THE CORONA RANGE AND LIVESTOCK RESEARCH RANCH

MULE DEER STUDY

BY

SAMUEL TURNER SMALLIDGE, B.S.

A Thesis submitted to the Graduate School

in partial fulfillment of the requirements

for the Degree

Master of Science

Major Subject: Wildlife Science

New Mexico State University

Las Cruces, New Mexico

December 1997

"The Corona Range and Livestock Research Ranch Mule Deer Study," a thesis prepared by Samuel Turner Smallidge in partial fulfillment of the requirements for the degree, Master of Science, has been approved by the following.

Timothy J. Pettibone

Timothy J. Pettibone
Dean of the Graduate School

Volney W. Howard Jr.

Volney W. Howard, Jr.
Chair of the Examining Committee

8-27-97

Date

Committee in charge.

Dr. Volney W. Howard, Jr., Chair

Dr. Gary B Donart

Dr. Marta D. Remmenga

Dr. Phillip J. Zwank

ACKNOWLEDGMENTS

I would like to express my gratitude to Dr. V.W. Howard, Jr. for his willingness to go above and beyond the responsibilities of a graduate student advisor. Dr. Howard always made time to answer my questions and keep me headed in the right direction. I would also like to thank him for his friendship, and the encouragement he gave me throughout my project.

My committee, Dr. Gary Donart, Dr. Marta Remmenga, and Dr. Phil Zwank all contributed greatly to my success. Thank you for taking time from your busy schedules to answer my questions and provide me with guidance.

I would like to thank Laura Mangold for all of her assistance in the field. Laura could always be relied upon in all situations, she helped me more than she will ever realize. She is a true friend. Rocky Alva deserves gratitude for his infallible friendship. I would also like to thank my friends Dr. Jon Boren and Byron Wright for their support and assistance throughout my studies.

My parents, Mr. and Mrs. R.L. Smallidge and Dr. and Mrs. W.P. McCafferty, deserve considerable thanks for their long distance support and inspiration. To my brothers and sisters, thank you for your encouragement.

To my wife, Maureen, and my son, John, thank you for your unconditional love, support, and understanding, without which my successes would not be possible. You are what makes my life complete, and my successes meaningful.

Finally, I would like to thank the Lord, with whom anything is possible.

VITA

October 5, 1968 -- Born in Lafayette, IN

1993 -- B.S. Purdue University, West Lafayette, IN

1993-1995 -- Wildlife Technician, Purdue University, West Lafayette, IN
Biological Technician, USDA-APHIS-ADC, West Lafayette, IN

1995-1997 -- Research Assistant, Department Fishery and Wildlife Sciences, New Mexico State University, Las Cruces

PROFESSIONAL AND HONORARY SOCIETIES

The Wildlife Society

Xi Sigma Pi

PUBLICATIONS

Smallidge, S.T., and V.W. Howard, Jr. 1997. Status of the Corona Range and Livestock Research Ranch mule deer herd. Page 29 *in* AZ-NM Chapters of The Wildlife Society and American Fisheries Society 30th Joint Annual Conference, February 1997, Gallup, New Mexico. Abstract.

FIELD OF STUDY

Wildlife Science

Mule deer population ecology

ABSTRACT

THE CORONA RANGE AND LIVESTOCK RESEARCH RANCH MULE DEER STUDY

BY

SAMUEL TURNER SMALLIDGE, B.S.

Master of Science in Wildlife Science
New Mexico State University
Las Cruces, New Mexico, 1997
Dr. Volney W. Howard, Jr., Chair

Encroachment of piñon-juniper (*Pinus edulis-Juniperus spp.*) woodlands into historic grassland and grassland savannah habitats is the result of overgrazing, wildfire suppression, and natural successional processes. Conversion of piñon-juniper woodlands to grasslands has received considerable attention from rangeland and wildlife scientists. Research into the effects of piñon-juniper conversion on mule deer use and population dynamics has been conducted. The ecological and economic importance of mule deer in the piñon-juniper ecosystem requires additional research into effects of piñon-juniper conversion on mule deer populations. The growing importance of mule deer as additional sources of income for some New Mexico ranching operations reinforces the need to understand the relationships between livestock management and wildlife management.

This study reports on a continuing long-term study of population trends, herd structure, adult doe home ranges, and a trophy fee hunting enterprise of mule deer inhabiting Corona Range and Livestock Research Ranch (CRLRR).

Results indicate a declining mule deer herd with a stable age and sex structure. Fall/winter population estimates are significantly higher than spring/summer estimates for both grassland ($P < 0.05$) and piñon-juniper ($P < 0.05$) habitats. This suggests a winter migration of mule deer to CRLRR from neighboring ranches to take advantage of the cover and forage CRLRR's piñon-juniper woodlands provide. Adult doe home ranges are similar to those determined in previous ranch studies. Home ranges of ranch adult does have a mean size of 1.7 km^2 and a range of 0.12 km^2 to 3.9 km^2. Vegetation composition in grassland and piñon-juniper habitats is 11.7 % and 7.7 % grasses, respectively. Canopy cover is 0.3 % and 19 % for grassland and piñon-juniper habitats, respectively. Mean age of harvested mule deer is 4.9 years, which is within the target age classes of 4 to 6 years. Optimal antler development is reached at 4 years of age but additional data are required to determine when antler development begins to decline in older aged animals. Body growth increases rapidly until 3 years of age with slight increases in subsequent years attributed to increases in body mass.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Corona Range and Livestock Research Ranch (CRLRR) was purchased by New Mexico State University (NMSU) in 1989. Its primary mission is to research and develop rangeland operations that are both ecologically and economically beneficial CRLRR is comprised of grassland and Colorado piñon - one-seed juniper (*Pinus edulis - Juniperus monosperma*) woodlands.

Piñon-juniper woodlands have been encroaching into areas historically classified as grasslands from overgrazing, wildfire suppression, and natural successional processes (Johnsen 1962, Aro 1971, Schott and Pieper 1987). Considerable research in converting piñon-juniper woodlands to grasslands for livestock forage production has been conducted (Arnold and Schroeder 1955, Arnold et al. 1964, Aro 1971, Schott and Pieper 1987). Effects of piñon-juniper conversion on big game also has received considerable attention (Reynolds 1964, McCulloch 1969, Short et al. 1977, Howard et al 1987). Results from these studies indicate that size of openings, location, and precipitation are important factors in increasing forage production and improving wildlife habitat

Mule deer (*Odocoileus hemionus*) are probably the dominant wildlife species both ecologically and economically in piñon-juniper ecosystems (Terrel and Spillett 1975). There remains ample room to further our knowledge on mule deer/piñon-juniper interactions and the effects of piñon-juniper conversion on mule deer populations. Also, identifying the best compromise between livestock operations and mule deer habitat is justified because of the economic importance mule deer can have to many landowners.

Diversification of income is necessary in today's ranching community (Scaling 1988), with fee hunting operations being one of the most prevalent forms of income diversification (Butler 1990). Economic costs and benefits tend to vary in fee hunting operations, usually influenced by the types of services provided for fee hunters (Wright 1997). Unique problems are associated with fee hunting operations in public land states (Jordan and Workman 1989, Wright 1997). Fee hunting operations in public land states must offer services or benefits that are not available on public lands. Economic returns from fee hunting operations can significantly contribute to ranch income (Ramsey 1965, Loomis et al. 1991).

Wildlife benefit from having a monetary value. Landowners are more willing to manage for wildlife when it generates income (Morrill 1988, Wunderlich et al. 1990). Tradeoffs between livestock operations and wildlife enterprises do exist; typically livestock numbers decline as wildlife habitat increases (Bernardo et al. 1994). There is a need to develop management techniques that benefit both livestock and wildlife (Terrel and Spillett 1975). Mule deer may or may not benefit from livestock grazing depending on vegetation composition, topography, intensity and duration of livestock grazing, and criteria used to assess deer response (Longhurst et al. 1981, McIntosh and Krausman 1981, Austin and Urness 1986, Stevens 1987).

Mule deer are valuable assets to some ranch operations as sources of additional

income and have the potential to become greater assets in the future. CRLRR provides a unique opportunity to study existing and experimental ranching techniques and how these techniques impact wildlife Cooperative efforts between NMSU's Department of Animal and Range Sciences and Department of Fishery and Wildlife Sciences will lead to a better understanding of ranch/wildlife interactions and the development of management techniques that improve habitat for both livestock and wildlife.

This study concludes the initial stages of a long term study at CRLRR. It was designed to collect base-line data on population dynamics, sex and age composition, home range, and harvest data for CRLRR's mule deer herd From these initial findings, hypotheses will be developed concerning the effects of livestock management practices on the ranch's mule deer population Objectives for this study are to. 1) monitor mule deer population trends through population and density estimates, 2) estimate sex and age composition of the mule deer herd, 3) monitor vegetation characteristics at CRLRR, 4) estimate home range of adult doe mule deer, and 5) monitor age and morphological characteristics of harvested mule deer.

STUDY AREA

New Mexico State University's 11,396 ha (28,160 ac) Corona Range and Livestock Research Ranch is located 22.5 km (14 miles) east of Corona, New Mexico, in northern Lincoln and southeastern Torrance counties. The topography is gently rolling hills and flat plains with elevations ranging from 1,740 m (5,710 ft) to 2,048 m (6,720 ft). The mean annual precipitation for this area over a 46-year period (1931-1977) was 39.19 cm (15.43 in) (Kunkel 1984).

CRLRR is classified as plains mesa grassland intermittently mixed with piñon-juniper savannah (Dick-Peddie 1993). This is considered the transition area between grasslands and piñon-juniper woodlands. Harrington (1992) classified the grasslands into five major categories: blue grama (*Bouteloua gracilis*), blue grama/purple threeawn/broom snakeweed (*B. gracilis/Aristida purpurea/Gutierrezia sarothrae*), wolftail (*Lycurus phleodies*), sideoats grama (*Bouteloua curtipendula*), and New Mexico feather grass (*Stipa neomexicana*). Grasslands occur predominantly in the northern and eastern portions of the ranch. Piñon-juniper woodlands are predominantly found in the south central portion of the ranch.

MATERIALS AND METHODS

Population Trends

Thirty-six pellet group transects covering 93.2 km^2 (36 $miles^2$) were permanently established on the CRLRR from 1990 to 1993 (Berry 1992, Moore 1994). A total of 10 circular plots covering 274.3 m (900 ft) comprised each transect. Rebar stakes acted as the center of each 0.004 ha (0 01 ac) circular plot. Plot boundaries were determined using a 3.6 m (11 ft 9 in) small dog chain with a 3.8 cm (1.5 in) diameter metal key-ring attached to one end. The key-ring was placed over the plot stake and the chain pulled taut to determine the plot boundary.

Berry (1992) and Moore (1994) located the center of each section with the aid of a truck odometer. Each transect was located as close to the center of a section as the existing road system allowed. This was to minimize the time required to collect pellet transect data. The same truck was used for installation of all pellet group transects. Pellet group transects were used to estimate densities of deer/259 ha (640 ac) and were combined for average densities for grassland and piñon-juniper habitats. Pellet group data also were used to calculate a ranch wide population estimate for both spring/summer and fall/winter seasons. Eight sections on the northern portion of the ranch were excluded because domestic sheep occupy that area and distinguishing between mule deer and sheep pellet groups is difficult (Nagy and Gilbert 1968, Howard and DeLorenzo 1974).

Pellet group data were collected by two observers circling the plot and marking pellet groups. One observer was stationed at the end of the chain, with the other stationed at the center of the chain. Pellet groups were marked with bright orange Eco-Spot® tree and log marking paint (Nelson Paint Company, Inc., Kingsford, MI) to ensure they were counted only once (Kufeld 1968). A minimum of 15 pellets approximately the same size, shape, and age were required to count as a pellet group. The majority (> 50%) of pellets in a group had to occur within the plot to be counted (Neff 1968).

Pellet group data were collected biannually in October and April. The October data collection period was used for estimating spring/summer densities, while the April collection period was used in estimating fall/winter densities. Densities of mule deer/259 ha were estimated using a modification of Eberhardt and Van Etten's (1956) formula:

$$\text{Mule deer/mile}^2 \text{ (259 ha)} = G * R * A / D * T$$

Where: G = number of pellet groups per transect
R = reciprocal of area sampled per 259 ha (640 ac)
A = area for which density estimates is being made
D = daily defecation rates per mule deer
T = elapsed time in number of days from last estimates

The reciprocal of the area being sampled was 10 because there were 10, 0.01 acre (0 004 ha) plots per transect. The daily defecation rate used was 13 pellet groups/day/deer (Rasmussen and Doman 1943, Eberhardt and Van Etten 1956, Rogers et al. 1958, Smith 1964).

Vegetation Transects

Vegetation data were collected biennially in September, using the line-point method described by Pieper (1978), for 72 transects. Data collection began in 1991 (Berry 1992) for 56 transects. Moore (1994) continued data collection after expanding the number of transects to 72. Two randomly selected pellet group plots served as initial points for vegetation transects. Direction of each transect was randomly selected. End stakes provided support for a 30.5 m (100 ft) metal surveyor's tape marked in 30 5 cm (12 in) increments, and a special spring-loaded suspension system (Howard 1966).

Vegetation data were collected by an observer walking beside the surveyor's tape and calling out the vegetation classification at each marked point on the surveyor's tape. A recorder, centrally located along the transect, recorded data. Data recorded included bare ground, litter, or a specific plant species. A species was recorded if a main stem or basal rosette was directly beneath an imaginary line running perpendicular to the metal tape and through the marked points. Canopy cover was recorded where woody vegetation intercepted the vegetation transect. Height of woody vegetation was estimated within 15 2 cm (6 in) and recorded. No understory data were recorded where canopy cover intercepted the transect Data were summarized into percent composition and percent cover by species and vegetative type.

Herd Composition Counts

Mule deer were classified at CRLRR to estimate sex and age ratios. Sex and age classifications of deer were recorded as adult buck, adult doe, fawn, or unclassified. Deer were classified by driving a predetermined, non-overlapping trend route.

Berry's (1992) trend route was relocated and expanded in the fall of 1994, from 21.7 km (13.5 miles) to 39.9 km (24.8 miles), to increase sample size and better represent the ranch's vegetation types. Herd composition count data were collected November through January during early morning and late evening hours, thus increasing the probability of seeing animals in family groups and observing a representative number of bucks (Dasmann and Taber 1956).

Procedures for collecting herd composition data involved 2 observers classifying all deer observed along the trend route while driving approximately 32 km/hr (20 miles/hr). This speed seemed to optimize the number of deer classified within an approximate 2-hour time limit. Trend routes began at sunrise and 2 hours prior to sunset. Data were collected over 2 consecutive days, at least once a month. Morning and evening routes were followed in a predominately westerly and easterly direction, respectively, to minimize missing animals because of low angle sunlight (Dasmann and Taber 1956). Animals not easily identified with the unaided eye were identified with 10 X 50 wide-angle binoculars.

Home Range Estimation

Home ranges were estimated from monitoring 7 radio-tagged adult female mule deer. Individuals were chemically immobilized using powder charge dart rifles and fitted with radio collars (Telonics® MOD-500) between November 1995 and August 1996. Deer were located using a Telonics® TR-2E receiver, Realistic® Pro-60 earphones, Yagi antenna, and a Silva Ranger® 15C compass with declination set at 11 degrees east. Permanent telemetry stations were established prior to data collection. Telemetry stations were added as necessary to obtain accurate locations. Stations were entered into a G.P S. unit (Magellan® Nav Pro 5000) to determine Universal Transverse Mercator (UTM) coordinates (Grubb and Eakle 1988) for plotting on a 1:24,000 scale topographic map (U.S. Geological Survey 1981). All telemetry stations were located a minimum of 0.80 km (0 50 miles) apart.

Criteria for usable animal location data were explained by Moore (1994) Two compass bearings were determined and later plotted on the topographic map to estimate their UTM coordinates. If deer's location did not seem to vary significantly over 3 consecutively determined locations, the observer would walk toward the deer until viability could be determined.

Age and Morphological Characteristics

An annual fee hunt was held each November at CRLRR for mule deer. Two separate hunts were held in 1994 for 9 and 16 people, respectively. The number of separate hunts was expanded to 3 for 1995 with 28 total hunters. The 1996 season had 2 hunts with 9 and 16 hunters, respectively. Hunters were required to bring harvested bucks to a check station for morphological data collection.

Age Determination

The first incisor, I1 (Dimmick and Pelton 1994), was removed from each harvested deer and placed in an envelope to be used in aging. The envelope was labeled with a number corresponding to the body measurement data sheet. Use of the first incisor for determining age in mule deer is well researched and considered accurate (Low and Cowan 1963, Erickson and Seliger 1969, Thomas and Bandy 1973).

Procedures for tooth preparation were similar to those of Carrel (1980). Tooth sections were cut using an 11-1180 AB Isomet® Saw (Buehler Ltd., Evanston, IL). Four, 20 micron sections were removed from the lower 1/3 of the tooth. The root tip was removed at the point where a cross-sectional view of the tooth became approximately perpendicular to the root canal. Slides were placed under a Bausch and Lomb® light microscope set at 100X magnification. Each section was scanned to locate the optimal definition of annual growth rings. Rings were counted on each of the 4 tooth sections to ensure accuracy. If tooth section quality was poor, new sections were cut and prepared. A second observer checked results to ensure accuracy. One year was added to the number of rings counted to obtain the age of the harvested buck because the I1 tooth does not become permanent in mule deer until approximately 12 months of age (Robinette et al. 1957, Larson and Taber 1980).

Antler Measurements

Five antler measurements were taken from harvested mule deer (Fig. 1). Measurements are modified from Boone and Crockett Club scoring criteria to be easily obtained under field conditions and remain accurate. A modified Boone and Crockett Club antler score was developed (V.W. Howard, Jr., pers. comm.) to better represent field measurements (Fig. 2).

Body Measurements

Six body measurements were taken of mule deer carcasses (Fig. 3). Measurement data were recorded on a data sheet that detailed the hunter's name, location of harvest, and body measurement data. A body index was developed (V.W. Howard, Jr. pers. comm.) to aid in individual animal comparisons (Fig. 4).

Statistical Procedures

Means and standard errors were computed for seasonal deer density estimates using pellet group data and were reported by season within years Matched pair t-tests were conducted over all 3 years (1994-1996) of mule deer density estimates to determine if there was a difference between seasonal densities within grassland and the piñon-juniper habitats Population estimates from pellet group data were reported by seasons within years.

Means and standard errors of percent composition were computed for six vegetation categories (bare ground, litter, grasses, forbs, shrubs, and cactus/yucca) for grassland and piñon-juniper vegetative types. Percent canopy cover also was

ANTLER MEASUREMENTS

- Number of points
- Base circumference of each antler
- Inside spread of main beams
- Antler height for each individual antler
- Main beam tip-to-tip spread

Figure 1. Five antler measurements taken on mule deer harvested at CRLRR.

ANTLER SCORE

(# Points X 3) + (Base circumference X 4) + Inside spread + Antler heights = ANTLER SCORE

Figure 2. Antler score formula for mule deer harvested at CRLRR.

BODY MEASUREMENTS

- Body length
- Total length (body length + tail length)
- Shoulder height
- Neck circumference
- Chest circumference
- Hind foot length

Figure 3. Six body measurements taken on mule deer harvested at CRLRR.

BODY INDEX

Body length + Chest circumference + Neck circumference = BODY INDEX

Figure 4 Body index formula for mule deer harvested at CRLRR.

determined from vegetational data.

Herd composition counts were reported using a doe:buck:fawn ratio, standardized to 100 does, and as percentages. Standard errors of percentages were determined among individual route totals within months, and by months within years, from 1994 through 1997.

The Adaptive Kernel Method was used in computer program CALHOME (Kie 1996) to estimate the 95%, 90%, and 50% of the area used by the animal during the spring season (Worton 1989, 1995). The contour lines in the home range estimates represent the percentages of area used by adult does.

Means and standard errors of ages, antler scores, and body index scores were calculated within years, across years, and within age class across years. These calculations were used for making comparisons between years and age classes.

RESULTS AND DISCUSSION

Population Trends

Pellet group data were collected in October and April to obtain spring/summer and fall/winter density estimates, respectively for each year (1994 through 1997). Estimates were reported by major habitat type as mean deer/259 ha ± standard error (Table 1). Averaged over 3 years, fall/winter mule deer densities on CRLRR are higher than spring/summer densities in both grassland habitat (P = 0.04) and piñon-juniper habitat (P ≤ 0.0001) for 1994-1997 (Table 2).

Table 1. Mean seasonal density estimates for mule deer (deer/section ± standard error) on CRLRR in two major habitat types each year for 1994-1997.

SEASON/YEAR	GRASSLAND (*n* = 11)	PIÑON-JUNIPER (*n* = 25)
Spring/Summer 1994	16.7 ± 4.5	24.9 ± 2.5
Fall/Winter 1994-1995	18.5 ± 3.5	37.8 ± 4.6
Spring/Summer 1995	10.8 ± 3.6	20.9 ± 2.9
Fall/Winter 1995-1996	22.7 ± 9.7	32.7 ± 3.5
Spring/Summer 1996	5.7 ± 1.7	17.1 ± 2.9
Fall/Winter 1996-1997	11.7 ± 2.2	25.0 ± 3.2

Table 2. Mean seasonal density estimates for mule deer (deer/section ± standard error) on CRLRR in two major habitat types averaged over years for 1994-1997.

SEASON/YEAR	GRASSLAND	PIÑON-JUNIPER
	(*n* = 33)	(*n* = 75)
Spring/Summer 1994-1996	11.05 ± 2.1	20.9 ± 1.6
Fall/Winter 1994-1997	17.61 ± 3.5	31.8 ± 2.3

Fall/winter population estimates were consistently higher than spring/summer estimates over an 8-year period (Table 3). The single 1992 spring/summer anomaly resulted from a large piñon-juniper conversion project taking place on a ranch bordering to the south. Several sections of piñon-juniper woodland were removed using bulldozers. The 1996 spring/summer population estimate may be low. A heavy

Table 3. Population estimates ± standard error for mule deer on CRLRR from pellet group data, by season, 1989-1996.

YEAR	*N*	SPRING/SUMMER	*N*	FALL/WINTER
1989	--	-----	17	765
*1990	17	844 ± 77	18	1020 ± 77
*1991	17	883 ± 84	28	950 ± 75
*1992	28	1056 ± 164	36	1008 ± 152
*1993	36	618 ± 88	36	1064 ± 137
1994	36	805 ± 82	36	1147 ± 132
1995	36	642 ± 87	36	1067 ± 137
1996	36	489 ± 81	36	754 ± 92

* Berry 1992, Moore 1994.

rain , 5.8 cm (2.3 in), fell on 8 August 1996. This rain washed an undetermined number of pellet groups off some plots. The extent to which this washing occurred varied with terrain and location on the ranch. This rain may have caused a lowered count of the number of pellet groups on approximately 9 pellet group transects. Similar results were found by Wallmo et al. (1962). Because 25% of the plots had some pellet loss, the population size is most likely under estimated for spring/summer 1996. Although the spring/summer 1996 estimate may be too low, the fall/winter 1996 estimate shows a declining trend from previous years.

Population estimates are in a downward trend since 1994 Spring/summer estimates declined 21% and 24% from 1994 to 1995 and 1995 to 1996, respectively. Fall/winter estimates declined 6% and 30% from 1994 to 1995 and 1995 to 1996, respectively. This trend indicates a declining population.

Early in the 1960s, state wildlife management agencies became concerned with an apparent decline in the West's mule deer populations (Connolly 1981*a*) This decline was thought to be the result of several factors including poor fawn survival, severe winters on winter ranges, habitat deterioration or loss, over hunting, disease, and drought.

Habitat modification and drought may explain the downward trend in mule deer numbers on CRLRR. Considerable modifications to CRLRR have been taking place since its purchase in 1989. Fencing to create new pastures and installation of water tanks in these pastures are the primary modifications. Also, in 1995, the herbicide tebuthiuron was applied in strips to several sections of piñon-juniper woodlands resulting in increased openings. Literature suggests, however, that if openings are of proper size and location, mule deer benefit from increases in forage production (Reynolds 1964, McCulloch 1969, Short et al. 1977, Howard et al 1987). Literature further suggests that establishment of permanent water sources greatly benefits wildlife (Wood et al. 1970, Remington et al. 1984).

Drought greatly affects forage production and quality, which impact mule deer populations. In semiarid areas even an annual drought can significantly reduce mule deer numbers (Urness 1981). Data from NMSU Department of Animal and Range Sciences rain gauges indicate annual precipitation was 60% of the annual long-term average in 1995 (Appendix A). Annual precipitation was 8% and 5% above average in 1994 and 1996, respectively. Although precipitation was above average during 2 years of the study, timing of precipitation dramatically affects forage production. The 1996 growing season from May to September had 39% above the long-term average precipitation, but the majority of the precipitation occurred during July and August. As fawns are born in July, rains fell too late to provide adequate nutritious forage for gestating does and lactating does with new born fawns. Below average rainfall in 1995 and inopportune timing of rainfall in 1996 may have resulted in poor quality habitat in these 2 years.

While deer are more susceptible to disease and parasitism if they become stressed from environmental conditions (Swank 1958, Hibler 1981), no evidence of these were observed at CRLRR. No indication of unthrifty individuals or widespread disease were seen in the population. No diseased carcasses, suggesting a large scale die off, were found at CRLRR.

A final possibility is that the population is declining as a response to habitat quality. Modifications made at CRLRR may have altered habitat causing mule deer numbers to increase Either through habitat utilization or successional change, habitats became less favorable for deer resulting in a declining population. If deer numbers are higher than the habitat can support, the quality of the habitat can be quickly reduced and increases in mortality may result One or a combination of these previously mentioned factors may be causing the apparent decline in mule deer.

Higher fall/winter population estimates, compared to spring/summer estimates, may indicate migratory behavior of area mule deer. Deer may move to CRLRR from neighboring ranches that have less piñon-juniper woodlands to take advantage of thermoregulation benefits, better forage availability, or both (Wilkins 1957, Lovaas 1958). According to Peek et al. (1982) thermal cover is not as important to mule deer as forage availability. Joseph (1995) showed that winter mule deer fecal content at CRLRR was 89% browse, with 50% being one-seed juniper. Some neighboring ranches have little piñon-juniper cover available to mule deer. Particularly, ranches to the south have converted several sections of piñon-juniper woodlands to grasslands. This lack of, and decline in, piñon-juniper habitat may force deer inhabiting these areas to seek additional sources of food and cover during winter. Some of these ranches also might have more intensive livestock management practices, which may cause deer to shift forage patterns during winter months (Bowyer and Bleich 1984, Kie et al. 1991, Kie and Boroski 1995).

Speculation on deer migration and population decline is based upon estimation techniques that have some constraints. Ungulate censuses are important to wildlife managers but many census methods, including the pellet group technique, have certain limitations (Boyd et al. 1986) Variability found in seasonal estimates may be the result of sampling error. The 2 most common errors are overlooking pellet groups and classifying new groups as old (Van Etten and Bennett 1965). These both would lead to under estimation of population size Other possible errors may be the result of plot size Robinette et al. (1958) and Smith (1968) suggest the use of 0.0004 ha (0 001 ac) circular plots, instead of 0.004 ha (0.01 ac) circular plots for most habitat types because smaller plot sizes are thought to be more accurate and a single observer is less likely to overlook or miss count pellet groups. Smith (1968) found no statistical difference between 0.0004 and 0.004 ha plots in piñon-juniper habitat To minimize potential problems with pellet group data collection in this study, 3 procedures were followed. 2 observers counted pellet groups on each plot, 2 revolutions were made of each plot, and all pellet groups were painted.

The factor most influencing density and population estimates generated from pellet group data is the daily defecation rate selected for use in estimate calculations. Several articles have reported defecation rates for both mule deer (Rasmussen and

Doman 1943, Dasmann and Taber 1955, Rogers et al. 1958, Smith 1964) and white-tailed deer (*Odocoileus virginianus*) (Eberhardt and Van Etten 1956, Rollins et al. 1984, Rogers 1987, and Sawyer et al 1990) A review of the technique was conducted by Neff (1968). These articles suggest that defecation rates are not linear but fluctuate with season and the type of forage available. Typically, daily defecation rates increase when deer diets consist largely of succulent vegetation. Despite these differences, Dasmann and Taber (1955) and Freddy and Bowden (1983) found that pellet group population estimates approximated other estimate techniques.

A daily defecation rate of 13 pellet groups/day/deer was selected to remain consistent with previous estimates of the mule deer population, but actual defecation rates and their seasonal changes were unknown. Use of the same defecation rate through time allows for relative comparisons between years.

Vegetation Transects

Vegetation composition data were collected in September 1996. Mean estimates ± standard of percent composition and canopy cover for 6 categories were calculated from data along 22 grassland and 50 piñon-juniper transects (Table 4). The cactus/yucca category includes species not easily categorized in previously mentioned classes (Appendix B).

Bare ground comprised the largest portion of the transects in grassland (79.9 %) and piñon-juniper (63.7 %) habitats on CRLRR. Grasses comprised the largest vegetative class for both grassland (11.7 %) and piñon-juniper (7 7 %) habitats.

Litter, forbs, shrubs, and cactus/yucca classes comprised less than 6% each. Areas directly under tree overstory were not recorded. These areas were predominantly comprised of bare ground and litter, which leads to an underestimation of bare ground and litter percentages.

Percent canopy cover for grassland and piñon-juniper habitats were 0.3 % and 19.3 %, respectively (Table 4). The percent canopy cover for piñon-juniper habitat will likely decrease next year because of the 1995 herbicide application used to control piñon-juniper invasion. Decreases in tree overstory should lead to increases in grass and forb density and diversity (Arnold et al. 1964, Schott and Pieper 1987).

Table 4. Means ± standard errors of percent composition and canopy cover in grassland and piñon-juniper vegetative types on CRLRR, September 1996.

VEGETATION CLASSES	GRASSLAND ($n = 11$)	PIÑON-JUNIPER ($n = 25$)
Bare ground	79.9 ± 2.0	63.7 ± 2.5
Litter	2.7 ± 0.6	5.6 ± 0.9
Grasses	11.7 ± 1.2	7.7 ± 1.0
Forbs	3.6 ± 0.9	2.1 ± 0.8
Shrubs	0.0 ± 0.0	0.2 ± 0.1
Cactus/Yucca	1.8 ± 0.6	1.4 ± 0.3
Canopy cover	0.3 ± 0.2	19.3 ± 2.8

Herd Composition Counts

Data collected from 12 trend routes driven each year in 1994, 1995, and 1996 were used to estimate doe:buck fawn ratios (Table 5). Ratios were standardized to 100 does which may mask changes in the female portion of the population, but its use is appropriate because of the influence of does on herd population dynamics (McCullough 1994). Further, calculating mean percentages ± standard errors of does, bucks, and fawns, by year, may remove any potential masking effects (Table 6). While caution should be used in making inferences about populations from sex and age ratios and percentages, it appears that the sex ratio and age structure are relatively stable at CRLRR. McCullough (1994) recommends the use of an independently derived population estimate.

Table 5. Ratios of buck and fawns per 100 does, by year, on CRLRR.

YEAR	RATIO (doe:buck:fawn)	# DEER CLASSIFIED
*1990-1991	100 : 52 : 63	273
*1991-1992	100 : 48 : 71	127
*1992-1993	100 :38 : 56	131
*1993-1994	100 : 56 :44	287
**1994-1995	100 : 46 : 43	818
1995-1996	100 : 43 : 86	1169
1996-1997	100 : 50 : 53	854

* Berry 1992, Moore 1994.

** Trend route relocated and expanded in 1994

Using independently derived population estimates in relation with herd composition ratios or percentages allows for some inference about herd composition in relation to population trends.

Because CRLRR's mule deer population is declining and the herd composition is stable then it is reasonable to assume that density independent factors are causing the population decline. The most likely reason for the population decline at CRLRR is inadequate rainfall in 1995 and inopportune timing in the 1996 growing season. This would impact all age classes of the mule deer population. Adult deer become physically stressed and more susceptible to starvation and disease during these conditions. Fawn mortality would increase when forage conditions are poor (Swank 1958, Robinette et al 1973, Smith and LeCount 1979). This increased mortality is illustrated by the 1995-1996 doe:fawn ratio of 100:86; indicating fawn production was high. A severe spring drought and a low spring/summer 1996 population estimate suggests that fawn survival was extremely low. This is further supported by 16 and 11 incidental observations of dead fawns and yearlings near ranch roads by 2 ranch hands and me, respectively.

Table 6. Mean percentages ± standard errors of does, bucks, and fawns seen during trend route data collection on CRLRR, by year (*n* = 3).

YEAR	% DOES	% BUCKS	% FAWNS
1994-1995	51.9 ± 3.8	25.6 ± 3.8	22.5 ± 3.7
1995-1996	43.6 ± 2.0	19.1 ± 2.8	37.3 ± 3.1
1996-1997	45.8 ± 3.1	22.9 ± 4.0	31 3 ± 4.3

December appears to be the optimal month for collecting herd composition data (Table 7). The percentages of observed does and bucks are less variable during this month resulting in a better estimate of the doe:buck ratio. Differences in doe and fawn ratios between months and years may be the result of differences in fawn mortality and reproductive success. If December is the only month in which trend routes are driven, then it would be necessary to increase the number of samples taken that month to minimize sampling variation (McCullough 1993).

Table 7 Means ± standard errors of percentage of mule deer classified during trend route data collection on CRLRR, by month (n = 4).

YEAR	MONTH	DOE	BUCK	FAWN
1994-1995	November	51.0 ± 4.0	24.0 ± 3.2	25.0 ± 2.0
	December	46.7± 1.1	27.7 ± 4.7	25.6 ± 3.8
	January	57.9 ± 1.2	25.1± 2.3	17.0 ± 2.0
1995-1996	November	44.8 ± 1.5	16.3 ± 0.6	38.8 ± 1.8
	December	41.2 ± 2.5	23.4 ± 2.0	35.4 ± 3.7
	January	44.7 ± 0.4	17.6 ± 2.9	37.7 ± 2.8
1996-1997	November	44.8 ± 2.1	22.3 ± 4.8	28.8 ± 4.0
	December	47.1 ± 2.1	24.7 ± 3.2	28.3 ± 4.3
	February	41.4 ± 2.9	21.8 ± 2.8	36.8 ± 0.5

An assumption associated with herd composition counts is the equal probability of seeing any given sex or age class (Connolly 1981*b*, McCullough et al.

1994). It is difficult to show that this assumption is valid (Connolly 1981*b*). It is hypothesized that different behavioral characteristics of the sex and age classes influence observability (McCullough 1993). This hypothesis was supported by Downing et al. (1977) who states that differences in observability were caused by differences in feeding and bedding behavior. Weather and time of day also may affect observability (Dasmann and Taber 1956) Literature suggests that the best time for deriving sex ratios may not be the best for determining age structure (Dasmann and Taber 1956, Connolly 1981*b*, and McCullough et al. 1994). In this study, problems associated with herd composition counts were partially accounted for by standardizing routes, time of daily data collection, and time of year when routes were driven (McCullough et al. 1994).

Home Range Estimation

Home range sizes averaged 2.0 km ^{2} and ranged from 1 1 km ^{2} to 3.9 km ^{2}, based on 14 to 21 independent animal locations, for deer captured both in the interior and on the periphery of the ranch (Appendix C) One deer (number 3) died prior to completion of the study and was omitted from home range estimates. Home range estimates of adult doe mule deer may have been affected by 1997 spring precipitation, which was 2 16 X the long term average for May and June (Kunkel 1984). With this exceptional rainfall, habitat quality may have been high enough to allow does to survive in restricted areas. The average home range for this study is smaller than Berry's (1992) spring/summer home range average of 2.21 km ^{2} for adult does at

CRLRR.

All mule deer were captured on the ranch. Those captured on or near the boundaries used the ranch to varying degrees. Deer number 1 was never located on the ranch again after capture. Deer number 2 used both grasslands and piñon-juniper woodlands on the ranch and predominantly piñon-juniper woodlands off the ranch. Deer number 4 consistently used the grasslands on the western end of the ranch. Based on personal observations, her primary purposes for visits to the ranch were for forage and water. Her use of the neighboring ranch took advantage of that ranch's piñon-juniper woodlands. Deer number 5 was the only deer whose home range did not cross ranch boundaries. Deer number 6's and 7's home ranges were predominantly in piñon-juniper woodlands while on CRLRR and a combination of piñon-juniper and grassland habitats while on neighboring ranches.

These animal home ranges should be interpreted cautiously. The sample size is insufficient to make generalizations on doe mule deer home range size at CRLRR. It would be advantageous to increase sample size (White and Garrott 1990). Additionally, caution needs to be taken when comparing home range sizes determined by different methods. Berry (1992) computed home range estimates using a Harmonic Mean Transformation (HMT). The Adaptive Kernel method was used in this study, which is less sensitive to grid size changes used in data analysis than the HMT method (Worton 1989, 1990; Boulanger and White 1990).

Age and Morphological Characteristics

Seventy-eight hunters, providing $54,000 in revenues, harvested 69 mule deer bucks during sanctioned hunts from 1994 through 1996. Means ± standard errors for age, antler score, and body index of harvested mule deer appear stable over years (Table 8). Hunter success was 88%, 93%, and 88% for 1994, 1995, and 1996, respectively.

Table 8. Means ± standard errors of age, antler score and body index of hunter harvested mule deer on CRLRR, within years. Hunter success reported as a percentage within years.

YEAR	AGE	ANTLER SCORE	BODY INDEX	HUNTER SUCCESS
1994 ($n = 22$)	4.5 ± 0.4	117.9 ± 3.0	122.3 ± 1.4	88
1995 ($n = 26$)	5.8 ± 0.3	118.8 ± 2.8	120.8 ± 1.5	93
1996 ($n = 21$)	4.3 ± 0.4	111.3 ± 3.4	121.0 ± 1.7	88

The target age range (4 to 6 years) for harvested bucks has been realized over these years (4.9 ± 0.2 SE). The target age range for harvest was selected based on information available for white-tailed deer suggesting that maximum antler development peaks between 4 and 6 years of age (Armstrong et al. 1984). Quality and quantity of forage, age, and genetic potential are the main factors determining potential antler development.

Mean antler score by age class over years show increasing scores until bucks are 4 years old (Fig. 5). Scores then appear similar through 8 years of age. Conclusions on how long an animal is in prime antler development would be premature based on this study. Sample size for age classes 7 through 10 are small making conclusions questionable. These mean antler scores are elevated because animals represented in these age classes were probably above average in antler development making them more susceptible to harvest. Even as data are collected in the future, older age classes may be misrepresented because hunters harvest bucks that exhibit the highest trophy quality. This could result in a harvest of older bucks that exhibit above average antler development.

Mean body indexes seem to stabilize after 3 years with only slight increases in later years (Fig. 6). Basic skeletal structure appears fully developed in animals by 3 years. This is slightly earlier than previous studies indicate (Anderson et al. 1974, Anderson 1980). Most increases in body index, after 3 years, can be attributed to increases in body mass.

To better determine the optimal age for antler growth of the CRLRR mule deer herd, it would be necessary to increase sample size in the older age classes. Currently no contractual restrictions are placed upon the hunters. By requiring hunters to harvest the older bucks, additional information could be gathered on these older age classes. Another approach would be to allow hunters to take an additional deer as a cull deer. This would have to be approved through the New Mexico State Game and Fish Commission. If 2 deer per hunter per season are not possible, a separate cull hunt could be held to remove older and undesirable deer.

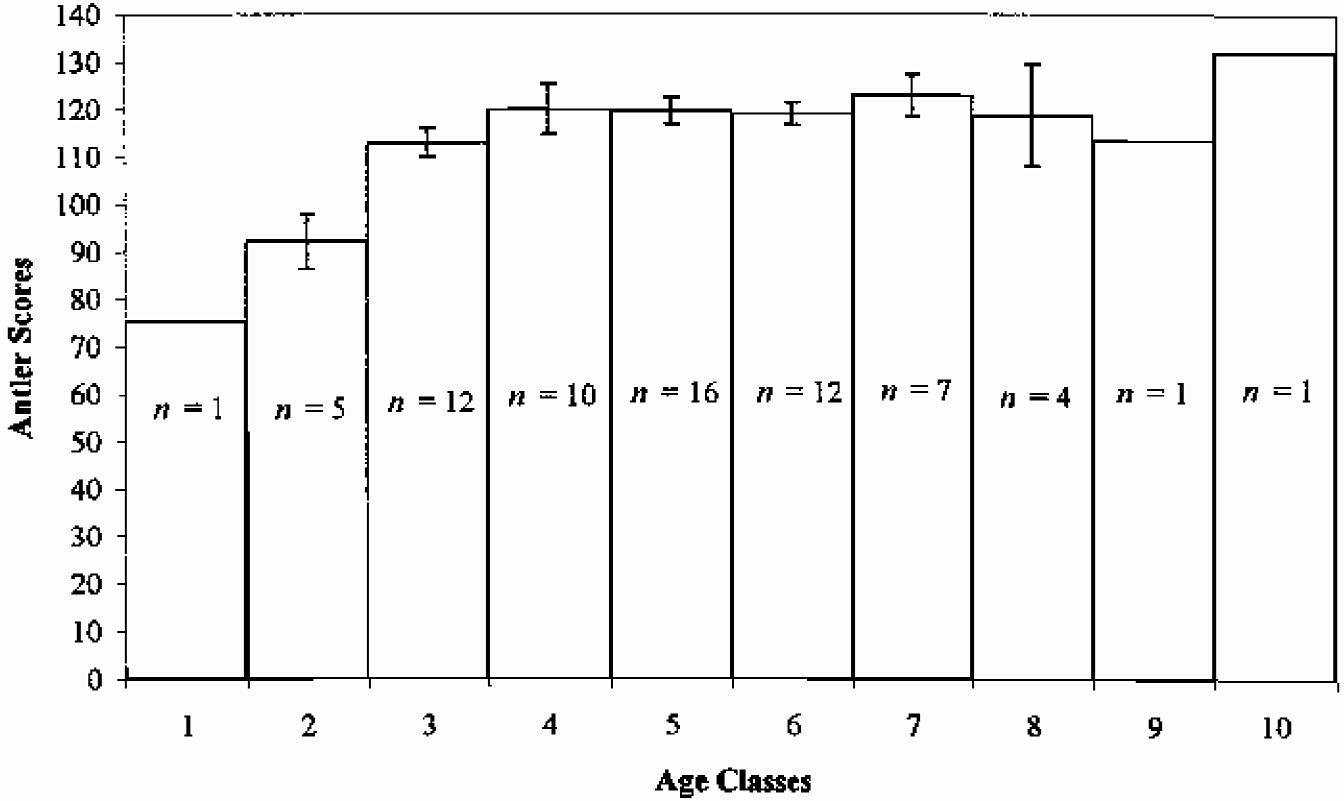


Figure 3. Mean antler scores, by age class, of mule deer harvested at CRLRR, 1994-1996. (Bars = s.e.)

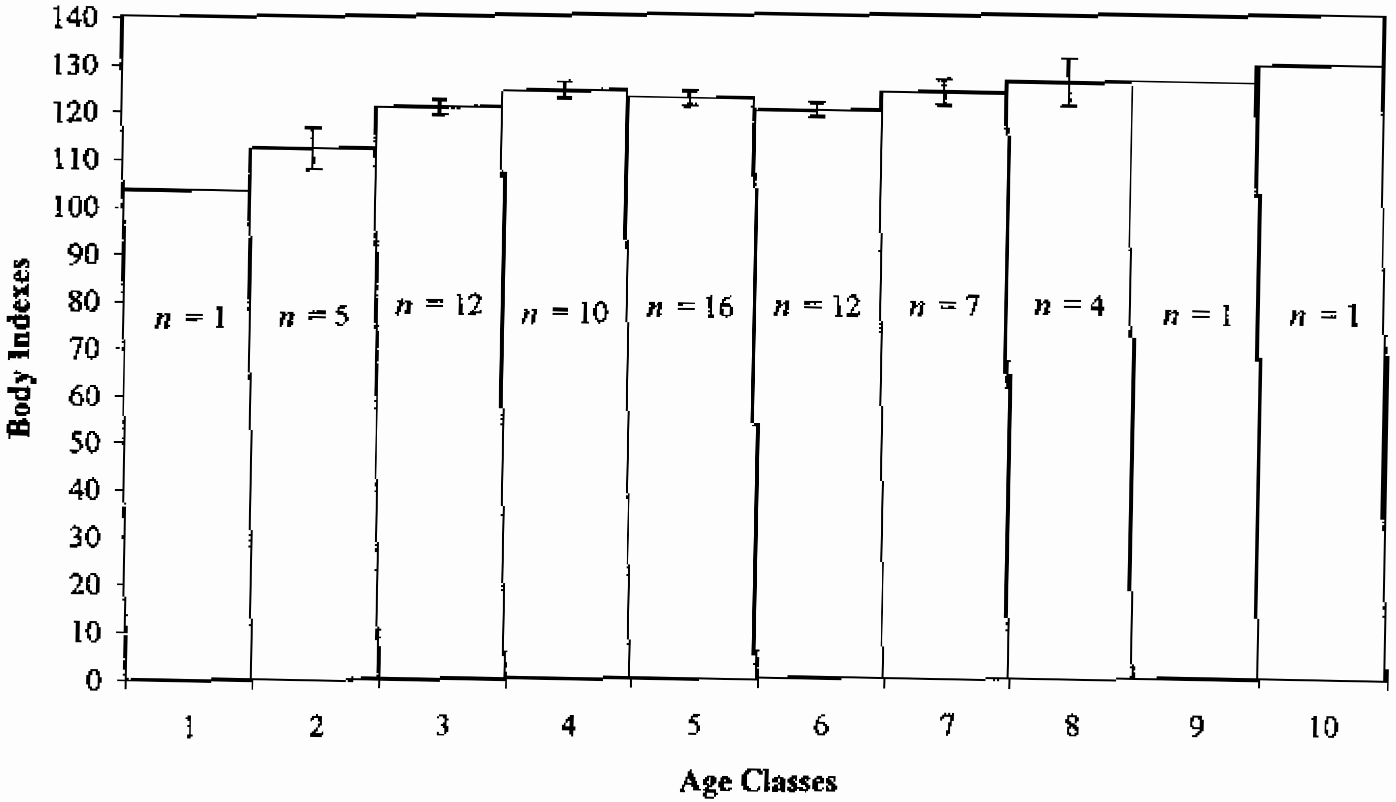


Figure 4. Mean body indexes, by age class, of mule deer harvested at CRLRR, 1994-1996. (Bars = s.e.).

CONCLUSIONS

Population demographics of mule deer on CRLRR were examined using mule deer population estimates, density estimates, and herd composition ratios. The CRLRR mule deer population has been declining since 1994 The decline is likely the result of below average precipitation during winter months and spring growing season. Piñon-juniper woodlands may be the predominant factor explaining the higher fall/winter, compared to spring summer, population estimates. Piñon-juniper woodlands provide winter cover that is not readily available on neighboring ranches resulting in an apparent winter deer migration to CRLRR. Piñon-juniper woodlands are in the process of being converted to grassland or savannah habitats with the use of strip herbicide applications. This may result in an increase in deer numbers through improved habitat. However, if piñon-juniper conversion exceeds an as yet undetermined amount, winter deer numbers may decrease. Piñon-juniper conversion should be further investigated to determine optimal stand density for mule deer

Home range sizes of CRLRR mule deer does estimated in this study appear to be representative of previous studies estimating spring/summer home range sizes for mule deer (Berry 1992). A surprisingly small home range was estimated for 1 deer that is possibly the result of exceptional spring 1997 precipitation and the resultant forage production. Home range estimation could be correlated to habitat quality. This would require a change in the present method of vegetation data collection. If vegetation data were collected more frequently and in areas where collared animals live, it would allow for some comparisons between seasonal home range size and available forage. Additionally, home range size could be compared to stocking rate to investigate potential spatial relationships between mule deer and cattle. It would require frequent animal location data collection and accurate records on stocking rates. By cooperating with the NMSU Department of Animal and Range Sciences it may be possible to manipulate stocking rates to quantify effects of livestock stocking rates on doe mule deer home ranges.

Antler scores of harvested CRLRR mule deer indicate that trophy class is reached at 4 years of age. Additional information needs to be gathered on older age class animals to determine when antler development begins to decline. Body indexes indicate that adult body size is reached at 3 years of age with only slight increases thereafter. Further research into antler development and related age should be investigated because knowing the age range in which antler development peaks makes trophy management decisions easier.

Ultimately, management of wildlife and wildlife habitat on private land are dependent upon economic gains wildlife provides. By continuing research on compatible management strategies for both livestock and wildlife, the rancher, livestock and wildlife can all benefit.

LITERATURE CITED

Anderson, A.E. 1981. Morphological and physiological characteristics. Pages 27-97 *in* O.C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln.

_____, D.E. Medin, and D.C. Bowden. 1974. Growth and morphometry of the carcass, selected bones, organs, and glands of mule deer. Wildl. Monogr. 39. 122pp.

Armstrong, B., D. Harmel, and B. Young. 1984. The management of spike bucks in a white-tailed deer population. Texas Parks and Wildlife PWD LF N7100-247. 2pp.

Arnold, J.F., D.A. Jameson, and E.H. Reid. 1964. The pinyon-juniper type of Arizona: effects of grazing, fire, and tree control. U.S. For. Serv., Production Res. Rep. 84. 28pp.

_____, and W.L. Schroeder. 1955. Juniper control increases forage production on the Fort Apache Indian Reservation. U.S. For. Serv. Rocky Mtn. For. and Range Exp. Stn., Fort Collins, Colo. Paper 18. 35pp.

Aro, R.S. 1971. Evaluation of pinyon-juniper conversion to grassland. J. Range Manage. 24:188-197.

Austin, D.D., and P.J. Urness. 1986. Effects of cattle grazing on mule deer diet and area selection. J. Range Manage. 39:18-21.

Bernardo, D.J., B.W. Boudreau, and T.C. Bidwell. 1994. Economic tradeoffs between livestock grazing and wildlife habitat: a ranch-level analysis. Wildl. Soc. Bull. 22:393-402.

Berry, R.J. 1992. Initial mule deer study at the New Mexico State University Corona Research Ranch. M.S. Thesis, New Mexico State Univ., Las Cruces. 68pp.

Boulander, J.G., and G.C. White. 1990. A comparison of home-range estimators using Monte Carlo simulation. J. Wildl. Manage. 54:310-315.

Bowyer, R.T., and V.C. Bleich. 1984. Effects of cattle grazing on selected habitats of southern mule deer. Calif. Fish and Game. 70:240-247.

Boyd, R.J., A.Y. Cooperrider, P.C. Lent, and J.A Bailey. 1986. Ungulates. Pages 519-564 *in* A.Y. Cooperrider, R.J Boyd, and H.R. Stuart, eds. Inventory and monitoring of wildlife habitat. USDI Bur. Land Manage. Service Center. Denver, Colo.

Butler, L D. 1990. Nontraditional uses of rangelands for income producing activities Pages 122-127 *in* W.N. Grafton, A. Ferrise, D. Colyer, D.K. Smith, and J.E. Miller, eds. Proc from the conference on: Income opportunities for the private landowner through management of natural resources and recreational access. West Virginia Univ. Extension Serv. and Cooperative Extension Serv. Univ. of Maryland System. R.D. 740.

Carrel, W.K. 1980. Aging Arizona game animals by annuli in dental cementum: a final report. Ariz. Dept. Game and Fish. Federal aid in wildlife restoration Project W-78-R. Work plan 1, Job 8 8pp.

Connolly, G.E. 1981a. Trends in populations and harvests. Pages 225-243 *in* O.C. Wallmo, ed. Mule and black-tailed deer on North America. Univ. Nebraska Press, Lincoln.

_____. 1981b. Assessing populations. Pages 287-345 *in* O C. Wallmo, ed. Mule and black-tailed deer on North America. Univ. Nebraska Press, Lincoln.

Dasmann, R.F., and R.D. Taber. 1955. A comparison of four deer census methods. Calif. Fish and Game. 41:225-228

_____, and _____. 1956. Determining structure in Columbian black-tailed deer populations. J. Wildl. Manage. 20:78-83.

Dick-Peddie, W A 1993. New Mexico vegetation; past present and future. Univ. New Mexico Press, Albuquerque. 244pp.

Dimmick, R.W., and M.R. Pelton. 1994. Criteria of sex and age. Pages 169-214 in T.A. Bookout, ed. Research and management techniques for wildlife and habitats. Fifth ed. The Wildlife Society, Bethesda, Md.

Downing, R.L., E.D. Michael, and R.J. Poux, Jr. 1977. Accuracy of sex and age ratio counts of white-tailed deer. J. Wildl. Manage. 41:709-714.

Eberhardt, L., and R.C. Van Etten. 1956. Evaluation of the pellet group count as a deer census method. J. Wildl. Manage. 20:70-74.

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

Freddy, D.J., and D.C. Bowden. 1983. Sampling mule deer pellet-group densities in juniper-pinyon woodland. J. Wildl. Manage. 47:476-485.

Grubb, T.G., and W.L. Eakle. 1988. Recording wildlife locations with Universal Transverse Mercator (UTM) grid system. USDA Forest Service, Rocky Mtn. Forest and Range Exp. Sta. Res. Note RM-483. 3pp.

Harrington, R.D. 1992. The use of remote sensing and a geographical information system for a rangeland inventory. M.S. Thesis,. New Mexico State Univ., Las Cruces. 64pp.

Hibler, C.P. 1981. Diseases. Pages 129-155 *in* O.C. Wallmo, ed. Mule and black-tailed deer on North America. Univ. Nebraska Press, Lincoln.

Howard, V.W., Jr. 1966. Mule deer density in relation to habitat on the Fort Stanton range. M.S. Thesis, New Mexico State Univ., Las Cruces. 30pp.

_____. 1967. Identifying fecal groups by pH analysis. J. Wildl. Manage. 31:190-191.

_____, and D.G. DeLorenzo. 1974. Specific differentiation of herbivore pellet groups by pH. J. Wildl. Manage. 38:948-949.

_____, K.M. Cheap, R.H. Hier, T.G. Thompson, and J.A. Dimas. 1987. Effects of cabling pinyon-juniper on mule deer and lagomorph use. Wildl. Soc. Bull. 15:242-247.

Johnsen, T.N., Jr. 1962. One-seed juniper invasion of northern Arizona grasslands. Ecol. Monogr. 32:187-207.

Joseph, J.O. 1995. Seasonal food habits of mule deer at the Corona Range and Livestock Research Ranch, central New Mexico. M.S. Thesis, New Mexico State Univ., Las Cruces. 59pp.

Jordan, L.A., and J.P. Workman. 1989. Overview of fee hunting for deer and elk on private land in Utah. Trans. N. Am. Wildl. & Nat. Res. Conf. 54:190-195.

Kie, J.G., J.A. Baldwin, and C.J. Evans. 1996. CALHOME: a program for estimating animal home ranges. Wildl. Soc Bull. 24:342-344

_____, and B.B. Boroski. 1995. The effects of cattle grazing on black-tailed deer during winter on the Tehama Wildlife Management Area. U S. For. Serv., Pacific Southwest Res. Stn., Fresno, Calif. 36pp.

_____, C J. Evans, E.R. Loft, and J W Menke. 1991. Foraging behavior by mule deer: the influence of cattle grazing. J. Wildl. Manage. 55:665-674.

Kufeld, R.C. 1968. Use of paint for marking deer pellet groups. J. Wildl. Manage. 32.592-596.

Kunkel, K.E. 1984. Temperature and precipitation summaries for selected New Mexico locations. New Mexico Dep. Agric. 190pp.

Larson, J.S., and R.D. Taber. 1980. Criteria of sex and age. Pages 143-202 *in* S.D. Schemnitz, ed. Wildlife management techniques manual. Fourth ed. The Wildlife Society, Bethesda, Md.

Longhurst, W.M., R.E. Hafenfeld, and G.E. Connolly. 1981. Deer-livestock interrelationships in the western states. Pages 409-420 *in* L. Nelson, Jr., and J M. Peek, eds. Proc. of the wildlife-livestock relationship symposium. Univ. Idaho, Moscow.

Loomis, J.B., E.R. Loft, D.R. Updike, and J G. Kie. 1991. Cattle-deer interactions in the Sierra Nevada: a bioeconomic approach. J. Range Manage. 44:395-399.

Lovaas, A.L. 1958. Mule deer food habits and range use, Little Belt Mountains, Montana J. Wildl. Manage. 22:275-283.

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

McCulloch, C Y. 1969. Some effects of wildfire on deer habitat in pinyon-juniper woodland. J. Wildl. Manage. 33:778-784

McCullough, D.R. 1993. Variation in black-tailed deer herd composition counts. J. Wildl. Manage. 57:890-897.

_____. 1994. What do herd composition counts tell us? Wildl. Soc. Bull. 22:295-300.

_____, F.W. Weckerly, P.I. Garcia, and R.R. Evett. 1994. Sources of inaccuracy in black-tailed deer herd composition counts. J. Wildl. Manage. 58:319-329.

McIntosh, B.J., and P.R. Krausman. 1981. Elk and mule deer distributions after a cattle introduction in northern Arizona. Pages 545-552 *in* L. Nelson, Jr., and J.M. Peek, eds. Proc. of the wildlife-livestock relationship symposium. Univ. Idaho, Moscow.

Moore, W.J. 1994. Preliminary evaluation of the Corona Range and Livestock Research Ranch mule deer herd. M.S. Thesis, New Mexico State Univ., Las Cruces. 65pp.

Morrill, W.I. 1988. Overview of wildlife ranching in the U.S.A. Pages 30-36 *in* R. Valdez, ed., and J. Knight tech. ed Proc. of the First International Wildlife Ranching Symposium. USDA Cooperative Extension Service, New Mexico State Univ., Las Cruces.

Nagy, J.G., and J.G. Gilbert. 1968. Fecal pH values of mule deer and grazing domestic sheep. J. Wildl. Manage. 32:961-962.

Neff, D.J. 1968. The pellet-group count technique for big game trend, census, and distribution: A review. J. Wildl. Manage. 32:597-614.

Peek, J.M., M.D. Scott, L.J. Nelson, D.J. Pierce, and L.L. Irwin. 1982. Role of cover in habitat management for big game in Northwestern United States. Trans. N. Am. Wildl. Conf. 47:363-373.

Pieper, R.D. 1978. Measurement techniques for herbaceous and shrubby vegetation. New Mexico State Univ., Las Cruces. 148pp.

Ramsey, C.W. 1965. Potential economic returns from deer as compared to livestock in the Edwards Plateau region of Texas. J. Range Manage. 18:247-250.

Rasmussen, D.I., and E.R. Doman. 1943. Census methods and their application in the management of mule deer. Trans. N. Am. Wildl. Conf. 8: 369-380.

Remington, R., W.E. Werner, K.R. Rautenstrauch, and P.R. Krausman. 1984. Desert mule deer use of a new permanent water source. Pages 92-94 *in* P.R. Krausman, and N.S. Smith, eds. Deer in the Southwest: A workshop. Arizona Coop. Wildl. Res. Unit, Univ. of Arizona, Tucson.

Reynolds, H.G. 1964. Elk and deer habitat use of a pinyon-juniper woodland in southern New Mexico. Trans N. Am. Wildl. Conf 29:438-444.

Robinette, W.L. 1966. Mule deer home range and dispersal in Utah. J. Wildl. Manage 30:335-349.

_____, C.H. Baer, R.E. Pillmore, and C.E. Knittle. 1973. Effects of nutritional change on captive mule deer. J. Wildl. Manage. 37:312-326.

_____, R.B. Ferguson, and J.S. Gashwiler. 1958. Problems involved in the use of deer pellet group counts. Trans. N. Am. Wildl. Conf. 23:411-425.

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

Rogers, G., O. Julander, and W.L. Robinette. 1958. Pellet-group counts for deer census and range-use index. J. Wildl. Manage. 22: 193-199.

Rogers, L.L. 1987 Seasonal changes in defecation rates of free-ranging white-tailed deer. J. Wildl. Manage. 51:330-333.

Rollins, D., F.C. Bryant, and R. Montandon. 1984. Fecal pH and defecation rates of eight ruminants fed known diets. J. Wildl. Manage. 48:807-813.

Sawyer, T.G., R.L. Marchinton, and W. Mac Lentz. 1990. Defecation rates of female white-tailed deer in Georgia. Wildl. Soc. Bull. 18: 16-18.

Scaling, W. 1988. A national outlook on ranching's future. Rangelands 10:160-162.

Schott, M.R., and R.D. Pieper. 1987. Succession of pinyon-juniper communities after mechanical disturbance in south central New Mexico. J. Range Manage. 40:88-94.

Short, H.L., W. Evans, and E.L. Boeker. 1977. The use of natural and modified pinyon pine-juniper woodlands by deer and elk. J. Wildl. Manage. 41 543-559.

Smith, A.D. 1964. Defecation rates of mule deer. J. Wildl. Manage. 28:435-444.

Smith, R.H. 1968. A comparison of several sizes of circular plots for estimating deer pellet-group density. J Wildl. Manage. 32:585-591.

_____, and A. LeCount. 1979. Some factors affecting survival of desert mule deer fawns. J. Wildl. Manage. 43:657-665.

Stevens, R. 1987. Thirty years of pinyon-juniper big game habitat improvement projects: What have we learned? Pages 558-570 *in* Proceedings of Pinyon-Juniper Conf. U.S. For. Serv., Gen. Tech. Rep. INT-215.

Swank, W.G. 1958. The mule deer in Arizona chaparral. Arizona Dept. Game and Fish. Federal aid in wildlife restoration, project W-71-R, Wildl. Bull. No. 3. 109pp.

Terrel, T.L., and J.J. Spillett. 1975. Pinyon-juniper conversion: its impact on mule deer and other wildlife. Pages 105-119 *in* The Pinyon-Juniper Ecosystem: A Symposium. Utah State Univ., Logan.

Thomas, D.C., and P.J. Bandy. 1973. Age determination of wild black-tailed deer from dental annulations. J. Wildl. Manage. 37:232-235

Urness, P.J. 1981. Desert and chaparral habitats. Pages 347-385 *in* O C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln.

Van Etten, R.C., and C.L. Bennett. 1965. Some sources of error in using pellet-group counts for censusing deer. J. Wildl. Manage. 29:723-729.

Wallmo, O C., A.W. Jackson, T.L. Hailey, and R.L. Carlisle. 1962. Influence of rain on the count of deer pellet groups. J. Wildl. Manage. 26:50-55.

White, G.C., and R.A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, CA. 383pp.

Wilkins, B.T. 1957. Range use, food habits, an agricultural relationships of the mule deer, Bridger Mountains, Montana J. Wildl. Manage. 21:159-169.

Wright, B.D. 1997. Comparisons between New Mexico fee hunting enterprises on public and private land ranches. M.S Thesis, New Mexico State Univ., Las Cruces. 54pp.

Wood, J.E., T.S. Bickle, W. Evans, J.C. Germany, and V.W. Howard, Jr. 1970. The Fort Stanton mule deer herd. New Mexico Agric. Exp. Sta., Las Cruces. Bulletin 567. 32pp.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

_____. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. J. Wildl. Manage. 59:794-800.

Wunderlich, K., J.J. Jacobs, and D.T. Taylor. 1990. Hunting enterprises: Costs and returns. Rangelands 12:119-121.

APPENDIX A

Mean monthly precipitation values from Corona Range and Livestock Research Ranch, 1994-1997

MONTH	1994 Precipitation mm	1995 Precipitation mm	1996 Precipitation mm	1997 Precipitation mm
January	2.52	3.30	0.00	20.57
February	2.03	0.00	16.25	15.49
March	13.68	21.59	5.08	8 89
April	13.19	0.00	0.00	39.88
May	107.66	13.46	0.00	28.70
June	21.07	24.64	66.29	104.90
July	52 81	54.61	110.74	6.88
August	96.38	62.99	106.93	0.00
September	41.62	45.97	70.87	0.00
October	32.62	0.00	36.32	0 00
November	19.29	0.00	1.78	0.00
December	15.52	5.08	0.00	0.00

APPENDIX B

Plant species identified on vegetation transects, at Corona Range and Livestock Research Ranch, 1996

GRASSES

Scientific Name	Common Name
Aristida spp.	threeawn
Bouteloua curtipendula	sideoats grama
Bouteloua eriopoda	black grama
Bouteloua gracilis	blue grama
Bouteloua hirsuta	hairy grama
Cenchrus incertus	sandbur
Eragrostis spp.	lovegrass
Lycurus phleoides	wolftail
Muhlenbergia montana	mountain muhly
Muhlenbergia richardsonis	mat muhly
Muhlenbergia torreyi	ring muhly
Munroa squarrosa	false buffalo grass
Panicum obtusum	vine mesquite
Schizachyrium scoparium	little bluestem

(continued)

APPENDIX B (cont.)

FORBS

Scientific Name	Common Name
Ambrosia spp.	ragweed
Allionia incarnata	trailing four o'clock
Argemone squarrosa	prickly poppy
Calliandra eriophylla	mesquitilla
Chamaesyce spp.	spurge
Chenopodium graveolens	fetid goosefoot
Cyperus fendleriamus	sedge
Dalea polygonoides	Dalea
Gutierrezia sarothrae	broom snakeweed
Helianthus petiolaris	prairie sunflower
Pectis papposa	cinch weed
Portulaca oleracea	common purslane
Ratibida comlumnifera	prairie cone flower
Salsola Kali	Russian thistle
Solanum elaeagnifolium	white silverleaf nightshade
Sphaeralcea parvifolia	globemallow
Zinnia gradiflora	Zinnia
Portulaca parvula	purslane

(continued)

APPENDIX B (cont.)

SHRUBS

Scientific Name	Common Name
Artemisia bigelovii	Bigelow sagebrush
Ceratoides lanata	winter fat
Chrysothamnus nauseosus	rubber rabbitbrush
Quercus spp.	oak brush

TREES

Juniperus monosperma	one-seed juniper
Pinus edulis	Colorado piñon pine

CACTUS/YUCCA

Nolina microcarpa	bear grass
Opuntia imbricata	cholla
Opuntia spp.	prickly pear
Yucca spp.	yucca

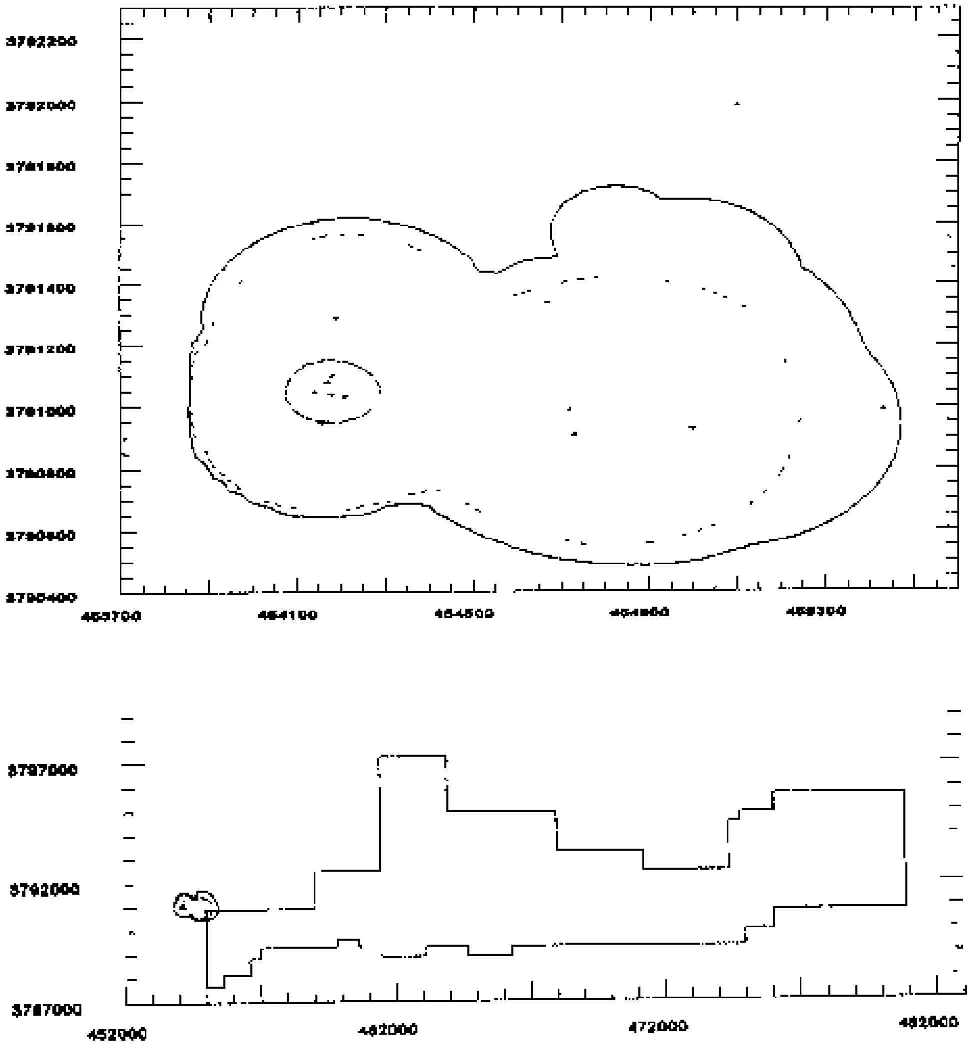
APPENDIX C

Adaptive Kernel home range estimates and ranch locations of radio-collared adult does at Corona Range and Livestock Research Ranch.

DEER NUMBER	EAR TAG NUMBER	RADIO FREQUENCY
1	EB2816	159.331
2	EB2822	159.448
*3	EB2819	159.893
4	EB2821	159.107
5	EB2817	159.223
6	EB2814	159.445
7	EB2815	159.662

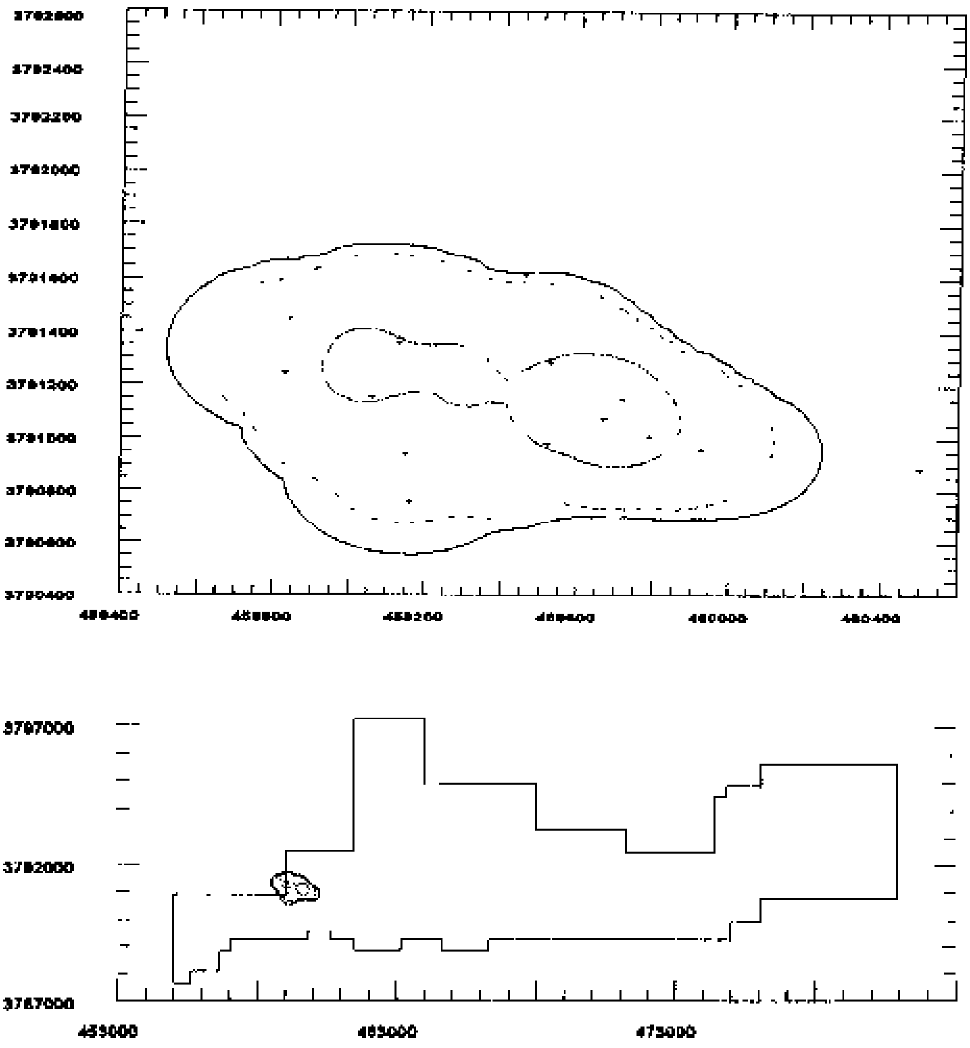
*Died prior to completion of study, therefore omitted from home range analysis.

APPENDIX C (cont.)



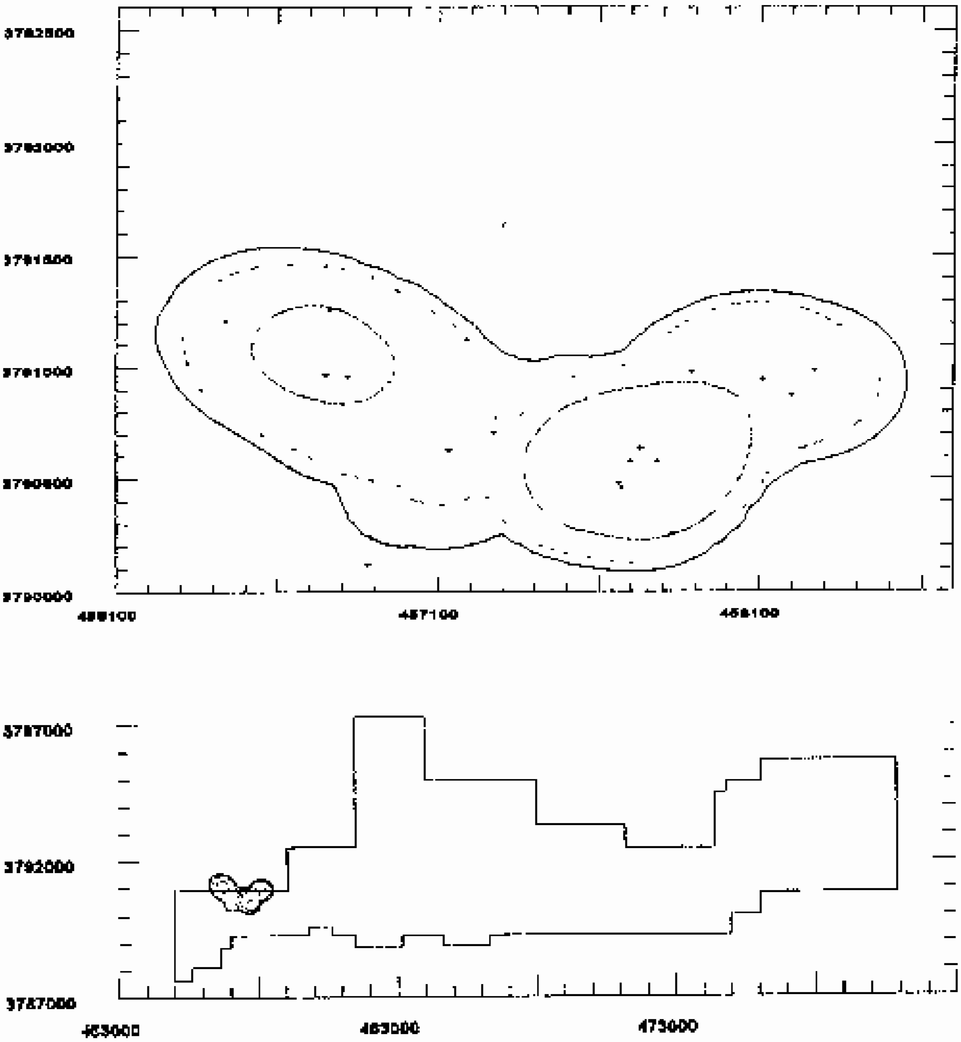
Deer #1: Home range (1.5 km^2) estimated using the Adaptive Kernel method in program CALHOME (n = 14). Areas of 90% and 50% utilization distributions are 1.0 km^2 and 0.03 km^2, respectively.

APPENDIX C (cont.)



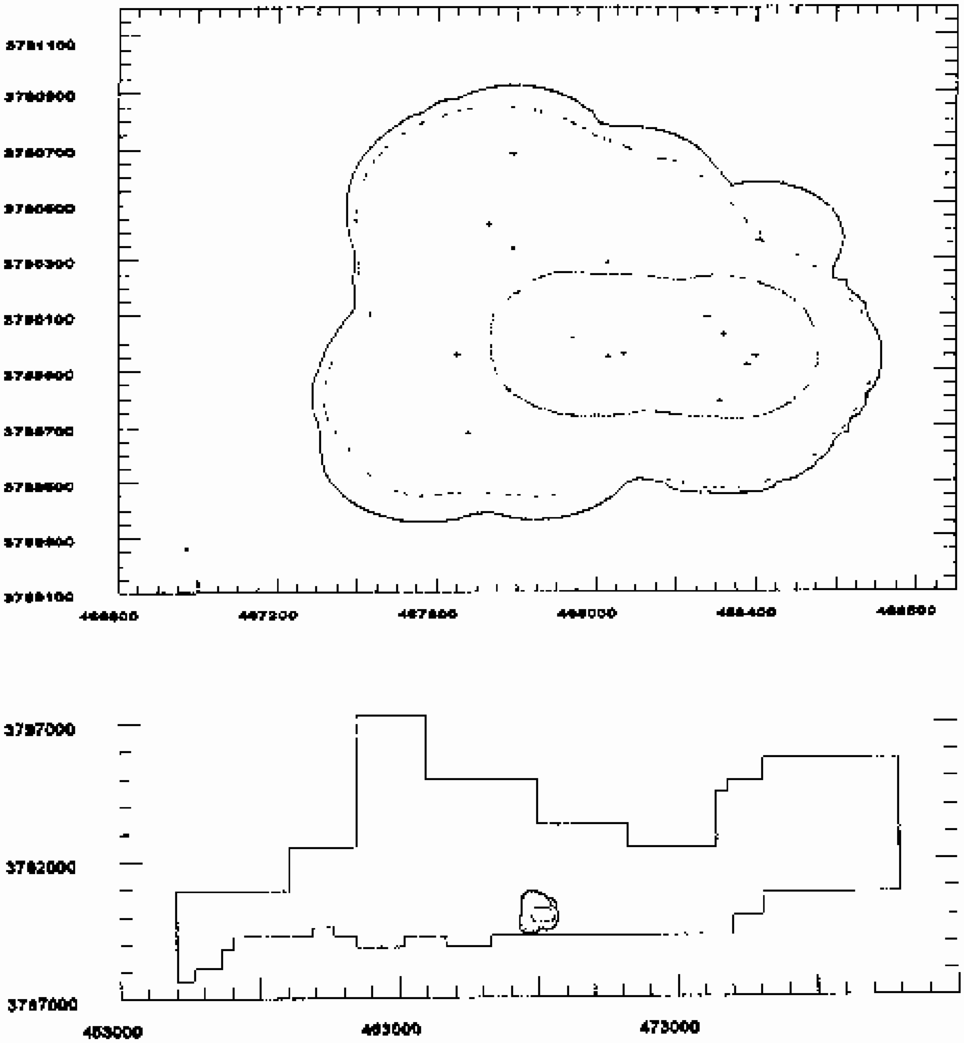
Deer # 2: Home range (1.4 km^2) estimated using the Adaptive Kernel method in program CALHOME (n = 16). Areas of 90% and 50% utilization distributions are 1.1 km^2 and 0.25 km^2, respectively.

APPENDIX C (cont.)



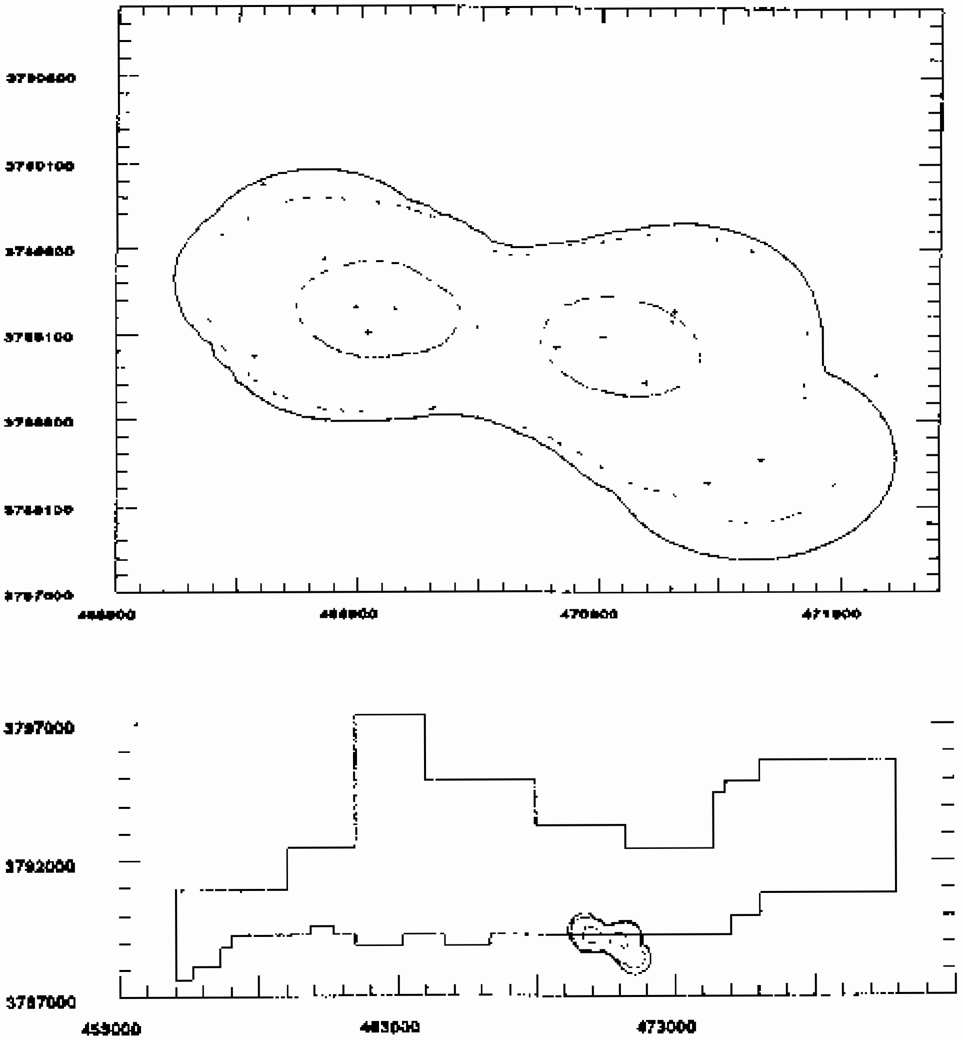
Deer # 4: Home range (2.1 km^2) estimated using the Adaptive Kernel method in program CALHOME (n = 20). Areas of 90% and 50% utilization distributions are 1.6 km^2 and 0.5 km^2, respectively.

APPENDIX C (cont.)



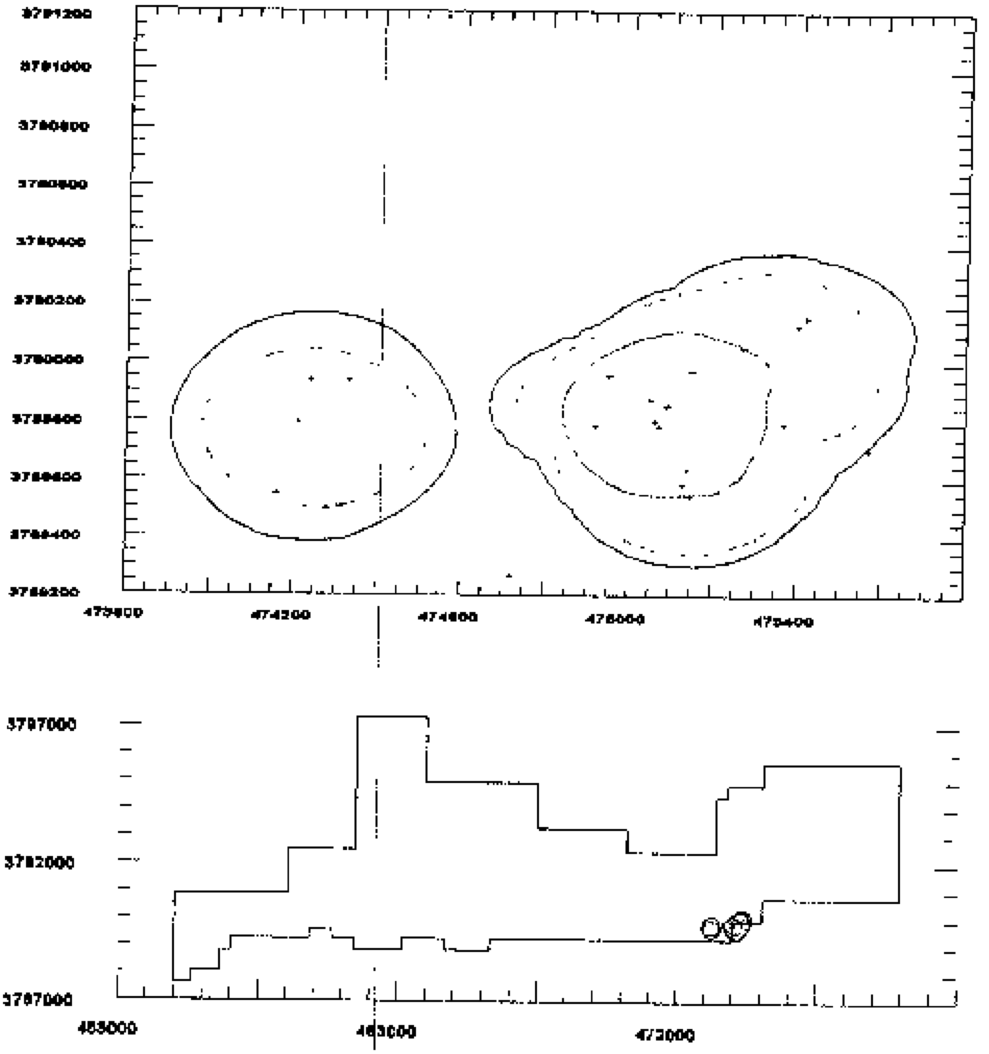
Deer # 5. Home range (1.7 km^2) estimated using the Adaptive Kernel method in program CALHOME ($n = 18$). Areas of 90% and 50% utilization distributions are 1.4 km^2 and 0.4 km^2, respectively.

APPENDIX C (cont.)



Deer #6: Home range (3.9 km^2) estimated using the Adaptive Kernel method in program CALHOME (n = 15). Areas of 90% and 50% utilization distributions are 3.1 km^2 and 0 6 km^2, respectively.

APPENDIX C (cont.)



Deer # 7: Home range (1.1 km^2) estimated using the Adaptive Kernel method in program CALHOME (n = 21). Areas of 90% and 50% utilization distributions are 0.8 km^2 and 0.2 km^2, respectively.

Stuwe, M. 1988. Micro-computer programs for the analysis of animal locations. Conservation and Research Center, Smithsonian Institution. Front Royal, VA. 30pp.

Taylor, W.P. 1961. The deer of North America. The white-tailed, mule and black-tailed deer, genus Odocoileus. Their history and management. The Wildlife Management Institute, Washington, D.C.

Terrel, T.L. 1973. Mule deer use patterns as related to pinyon-juniper conversion in Utah. Doctoral Dissertation, Utah State Univ., Logan.

Thomas, D.C. and P.J. Bandy. 1973. Age determination of wild black-tailed deer from dental annulations. J. Wildl. Manage. 37:232-235.

U.S. Department of Agriculture Soil Conservation Service. 1970. Soil Survey Torrance area New Mexico. U.S. Government Printing Office, Washington D.C.

White, G.C. and R.A. Garrott. 1982. Age and sex selectivity in trapping mule deer. J. Wildl. Manage. 46:1083-1086.

_____ and _____. 1990. Analysis of wildlife radio-tracking data. Academic Press Inc., San Diego, Calif. 383pp.

Wood, J.E., S.B Thomas, E. Wainwright, W. Evans, J.C. Germany, and V.W. Howard, Jr. 1970. The Fort Stanton mule deer herd: some ecological and life history characteristics with special emphasis on the use of water. New Mexico Agr. Exp. Sta. Bull. No.567. 32pp.

Zalunardo, R.A. 1965. The seasonal distribution of a migratory mule deer herd. J. Wildl. Manage. 29:345-351.

APPENDIX A

LIST OF COMMON AND SCIENTIFIC NAMES OF GRASSES, FORBS, SHRUBS, CACTI, AND TREES

Scientific Name	Common Name
GRASSES	
Bouteloua gracilis	Blue grama
Bouteloua eriopoda	Black grama
Bouteloua hirsuta	Hairy grama
Bouteloua curtipendula	Sideoats grama
Lycurus phleoides	Wolftail
Sporobolus cryptandrus	Sand dropseed
Sitanion jubatum	Big squirrel tail
Muhlenbergia richardsonis	Mat muhly
Panicum obtusum	Vine mesquite
Muhlenbergia torreyi	Ring muhly
Muhlenbergia eludens	Fine muhly
Hilaria jamesii	Galleta
Munroa squarrosa	False buffalo grass
Muhlenbergia montana	Mountain muhly
Aristida spp.	Three awn
FORBS	
Argemone squarrosa	Prickly poppy
Amaranthus hybridus	Pigweed
Chenopodium fremontii	Lamb's quarters
Pectis angustifolia	Lemon weed
Euphorbia spp.	Spurge
Salsola kali	Russian thistle
Helianthus petiolaris	Prairie sunflower
Solanum elaeagnifolium	White silver leaf night shade
Allionia incarnata	Trailing four o'clock
Physalis virginiana	Ground cherry
Urtica gracilis	Stinging nettle
Grindelia squarrosa	Curlycup gumweed
Psilostrophe tagentina	Paper daisy
Thelesperma megapotamicum	Greenthread
Sphaeralcea parvifolia	Globe mallow
Dithyrea wislizenii	Spectacle pod
Senecio longilobus	Threadleaf groundsel
Mentha arvensis	Mint
Carex filifolia	Threadleaf sedge
Lepidium montanum	Pepperweed
Ipomoea hirsutula	Wild morning glory
Ambrosia artemisiifolia	Ragweed
Heterotheca villosa	Hairy goldaster
Oxytropis lambertii	Locoweed
Zinnia grandiflora	Wild zinnia
Verbena ambrosifolia	Verbena

Scientific Name	Common Name
	FORBS(cont'd)
Ratibida columnifera	Prairie cone flower
Gutierrezia sarothrae	Broom snakeweed
	SHRUBS
Ribes cereum	Squaw currant
Krameria parvifolia	Range ratany
Fallugia paradoxa	Apache plume
Artemisia tridentata	Big sagebrush
Chrysothamnus nauseosus	Rubber rabbitbrush
Ceratoides lanata	Winter fat
Berberis fremontii	Algerita
Quercus gambelii	Gambel's oak
	CACTUS
Opuntia spp.	Prickly pear
Nolina microcarpa	Bear grass
Opuntia imbricata	Walking stick cholla
Yucca elata	Soaptree yucca
Yucca baccata	Banana yucca
	TREES
Juniperus monosperma	One-seed juniper
Pinus edulis	Pinyon pine
Pinus ponderosa	Ponderosa pine[1]

---

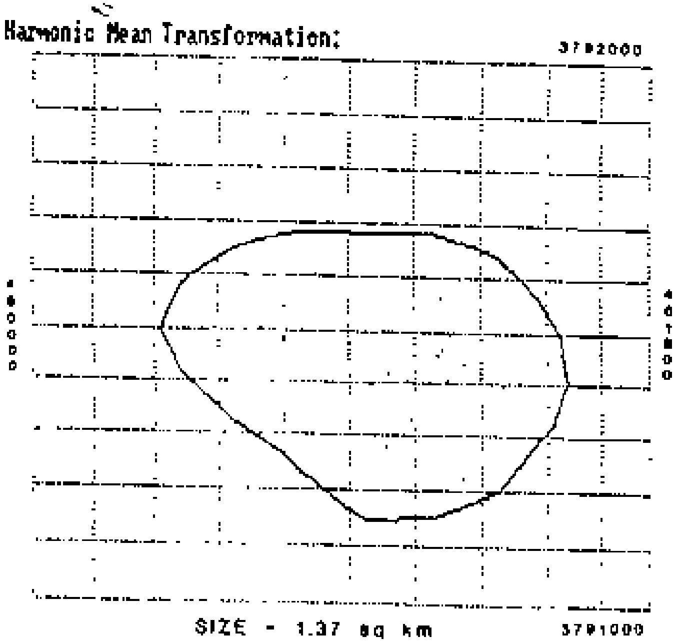
[1] Ponderosa pine was not identified on the vegetation transects but does exist on the research area.

APPENDIX B

SUMMER AND WINTER HOME RANGE SIZES

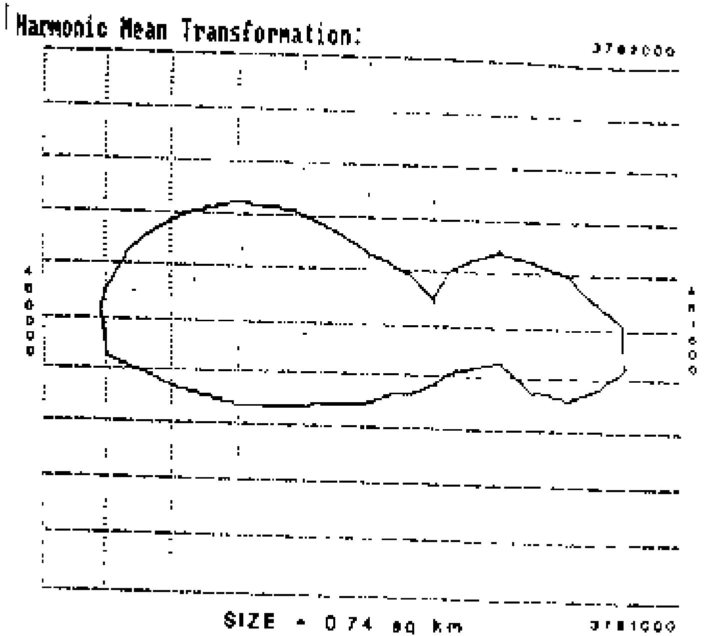
SUMMER AND WINTER HOME RANGE SIZES OF THE RED/GREEN RADIOCOLLARED DOE

SUMMER



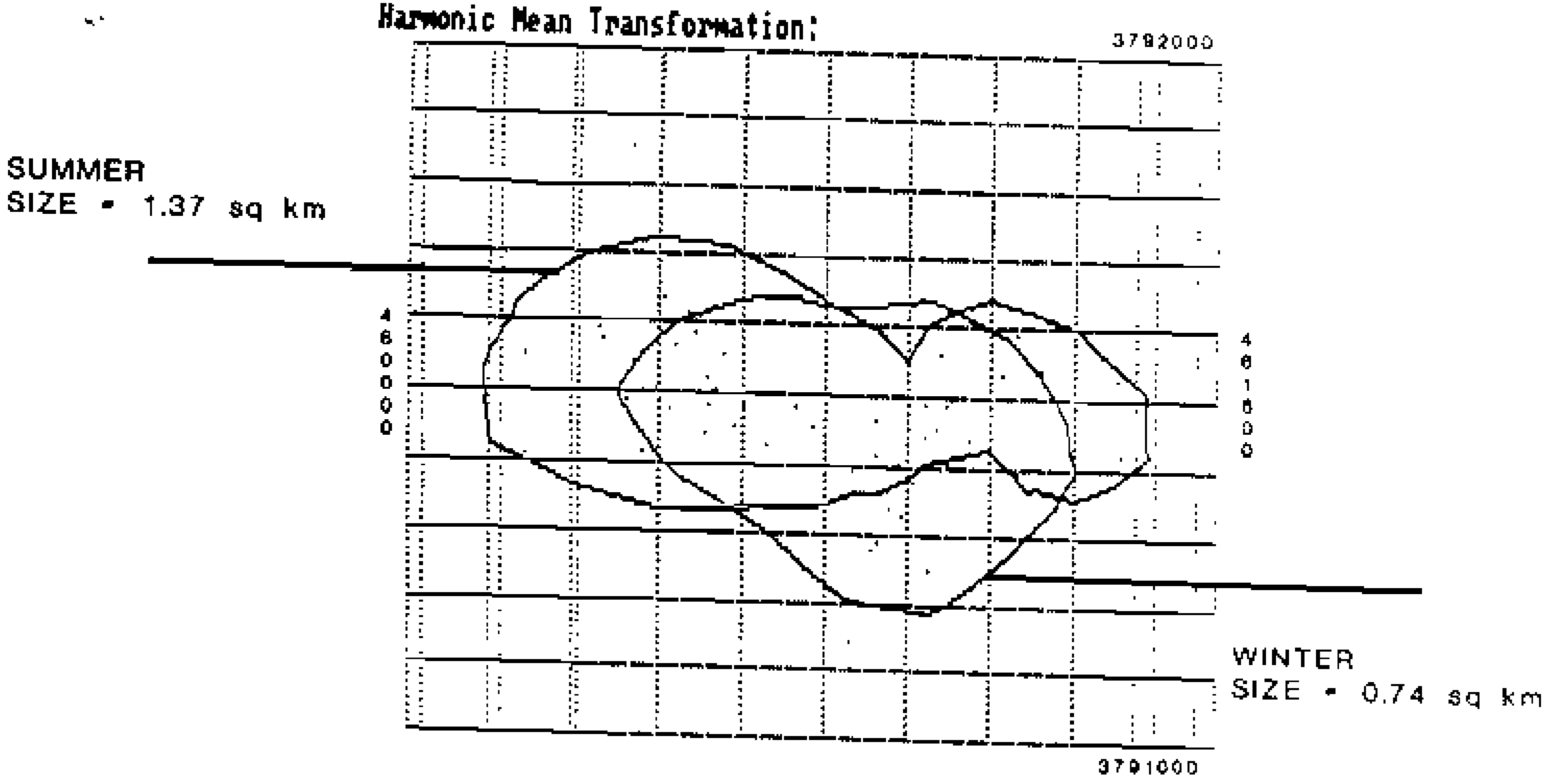
SIZE - 1.37 sq km
LOCATION, ORTIZ PASTURE

WINTER



SIZE - 0.74 sq km
LOCATION ORTIZ PASTURE

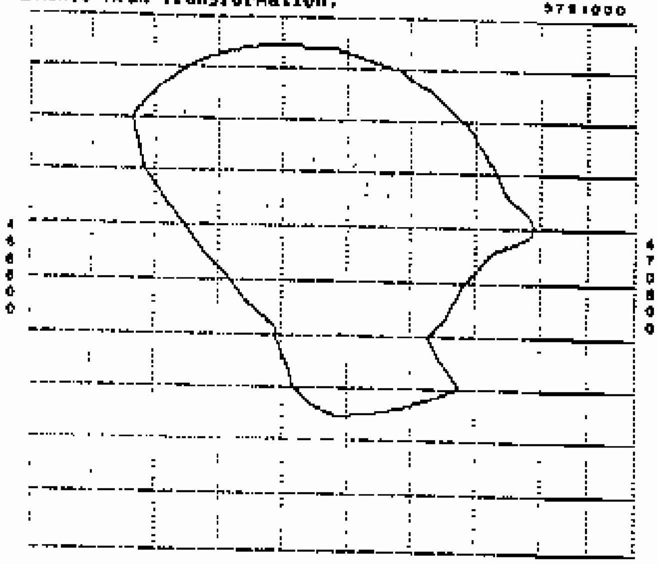
WINTER HOME RANGE OVERLAID ONTO SUMMER HOME RANGE OF RD/GRN RADIOCOLLARED DOE



SUMMER AND WINTER HOME RANGE SIZES OF THE BLACK RADIOCOLLARED DOE

SUMMER

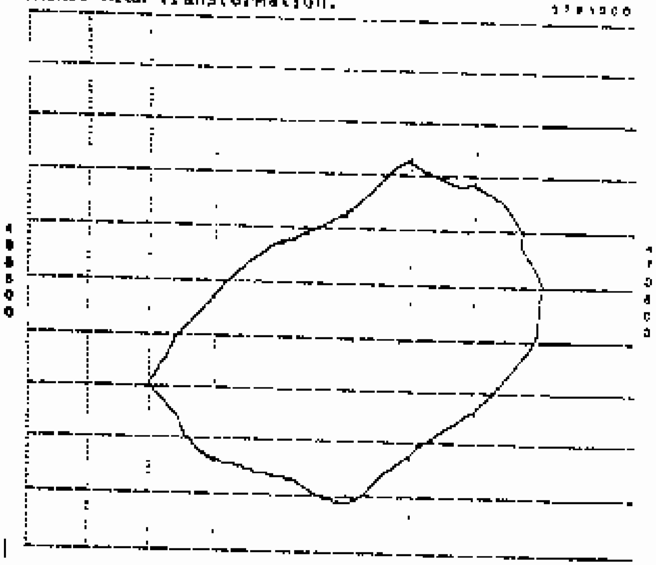
Harmonic Mean Transformation:



SIZE = 2.96 sq km
LOCATION. GENERATOR PASTURE

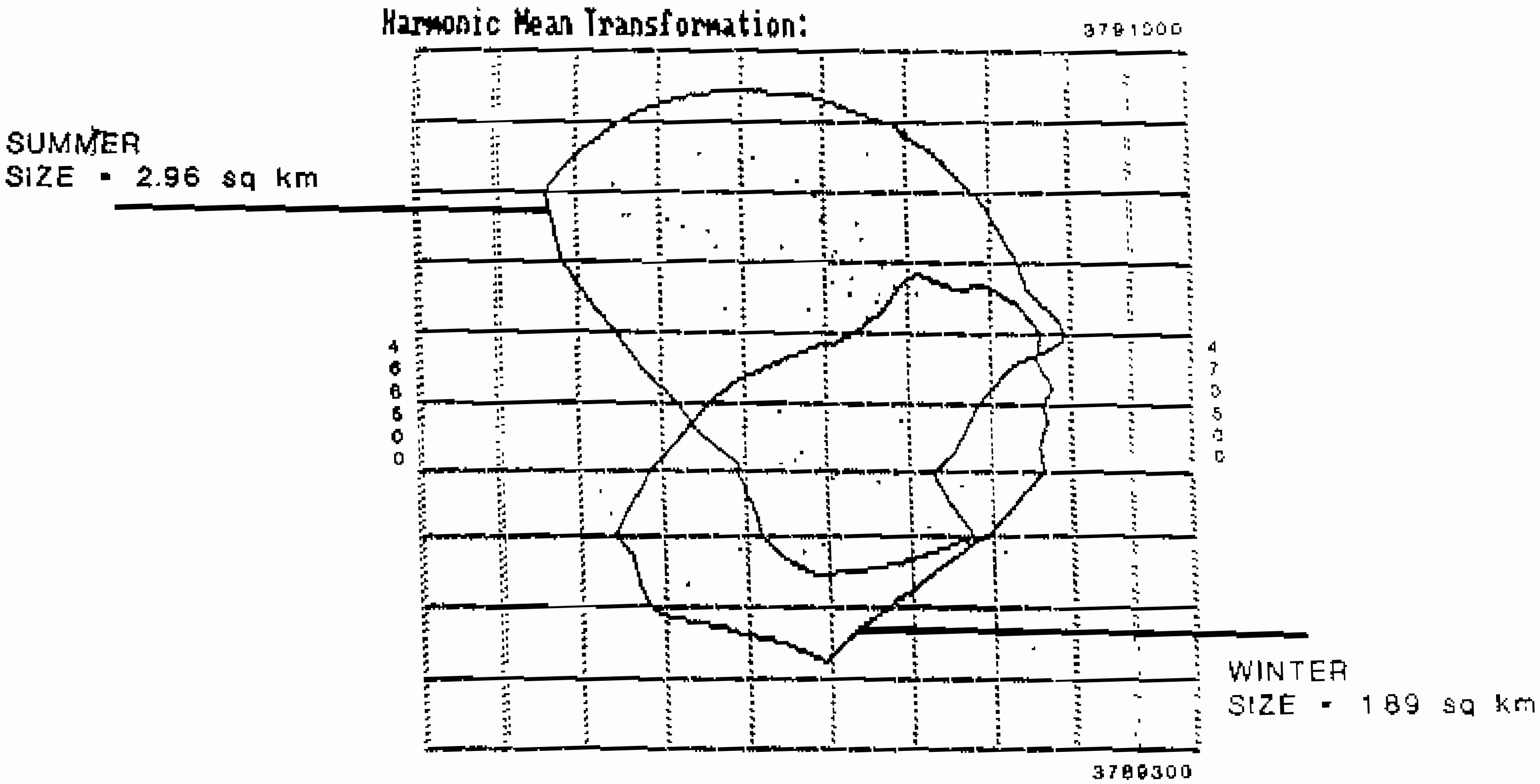
WINTER

Harmonic Mean Transformation:



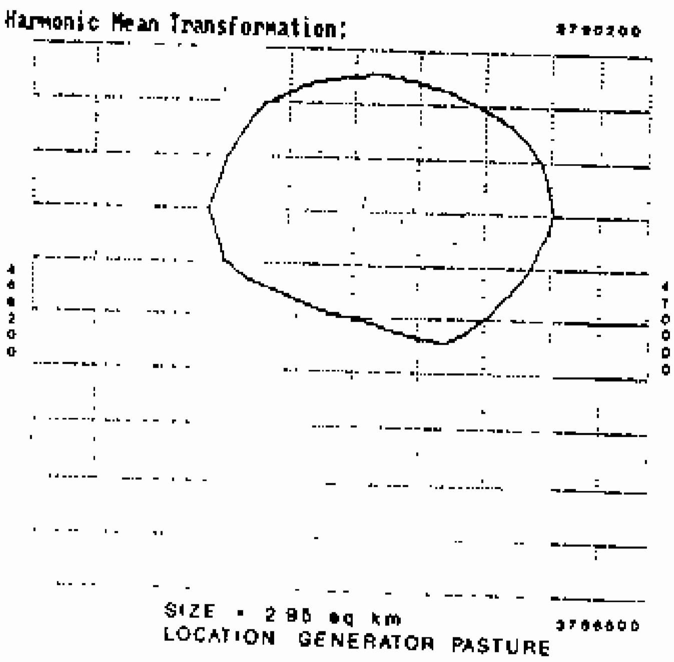
SIZE = 1.89 sq km
LOCATION. GENERATOR PASTURE

WINTER HOME RANGE OVERLAID ONTO SUMMER HOME RANGE OF BLACK RADIOCOLLARED DOE

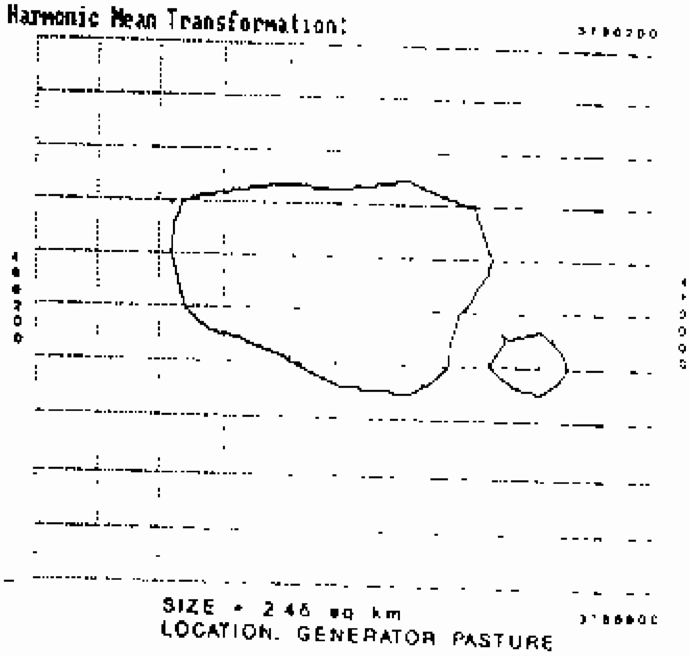


SUMMER AND WINTER HOME RANGE SIZES OF THE RED RADIOCOLLARED DOE

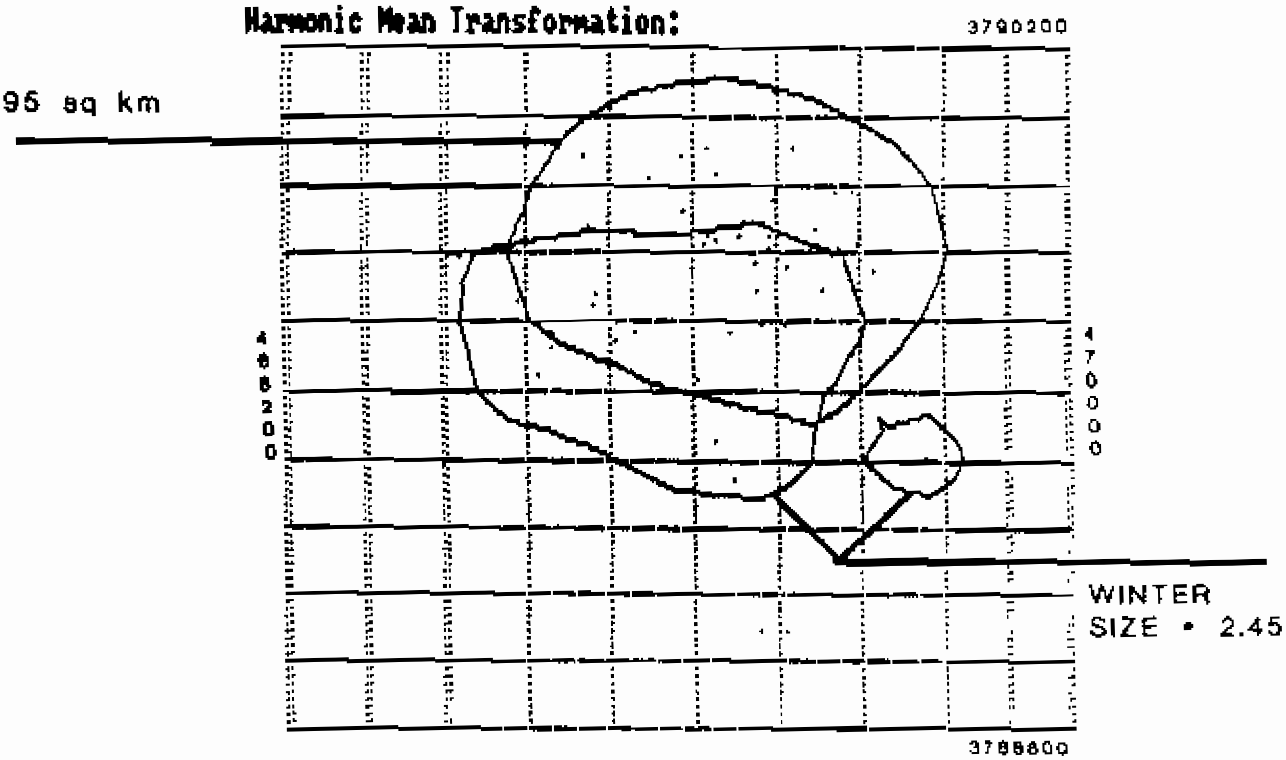
SUMMER



WINTER



WINTER HOME RANGE OVERLAID ONTO SUMMER HOME RANGE OF RED RADIOCOLLARED DOE

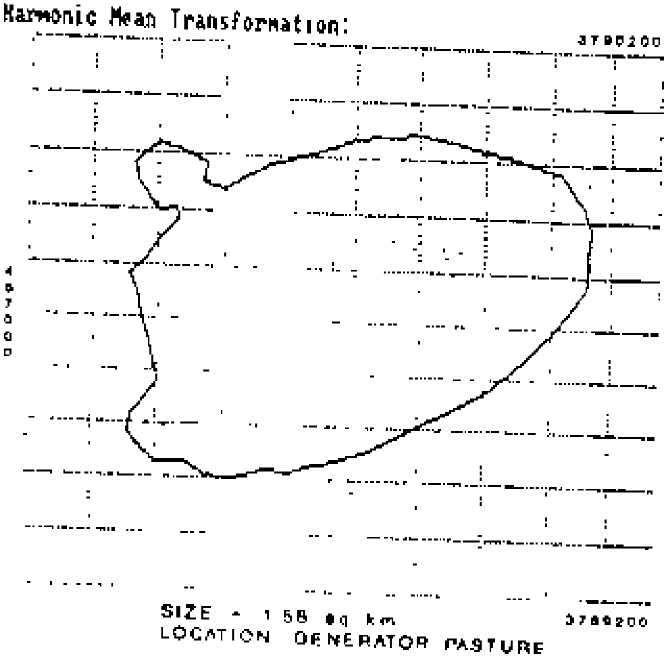


SUMMER
SIZE = 2.95 sq km

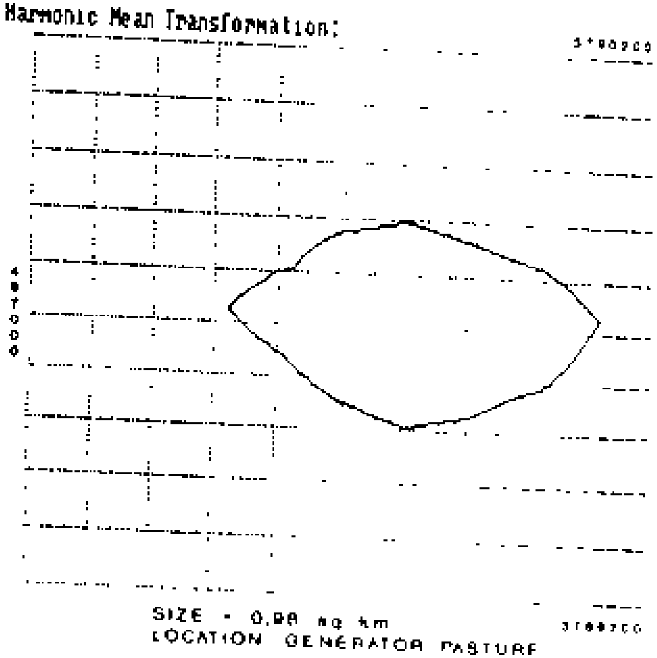
WINTER
SIZE = 2.45 sq km

SUMMER AND WINTER HOME RANGE SIZES OF THE BLACK/WHITE RADIOCOLLARED DOE

SUMMER

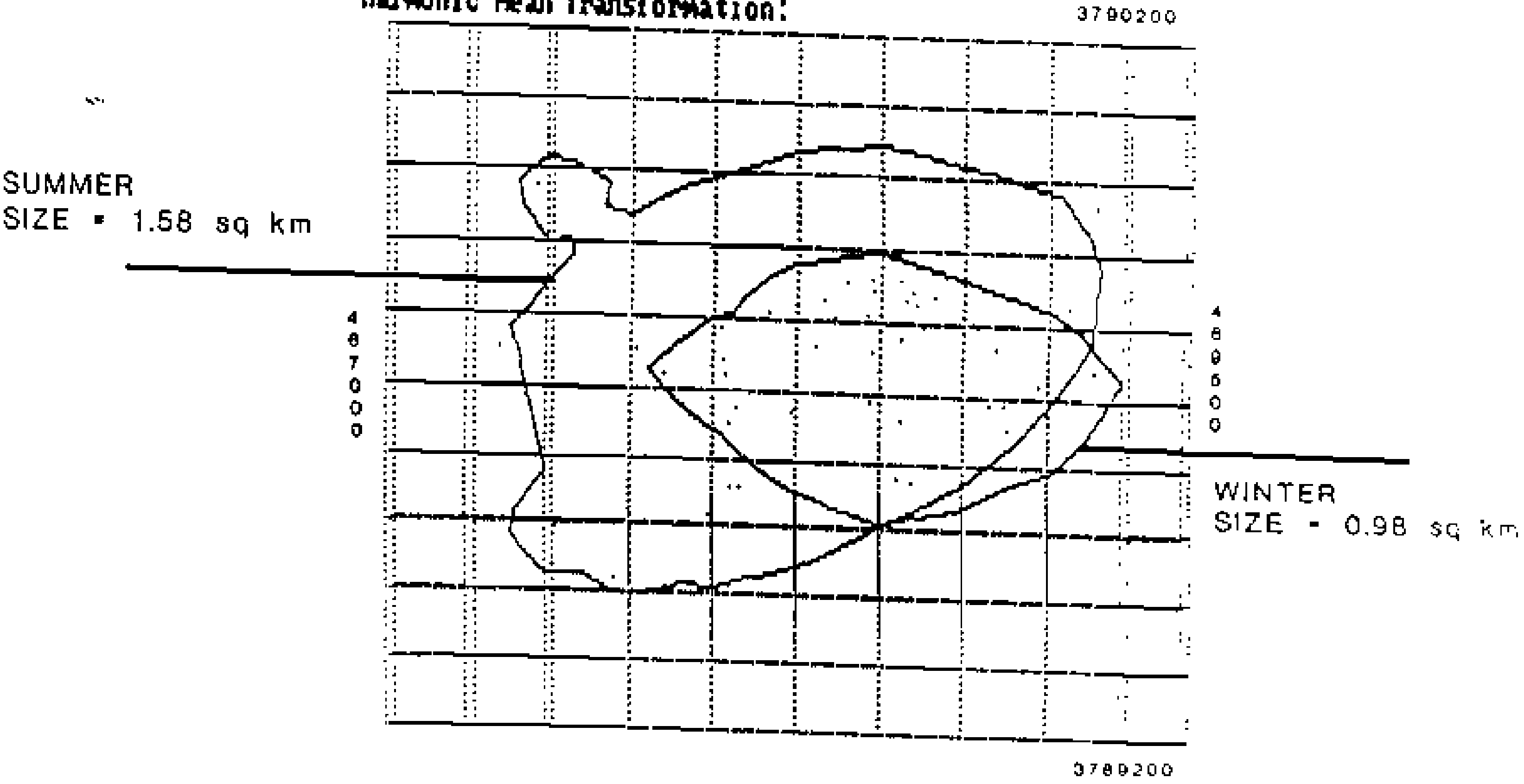


WINTER



WINTER HOME RANGE OVERLAID ONTO SUMMER HOME RANGE OF BLK/WHT RADIOCOLLARED DOE

Harmonic Mean Transformation:



SUMMER
SIZE = 1.58 sq km

WINTER
SIZE = 0.98 sq km

APPENDIX C

RESULTS FROM MULTIPLE REGRESSION ANALYSIS, CLUSTER ANALYSIS, AND PEARSON CORRELATION COEFFICIENTS

```
                         PEARSON CORRELATION COEFFICIENTS FOR ALL
                     SEVEN VARIABLES FROM 1991 VEGETATION TRANSECT READINGS

VARIABLE      N          MEAN           STD DEV             SUM         MINIMUM         MAXIMUM

BARE         28    0.50071429        0.07892465     14.02000000      0.28000000      0.65000000
LITTER       28    0.16535714        0.11672957      4.63000000      0.01000000      0.40000000
GRASS        28    0.21428571        0.08608474      6.00000000      0.03000000      0.37000000
FORB         28    0.10571429        0.08261596      2.96000000      0.01000000      0.33000000
CACTUS       28    0.01928571        0.02637740      0.54000000      0.00000000      0.08000000
SHRUB        28    0.00571429        0.00878912      0.16000000      0.00000000      0.04000000
TREE         28    0.15892857        0.13668941      4.45000000      0.00000000      0.40000000

        PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 28

                  BARE    LITTER     GRASS      FORB    CACTUS     SHRUB      TREE

BARE           1.00000  -0.45270   0.15816  -0.42268  -0.12962  -0.11823  -0.34942
                0.0000    0.0156    0.4215    0.0250    0.5109    0.5491    0.0684

LITTER        -0.45270   1.00000  -0.71151  -0.23296  -0.00833  -0.12480   0.92817
                0.0156    0.0000    0.0001    0.2329    0.9664    0.5269    0.0001

GRASS          0.15816  -0.71151   1.00000  -0.19209  -0.07853   0.19161  -0.65838
                0.4215    0.0001    0.0000    0.3275    0.6912    0.3287    0.0001

FORB          -0.42268  -0.23296  -0.19209   1.00000  -0.07794  -0.12314  -0.29133
                0.0250    0.2329    0.3275    0.0000    0.6934    0.5324    0.1325

CACTUS        -0.12962  -0.00833  -0.07853  -0.07794   1.00000   0.11411  -0.02487
                0.5109    0.9664    0.6912    0.6934    0.0000    0.5631    0.9000

SHRUB         -0.11823  -0.12480   0.19161  -0.12314   0.11411   1.00000  -0.08104
                0.5491    0.5269    0.3287    0.5324    0.5631    0.0000    0.6819

TREE          -0.34942   0.92817  -0.65838  -0.29133  -0.02487  -0.08104   1.00000
                0.0684    0.0001    0.0001    0.1325    0.9000    0.6819    0.0000
```

```
                                    MULTIPLE REGRESSION USING ESTIMATED NUMBER OF DEER/SECTION
                                         AND ALL SEVEN VARIABLES FROM 4/92  READINGS
DEP VARIABLE: DEER
                                                       ANALYSIS OF VARIANCE

                                                SUM OF          MEAN
                                SOURCE     DF  SQUARES        SQUARE       F VALUE       PROB>F

                                MODEL       7  2021.95081    288.85012       1.225       0.3352
                                ERROR      20  4716.72776    235.83639
                                C TOTAL    27  6738.67857

                                   ROOT MSE    15.35697     R-SQUARE       0.3001
                                   DEP MEAN    26.60714     ADJ R-SQ       0.0551
                                   C.V.        57.71745

                                                       PARAMETER ESTIMATES

                                            PARAMETER       STANDARD      T FOR H0:
                            VARIABLE  DF     ESTIMATE          ERROR     PARAMETER=0      PROB > |T|

                            INTERCEP   1   1032.76299      476.79372           2.166          0.0426
                            BARE       1  -1006.24205      471.75281          -2.133          0.0455
                            LITTER     1   -899.36643      475.62000          -1.891          0.0732
                            GRASS      1   -984.68193      472.53616          -2.084          0.0502
                            FORB       1   -949.03297      463.92475          -2.046          0.0542
                            CACTUS     1   -842.65049      419.57521          -2.008          0.0583
                            SHRUB      1  -1761.21160      874.20507          -2.015          0.0576
                            TREE       1   -100.38860    60.46887923          -1.660          0.1125
```

CLUSTER FUNCTION USING ALL SEVEN VARIABLES
TO DETERMINE IF CERTAIN TRANSECTS HAVE SIMILAR VEG COMP

COMPLETE LINKAGE CLUSTER ANALYSIS