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SEASONAL DENSITIES AND HABITAT USE OF DESERT MULE DEER

IN A SEMIDESERT GRASSLAND

by

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DEDICATION

I dedicate this thesis to my parents Harry and Myrtle Koenen who provided me with my love of life, the respect for all earth's creatures, and the opportunities to make dreams come true. Mom you are my inspiration here on earth and Dad, I know you are smiling down from heaven!

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ABSTRACT

I determined density and habitat use of desert mule deer (*Odocoileus hemionus crooki*) on the Buenos Aires National Wildlife Refuge, a semidesert grassland in southeastern Arizona, in 1996. I observed 219 groups of deer; densities varied from 0.9 ± 0.3 (SE) deer/km^2 in summer to 2.5 ± 1.3 in winter. Herd size varied from 1.5 ± 0.1 deer/group in summer to 9.7 ± 2.0 in winter. Density of females was greater than males (0.9 ± 0.3 and 0.03 ± 0.04, respectively). Mule deer used subshrub-grass more in summer ($\chi^2 = 54.8$, 6 df, $P < 0.0001$) and Russian thistle (*Sallsola kali*) less and cactus more in autumn ($\chi^2 = 60.2$, 6 df, $P < 0.0001$) than expected. Deer used mesquite (*Prosopis velutina*) less than expected, which may have been due to the difficulty of observing deer in dense cover. In general, the mule deer population was widespread, had a high proportion of females, and used vegetation associations as available.

INTRODUCTION

The following chapters constitute partial fulfillment of the requirements for the degree of Master of Science in Wildlife and Fisheries Science in the Graduate College at The University of Arizona. The chapters are written in thesis format and consist of 2 manuscripts that will be reformatted for submission to peer-reviewed journals. Chapter 1 is intended for submission to The Journal of Wildlife Management, and Chapter 2 is intended for submission to The Southwestern Naturalist. The chapters represent my ideas, analyses, and writing abilities. I designed the studies, collected and analyzed the majority of data, and prepared the manuscripts. For co-authorship I used the guidelines provided by Dickson and Conner (1978. Guidelines for authorship of scientific articles. Wildlife Society Bulletin 6:260-261). I am senior author for both articles; S. DeStefano, and P. R. Krausman will be coauthors for Chapter 1 and P. R. Krausman will be coauthor for chapter 2.

CHAPTER 1

SEASONAL DENSITIES OF DESERT MULE DEER

IN A SEMIDESERT GRASSLAND

Abstract: Since 1992 there has been an apparent increase in the number of desert mule deer (*Odocoileus hemionus crooki*) on the Buenos Aires National Wildlife Refuge (BANWR) in southeastern Arizona, while concurrent surveys throughout southern Arizona have indicated decreasing populations. I estimated density and examined herd composition of desert mule deer on BANWR in 1996. I used distance sampling at 971 point transects to determine density, herd size, and distribution of desert mule deer on the refuge. Densities varied from 0.9 ± 0.3 (SE) deer/km^2 in summer to 2.5 ± 1.3 in winter. Herd size varied from 1.5 ± 0.1 deer/group in summer to 9.7 ± 2.0 in winter. Density of females was greater than males (0.9 ± 0.3 and 0.03 ± 0.04, respectively) for all seasons combined. Densities of deer and herd sizes were intermediate during spring and autumn. Deer apparently gathered on the refuge and formed larger groups during winter, and were more widely dispersed and in much smaller groups during summer.

Since the late 1800s desert grasslands in the southwestern United States have been reduced through urbanization (Humphrey 1952), cattle grazing (Brown 1994), fire suppression (Bahre 1995, McPherson 1995), and climatic shifts that have increased aridity (McPherson 1995). Land clearing, irrigation, and invasive introduced species have accelerated shrub invasion and loss of native grasslands (Humphrey 1958, Brown 1994). Before 1985 the BANWR was a working cattle ranch. It is now one of the largest protected grasslands in southern Arizona (S. P. McLaughlin, The University of Arizona, unpublished data). The refuge was established by the United States Fish and Wildlife Service (USFWS) to restore and preserve this grassland ecosystem for native wildlife and for the translocation of the endangered masked bobwhite quail (*Colinus virginianus ridgwayi*) to its former range in the United States (USFWS 1995). Initial vegetation management included eliminating livestock grazing and implementing prescribed burning, disc-plowing, and reseeding of native grasses. Other management included the repair and addition of water (e.g., stock watering ponds, cement tanks, catchments) for wildlife (W. D. Young and L. L. Cunningham. 1993. Special Project Report, USFWS, BANWR, Arizona, USA).

In conjunction with grassland restoration efforts, the Arizona Game and Fish Department (AGFD) reported an increase in the number of desert mule deer on the refuge since 1992, while concurrent surveys throughout southeastern Arizona indicated decreasing deer populations (AGFD, Game Management Performance Report. 1995. Tucson, Arizona, USA). In addition, AGFD reported a reduction in the number of

yearlings harvested on and near the refuge, as well as the presence of epizootic hemorrhagic disease and a decrease in antler size and carcass mass (AGFD, Game Management Performance Report, 1994. Tucson, Arizona, USA). These conditions may be indices of declining nutrition by a population approaching range carrying capacity (Anderson 1981, McCullough 1984:233, Brown 1990, Leberg and Smith 1993, Roffe et al. 1994) and of density pressures that may facilitate spread of disease among animals (Davidson and Nettles 1988).

On a statewide management basis, current survey efforts for mule deer by AGFD may be adequate for general hunt management. Refuge managers, however, were interested in deer management within refuge boundaries. My objectives were to determine the seasonal density and distribution of desert mule deer by sex and age class on the refuge.

STUDY AREA

The BANWR (46,540 ha) is 90 km southwest of Tucson, Pima County, Arizona within the broad basin of the Altar Valley (31°41′ N, 111°27′ W). It is bordered on the east and west by mountain ranges and on the south by Mexico. Two major highways separate the refuge into 3 sections that are part of state Game Management Units 36A, 36B, 36C (AGFD, Arizona hunting regulations, Phoenix, 1996) (Fig. 1). Elevations range from 925 to 1,400 m but most of the refuge is relatively flat and <1,150 m.

Mean annual precipitation is 410 mm (Sellers et al. 1985). The distribution of rainfall is biseasonal, with a distinct summer peak in July and August and a less marked winter peak from December to February (McLaughlin 1992). Temperatures ranged from 4°C in December to 28°C in June (National Oceanic and Atmospheric Administration 1996). Seasons include winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and autumn (Oct-Dec) (Fox and Krausman 1994).

The refuge is a semidesert grassland with historic remnants of savanna grassland (Brown 1994). Predominant vegetation includes exotic grassland invaders (i.e., Lehmann lovegrass [*Eragrostis lehmanniana*]), mixtures of native weedy subshrubs (i.e., snakeweed [*Gutierrezia sarothrae*] and burroweed [*Isocoma tenuisecta*]), and stands of mesquite (*Prosopis velutina*) (McLaughlin 1992, Brown 1994:127). A prescribed burn and reseeding program, initiated in 1988, is replacing these species with a mosaic of native grasses (i.e., dropseeds [*Sporobolus* spp.], grammas [*Bouteloua* spp.], threeawns [*Aristida* spp.], Arizona cottontop [*Digitaria californica*], plains lovegrass [*Eragrostis*
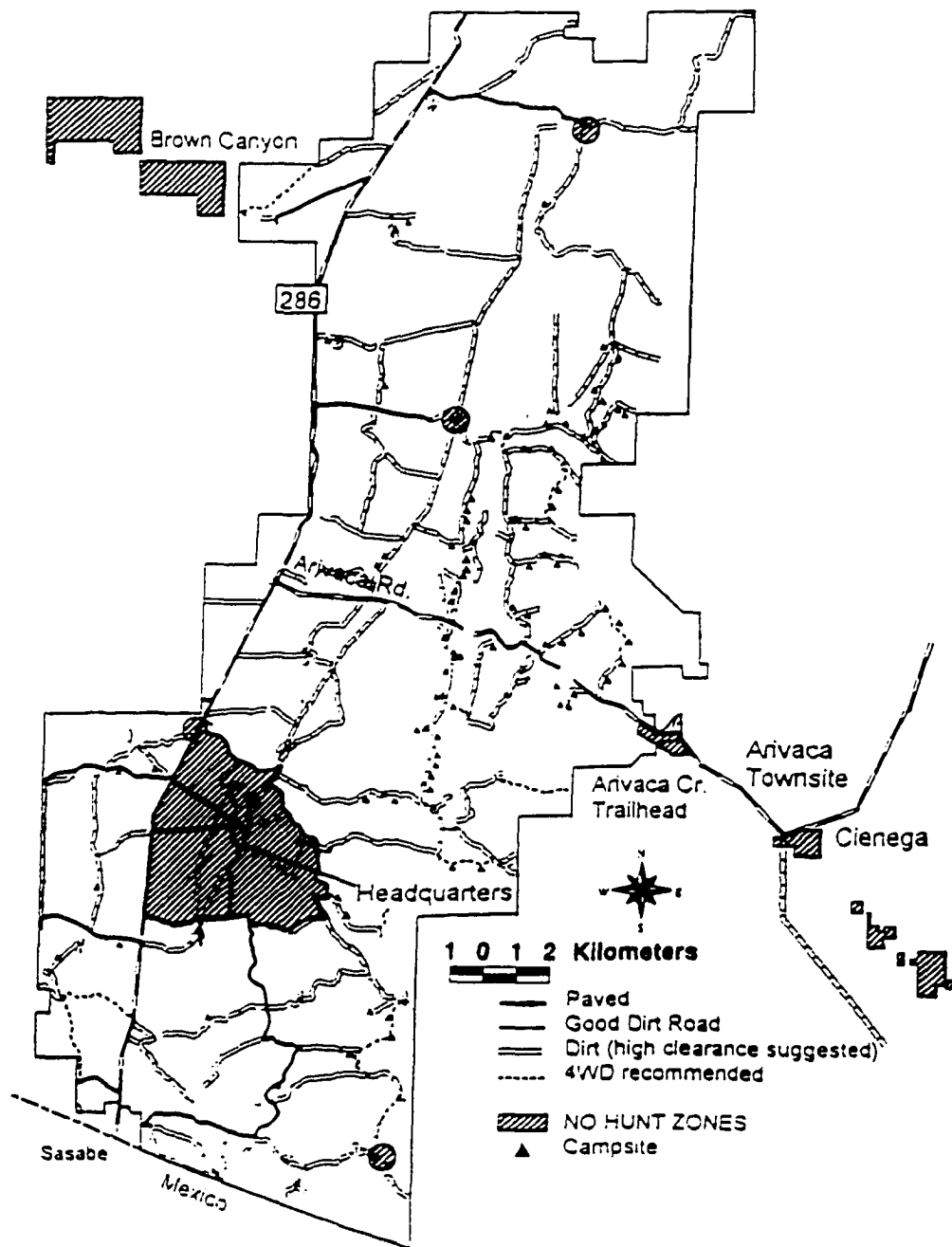
Figure 1. The Buenos Aires National Wildlife Refuge with road systems and state Game

Management Units (36A north refuge, 36B south refuge, and 36C west refuge), Arizona,

1996.

intermedia]. and wild buckwheats [*Eriogonum* spp.]) (McLaughlin 1992). The deeper

soils of wash basins are characterized by a mixture of Johnson grass (*Sorghum*

halepense), sacaton (*Sporobolus* spp.), and Russian thistle (*Sallsola kali*). Upland areas

and rocky slopes along the extreme east and west boundaries are a mixture of grasses,

subshrubs, agave (*Agave spp.*), cholla (*Opuntia* spp.), ocotillo (*Fouquieria splendens*),

prickly pear (*Opuntia* spp.) and yucca (*Yucca elata*) (McLaughlin 1992). Plant names

follow Lehr (1978) and Lehr and Pinkava (1980, 1982).

There are >130 seasonal water sources (i.e., catchments, irrigation lakes)

throughout the refuge. In February 1996, 27 stockponds contained water (i.e., 13 in the

northern half and 14 in the southern half of the refuge) (R. Madsen, USFWS, unpublished

data).

The refuge is open annually to the public for viewing wildlife, and seasonally to

hunt migratory birds, big game, and lagomorphs. White-tailed deer (*O. virginianus*)

occur at higher elevations and along the foothills, collared peccary (*Pecari tajucu*) are

dispersed throughout the area, and there is an unhunted population of $\leq$60 pronghorn

antelope (*Antilocapra americana*) on the southern half of the refuge. There is an

extensive network of roads (>330 km) and trails throughout the refuge (Fig. 1) that are

open for travel by vehicle, horse, mountain bike, or foot, and primitive camping.

METHODS

I used distance sampling (Buckland et al. 1993) to estimate seasonal densities of desert mule deer. This technique accounts for decreasing detectability of animals with increasing distance from the observer and estimates density while allowing for some animals (i.e., objects) to go undetected (Buckland et al. 1993). There are 4 major assumptions of distance sampling: lines or transects are placed randomly, objects on the line or point are always detected, objects are detected at their initial location before any movement in response to the observer, and distances are measured accurately (Buckland et al. 1993:18-19).

I used point transects as a framework for distance sampling and collecting information on distribution of mule deer by sex and age. A point transect is a modification of line transect sampling where points characterize a line of zero length (Bibby et al. 1992:85-104, Buckland et al. 1993:6). Distance sampling from point transects has been used for bird surveys (Ralph and Scott 1981, Bibby et al. 1992, Buckland et al. 1993) and although there is no compelling reason why it can not used, I could not locate any published literature reporting the use of point transects for large mammals. Point transect sampling has the advantage over line transects because a well spaced series of random or systematic points in an area will provide more representative data then a few line transects (Bibby et al. 1992) and has the advantage of allowing more time to detect and locate animals in patchy habitats, which can be sampled more easily by points than lines (Buckland et al. 1993).

Use of roads and trails may not represent available vegetative cover and thus may bias the sample selection often associated with "road counts" (Buckland et al.1993:298-299, Caughly and Sinclair 1994:198). To test for a difference in vegetative cover along roads and cover available throughout the refuge, I compared proportions of vegetative cover on 2.6-km^2 blocks using a Geographic Information System (GIS) vegetation map of the refuge with proportion of vegetative cover on a sample of 1-km^2 blocks along refuge roads; 2.6-km^2 blocks were the established grid size for the GIS map, and 1-km^2 was a general area size that was viewable in the field. I scored each survey block as covered ($\geq$30% tree canopy) or open (<30% tree canopy).

I used refuge roads to access 2.6-km^2 blocks to survey for desert mule deer. Of 171. 2.6-km^2 blocks that were completely within the refuge boundary (I did not include partial blocks that had <75% of their area within the refuge boundary), $\geq$ 90% of the blocks had roads that entered or ran adjacent to the block. Each block was assigned a unique number. I used a random number table to chose a subsample of up to 50 blocks to sample without replacement for each month (Cochran 1977:18). I measured the length of road within the random block in 0.10 mile increments (based on my vehicle odometer) and numbered each increment in the series (i.e., first 0.10 mile = 1, second 0.10 mile = 2, etc.). I then took a random drawing from this series to choose my starting sampling point within the block. I used a combination of coin flips to randomly select direction of travel along roads (N vs. S and E vs. W).

I drove <10 kph to point locations to minimize disturbance to deer. Once I

established the direction of travel for the survey. I approached the block from a different direction to avoid disturbing deer along the survey route. From the random starting point, I systematically sampled a series of 2-3 transect points at ≥ 1.6 km intervals along the road (i.e., each systematic transect point was located in a unique sampling block). Systematic sampling simplifies the selection process, reduces time and travel requirements, and can improve precision by increasing sample size (Caughley 1977:32, Thompson 1992:119-123, Buckland et al. 1993:299, Schaeffer et al. 1996). To avoid counting the same deer >1 time, each point in the series was ≥ 1.6 km from the others in all directions (e.g., when points are located along curves or bends in the road). I skipped a point if there was an obvious disturbance nearby (e.g., active campsite, parked vehicles).

Sample periods were within 3 hours after sunrise and 3 hours before sunset. These sampling times were selected to optimize deer observations during the diurnal activity times of desert mule deer (Suring and Vohs 1979, Hervert and Krausman 1986, Leopold and Krausman 1987, Thompson and Bleich 1993) and avoid midday hours when high ambient temperatures caused heat waves that can diminish optical viewing abilities.

As I approached each transect point, I assumed my approach disturbed deer if deer orientated toward and looked at observers. I classified deer activity as moved away, stood, fed, or bedded. When I arrived at each transect point I conducted a 360° scan with 10 x 50 binoculars from within the vehicle to minimize disturbance of deer. I scanned a 200 to 300 m radius for ≤ 2 minutes and counted and measured distances to deer. This was followed by a systematic scan using a 20x power spotting scope placed on the hood

of the truck to maximize my viewing area.

I divided transect points into 4 quadrants: NW, NE, SE, and SW. The starting quadrant and direction for each visual scan was determined by the location of deer during the binocular scan, or by a combination of coin flips (i.e., N vs. S and E vs. W) if no deer were seen. Scan effort was held consistent at each point by systematically sweeping the scope from side to side in overlapping viewing areas within each quadrant until the entire area was searched.

At each transect point I measured the distance from the observer to the geometric center of the group of deer. A group was defined as a cohesive aggregation of ≥ 1 deer that was >200 m from another aggregation. I used a rangefinder (1200 Rangematic®, Crosman Manufacturing, Bloomfield, N.Y.), calibrated before each survey period, to measure distances. The maximum distance measuring capability with the rangefinder was 1,000 m so distances were truncated at 1,000 m.

I recorded the number of deer in each group and classified individuals to sex and age. Classifications were adult male or adult female (≥ 1 year), juvenile or fawn (<1 year), or unknown. I recorded group behavior as bedded, standing, feeding (i.e., head down in vegetation or visibly chewing), or traveling (i.e., moving away from initial observation location).

I conducted a pilot study from 15 January to 30 March 1996 to test survey design, to gain experience in observing deer, measuring distances, and recording ancillary data, and to train observers (Buckland et al. 1993:295). These data were analyzed using the

computer program DISTANCE (Laake et al. 1994) and were incorporated into the final analysis.

I used DISTANCE (Laake et al. 1994) to estimate densities of mule deer and deer groups for each season. To assess goodness-of-fit, I first examined histograms of the distance data to ascertain where I might establish cutpoints and thus arrange the data into logical distance intervals. I then entered the data for each season as exact measurements (i.e., from point to single deer or center of group) and as 2 different sets of intervals. The first set of distance intervals included 6 cutpoints, at 200, 400, 600, 700, 800, and 900 m, which created 7 intervals (0-300 m, 301-400 m,....). The second set of intervals included cutpoints, at 300, 500, 700, and 900 m, creating 5 intervals. Models were compared using Akaike's Information Criterion (AIC) (Burnham and Anderson 1998). By definition, the best model was the model with the lowest AIC value for a given season; competing models were those within 2 AIC values.

RESULTS

Survey of Tree Cover

I surveyed 158 km of refuge roads and scored 263 1-km^2 blocks as open ($n = 171$) or covered ($n = 92$) and 186 2.6-km^2 blocks on the refuge GIS vegetation map as open ($n = 121$) or covered ($n = 65$). There was no difference in the proportion of open to cover blocks between the road survey and the GIS-based refuge map; both had 35% of the area in tree cover and 65% open vegetation ($x^2 = 0.0006$, 1df, $P = 0.99$).

Observations of Deer

I observed deer at 152 of 971 (16%) point transects from January to December 1996. Proportion of points where I saw deer was consistent among seasons: 19, 12, 19, and 15% of all points had deer in winter, spring, summer, and autumn, respectively. I saw 830 deer in 219 groups. Of these, 50% were adult females, 4% adult males, 17% juveniles, and 29% were individuals of unknown age and/or sex (Table 1).

Seasonal Estimates of Density

I ran variations on uniform, half-normal, and hazard rate detectability models (Buckland et al. 1993) to estimate density of individual deer within groups and for groups during each season. Data format for best models were in 5 distance intervals for winter and summer and in exact distances for spring and autumn. Competing models showed good fit ($P = 0.39$-0.96) and similar density estimates within each season (Table 2). Density of groups of deer varied from 0.26 ± 0.13 groups/km^2 in winter to 0.56 ± 0.19 groups/km^2 in summer; 95% confidence intervals were also widely overlapping (Table 3).

Table 1. Numbers, age, and sex of desert mule deer observed at point transects on the

Buenos Aires National Wildlife Refuge, southeastern Arizona, 1996.

Season	Age and sex			
	Adult female	Adult male	Juvenile	Unknown
Winter (Jan-Mar)	128	4	42	137
Spring (Apr-Jun)	67	2	35	81
Summer (Jul-Sep)	107	17	20	9
Autumn (Oct-Dec)	112	10	42	17
Total (Jan-Dec)	414	33	139	244

Table 2. Competing models and associated number of model parameters (k), Akaike's Information Criterion (AIC) values, goodness-of-fit (GOF) P-values, and density estimates (D = density of individuals, DS = density of clusters or groups of deer) for distance data collected for mule deer (ages and sexes combined) during 4 seasons on the Buenos Aires National Wildlife Refuge, Arizona, 1996.

Season	Model key	Adjustments	k	AIC	GOF	D	SE(D)	DS	SE(DS)
Winter	Half-normal	None	1	96.38	0.70	2.50	1.34	0.26	0.13
(Jan-Mar)	Uniform	Cosine 1	1	96.61	0.64	2.28	1.15	0.23	0.11
	Half-normal	Cosine 2	2	98.00	0.58	3.26	2.11	0.34	0.21
Spring	Hazard rate	None	2	718.54	0.89	1.31	0.76	0.38	0.21
(Apr-Jun)	Uniform	Cosine 1,2,3	3	719.09	0.74	1.34	0.75	0.38	0.20
	Half-normal	Cosine 2	2	719.58	0.96	1.57	0.89	0.44	0.24
	Uniform	Cosine 1,2	2	719.60	0.43	1.00	0.54	0.28	0.15
	Uniform	Cosine 1,2,3,4	4	720.09	0.83	1.56	0.90	0.44	0.24
	Hazard rate	Cosine 2	3	720.54	0.77	1.33	0.78	0.38	0.21
Summer	Half-normal	None	1	193.52	0.76	0.87	0.30	0.56	0.19
(Jul-Sep)	Half-normal	Cosine 2	2	195.30	0.67	0.91	0.37	0.62	0.25
Autumn	Half-normal	Cosine 2	2	744.79	0.54	1.20	0.66	0.36	0.19
(Oct-Dec)	Hazard rate	None	2	747.17	0.39	1.80	2.01	0.54	0.60

Table 3. Estimates of mule deer and mule deer cluster (herd) densities (i.e., individuals [D] and groups [DS] /km², respectively) by season on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Parameter estimates and associated measures of variance were based on the lowest Akaike's Information Criterion values model.

Season	No. points	Points with deer	No. clusters	D	SE	95% CI	DS	SE	95% CI	$\bar{x}$ cluster size	SE	95% CI
Winter (Jan-Mar)	129	25	32	2.50	1.34	0.91, 6.89	0.26	0.13	0.10, 0.67	9.72	1.95	6.48, 14.58
Spring (Apr-Jun)	320	39	53	1.31	0.76	0.45, 3.84	0.38	0.21	0.13, 1.06	3.49	0.58	2.51, 4.85
Summer (Jul-Sep)	276	52	80	0.87	0.30	0.44, 1.71	0.56	0.19	0.29, 1.10	1.54	0.10	1.35, 1.76
Autumn (Oct-Dec)	246	36	54	1.20	0.66	0.43, 3.36	0.36	0.19	0.13, 0.98	3.35	0.40	2.64, 4.25

Density estimates for individuals varied from 0.87 ± 0.03 deer/km² in summer to 2.50 ±

1.34 deer/km² in winter; 95% confidence intervals were widely overlapping (Table 3).

Number of deer on the refuge ranged from 405 (205-795) in summer to 1,162 (423-3,204)

in winter. Mean group size varied among seasons and was smallest in summer and

largest in winter (Table 3); 95% confidence intervals for mean group size did not overlap

as seasons progressed from winter to autumn (i.e., winter to spring, spring to summer,

etc.) (Fig. 2).

Age- and Sex-Specific Density Estimates

For females, males, and juveniles, I combined the 4 seasons and structured the

distance data in the same 3 formats as for the seasonal estimates of density (i.e., exact

distances and 2 different sets of intervals). Grouped distances were used for all 3 age and

sex classes: 5 intervals for females and juveniles and 7 intervals for males.

Goodness-of-fit test indicated a good fit of the data to a distance model for each age and

sex class: adult females (χ^2 = 1.64, 2df, P = 0.44), adult males (χ^2 = 0.52, 4df, P = 0.97)

and juveniles (χ^2 = 0.52, 4df, P = 0.97). I again ran variations on uniform, half-normal,

and hazard rate detectability models to estimate densities. Competing models showed

good fit (P = 0.42-0.99) and similar density estimates within each age and sex class

(Table 4). Density of females was 2x greater than for juveniles and almost 30x greater

than for males; 95% confidence intervals did not overlap between estimates of density for

females and males (Table 5). Group size averaged 2 individuals for females and 1 for

males and 95% confidence intervals did not overlap.
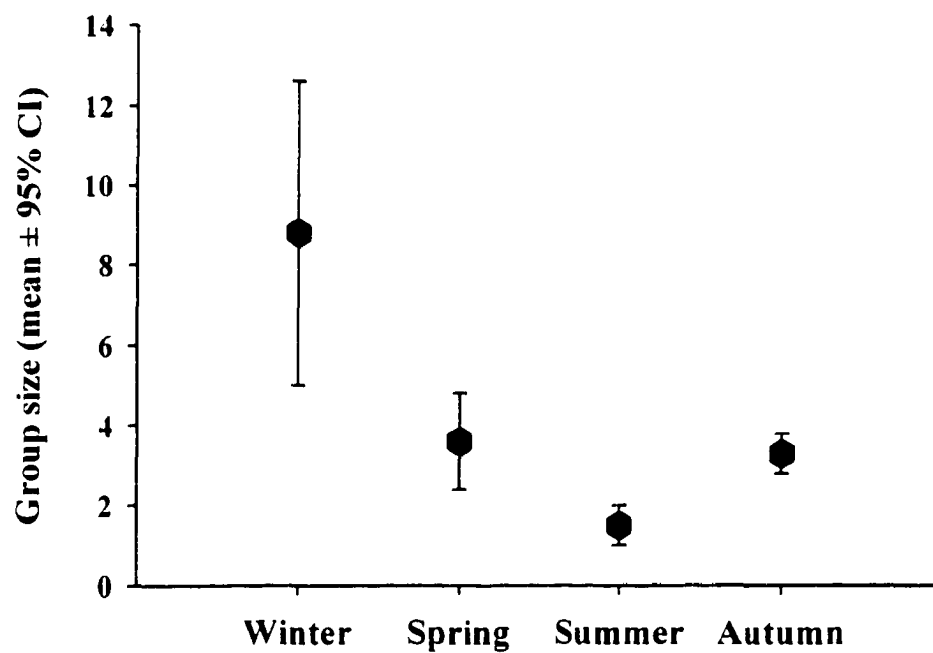
Figure 2. Mean group size of mule deer on the Buenos Aires National Wildlife Refuge, Arizona, with 95% confidence intervals.

Table 4. Competing models and associated number of model parameters (k), lowest Akaike's Information Criterion (AIC) values, goodness-of-fit

(GOF) P-values, and density estimates (D = density of individuals, DS = density of clusters or groups of deer) for distance data collected for mule deer

(by age and sex) on the Buenos Aires National Wildlife Refuge, Arizona, 1996.

Age/sex	Model key	Adjustments	k	AIC	GOF	D	SE(D)	DS	SE(DS)
Adult	Half normal	Cosine 2	2	469.65	0.44	0.89	0.28	0.44	0.13
female	Hazard rate	None	2	469.82	0.42	0.88	0.44	0.44	0.22
	Uniform	Cosine 1,2,3	3	470.05	0.91	0.82	0.25	0.40	0.12
	Half-normal	Cosine 2,3	3	470.14	0.75	0.95	0.33	0.39	0.13
	Hazard rate	Cosine 2	3	471.63	0.92	0.96	0.31	0.39	0.12
Adult	Uniform	Cosine 1	1	103.51	0.97	0.03	0.04	0.03	0.03
male	Half-normal	None	1	103.87	0.99	0.03	0.04	0.03	0.03
	Uniform	Cosine 1,2	2	104.99	0.91	0.04	0.05	0.03	0.04
	Hazard rate	None	2	105.12	0.96	0.03	0.04	0.03	0.03
Juveniles	Hazard rate	None	2	207.04	0.86	0.41	0.36	0.22	0.19
	Half-normal	Cosine 2	2	207.77	0.58	0.38	0.21	0.20	0.11
	Hazard rate	Cosine 2	3	209.00	0.51	0.33	0.19	0.18	0.10

Table 5. Estimates of mule deer and mule deer cluster (herd) densities (i.e., individuals [D] and groups [DS] /km², respectively) by age and sex on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Parameter estimates and associated measures of variance were based on the lowest Akaike's Information Criterion values.

Age/sex	No. points	Points with deer	No. clusters	D	SE	95% CI	DS	SE	95% CI	$\bar{x}$ cluster size	SE	95% CI
Adult females	971	119	168	0.89	0.28	0.49, 1.62	0.44	0.13	0.25, 0.79	2.01	0.13	1.78, 2.28
Adult males	971	27	29	0.03	0.04	0.004, 0.21	0.13	0.03	0.004, 0.19	1.14	0.10	1.00, 1.35
Juveniles	971	62	74	0.41	0.36	0.09, 1.81	0.22	0.19	0.05, 0.96	1.88	0.15	1.61, 2.19

DISCUSSION

Seasonal Densities and Herd Size

Estimates of deer density suggest that there were more deer in winter than in summer on the refuge. Mule deer may have moved onto the refuge from surrounding lands in the winter or were using more dense vegetation during the summer to escape the heat and were not as readily detected during surveys.

Mean group size was highest in winter (10 deer/group), lowest in summer (2 deer/group), and intermediate in spring and autumn (3 deer/group). Differences in mean group size were significant from one season to the next. Deer gathered in large groups (> 40 individuals) in winter, split up in spring, formed small groups in summer (typically does and fawns or solitary males), and joined into larger groups in autumn.

Characteristics of Age and Sex Structure

The observed age-sex ratio based on count data was 8 males and 34 juveniles per 100 females on the refuge for all seasons. These counts were consistent with my yearly estimates of density for each of these age-sex groups. However, up to 29% of my observations of deer throughout the year were classified as unknowns. This uncertainty could bias my age and sex composition counts. With a group size of >5 animals it was difficult to classify all individuals because of movements of individual animals, obstructed views, and time constraints imposed on survey protocol to keep survey effort consistent among points. The highest number of deer recorded as unknowns occurred in the winter (44% of all observations) when group size was largest. The lowest number of

unknowns was in summer (6% of all observations) when group size was smallest.

I did not classify animals to age or sex unless I could positively age and sex the individual. This classification was especially difficult at times when antlers were first growing or when they were shed. This could also be exacerbated by considerable overlap in timing of antler development and shedding of antlers among male mule deer in the same geographical area (Gross 1963, Anderson and Medin 1971). Although other characteristics such as body size, stature, behaviors, and primary sexual structures can be used to distinguish adult males from adult females, there were a 1 to 3 months in late winter to early spring when it was difficult to distinguish the sex of some adults.

The AGFD conducts mule deer surveys on a large area that encompasses the refuge. These data are difficult to compare with my study because of the variety of AGFD survey methods and effort (e.g., non-random population trend counts by aircraft, horseback, vehicle, and on foot versus my ground-based random point transects), timing of surveys, and area management units surveyed. Because AGFD calculates a mule deer age-and-sex ratio for deer counts conducted in mid December of one year (e.g., 1995) through mid February of the next year (e.g., 1996) in each of 3 management areas that include part of the refuge (i.e., units 36A, B, and C), I averaged the age and sex ratios from these units reported for their 1995-1996 survey to compare with my winter sex and age ratios for 1996. The resulting age and sex ratio was 14 males:49 juveniles:100 females (AGFD, Game Management Performance Report, 1996. Tucson, Arizona, USA). I then calculated an age and sex ratio from my data for January and February 1996 to use as a

comparison (I did not have data for December 1995 for this comparison). My age and sex

estimate for this period was 5 males:45 juveniles:100 females. This was relatively the

same for juveniles and 2.8 times lower for males than AGFD mule deer age and sex

estimates. However, even with these differences in mind, both estimates corroborate a low

male to female ratio for mule deer on the refuge.

Harvest Strategy and K

Density of adult females was greater than males by 30x on the refuge in all

seasons. This high female density may indicate that the population is at or approaching

range carrying capacity, a situation often observed in populations where only males are

harvested. Such high adult female density is typically seen in white-tailed deer

populations with male only harvests (McCullough 1979). For >10 years, McCullough

(1979) studied the role of density on population dynamics of white-tailed deer in an

enclosure by removing individuals of various ages and sexes. His work demonstrated that

white-tailed deer populations with male-only harvests had a high density of females, low

overall recruitment rate, and low percentage of adult males. These conditions also held for

a similar enclosure experiment for black-tailed deer (*O. h. columbianus*) at Hopland Field

Station in California (McCullough 1984). When only males were harvested, the residual

population became dominated by adult females as it grew towards carrying capacity (K),

and productivity was reduced.

It is unclear whether this condition holds true for desert mule deer. In a review of

effects of hunting on deer numbers, Connolly (1981:255) noted that the effects of harvest

manipulations on 2 populations of desert mule deer studied for >7 years in Arizona and Texas, respectively, indicated variations in fawn survival from 11 to 49 per 100 females was suspected to influence these populations trends more than the harvest manipulations. Furthermore, Caughley (1974) cautioned that sex and age ratios do not necessarily reflect changes in population size.

Effective herd management based on vegetation manipulation or alternate harvest strategies relies on accurate information on deer densities, age and sex ratios, fawn survival, and deer movements. My study demonstrated that distance sampling and observations of deer from point transects can provide information on seasonal population density and age/sex ratios for desert mule deer on the BANWR. My data indicate that numbers of deer and herd size varied by season and suggested that age and sex ratios were skewed towards a predominant adult female population.

MANAGEMENT IMPLICATIONS

On the BANWR, managers should determine if the number of deer are influencing restoration of grassland vegetation or recovery of endangered masked bobwhite quail or other plant and animal populations. My study represents a starting point in a long-term effort to monitor deer populations. This effort should be coordinated and incorporated into regional surveys conducted by AGFD in southeastern Arizona. With additional years of data on herd size. composition, and movements, managers will be able to correlate deer population characteristics with the refuge's long-term vegetation goals and management plans.

Future management should include a long-term, standardized monitoring program that incorporates distance sampling and implements improved methods for monitoring age and sex ratios. Survey methods, including routes, points, and timing, should be standardized and well documented so that methodology is repeatable by different observers over time. Increased numbers of samples (i.e., distances from point to deer and numbers of deer observed) will improve accuracy of density estimates (Buckland et al. 1993). McCullough et al. (1994) evaluated composition counts for biases by comparing known behavior of a sample of radio-collared animals with systematic dawn and night herd composition. They found that differential use of habitats accounted for most of the bias in population counts, and differential behavior was the most compelling explanation for seasonal differences in composition counts for black-tailed deer. In addition, McCullough's (1993) research on black-tailed deer indicated that fawn to female ratios

were highly variable from month to month; this variability could bias composition

estimates from autumn-winter counts that are normally used to determine sex ratios or

herd abundance. Stratifying the survey throughout the year could help account for

possible variations in seasonal sex ratios and herd abundance (McCullough et al. 1994).

Deer should be marked (e.g., ear tags, visual collars, or radiocollars) and

movements on and off the refuge should be monitored to determine if the animals seen on

the refuge are annual residents, how much time individuals spend on the refuge, and how

management actions on the refuge (e.g., altering harvest) would affect outlying areas.

Alternate deer harvest strategies (e.g., female harvest) could be implemented to manipulate

deer numbers, but I caution that a female harvest may not be the solution if there is low

survival of fawns due to other factors (e.g., predation) in addition to nutritional constraints.

CHAPTER 2

DESERT MULE DEER HABITAT USE IN A SEMIDESERT GRASSLAND

Abstract: There has been an increase in the number of desert mule deer (*Odocoileus hemionus crooki*) on the Buenos Aires National Wildlife Refuge, a semidesert grassland in southeastern Arizona, since 1992. I used point transect sampling to determine habitat use by desert mule deer relative to sex, age, and distribution on the refuge in 7 vegetation associations in 1996. I surveyed at 971 point locations and observed 219 groups of deer (50% were adult females, 33% adult males, 17% juveniles and fawns, and 29% unknown age or sex). I divided points into quadrants (patches) to account for patchiness of vegetation and found no difference between expected and observed use by mule deer in either homogeneous associations or in mixed patch arrangements. In general deer were widespread on the refuge and use of vegetation associations differed from availability (χ^2 = 61.5, 6 df, P < 0.0001). Mule deer used subshrub-grass more in summer (χ^2 = 54.8, 6 df, P < 0.0001) and used Russian thistle (*Sallsola kali*) less and cactus (*Opuntia* spp.) more in autumn (χ^2 = 60.2, 6 df, P < 0.0001) than expected by chance alone. Deer used mesquite (*Prosopis velutina*) association less than expected throughout the year, which may have been due to the difficulty of observing deer in dense cover. Incorporating a sampling plan to monitor deer use of specific vegetation associations would provide managers with information for managing mule deer in conjunction with other species management on the refuge.

Efforts to improve desert grassland for the translocation of endangered masked

bobwhite quail (*Colinus virginianus ridgwayi*) on the Buenos Aires National Wildlife

Refuge (BANWR) may be benefitting desert mule. Since the late 1800s desert grasslands

in the southwestern United States have been reduced or altered through urbanization,

cattle grazing, fire suppression, and climatic shifts that have increased aridity (Leopold

1924, Humphrey 1952, Brown 1994, Bahre 1995, McPherson 1995). Land clearing,

irrigation, and planting exotic species have accelerated shrub invasion and loss of native

grasslands and related wildlife (Humphrey 1958, Brown 1994). In 1985 the BANWR

was established by the United States Fish and Wildlife Service (USFWS) to restore and

preserve a grassland ecosystem for masked bobwhite quail (USFWS 1995). Initial

vegetation management included eliminating livestock grazing and implementing

prescribed burning, disc-plowing of top soil, and reseeding of native grasses (USFWS

1995). Other management activities included repairing stock watering ponds and

installing additional tanks to provide water for wildlife (W. D. Young and L. L.

Cunningham. 1993. Special Project Report, USFWS, BANWR, Arizona, USA). The

BANWR was a working cattle ranch but is now one of the largest tracts of grassland

under protected status in southern Arizona (S. P. McLaughlin, University of Arizona,

unpublished report).

In conjunction with the grassland restoration efforts, the Arizona Game and Fish

Department (AGFD) reported an apparent increase in the number of desert mule deer on

the refuge since 1992, while concurrent surveys throughout southeastern Arizona

indicated decreasing mule deer populations (AGFD, Game Management Performance

Report, Tucson, 1994). Because of grassland restoration efforts for masked bobwhite

quail it was important for managers to know how some efforts can be influenced by deer.

No studies had been conducted to determine habitat use by mule deer in concurrence with

grassland restoration efforts. Quantitative information on the distribution of deer in

relation to habitat components was needed to provide managers insights into factors

influencing species occurrence, density, and limitations, and for modeling and projecting

impact of habitat change (Brown 1994). My objective was to determine seasonal habitat

use by desert mule deer on the refuge.

STUDY AREA

This study was conducted on the 46,540-ha BANWR located 90 km southwest of Tucson, Pima County, Arizona (31°41' N, 111°27' W). The refuge lies in the broad basin of the Altar Valley and is bordered on the east and west by mountain ranges and on the south by Mexico (Fig. 1). Elevation ranges from 925 m to 1,400 m and the topography is relatively flat below 1,150 m.

Mean annual precipitation was 410 mm (Sellers et al. 1985) and the distribution of rainfall was biseasonal, with a distinct summer peak in July and August and a less marked winter peak from December to February (McLaughlin 1992). Temperatures ranged from 24 to 28°C in April through September to 4 to 7°C in October through March (National Oceanic and Atmospheric Administration 1996). Seasons include winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and autumn (Oct-Dec) (Fox and Krausman 1994).

The biotic community on the refuge is primarily a semidesert grassland with historic traces of savanna grassland (Brown 1994). Predominant vegetation includes exotic grassland invaders (i.e., Lehmann lovegrass [*Eragrostis lehmanniana*]), mixtures of native weedy subshrubs (i.e., snakeweed [*Gutierrezia sarothrae*] and burroweed (*Isocoma tenuisecta*]), and extensive stands of mesquite (McLaughlin 1992, Brown 1994:127). A prescribed burn and reseeding program, initiated in 1988, is replacing these species with a mosaic of native grasses such as the dropseeds (*Sporobolus spp.*), grammas (*Bouteloua spp.*), threeawns (*Aristida spp.*), Arizona cottontop (*Digitaria californica*),
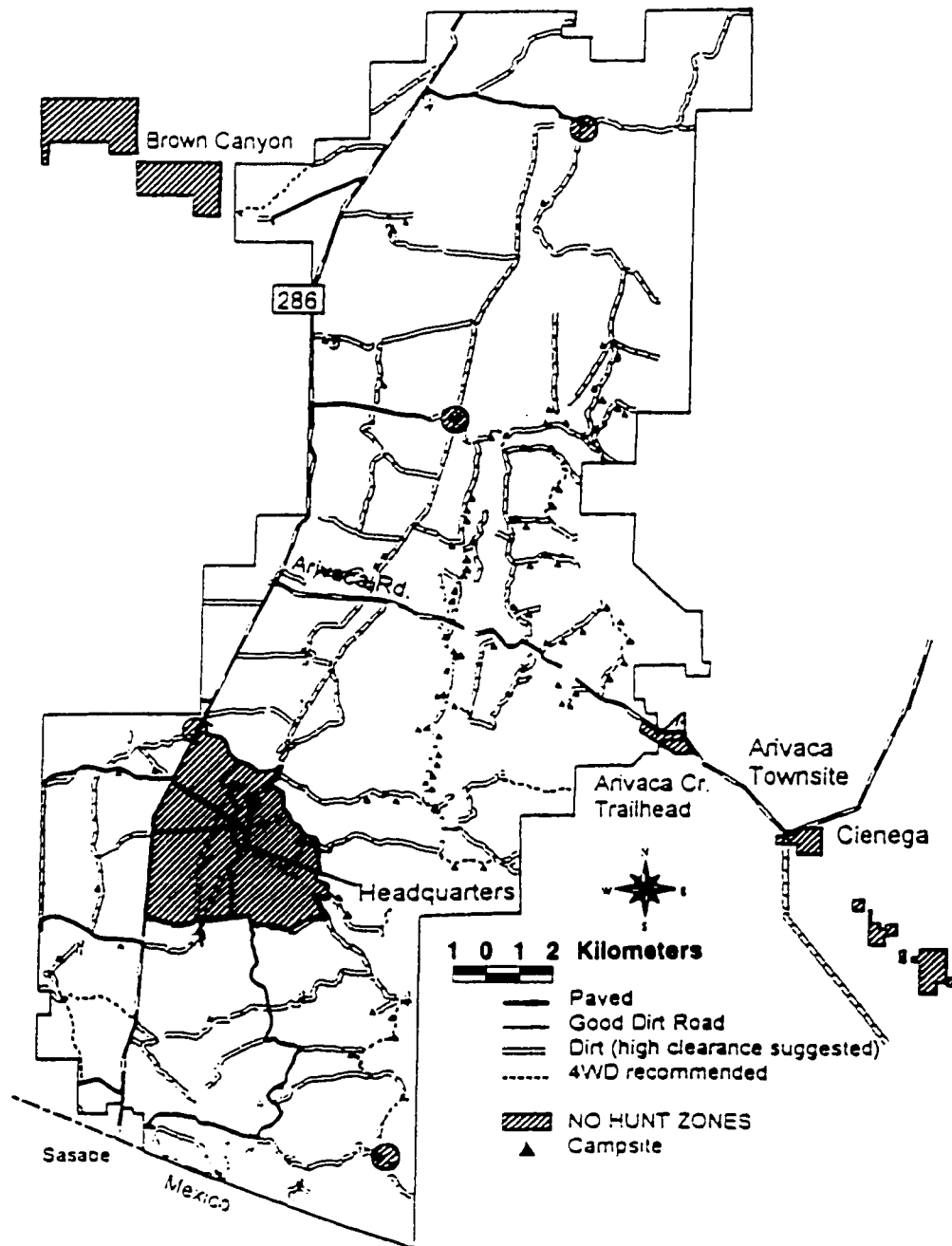
Figure 1. The Buenos Aires National Wildlife Refuge, southern Arizona, and road systems, 1996.

plains lovegrass (*Eragrostis intermedia*), and wild buckwheats (*Eriogonum spp.*) (McLaughlin 1992; USFWS 1995). The deeper soils of wash basins are characterized by a mixture of Johnson grass (*Sorghum halepense*), sacaton (*Sporobolus spp.*), and Russian thistle. Upland areas and rocky slopes along the extreme east and west boundaries are a mixture of grasses, subshrubs, agave (*Agave spp.*), cholla (*Opuntia* spp.), ocotillo (*Fouquieria splendens*), prickly pear (*Opuntia* spp.), and yucca (*Yucca elata*) (McLaughlin 1992). Plant names follow Lehr (1978) and Lehr and Pinkava (1980, 1982).

The refuge is open all year to the public for viewing wildlife, and seasonally to hunt migratory birds, big game, and lagomorphs. White-tailed deer (*O. virginianus*) occur at higher elevations and along the foothills, collared peccary (*Pecari tajucu*) are dispersed throughout the area, and there is an unhunted population of ≤60 pronghorn antelope (*Antilocapra americana*) on the southern half of the refuge. And although cattle grazing no longer occurs on the refuge, cattle are present on surrounding off-refuge lands.

Water is available year-round at >30 stockponds and cement tanks that are distributed throughout the refuge and seasonally within soil depressions, washes, and old irrigation lakes. A network of ≥330 km of unimproved roads and trails traverse the refuge and these roads do not follow specific topographic or human-made features such as ridge tops, washes, or fences, and do not correspond to particular vegetation features. Roads are open to travel by vehicle, horse, mountain bike, or foot, and for access to >100 designated primitive camping sites.

METHODS

I used point transects to collect information on use of vegetative associations by desert mule deer. Point transect sampling is a modification of line transect sampling and is appropriate for sampling in patchy habitats because it allows the observer to classify habitat components (e.g., proportions of vegetation associations) within a specific area (i.e., circles) while concentrating on locating animals (Buckland et al. 1993).

I measured use and availability of vegetation associations for deer on BANWR on a macro-habitat scale. All vegetation associations were considered the universe of available resource units (Manly et al. 1993:5). I based the classification of vegetation associations on characteristic vegetation features such as percent tree canopy and prevalent plant species (e.g., grass, subshrub, cactus). An additional criterion for this selection was that the classification had to be easily recognizable without having to transverse an area on foot to identify individual plants and potentially disturb and move deer. I satisfied the assumptions that must be met for use/availability analysis: animals can select any habitat category that is available and observations are collected in a random and unbiased manner (Neu et al. 1974, Manly et al. 1993).

I used ground reconnaissance to refine and modify 8 vegetation association classifications proposed for the refuge habitat restoration program (USFWS, BANWR unpublished report). Modifications to these vegetation associations included combining the grass categories of native and non-native grasses into a mixed-matrix grass association and adding a classification to incorporate the cactus-mixed upland areas.

Sample periods were within 3 hours after sunrise (morning) and 3 hours prior to sunset (evening). I chose these sampling times to optimize the diurnal activity times of desert mule deer (Suring and Vohs 1979, Hervert and Krausman 1986, Leopold and Krausman 1987, Thompson and Bleich 1993) and avoid midday hours when high ambient temperatures cause heat waves that diminish visibility.

I located transect points along refuge roads because road coverage was extensive and did not follow particular ridge lines, washes, or fences. Use of roads and trails may not represent available vegetative cover and thus may bias the sample selection often associated with "road counts" (Buckland et al.1993:298-299, Caughly and Sinclair 1994:198). To test for a difference in vegetative cover along roads and cover available throughout the refuge, I compared proportions of vegetative cover on 2.6-km^2 blocks using a Geographic Information System (GIS) vegetation map of the refuge with proportion of vegetative cover on a sample of 1-km^2 blocks along refuge roads; 2.6-km^2 blocks were the established grid size for the GIS map, and 1-km^2 was a general area size that was viewable in the field. I scored each survey block as covered ($\geq$30% tree canopy) or open (<30% tree canopy).

I used the 2.6-km^2 block grid system for choosing random points to survey availability of vegetation associations and the presence of mule deer. Each block was assigned an unique number and contained only 1 point transect within a sampling period. I randomly selected 50 blocks each month to sample without replacement (Cochran 1977:18). Each sample period started with a random transect point; from this a series of

2-3 points were located systematically at ≥ 1.6-km intervals along the road (i.e., each

subsequent systematic transect point was located in a unique sampling block). This

systematic sampling scheme simplified the selection process, reduced time and travel

requirements, and could improve precision by increasing sample size (Caughley 1977:32,

Buckland et al. 1993:299, Schaeffer et al. 1996).

I drove <10 kph to point locations to minimize disturbance to deer. Once I

established the direction of travel for the survey, I approached the block from a different

direction to avoid disturbing deer along the survey route. To avoid counting the same

deer >1 time, each point in the series was ≥ 1.6 km from the others in all directions (e.g.,

when points are located along curves or bends in the road). I skipped a point if there was

an obvious disturbance nearby (e.g., active campsite, visitors).

When I arrived at each transect point I made a 360° scan with 10 x 50 binoculars

from within the vehicle to minimize deer movements from near the center of the point. I

scanned a 200 to 300 m radius for ≤ 2 minutes and recorded any deer seen. This was

followed by a systematic scan using a 20x power spotting scope placed on the hood of the

truck to maximize the viewing area.

A survey area encompassed a 1,000-m viewable radius from the center of the

point transect. This was the maximum distance I could consistently determine specific

vegetation associations and identify sex and age of deer. To account for the patchiness of

vegetation associations within each circle I divided each transect point into 4 equal

quadrants (NW, NE, SE, SW) and assigned a vegetation association number to each

quadrant (patch). I also recorded the vegetation associations for the patch where deer were observed. Because animals were not marked and followed I could not measure their presence in areas that were not surveyed during my point transects; availability was thus defined as the total number of vegetation association patches at each transect point. Use of vegetation association was defined as the number of times mule deer were present in specific vegetation association during point transect surveys.

I recorded the number of deer in each group and classified individuals to sex and age. Classifications were adult male or adult female (≥ 1 year), juvenile or fawn (<1 year), or unknown.

To evaluate if there were differences in deer activity within vegetation associations, I assigned an activity code for bedded, standing, feeding (i.e., head down in vegetation and/or visibly chewing), or traveling (i.e., moving from initial observation location). To examine if there was differential use of tree cover by deer on the refuge I rated the group as in cover if $\geq 50\%$ of the individuals were under any proportion of tree canopy and as in open if $<50\%$ of the individuals were not under tree canopy.

I did ground reconnaissance and conducted a pilot study 15 January to 30 March 1996 to refine survey design, to gain experience in using equipment, observing deer and recording vegetation associations data, and to train other observers. These data were incorporated into the final analysis.

To test for differences in deer presence in vegetation associations versus availability of vegetation associations, I compared the vegetation at points with groups of

deer (i.e., ≥1 deer) to vegetation associations available at all points. I took a hierarchal approach to use/availability data analysis from a broad-scale overview of patch composition at each point (i.e., without regards to a specific vegetation association) to analysis of specific vegetation association patches at each point. For the first approach, I wanted to determine if the distribution of vegetation at each point was homogenous or patchy. For example, if all 4 quadrants (i.e., patches) surrounding a point had the same vegetation association, that point type would be classified as AAAA (i.e., all 4 patches had the same vegetation, regardless of the specific association). At the other extreme, if all 4 patches had different vegetation associations, that point type would be classified as ABCD. I did this analysis to examine use of patchy versus homogenous vegetation by deer. I then examined deer use of specific vegetation associations among age-sex groups within these patch types. For the second level of analysis I examined the use of specific vegetation association patches available regardless of point type arrangements (e.g., all mesquite-grass patches, mesquite-subshrub-grass, grass) and compared that to use by sex and age, and season.

I used 2 tests to look for differences in use versus availability: chi-square test of homogeneity for all vegetation association categories and Bonferroni simultaneous confidence intervals (95%; Byers et al. 1984) to evaluate the preference or avoidance of a specific vegetation association type by deer (Neu et al. 1974, Byers et al. 1984, Manly et al. 1993).

I looked for differences in use of vegetation associations by all deer (i.e., age and

sexes combined) for year and among seasons. I pooled seasons to look for differences in

vegetative use among age-and-sex groups because of small sample sizes of adult males

and juveniles within seasons.

RESULTS

Vegetation Associations

I identified 7 vegetation associations on the refuge: (1) mesquite-grass (30-60%

mesquite cover with 35-65% mixed-matrix of grasses), (2) mesquite-subshrub-grass (30-

60% mesquite/tree cover with 35-65% sub-shrub and a mixed matrix of grasses), (3)

grass (mixture of 35-65% mixed-matrix of grasses with <30% mesquite cover), (4)

subshrub-grass (35-65% sub-shrubs [e.g., snakeweed-burroweed] with a mixture of

grasses and <30% mesquite canopy), (5) Russian thistle mix (35-60% mixture of Russian

thistle-Johnson's grass and native woody species), (6) mesquite (>60% mesquite cover),

and (7) cactus mix (≥5% cactus and yucca-ocotillo-agave mixed with 35-65% subshrub

and/or grasses and <10% mesquite cover).

Vegetative Cover and Road Access

There were 171-km^2 blocks that were completely within the refuge boundary (I

did not include blocks that had <75% of their area within the refuge boundary), and ≥90%

had road access (i.e., roads entered or ran adjacent to the block). I surveyed 158 km of

refuge roads and classified 263 1-km^2 blocks as open (n = 171) or cover (n = 92). In

comparison, I classified 186 2.6-km^2 blocks on the refuge GIS vegetation map as open (n

= 121) or cover (n = 65). There was no difference in the proportion of tree cover found

along roads versus the proportion of available cover throughout the refuge (χ^2 = 0.0006,

1df, P = 0.99).

Observations of Deer

I observed 219 groups of deer (n = 830 individuals) at 152 of 971 (16%) point

transects surveyed from January to December 1996. Proportion of points where and time

of day when I saw deer was consistent among seasons: 19%, 12%, 19%, and 15% of all

points had deer in winter, spring, summer, and autumn, respectively. There were 96

groups at 74 points in the morning and 123 groups at 78 points in the evening. Of these

deer, 50% (n = 414) were adult females, 4% (n = 33) adult males, 17% (n = 139)

juveniles and fawns, and 29% (n = 244) individuals of unknown age and/or sex.

Patch Distribution

I first examined patterns of vegetation patches without regard to specific

vegetation associations. At this level of analysis it did not matter which particular

vegetation association was at the point but rather the arrangement of like and unlike

combinations of the associations (i.e., patch type). Patch types ranged from homogeneous

(AAAA; n = 502), combinations of 3 patches with the same associations and 1 different

patch (AAAB; n = 225), 2 patches with the same association and 2 that were different

(AABC; n = 56), 2 different patches (AABB; n = 185), to heterogeneous (ABCD; n = 3).

I omitted the heterogeneous patch type from this analysis because of low sample size. I

found no difference between the expected use of patch types and availability in either

homogeneous associations or in mixed patch arrangements (χ^2 = 3.191, 3 df, P =

0.3631).

Patch Type

I next examined the specific vegetation associations within each particular patch type (i.e., AAAA, AAAB, AABC, AABB) to see if there was a difference in expected use of vegetation associations within a patch type by groups of mule deer. At this level of analysis it did matter which particular vegetation association was at the point. For example, within a specific vegetation association (e.g., vegetation association 1 = mesquite/grass), I examined differences in use versus availability for combinations such as 1111, 111X, 11XX ..., where X could be any vegetation association other than mesquite/grass. I found differences in use of specific vegetation associations compared to availability within 2 patch types, AAAA, AAAB, but sample sizes were too low to detect differences within patch types AABC and AABB. Deer used all the available homogeneous types AAAA as expected except for the mesquite association ($\chi^2 = 27.484$, 6 df, $P = 0.0001$), which was used less than would be expected by chance alone (actual proportion = 0.04; expected proportion = 0.215; Bonferroni interval $0 \leq P \leq 0.093$). Deer used all AAAB patch types as available except they did not use thistle or mesquite associations when they equaled 3 patches at a point ($\chi^2 = 18.823$, 6 df, $P = 0.0045$).

Patch Type Use Among Age-Sex Groups

The homogeneous patches were the most common (52%) vegetation pattern and were the only types with adequate sample sizes for chi-square analysis (Sokal and Rohlf 1995) to examine patch use among age-sex groups. For this analysis I looked for within year differences in use between groups of adult females with no juveniles, groups with

juveniles and fawns, and groups with adult males. Sample sizes were too low for within season comparisons and for adult males (n =16) across all seasons. Adult female groups without juvenile-fawns (n = 76) used the mesquite association less (actual proportion = 0.026) than would be expected (expected proportion = 0.215) by chance (χ^2 = 25.49, 6 df, P = 0.0003; Bonferroni interval $0 \leq P \leq 0.075$). Females with juveniles or fawns in AAAA (n = 27) used more of the cactus association (actual proportion = 0.296) than would be expected (expected proportion = 0.076) by chance (χ^2 = 9.022, 3 df, P = 0.090; Bonferroni interval $0.077 \leq P \leq 0.516$).

Vegetation Associations

I then examined mule deer use of specific vegetation associations available within each quadrant at 3 levels: (1) per year (i.e., all seasons combined), (2) per season (i.e., winter, spring, summer, autumn), and (3) per season by adult-only groups and groups with juvenile-fawns. To avoid design limitation bias, because deer were more difficult to view in the >60% tree cover mesquite vegetation association than in the other more open vegetation associations, I analyzed preference with and without the mesquite vegetation association (Spencer 1987, Thomas and Taylor 1990).

Use by all mule deer groups– The availability of vegetation associations ranged from mesquite-grass as the most common (26%, n = 1,015 quadrants available), to cactus as the least common (6%, n = 233 quadrants available). Groups of deer were seen most often (26%, n = 58 times) in the mesquite-grass association and were seen least often in the mesquite association (3%, n = 6 times out of 723 mesquite association quadrants).

Mule deer use of available vegetation associations within the year differed

significantly from availability with mesquite association (χ^2 = 61.5, 6 df, P < 0.0001) and

without the mesquite association (χ^2 = 21.99, 5 df, P < 0.0005) (Table 1). When the

mesquite association was included in analysis mule deer used the subshrub-grass

associations more and mesquite associations less than expected by chance alone. When

the mesquite association was not used in the analysis, the subshrub-grass association was

used as expected and the mesquite-subshrub-grass association was used less than

expected by chance alone (Table 1).

Seasonal use of specific vegetation associations by all groups of deer did not

differ significantly during winter (n = 32; χ^2 = 10.5, 6 df, P < 0.1053 with mesquite and n

= 32; χ^2 = 6.0, 5 df, P < 0.3070 without mesquite) or spring (n = 53; χ^2 = 7.6, 6 df, P <

0.2686 with mesquite and n = 49; χ^2 = 2.7, 5 df, P < 0.7396 without mesquite) whether or

not the mesquite association was included in the analysis. However, there were

differences in use versus availability by all groups of deer in summer and autumn. In

summer, use differed from availability when the mesquite association was included (χ^2 =

54.8, 6 df, P < 0.0001) and when the mesquite association was excluded from analysis (χ^2

= 19.6, 5 df, P < 0.0015). When the mesquite association was included deer groups used

the subshrub-grass association more and the mesquite association less than expected by

chance alone; when the mesquite association was excluded the cactus association was

used less than expected by chance alone (Table 2). In autumn there was a difference in

use versus availability with (χ^2 = 60.2, 6 df, P < 0.0001) and without (χ^2 = 51.6, 5 df, P <

Table 1. Yearly utilization-availability data for vegetation association quadrants surveyed at 971 point transects on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Simultaneous interval data include results with mesquite associations (n = 3,884) and without mesquite associations (n = 3,161). Utilization is based on 219 mule deer group locations for all available and 213 groups when the mesquite association was excluded from analysis.

	Expected proportion		Actual proportion		Bonferroni intervals for P_i	
Vegetation association	With mesquite	Without mesquite	With mesquite	Without mesquite	With mesquite	Without mesquite
Mesquite-grass	0.261	0.321	0.265	0.272	$0.185 \le P_1 \le 0.345$	$0.192 \le P_1 \le 0.353$
Mesquite-subshrub-grass	0.175	0.214	0.119	0.122	$0.060 \le P_2 \le 0.178$	$0.063 \le P_2 \le 0.181^a$
Grass	0.113	0.138	0.169	0.174	$0.101 \le P_3 \le 0.237$	$0.105 \le P_3 \le 0.242$
Subshrub-grass	0.096	0.117	0.164	0.169	$0.097 \le P_4 \le 0.232^a$	$0.101 \le P_4 \le 0.237$
Thistle	0.110	0.135	0.137	0.141	$0.075 \le P_5 \le 0.200$	$0.078 \le P_5 \le 0.204$
Mesquite	0.186	-----	0.027	-----	$0^b \le P_6 \le 0.057^a$	-----
Cactus	0.060	0.074	0.119	0.122	$0.060 \le P_7 \le 0.178$	$0.063 \le P_6 \le 0.181$

[a] Indicates a difference at the 0.05 level of significance.

[b] 0 was used in place of negative numbers.

Table 2. Summer (Jul-Sep) utilization-availability data for of vegetation association quadrants surveyed at 276 point transects on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Simultaneous interval data include results with mesquite associations (n =1,104) and without mesquite associations (n =785). Utilization is based on 80 mule deer group locations for all available and 79 groups when the mesquite association was excluded from analysis.

Vegetation association	Expected proportion		Actual proportion		Bonferroni intervals for P_i	
	With mesquite	Without mesquite	With mesquite	Without mesquite	With mesquite	Without mesquite
Mesquite-grass	0.312	0.438	0.388	0.392	$0.241 \leq P_1 \leq 0.534$	$0.247 \leq P_1 \leq 0.537$
Mesquite-subshrub-grass	0.133	0.187	0.100	0.101	$0.010 \leq P_2 \leq 0.190$	$0.012 \leq P_2 \leq 0.191$
Grass	0.083	0.117	0.150	0.152	$0.043 \leq P_3 \leq 0.257$	$0.045 \leq P_3 \leq 0.259$
Subshrub-grass	0.056	0.079	0.200	0.203	$0.080 \leq P_4 \leq 0.320$[a]	$0.083 \leq P_4 \leq 0.322$[a]
Thistle	0.070	0.098	0.125	0.127	$0.026 \leq P_5 \leq 0.225$	$0.028 \leq P_5 \leq 0.225$
Mesquite	0.289	-----	0.013	-----	$0^b \leq P_6 \leq 0.046$[a]	-----
Cactus	0.057	0.080	0.025	0.025	$0^b \leq P_7 \leq 0.072$	$0 \leq P_6 \leq 0.072$[a]

[a] Indicates a difference at the 0.05 level of significance.

[b] 0 was used in place of negative numbers.

0.0001) the mesquite association included in the analysis (Table 3). For both levels of analysis, deer groups used cactus more than expected by chance alone (Table 3). There was a difference, however, between the with and without mesquite analysis for mesquite-subshrub-grass and thistle associations. Mesquite-subshrub-grass and thistle were used less than available when the mesquite association was excluded from the analysis, while they appeared to be used as expected when the mesquite association was included in the analysis (Table 3).

Use by adult-only and juvenile-fawn groups - Use of vegetation associations differed seasonally by adult-only deer groups and groups with juveniles and fawns. In winter, groups with juveniles and fawns were not observed in the mesquite association. The adult-only groups were not observed in the mesquite or in the mesquite-subshrub-grass associations. In the spring juvenile and fawn groups were not observed in the cactus association.

There was a difference in summer use for adults groups (χ^2 = 46.2, 6 df, $P <$ 0.0001) and juvenile-fawn groups (χ^2 = 12.7, 6 df, $P < 0.0478$). When the mesquite association was included in the analysis, both groups used the mesquite association less than expected and adult-only groups used the subshrub-grass more than expected. When the mesquite association was excluded from analysis, there was no difference in use versus availability for groups with juveniles and fawns, but there were differences in use by adult-only groups (χ^2 = 17.7, 5 df, $P < 0.0034$). Adult groups used the subshrub-grass as available and used the cactus association less in summer than expected (Table 4).

Table 3. Autumn (Oct-Dec) utilization-availability data for of vegetation association quadrants surveyed at 246 point transects on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Simultaneous interval data include results with mesquite associations (n =984) and without mesquite associations (n =881). Utilization is based on 54 mule deer group locations for all available and 53 groups when the mesquite association was excluded from analysis.

Vegetation association	Expected proportion		Actual proportion		Bonferroni intervals for P	
	With mesquite	Without mesquite	With mesquite	Without mesquite	With mesquite	Without mesquite
Mesquite-grass	0.122	0.136	0.074	0.075	$0^b \le P_1 \le 0.170$	$0^b \le P_1 \le 0.171$
Mesquite-subshrub-grass	0.189	0.211	0.093	0.094	$0^b \le P_2 \le 0.199$	$0^b \le P_2 \le 0.200^a$
Grass	0.205	0.229	0.185	0.189	$0.043 \le P_3 \le 0.327$	$0.047 \le P_3 \le 0.331$
Subshrub-grass	0.150	0.168	0.185	0.189	$0.043 \le P_4 \le 0.327$	$0.047 \le P_4 \le 0.331$
Thistle	0.154	0.173	0.074	0.075	$0^b \le P_5 \le 0.170$	$0^b \le P_5 \le 0.171^a$
Mesquite	0.105	-----	0.019	-----	$0^b \le P_6 \le 0.068^a$	-----
Cactus	0.074	0.083	0.370	0.377	$0.194 \le P_7 \le 0.547^a$	$0.202 \le P_6 \le 0.553^a$

[a]Indicates a difference at the 0.05 level of significance.

[b]0 was used in place of negative numbers.

Table 4. Summer (Jul-Sep) utilization-availability data for adult-only mule deer groups for vegetation association quadrants surveyed at 276 point transects on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Simultaneous interval data include results from all available ($n = 1,104$) vegetation associations with mesquite association and all available ($n = 785$) without mesquite associations. Utilization is based on 64 adult-only mule deer group locations for all available and 63 groups when the mesquite association was excluded from analysis.

Vegetation association	Expected proportion		Actual proportion		Bonferroni intervals for P_i	
	With mesquite	Without mesquite	With mesquite	Without mesquite	With mesquite	Without mesquite
Mesquite-grass	0.312	0.438	0.406	0.413	$0.241 \leq P_1 \leq 0.571$	$0.249 \leq P_1 \leq 0.576$
Mesquite-subshrub-grass	0.133	0.187	0.094	0.095	$0^b \leq P_2 \leq 0.192$	$0^b \leq P_2 \leq 0.193$
Grass	0.083	0.117	0.156	0.159	$0.034 \leq P_3 \leq 0.278$	$0.037 \leq P_3 \leq 0.280$
Subshrub-grass	0.056	0.079	0.203	0.206	$0.068 \leq P_4 \leq 0.338^a$	$0.072 \leq P_4 \leq 0.341$
Thistle	0.070	0.098	0.109	0.111	$0.004 \leq P_5 \leq 0.214$	$0.007 \leq P_5 \leq 0.216$
Mesquite	0.289	-----	0.016	-----	$0^b \leq P_6 \leq 0.057^a$	-----
Cactus	0.057	0.080	0.016	0.016	$0^b \leq P_7 \leq 0.057$	$0^b \leq P_6 \leq 0.057^a$

[a]Indicates a difference at the 0.05 level of significance.

[b]0 was used in place of negative numbers.

In autumn there was a difference in use for adult-only groups and groups with juveniles and fawns when the mesquite association was included (χ^2 = 16.3, 5 df, $P <$ 0.0121 and χ^2 = 77.6, 5 df, $P <$ 0.0001, respectively). The adult-only groups were not observed using the mesquite association and there was no difference in use versus availability for adult only groups when mesquite was excluded from the analysis. Deer groups with juveniles-fawns used the grass association less and the cactus association more than expected by chance alone whether or not the mesquite association was included in the analysis (Table 5).

Activity

Mule deer foraged 39% of the time, traveled 29%, stood 26%, and bedded 6%. There was no differences in these activities among or within the 7 vegetation associations throughout the year. The only activity that was not observed in all the associations was bedding. No mule deer were observed bedded in mesquite/grass and mesquite associations (expected proportion = 0.265 and 0.027, respectively).

Tree Cover Versus Open Areas

There was no significant difference in deer use in tree cover or in open areas (in open = 116 and in cover = 103) within or among seasons (χ^2 = 6.894, 3 df, P = 0.0754), nor was there a significant difference in association with use of cover and or open vegetative areas between the morning (n = 96) and afternoon (n = 123) observations (χ^2 = 0.604, 1 df, P = 0.4369).

Table 5. Autumn (Oct-Dec) utilization-availability data for mule deer groups with juvenile and fawns for vegetation associations quadrants surveyed at 246 point transects on the Buenos Aires National Wildlife Refuge, Arizona, 1996. Simultaneous interval data include results from all available (n = 984) vegetation associations with mesquite association and all available (n = 881) without mesquite associations. Utilization is based on 24 mule juvenile and fawns mule deer group locations for all available and 23 groups when the mesquite association was excluded from analysis

Vegetation association	Expected proportion		Actual proportion		Bonferroni intervals for P_i	
	With mesquite	Without mesquite	With mesquite	Without mesquite	With mesquite	Without mesquite
Mesquite-grass	0.122	0.136	0.083	0.087	$0^b \leq P_1 \leq 0.235$	$0^b \leq P_1 \leq 0.242$
Mesquite-subshrub-grass	0.189	0.211	0.083	0.087	$0^b \leq P_2 \leq 0.235$	$0^b \leq P_2 \leq 0.242$
Grass	0.205	0.229	0.042	0.043	$0^b \leq P_3 \leq 0.151^a$	$0^b \leq P_3 \leq 0.156^a$
Subshrub-grass	0.150	0.168	0.083	0.087	$0^b \leq P_4 \leq 0.235$	$0^b \leq P_4 \leq 0.242$
Thistle	0.154	0.173	0.083	0.087	$0^b \leq P_5 \leq 0.235$	$0^b \leq P_5 \leq 0.242$
Mesquite	0.105	-----	0.042	-----	$0^b \leq P_6 \leq 0.151$	-----
Cactus	0.074	0.083	0.583	0.609	$0.313 \leq P_7 \leq 0.854^a$	$0.340 \leq P_6 \leq 0.877^a$

[a] Indicates a difference at the 0.05 level of significance.

[b] 0 was used in place of negative numbers.

DISCUSSION

Habitat Use

Desert mule deer diets are highly variable and can vary significantly from year to year and season to season depending on local forage availability (McCulloch 1973, Peek and Krausman 1996, Krausman et al. 1997). I found a mosaic of vegetation associations throughout the refuge. There was no significant difference in deer use of patch types versus patch availability. Groups of deer were observed using all 7 vegetation associations in all seasons except in winter, when deer were not observed in the mesquite vegetation association. When mesquite was <60% of the vegetation association (i.e., mesquite-grass and mesquite-subshrub-grass) these associations were used by deer as would be expected, but when mesquite made up $\geq$60% of the vegetation association at survey point deer appeared to use this area less than expected. This difference in use could be because it is difficult for observers to see deer in dense tree cover or that deer may use closed vegetation differently than more open areas throughout a 24 hour period (Beier and McCullough 1989). To avoid bias regarding this possibility, I analyzed the data with and without inclusion of the mesquite association. Results from these analyses yielded a difference in yearly preference and avoidance of vegetation by deer; when the mesquite association was included deer appeared to select for the subshrub-grass association and avoid the mesquite association, and when the mesquite association was excluded from the analysis deer appeared to avoid the mesquite-subshrub-grass association.

Summer and autumn appeared to be the most prevalent period that indicated a

seasonal shift in habitat use on the BANWR by desert mule deer. In summer mule deer

groups with adults only appeared to avoid the cactus association when mesquite was

excluded from analysis and select for subshrub-grass when mesquite was included in

analysis. It was during autumn when Russian thistle was used less by all groups of deer

and when deer groups with juveniles and fawns appeared to use the grass association less

and the cactus association more than expected by chance alone, whether or not the

mesquite association was included in the analysis. Deer appeared to avoid areas in

autumn where there was >75% Russian thistle vegetation associations and to select areas

with cactus association when there were fawns present.

In conclusion, desert mule deer did not appear to show strong selectivity for the

vegetation associations on the BANWR, with the following exceptions. In the autumn

deer generally avoided the Russian thistle association and groups with juvenile and fawns

exhibited a preference for upland cactus associations. Succulents can be an important

source of nutrition and water for deer in arid conditions (Krausman 1978) and mule deer

groups with fawns on the Buenos Aires Refuge appeared to select for exposed areas with

cactus primarily in the autumn when ambient temperatures are less severe. Adult groups

avoided the open upland cactus associations the summer when ambient temperatures can

exceed 33 °C (Leopold and Krausman 1987). It was in the summer when deer groups

selected for the mixed subshrub-grass associations. However, mule deer can be

considered opportunistic in their selection of habitat (Peek and Krausman 1996), and the

mix of vegetation types on the refuge likely provided adequate cover and a diversity of food plants. Also, patches of vegetation were small and highly interspersed, creating a mosaic of food and cover plants; deer on the refuge were widely dispersed and made use of these varied patches throughout the year. Current management practices, although primarily directed for masked bobwhite quail conservation, appear to be benefitting mule deer.

Recommendations

Managers should consider the possibility that deer may be shifting to the refuge in response to cattle grazing on surrounding off refuge lands, in addition to mule deer using the variety of vegetation communities within the refuge boundaries. Peek and Krausman (1996) noted in their review of grazing and mule deer that there were more deer in areas ungrazed by cattle, and several studies found where cattle were present, the occurrence of mule deer decreased (Skovlin et al. 1968, McItosh and Krausman 1982, Wallace and Krausman 1987, Ragotzkie and Bailey 1991). Future research is needed to include a monitoring plan to examine deer and cattle use off refuge in order to explore this possibility.

Researchers should explore alternative methodology for sampling vegetation use (e.g., line transects, thermal imaging) in dense vegetation (e.g., >60% mesquite cover) to improve use and availability comparisons for those cover types. Also, standardizing composition counts (e.g., by route, point, season) for deer populations within dense habitats will help to avoid possible fluctuation biases in demographic estimates in these

types (McCullough et al. 1994).

Incorporating a sampling plan to monitor deer use of vegetation associations on a more micro-habitat scale (i.e., species level) to ascertain deer use of specific vegetation types would provide managers with information on which to base sound management decisions. This level of information is extremely important in light of the refuge's mandate to restore and maintain this semidesert grassland for endangered bobwhite quail and other wildlife and native grassland plants.

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