PRELIMINARY EVALUATION OF THE CORONA RANGE AND LIVESTOCK RESEARCH RANCH MULE DEER HERD

BY

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ABSTRACT

PRELIMINARY EVALUATION OF THE CORONA RANGE AND LIVESTOCK RESEARCH RANCH MULE DEER HERD

BY

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Master of Science in Wildlife Science

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Las Cruces, New Mexico, 1994

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The Corona Range and Livestock Research Ranch (CRLRR) was purchased in 1989 for the purpose of developing ecologically and economically sound rangeland management practices. Monitoring of the mule deer (Odocoileus hemionus) herd on the CRLRR began in the fall of 1989, to determine what effects future rangeland practices might have on the herd.

Herd density estimates range from 17.2 deer/259ha to 30.5 deer/259ha. Herd Composition ratios also exhibited a great deal of variability with an annual reduction of 57% in the proportion of bucks between 1991 and 1992, and a decline of 29% in the proportion of fawns between 1990 and

1991.

Large discrepancies between individuals were also apparent. Ninety percent Harmonic Mean measurements (HM) ranged from 2.1 km^2 to 6.9km^2. However, some of the radio collared animals also exhibited a tendency to travel from their "typical" area of use as indicated by 100% HM measurements as high as 19.2km^2. Gross habitat use differed between radio collared animals as well, with some animals being located >90% of the time in the piñon-juniper (Pinus edulis-Juniperus monosperma) habitat, while others were located >90% of the time in the grassland community.
There were no apparent trends in the harvest data through time. Correlations between age, and antler and body measurements were also weak but certain trends are apparent.

One undisputed fact is that the CRLRR mule deer herd has proven to be a valuable economic asset earning more than $70,000.00 in the past 5 years. Considering the economic uncertainty associated with the livestock industry, this added income potential should be very appealing to livestock operators in New Mexico. Therefore, the likelihood of wildlife receiving consideration in a ranch management plan is greatly increased. Thus both the operator and wildlife could benefit from this new arrangement.

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INTRODUCTION

The Corona Range and Livestock Research Ranch (CRLRR) was purchased by New Mexico State University (NMSU) for the purpose of developing ecologically and economically sound rangeland management practices, with the primary emphasis centering around livestock production. To date, efforts have focused on establishing the proper infrastructure such as fencing and watering points, and vegetation inventories. Future plans include evaluating such management practices as specialized grazing systems and brush control.

Range improvements can be extremely capital intensive (Holechek 1992), and results are by no means guaranteed. Considering today's economic climate, a wrong decision can result in financial disaster. Many ranchers have realized that one way to combat this problem is to diversify their income source.

In some areas, economic returns from wildlife have met or exceeded those returns obtained from livestock (Ramsey 1965). If managed correctly, wildlife enterprises will not only add to the economic stability of the ranch but wildlife will benefit because they now possess a tangible value for the rancher. Under this new scenario, the likelihood of wildlife being included in a ranch management plan is greatly increased.

Although the practice of deriving income from wildlife is becoming more common in New Mexico (Morgan 1988), with the exception of Texas, fee hunting operations are relatively new to the agricultural industry (Knight 1985). Therefore, many ranchers may be reluctant to begin an operation because they are unaware of the type or degree of management that may be required.

Although the amount of literature published on mule deer (Odocoileus hemionus) is astronomical (see Wallmo 1981 for an example), gaps in knowledge are still apparent. As Connolly (1981a) stated when referring to the large scale decline of mule deer across the western United States in the 1960's and early 1970's and gradual recovery in the late 1970's

> ...Just as they were powerless to halt the decline, the biologists and managers now are unable to show any scientifically acceptable way that improved management put the herds on the road to recovery. Nor can they assure the public that mule deer are now secure. (p. 243)

New Mexico's mule deer population was not immune to these past declines (Jacquez 1982). The herd suffered a 32% decline between 1967 and 1975, with the majority of the decline occurring on private lands (Snyder 1976). Therefore, it is imperative that private land owners have at their disposal the necessary guidance for the management of wildlife on their lands.

Thus, one objective on the CRLRR is to develop a working management plan for mule deer, which can be adapted to other ranches across New Mexico. However, before this objective can be accomplished a baseline survey of the population dynamics, home range, habitat use and harvest trends of the mule deer on the CRLRR must be conducted. This survey was begun by Berry (1992), but data collection was limited. Therefore, this portion of the study is focused upon continuing this initial phase. Research objectives include:

1) Monitoring vegetation transects.

2) Monitoring herd population trends.

3) Estimation of annual herd composition.

4) Estimation of home range size and gross habitat use of adult females.

5) Monitoring mule deer harvest trends.

This information will be used to derive specific hypothesis tests in the future.

STUDY AREA

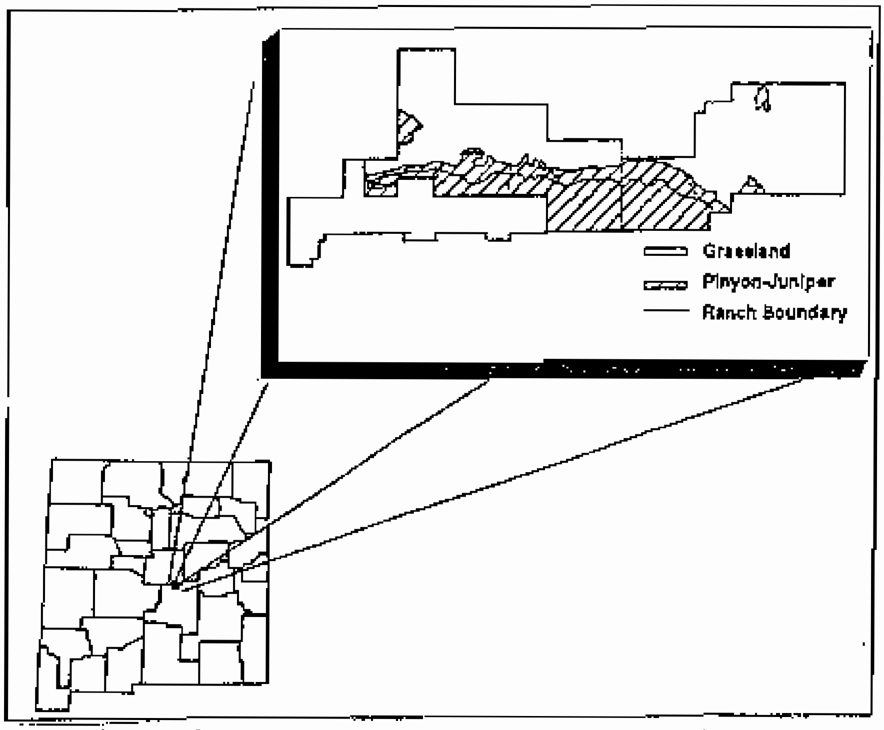

Figure 1. Location, boundaries, and major habitat types of the CRLRR.

This study was conducted on the 11,400ha (28,160 acre) New Mexico State University, Corona Range and Livestock Research Ranch (CRLRR). The CRLRR is located approximately 19.2km (12 miles) east of Corona, New Mexico (lat. 34°15'05" long. 105°35'30") with portions lying in northern Lincoln county and extreme southeastern Torrance county (Fig. 1). This region is commonly referred to as the Central High Plains of New Mexico.

Climate

The climate in this region is classified as semiarid continental (USDA 1983). Based on a 55-year average

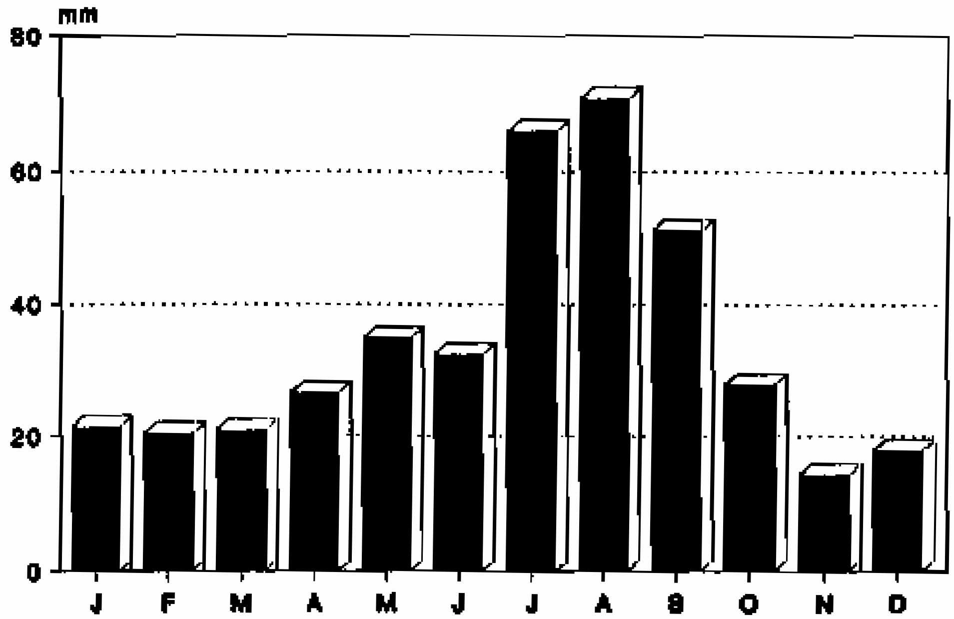

Figure 2. Mean monthly precipitation (mm) recorded at Corona, New Mexico (USDA 1970).

(1906-1960), the Corona, New Mexico, area receives 403mm of precipitation annually, with nearly half coming in the form of high intensity short duration thunderstorms during the period of July to September (Fig. 2). The mean monthly minimum and maximum temperatures are 3.3°C and 18.9°C, with January being the coolest month (-5.6°C/7.8°C) and July being the warmest (12.8°C/28.9°C) (Fig. 3).

Late winter and spring are characterized by prevalent westerly and southwesterly winds, which can cause severe soil drying and erosion. On average, the first killing frost occurs October 10 and the last occurs May 6 (Houghton 1974). This results in a mean annual frost-free period of 161 days.

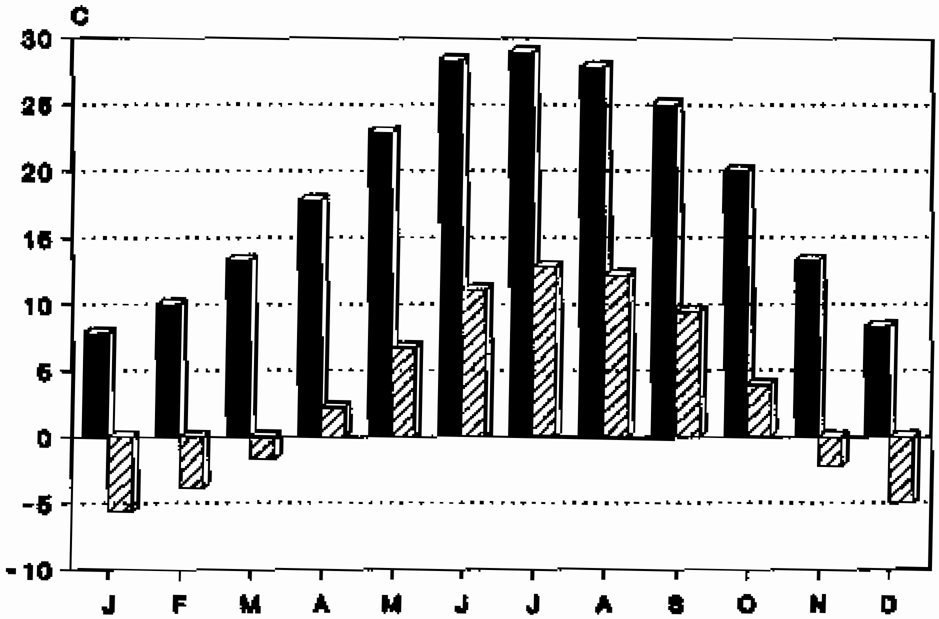

Figure 3. Mean maximum and minimum monthly temperatures (°C) recorded at Corona, New Mexico (USDA 1970).

Vegetation

Dick-Peddie (1993) classified the vegetation surrounding the CRLRR as plains-mesa grassland mixed intermittently with juniper savannah, which he described as the ecotone between the grassland community and the piñon-juniper (Pinus spp.)-(Juniperus spp.) woodland. Brown and Lowe (1980) delineated the area as great basin conifer woodland and plains, and great basin grassland. Donart et al. (1978) mapped the state according to potential natural vegetation. The area surrounding the CRLRR was classified primarily as a mixed grama (Bouteloua spp.)-juniper association and a sideoats grama (Bouteloua curtipendula), little bluestem (Schizachyrium scoparium)-juniper association. Both associations are dominated by warm season perennial grasses.

Primary vegetation types on the CRLRR are Colorado piñon (Pinus edulis) - one-seed juniper (Juniperus monosperma) woodland and grassland. Based upon a Landsat satellite vegetational image (Harrington 1992), 19.6% of the CRLRR is composed of a dense piñon-juniper community. The majority of this occurs as one large contiguous block extending roughly along the south boundary of the CRLRR (Fig. 1). Another 12.9% of the pixels were delineated as the ecotone between the piñon-juniper woodland and grassland communities. Primary understory species in the piñon-juniper woodland include blue grama (Bouteloua gracilis) and wolftail (Lycurus phleoides). Other common plant species are cholla (Opuntia imbricata) and broom snakeweed (Gutierrezia sarothrae). The midstory in this community is minimal to nonexistent. However, in some of the more open areas yucca (Yucca elata) or oak (Quercus spp.) occasionally occur.

Harrington (1992) evaluated a major portion of the grassland community on the CRLRR. Based upon dominant species, 5 communities were delineated (Table 1).

Topography and Soils

Elevation on the CRLRR ranges from 1740m (5,710 ft.) to 1,911m (6,720 ft.). With the exception of the extreme

Table 1. Vegetational community type, based upon dominant species, in the grassland community on the CRLRR (Harrington 1992).

Community Type	% of Sampled Locations (*n*=196)
Bouteloua gracilis	36%
Bouteloua curtipendula	22%
Bouteloua gracilis *Aristida purpurea* *Gutierrezia sarothrae*	20%
Lycurus phleoides	16%
Stipa neomexicana	6%

southwestern portion of the ranch, topographic relief is slight to nonexistent. Overall aspect of the ranch is in an easterly direction. The topography is intermittently characterized by karst sinks. These sinks, which range in size from a few meters to several hundred meters wide, were formed when surface material collapsed after water eroded the underlying limestone parent material (Harrington 1992).

The CRLRR occurs in both the Lincoln County Area and Torrance County Area Soil Conservation Service (SCS) soil surveys. The most common soil on the ranch is the Piñon Channery Loam, which conforms roughly to the boundaries of the piñon-juniper woodland. Primary soils in the grassland community include Davvey Pastura, Deama Pastura, Kim Pastura and Tapia-Dean Loams (USDA 1970, 1983).

These soils occur on areas with relatively flat topography and are derived primarily from limestone material. Because of their high erosion potential and low water holding capacity, they are not well suited for cultivation, but they can support sustainable livestock production (USDA 1970, 1983).

Land Use

The CRLRR was purchased to serve as a field research station for NMSU. As implied by its name, primary emphasis will focus on proper range management for livestock production. The area has a history of livestock grazing. Currently both cattle and sheep are present on the ranch.

The ranch is enclosed by net wire fencing with a buried apron. Interior fences are a mixture of net wire (with apron) and suspended 4-strand barbed wire. Permanent water sources are restricted to livestock troughs. Except for the eastern most pastures these troughs are fairly well distributed. However, future plans include establishing several troughs in these pastures, as well.

Present and future wildlife research on the CRLRR is focused on mule deer and pronghorn (Antilocapra americana). The ranch has a profitable mule deer fee hunting operation, which not only adds to the diversity of land use but also aids in the economic stability of the CRLRR.

MATERIALS AND METHODS

Pellet Group/Vegetation Transects

Thirty-six permanent pellet group transects have been established on the CRLRR (Fig. 4) for the purpose of monitoring mule deer densities and population trends. Each pellet transect also serves as the starting point for 2 vegetation transects, which were established to monitor any correlations between long-term vegetation trends and mule deer population trends.

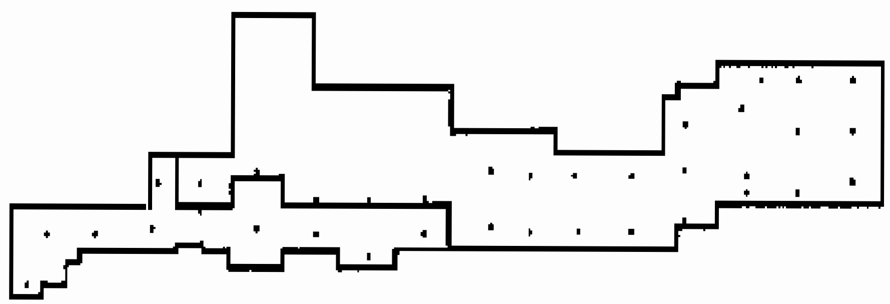

Figure 4. Location of the pellet group/vegetation transects on the CRLRR.

<u>Pellet Group Transects</u>

The pellet group transect locations were selected as to permit only 1 transect per section of land (as denoted on United States Geological Service, 1:24,000 topographic maps). An effort was made to establish these transects near the center of each section. However, due to the large number of transects and the amount of time required for data collection, transects were established as near the center of each section as the road system would allow.

As mentioned earlier, sheep are present on the CRLRR but are limited to the northwest corner of the ranch. Differentiation between sheep and deer pellet groups can be extremely difficult (Howard 1967). Due to this difficulty pellet group transects were not established in the sheep pastures.

Once this "point" was located, an installer paced approximately 100m (310 ft) from the road and a hammer was thrown into the air. Wherever the hammer landed, a metal stake was driven into the ground. This stake became the center point for plot number 1. A random transect direction was then selected using the sweep second hand on an installer's watch. Nine more plots (10 total) were constructed along this azimuth at 30.5m (100 ft) intervals. A metal tag identifying the transect number and plot number was attached to each stake.

Plot size was delineated with the use of a 3.6m (11' 9") chain which was looped over the metal stake in the center of each plot. This chain length allowed for a circular plot which was .004 ha (.01 acre) in size.

Data collection involved 2 observers, one at the end and one in the middle of the chain, who circled the plot and recorded the number of deer pellet groups within the plot boundary. A minimum of 15 pellets, with the majority occurring on the plot, had to be present before they could be counted as a group (Neff 1968). Pellet groups were painted to avoid the possibility of recounting them in later surveys.

Pellet group data were collected biannually. This included collections in October, to estimate spring/summer densities, and in April, to estimate fall/winter densities. Mule deer densities were estimated using the formula in Rogers et al. (1958).

$$\text{Deer/Section} = G \times R \times 640 \text{ acres} / D \times T$$

Where: G = # of groups present on the transect
R = Reciprocal of area sampled per section
D = Daily defecation rate of deer
T = # of days of pellet accumulation

A defecation rate of 13 groups/day was used. This rate was recommended by Smith (1964) for deer on native range, and by Rogers et al. (1958) where variety of mule deer forage is limited.

Vegetation Transects

Prior to establishment of the pellet transects, 2 plots were randomly selected as starting points for vegetation transects. Once again, transect direction was randomly determined with the aid of the sweep second hand on an installer's watch.

Once the azimuth was selected, a metal stake was driven just outside the boundary of the pellet group plot with another stake being driven approximately 31m (102 ft) further along the selected azimuth. A 30.5m (100 ft) metal tape (marked in 1 foot increments), which was attached to two 45.7cm (18in) conduit poles, was suspended along this line by sliding the conduit poles over the 2 metal stakes (Howard 1966).

Ground cover was recorded at each of the 100-point intersections as bare, litter, or plant species. Before a plant could be recorded, the basal portion had to be located directly beneath the point in question on the tape. Canopy cover which extended over the tape was also recorded, along with a height estimate to the nearest half meter of the shrub in question.

Study design dictated that vegetation data would be collected biennially during late September, which is the approximate end of the major growing season on the CRLRR. These data were collected in 1991 (Berry 1992) for 27 transects, and were recorded for all 36 transects during 1993.

Herd Composition Counts

In an effort to classify the mule deer herd on the CRLRR, a trend route was established by Berry (1992). This route roughly traversed the northern edge of the piñon-juniper community and was approximately 21.73km (13.5

miles) in length. As outlined in Berry (1992), the routes were conducted around the time of the mating season (November through early January) to increase the probability that all segments of the population were equally visible.

The trend route procedure involved 2 observers, which drove at a slow rate of speed along the predetermined route, beginning at sunrise and 1 hour before sunset. Deer observed along the route were classified as either buck, doe, or fawn. In an attempt to increase the accuracy of the classification process, 7 x 35 binoculars were used whenever necessary.

Due to the low "counts" obtained during the morning and evening routes, routes were conducted at night with the aid of a spotlight. The same procedure used for the morning/evening routes was used for the spotlight counts except that the routes began approximately 1 hour after sunset and 3 observers were required.

Home Range Delineation and Habitat Use

The movements of 10 mule deer equipped with pulsed signal transmitters (Telonics model MOD-500) were recorded from August 1992 to May 1993 with the aid of a Telonics receiver (model TR-2E) and Yagi antenna (See Berry 1992 for capture techniques). During the initial phases of the project, an attempt was made to limit the amount of time between locations to a maximum of 2 weeks. However, due to the amount of time and expense required to reach the study site, this was not a feasible option.

The process of obtaining locations on the collared deer began by traveling to positions easily discernable on USGS topographic maps within the area where the animal in question was expected to be found. While there, the telemetry receiver was activated and the surrounding area was scanned for a signal. If a signal was detected, an exact bearing was obtained with the aid of a Silva compass. Eleven degrees was added to this reading to allow for declination. The point at which the bearings crossed was determined to be the location of the animal. Bearings were usually taken from only 2 points within a 15-minute time span to obtain an estimate of an animal's location. However, a third and fourth bearing were often taken to check for reliability of the point estimate. The time and habitat type (piñon-juniper or grassland) of the location were also recorded.

In an attempt to increase the accuracy of the telemetry data, certain restrictions were established as follows:

1) The bearings had to be collected within a 15-minute time span. This was done to reduce the amount of error which occurs due to animal

movement.

2) The estimated location of the animal (e.g., where the bearings crossed) had to be within 1.6km (1 mile) of the telemetry stations. This distance was usually within 1.2km (.75 mile). The amount of potential error decreases as the distance between the telemetry station and the animal decreases.

3) The angle at which the 2 bearings intersected (x) was required to be $30° \leq x \leq 150°$. By increasing the angle of intersection, the amount of error, due to an incorrect bearing estimate, would be reduced.

4) A minimum of 4 hours was allowed to elapse between data collection times. This was done to increase the probability that the observations were independent.

Error polygons were not implemented in this study. Instead the habitat type of the point estimate was used. This method avoids the problem of determining which habitat type to select when an error polygon overlaps more than one habitat. White and Garrott (1990) believed this method was valid as long as the habitat types do not exert different influences upon the telemetry system. The obvious lack of habitat interspersion on the CRLRR also minimized the need for greater accuracy.

All animal locations were converted to Universal Transverse Mercator (UTM) (Grubb and Eakle 1988) coordinates and then entered into a computer software program known as McPaal (Stuwe 1988). McPaal is a basic computer program that will supply the user with various home range estimates on the inputed data set.

The home range estimate known as the Harmonic Mean (Dixon and Chapman 1980) was selected for use in this study. This method was chosen because unlike many other methods it allows the animals actual use pattern to determine shape delineation (Samuel and Fuller 1994).

Harvest Data

Mule deer fee hunts on the CRLRR have been closely monitored since it was purchased by NMSU in 1989. Twenty to 25 permits have been sold each year. These permits allow a hunter to harvest 1 legal buck, which is defined in New Mexico as having a visible fork on at least 1 side of its antlers. The hunters are instructed to bring all harvested animals through a check station where various morphological measurements are taken. An incisor (I_1) is also removed to estimate age.

Antler and Body Measurements

Whenever possible, 5 antler and 6 body measurements were taken from mule deer bucks harvested on the CRLRR

HARVEST DATA

Antler Measurements	Body Measurements
1. # Points	1. Total Length
2. Base Circumference	2. Body Length
3. Inside Spread	3. Shoulder Height
4. Antler Height	4. Neck Circumference
5. Tip to Tip Spread	5. Chest Circumference
	6. Hind Foot Length

• An incisor was also collected to estimate age.

Figure 5. Harvest data collected on the CRLRR.

(Fig. 5). Body measurements taken include: body length, total length (body length + tail length), hind foot length, neck circumference, chest circumference, and shoulder height. Antler measurements include number of points (> 1"), tip to tip spread, inside main beam spread, left and right antler height, and left and right antler circumference. For purposes of data summation and to make individual animal comparisons more meaningful, an arbitrary antler score and body mass index were developed (Fig. 6).

Aging

Harvested mule deer were aged by means of the cementum annuli technique (Dimmick and Pelton 1994), with the procedures closely following those outlined in Carrel (1980).

An incisor (I_1) was removed from the mule deer brought

ANTLER SCORE

(# Points x 3) + (Base Circumferences x 4) + Inside Spread + Antler Heights = SCORE

BODY MASS INDEX

Body Length + Heart Circumference + Neck Circumference = INDEX

Figure 6. Mule deer antler score and body mass index values used on the CRLRR.

through the check station. Four, 20-micron sections were cut from the lower one-third of the tooth root, with an 11-1180 AB Isomet Saw (Buehler Ltd., Evanston, IL). The sections were then placed in plastic capsules and cleaned, in an ultrasonic cleaner filled with water and liquid detergent, for 20 minutes. Excess soap was removed with tap water, and the capsules were placed in a 10% formic acid solution for 2 hours. The capsules were rinsed with tap water and placed in a saturated solution of lithium carbonate in 70% alcohol for 2 hours. At this point, the capsules were removed, rinsed with tap water, and then rinsed with distilled water before being dipped in Alizarin Red dye for 30 seconds.

Processed sections were placed on a microscope slide and examined under a Bausch and Lomb 10X bright field, light microscope. The observer scanned each of the 4 sections to locate the section which had the most visible and easily discernable rings. Once this was accomplished, the number of rings were counted and recorded. The age of the deer was determined by adding 1 to the number of rings present. This was done because the first incisor (I_1), which was removed in this study, does not become permanent until approximately 12 months of age in mule deer (Larson and Taber 1980).

The counts were periodically double checked by a second and sometimes a third observer. If there was major disagreement between observers, or if the quality of the sections were poor, then another set of sections were cut and processed.

Statistical Procedures

This project was designed to be a preliminary information gathering process. Therefore, statistical procedures were very simplistic. All of the procedures were performed with the Statistical Analysis System (SAS) program on the NMSU computer system.

Means were calculated for the vegetational and pellet group data. Confidence intervals for the seasonal pellet group counts were also tabulated along with correlation analysis between pellet densities and canopy cover.

The standard practice of reporting herd composition ratios between the number of bucks and fawns per 100 does was followed. Standard deviations were calculated between the individual route totals obtained in 1992 and 1993 as a way of exhibiting the amount of variability associated with the samples.

Means and standard deviations were calculated for the harvest data through years and cohorts. Correlation analysis was conducted for cohorts and years.

RESULTS AND DISCUSSION

Vegetational Data

Seventeen forbs, 11 grasses, 6 shrubs, and 4 cacti species were identified on the vegetation transects (Appendix A). Mean ground cover was 41% with litter comprising 17% and vegetation the remaining 24%. Grass comprised 74% of the vegetative cover, with shrubs (11%), forbs (9%), and cacti (6%) comprising the remaining 26%. Vegetational data are summarized in Table 2.

Mean canopy cover was 11%. However, this value is misleading considering several transects (49%) occurred in the absence of canopy cover. When the transects are divided according to this criterion, the amount of variability present in the data decreases (Table 2), and certain relationships become apparent. For example, mean vegetational cover is higher (32% vs. 17%) and litter accumulation is lower (6% vs. 27%) for those transects which do not possess canopy cover.

These overstory-understory relationships have been well established in a piñon-juniper environment for some time (Clary 1987). In essence, piñon-juniper is capable of reducing or eliminating ground vegetation production, and increasing litter accumulation (Jameson 1967, Schott and Pieper 1986). Therefore, as expected, canopy cover has a positive correlation with litter ($r = 0.89$) and negative

Table 2. Summary of vegetational data collected in areas with and without canopy cover on the CRLRR, 1993.

VARIABLE	WITH (n=37)	WITHOUT (n=35)	TOTAL (n=72)
Litter	27%	6%	17%
Grass	13%	22%	18%
Forb	<1%	3%	2%
Shrub	<1%	4%	3%
Other	1%	2%	2%
Total Ground Cover	44%	37%	41%
Canopy Cover	22%	-	11%

correlations with grass (r = -0.68), forb (r = -0.39), and shrub (r = -0.35) ground cover.

Pellet Group Counts

Since 1989, deer density estimates range from 30.5 to 17.1 deer/mile^2 (Table 3). Except for 1992, density estimates have been higher for the fall/winter periods (Fig. 7). Assuming a nonmigratory population, density estimates should be greatest during the summer after fawning has taken place and before winter mortality has occurred. The fact that fall/winter estimates were higher 3 of the 4 years could be indicative of deer migrating to the CRLRR during the winter from surrounding areas.

The majority of land surrounding the CRLRR superficially appears to be very similar to the habitat and topography on the CRLRR. Therefore, a plausible

Table 3. Summary of mule deer density estimates obtained on the CRLRR, using the pellet group technique.

SEASON	n	*MEAN	95% C.I.
Fall/Winter 1989	9	21.3	12.3 - 30.2
Spring/Summer 1990	17	23.4	14.6 - 32.3
Fall/Winter 1990	18	28.3	20.0 - 36.7
Spring/Summer 1991	17	24.5	14.8 - 34.2
Fall/Winter 1991	28	26.4	20.6 - 32.2
Spring/Summer 1992	36	30.5	22.0 - 39.0
Fall/Winter 1992	36	28.0	19.7 - 36.2
Spring/Summer 1993	36	17.2	12.3 - 22.0
Fall/Winter 1993	36	29.6	22.1 - 37.0

* Mean # per 259ha ($mile^2$)

explanation for a migration is not obvious unless it is somehow related to differences in land management practices such as stocking rate, water distribution or even greater human disturbance. Theoretically, browse or some other habitat component may also be more plentiful on the CRLRR, thus attracting deer from surrounding areas. In any event, considering the size and shape of the CRLRR, it is obvious that the surrounding ranches have the potential to exert a significant amount of influence upon the CRLRR mule deer herd.

The difference could also be related to sampling variability. Although the means for the fall/winter periods are slightly higher, the 95% confidence intervals associated with the spring/summer and fall/winter density estimates are broad enough to include any differences the

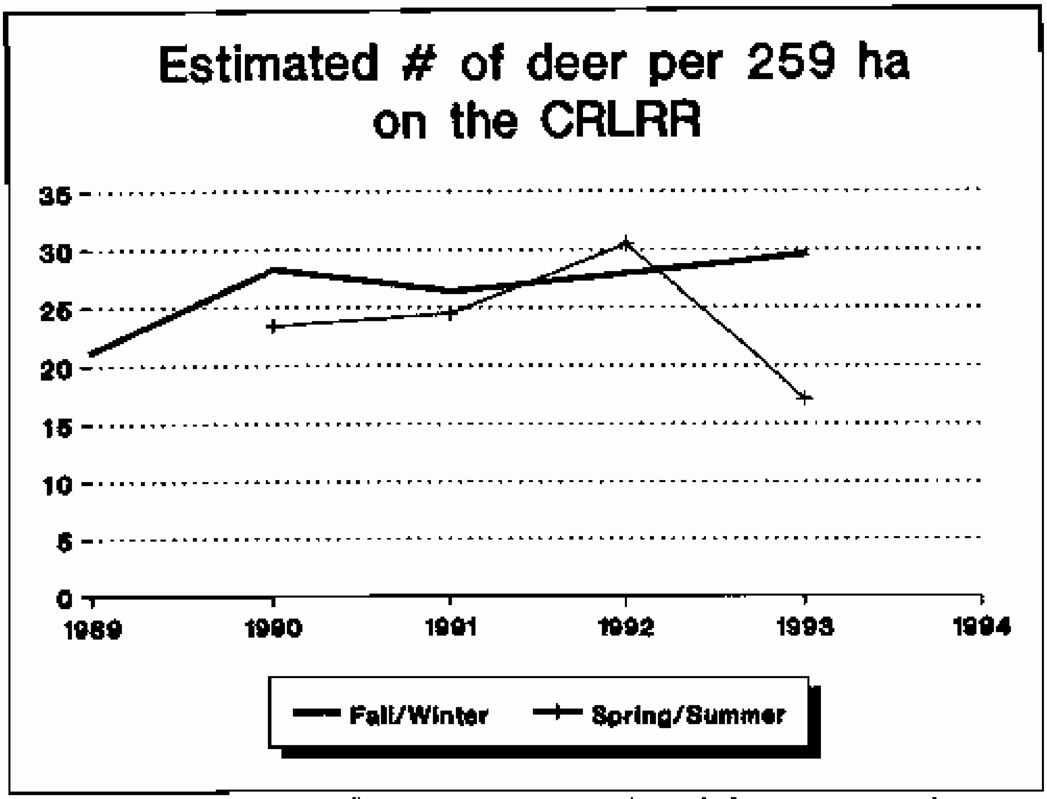

Figure 7. Estimated # of deer per 259 ha (640 acres) on the CRLRR, based on the pellet group technique.

(Table 3). The only mean value which exhibits any amount of variation from the other values is the 1993 spring/summer estimate, which revealed a 38% decline from 1992 fall/winter estimate. However, the 1993 fall/winter estimate returned to prior levels. This increase could not have occurred unless animals were migrating into the area. However, it is hard to draw any strong conclusions with such a large amount of variability associated with the values.

The pellet group technique (as with most big game survey methods) is dependent upon the reliability of several assumptions. These assumptions include that the defecation rate will remain constant regardless of feed intake, forage moisture content, age of the animal, or changes in diets. However, reports have challenged the reliability of these assumptions (Neff 1968, Connolly 1981c, Rogers 1987). The estimates can sometimes be erratic as well. For example, Fuller (1991) found that pellet group density doubled in 1 year and concluded that its use to index deer numbers or population change is limited.

Almost every big game census method to date has the same problem of relying upon questionable assumptions (Boyd et al. 1986). One possible solution may be to use the pellet group counts as an index to population change rather than attempting to derive an exact density estimate. Rasmussen and Doman (1943) concluded that this type of trend data is much easier to obtain and nearly equal in value for management decisions.

As stated earlier, vegetation transects were established to evaluate long-term trends between vegetational attributes and pellet group counts. Under the current monitoring scheme, pellet group counts are collected twice annually and vegetation data are collected once biennially. Considering the variability associated with vegetational production in New Mexico, this level of sampling intensity makes it difficult to draw conclusions for such a short time frame. Also the pattern of pellet group distribution is unknown. In other words, were the pellet groups on a transect distributed evenly throughout the 6-month sampling period or were the majority deposited within a short period of time perhaps to take advantage of a limited yet preferred food source? If the latter case is true then it would be invalid to make comparisons on the vegetation present when the vegetation transects were read because heavy deer utilization in the area may have occurred 5 months prior when the vegetation was much different.

One attribute, which should not vary greatly under normal conditions, is canopy cover. This habitat component can be important as year round hiding/escape cover and can also serve as a seasonal food source (Short et al. 1977). However, correlation analysis failed to reveal significant relationships with seasonal as well as yearly pellet group densities.

Herd Composition Ratios

Seven trend routes were conducted on the CRLRR in 1992, with a total of 131 deer (78 does, 25 bucks, and 39 fawns) being classified. This yields a 100:32:50 (doe:buck:fawn) herd composition ratio. In 1993, 8 trend routes were conducted, including 2 night time spotlight

Table 4. CRLRR annual herd composition ratios calculated by combining all routes into 1 sample.

YEAR	RATIO (D:B:F)	n
*1990	100:75:68	273
*1991	100:71:48	127
1992	100:32:50	131
1993	100:58:41	287

* Berry 1992

counts. A total of 287 deer were classified (144 does, 84 bucks, 59 fawns). The resultant herd composition ratio was 100:58:41.

Buck ratios for 1992, and to some extent 1993, exhibited a great deal of variability from those reported by Berry (1992) for 1990 and 1991 (Table 4). In fact, there appears to have been a 57% decrease in the proportion of bucks between 1991 and 1992. The proportion of fawns per 100 does decreased 29% between 1990 and 1991. Since that time, fawn abundance appears to have stabilized

Hunting pressure has often been given as a possible solution for declines in buck ratios (Connolly 1981b). However, hunter harvests on the CRLRR are extremely low and have remained constant since 1990. Herd composition could have been altered due to naturally occurring sex differential mortality (Taber and Dasmann 1954). Sex differential mortality is a widely accepted phenomenon (Connolly 1981c), and it does explain why the proportion of bucks in the population is less than that of does.

Table 5. CRLRR annual herd composition ratios and standard deviations calculated by treating route totals as the sample unit.

YEAR	n	RATIO (D:B:F)	Std. dev. (Bucks)	Std. dev. (Fawns)
1992	7	100:47:50	39	29
1993	8	100:60:45	32	23

However, it does not explain why the proportion of bucks would suddenly decline.

Another possible solution for the declines could be sampling variability. In an attempt to assess this possibility, the data were analyzed using the individual routes as the sample unit instead of the yearly total. This method allows for a variance measure to be placed upon the data. The resultant herd composition estimates now become 100:47:50 and 100:60:45 for 1992 and 1993, respectively (Table 5). Individual route totals were not available for 1990 or 1991. Buck and fawn ratio estimates are still below the 1990 estimate but the amount of variability associated with them could account for the year to year discrepancies.

The most obvious solution to this sampling problem would be to increase the number of samples taken. However, if herd composition counts are to estimate accurately the relative abundance of each sex and age class, then the probability of observing each class must be relatively equal (Connolly 1981c). Research has shown that this probability is not equal and that the probability of viewing the same class will also vary between seasons (Downing 1980, McCullough 1982 1993 1994). Therefore, if valid comparisons are to be made, the time of year when samples are taken must be standardized. This standardization and the logistical problems involved with collecting samples on the CRLRR drastically limit the number of routes which can be conducted.

In an attempt to overcome these problems, some researchers have developed specialized sampling techniques (Bowden et al. 1984, Samuel et al. 1992). However, they still encounter the same problem of behavioral differences between classes, and at least 1 researcher has concluded that refined techniques and elaborate survey designs will not eliminate bias (Caughley et al. 1976). Therefore, the key to developing useful data appears to be through standardization of technique (Progluske and Duerre 1964) and time of year, while concurrently maximizing sample size (Dasmann and Taber 1956).

Although the amount of sampling variability presents a plausible solution for the decline in buck and fawn abundance on the CRLRR, it presents another problem which is how to interpret the results. Due to the amount of variability being encountered in the yearly samples and the relatively small sample sizes, it is impossible to draw substantive conclusions. Berry (1992) also noted a concern pertaining to inadequate sample sizes.

Based on the limited results obtained on the CRLRR, it appears the spotlight technique will yield larger sample sizes than morning/evening trend routes (53 vs. 30). This conclusion has been drawn by other researchers (McCullough et al. 1994). Therefore, I believe the spotlight technique combined with a longer standardized route should be considered as the primary technique for future mule deer herd classification ratios on the CRLRR.

Home Range/Habitat Use

A total of 736 acceptable location estimates were obtained on the radio collared mule deer. The number of locations ranged from 64 to 79 per individual. Mean elapsed time between locations was 8 days with the greatest period being 22 days.

Capture data indicated that all of the radio collared animals were collared as adult does (>1.5 years). Personal observation revealed that this was not the case. Frequency #159.100, which was reported as an adult doe (Berry 1992), was a buck. Also based on morphological characteristics, I strongly believe that frequency #159.030 was collared as a fawn. The remaining animals with the exception of #159.070, upon which I was unable to obtain a visual observation throughout the entire course of the study, appeared to be adult does. However, these differences in sex and age classes may have resulted in some of the variability observed between animals.

<u>Home Range</u>

Location estimates on the radio collared deer were subjected to several Harmonic Mean (HM) delineations. The basis for this was due to the difficulty in defining what is truly a home range. Burt (1943) defined home range as "the area traversed by the individual in its normal activities." Robinette (1966) expressed home range as "proportion of an animals activity spent within a given distance from the center of activity". Definitions such as these require arbitrary decision making in determining when an animal is exhibiting normal movements (White and Garrott 1990).

A 100%, 90% and 50% HM are reported (Table 6). The 90% HM was selected to represent the home range size, because the inclusion of the outer most points in the 100% HM increased the area of use from 4.5 ± 1.3km^2 (90% HM) to 11.8 ± 4.39km^2 (100%HM). Thus, the 90% HM is believed to more accurately depict the "normal" movements of these animals. A 50% HM was selected to represent the respective animals center of activity (Dixon and Chapman 1980). This delineation was chosen because it is relatively small (0.9 ± 0.28km^2) with locations being closely compacted. Also,

Table 6. Calculated harmonic mean delineations (km^2) for mule deer on the CRLRR (August 1993-April 1994).

Frequency	n	50% HM	90% HM	100% HM
159.480	75	1.0	3.6	5.9
159.380	75	0.4	2.1	6.3
159.160	73	0.7	3.5	8.1
159.440	76	0.8	4.4	11.1
159.100	77	1.3	4.5	11.2
159.410	64	0.9	4.5	12.2
159.030	73	0.9	4.2	12.8
159.130	72	0.8	4.7	13.5
159.070	72	1.1	6.1	17.7
159.520	79	1.2	6.9	19.2

locations were obtained within this boundary on a fairly regular basis throughout the study.

The movements of these animals often times appeared erratic. For example, radio triangulations followed up immediately with visuals upon the color coded collar of frequency #159.520 revealed that she traveled a straight line distance in excess of 3.9km and back to her original starting point within 3 days. The reason for such extended movements is not fully understood. Garrott et al. (1987) termed this type of movement as exploratory ventures and believed they could be related to dispersal because 75% of the irregular movements observed in their study, were exhibited by yearlings. However, with the exception of

#159.030, which I believe was a yearling and #159.440 which was never seen, all the animals in this study appeared to possess adult features. Therefore, I do not believe dispersal is a logical explanation of these movements for the remaining animals.

Other reasons for these extended movements could be hunting pressure (Robinette 1966), predatory pressure, or forage availability (Loveless 1964). Koerth et al. (1985) noted 1 adult doe in the Texas Panhandle which traveled 2.4 km, apparently to take advantage of increased forage supplies on nearby grain fields. Another possibility for these extended movements, which has been reported in the southwest, is limited water availability during the dry season (Rautenstrauch and Krausman 1989). Wood et al. (1970) also believed that water availability could have a substantial impact on mule deer movements.

Hunting pressure can be ruled out as a cause for these extended movements because the majority (70%) were recorded during the period of April to August, while the hunting season occurs in November. Water availability can also be eliminated because water troughs were present and operational in close proximity to all the animal's core areas. Although mule deer on the CRLRR have been preyed upon by cougars (*Felis concolor*), I believe predatory pressure can be eliminated due to the apparently limited number of predators present on the CRLRR which are capable of preying upon adult deer. This leaves forage availability as a possible solution for these extended movements. Considering the time of year when these movements took place (spring and summer), the deer could be seeking new forage growth, since nutritional requirements for lactating does are greatest during this period. Nutritional requirements for bucks are also great at this time due to antler development. Dietary studies which are presently being conducted on the CRLRR should afford more insight into this possibility.

One interesting factor to note from the Harmonic Mean delineations is the obvious lack of locations off the CRLRR (see Appendix B). Considering the shape of the CRLRR, it was expected that the radio collared animals would spend a substantial amount of time off of the CRLRR. This lack of movement onto adjoining ranches lends support to the idea that conditions on the CRLRR are more conducive to mule deer viability.

Habitat Use

There were large discrepancies found between animals in the proportion of time they were located in the different habitat types (Fig. 8). Six of the animals were located in the piñon-juniper woodland greater then 80% of the time, while 2 exhibited approximately the same level of

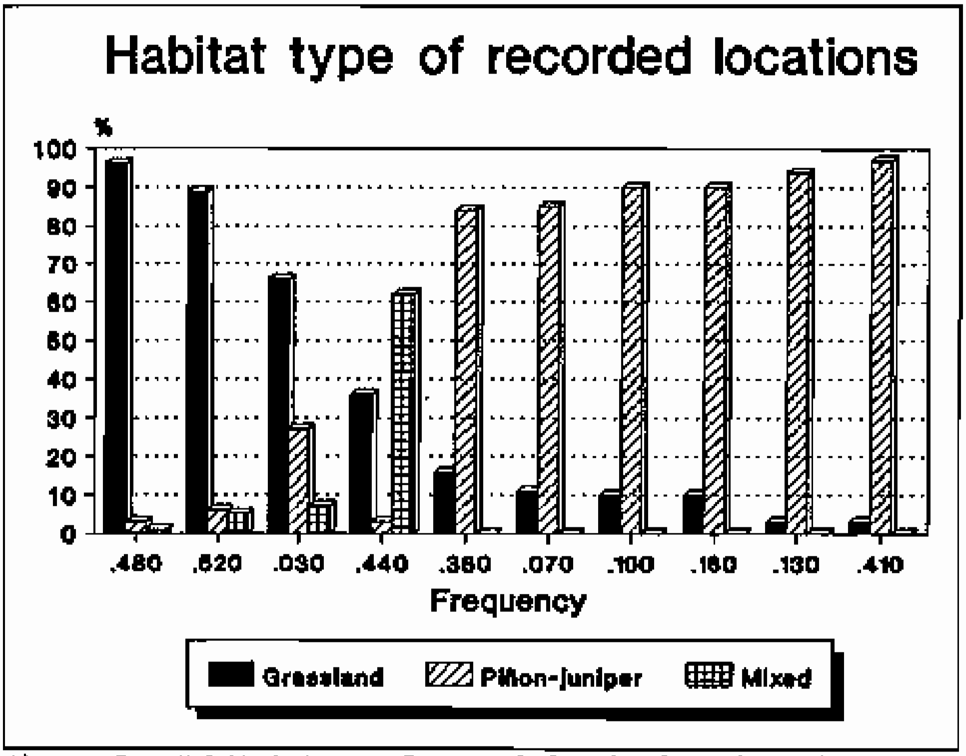

Figure 8. Habitat type of recorded mule deer locations on the CRLRR (August 1993 - April 1994).

association with the grassland community.

Overall, frequency #159.030 exhibited greater uniformity in the number of locations obtained in the grassland (66%) and piñon-juniper (27%) communities. However, prior to April 1993 this animal was located almost exclusively within the piñon-juniper community (86%). Since that time, it was found almost exclusively within the grassland community (88%). This change could be the result of dispersal. As indicated earlier, this animal appears to have been collared as a fawn and could have been following the movements of its mother before dispersing in the spring.

Frequency #159.440 occupied an area that was a transition between the piñon-juniper community and grassland community. Therefore, habitat delineations were not as clear. Greater then 60% of the locations were determined to be within this mixed (juniper savannah) habitat.

Overall, there appears to be no distinct pattern to the habitat use exhibited by these animals. Although 6 of the 10 animals did exhibit a preference for the piñon-juniper community and only 2 exhibited a comparable level of association with the grassland community. As mentioned earlier, correlation analysis failed to detect relationships between pellet group densities and canopy cover for the herd as a whole. However, these results are only preliminary and should not be interpreted to mean that the presence of piñon-juniper on the CRLRR is unimportant to mule deer viability.

Past studies have concluded that deer in a piñon-juniper environment require good habitat interspersion of the piñon-juniper for cover, and open areas for feeding and that the open areas should be in close proximity to adequate cover (Box 1964, McCulloch 1969, Short et al. 1977). The CRLRR has an obvious lack of habitat interspersion, which could be influencing both the habitat use and home range size of the mule deer. Therefore, future plans to remove portions of the piñon-juniper habitat may result in smaller areas of use by the mule deer and more even habitat utilization patterns. These changes could result in greater deer densities.

One problem with drawing conclusions on these data is that the deer which were collared were not selected with any specific hypothesis in mind. Therefore, there were many factors which were not consistent for all animals. For example, animals which inhabited primarily the grassland community were subjected to grazing by sheep, while the animals within the piñon-juniper community were subjected to cattle grazing. This difference alone could result in significant variability. Also, the location of certain animals resulted in greater human disturbance. As mentioned earlier, there were also differences in the sex and age classes. These factors should be considered before drawing any conclusions from the data which the study design did not intend.

Harvest Data

One hundred five mule deer bucks have been harvested on the CRLRR, since 1989. However, harvest data were not collected from every animal due to damage to the carcass or hunters failing to go through the check station before leaving. Estimated age at harvest ranges from 1 to 9 years

Table 7. Age distribution of the mule deer harvest on the CRLRR (1989-1993)[1].

AGE	1	2	3	4	5	6	7	8	9
FREQUENCY	3	13	30	20	13	9	1	5	1

[1] Age was not estimated for 10 animals due to hunters failing to check their animals through the check station.

with the majority (50/95) being 3 or 4 years of age (Table 7). Hunter success has been maintained at or above 85% for each of the 5 seasons.

Due to limited hunting pressure and hunter selectivity, mean age of the harvest is expected to increase with time until gradually reaching a plateau where it will stabilize. This increase in age is expected to result in increased antler and body sizes. The significance of these plateaus would be to signify the "level of quality" which landowners in that region might expect from a proposed fee hunting operation on their lands without significant management activities.

Harvest Trends

Mean age of the harvest (MAH) ranges from a low of 2.67 ± 0.62 years (1990) to a high of 4.43 ± 1.38 years (1993). The expected trend of a gradually increasing MAH is not that apparent (Table 8). In fact, MAH declined between 1989 and 1990.

Certain factors probably contributed to this decline. For example, the hunting party in 1989 was believed to be

Table 8. Mean age, antler score, body index and hunter success rates for the CRLRR[1].

YEAR	HARVEST SIZE	HUNTER SUCCESS	AGE	ANTLER SCORE	BODY INDEX
1989	16	85	3.94	108.56	115.66
1990	19	95	2.67	113.53	125.07
1991	23	92	3.86	122.27	121.74
1992	23	92	4.35	113.34	120.82
1993	24	96	4.43	118.04	118.59

[1] Age, antler score and body index measurements were not taken from every animal due to damages incurred on the carcass or hunters sometimes leaving without checking a deer out.

participating in unethical (and possibly illegal) behavior which could have resulted in increasing the MAH. Thus this group of hunters were not allowed to return. Instead a new group of hunters secured hunting rights in 1990. The core of this new group has remained constant since that time. This change in hunters could have altered the MAH simply due to differences in hunter selectivity. If 1989 is deleted there appears to be a gradually increasing trend in MAH with the degree of difference between the years gradually decreasing (Table 8). This could indicate that the MAH is approaching the expected plateau which the present level of hunter density is able to achieve.

Antler score (r = 0.142) and body index (r = 0.002) also revealed very weak correlations with time. Mean body index per season has actually been decreasing slightly since 1990 (Table 8). Because mule deer selectivity on the

CRLRR is primarily for antler size, the weak body index trend is not totally unexpected. In other words, hunters which frequent fee hunting operations are seeking "trophy class" antlers. Therefore, body size is of only secondary value.

Antler scores did increase from a low of 108.56 ± 20.60 (1989) to a high of 122.27 ± 17.59 in 1991 (Table 8). Mean antler score declined in 1992, but rebounded to near the 1991 high in 1993 (Table 8).

The limited hunting pressure which is now being maintained on the CRLRR has failed to result in any substantial trends over the past 5 years. One possible explanation for this lack of change is that hunting pressure prior to 1989 was also very low. Therefore, the change in ownership did not have an affect on the age structure of the harvest. The fact that hunting pressure is so minimal may also be a problem. The harvest could be too small (x = 21) to adequately reflect any changes.

Nutrition could be a contributing factor for the lack of any trends in the antler size of the harvest. Bucks require a high nutritional plane for maximum antler growth and development (Anderson 1981). Because forage quality and quantity can vary substantially on an annual basis, it seems likely that antler development would be affected on the CRLRR. If this is the case, future plans to supplement

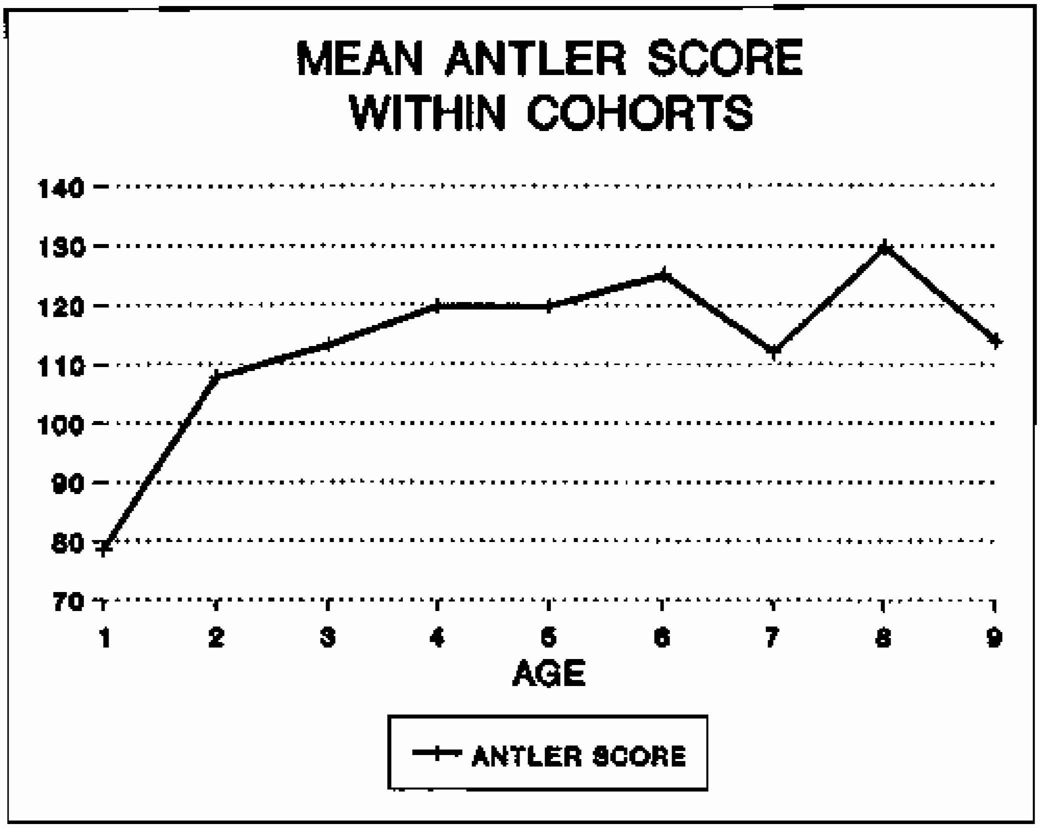

Figure 9. Mean antler score of bucks harvested on the CRLRR from 1989 to 1993.

a portion of the herd's diet, during antler development, could eliminate some of the variation and actually increase mean antler size. The potential earning power of the fee hunting operation could be affected positively as well.

Correlations With Age

Unlike other studies (Anderson et al. 1974), the correlation coefficients between age and antler and body measurements failed to reveal strong relationships. The combined values, antler score ($r = 0.42$) and body index ($r = 0.25$) also exhibited weak correlations.

One problem with this data set is that certain cohorts do not have an adequate sample (Table 7). However, combining cohorts into age classes did not strengthen the correlation values.

Although they can not be represented statistically, certain trends are apparent in the data. For example, the plot of mean antler score x age (Fig. 9) exhibits a gradually increasing trend between 1 and 6 years of age with a substantial increase between 1 and 2 years of age. Beyond 6 years of age the trend becomes obscure, but the 7 and 9 year cohorts are each represented by only 1 individual. I believe this and other trends will become more apparent as sample size increases in the future.

Fee Hunting Economics

The fee hunting operation resulted in $12,000.00 in revenue in 1989 and 1990, and $15,000.00 in 1991 and 1992. This increase resulted from increasing the number of hunters from 20 to 25. In 1993 the fee per gun was increased from $600.00 to $750.00, which resulted in $18,750.00 in revenue. No one can dispute that this operation has supplied a substantial amount of revenue to the CRLRR.

The quality of the harvest is not declining as a result of hunting pressure, and the hunters are satisfied with their experience, which is evident in their returning year after year. Therefore, this operation appears to have the ability to continue to supply a stable income source for some time. Considering the present and future outlook for the livestock industry this added yet stable income source may be the "shot in the arm" that many livestock producers in New Mexico need in order to remain stable in today's financial markets.

SUMMARY

Until now, mule deer research has been concerned with gaining some insight into the population dynamics, home range, habitat use and harvest trends of the herd on the CRLRR. The infrastructure of the ranch is almost complete and plans are being made to begin livestock improvement practices in the near future. Therefore, future mule deer research will be focused upon determining the effects (if any) that these practices may have on the mule deer population. Coordinated planning between the NMSU Department of Animal and Range Sciences and the NMSU Department of Fishery and Wildlife Sciences is essential to ensure the utmost quality of this research endeavor.

The data to this point provide a foundation upon which future hypothesis tests can be based. As in almost any research project, problems are apparent in the data set which need to be addressed. For example, the present method of deriving deer density estimates by means of the pellet group technique should be evaluated. Estimates obtained so far are extremely variable, which means a substantial change would have to occur in the population before it could be detected. This is not to say that the technique is not useful, but rather if a high degree of precision is needed from the estimates in the future then a different sampling scheme may need to be devised. Other problems were noted in the text. However, if a change takes place, each decision should be evaluated based upon future data needs and available resources.

I believe the mule deer herd has proven to be a valuable economic resource to the CRLRR. The recent introduction of pronghorn makes wildlife enterprises on the ranch even more lucrative.

Although economics should not be the only motivation for decisions regarding wildlife on New Mexico rangelands, it is a factor for ranchers to consider when developing a range management plan. Therefore, both the rancher and wildlife can directly benefit in the future.

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A. PLANT SPECIES IDENTIFIED ON THE VEGETATION TRANSECTS, CRLRR (1993).

Grasses

Aristida spp.	Three awns
Bouteloua curtipendula	Sideoats grama
Bouteloua eriopoda	Black grama
Bouteloua gracilis	Blue grama
Bouteloua hirsuta	Hairy grama
Eragrostis spp.	Lovegrass
Hilaria jamesii	Galleta
Lycurus phleoides	Wolftail
Muhlenbergia spp.	Muhly
Panicum obtusum	Vine mesquite
Sporobolus cryptandrus	Sand dropseed

Forbs

Ambrosia artemisiifolia	Ragweed
Argemone squarrosa	Prickly poppy
Astragalus spp.	Loco weed
Eriogonum spp.	Wild buckwheat
Euphorbia micromera	Spurge
Heterotheca villosa	Hairy goldaster
Marubium vulgare	Horehound
Pectis angustifolia	Lemon weed
Portulaca aleracea	Purslane
Salsola kali	Russian thistle
Senecio longilobus	Threadleaf groundsel
Sphaeralcea spp.	Globemallow

Solanum elaeagnifolium	Silverleaf nightshade
Thelesperma longipes	Cota greenthread
Zinnia grandiflora	Zinnia

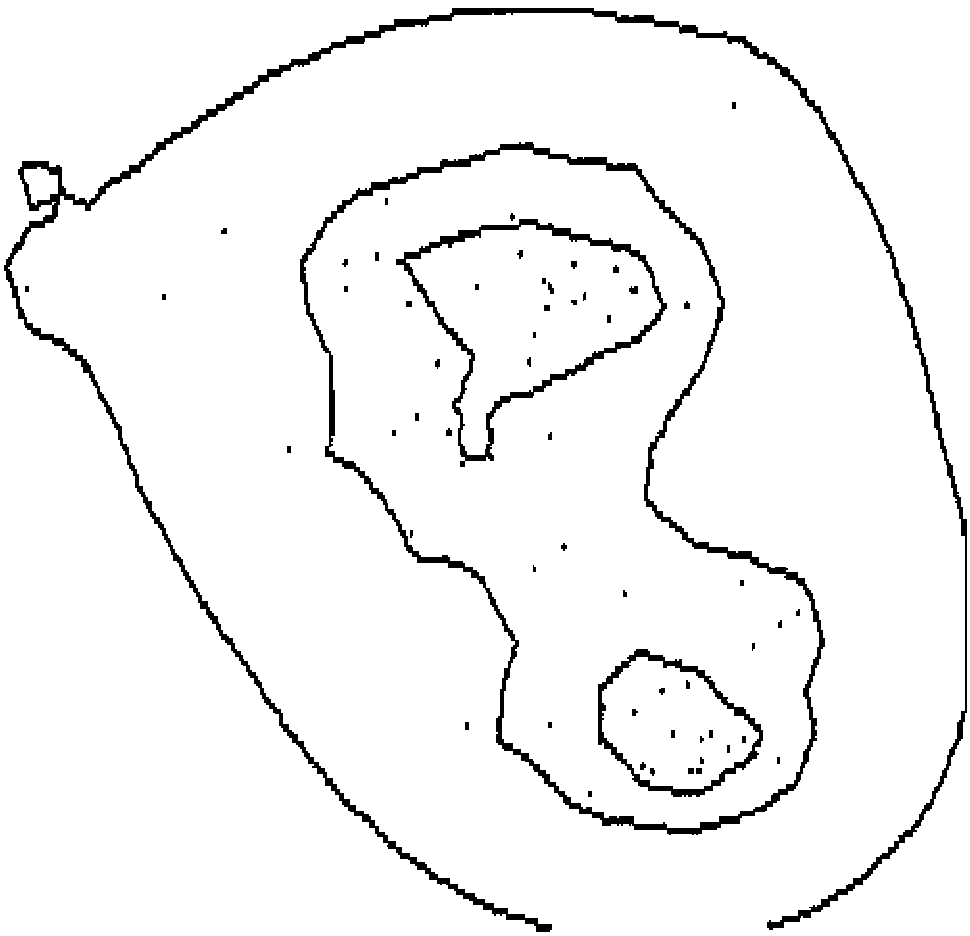
Shrubs

Artemisia bigelovii	Bigelow sagebrush
Ceratoides lanata	Winterfat
Gutierrezia sarothrae	Broom snakeweed
Quercus spp.	Oak brush
Rhus trilobata	Skunkbrush summac
Symphoricarpos spp.	Wolfberry

Cacti

Nolina microcarpa	Bear grass
Opuntia spp.	Prickly pear
Yucca spp.	Yucca

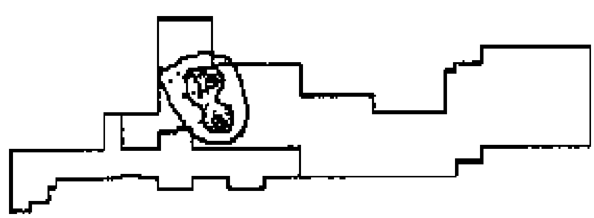
B. HARMONIC MEAN DELINEATIONS, HABITAT USE, AND RANCH LOCATIONS OF THE RADIO COLLARED DEER.



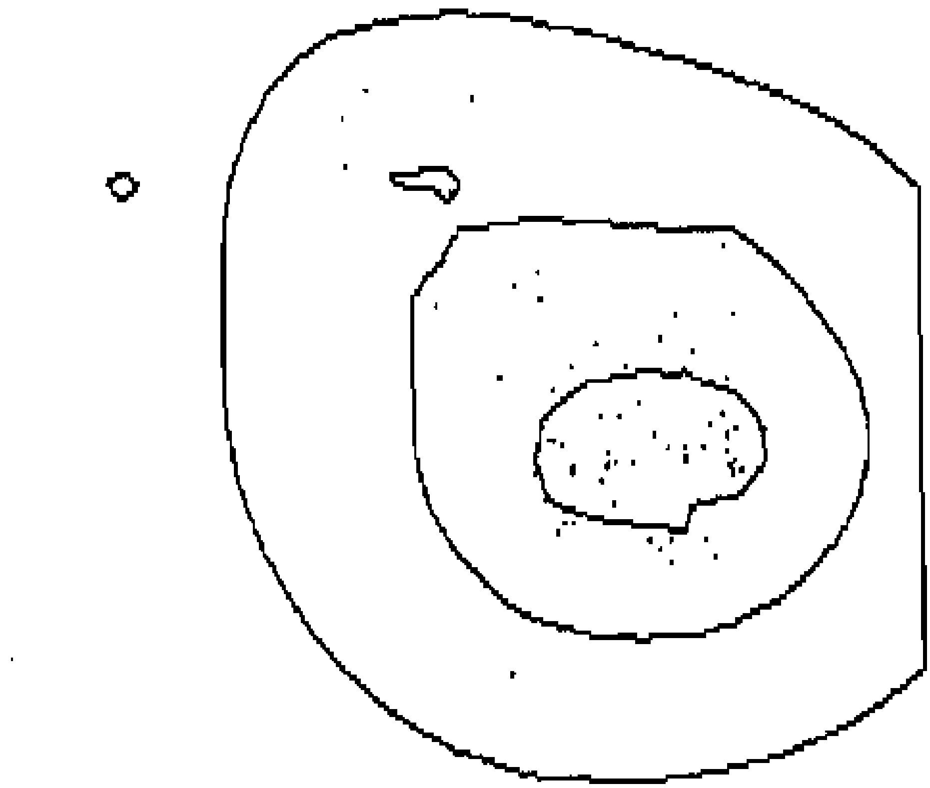
100% = 12.7520km^2
90% = 4.2410km^2
50% = 0.6368/0.3048km^2

Habitat Use

Grassland	66%
Piñon-juniper	27%
Mixed	7%



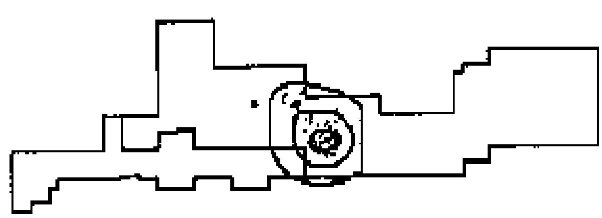
Harmonic mean delineations, habitat use, and location of deer frequency #159.030 (n = 73).



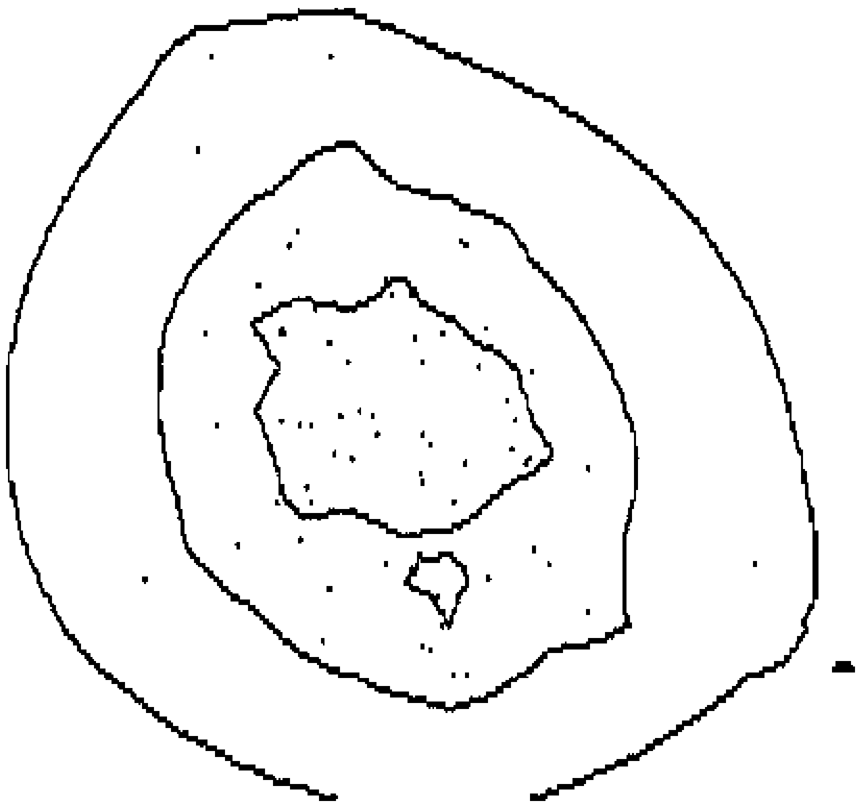
100% = 17.7041/0.0182km²
90% = 6.0783/0.0408km²
50% = 1.0707km²

Habitat Use

Grassland	15%
Piñon-juniper	85%



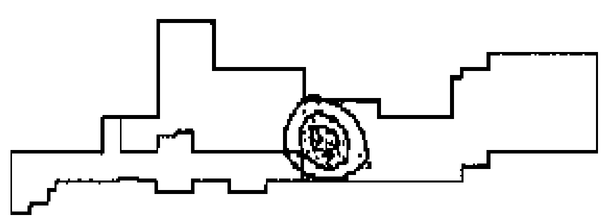
Harmonic mean delineations, habitat use, and location of deer frequency #159.070 (n = 72).



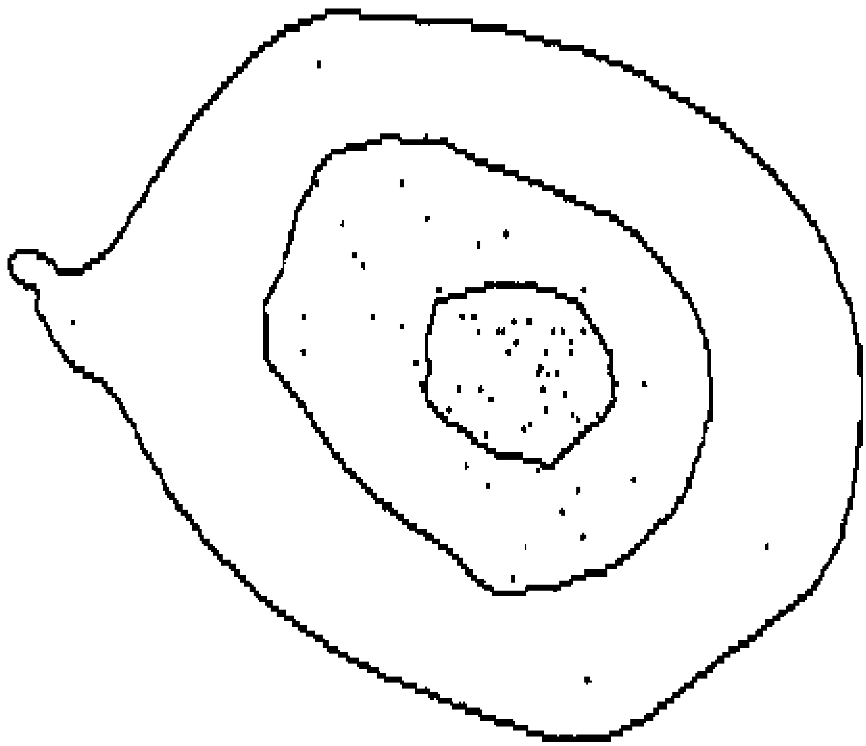
100% = 11.20148/0.0023km²
90% = 4.5046km²
50% = 1.2118/0.0522km²

Habitat Use

Grassland	10%
Piñon-juniper	90%



Harmonic mean delineations, habitat use, and location of deer frequency #159.100 (n = 77).

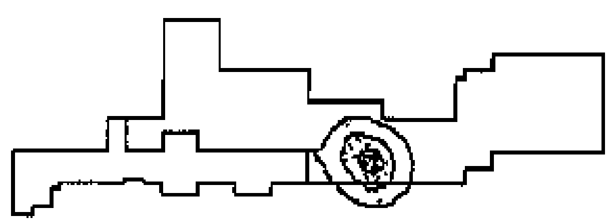


100% = 13.4938km²

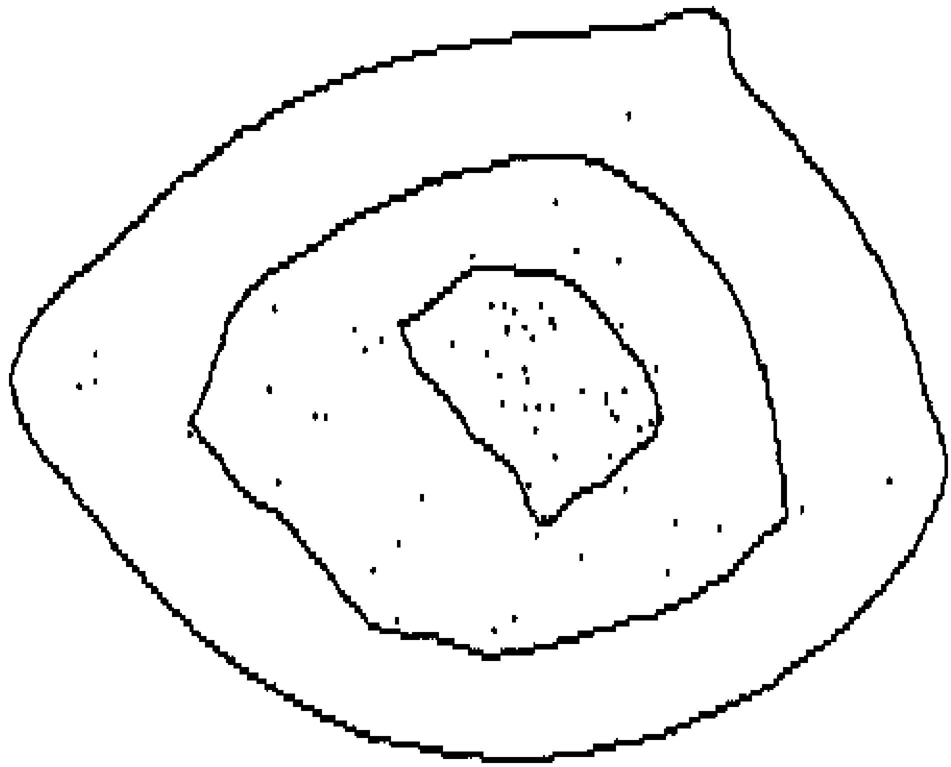
90% = 4.6551km²

50% = 0.8433km²

Habitat Use	
Grassland	3%
Piñon-juniper	94%
Unknown	3%



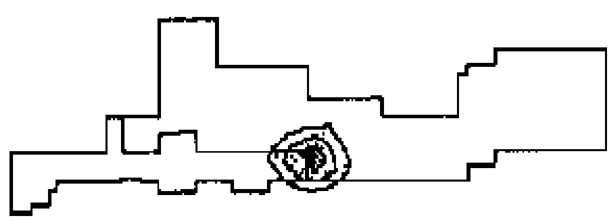
Harmonic mean delineations, habitat use, and location of deer frequency #159.130 (n = 72).



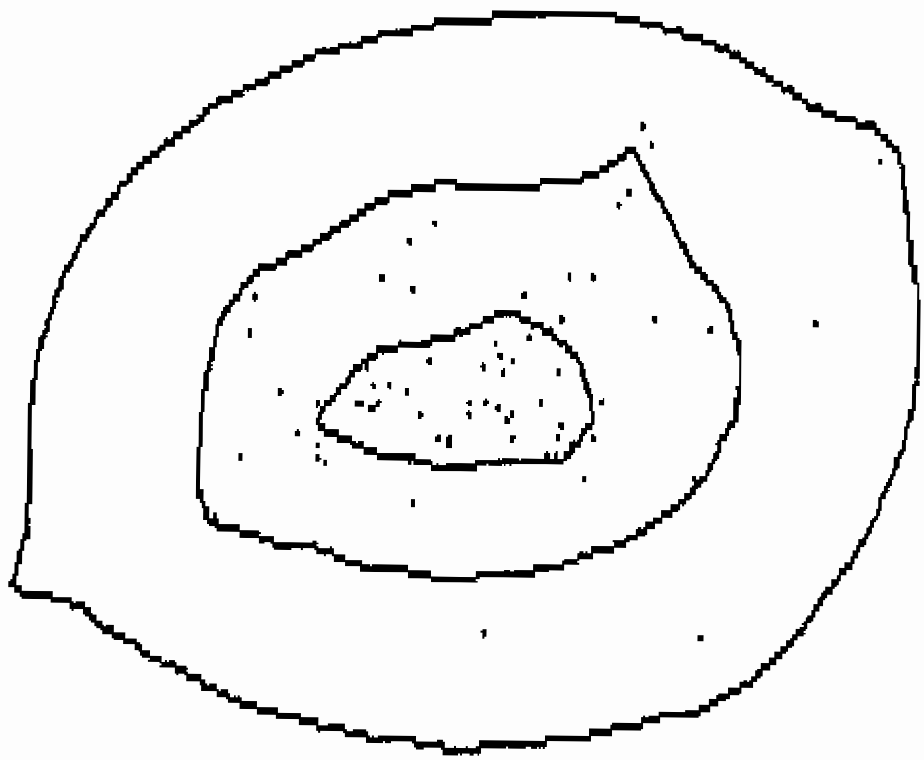
100% = 8.0920km²
90% = 3.4833km²
50% = 0.6500km²

Habitat Use

Grassland	10%
Piñon-juniper	90%



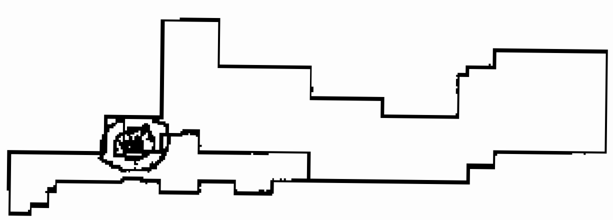
Harmonic mean delineations, habitat use, and location of deer frequency #159.160 (n = 73).



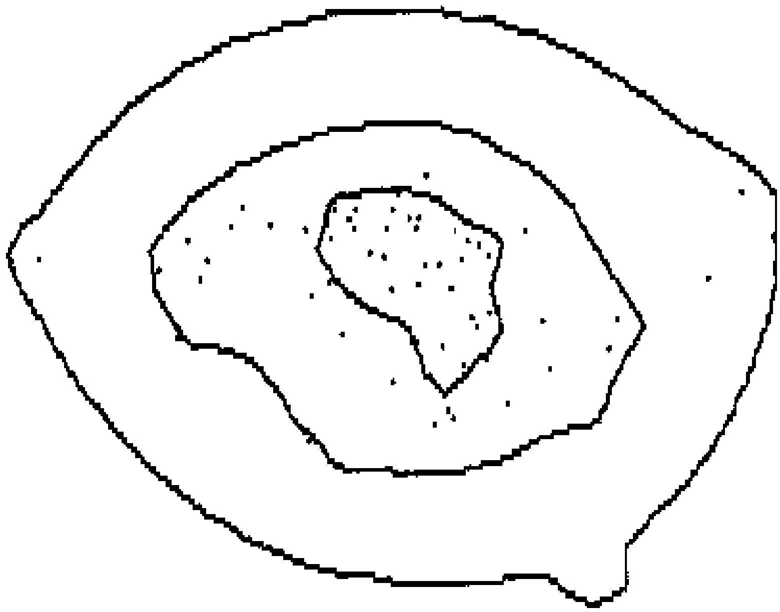
100% = 6.2507km²
90% = 2.0514km²
50% = 0.3521km²

Habitat Use

Grassland	16%
Piñon-juniper	84%



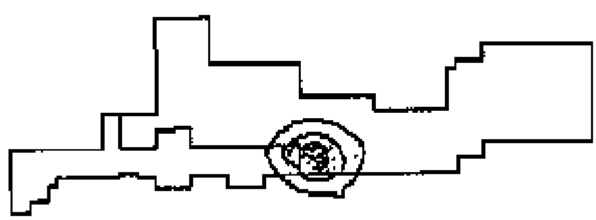
Harmonic mean delineations, habitat use, and location of deer frequency #159.380 (*n* = 75).



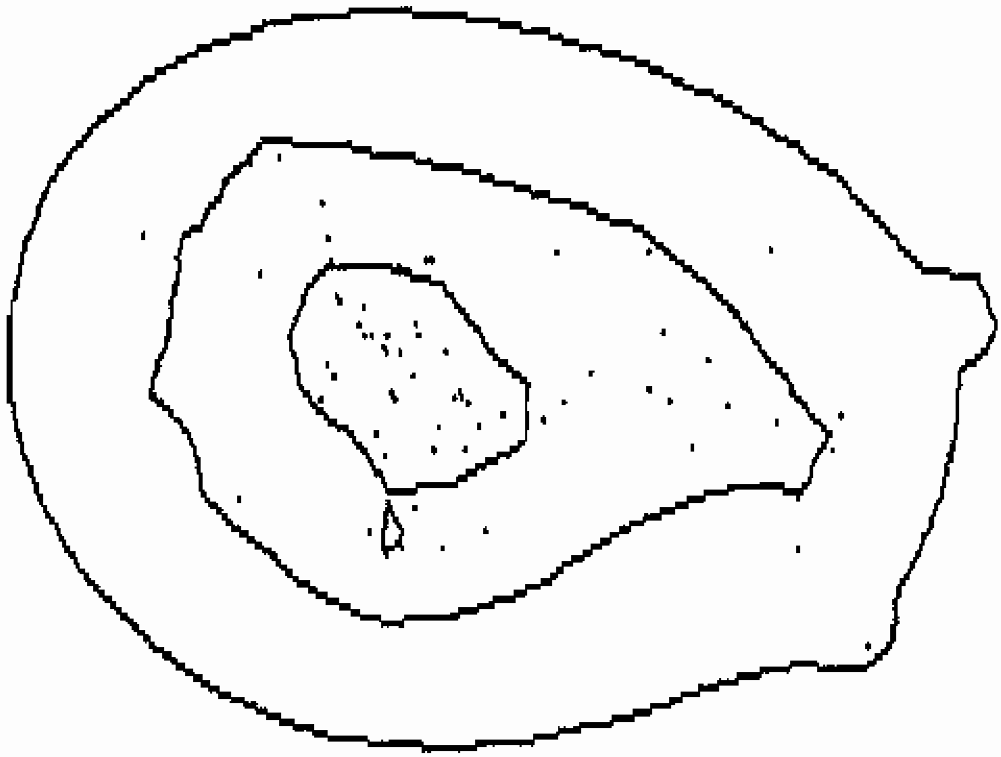
100% = 12.2393km²
90% = 4.5071km²
50% = 0.8579km²

Habitat Use

Grassland	3%
Piñon-juniper	97%

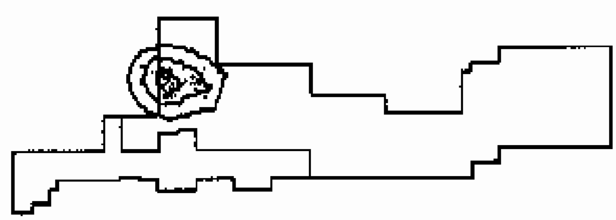


Harmonic mean delineations, habitat use, and location of deer frequency #159.410 (n = 64).

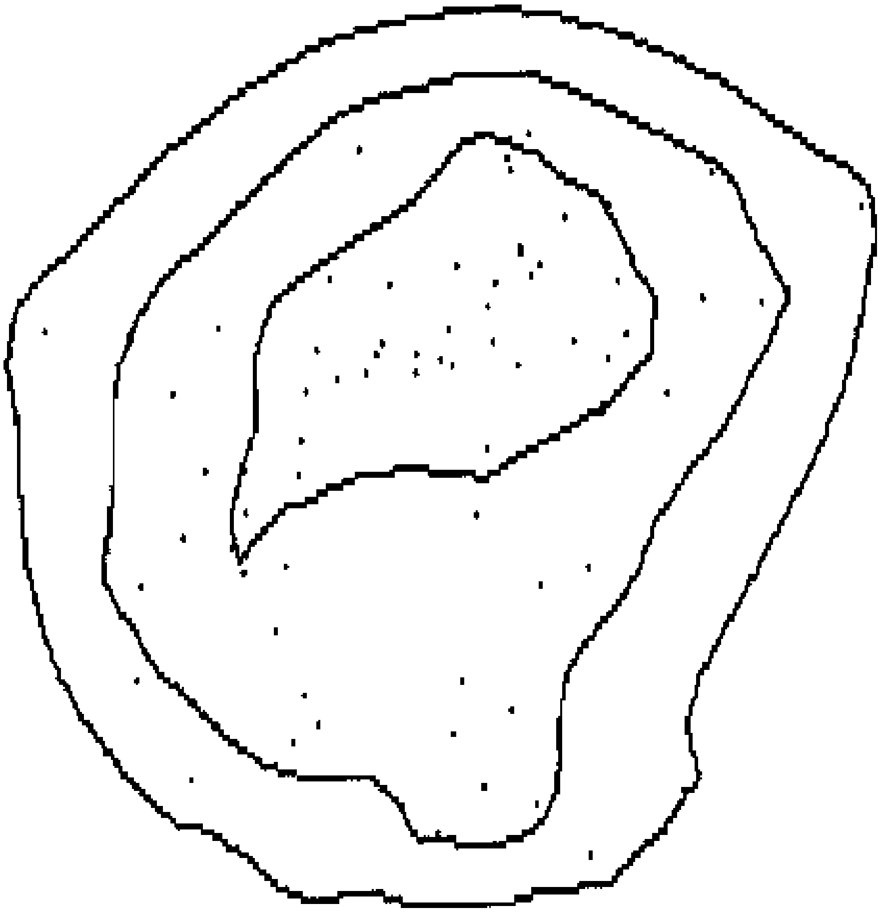


100% = 11.1002 km^2
90% = 4.3803 km^2
50% = 0.7488/0.0108 km^2

Habitat Use	
Grassland	36%
Piñon-juniper	3%
Mixed	62%



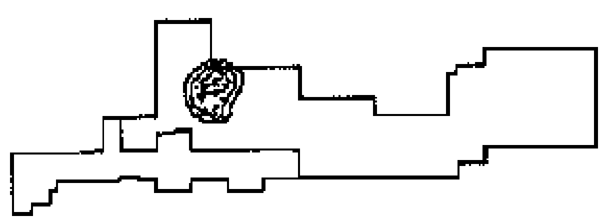
Harmonic mean delineations, habitat use, and location of deer frequency #159.440 (*n* = 76).



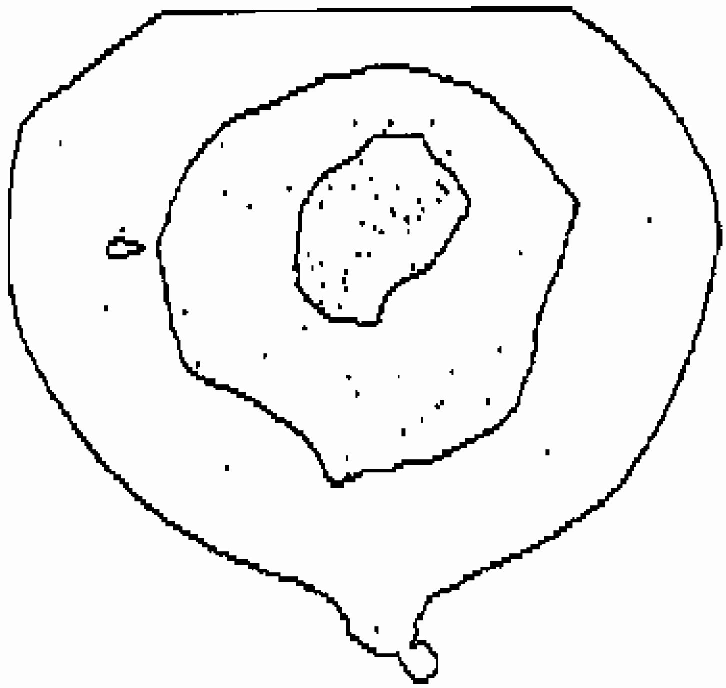
100% = 5.9215km²
90% = 3.6201km²
50% = 1.0325km²

Habitat Use

Grassland	96%
Piñon-juniper	3%
Mixed	1%



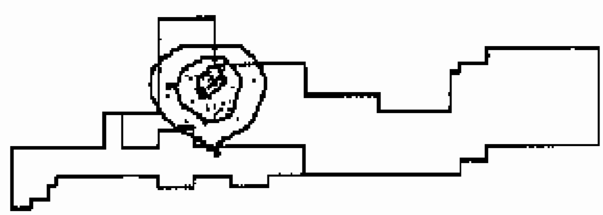
Harmonic mean delineations and location of deer frequency #159.480 (n = 75)



100% = 19.1725km^2
90% = 6.9128/0.0198km^2
50% = 1.1949km^2

Habitat Use

Grassland	89%
Piñon-juniper	6%
Mixed	5%



Harmonic mean delineations, habitat use, and location of deer frequency #159.520 (*n* =79).