 ± 6.93

* Significant at $P < 0.05$ level.

** Significant at $P < 0.001$ level.

also noted that heavy utilization (> 60%) increased stem production temporarily, but that after a few years vitality declined. Garrison (1953) also reported a decrease in seed production under sustained heavy utilization. Observations on mountain mahogany in the park indicate that seed production was depressed throughout the study period. On the other hand, Shepherd (1956) simulated 80.0% use of annual growth on mountain mahogany for a 6 year period in Colorado and found no reduction in forage production. Thus, mountain mahogany may be tolerant to heavy browsing in some regions of the United States, while being sensitive to overuse in other areas. If a decrease in seed production is indicative of reduced vigor through overuse, plants in the park are apparently under excessive browsing pressure at the present time.

Desert ceanothus production also showed a significant difference between caged and uncaged plants (Table 32). Utilization on this species was heavy, averaging 66.75 $\pm$ 8.74%. Swank (1958) found the desert ceanothus in Arizona could not withstand continuous heavy browsing which could result in plant mortality. Observations throughout the park indicated a large proportion of ceanothus plants were either dead or decadent. These conditions indicated that continued heavy use could eliminate ceanothus from the forage complex.

The average leader production for caged and uncaged Apache plume is shown in Table 32. Utilization on this plant was heavy, averaging 68.75 $\pm$ 1.70%. However, research has shown that Apache plume has a fair potential for recovery following sustained heavy utilization (Judd 1962).

Utilization of both cliff fendlerbrush and Hitchcock's mockorange was light, averaging 17.0 $\pm$ 9.93% and 23.3 $\pm$ 6.93% respectively (Table 32). No research has been conducted on how these plants react under a continuous heavy browsing regime, but Garrison (1972) has hypothesized that many browse

species can be used safely up to 50.0% removal of annual growth.

BROWSE UTILIZATION

The browse utilization survey conducted to assess trends in vegetation, indicated that of the 37 transects established in the park in 1973 and reassessed during this study, 14 showed an upward trend in vegetation, 6 showed no-change, and 17 declined in vegetation condition. The latter group was surprising in light of the fact that most livestock had been removed from the park in the late 1960's, and there apparently had been no increases in elk and mule deer numbers in the interim period. Removal of livestock grazing pressures alone should have resulted in some degree of range rehabilitation. The absence of increased ungulate populations should have enhanced further conditions for range improvement, despite the semiarid environment in this region.

In fact, the Dog Canyon - West Dog Canyon Range was the only area of the park which showed improvement in overall range condition. It should be noted that this area contained a single permanent water source, the spring at Dog Canyon. Temporary water was available seasonally in several earthen tanks. As a result, elk and mule deer utilization of much of this range was seasonal and, in effect, a deferred grazing system emerged, dependent on local water availability. Long periods of minimal utilization were interspersed with high intensity use when water became available away from the permanent spring. Thus, it is reasonable that the range condition in this area would have improved since 1973 under these utilization patterns.

Examination of possible causative factors for lack of change or downward trends observed on 23 of the re-assessed transects indicated that distance from permanent water provided a possible explanation (Fig. 30). With removal of livestock from the park, man-made water points such as The Bowl tank, Cox tank, and several other earthen tanks had been abandoned, became silted up, and no longer provided water for wildlife for more than limited periods. This resulted in greater concentrations of elk and mule deer around the remaining permanent water sources, placing heavier utilization pressure on adjacent vegetation. This vegetation was therefore essentially under a continuous grazing regime and range rehabilitation could not be expected to take place.

Thus, the major ungulate impact areas in the park were closely linked to permanent water sources (Fig. 30), and the data presented on habitat and movement substantiated this fact. These latter results showed that 60.0% of all elk sightings were within 1.6 km radius of permanent water. Mule deer were even more closely associated to permanent water than elk, with 70.0% of all sightings within the 1.6 km radius limit. As good- and fair-browse plant availability in close proximity to permanent water decreases animals will be forced to utilize poor-browse species or move to areas farther away from water, beyond which they are unable to survive. Concentration of elk and mule deer populations within this maximum foraging distance will ultimately decimate the vegetation resource at permanent waterpoints.

In summary, browse utilization exclosures, established within 1.6 km of permanent water, substantiated that many of the good-browse species close to water were overutilized by elk and mule deer. Data showed that 3 of the 5 species evaluated were utilized well above recommended rates, decreasing

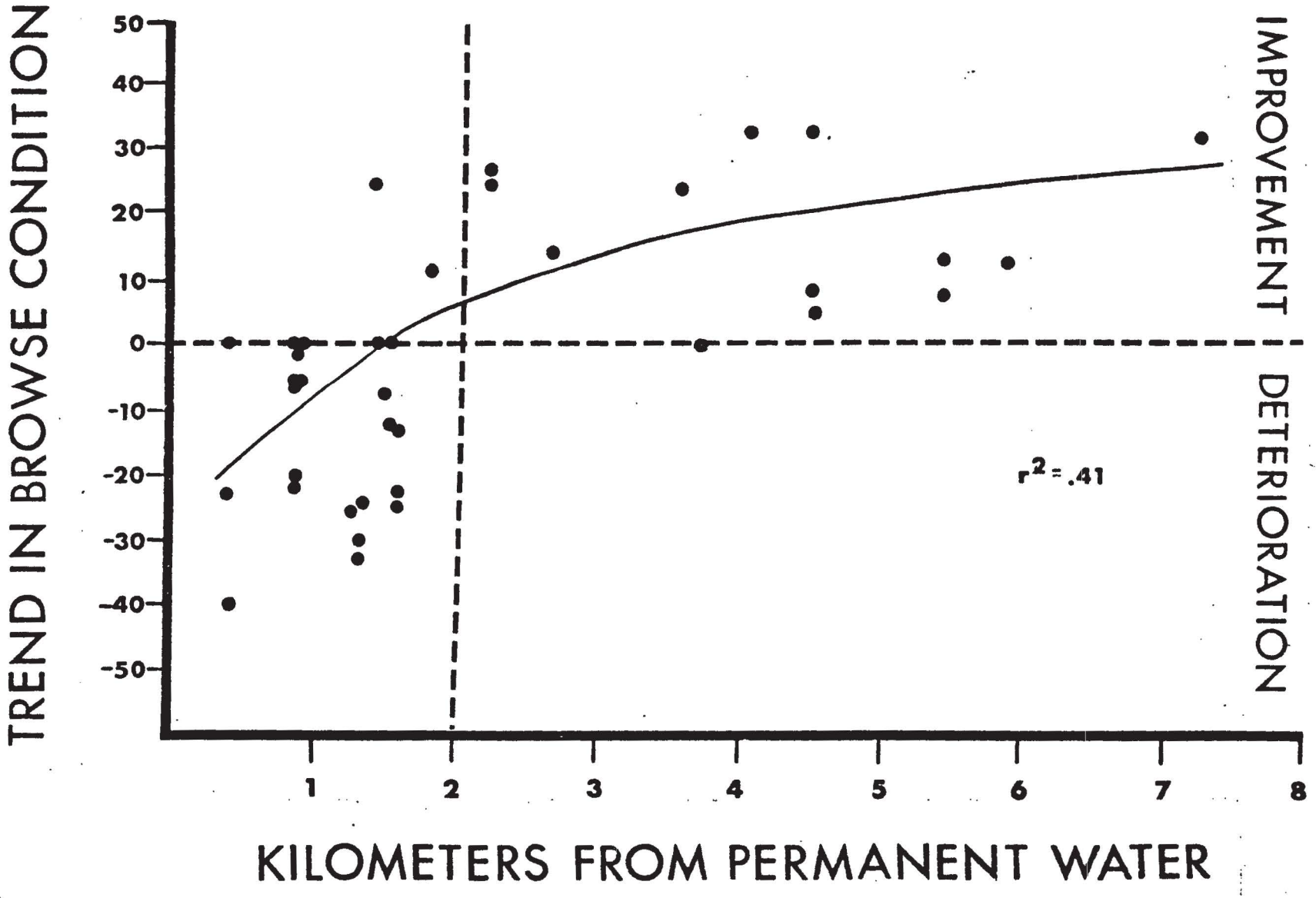


Fig. 30. Regression plotting trend in browse condition against distance from permanent water, to show impact on vegetation by

plant vigor and possibly interfering with seed production. On the assumption that these 5 preferred plants were truly representative of major browse plants utilized by elk and mule deer in the park, these data suggested that there may be considerable overutilization on most good-browse plant species occurring close to water.

Good- and fair-browse species were utilized heavily throughout the year by both elk and mule deer. This high degree of utilization reduced the vigor of many preferred browse species throughout the park and allowed poor-browse species to increase in abundance and distribution. Results of this study indicated that although many poor-browse species were abundant in the park, ungulate utilization of these was only seasonal and they did not yet constitute a major portion of the annual diet (Table 33). However, Keller (1975) has shown that further south, in the more arid areas of Trans-Pecos Texas, many of the same poor-browse species encountered in the park (e.g. Viguera spp., Parthenium incanum, Mimosa biuncifera) comprised a substantial portion of the annual diet of mule deer. His results suggested that many poor-browse species occurring in the park would be sufficient to maintain healthy mule deer populations in the event that good- and fair-browse plants were so depeleted as to no longer be readily available to animals. This poor-browse species represent an untapped food resource in the park. Due to this, animal population numbers could theoretically increase above the appropriate carrying capacity for good- and fair-browse species depleting this preferred vegetation severely, while finding sufficient forage in poor-browse species. As a result, population numbers would continue to increase because food availability would not act as a limiting factor to population growth.

We believe that these circumstances would lead to population expansion beyond reasonable resource availability. A severe decline in mule deer and elk population numbers could be expected as available forage resources ultimately re-establish equilibria.

CONCLUSION

SUMMARY

Data collected during this research in the Guadalupe Mountains substantiated fears of NPS personnel that perhaps ecological equilibra were not as well balanced as they should have been. The findings of this study also revealed important facts pertinent to future management of the vegetation, and of elk and mule deer populations in GMNP.

The pre-park history of land use in the area is one of overexploitation of the range resource through heavy livestock grazing. Much of the Front Country and the northern reaches of Upper Dog and West Dog Canyon, where natural springs or earthen tanks gave watering points for livestock, were grazed on a year round system, while the High Country was principally used for summer grazing. The impact of this intensive livestock use for some 60 years had a serious debilitating effect on the range condition in GMNP which, in the fragile semi-arid ecosystem of the Chihuahuan Desert, will take many years to recover.

A part of the land use in pre-park times resulted in development of artificial water sources to maintain livestock throughout much of the waterless range on a year round basis. These artificial watering points were beneficial to large ungulates and other wildlife in the area and increased

population carrying capacities for many species. This study has clearly demonstrated the decline of the elk, and later the mule deer populations following termination of maintenance on these artificial water sources. Concomitant to the reduction of available surface water through the year, there was movement of elk and mule deer away from the High Country during the dry months, to more permanent water sources at lower elevations. Presently, some 20 years later, an annual movement is found in the elk population of GMNP, The Dog Canyon herd seasonally moves into New Mexico and back to the park, while a longer movement occurs from Plowman Tank in New Mexico, south to the High Country around The Bowl during the wet season. No such clear movements were found for mule deer, with the vast majority of the population remaining within 3.2 km of available water.

This obvious water dependency of both elk and mule deer had another serious implication. With aggregations of both species around available water, there was heavy utilization and trampling of forage adjacent to these water points while relatively low vegetation use was recorded beyond 3.2 km from these activity centers. The distance that elk and mule deer moved from water sources recorded in the study reflected the degree to which plant availability influenced foraging. Apparently there were still adequate forage resources adjacent to watering points to permit animal concentrations.

The ramification of this concentrated feeding activity were clearly apparent in the utilization and range condition parameters measured on the permanent vegetation transects. A further, more insidious, impact was seen in the frequency and utilization of good-, fair-, and poor-browes species in relation to distance from available water. A decrease in abundance of good-browse plants was recorded as distance form water decreased with a

reciprocal increase in the abundance of poor-browse species. Ungulate use evaluations reflected the origins of these gradients. Good-browse species near water showed heavy use with a decreasing degree of use noted as distance from water increased. Poor-browse species near water showed lower use which progressively decreased to no use away from activity centers.

When these gradients in species composition and utilization are viewed in relation to the food habits of elk and mule deer in GMNP further compounding effects are apparent. The high similarity indices in the three browse forage classes indicated heavy use of preferred species (good-browse species) by both ungulates around activity centers. With both animals competing for the same resource in relatively small areas, the inevitable result has been overutilization. Sustained overutilization has further reduced availability and led to the gradual disappearance of these preferred species from the immediate vicinity of water sources.

Despite the relatively high dietary similarity between elk and mule deer found in this study, it is unlikely that the 2 species will become detrimentally competitive. A more probable response to reduced availability of preferred forages will be a switch by both ungulates to a different, less similar food base. Elk will likely take greater proportions of grasses, as they do elsewhere in their distribution. Mule deer are recorded elsewhere thriving on fair- and poor-browse species and would undoubtedly change their diets in that direction. Thus reduction in the quality of forage available is unlikely to have any immediate effects on population numbers of elk or mule deer in GMNP.

In the face of lowered availability of good-browse plants around activity centers, elk and mule deer will be forced to forage further from the watering

points, as well as to increasingly utilize less desirable plants (fair- and poor-browse species). The browse utilization data as well as results of transect re-evaluations indicate that the changeover from preferred forages to less desirable plants is already underway. Future monitoring of distances that elk and mule deer are seen from water sources will indicate progressive declines in range condition adjacent to water. Ultimately the maximum distance at which either elk or mule deer will forage from water will be reached as declining food availability forces animals to forage further afield. When this situation is achieved, natural controls are likely to determine population numbers, but irreparable damage will have been done to the vegetation in some areas of the park.

MANAGEMENT ALTERNATIVES

Before any remedial decisions can be made it is necessary to establish if indeed there is a problem developing in GMNP. The data presented here clearly show that several factors are working toward change in the range condition, species composition, water availability and population numbers for both elk and mule deer. We feel these changes collectively represent a downgrading of the ecosystem in GMNP, and that remedial action is appropriate.

Alternative 1. Continue with present management policy based on non-interference in natural balances.

We believe that this study has clearly shown trends developing in both elk and mule deer populations and in the vegetation in local areas adjacent to watering points used by these 2 species. In continued non-interference, the vegetation change will continue and seriously downgraded range conditions

will result around water sources. Both elk and mule deer are not likely to be affected initially as both species have the capacity to switch to alternative, presently unused, forage resources. Ultimately the forage will become so depleted that population carrying capacities will drop and an ungulate die-off can be expected.

From a positive viewpoint this would tend to restore the ecosystem equilibrium between forage and ungulates. However, the damage to the unique flora of the area may take considerable time to repair itself, if it ever does so, and the near-pristine quality presently in the park would be lost.

Alternative 2. Establish manipulative management capability on existing wildlife water resources.

Alternative 3. Develop additional wildlife water sources in presently waterless areas of the park.

These 2 alternatives demand active intervention in the present trends. In either case, some form of manipulative management of water available for wildlife would have to be applied or the problem merely becomes postponed to magnify with time. Simple development of new water sources would spread animal distributions to utilize presently unused forage resources. However, elk and mule deer population can be expected to increase and overutilization of the newly available range would follow.

In the event that existing (and future alternative) water sources were capable of being manipulated, an effective management mechanism would be available to control animal use of the range. By closing off some water sources, and making available other water sources located in better range

condition areas, elk and mule deer could be moved off overutilized range. These downgraded areas could then be rested to recover before range condition deteriorated too severely.

The principal objection to this alternative appears to be in NPS policies regarding development and management within the National Park. In GMNP these restraints are further compounded by the recent establishment of wilderness status for much of the elk and mule deer range.

Alternative 4. Establish artificial mineral and salt supplement stations in areas away from water sources as a means of improving animal dispersal and range utilization.

This type of forage utilization management is used very successfully with livestock on western ranges. By sitting salt/mineral supplement stations some distance from water, animals are attracted away from activity centers and utilize forage further afield in the process. Regular changing of the locations of these supplement stations ensures that forage resources are used to their optimum level without overutilization.

Alternative 5. Capture, and translocate surplus mule deer (and elk, if numbers increase) to areas outside the park, or initiate an annual reduction program.

While this alternative will achieve both reduction of animal populations and decrease forage use, the effect will be, at best, a temporary measure. The capture and translocation of surpluses is expensive, requires extra man-power, will need to be repeated regularly, and is likely to receive an adverse public response. It also requires careful study of the population dynamics of the ungulate herds so that removals can be accomplished with a

minimum of disruptive impact on the remaining animals. In the present vocal climate against, any form of killing on national lands, shooting reduction of surpluses is not recommended except in crisis situations.

Several management alternatives are available, each geared toward a different endpoint, but nothing can be initiated until long-term priorities for GMNP have been clearly established. There is no doubt that the floral component of the park's natural resources is a unique one, worthy of careful management and preservation for posterity. The fact that this occurs in an arid, fragile environment, where downgrading can occur rapidly but rehabilitation is extremely slow, compounds custodial problems for the NPS. The wildlife of GMNP also represent a natural resource to be preserved, but this resource is much more dynamic and resiliant. However, it cannot be maintained in near-pristine state without adequate habitat. Thus should the flora change drastically through overutilization, the wildlife it supports will also be severely affected. This study has clearly demonstrated the impacts of wildlife on the range condition and flora of GMNP, and documented a progressive downward trend. It is imperitive that this decline be reversed if the very purposes for which a National Park is established are to be achieved. The situation calls for high priority decision-making and adoption of a positive resource management plan.

Table 33. Availability, utilization class, and proportion of annual diet of mule deer and elk, for 11 abundant browse plants of Guadalupe Mountains National Park, Texas.

Food Plants		Browse class	Utilization class	Availability (%)	Annual utilization (%)	
					Mule deer	Elk
Mountain mahogany	Cercocarpus montanus	Good	Heavy	20.0	16.0	3.0
Desert ceanothus	Ceanothus greggii	Good	Heavy	7.0	13.0	10.0
Apache plume	Fallugia paradoxa	Good	Heavy	1.0	6.0	T
Oak	Quercus spp.	Fair	Moderate	28.0	45.0	75.0
Juniper	Juniperus spp.	Fair	Moderate	1.0	8.0	4.0
Skunkbush	Rhus aromatica	Fair	Moderate	3.0	2.0	T
	Viguera spp.	Poor	Light	7.0	T	T
Mariola	Parthanium incanum	Poor	Light	1.5	T	T
Big Bend silverleaf	Leucophyllum minus	Poor	Light	3.0	T	T
Sandpaper bush	Mortonia scabella	Poor	Light	6.0	1.0	T
Catclaw mimosa	Mimosa biuncifera	Poor	Light	3.0	T	T

T = Accounts for < 0.5% of the annual diet.

Literature Cited

Aldous, C. M. 1945. A winter study of mule deer in Nevada. J. Wildl. Manage. 9:145-154.

Anderson, S., and R. Barlow. 1978. Taxonomic status of Cervus elaphus merriami (Cervidae). Southwest. Nat. 23:63-70.

Anderson, A. E., W. Snyder, and G. W. Brown. 1965. Stomach content analysis related to condition in mule deer, Guadalupe Mountains, New Mexico. J. Wildl. Manage. 29:352-366.

Anonymous. 1929a. Wind Cave Game Preserve, South Dakota disposal of surplus animals. Unpubl. report. 3pp.

Anonymous. 1929b. Carload of elk for McKittrick. Carlsbad Current-Argus, Carlsbad, N. M. 1929 April 16: p. 1.

Anonymous. 1929c. Five elk bulls arrive by express. Carlsbad Current-Argus, Carlsbad, N. M. 1929 April 23: p. 1.

Anthony, R. G., and N. S. Smith. 1974. Diet overlap of deer, elk, and cattle in Southern Colorado. J. Range Manage. 28:43-47.

Asdell, S. A. 1964. Patterns of mammalian reproduction. Cornell Univ. Press, Ithaca, New York. 670pp.

Bailey, V. 1905. Biological survey of Texas. N. Amer. Fauna 25:1-222.

_____. 1931. Mammals of New Mexico. N. Amer. Fauna 53:1-412.

Boeker, E. L., V. E. Scott, H. G. Reynolds, and B. A. Donaldson. 1972. Seasonal food habits of mule deer in Southwestern, New Mexico. J. Wildl. Manage. 36:56-63.

Boyd, R. J. 1978. American elk. Pages 11-29 in J. L. Schmidt and D. L. Gilbert, (Eds.). Big Game of North America. Stackpole Books, Harrisburg, Pa. 494pp.

Buechner, H. K., I. O. Buss, and H. F. Bryan. 1951. Censusing elk by airplane in the Blue Mountains of Washington. J. Wildl. Manage. 15:81-87.

Bunting, S. C. 1978. The vegetation of the Guadalupe Mountains. Ph.D. Dissertation. Texas Tech Univ., Lubbock, Texas, 183pp.

Burt, T., Jr., and G. H. Gates. 1959. Pecos elk reproductive and food habits studies. New Mex. Dep. Game and Fish. Fed. Aid. Compl. Rep. Proj. W-93-R-1, WP-3, J-6. 19pp.

Cahalane, V. H. 1939. Mammals of the Chiricahua Mountains, Cochise County, Arizona. J. Mammal. 20:418-440.

Caughley, G. 1966. Mortality patterns in mammals. Ecology 47:906-918.

_____. 1971. Demography, fat reserves and body size of a population of red deer (Cervus elaphus) in New Zealand. Mammalia 35:369-383.

_____. 1977. Analysis of vertebrate populations. John Wiley and Sons, London. 234pp.

Clover, M. R. 1954. A portable deer trap and catch-net. Calif. Fish and Game 40:367-373.

Cockrum, E. L. 1961. The recent mammals of Arizona, their taxonomy and distribution. Univ. Arizona Press, Tucson. 276pp.

Correll, D. S., and M. C. Johnston. 1970. The manual of the vascular plants in Texas. Texas Res. Foundation, Renner, Texas. 1881pp.

Craighead, J. J., F. C. Craighead, Jr., R. L. Ruff, and B. W. O'Gara. 1973. Home ranges and activity patterns of nonmigratory elk of the Madison Drainage herd as determined by biotelemetry. Wildl. Monogr. 33. 50pp.

Davis, W. B. 1940. Mammals of the Guadalupe Mountains of western Texas. Occas. Pap., Mus. Zool., Louisiana State Univ. 7:69-84.

_____. 1974. The mammals of Texas. Texas Parks and Wildl. Dep. Bull. 41. 294pp.

_____, and J. L. Robertson. 1944. The mammals of Culberson, Texas. J. Mammal. 25:254-273.

Deevey, E. S. 1947. Life tables for natural populations of animals. Quart. Rev. Biol. 22:283-314.

DeNio, R. M. 1938. Elk and deer foods and feeding habits. Trans. N. Amer. Wildl. Conf. 3:421-427.

Dickinson, T. G. 1978. Seasonal movements, home ranges, and home range use of desert mule deer in Pecos County, Texas. M.S. Thesis. Sul Ross State Univ., Alpine, Texas. 156pp.

Eberhardt, L. L. 1971. Population analysis. Pages 457-495 in R. H. Giles, (Ed.). Wildlife Management Techniques. The Wildl. Soc., Washington, D.C. 633pp.

Emory, W. H. 1857. Report on the United States and Mexican boundary survey. Cornelius Wendell, Washington. 230pp.

Erickson, J. A., and W. G. Seliger. 1969. Efficient sectioning of incisors for estimating ages of mule deer. J. Wildl. Manage. 33:384-388.

Errington, P. L. 1934. Vulnerability of bobwhite populations to predation. Ecology 15:110-127.

Follis, T. B., and J. J. Spillet. 1974. Winter pregnancy rates and subsequent fall cow/calf ratios in elk. J. Wildl. Manage. 38:789-791.

Free, C. J., R. M. Hansen, and P. L. Sims. 1970. Estimating dry weights of food plants in feces of herbivores. J. Range Manage. 23:300-302.

Garrison, G. A. 1953. Effects of clipping on some range shrubs. J. Range Manage. 6:309-317.

_____. 1972. Carbohydrate reserves and response to use. Pages 271-278 in C. M. McKell (Ed.). Wildland Shrubs—Their biology and utilization. U.S. For. Serv. Gen. Tech. Rep. INT-1. 494pp.

Gates, G. H. 1967. Elk. New Mexico Wildlife Management. New Mex. Dep. Game and Fish, Santa Fe. pp. 31-41.

Gehlbach, F. R. 1967. Vegetation of the Guadalupe Escarpment, New Mexico-Texas. Ecology 48:404-419.

Genoways, H. H., R. J. Baker, and J. E. Cornely. 1977. Mammals of the Guadalupe Mountains National Park, Texas. Pages 271-332 in H. H. Genoways and R. J. Baker (Eds.). Biological Investigations in the Guadalupe Mountains National Park, Texas. Natl. Park Serv. Proc. and Trans. Ser. No. 4.

Glass, M. R., R. E. Reisch, and G. M. Ahlstrand. 1974. Range condition survey and wildlife browse analysis, Carlsbad Caverns and Guadalupe Mountains National Parks. Inter-agency Rep., Natl. Park Serv. 44pp.

Hailey, T. L. 1963a. Trans-Pecos game management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-10, J-2. 8pp.

_____. 1963b. Trans-Pecos game management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-11, J-2. 8pp.

_____. 1963c. Trans-Pecos game management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-12, J-2. 8pp.

_____. 1964. Trans-Pecos game management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-13, J-2. 8pp.

_____. 1966a. Trans-Pecos game management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-14, J-2. 8pp.

_____. 1966b. Trans-Pecos game management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-15, J-2. 8pp.

_____. 1969a. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job compl. Rep. Proj. No. W-57-R-16, J-2. 12pp.

_____. 1969b. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-17, J-2. 9pp.

_____. 1970. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-19, J-2. 12pp.

_____. 1971a. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-18, J-2. 13pp.

_____. 1971b. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-20, J-2. 13pp.

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America, Vol. II. The Ronald Press Co., New York. pp. 547-1083.

Hanks, J. P., and W. A. Dick-Peddie. 1974. Vegetation patterns of the White Mountains, New Mexico. Southwest. Nat. 18:371-382.

Hansen, R. M., and L. D. Reid. 1974. Diet overlap of deer, elk, and cattle in Southern Colorado. J. Range Manage. 28:43-47.

Hanson, W. R., and C. Y. McCulloch. 1955. Factors influencing mule deer on Arizona brushlands. Trans. N. Amer. Wildl. Conf. 20:568-588.

Harper, J. A. 1962. Daytime feeding habits of Roosevelt elk on Boyes Prairie, California. J. Wildl. Manage. 26:97-100.

Hayes, P. T. 1964. Geology of the Guadalupe Mountains, New Mexico. U.S. Geol. Surv. Prof. Pap. 446. 69pp.

Hinckley, L. C. 1944. The vegetation of the Mount Livermore area in Texas. Am. Midl. Nat. 32:236-250.

Holling, C. S. 1959. The components of predation as revealed by a study of small-mammal predation of the European pine sawfly. Can. Ent. 91:293-320.

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

Jackson, A. T. 1938. Picture writing of Texas Indian's. Bur. Res. Soc. Sci. No. 27. Univ. Texas Press, Austin. 490pp.

Johnson, D. E. 1951. Biology of the elk calf, Cervus elaphus nelsoni. J. Wildl. Manage. 15:396-410.

Judd, B. I. 1962. Principal forage plants of southwestern ranges. Rocky Mtn. For. and Range Exp. Stn. Fort Collins. 93pp.

Katz, S. R., and P. R. Katz. 1974. An inventory and interpretation of prehistoric resources in Guadalupe Mountains National Park, Texas. Natl. Park Serv. Rep. 70pp.

Keiss, R. E. 1969. Comparison of eruption-wear patterns and cementum annuli as age criteria in elk. J. Wildl. Manage. 33:175-180.

Keller, G. L. 1975. Seasonal food habits of desert mule deer on a specific mule deer-cattle range in Pecos County, Texas. M.S. Thesis, Texas A&M Univ., College Station, Texas. 80pp.

Kelker, G. H. 1947. Computing the rate of increase for deer. J. Wildl. Manage. 11:177-183.

Kilpatric, J. 1973a. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-21, J-2. 4pp.

_____. 1973b. Trans-Pecos game management survey: to formulate deer, elk and antelope harvest regulations. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-22, J-2. 4pp.

Kimball, J. F., and M. L. Wolfe. 1974. Population analysis of a northern Utah elk herd. J. Wildl. Manage. 38:161-175.

King, P. B. 1948. Geology of the southern Guadalupe Mountains, Texas. U.S. Geol. Surv. Prof. Pap. 215. 183pp.

Kittams, W. H., S. L. Evens, and D. C. Cooke. 1975. Food habits of mule deer on foothills of Carlsbad Caverns National Park. Symp. Biological Investigations in the Guadalupe Mountains National Park, Texas. Presented at Texas Tech Univ., April 4 and 5, 1975.

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

Koerth, B. H. 1981. Habitat use, productivity, and seasonal movements of mule deer in the Texas Panhandle. M.S. Thesis. Texas Tech Univ., Lubbock, Texas. 88pp.

Krysl, L. J. 1979. Food habits of mule deer and elk and their impact on vegetation in Guadalupe Mountains National Park. M.S. Thesis. Texas Tech Univ., Lubbock, Texas. 131pp.

Kufeld, R. C. 1973. Foods eaten by the Rocky Mountain elk. J. Range Manage. 26:106-113.

_____, O. D. Wallmo, and Charles Feddema. 1973. Foods of the Rocky Mountain mule deer. USDA For. Serv. Res. Pap., Fort Collins, Colo. 31pp.

Lang, E. M. 1958. Elk of New Mexico. New Mex. Dep. Game and Fish. Bull. No. 8. 33pp.

Laws, R. M. 1952. A new method of age determination for mammals. Nature 169:972-973.

Leftwich, T. J. 1977. Man's past and present impact of status and distribution of the Texas pronghorn. M.S. Thesis. Texas Tech Univ., Lubbock, Texas. 132pp.

Leopold, A. 1933. Game management. Charles Scribner's Sons. New York. 481pp.

Ligon, J. S. 1927. Wildlife of New Mexico: its conservation and management. New Mex. Dep. Game and Fish. 8pp.

Lockart, G. R. 1972. Further studies of dental annuli for aging white-tailed deer. J. Wildl. Manage. 36:46-55.

Low, W. A., and I. McT. Cowan. 1963. Age determination of deer and annualar structure of dental cementum. J. Wildl. Manage. 27:466-471.

Lowe, V. P. W. 1969. Population dynamics of the red deer (Cervus elaphus L.) on Rhum. J. Anim. Ecol. 38:425-457.

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

Maker, H. J., H. E. Dregne, V. C. Link, and J. U. Anderson. 1974. Soils of New Mexico. New Mex. State Univ. Agr. Exp. Stn. Res. Rep. 285. 132pp.

Marcy, R. B. 1849. Report of Cpt. R. B. Marcy. House Executive Doc. 45, 31st Congress, 1st session, Public Doc. 577. Washington, D.C. 83pp.

McCullough, D. R. 1969. The Tule elk, its history, behavior, and ecology. Univ. Calif. Publ. Zool., Vol. 88. Univ. Calif. Press. 209pp.

Mearns, E. A. 1907. Mammals of the Mexican boundary of the United States. Government Printing Office, Washington, D.C. 530pp.

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

Moody, J. D., and C. D. Simpson. 1977a. Population status and seasonal distribution of elk in Guadalupe Mountains National Park. Rep. Natl. Park Serv. 29pp.

_____. 1977b. Ecology and population dynamics of elk in Guadalupe Mountains National Park, Texas. Rep. Natl. Park Serv. 8pp.

_____. 1978. Ecology and population dynamics of elk in Guadalupe Mountains National Park, Texas. Rep. Natl. Park Serv. 8pp.

Moran, R. J. 1973. The Rocky Mountain elk in Michigan. Mich. Dep. Nat. Res. Research and Development Rep. No. 267. 93pp.

Morris, M. S., and J. E. Schwartz. 1957. Mule deer and elk food habits on the National Bison Range. J. Wildl. Manage. 21:189-193.

Murphy, D. A. 1963. A captive elk herd in Missouri. J. Wildl. Manage. 27:411-414.

Murie, A. 1944. The wolves of Mount McKinley. Fauna Natl. Parks, Fauna Series 5. 238pp.

Murie, O. J. 1951. The elk of North America. The Stackpole Co., Harrisburg, Pa. and Wildl. Manage. Inst., Washington, D.C. 376pp.

Nelson, E. W. 1902. A new species of elk from Arizona. Bul. Amer. Mus. Nat. Hist. 16:1-12.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Newcomb, W. W., Jr. 1961. The Indians of Texas. Univ. Texas Press, Austin. 404pp.

Nicholson, A. J. 1933. The balance of animal populations. J. Anim. Ecol. 2:132-178.

Oosting, H. J. 1956. The study of plant communities. Witt. Freeman and Co. San Francisco. 440pp.

Picton, H. D. 1961. Differential hunter harvest of elk in two Montana herds. J. Wildl. Manage. 25:415-421.

Quimby, D. C., and J. E. Gaab. 1952. Preliminary report on a study of elk dentition as a means of determining age classes. Proc. Ann. Conf. W. Assoc. State Game and Fish Comm. 32:225-227.

_____. 1957. Mandibular dentition as an age indicator in Rocky Mountain elk. J. Wildl. Manage. 21:435-451.

Ramsey, C. W. 1968. Drop-net deep trap. J. Wildl. Manage. 32:187-190.

Reid, J. C. 1935. Reid's tramp, or a journal of the incidents of ten months travel through Texas, New Mexico, Arizona, Sonora, and California. The Steck Co., Austin, Tx. 245pp.

Robinette, W. L., D. A. Jones, G. Rogers and J. S. Gashwiler. 1957a. Notes on tooth development and wear for Rocky Mountain mule deer. J. Wildl. Manage. 21:134-153.

_____, J. S. Gashwiler, and D. A. Jones. 1957b. Differential mortality by sex and age among mule deer. J. Wildl. Manage. 21:1-16.

Robinson, W. B. 1952. Some observations on coyote predation in Yellowstone National Park. J. Mammal. 33:470-476.

Ross, J. S. 1973. Guadalupe division wildlife management plan. Lincoln Natl. For. U.S. For. Serv. Rep. 111pp.

Rowan, W. 1923. An unusual wapiti head. J. Mammal. 4:12.

Rue, L. L. III. 1978. The deer of North America. Times Mirror Mag. Inc. 463pp.

Rush, W. M. 1932. Northern Yellowstone elk study. Montana Fish and Game Comm. p. 76.

Rust, H. J. 1946. Mammals of northern Idaho. J. Mammal. 27:308-327.

Schlegal, M. 1976. Factors affecting calf elk survival in north central Idaho. Proc. West. Assoc. Fish and Game Comm. Annu. Meeting 56:342-355.

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

Severson, K. E., and A. V. Carter. 1978. Movements and habitat use by mule deer in the Northern Great Plains, South Dakota. Proc. First Int. Range Con. 1:466-468.

Shepherd, H. R. 1956. How much use can browse plants stand? Rep., West Browse Res. Comm., 1(2).

Simpson, C. D., and T. J. Leftwich. 1978. Historic range changes in the Texas Pronghorn. Proc. Bien. Antelope States Workshop 8:121-146.

_____. 1981. Historical review of mule deer in Texas. Occ. Pap. Texas Tech Mus. (In press).

Smith, J. G. 1895. Forage conditions of the prairie regions, pages 309-325. In USDA Year Book 14:57-72.

Snedecor, G. W., and W. G. Cochran. 1973. Statistical Methods. Iowa State Univ. Press, Ames, Iowa. 593pp.

Snyder, W. A. 1961. A chemical analysis of thirteen major deer forage plants from the Guadalupe Mountains of New Mexico and their adequacy for maintaining deer. M.S. Thesis. New Mexico State Univ., University Park. 58pp.

Sparks, D. R., and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range Manage. 21:264-265.

Stevens, D. R. 1966. Range relationships of elk and livestock, Crew Creek Drainage, Montana. J. Wildl. Manage. 30:349-363.

Stewart, R. H. 1959. Deer food habits study. New Mex. Dep. Game and Fish Fed. Aid Compl. Rep. Proj. W-75-R-8, WP-13, J-5. 33pp.

Swank, W. G. 1958. The mule deer in Arizona chaparral. Ariz. Game and Fish Dep. Phoenix, Ariz. 109pp.

Swanson, G. A., M. I. Meyer, and J. R. Serie. 1974. Feeding ecology of breeding blue-winged teals. J. Wildl. Manage. 58:396-407.

Tabor, R. D., and R. F. Dasmann. 1957. The dynamics of three natural populations of the deer Odocoileus hemionus columbianus. Ecology 38:233-246.

Taylor, W. P. (Editor). 1956. The deer of North America. Pennsylvania, The Stackpole Co., and The Wildl. Manage. Inst., Washington, D.C. 668pp.

Texas Game, Fish, and Oyster Commission. 1945. Principal game birds and mammals of Texas. 149pp.

Trout, L. C., and T. A. Leege. 1971. Are the Northern Idaho elk herds doomed? Idaho Wildl. Rev. 24:3-6.

Uzzell, P. B. 1954. Trans-Pecos management survey: game populations and their trends. Texas Parks and Wildl. Dep. Job Compl. Rep. Proj. No. W-57-R-3, J-2. 12pp.

Varland, K. L., A. L. Lovaas, and R. B. Dahlgren. 1978. Herd organization and movements of elk in Wind Cave National Park, South Dakota. Natl. Park Serv. Nat. Resources Rep. No. 13. 28pp.

Whitehead, . . 1972. Deer of the world. Constable, London. 194pp.

Wilkens, B. T. 1957. Range use, food habits, and agricultural relationship of mule deer, Bridger Mountains, Montana. J. Wildl. Manage. 21:506-510.

Wilkey, J. S. 1979. Effects of aspect and elevation on soil properties in Guadalupe Mountains National Park, Texas. M.S. Thesis. Texas Tech Univ., Lubbock, Texas 92pp.

Wright, G. M., and B. H. Thompson. 1934. Wildlife management in the National Parks. Fauna Natl. Parks 2:102-102.

Appendix A: BROWSE CONDITION CLASS SCORECARD

To use scorecard: Apply basic data (on composition, density, vigor, and availability) from condition transect record to scorecard . Start at highest class in each category and work down until data fits a condition class description.

Example (for composition only): A shrub stand has 31% bitterbrush (A), 46% sage (B), 13% skunkbush (C), 8% snowberry (C). It fails to fit "High" (too few A's.). It fits "Medium" (well over 50% A's and B's, with over 15% A's).

COMPOSITION

A and B species (must be two or more) making up 75% or more of the composition, with A species at least 45% of the composition.	H(high)
A and B species making up 50% or more of the composition with A at least 15% of the composition.	M(medium)
A and B species making up less than 50% of the composition, or A less than 15%.	L(low)

DENSITY

36% plus	H or V*
21 - 35%	H (high)
11 - 20%	M (medium)
0 - 10%	L (low)

*When density is in excess of 35%, the observer will make a rating decision between H and V. H if density appears beneficial to animal use and V if stand needs thinning for best use.

VIGOR

Hedging on "A" species mostly light or moderate with less than 16% of plants heavily hedged.	and	Decadent minus young **less than 16% of total number of plants.	H(High)
Hedging on "A" species mostly moderate, not more than 35% heavily hedged.	and	Decadent minus young not more than 35%	M(medium)
More than 35% of plants of "A" species heavily hedged.	or	Decadent minus young more than 35%	L(low)

**Subtract the number of "young" plants from the number of "decadents." The principle is that if young plants are replacing decadent plants, the condition is satisfactory. If there is an excess of decadent

plants, condition is unsatisfactory. Example: Assume transect indicates 27% of the "A" species heavily hedged. Decadent hits totaled 25 and young plants totaled 5.

Decadent - Young
25% - 5% = 20%

This is more than 16% and less than 35%; so according to score card, the browse vigor rating for this transect would be M (medium).

If however, 27% of the "A" species were heavily hedged but you had 45 decadent hits and only 5 young.

Decadent - Young
45% - 5% = 40%

This is more than 35% so your vigor class would have to rate L (low) regardless of your hedging class.

AVAILABILITY

% of "A" and "B" Species "Unavailable"	Rating
0 - 20	H
21 - 49	M
50% plus	L

SOIL STABILITY CONDITION CLASS

	Rating
Ground Cover index 65 plus	H (high)
Ground cover index 35-65	M (medium)
Ground cover index less than 35	L (low)

UNDERSTORY

Understory vegetation Totals 90 or more	and	20% plus are cool season growers	= H (high)
Understory vegetation Totals 65 or more	and	10% - 19% are cool season growers	= M (mediu
Understory vegetation Totals 35 or more	or	Less than 10% are cool season growers	= L (low)

APPENDIX B: Seasonal and annual relative frequencies of food plants utilized by elk in Guadalupe Mountains National Park, Texas

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
GRASSES:						
Curlyleaf muhly	Muhlenbergia setifolia	7.7	3.5	2.1	2.1	3.8
Blue grama	Bouteloua gracilis	7.1	7.7	7.0	4.7	9.1
Littleawn needlegrass	Stipa lobata	5.1	1.6	2.7	5.2	3.7
Western wheatgrass	Agropyron smithii	4.3	T	T	1.2	1.6
Wooton threeawn	Aristida pansa	3.4	0.5	0.6	T	1.2
Sideoats grama	Bouteloua curtipendula	3.3	0.9	0.6	T	1.2
New Mexico needlegrass	Stipa neomexicana	2.8	---	---	---	0.7
Mountain brome	Bromus anomalus	1.4	T	T	T	0.6
Spike dropseed	Sporobolus contractus	0.7	1.3	1.0	0.8	0.9
Creeping muhly	Muhlenbergia emersleyi	0.7	T	0.9	0.9	0.7
Indian ricegrass	Oryzopsis hymenoides	0.6	T	---	---	T
New Mexico muhly	Muhlenbergia pauciflora	T	T	---	---	T
Finestem needlegrass	Stipa tienuissima	T	---	---	T	T
Wright's threeawn	Aristida wrightii	T	T	0.7	T	T
Blue threeawn	Aristida glauca	T	1.0	0.7	1.2	0.8
Sand dropseed	Sporobolus cryptandrus	T	T	---	T	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
GRASSES: Continued		R.F.	R.F.	R.F.	R.F.	R.F.
Fowl mannagrass	Glyeeria stricta	T	T	1.6	---	0.5
Indiangrass	Sorghastrum avenaceum	T	3.9	3.8	1.5	2.3
Wolftail	Lycurus phleoides	T	4.4	2.9	2.8	2.5
Spike pappusgrass	Enneapogon desvauxii	T	---	---	---	T
Slim tridens	Tridens muticus	T	T	T	---	T
Green sprangletop	Leptochloa dubia	T	---	---	T	T
Hall's panicum	Panicum hallii	---	1.5	0.6	0.9	0.7
Hairy grama	Bouteloua hirsuta	---	0.9	T	---	T
Hooded windmillgrass	Chloris cuculata	---	0.8	T	---	T
Plains bristlegrass	Seteria leucopila	---	T	---	---	T
Sand bluestem	Andropogon hallii	---	T	T	T	T
Squirrel-tail	Sitanion longifolium	---	T	0.8	1.1	0.5
Barnyardgrass	Echinochloa crusgalli	---	T	---	T	T
Six-weeks fescue	Festuca octoflora	---	T	T	---	T
Cheatgrass brome	Bromus tectorum	---	T	---	0.8	T
Bulb panicum	Panicum bulbosum	---	---	0.7	---	T
Little bluestem	Schizachyrium scoparium	---	---	T	0.9	T
Black grama	Bouteloua eripoda	---	---	T	T	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
GRASSES: Continued						
Bermudagrass	Cynodon dactylon	---	---	---	T	T
Plains lovegrass	Eragrostis lugens	---	---	---	T	T
	TOTAL	38.7	41.0	28.7	26.0	33.6
FORBS:						
Scaley bladderpod	Lesquerella valida	2.9	---	---	---	0.8
Common horehound	Marrubium vulgare	3.0	3.4	11.7	19.1	9.2
Fendler bladderpod	Lesquerella fendleri	2.2	T	0.8	1.0	1.1
Prairie bluets	Hedyotis nigricans	0.9	T	---	T	T
Flannel mullein	Verbascum thapsus	0.8	---	T	---	T
Leatherweed croton	Croton pottsii	0.5	6.3	9.2	6.6	6.5
Desert-holly perezia	Perezia nana	T	T	---	---	T
Harebell	Campanula rotundifolia	T	---	---	---	T
Common ragweed	Ambrosia artemisifolia	T	0.8	0.7	---	0.5
Tall goldenrod	Solidago altissima	T	T	---	---	T
	Machaeranthera parviflora	T	---	---	---	T
Silverleaf nightshade	Solanum elaeagnifolium	T	0.9	T	T	T
Needleleaf bluets	Hedyotis acerosa	T	T	T	T	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Green puccoon	Lithospermum viride	T	T	T	T	T
Multiflower puccoon	Lithospermum multiflorum	T	1.3	T	T	T
Wavyleaf thistle	Circium undulatum	T	T	---	---	T
Wooly paperflower	Psilostrophe tagentina	T	---	---	---	T
Buffalobur	Solanum rostratum	T	T	T	---	T
Prairie coneflower	Ratibida columnaris	0.9	T	---	---	T
Pale false nightshade	Chamaesaracha pallida	T	T	T	T	T
Erect dayflower	Commelina erecta	T	T	T	T	T
Pinnate tansymustard	Descurania pinnata	0.7	T	T	T	T
	Sisymbrium linearifolium	T	---	---	---	T
Whitesage	Artemisia ludoviciana	---	T	1.1	1.4	0.7
Cocklebur	Xanthium strumarium	---	T	---	---	T
Fragrant heliotrope	Heliotropium greggii	---	T	---	---	T
Plains blackfoot	Melampodium leucanthum	T	T	T	1.5	T
Mealy sage	Salvia farinacea	---	T	---	---	T
Desert baileya	Baileya multiradiata	---	T	---	---	T
Tufted evening primrose	Oenothera caespitosa	---	T	---	T	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Tatalencho	Gymnosperma glutinosum	---	T	---	---	T
Stemmed bitterweed	Hymenoxys scaposa	---	T	---	---	T
Bluntscale bahia	Bahia pedata	---	T	---	---	T
Narrowleaf globemallow	Sphaeralcea angustifolia	0.5	2.0	3.5	2.5	2.2
Coulter conyza	Conyza coulteri	---	---	0.5	T	T
Woolly Indian wheat	Plantago patagonica	---	---	T	T	T
Florida snakecotton	Froelichia floridana	---	---	T	T	T
Showy menodora	Menodora longiflora	0.5	T	T	T	T
Plains zinnia	Zinnia grandiflora	T	0.7	0.6	0.6	0.5
Woolly loco	Astragalus mollissiums	T	---	---	T	T
Prickleaf gilia	Gilia rigidula	T	---	T	T	T
Nuttail milkvetch	Astragalus nuttaillianus	T	T	---	T	T
Pennycress	Thlaspi fendleri	T	---	---	---	T
Orange honeysuckle	Lonicera arizonica	T	T	---	---	T
Hairy paperflower	Psilostrophe villosa	T	T	T	T	T
Narrowleaf gromwell	Lithospermum incisum	T	T	T	---	T
Germander	Teucrium laciniatum	T	T	---	---	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Common winterfat	Eurotia lanata	T	T	T	T	T
	Dyssodia setifolia	T	T	T	T	T
Wislizizenus spectaclepod	Dithyraea wislizeni	T	T	---	---	T
Perennial verbena	Verbena perennis	T	T	T	---	T
Spinyleaf zinnia	Zinnia acerosa	T	T	T	T	T
Rabbits tobacco	Evax prolifera	T	---	---	T	T
Lyreleaf greeneyes	Berlandiera lyrata	T	T	T	T	T
Noseburn	Tragia ramosa	---	---	T	T	T
Colorado greenthread	Thelesperma megapotamicum	---	---	T	---	T
	Machaeranthera parviflora	---	---	T	---	T
Gray golden-aster	Heterotheca villosa	---	---	T	---	T
Meadow flax	Linum pratense	---	---	---	0.7	T
Showy mendora	Mendora longiflora	---	---	---	0.6	T
	Clematis filifera	---	---	---	T	T
Sweet rosemarymint	Poliomintha incana	---	T	---	---	T
Bush croton	Croton fruticulosus	---	---	---	T	T
Grandleaf milkwort	Polygala macradenia	---	---	---	T	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Wright's verbena	Berbena wrightii	---	---	---	T	T
Scarlet globemallow	Sphaeralcea coccinea	---	---	---	T	T
Common dyssodia	Dyssodia pentachaeta	---	---	---	T	T
American basketflower	Centaurea americana	---	---	---	T	T
Narrowleaf milkwort	Polygala longa	---	---	---	T	T
Unknown		0.9	0.6	T	T	0.5
	TOTAL	14.4	15.0	29.8	31.0	22.6
BROWSE:						
Oaks	Quercus spp.*	26.7	28.9	35.2	31.0	30.5
Desert ceanothus	Ceanothus greggii	9.0	9.5	2.1	T	5.2
Mountain mahogany	Cercocarpus montanus	3.8	2.2	0.5	0.6	1.8
Alligator juniper	Juniperus deppeana	3.2	---	0.6	4.1	2.0
	Opuntia spp.	1.0	T	T	0.5	0.5
Skunkbush	Rhus aromatica	1.0	T	T	T	T
Smallseed sacahuista	Nolina micrantha	0.7	T	T	T	T
Algerita	Berberis trifoliata	T	0.9	0.5	T	0.5
Apache plume	Fallugia paradoxa	0.5	---	T	0.6	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
BROWSE: Continued						
Plume bricklebush	Brickellia brachyphylla	T	T	T	T	T
Littleleaf sumac	Rhus microphylla	T	T	---	T	T
Mariola parthenium	Parthenium ineanum	T	---	---	---	T
Sunflower goldeneyes	Viguiera dentata	---	0.5	0.8	T	0.5
Utah serviceberry	Amelanchier utahensis	---	T	---	T	T
Mescalbean	Sophora secundiflora	---	T	---	---	T
Redberry juniper	Juniperus pinchoti	---	T	T	1.3	T
Hitchcock mockorange	Philadelphus hitchcockianus	---	---	T	---	T
	Yucca spp.	---	---	T	---	T
Rabbitbrush	Chrysothmnus spathulatus	---	---	---	2.2	0.5
Smooth sotol	Dasylirion leiophyllum	---	---	---	T	T
Cliff fendlerbush	Fendelera rupicola	---	---	---	T	T
Big Bend silverleaf	Leucophyllum minus	---	---	---	T	T
California brickellbush	Brickellia californica	---	---	---	T	T
Sandpaper bush	Mortonia scabrella	---	---	---	T	T
Catclaw acacia	Acacia greggii	---	---	---	T	T

APPENDIX B: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F	R.F.	R.F.	R.F.	R.F.
BROWSE: Continued						
Unknown		---	T	T	T	T
	TOTAL	46.9	44.0	41.5	43.0	43.8
	GRAND TOTAL	100.0	100.0	100.0	100.0	100.0
	Number of Species	(77)	(87)	(72)	(92)	(132)

1/ T = trace (< 0.5 R.F.)

* Includes Q. grisea, Q. undulata, Q. pungens, Q. muhlenbergia, Q. gambelli.

APPENDIX C: Seasonal and annual relative frequencies of food plants utilized by mule deer in Guadalupe Mountains National Park, Texas.

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
GRASSES:						
Littleawn needlegrass	Stipa lobata	0.7	T[1/]	0.8	0.8	0.6
Squirrel-tail	Sitanion longifolium	0.6	---	---	---	T
Curlyleaf muhly	Muhlenbergia setifolia	0.5	T	---	T	T
Blue threeawn	Aristida glauca	T	T	---	T	T
Creeping muhly	Muhlenbergia emersleyi	T	T	0.6	T	T
Hall's panicum	Panicum hallii	T	T	T	---	T
Wolftail	Lycurus phleoides	T	T	T	T	T
Western wheatgrass	Agropyron smithii	T	T	T	0.5	T
Blue grama	Bouteloua gracilis	T	T	T	T	T
Indiangrass	Sorghastrum avenaceum	---	---	T	T	T
Sideoats grama	Bouteloua curtipendula	---	---	T	---	T
Wright's threeawn	Aristida wrightii	---	---	T	---	T
Black grama	Bouteloua eripoda	---	---	T	---	T
Mountain brome	Bromus anomalus	---	---	T	---	T
	TOTAL	2.9	1.6	2.5	1.7	2.3

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS:						
Fendler bladderpod	Lesquerella fendleri	10.3	0.9	0.5	9.6	5.3
Grandleaf milkwort	Polygala macradenia	3.3	T	T	0.5	1.1
Scaley bladderpod	Lesquerella valida	1.7	---	T	T	0.5
Flannel mullein	Verbascum thapsus	0.8	T	2.5	1.5	1.3
Gordon bladderpod	Lesquerella gordoni	0.5	---	---	---	T
Needleleaf bluets	Hedyotis acerosa	0.5	T	T	---	T
Common horehound	Marrubium vulgare	0.5	T	1.1	2.2	1.1
Leatherweed croton	Croton pottsii	0.5	1.0	3.2	3.0	2.0
	Zinnia spp.	---	---	1.1	1.5	T
Bluntscale bahia	Bahia pedata	T	---	---	---	T
	Sisymbrium linearifolium	T	---	---	---	T
Gray golden-aster	Heterotheca villosa	T	T	---	T	T
Swordleaf blue-eyed grass	Sisyrinchium ensigerum	T	---	---	---	T
Meadow flax	Linum rigidum	T	---	---	---	T
Common dyssodia	Dyssodia pentachaeta	T	---	T	T	T
Colorado greenthread	Thelesperma megapotamicum	T	---	---	---	T
Silverleaf nightshade	Solanum elaeagnifolium	T	T	T	T	T

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Scarlet globemallow	Sphaeralcea coccinea	---	0.5	0.6	0.5	T
Prickleleaf gilia	Gilia rigidula	---	T	---	---	T
Woolly Indian wheat	Plantago patagonica	---	T	T	T	T
James nailwort	Paronychia jamesii	---	T	T	---	T
Sweet rosemarymint	Poliomintha incana	---	T	T	T	T
Wright's verbena	Verbena wrightii	---	T	---	---	T
Fendler meadowrue	Thalictrum fendleri	---	T	T	T	T
Texas filaree	Erodium texanum	---	T	T	---	T
Desert tobacco	Nicrotiana trigonophylla	---	T	---	---	T
Tall goldenrod	Solidago altissima	---	T	T	---	T
Indian rushpea	Hoffmanseggia glauca	---	T	---	---	T
Hawkweed buckwheat	Eriogonum hieracifolium	---	T	T	T	T
Prairie coneflower	Ratibida columnaris	---	T	T	0.5	T
Wholeleaf paintbrush	Castilleja integra	---	T	---	---	T
Western wallflower	Erysimum capitum	---	T	---	---	T
Tatlencho	Gymnosperma glutinosum	---	T	---	---	T
Rough coldenia	Coldenia hispidissima	---	T	---	---	T

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Bracted bedstraw	Galium microphyllum	---	T	T	---	T
Woolly tidestromia	Tidestromia lanuginosa	---	T	---	---	T
Prairie bluets	Hedyotis nigricans	---	T	T	T	T
Range ratany	Krameria glandulosa	---	T	---	---	T
Frankenia	Frankenia jamesii	---	T	---	T	T
Plains dozedaisy	Aphanostephus ramossissimus	---	T	---	---	T
Creeping barberry	Berberis repens	---	T	---	---	T
Wavey cloakfern	Notholaena sinuata	---	T	1.1	0.9	T
Silktassel	Garrya ovata	---	T	0.5	T	T
Bindweed	Convolvulus equitans	---	T	---	---	T
Scarlet gaura	Gaura coccinea	---	T	---	---	T
Florida snakecotton	Froelichia floridana	---	---	T	T	T
Mealy sage	Salvia farinacea	---	---	T	---	T
Spreading sida	Sida filicaulis	---	---	T	---	T
Jamaica sawgrass	Cladium jamaicensis	---	---	T	T	T
Wright's goldenrod	Solidago wrightii	---	---	T	---	T
White four-o'clock	Mirabilis albida	---	---	T	---	T

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
FORBS: Continued						
Common ragweed	Ambrosia artemisilifolia	---	---	T	T	T
Indian mallow	Abutilon incanum	---	---	T	---	T
Canyon sage	Salvia lyciodes	---	---	T	---	T
California filaree	Erodium circutarium	---	---	T	---	T
Woolly paperflower	Psilostrophe tagetina	---	---	T	---	T
Noseburn	Tragia ramosa	---	---	T	---	T
Groundsel	Senecio douglasii	---	---	T	---	T
Babywhite-aster	Leucelene ericoides	---	---	T	---	T
Narrowleaf milkwort	Polygala longa	---	---	T	---	T
American basketflower	Centaurea americana	---	---	T	0.5	T
Bush croton	Croton fruticulosus	---	---	T	T	T
Rocky Mountain sage	Salvia reflexa	---	---	T	T	T
Coulter conyza	Conyza coulteri	---	---	---	T	T
Hairyseed bahia	Bahia absinthifolia	---	---	---	T	T
Harebells	Campanula rotundifolia	---	---	---	T	T
	TOTAL	22.6	13.4	18.8	30.3	22.7

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
BROWSE:						
Oaks	Quercus spp.*	19.8	36.2	38.2	31.4	31.4
Desert ceanothus	Ceanothus greggii	16.7	13.6	5.3	2.2	9.5
Mountain mahogany	Cercocarpus montanus	16.0	8.3	16.9	10.5	12.9
Apache plume	Fallugia paradoxa	6.2	4.5	3.2	3.0	4.2
Alligator juniper	Juniperus deppeana	4.9	0.9	2.4	8.4	4.2
Sandpaper bush	Mortonia scabrella	2.2	1.4	T	1.2	1.2
Littleleaf sumac	Rhus microphylla	1.7	2.0	1.1	T	1.3
Pinyon pine	Pinus edulis	1.5	0.9	0.5	0.7	0.9
Cliff fendlerbush	Fendlera rupicola	0.7	T	T	T	T
Oneseeded juniper	Juniperus monosperma	0.7	---	T	0.6	T
Smooth sotol	Dasylirion leiophyllum	0.7	T	T	T	T
Big Bend silverleaf	Leucophyllum minus	0.6	1.6	T	---	0.6
Elbow-bush	Forestiera pubescens	0.5	---	T	---	T
Roundleaf snowberry	Symphoricarpos rotundifolius	T	T	---	---	T
Skunkbush	Rhus aromatica	T	5.7	3.2	0.7	2.5
Redberry juniper	Juniperus pinchoti	T	1.1	1.7	4.6	1.9
Ponderosa pine	Pinus ponderosa	T	---	T	---	T

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annual
		R.F.	R.F.	R.F.	R.F.	R.F.
BROWSE: Continued						
Hitchcock mockorange	Philadelphus hitchcockianus	T	T	---	---	T
Netleaf hackberry	Celtis reticulata	---	---	T	---	T
Rocky Mountain juniper	Juniperus scopulorum	---	---	T	---	T
Southwest rabbitbrush	Chrysothamnus pulchellus	T	---	---	---	T
Catclaw acacia	Acacia greggii	---	---	T	0.5	T
Unknown		0.6	T	0.5	T	T
	TOTAL	74.5	85.0	78.7	68.0	75.0
	GRAND TOTAL	100.0	100.0	100.0	100.0	100.0
	Number of Species	(72)	(99)	(100)	(85	(127)

1/ T = traces (< 0.5 R.F.)

* Includes Q. grisea, Q. undulata, Q. pungens, Q. muhlenbergia, Q. gambelli.

APPENDIX C: Continued

Common name	Scientific name	Spring	Summer	Fall	Winter	Annua
		R.F.	R.F.	R.F.	R.F.	R.F.
BROWSE: Continued						
Hitchcock mockorange	Philadelphus hitchcockianus	T	T	---	---	T
Netleaf hackberry	Celtis reticulata	---	---	T	---	T
Rocky Mountain juniper	Juniperus scopulorum	---	---	T	---	T
Southwest rabbitbrush	Chrysothamnus pulchellus	T	---	---	---	T
Catclaw acacia	Acacia greggii	---	---	T	0.5	T
Unknown		0.6	T	0.5	T	T
	TOTAL	74.5	85.0	78.7	68.0	75.0
	GRAND TOTAL	100.0	100.0	100.0	100.0	100.0
	Number of Species	(72)	(99)	(100)	(85	(127)

1/ T = traces (< 0.5 R.F.)

* Includes Q. grisea, Q. undulata, Q. pungens, Q. muhlenbergia, Q. gambelli.