

135
82

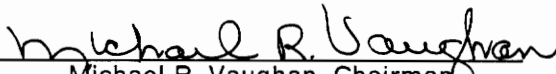
Mule Deer Response To Military Activity In Southeast Colorado

by

Thomas R. Stephenson

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
Master of Science
in
Fisheries and Wildlife Science

APPROVED:


Michael R. Vaughan, Chairman


Roy L. Kirkpatrick


Dean F. Stauffer

November 1989

Blacksburg, Virginia

C.2

LD
5655
V855
1989
S736
C.2

Mule Deer Response To Military Activity In Southeast Colorado

by

Thomas R. Stephenson

Michael R. Vaughan, Chairman

Fisheries and Wildlife Science

(ABSTRACT)

During January 1986 - September 1988 I studied the behavioral and demographic responses of mule deer (*Odocoileus hemionus*) to military activity on the Pinon Canyon Maneuver Site in southeastern Colorado. Military training was initiated on the site during August 1985 and recurred approximately 3 times yearly for periods of a month. During a maneuver, 3/7 of the site was used for training in accordance with a rotational land use schedule. I radio-collared fifty adult deer and 49 fawns. Female seasonal home ranges were larger in maneuver than nonmaneuver areas. During the nonsummer period female home ranges were larger in previous-maneuver than nonmaneuver areas. Fawn summer home ranges were larger in maneuver than previous-maneuver areas. Male home range sizes differed only for 50% harmonic mean transformation annual home ranges; bucks in maneuver areas had larger home ranges than in nonmaneuver areas. Female deer in maneuver areas exhibited significant home area shifts between premaneuver and maneuver periods more frequently (40%) than did deer in nonmaneuver (control) areas (12.5%). Mule deer in military training areas may have responded to human harassment, alteration of security cover, or destruction of the forage base. I suggest that deer may exhibit a more negative response to unpredictable than predictable disturbances. Demographic data were compared to previous baseline data (1983-1984). Buck annual survival rates did not differ during 1983-1988; doe annual survival rates also were similar during this period. Summer fawn survival differed only between 1984 and 1987, being higher in 1987. All fawn mortalities either were caused or scavenged by coyotes (*Canis latrans*). Pregnancy rates and fawn production ranged from 88-96% and 1.4-1.7 fawns/doe, respectively. Also, fawn:doe ratios were similar during 1983-1988. Although population estimates increased between 1984 and early 1988, the population declined during

late 1988. Two important confounding factors existed on the site during 1983-1988 which make it difficult to assess the effect of military activity on mule deer demographics. First, extensive cattle grazing occurred prior to acquisition of the site and continued through most of the baseline study. Secondly, coyote control was conducted during 1987-1988. These factors may have allowed the deer population to perform better under disturbance conditions. Aerial quadrat sampling was preferred over line transect sampling for censusing mule deer in low density pinyon-juniper (*Pinus edulis-Juniperus monosperma*) habitat. Management recommendations included training restrictions during fawning season and in severe winters, as well as revegetating disturbed areas.

Acknowledgements

First, I must thank Mike Vaughan, my major professor, for offering me such a great project and for being so helpful and supportive. I also would like to thank my other committee members, Drs. Kirkpatrick and Stauffer, for their comments and suggestions.

I greatly appreciate the financial and logistical support provided by Dave Andersen, Bill Mytton, and Bruce Rosenlund, U.S.F.W.S., and Al Pfister, Tom Warren, Chris Bandy, and Steve Emmons, Fort Carson, DEH. I owe much of my success to the numerous technicians who assisted me along the way. I especially wish to thank Scott Browning for his willingness to cooperate and his good humor, even in the most miserable situations. Mike Lane and Steve Byrd collected valuable data while I was taking classes. Ada Fowler, Matt Lentsch, George Fisher, Matt Zitzer, Kathy Firchow, Kristi Coughlon, Andrew Archuletta, Doug Middlebrook, and Jen Sanborn all provided unending field assistance. I also wish to thank my fellow Pinon Canyon researchers, Dave Andersen, Eric Gese, Tom Laurion, Angie Doroff, and Don Youkey, for their assistance with fieldwork and insightful discussions. Dan Sharps always was helpful around the ranch. I particularly thank Tom Gerlach for helping me to get started on the project.

A special thanks goes to my fellow graduate students at Virginia Tech for their willingness to discuss anything and everything, and for their friendship. I cannot thank my

wife, Amy, enough for being so supportive and understanding during all the long hours of fieldwork and analysis.

This project was supported by the U.S. Army, Environment, Energy, and Natural Resources Division, Fort Carson, Colorado; U.S. Fish and Wildlife Service, Virginia Cooperative Fish and Wildlife Research Unit; the U.S. Fish and Wildlife Service, Fish and Wildlife Assistance Office, Golden, Colorado; and the Virginia Polytechnic Institute and State University, Department of Fisheries and Wildlife Science.

Table of Contents

GENERAL INTRODUCTION	1
CHAPTER 1	2
MULE DEER MOVEMENTS IN RESPONSE TO MILITARY TRAINING IN SOUTHEAST	
COLORADO	2
INTRODUCTION	2
STUDY AREA	3
METHODS	6
Military Activity	6
Adult Capture	7
Fawn Capture	7
Telemetry Data Collection and Analysis	8
RESULTS	11
Military Activity	11
Home Range Size	11
Home Area Fidelity	17
DISCUSSION	22
Table of Contents	vi

LITERATURE CITED	29
CHAPTER 2	33
DEMOGRAPHIC RESPONSE OF MULE DEER TO MILITARY TRAINING IN SOUTHEAST	
COLORADO	33
INTRODUCTION	33
STUDY AREA	34
METHODS	35
Adult Capture	35
Fawn Capture	36
Survival	36
Productivity	37
Population Estimation	37
RESULTS	39
Adult Survival	39
Fawn Survival	40
Productivity	45
Population Estimation	50
DISCUSSION	53
LITERATURE CITED	55
CHAPTER 3	58
A COMPARISON OF LINE TRANSECT SAMPLING AND QUADRAT SAMPLING FOR	
ESTIMATING MULE DEER DENSITY	58
INTRODUCTION	58
STUDY AREA	59
METHODS	60
Line transect sampling	60
Table of Contents	vii

Quadrat sampling	62
RESULTS	63
Line Transect	63
Quadrat	65
DISCUSSION	65
Line Transect	65
Quadrat	68
CONCLUSIONS	69
LITERATURE CITED	71
CHAPTER 4	73
MANAGEMENT RECOMMENDATIONS FOR MULE DEER ON THE PINON CANYON	
MANEUVER SITE, COLORADO	73
INTRODUCTION	73
HABITAT	74
DISTURBANCE	76
POPULATION MONITORING	76
PRODUCTIVITY AND PREDATOR CONTROL	79
HARVEST	81
LITERATURE CITED	82
Vita	83

List of Tables

Table 1.	Tactical vehicle maneuver statistics for PCMS.	12
Table 2.	Mean (se) seasonal and annual home range size of adult females by training conditions on PCMS.	14
Table 3.	Mean (se) seasonal and annual home range size of fawns by training conditions on PCMS.	15
Table 4.	Mean (se) seasonal and annual home range size of adult males by training conditions on PCMS.	16
Table 5.	Home area fidelity of adult does by training conditions before and during maneuvers on PCMS, fall 1987.	18
Table 6.	Home area fidelity of adult does by training conditions before and during maneuvers on PCMS, winter 1988.	19
Table 7.	Home area fidelity of adult does by training conditions before and during maneuvers on PCMS, summer 1986.	20
Table 8.	Home area fidelity of adult does by training conditions before and during maneuvers on PCMS, summer 1988.	21
Table 9.	Minimum and maximum buck bimonthly survival rates (var) on PCMS.	41
Table 10.	Minimum and maximum doe bimonthly survival rates (var) on PCMS.	42
Table 11.	Minimum and maximum buck annual survival rates (var) on PCMS.	43
Table 12.	Minimum and maximum doe annual survival rates (var) on PCMS.	44
Table 13.	Minimum and maximum fawn monthly survival rates (var) on PCMS.	46
Table 14.	Minimum and maximum fawn bimonthly and annual survival rates (var) on PCMS.	47
Table 15.	Minimum and maximum fawn summer (June-Sept.) survival rates (var) on PCMS.	48
Table 16.	Buck: doe and fawn: doe ratios from quadrat surveys of mule deer on PCMS.	49

Table 17. Density estimates with 90% CI's, and unadjusted and adjusted population estimates for mule deer on PCMS. 51

Table 18. Hunting season (rifle) data for PCMS. 77

List of Illustrations

Figure 1. The Pinon Canyon Maneuver Site in southeast Colorado.	4
Figure 2. Locations of 5 maneuver sectors (A-E) and 2 off-limits areas (i.e., no land-based military training) on PCMS.	5
Figure 3. Thirty-seven randomly selected 2.6 km ² quadrats censused by helicopter on PCMS.	38
Figure 4. Unadjusted population estimates with 90% CI's from quadrat censuses on PCMS.	52
Figure 5. Sixty-one systematic-random line transects censused by helicopter on PCMS.	61
Figure 6. Density estimates (deer/km ²) with 95% CI's from line transect surveys and quadrat surveys of mule deer on PCMS.	64
Figure 7. Perpendicular distance distributions for line transect surveys on PCMS.	66
Figure 8. Mule deer distribution and density on PCMS.	75
Figure 9. Age structure of mule deer harvested during the 1987 rifle season on PCMS.	80

GENERAL INTRODUCTION

As human populations continue to expand, wildlife populations will be exposed to increasingly greater levels of human harassment. The high value of mule deer (*Odocoileus hemionus*) to the people of Colorado indicates that information on the effects of human activity is desirable and useful.

This research was the second phase of a project to assess and mitigate impacts to the Pinon Canyon Maneuver Site from military training. During 1983-1984 a baseline study was conducted to provide information on mule deer population dynamics. This study was conducted from January 1986 to September 1988. The primary objective was to determine behavioral and demographic responses of mule deer to military activity.

This thesis is presented in four chapters. The first chapter discusses changes in mule deer home range size and fidelity as a result of military activity. The effects of the high-level disturbance on mule deer survival, reproduction, and density are covered in Chapter 2. The third chapter evaluates the use of 2 types of aerial surveys for censusing mule deer. The final chapter is a management overview.

CHAPTER 1

MULE DEER MOVEMENTS IN RESPONSE TO MILITARY TRAINING IN SOUTHEAST COLORADO

INTRODUCTION

Research has been conducted to assess the effects of human activity on ungulate populations. Species studied include white-tailed deer (*Odocoileus virginianus*) (Dorrance et al. 1975; Eckstein et al. 1979), mule deer (Freddy et al. 1986; Hemker and Merrill 1984), elk (*Cervus elaphus*) (Edge et al. 1985; Peek and Hieb 1976), caribou (*Rangifer tarandus*) (Calef et al. 1976; Shideler et al. 1986), and mountain sheep (*Ovis canadensis*) (MacArthur et al. 1982). These studies concluded that disturbances such as recreation, development, mining, logging, and military activity may negatively impact ungulates. In order to effectively manage for disturbance, the response of the affected population to disturbance first must be assessed.

During 1983-84, Gerlach (1987) obtained baseline information on the population dynamics of mule deer on the Pinon Canyon Maneuver Site (PCMS) (Figure 1), Colorado, to aid in developing a comprehensive wildlife management plan for the area. He determined sex and age ratios, population estimates, adult and fawn survival, and mortality rates. In August 1985 military training began on the site and has recurred approximately 3 times yearly for periods of about one month. During any given maneuver, 3 of 7 sectors on the site (Figure 2) are used for training in accordance with a rotational land use schedule. Thus, the potential for impacts to the mule deer and their habitat exists. This study was designed to assess the impacts of military disturbance on the PCMS mule deer population. The objectives were (1) to quantify the level of disturbance on the PCMS, and (2) to assess the impacts of disturbance from military training on home range size and fidelity of mule deer on the PCMS.

STUDY AREA

The 1040 km² PCMS was located along the Purgatoire River in Las Animas County, Colorado, about 64 km northeast of Trinidad within the Great Plains Physiographic Province (U. S. Dept. of Army 1980). The topography of the site was characterized by broad sloping shortgrass prairie dissected by rocky canyons and breaks to the east and southeast, and bordered by pinyon-juniper (*Pinus edulis-Juniperus monosperma*) uplands to the north, northwest, and southwest. Elevations ranged from 1,311 m to 1,737 m. Mean annual precipitation was 30-40 cm and mean monthly temperatures ranged from -1 C in January to 23 C in July. The site has a history of dry-land cattle and sheep grazing; however grazing was discontinued in 1984. Aerial coyote (*Canis latrans*) gunning over the prairie occurred in January and May 1987 and March and April 1988 on the western half of the site.

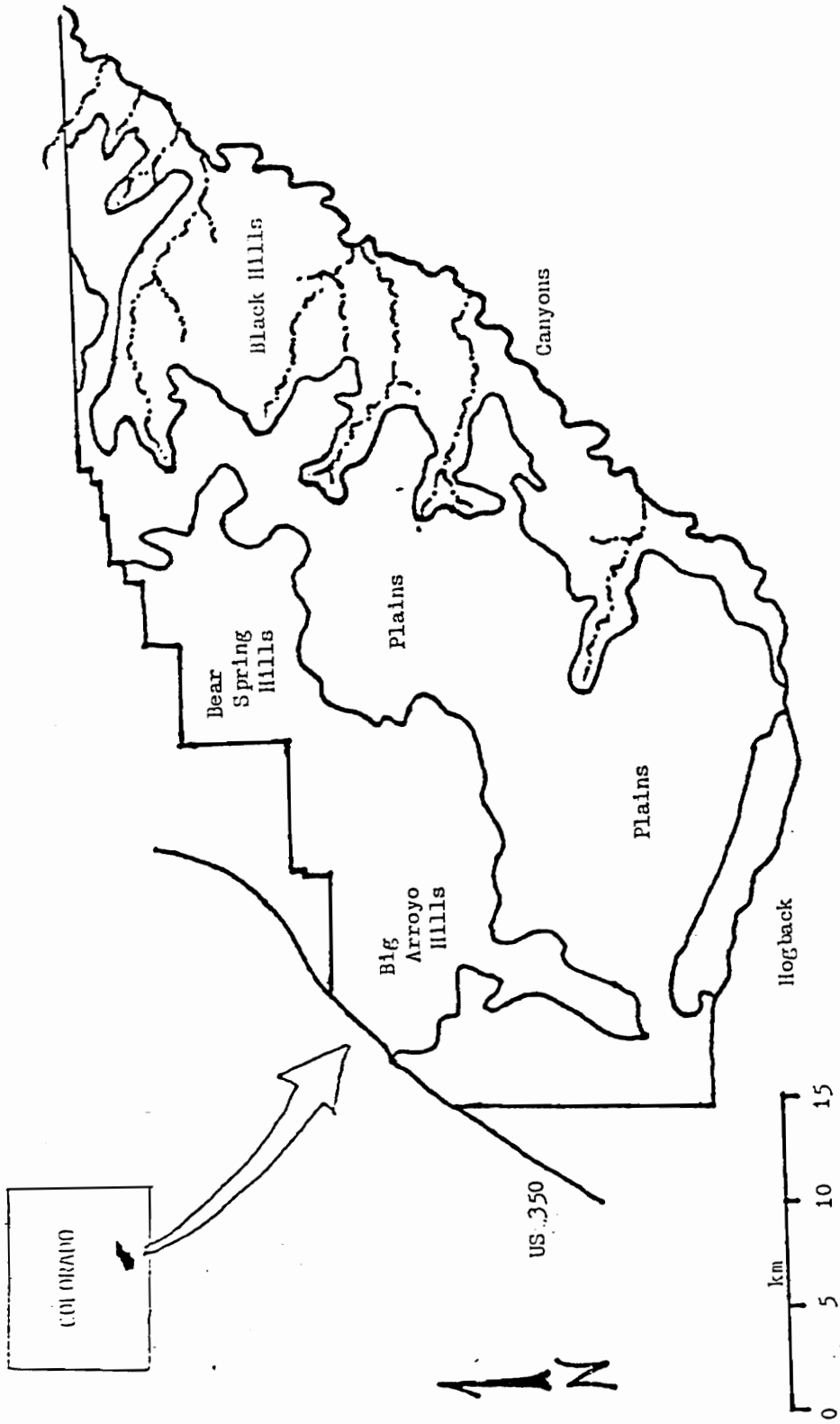


Figure 1. The Pinon Canyon Maneuver Site in southeast Colorado.

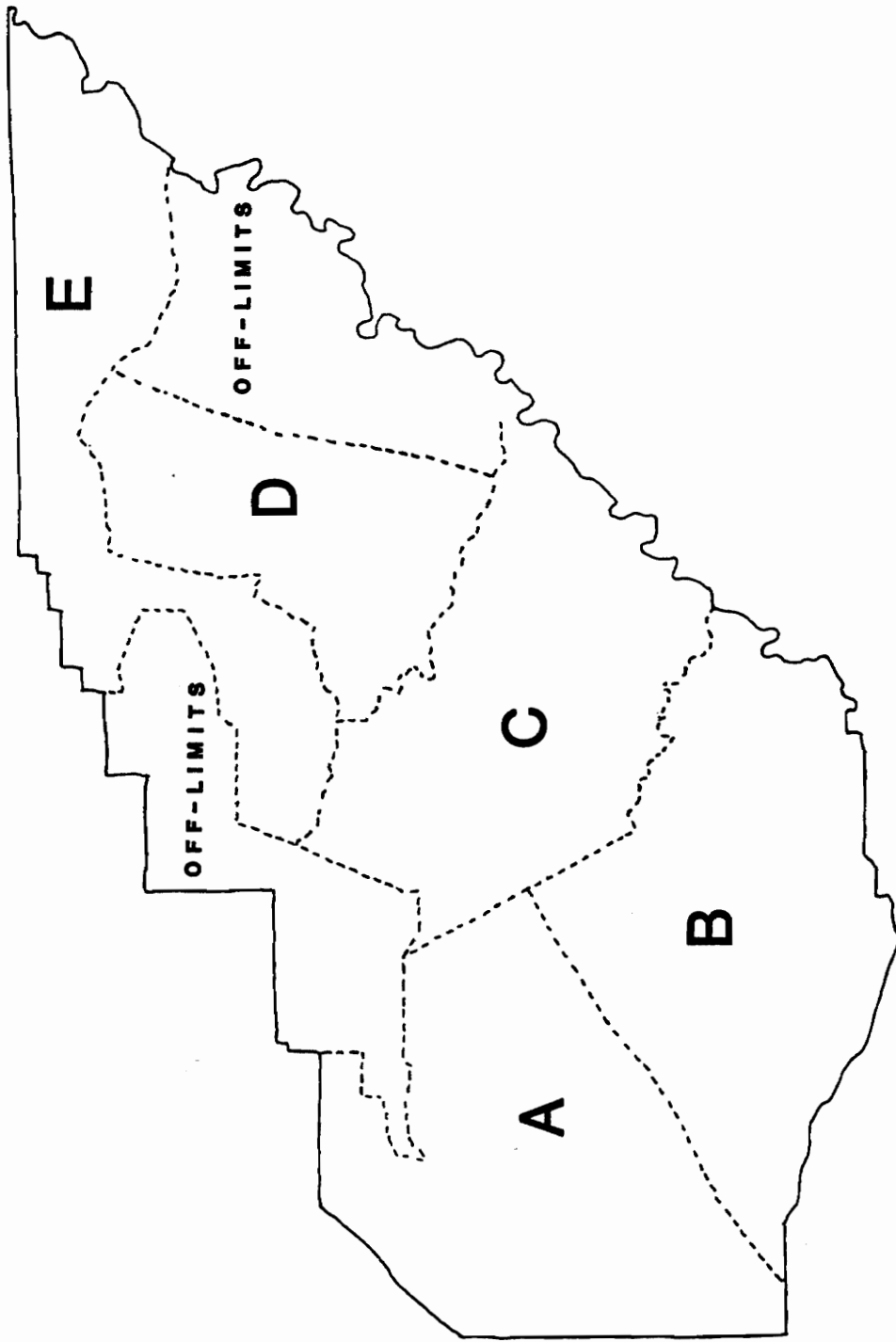


Figure 2. Locations of 5 maneuver sectors (A-E) and 2 off-limits areas (i.e., no land-based military training) on PCMS.

The vegetation consisted primarily of shortgrass prairie and pinyon-juniper woodland communities (Kendeigh 1961). The shortgrass prairie was dominated by blue grama (*Bouteloua gracilis*), in association with galleta (*Hilaria jamesii*), ring muhly (*Muhlenbergia torreyi*), western wheatgrass (*Agropyron smithii*), broom snakeweed (*Xanhocephalum sarothrae*), sand dropseed (*Sporobolus cryptandrus*), and bigelow sage (*Artemisia bigelovii*). In addition to pinyon-juniper, the woodlands included grasses and forbs such as blue grama, sand dropseed, galleta, needle-and-thread (*Stipa comata*), and broom snakeweed. Shrub species present were mountain mahogany (*Cercocarpus montanus*), fourwing saltbush (*Atriplex canescens*), skunkbush sumac (*Rhus trilobata*), currant (*Ribes* spp.), and rabbitbrush (*Chrysothamnus nauseosus*).

METHODS

Military Activity

Because military headquarters did not make available detailed records of troop movement, I personally collected this information while in the field. Land-based vehicular traffic and military activity were monitored daily while tracking deer. Periodic aerial telemetry flights further enabled identification of military traffic and encampments. Active encampments and movements that were not actually observed were approximated based on remaining disturbance to the landscape (i.e. fresh tank tracks, trash, and destroyed vegetation). Electronic road counters were not utilized because they could not withstand heavy tank traffic. Activity by helicopters and jet fighters also was recorded. Numbers of troops and tactical

vehicles per maneuver were obtained from Movement Control (PCMS and Fort Carson, Colorado).

Adult Capture

Adult mule deer were captured in Clover traps (Clover 1956), by drop net (Ramsey 1968), or by Coda net-gun (Coda Enterprises, Mesa, Arizona). Clover traps were baited with apple pulp and captured deer were manually restrained. The drop net, also baited with apple pulp, was used in areas of high deer density with open plateaus suitable for visibility and set-up. The Coda net-gun was fired from a Bell Salloy helicopter (Barrett et al. 1982). Target deer were hazed into suitable terrain for capture such as bare slopes, forest openings, or open grassland; haze time was limited to 20 minutes. Captured deer were marked with numbered color eartags and frequency-specific, color coded radio collars (164-165 MHz; 540 g) to enable individual identification. Radio collars placed on bucks were large enough to enable neck swelling during the rut. Deer age classes (fawn, yearling, and adult) were identified according to tooth replacement and wear (Robinette et al. 1957).

Fawn Capture

Newborn fawns were located during June and July by ground surveillance of radio-collared and unmarked does, then captured by hand. Fawns still moist with amniotic fluid were not handled or collared until the following day to avoid abandonment by the dam. Captured fawns were equipped with expandable break-away radio collars (135 g) (Trainer et al. 1981) and numbered button eartags. Sex, weight, and general condition of each fawn were recorded at capture. Ages and birthdates were estimated according to Robinette et al. (1973).

Telemetry Data Collection and Analysis

Radio-collared deer were located primarily from the ground using a hand-held 2-element Yagi antenna. Three techniques were used: visual observation, circling (mean radius of 50-100 m) the animal without disrupting it, and triangulation using multiple directional bearings obtained from remote bearing stations. Circling was the predominant location technique used. Visual observation was used at distances sufficient to avoid observer detection and to investigate mortalities or pregnancies. Less than 5% of locations were obtained by triangulation; of these, 75% were taken using 3 or more directional bearings within a 20 minute period at a distance of < 1 km. To estimate telemetry accuracy 22 transmitters in known locations were triangulated upon at distances up to 2 km by an individual to whom the true locations were unknown; 86% of bearings were accurate to within 100 m of the true location and average error polygon size was 2 hectares. Triangulation was used primarily to obtain nocturnal locations. Ground locations were supplemented by weekly or biweekly locations from a helicopter or fixed-wing aircraft with two 2-element Yagi antennae secured to opposite sides of the aircraft. All locations were plotted on U. S. Geological Survey 1:24,000 topographic maps and recorded using Universal Transverse Mercator grid coordinates to the nearest 100m. Most radio-collared adults and fawns older than 2 months were located every 1-10 days. Fawns younger than 2 months were located every 1-3 days.

Seasonal and annual home ranges were calculated using the minimum convex polygon (Hayne 1949), 95% ellipse (Jennrich and Turner 1969), and harmonic mean transformation (HMT) (Dixon and Chapman 1980) methods. Home ranges represent the entire area used by an individual during a given period (e.g. season or year). A 10- x 10-grid size with a 2.0 scaling factor was used in calculating the harmonic mean home ranges (Samuel et al. 1985). Observation-area curves were used to determine the minimum sample size for home range analysis (Odum and Kuenzler 1955). Mule deer home range sizes were compared among 3 treatment areas: maneuver, previous-maneuver, and nonmaneuver (control). Maneuver

areas were defined as those sectors in which a maneuver occurred during a given season. Previous-maneuver refers to a sector in which a maneuver had occurred during a previous season but was not currently disturbed by military training. Finally, non-maneuver areas served as undisturbed controls in which no training had occurred and was not currently occurring. Individual deer had multiple home ranges included in the analysis because factors that dictate home range size, such as military training conditions, differed among seasons. Furthermore, because Gerlach (1987) found no difference in home range size among different topographic areas of the site prior to military disturbance I directly compared maneuver, previous-maneuver, and non-maneuver home ranges. Because maneuvers were rotated among sectors of the site, an individual deer might have seasonal home ranges that fell into each of the 3 treatment categories.

Gerlach (1987) described the seasons on PCMS as defined by mule deer behavior. Winter (1 January to 15 March) began post-rut and continued through antler shedding and formation and break-up of winter groups. Spring (16 March until 31 May) was the prefawning period following break-up of family groups. Summer (1 June through 15 September) was the fawn rearing period, and fall (16 September until 31 December) encompassed the rut.

Female summer home ranges were analyzed separately from the other 3 seasons. Gerlach (1987) found summer home ranges to be significantly larger and there was no difference in home range sizes among fall, winter, and spring; analysis of our data supported this conclusion. Male fall home ranges were considered separately because they were significantly larger than all other seasons which were similar. Therefore, the nonsummer and nonfall classification for does and bucks, respectively, included seasonal home ranges which were pooled for the overall analysis. We used the Kruskal-Wallis multiple range test to test for significant differences in home range size. If the Kruskal-Wallis indicated a difference, we conducted a nonparametric protected Least Significant Difference (LSD) test to detect which treatment was different.

Home area fidelity (the tendency of a deer to remain within a previously occupied area during different periods of time) was examined by closely monitoring individual does in both

nonmaneuver control sectors and sectors subject to military training during a 3-week period immediately prior to training and during the training period. Relocation schedules were similar during both 3-week periods; deer were located every 2-4 days. In contrast to home ranges, home areas (or utilization areas) contained fewer points than required to define a true home range but represented the location used during each of the 3-week periods noted above. To test for locational shifts, each pair of premaneuver and maneuver period data for an individual was compared using multi-response permutation procedures (MRPP) (Mielke et al. 1976). Anderson (1988) noted that the P-values associated with each pair of monitoring periods indicate the probability that the distribution of the animal's locations were the same between periods. The proportion of deer exhibiting significant locational shifts was compared between control (nonmaneuver) and maneuver areas.

MRPP also was used to determine "average within group distances" for each individual doe during the premaneuver and maneuver 3-week periods. The "average within group distance" represents the average distance moved between consecutive locations during the period. This value is an index to movement during the period over which an individual is monitored. Among deer exhibiting significant shifts (using MRPP), those with similar "average within group distances" shifted their utilization area such that they were using entirely different areas of similar size during the disturbance compared to before it. When significant shifts occurred but the "average within group distance" was much larger during the disturbance period the deer was located in both its original utilization area and a new area during the maneuver period. Does that contracted their utilization areas and shifted this area during disturbance periods exhibited smaller "average within group distances".

RESULTS

Military Activity

Military training maneuvers occurred 7 times during January 1986 - September 1988 (Table 1). Training maneuvers averaged about 3 weeks in length. Number of personnel ranged from 2624 to 6619 and the total number of vehicles was between 854 and 2397. Prior to 13 March 1987 and 23 October 1987 no training had occurred in sectors D and E, respectively. Off-limits control areas were maintained disturbance-free throughout the study. Actual numbers of helicopters and other aircraft could not be obtained. In general, helicopters tended to operate in close proximity to land-based vehicular training.

Home Range Size

Seventy-one mule deer were monitored to obtain 2,994 telemetry locations for use in home range analysis. A minimum of 13 locations was used for each home range analysis based on observation-area curves (i.e., the curve reached an asymptote). Regression analysis indicated that there was no relationship between relocation sample size and home range size ($r=0.01$, $P>0.22$).

Mean seasonal home range size of female mule deer on PCMS during the nonsummer period (fall, winter, and spring) differed ($P<0.0017$), among military training conditions (Table 2). Maneuver home ranges ($n=26$) were larger than nonmaneuver home ranges ($n=17$) for convex polygon ($P=0.0008$), 95% ellipse ($P=0.0015$), 50% HMT ($P=0.0009$), and 95% HMT ($P=0.0005$). Maneuver and previous-maneuver home range sizes were similar ($P>0.43$). Previous-maneuver home ranges ($n=5$) also were larger than nonmaneuver home ranges

Table 1. Tactical vehicle maneuver statistics for the Pinon Canyon Maneuver Site, Colorado, Jan. 1986-Sept. 1988.

Maneuver	Dates	Occupied sectors	No. personnel ^a	No. wheeled vehicles ^a	No. tracked vehicles ^a
1986					
Winter	25 Feb-7 Mar	A,B,C	2951	483	371
Summer	8-29 July	A,B,C	3789	949	309
Fall	20 Oct-7 Nov	A,B,C	3290	771	495
1987					
Spring	13 Mar-1 Apr	B,C,D	6619	1833	564
Fall	23 Oct-9 Nov	C,D,E	3108	406	503
1988					
Winter	25 Jan-20 Feb	C,D,E	5900	1000	485
Summer	12 July-5 Aug	A,B	2624	730	401

^a These data are estimates from Movement Control Center, PCMS and Fort Carson, Colorado

during nonsummer for convex polygon ($P=0.0048$), 95% ellipse ($P=0.0033$), 50% HMT ($P=0.0188$), and 95% HMT ($P=0.0060$). Female summer home range size differed significantly among treatments in only 1 of 4 analyses (convex polygon technique, $P=0.0662$); maneuver ($n=21$) and nonmaneuver ($n=10$) were different ($P=0.0328$) whereas previous-maneuver ($n=11$) was not different from either maneuver ($P=0.1368$) or nonmaneuver ($P=0.5261$). Trends in annual female home range sizes (Table 2) were similar to seasonal data. However, only 95% HMT home ranges were significantly different ($P=0.0077$) among military training conditions. Maneuver ($n=33$, $P=0.0034$) and previous-maneuver ($n=6$, $P=0.0201$) conditions resulted in larger home ranges than nonmaneuver conditions ($n=13$); maneuver and previous-maneuver home ranges were similar ($P=0.9845$).

Fawn seasonal home ranges were calculated only for summer and fall (Table 3). Because we marked only one fawn in nonmaneuver areas, this category was not included in fawn home range analysis. Summer home ranges were larger in maneuver ($n=21$) than previous-maneuver ($n=12$) areas using convex polygon ($P=0.0026$), 95% ellipse ($P=0.0158$), and 95% HMT ($P=0.0033$). Fifty-percent HMT summer home ranges were not different ($P=0.2031$) between treatments. Fall maneuver ($n=3$) and previous-maneuver ($n=7$) home ranges were similar for convex polygon ($P=0.8192$), 95% ellipse ($P=0.8175$), 50% HMT ($P=0.1702$), and 95% HMT ($P=0.8192$) estimators (Table 3). Fawn annual home range sizes did not differ between maneuver ($n=4$) and previous-maneuver ($n=6$) conditions for any estimation techniques: convex polygon ($P=0.9148$), 95% ellipse ($P=0.5940$), 50% HMT ($P=0.7491$), and 95% HMT ($P=0.7491$).

For bucks, fall ($n=7$) and nonfall ($n=4$) seasonal home range analyses were similar ($P>0.59$) in maneuver and nonmaneuver areas (Table 4). The 50% HMT estimate of annual buck home ranges was larger ($P=0.0562$) under maneuver ($n=8$) than nonmaneuver ($n=7$) conditions. However, there was no difference among treatments for the convex polygon ($P=0.9539$), 95% ellipse ($P=0.6025$), and 95% HMT ($P=0.9539$) estimators.

Table 2. Mean (se) seasonal and annual home range size of radio-collared adult females by training conditions on the Pinon Canyon Maneuver Site, Colorado, Jan. 86- Sept. 88.

Period	Area conditions	N	Convex Polygon (km ²)	95% Ellipse (km ²)	50% HMT (km ²)	95% HMT (km ²)
Non-summer (Fall, Winter, Spring)						
	Maneuver	26	8.26 (1.34) a ^a	23.72 (3.80) a	2.24 (0.29) a	16.08 (3.48) a
	Previous-maneuver	5	6.96 (2.51) a	21.78 (7.54) a	1.64 (0.43) a	14.44 (7.20) a
	Nonmaneuver	17	2.30 (0.30) b	6.93 (0.74) b	0.77 (0.09) b	3.80 (0.39) b
Summer						
	Maneuver	21	9.71 (2.12) a	23.76 (6.20) a	2.08 (0.51) a	17.13 (4.86) a
	Previous-maneuver	11	5.44 (0.99) ab	13.09 (2.59) a	1.22 (0.14) a	7.91 (1.42) a
	Nonmaneuver	10	4.58 (0.88) b	11.62 (2.38) a	1.15 (0.33) a	7.69 (1.57) a
Annual						
	Maneuver	33	18.82 (2.27) a	35.10 (4.85) a	4.51 (0.53) a	26.63 (2.52) a
	Previous-maneuver	6	18.93 (3.30) a	26.12 (4.95) a	4.45 (0.90) a	24.80 (4.00) a
	Nonmaneuver	13	12.21 (1.66) a	21.16 (3.48) a	2.94 (0.58) a	14.16 (1.70) b

^a Means within the same column and period that share the same letter are not significantly different ($p > 0.1$) according to nonparametric protected LSD.

Table 3. Mean (se) seasonal and annual home range size of radio-collared fawns by training conditions on the Pinon Canyon Maneuver Site, Colorado, Jan. 86- Sept. 88.

Period	Area Conditions	N	Convex Polygon (km ²)	95% Ellipse (km ²)	50% HMT (km ²)	95% HMT (km ²)
Summer	Maneuver	21	5.86 (0.94) a [*]	16.75 (3.60) a	1.16 (0.24) a	11.42 (2.36) a
	Previous-maneuver	12	2.46 (0.55) b	6.54 (1.33) b	0.73 (0.16) a	4.16 (1.37) b
Fall	Maneuver	3	5.79 (2.20) a	16.32 (6.18) a	2.81 (1.08) a	7.76 (2.69) a
	Previous-maneuver	7	4.21 (0.59) a	13.37 (1.55) a	1.03 (0.11) a	6.74 (1.02) a
Annual	Maneuver	4	7.63 (1.83) a	11.35 (3.52) a	1.55 (0.60) a	11.02 (2.68) a
	Previous-maneuver	6	11.34 (4.19) a	17.89 (8.08) a	1.57 (0.30) a	14.33 (5.53) a

^{*} Means within the same column and season that share the same letter are not significantly different (p > 0.1) according to Wilcoxon Rank Sum test.

Table 4. Mean (se) seasonal and annual home range size of radio-collared adult males by training conditions on the Pinon Canyon Maneuver Site, Colorado, Jan. 86- Sept. 88.

Period	Area Conditions	N	Convex Polygon (km ²)	95% Ellipse (km ²)	50% HMT (km ²)	95% HMT (km ²)
Fall	Maneuver	3	11.34 (3.34) a [*]	31.56 (16.82) a	1.43 (0.77) a	22.43 (7.59) a
	Nonmaneuver	4	18.56 (9.85) a	71.52 (42.05) a	2.35 (0.93) a	43.43 (22.75) a
Non-fall (Winter, Spring)						
Annual	Maneuver	3	6.46 (2.35)	19.04 (7.87)	2.10 (0.87)	8.33 (2.43)
	Nonmaneuver	1	2.04	8.15	0.56	1.98
Annual	Maneuver	8	28.89 (11.12) a	56.92 (24.92) a	5.79 (1.19) a	47.87 (16.10) a
	Nonmaneuver	7	41.67 (18.72) a	71.38 (28.27) a	3.36 (0.46) b	74.21 (36.03) a

^{*} Means within the same column and period that share the same letter are not significantly different ($p > 0.1$) according to Wilcoxon Rank Sum test.

Home Area Fidelity

Shifts in location or use patterns of home areas were detected by directly comparing distributions of locations for individual animals during a 3-week period prior to maneuvers with distributions during the maneuver period. Due to sample size restrictions, this analysis was performed using only adult females. Over all seasons a greater percentage of deer in maneuver areas (40%) exhibited significant locational shifts between the 2 periods than did deer in nonmaneuver (control) areas (12.5%). During fall 1987 1 of 4 deer in maneuver areas exhibited a significant shift ($P < 0.02$) between the premaneuver and maneuver periods, whereas none of 4 deer in control areas shifted ($P > 0.30$) (Table 5). Following the shift similar movement was exhibited by the doe during the maneuver. Similarly, 2 of 6 deer shifted between periods ($P < 0.003$) in the maneuver areas and 0 of 4 shifted ($P > 0.15$) in the control area during winter 1988 (Table 6). Both deer that shifted moved greater "average within group distances" during the maneuver.

In summer 1986, 4 of 10 does in maneuver areas ($P < 0.1$) and none of 4 does in the control ($P > 0.2$) exhibited shifts (Table 7). Of the 4 that shifted, 1 moved greater distances, 2 moved similar distances, and 1 moved shorter distances during the maneuver when compared to before it. However, during summer 1988 (Table 8) 2 of 4 control area deer made shifts ($P < 0.006$) and 5 of 10 in the maneuver area shifted ($P < 0.04$). The 2 control does that shifted moved shorter average distances. Four of the 5 maneuver deer that shifted moved shorter distances and 1 moved similar distances. Although sample sizes during postmaneuver periods were insufficient to enable statistical testing, all does that exhibited locational shifts eventually returned to prior home areas.

Table 5. Home area fidelity of radio-collared adult does by training conditions before and during maneuvers on PCMS, Colorado, fall 1987, as determined by MRPP^a analysis.

Area conditions	Doe no.	Average within group distance (km)		δ^b	P-value
		Before (n)	During (n)		
Maneuver (treatment)					
	153	1.94 (6)	1.58 (6)	1.76	0.112
	164	1.94 (6)	1.58 (6)	1.76	0.112
	543	1.76 (5)	1.85 (10)	1.82	0.016
	693	1.32 (5)	1.62 (9)	1.51	0.514
Nonmaneuver (control)					
	051	0.88 (5)	1.13 (6)	1.02	0.874
	133	1.63 (5)	1.74 (7)	1.69	0.750
	933	0.89 (5)	0.86 (7)	0.87	0.346
	983	0.66 (5)	0.82 (5)	0.74	0.775

^a Multi-response permutation procedures

^b MRPP test statistic

Table 6. Home area fidelity of radio-collared adult does by training conditions before and during maneuvers on PCMS, Colorado, winter 1988, as determined by MRPP^a analysis.

Area conditions	Doe no.	Average within group distance (km)		δ^b	P-value
		Before (n)	During (n)		
Maneuver (treatment)					
	153	2.88 (8)	2.17 (8)	2.52	0.325
	164	3.13 (8)	2.56 (7)	2.86	0.453
	241	1.17 (8)	1.41 (5)	1.26	0.474
	251	1.06 (8)	5.26 (10)	3.40	0.005
	543	1.87 (5)	2.33 (11)	2.18	0.403
	693	1.02 (10)	5.58 (9)	3.18	0.002
Nonmaneuver (control)					
	051	0.90 (5)	0.72 (6)	0.81	0.173
	133	1.03 (5)	1.61 (6)	1.34	0.157
	933	0.81 (6)	0.60 (6)	0.71	0.294
	983	1.09 (5)	1.51 (5)	1.30	0.202

^a Multi-response permutation procedures

^b MRPP test statistic

Table 7. Home area fidelity of radio-collared adult does by training conditions before and during maneuvers on PCMS, Colorado, summer 1986, as determined by MRPP^a analysis.

Area conditions	Doe no.	Average within group distance (km)		δ^b	P-value
		Before (n)	During (n)		
Maneuver (treatment)					
	034	1.76 (10)	0.56 (12)	1.11	0.029
	053	1.34 (8)	1.04 (11)	1.17	0.717
	054	1.55 (12)	1.01 (10)	1.30	0.626
	063	1.15 (7)	0.93 (5)	1.06	0.459
	093	0.96 (8)	1.34 (13)	1.20	0.050
	113	1.69 (6)	1.74 (10)	1.72	0.241
	123	0.92 (13)	0.92 (8)	0.92	0.091
	152	0.98 (10)	1.18 (6)	1.06	0.791
	194	1.70 (5)	1.82 (6)	1.76	0.007
	243	1.45 (6)	1.70 (7)	1.58	0.773
Nonmaneuver (control)					
	133	1.80 (5)	1.31 (8)	1.50	0.812
	143	1.10 (5)	1.35 (9)	1.26	0.210
	172	1.26 (8)	1.39 (9)	1.33	0.931
	693	2.21 (5)	1.54 (7)	1.82	0.420

^a Multi-response permutation procedures

^b MRPP test statistic

Table 8. Home area fidelity of radio-collared adult does by training conditions before and during maneuvers on PCMS, Colorado, summer 1988, as determined by MRPP^a analysis.

Area conditions	Doe no.	Average within group distance (km)		δ^b	P-value
		Before (n)	During (n)		
Maneuver (treatment)					
	034	1.38 (9)	0.31 (11)	0.79	0.0009
	054	1.27 (9)	0.62 (10)	0.93	0.1001
	065	1.40 (9)	1.41 (11)	1.40	0.128
	073	3.13 (9)	3.39 (11)	3.27	0.00006
	152	3.68 (9)	0.04 (11)	1.67	0.0001
	163	1.03 (9)	2.47 (11)	1.82	0.165
	172	2.11 (7)	1.56 (10)	1.79	0.576
	243	2.06 (11)	1.15 (14)	1.55	0.005
	893	2.60 (6)	1.84 (8)	2.17	0.671
	914	1.89 (9)	0.79 (10)	1.31	0.0004
Nonmaneuver (control)					
	133	1.49 (7)	0.79 (6)	1.17	0.008
	141	1.24 (7)	0.73 (5)	1.03	0.431
	241	1.40 (8)	1.31 (5)	1.37	0.038
	693	2.14 (7)	1.31 (5)	1.79	0.521

^a Multi-response permutation procedures

^b MRPP test statistic

DISCUSSION

Mule deer responded to military disturbance by increasing their home range size. Four home range estimation techniques were considered. Convex polygon was valuable because infrequent outlying points which occur as a result of disturbance represent increased movement and increased energy expenditure (Freddy et al. 1986). The 95% ellipse and 95% HMT estimators describe the area required by an individual without being heavily influenced by infrequent extreme outlying locations. The 50% HMT home range size represents a core area used most intensively by an animal. Differences with each of the 4 estimators were important because they may represent disturbance effects ranging from short-term (convex polygon), when rare outliers are included, to long-term (50% HMT) responses.

Mean convex polygon home range size of radio-collared does was 4.6X and 3.1X greater in maneuver than in non-maneuver areas during the non-summer and summer periods, respectively. The 95% ellipse, 50% HMT, and 95% HMT estimators also reflected this large difference in home range size between disturbed and undisturbed animals indicating that infrequent outlying locations that may have occurred during maneuvers were not the only response. Furthermore, does located in areas exposed to previous, but not current, maneuvers used larger areas than animals in nonmaneuver areas. Thus, deer used larger areas for extended periods when exposed to military training. Although fawn home ranges were not compared using nonmaneuver controls, fawns in active training areas used larger home ranges than fawns in previously-maneuvered, but not currently disturbed areas. With low sample sizes and high variability, no statistical differences were detected in buck seasonal home ranges. However, as estimated by the 50% HMT estimator, bucks in maneuver sectors had significantly larger annual home ranges than those in nonmaneuver sectors. This difference may appear only with the 50% HMT home ranges because the other 3 estimators include distant locations that occurred on excursions during the fall rut.

Factors affecting deer movements during maneuvers included both direct harassment and habitat destruction. Harassment to deer in maneuver sectors may have been both unintentional and intentional. Deer were exposed to battlefield simulations involving machine gun and cannon fire (no live ammunition). Traffic during training included jeeps, trucks, armored personnel carriers, tanks, helicopters, and jet fighter overflights. Bivouacs and encampments provided longer-term disturbance to specific sites. Occasionally, tactical vehicles were observed actively pursuing pronghorn across the prairie (T. P. Gerlach, pers. commun.). Extensive smoke screens and tear gas clouds of several hectares in size used in training exercises also may have been responsible for deer movement. Although the majority of the mock battles and offensive encounters occurred on the prairie, the pinyon-juniper/grassland interface was used extensively for bivouacs and encampments (Figure 1). The pinyon-juniper and shrub vegetation types, which were primary deer habitat (Gerlach 1987), provided excellent camouflage for military vehicles. In addition, the large volume of dust generated by convoys often coated vegetation associated with heavily traveled roads. Vegetation covered with dust may have been unpalatable to deer and may have resulted in movement of deer to locate more palatable forage.

Habitat destruction resulting from military training (Shaw and Diersing 1989) also affected deer movements. Shaw and Diersing (1989) noted that pinyon-juniper and shrubby vegetation densities on PCMS were significantly reduced by 7% and 32-46%, respectively, under maneuver conditions. Grass species composition exhibited a shift from perennial to annual vegetation and the percentage of bare ground increased on disturbed areas (Shaw and Diersing 1989). Such an impact on PCMS vegetation at least in part explains the increased home range sizes seen for does in previous-maneuver areas. Deer in previous-maneuver areas apparently required a larger area to meet forage and cover requirements. The habitat destruction, in addition to direct harassment, may have contributed to the increase in home ranges during maneuvers. In summary, deer in military training areas may have responded to (1) human harassment associated with military activity, (2) alteration of security cover as a result of training, and (3) destruction of the forage base due to the disturbance.

During winter and fall maneuvers, some deer in disturbed areas but not in control areas exhibited significant shifts in their utilization areas as illustrated using MRPP. Not only did deer temporarily abandon areas, but during the winter 1988 maneuver 2 does moved much greater distances during the disturbance period. The appearance of utilization shifts resulting in a contraction of area of use during the summer seasons may be related to the behavior of does with young fawns. Does with fawns were unable to continue moving large distances to escape disturbance, so they occupied a limited area beyond their usual utilization area instead. This indicates that mule deer does exposed to high-level disturbance refused to abandon their fawns. No instances of radio-collared does abandoning their radio-collared fawns in response to military disturbance were observed. It is unclear why 2 does in nonmaneuver areas exhibited shifts between periods during summer 1988.

Although military activity was monitored to determine general impact areas, it was impossible to continuously observe military activity with respect to its proximity to radio-collared deer. Therefore, we cannot be certain of the cause of differential deer behavior in maneuver sectors. All deer in maneuver sectors were exposed to military activity but some undoubtedly at greater levels than others. Either individual-specific responses or undetected instances of intense military activity may explain the extremes in deer movements observed.

Deer may have exhibited a greater response to the unexpected military activity on PCMS than if it were continuous and predictable in its occurrence (e.g. Fort Carson, Colorado). Geist (1971a) observed that big game animals easily become accustomed to and less alarmed by predictable events, which may have initially been disturbing. Mountain sheep (*Ovis canadensis*) heart rates and behavior were more sensitive to the unexpected approach of humans from over a ridge than from the expected approach from a road (MacArthur et al. 1982). Similarly it may be more alarming for deer to be exposed to tank and other tactical vehicles that are not restricted to road travel than if the vehicles kept to roads. Espmark and Langvatn (1985) noted that newborn red deer (*Cervus elaphus*) calves rapidly habituated to alarm stimuli presented in a repeated, standardized, and monotonous manner.

Additional evidence illustrates that unpredictable disturbances may negatively affect deer behavior and energetics. Dorrance et al. (1975) observed that white-tailed deer (*Odocoileus virginianus*) disturbed by snowmobile traffic increased the sizes of their home ranges and increased movement, and some deer changed home ranges entirely. However, most displaced deer returned to original areas within hours after snowmobiling ceased. Eckstein et al. (1979) noted increased movement by deer exposed to snowmobiling. White-tailed deer in Wisconsin and Maine were more likely to flee from humans hiking or skiing (Eckstein et al. 1979; Richens and Lavigne 1978), and adult female mule deer in Colorado responded more to persons afoot than to snowmobiles (Freddy et al. 1976). Disturbance to mule deer resulted in greater energy expenditure due to interrupted grazing and decreased food intake, disrupted bedding, and provoked running (Freddy et al. 1976).

Data from a number of species of ungulates suggest that harassment by unexpected aircraft will elicit an alarm response. Krausman et al. (1986) reported that 7 of 70 responses by desert mule deer in Arizona to intentional aerial overflights involved movements of 0.43 to 1 km, but movements were not between habitat types. Observations of radio-collared deer located by helicopter during the present PCMS deer study indicate that over 70% of deer fled from an approaching helicopter. Miller and Gunn (1979) found that 64% and 44% of Peary caribou (*Rangifer tarandus*) and muskoxen (*Ovibos moschatus*), respectively, responded overtly to helicopter overflights simulating gas pipeline construction activity. Seventy-five percent of barren-ground caribou exhibited panic reactions or strong escape reactions when exposed to low-level aircraft overflights (Calef et al. 1976).

Similar to the negative responses exhibited by deer, coyotes on PCMS responded to military activity by expanding, contracting, or abandoning home ranges (Gese et al. 1989). Most disturbed coyotes returned to their original home ranges following maneuvers.

In contrast to unpredictable disturbances, several forms of human activity generally occur with a more routine presence. Most evidence indicates that deer can habituate to this type of activity. Mule deer exposed to simulated and real mining activities exhibited home areas and linear movements similar in size and distance to undisturbed control deer (Hemker

and Merrill 1984). Irby et al. (1987) were unable to detect a response by mule deer to low intensity oil or gas exploration and drilling activities in Montana. Geist (1971b) noted that mule deer, given protection from hunting and poaching, habituated quite well to humans and housing developments in Alberta. Kufeld et al. (1988) concluded that hunting pressure did not cause deer to move greater distances or alter home range fidelity. Deer have illustrated the ability to habituate to some logging activity. Geist (1978) noted that deer, after the initial fright response, sometimes learn to associate the sound of chainsaws with food. Lyon and Jensen (1980) reported that deer have much lower security requirements than elk. They found that the presence of active roads severely reduced elk, but not deer, use of clearcuts.

Other big game species habituate to continuous, predictable disturbance further supporting the hypothesis that wildlife show less of a response to regular than irregular human activity. In Alberta, radio-collared black bears (*Ursus americanus*) did not alter either the size or the location of the areas over which they ranged in response to the establishment of oil sites (Tietje and Ruff 1983). Females continued using traditional areas, whereas males expressed more variability. However, the activity patterns of one female with cubs was altered by oil site operations. Edge et al. (1985) found no differences in home range size of elk disturbed and undisturbed by logging activity in Montana. However, Edge and Marcum (1985) suggested where cover is limited, logging disturbance may cause elk to increase home range size and reduce home range fidelity. Elk moved significantly further from than toward disturbances and they maintained a buffer zone of 500 to 1000m from active logging units and moved randomly, probably in response to forage, beyond this zone (Edge and Marcum 1985). They did not move out of established home ranges and movement into logging areas occurred during inactive periods. Elk disturbed by mining showed a significant degree of fidelity to spring and summer home ranges (Johnson 1984). Cow elk used mining areas extensively during the calving and summer periods. During the calving period, cow elk spent 25% of their time within 500m of active mining areas, and activity centers of these animals averaged 720m from the disturbance.

Elk calves disturbed by "simulated" mining activity moved greater distances, used larger areas, selected suboptimal habitat, and lacked selection for favorable physiographic parameters (Kuck et al. 1985). However, it must be emphasized here that this mining activity was simulated as opposed to real and continuous. Thus, if the disturbance had been predictable, and more closely represented an actual mining site, the elk might have habituated to it as long as suitable habitat still remained. As the study was conducted, the disturbance was irregular and more closely represented the type of activity seen on PCMS. Disturbance of calves occurred during a 2-week period in July and harassment occurred for 3 hours every couple of days. Kuck et al. (1985) also noted that although cows did not abandon calves due to human and simulated mining disturbance, traditional calf-rearing areas were abandoned by cow/calf pairs. They suggest that disturbance can result in withdrawal from available habitat and the use of smaller, less favorable areas may be imprinted on calves who will continue using marginal habitat throughout life.

The PCMS deer population increased movement and activity in response to unpredictable military activity. The short-term behavioral responses exhibited by individual deer could have negative long-term population implications if sustained. Harassment acts as a stressor which might increase overwinter mortality during severe winters or decrease the productivity of does. Geist (1971b) noted that single incidents of harassment may be insignificant, but the effects are cumulative and could lead to a decline in juvenile survival or aborted fetuses in females. Hobbs (1989) considered the effect of human disturbance using a mule deer deer energetics model. He determined that extreme harassment (2 disturbances/day, each causing animals to move 500 m) during severe winter could double doe mortality. Thomas (1982) found that pregnancy rates in Peary caribou declined with decreasing levels of fat reserves and body weights. The increased movement exhibited by adult does exposed to maneuvers on PCMS could result in lower fecundity. Disturbed does produced fawns during this study, but a severe winter or summer drought coupled with increased military training might cause a decline in fecundity.

Overwinter survival of deer, particularly fawns, may decrease in response to disturbance. Any disruption in fat deposition or conservation prior to or during winter could result in fawns entering winter less able to thermoregulate under cold stress. Moen (1978) noted the necessity of fall weight gain in deer and believed that any disturbance interfering with foraging at this time may directly or indirectly increase mortality or decrease natality. Energy conservation is an adaptation for winter, and disturbances that alter this mechanism can possibly depress productivity. During harsh winters deer should remain as undisturbed as possible; harassment resulting in excess activity is counter to their long-term physiological and behavioral adaptations (Moen 1976).

Suitable habitat is essential to deer regardless of whether disturbance is predictable or not. Mackie and Pac (1980) expressed concern over the loss of deer habitat, particularly winter range, to subdivision housing developments in Montana. The importance of sufficient protective cover in reducing the impact of harassment has been illustrated for deer (Eckstein et al. 1979; Richens and Lavigne 1978). If maneuver rotations continue at the present rate and magnitude, pinyon-juniper forest and shrub cover, which are essential for deer security, likely will decline. Shaw and Diersing (1989) noted that 6-20 years is required for shortgrass prairie to recover to even a short-lived perennial plant community following extensive denuding. It would require considerably longer (75-150 years) for pinyon-juniper forest to recover. By continual use of the pinyon-juniper edge, that edge could continue move back until much of the pinyon-juniper is gone. At present on PCMS a maximum of 2 years of recovery time is provided for recovery. Furthermore, PCMS headquarters is under pressure by the Department of the Army to increase training use (T. Warren, pers. comm.). PCMS currently depends on annual plant cover to maintain soil erosion rates at an acceptable level (Shaw and Diersing 1989). However, during periods of below normal precipitation loss of annual cover would expose soils to excessive erosion. Thus, it is probable that less security cover and forage will be available for deer on PCMS under the present maneuver schedule.

The Army recently proposed foot soldier training that would include the use of current off-limits (control) areas, during the winter and spring deferment periods. As previously noted,

numerous studies have shown that deer respond more to humans on foot than to vehicles (Eckstein et al. 1979; Richens and Lavigne 1978; Freddy et al. 1986). This could result in a much greater impact to deer during winter and the fawning season, especially because a substantial portion of undisturbed deer habitat would be opened to training.

LITERATURE CITED

- Anderson, E. M. 1988. Effects of male removal on spatial distribution of bobcats. *J. Mammal.* 69:637-641.
- Barrett, M. W., J. W. Nolan, and L. D. Roy. 1982. Evaluation of a hand-held net-gun to capture large mammals. *Wildl. Soc. Bull.* 10:108-114.
- Calef, G. W., E. A. DeBock, and G. M. Lortie. 1976. The reaction of barren-ground caribou to aircraft. *Arctic* 29:201-212.
- Clover, R. B. 1956. Single-gate deer trap. *Calif. Fish and Game* 42:199-201.
- Dixon, K. R. and J. A. Chapman. 1980. Harmonic mean measure of animal activity areas. *Ecology* 61:1040-1044.
- Dorrance, M. J., P. J. Savage, and K. E. Huff. 1975. Effects of snowmobiles on white-tailed deer. *J. Wildl. Manage.* 39:563-569.
- Eckstein, R. G., T. F. O'Brien, O. J. Rongstad, and J. G. Bollinger. 1979. Snowmobile effects on movements of white-tailed deer: a case-study. *Environ. Conserv.* 6:45-51.
- Edge, W. D., C. L. Marcum, and S. L. Olson. 1985. Effects of logging activities on home-range fidelity of elk. *J. Wildl. Manage.* 49:741-744.
- Edge, W. D. and C. L. Marcum. 1985. Movements of elk in relation to logging disturbances. *J. Wildl. Manage.* 49:926-930.

- Espmark, E. and R. Langvatn. 1985. Development and habituation of cardiac and behavioral responses in young red deer calves (*Cervus elaphus*) exposed to alarm stimuli. *J. Mammal.* 66:702-711.
- Freddy, D. J., W. M. Bronaugh, and M. C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. *Wildl. Soc. Bull.* 14:63-68.
- Geist, V. 1971a. Is big game harassment harmful? *Oil Week.* June 14:12-13.
- , 1971b. A behavioral approach to the management of wild ungulates. Pages 413-424 *in* E. Duffey and A. S. Watt, eds. *The scientific management of animal and plant communities for conservation.* Blackwell Sci. Publ., Oxford, U. K.
- , 1978. Behavior. Pages 283-296 *in* Schmidt, J. L. and D. L. Gilbert, eds. *Big game of North America, ecology and management.* Stackpole Books, Harrisburg, PA 494 pp.
- Gerlach, T. P. 1987. Population ecology of mule deer on Pinon Canyon Maneuver Site, Colorado. unpubl. M. S. Thesis, Virginia Polytechnic Inst. and St. Univ. 61 pp.
- Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1989. Changes in coyote movements due to military activity. *J. Wildl. Manage.* 53:334-339.
- Hayne, D. W. 1949. Calculation of size of home range. *J. Mammal.* 30:1-18.
- Hemker, T. P. and E. H. Merrill. 1984. Mule deer summer range quality and impacts of disturbance. Pages 310-355 *in* L. Kuck (ed.) *Cooperative Wildlife-Phosphate Study. Final Report. Phase 2: Mining Impact Studies.* Idaho Dept. of Fish and Game.
- Hobbs, N. T. 1989. Linking energy balance to survival in mule deer: development and test of a simulation model. *Wildl. Monogr.* 101, 1-39.
- Irby, L. R., R. J. Mackie, H. I. Pac, and W. F. Kasworm. 1987. Management of mule deer in relation to oil and gas development in Montana's overthrust belt. *Thorne Ecol. Inst. Tech. Publ.*
- Jennrich, R. I. and F. B. Turner. 1969. Measurement of noncircular home range. *J. Theoretical Biology* 22:227-237.
- Johnson, T. K. 1984. Impact of surface coal mining on elk calving: a progress report. *Thorne Ecol. Inst. Tech. Publ.* 14:133-137.

- Kendeigh, S. C. 1961. *Animal Ecology*. Prentice-Hall, New Jersey. 468 pp.
- Krausman, P. R., B. R. Leopold, D. L. Scarbrough. 1986. Desert mule deer response to aircraft. *Wildl. Soc. Bull.* 14:68-70.
- Kuck, L., G. L. Hompland, and E. H. Merrill. 1985. Elk calf response to simulated mine disturbance in southeast Idaho. *J. Wildl. Manage.* 49:751-757.
- Kufeld, R. C., D. C. Bowden, and D. L. Schrupp. 1988. Influence of hunting on movements of female mule deer. *J. Range Manage.* 41:70-72.
- Lyon, L. J. and C. E. Jensen. 1980. Management implications of elk and deer use of clear-cuts in Montana. *J. Wildl. Manage.* 44:352-362.
- MacArthur, R. A., V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. *J. Wildl. Manage.* 46:351-358.
- Mackie, R. J. and D. F. Pac. 1980. Deer and subdivisions in the Bridger Mountains, Montana. *Proceedings 60th Annual Conf. West. Assoc. Fish and Wildl. Agencies.*
- Mielke, P. W., K. J. Berry, and E. S. Johnson. 1976. Multiresponse permutation procedures for *a priori* classifications. *Communications Stat. - Theory Methods*, A5:1409-1424.
- Miller, F. M. and A. Gunn. 1979. Responses of Peary caribou and muskoxen to helicopter harrassment, Prince of Wales Island, NW Territories, 1976-77. *Canad. Wildl. Serv. Occas. Pap. No. 40*. Min. Supply and Serv. Canada, Ottawa. 90pp.
- Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. *J. Wildl. Manage.* 42:715-738.
- 1976. Energy conservation by white-tailed deer in the winter. *Ecology* 57:192-198.
- Odum, E. P. and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. *Auk* 72:128-137.
- Peek, J. M, and S. R. Hieb, editors. 1976. Elk-logging-roads symposium. Univ. Idaho For., Wildl., and Range Exp. Stn., Moscow. 142pp.
- Ramsey, C. W. 1968. A drop-net deer trap. *J. Wild. Manage.* 32:187-190.
- Richens, V. B. and G. R. Lavigne. 1978. Responses of white-tailed deer to snowmobiles and snowmobile trails in Maine. *Can. Field-Nat.* 92:334-344.

- Robinette, W. L., P. A. Jones, G. Rogers, and J. S. Gashwiler. 1957. Notes on tooth development and wear for Rocky Mountain mule deer. *J. Wildl. Manage.* 21:134-153.
- , C. H. Baer, R. E. Pilmore, and C. E. Knittle. 1973. Effects of nutritional change on captive mule deer. *J. Wildl. Manage.* 37:312-326.
- Samuel, M. D., D. J. Pierce, E. O. Garton, L. J. Nelson, and K. R. Dixon. 1985. User's manual for program home range. *For., Wildl., and Range Exp. Stn. Tech. Rep. 15.* Univ. Idaho, Moscow. 70pp.
- Shaw, R. B. and V. E. Diersing. 1989. Impact of 2 years of tracked vehicular training on the vegetation at the U. S. Army's Pinon Canyon Maneuver Site, Colo. *J. Environ. Quality* (In Press).
- Shideler, R. T., M. H. Robus, J. F. Winters, and M. Kuwada. 1986. Impacts of human developments and land use on caribou: a literature review. Vol. I & II. Alaska Dept. of Fish & Game Tech. Rep. 86-2,3.
- Thomas, D. C. 1982. The relationship between fertility and fat reserves of Peary caribou. *Can. J. Zool.* 60:597-602.
- Tietje, W. D. and R. L. Ruff. 1983. Responses of black bears to oil development in Alberta. *Wildl. Soc. Bull.* 11:99-112.
- Trainer, D. E., J. C. Remos, T. P. Kistner, W. C. Lightfoot, and D. E. Towerill. 1981. Mortality of mule deer fawns in southeastern Oregon, 1968-1979. *Oregon Wildl. Res. Report No. 10.* 113pp.
- U. S. Dept. of Army. 1980. Draft: Environmental impact statement for acquisition of training land in Huerfano, Las Animas, and Pueblo counties, Colorado. Fort Carson, Colorado.

CHAPTER 2

DEMOGRAPHIC RESPONSE OF MULE DEER TO MILITARY TRAINING IN SOUTHEAST COLORADO

INTRODUCTION

As discussed in Chapter 1, considerable research has been conducted on behavioral responses of ungulates to human activity. However, few studies have evaluated the effects of disturbance on demographics.

During 1983-84, Gerlach (1987) obtained baseline information on the population dynamics of mule deer (*Odocoileus hemionus*) on the Pinon Canyon Maneuver Site (PCMS), Colorado, to aid in developing a comprehensive wildlife management plan for the area. He determined sex and age ratios, population estimates, adult and fawn survival, and mortality rates. In August 1985 military training began on the site and has recurred approximately 3 times yearly

for periods of about one month. During any given maneuver, 3 of 7 sectors on the site are used for training in accordance with a rotational land use schedule. Thus, the potential for impacts to the mule deer and their habitat exists. This study was designed to assess the impacts of military disturbance on the PCMS mule deer population. The objectives of this study were (1) to assess the impacts of disturbance from military training on the survival, reproduction, and density of mule deer on the PCMS, and (2) to quantify the level of disturbance on the PCMS.

STUDY AREA

The 1040 km² PCMS was located along the Purgatoire River in Las Animas County, Colorado, about 64 km northeast of Trinidad within the Great Plains Physiographic Province (U. S. Dept. of Army 1980). The topography of the site was characterized by broad sloping shortgrass prairie dissected by rocky canyons and breaks to the east and southeast, and bordered by pinyon-juniper (*Pinus edulis-Juniperus monosperma*) uplands to the north, northwest, and southwest. Elevations ranged from 1,311 m to 1,737 m. Mean annual precipitation was 30-40 cm and mean monthly temperatures ranged from -1 C in January to 23 C in July. The site has a history of dry-land cattle and sheep grazing, which was discontinued in 1984. Aerial coyote (*Canis latrans*) gunning over the prairie occurred in January and May 1987 and March and April 1988 on the western half of the site.

The vegetation consisted primarily of shortgrass prairie and pinyon-juniper woodland communities (Kendeigh 1961). The shortgrass prairie was dominated by blue grama (*Bouteloua gracilis*), in association with galleta (*Hilaria jamesii*), ring muhly (*Muhlenbergia torreyi*), western wheatgrass (*Agropyron smithii*), broom snakeweed (*Xanthocephalum sarothrae*), sand dropseed (*Sporobolus cryptandrus*), and bigelow sage (*Artemisia bigelovii*).

In addition to pinyon-juniper, the woodlands included grasses and forbs such as blue grama, sand dropseed, galleta, needle-and-thread (*Stipa comata*), and broom snakeweed. Shrub species present were mountain mahogany (*Cercocarpus montanus*), fourwing saltbush (*Atriplex canescens*), skunkbush sumac (*Rhus trilobata*), currant (*Ribes* spp.), and rabbitbrush (*Chrysothamnus nauseosus*).

METHODS

Adult Capture

Adult mule deer were captured in Clover traps (Clover 1956), by drop net (Ramsey 1968), or by Coda net-gun (Coda Enterprises, Mesa, Arizona). Clover traps were baited with apple pulp and captured deer were manually restrained. The drop net, also baited with apple pulp, was used in areas of high deer density with open plateaus suitable for visibility and set-up. The Coda net-gun was fired from a Bell Salloy helicopter (Barrett et al. 1982). Target deer were hazed into suitable terrain for capture such as bare slopes, forest openings, or open grassland; haze time was limited to 20 minutes. Captured deer were marked with numbered color eartags and frequency-specific, color coded radio collars (164-165 MHz; 540 g) to enable individual identification. Radio collars placed on bucks were large enough to enable neck swelling during the rut. Deer age classes were identified according to tooth replacement and wear (Robinette et al. 1957).

Fawn Capture

Newborn fawns were located during June and July by ground surveillance of radio-collared and unmarked does, then captured by hand. Fawns still moist with amniotic fluid were not handled or collared until the following day to avoid abandonment by the dam. Captured fawns were equipped with expandable break-away radio collars (135 g) (Trainer et al. 1981) and numbered button eartags. Sex, weight, and general condition of each fawn were recorded at capture. Ages and birthdates were estimated according to Robinette et al. (1973).

Survival

Maximum and minimum survival rates were determined using radio-telemetry data as described by Trent and Rongstad (1974) and Heisey and Fuller (1985). Maximum survival rates were calculated using only confirmed mortalities, whereas confirmed mortalities plus radio-collared deer with which radio contact was lost were used to calculate minimum survival estimates. Bimonthly and annual rates were calculated for adult deer. For fawns, the monthly and summer (120 day interval; June-Sept.) estimates were calculated for comparison with Gerlach's (1987) data. Annual fawn survival rates were calculated from June through May. Pairwise multiple comparisons of annual rates among years were conducted using a Z-test. The experiment-wise error rate was set at $\alpha = 0.1$. The significance level for each comparison was obtained by dividing 0.1 by the total number of comparisons.

Productivity

Radio-collared does were visually monitored every 1-3 days during 1 June-31 July to determine fecundity. Minimum fawn production was determined based on the number of fawns located with radio-collared dams during this period. Pregnancy rate was calculated based on our sample of radio-collared does. A doe was considered pregnant if she had fawns present, a distended udder, or an enlarged abdomen clearly seen during multiple observations.

Population Estimation

Thirty-seven 2.6 km² quadrats (Figure 3) were selected for censusing following a stratified random sampling technique. Based on preliminary relative density estimates, PCMS was stratified into low and high deer density areas (Gerlach 1987). Of a possible 199 2.6 km² quadrats, 12 and 25 were randomly selected in low and high deer density areas, respectively, based on the proportion of deer habitat those areas composed. Surveys were flown using a military UH-1 helicopter with a pilot, copilot, navigator, and 2 observers. The helicopter flew 25 to 35 m above ground at a speed of 55-80 km/hr. Although quadrat boundaries were not marked permanently, they were easily identified using U. S. Geological Survey 1:24,000 topographic maps. The perimeter of each quadrat was flown first upon reaching it. The helicopter then proceeded from one side of the quadrat to the other following a series of parallel lines at 200 m intervals; canyons and ridges were followed to increase observability. Movement of deer within a quadrat was noted to avoid double counting. Density and population estimates were calculated according to Gill (1969).

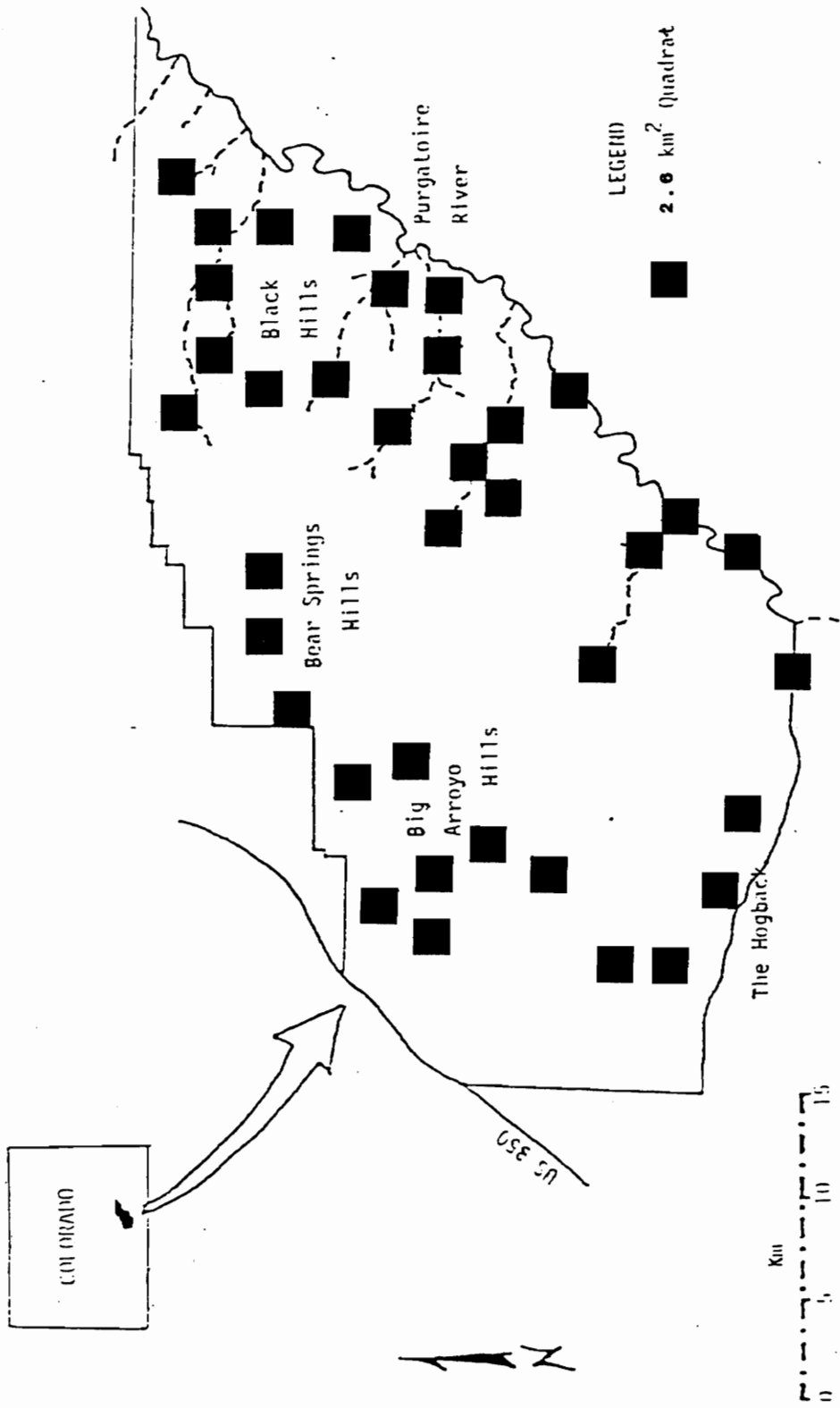


Figure 3. Thirty-seven randomly selected 2.6 km² quadrats censused by helicopter on PCMS.

The proportion of radio-collared deer sighted during helicopter telemetry trials was used to estimate observability during quadrat surveys. Telemetry was conducted following completion of surveys. Radio-marked deer were located visually or a definite locational fix was obtained using standard aerial telemetry technique (Mech 1983). Search patterns were similar (i.e. contours were followed) for both quadrat surveys and telemetry flights, except that more passes were made for telemetry flights. This observability estimate represents maximum observability.

RESULTS

Adult Survival

Maximum and minimum bimonthly survival rates for bucks (Table 9) and does (Table 10) were high. Adult mortalities generally occurred in winter or early spring. However, one 3-year old buck was found scavenged by predators in July 1987. Hunter harvest was responsible for 5 of 12 (42%; 4 bucks and 1 doe) mortalities that occurred during the study. An additional 3 radio-collared bucks were harvested in December 1988, but these were not included in survival rate calculations because the telemetry study ceased in September 1988. Three does were found scavenged by predators but the cause of death could not be determined. The age of another doe found dead was 9 years and necropsy indicated malnutrition to be the cause of death; although the rumen was full, there was virtually no fat on the carcass, kidney fat index was 0, and the femur marrow was red and gelatinous. Two radio-collared adult bucks, ages 10 and 9, also were found dead. The carcass of the first buck was largely scavenged so the cause of death could not be determined but the teeth were

extremely worn and the femur marrow was red and gelatinous indicating poor condition (Kirkpatrick 1980). The second buck's carcass also was scavenged, but in this case the femur marrow was a healthy pinkish white with a firm consistency. However, the ball of the femur at the pelvic socket was broken from the remainder of the bone indicating a possible injury. The completely intact nature of the skeleton and its location in rugged terrain suggest that the crippling injury may be the ultimate cause of the animal's death. If predation was responsible for the breakage, then the skeleton likely would have been scattered.

Maximum annual survival rates for bucks (Table 11), using an experiment-wise α rate of 0.1 (comparison-wise rate = 0.01), did not differ among years during 1983-88. However, when compared to the 1984 rate, the 1986 ($P=0.0146$), 1987 ($P=0.0618$), and 1988 ($P=0.0516$) rates in particular tended to be lower. All other annual buck rates tended to be similar ($0.13 < P < 0.42$).

Similarly, using a comparison-wise rate of 0.01, annual doe maximum survival rates during 1983-88 did not differ (Table 12). The 1984 ($P=0.0329$), 1987 ($P=0.0708$), and 1988 ($P=0.0708$) rates tended to be lower than the 1983 rate. The remaining annual doe rates were similar ($0.10 < P < 0.45$).

Fawn Survival

Maximum and minimum monthly fawn survival rates were calculated during summer 1986-88 (Table 13) in addition to bimonthly survival rates during 1986-88 (Table 14). Again maximum survival rates will be discussed because most lost signals resulted from expected transmitter failure at the end of the projected longevity period. All fawn mortalities occurred during summer within 2 months after birth. Coyote predation was responsible for 5 of 13 (38%) fawn mortalities and the remaining 8 mortalities were coyote scavenged. One fawn was abandoned after capture and died of starvation within 3 days; it was excluded from

Table 9. Minimum and maximum buck bimonthly survival rates (var) on the Pinon Canyon Maneuver Site, Colorado, Jan. 1986-Aug. 1988.

Bimonthly period	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1986							
Jan, Feb	7	347	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Mar, Apr	8	445	0	1.0000(0.0000)	1.0000-1.0000	0.8718(0.0143)	0.6658-1.0000
May, Jun	7	427	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Jul, Aug	7	434	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Sep, Oct	7	427	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Nov, Dec	10	360	3	0.6002(0.0313)	0.3359-1.0000	0.6002(0.0313)	0.3359-1.0000
1987							
Jan, Feb	13	719	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Mar, Apr	13	793	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
May, Jun	13	793	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Jul, Aug	13	774	1	0.9230(0.0055)	0.7886-1.0000	0.9230(0.0055)	0.7886-1.0000
Sep, Oct	12	732	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Nov, Dec	12	687	1(1) ^b	0.9150(0.0066)	0.7685-1.0000	0.8371(0.0111)	0.6539-1.0000
1988							
Jan, Feb	10	584	0(1)	1.0000(0.0000)	1.0000-1.0000	0.9023(0.0086)	0.7373-1.0000
Mar, Apr	9	493	2(1)	0.7804(0.0187)	0.5529-1.0000	0.6891(0.0219)	0.4515-1.0000
May, Jun	6	366	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Jul, Aug	6	327	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000

^aConfidence interval

^bMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

Table 10. Minimum and maximum doc bimonthly survival rates (var) on the Pinon Canyon Maneuver Site, Colorado, Jan. 1986-Aug. 1988.

	Bimonthly period	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1986	Jan, Feb	26	1429	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	Mar, Apr	29	1677	1	0.9643(0.0012)	0.8978-1.0000	0.9643(0.0012)	0.8978-1.0000
	May, Jun	28	1623	0(3) ^b	1.0000(0.0000)	1.0000-1.0000	0.8933(0.0034)	0.7861-1.0000
	Jul, Aug	25	1550	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	Sep, Oct	25	1525	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	Nov, Dec	26	1510	0(1)	1.0000(0.0000)	1.0000-1.0000	0.9604(0.0015)	0.8872-1.0000
1987	Jan, Feb	29	1587	1(2)	0.9635(0.0013)	0.8957-1.0000	0.8944(0.0033)	0.7881-1.0000
	Mar, Apr	26	1586	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	May, Jun	27	1616	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	Jul, Aug	27	1674	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	Sep, Oct	27	1647	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	Nov, Dec	27	1586	1(1)	0.9622(0.0014)	0.8923-1.0000	0.9259(0.0025)	0.8322-1.0000
1988	Jan, Feb	29	1626	1	0.9638(0.0013)	0.8964-1.0000	0.9638(0.0013)	0.8964-1.0000
	Mar, Apr	29	1677	1	0.9643(0.0012)	0.8978-1.0000	0.9643(0.0012)	0.8978-1.0000
	May, Jun	31	1784	0(3)	1.0000(0.0000)	1.0000-1.0000	0.9024(0.0029)	0.8034-1.0000
	Jul, Aug	29	1402	0(2)	1.0000(0.0000)	1.0000-1.0000	0.9153(0.0033)	0.8095-1.0000

^aConfidence interval^bMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

Table 11. Minimum and maximum buck annual survival rates (var) on the Pinon Canyon Maneuver Site, Colorado, Jan. 1983-Aug. 1988.

Year	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1983	7	1675	1	0.8041(0.0307) ^b	0.5440-1.0000	0.8041(0.0307)	0.5440-1.0000
1984	8	2386	0(2) ^c	1.0000(0.0000) ^a	1.0000-1.0000	0.7363(0.0254)	0.4817-1.0000
1986	10	2440	3(1)	0.6382(0.0274) ^a	0.3838-1.0000	0.5494(0.0271)	0.3054-0.9876
1987	13	4498	2(1)	0.8502(0.0095) ^a	0.6788-1.0000	0.7839(0.0012)	0.5950-1.0000
Jan.-Aug. 1988	10	1770	2(2)	0.7589(0.0219) ^a	0.5176-1.0000	0.5758(0.0252)	0.3350-0.9884

^aConfidence interval

^bMaximum rates that share the same letter are not significantly different (experiment-wise $\alpha = 0.1$) according to pairwise Z-tests.

^cMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

Table 12. Minimum and maximum doe annual survival rates (var) on the Pinon Canyon Maneuver Site, Colorado, Jan. 1983-Aug. 1988.

Year	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1983	8	2091	0(1) ^b	1.0000(0.0000) ^{a,c}	1.0000-1.0000	0.8398(0.0215)	0.5963-1.0000
1984	29	8931	3(1)	0.8846(0.0039) ^a	0.7699-1.0000	0.8492(0.0048)	0.7234-0.9967
1986	29	9314	1(4)	0.9616(0.0014) ^a	0.8905-1.0000	0.8220(0.0052)	0.6922-0.9760
1987	29	9696	2(3)	0.9275(0.0024) ^a	0.8355-1.0000	0.8284(0.0049)	0.7023-0.9770
Jan.-Aug. 1988	31	6489	2(5)	0.9275(0.0024) ^a	0.8357-1.0000	0.7685(0.0058)	0.6322-0.9339

^aConfidence interval

^bMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

^cMaximum rates that share the same letter are not significantly different (experiment-wise $\alpha = 0.1$) according to pairwise Z-tests.

survival calculations. In addition, 2 fawns were harvested during December 1988 but this occurred beyond completion of the telemetry study.

Fawn 120 day interval (June-Sept.) maximum survival rates were compared using an experiment-wise α rate of 0.1 (Table 15). Summer survival in 1987 was higher ($P=0.0048$) than 1984 summer survival. Although not significantly higher, 1986 ($P=0.0250$) and 1988 ($P=0.0934$) summer survival tended to be higher than 1984 summer survival. All other summer survival rates were similar ($0.10 < P < 0.49$). Furthermore, annual fawn survival during 1986-87 and 1987-88 were not different ($P=0.4286$) (Table 14).

Productivity

Pregnancy rates of radio-marked adult does were 90% ($n=19$), 90% ($n=19$), and 88% ($n=24$) for 1986, 1987, and 1988, respectively. Minimum pregnancy rates (using only does known to have produced fawns) were 63%, 79%, and 67% for 1986, 1987, 1988, respectively. Minimum fawn production, calculated from radio-collared does seen with newborn fawns was 1.4 fawns/doe ($n=12$), 1.5 fawns/doe ($n=15$), and 1.4 fawns/doe ($n=15$) for adults in 1986, 1987, and 1988, respectively. These values are similar to those reported by Gerlach (1987) for PCMS during 1983-84. Yearling pregnancy rate was 100% ($n=6$) during 1986-88 and minimum fawn production was 1 fawn/doe ($n=4$) during this period. Although the sample sizes are low, these yearling pregnancy rates and fawn production levels are higher than those observed by Gerlach (1987). Fawn: doe ratios were not significantly different ($P > 0.05$; comparison-wise α rate = 0.017) among years of the study (Table 16).

Table 13. Minimum and maximum fawn monthly survival rates (var) on the Pinon Canyon Maneuver Site, Colorado, Jan. 1986-Aug. 1988.

Year	Month	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1986	June	7	41	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	July	8	209	2	0.7422(0.0245)	0.4897-1.0000	0.7422(0.0245)	0.4897-1.0000
	August	6	160	0(1) ^b	1.0000(0.0000)	1.0000-1.0000	0.8234(0.0256)	0.5612-1.0000
	September	5	150	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
1987	June	5	28	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	July	13	313	3	0.7419(0.0164)	0.5282-1.0000	0.7419(0.0164)	0.5282-1.0000
	August	10	310	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	September	10	300	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
1988	June	11	58	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
	July	19	458	4(1)	0.7619(0.0107)	0.5830-1.0000	0.7116(0.0117)	0.5273-0.9575
	August	14	373	4(1)	0.7159(0.0143)	0.5150-0.9916	0.6581(0.0152)	0.4551-0.9476
	September	9	255	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000

^aConfidence interval^bMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

Table 14. Minimum and maximum fawn bimonthly and annual survival rates (var) on Pinon Canyon Maneuver Site, Colorado, June 1986-May 1988.

Bimonthly period	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1986							
Jun,Jul	8	250	2	0.6126(0.0450)	0.3095-1.0000	0.6126(0.0450)	0.3095-1.0000
Aug,Sep	6	310	0(1) ^b	1.0000(0.0000)	1.0000-1.0000	0.8211(0.0262)	0.5573-1.0000
Oct,Nov	5	305	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Dec,Jan	5	310	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
1986-87							
Feb,Mar	5	297	0(2)	1.0000(0.0000)	1.0000-1.0000	0.6712(0.0358)	0.3853-1.0000
Apr,May	4	87	0(3)	1.0000(0.0000)	1.0000-1.0000	0.1176(0.0211)	0.0099-1.0000
Annual	8	1559	2(6)	0.6259(0.0430) ^{a,c}	0.3268-1.0000	0.1529(0.0103)	0.0415-0.5605
1987-88							
Jun,Jul	13	341	3	0.5833(0.0330)	0.3160-1.0000	0.5833(0.0330)	0.3160-1.0000
Aug,Sep	10	610	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Oct,Nov	10	610	0(2)	1.0000(0.0000)	1.0000-1.0000	0.8185(0.0134)	0.6196-1.0000
Dec,Jan	8	457	0(2)	1.0000(0.0000)	1.0000-1.0000	0.7619(0.0215)	0.5221-1.0000
Feb,Mar	6	420	0	1.0000(0.0000)	1.0000-1.0000	1.0000(0.0000)	1.0000-1.0000
Apr,May	6	330	0(4)	1.0000(0.0000)	1.0000-1.0000	0.4752(0.0312)	0.2282-0.9810
Annual	13	2768	3(8)	0.6724(0.0237) ^a	0.4290-1.0000	0.2328(0.0105)	0.0983-0.5504

^aConfidence interval

^bMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

^cMaximum annual rates that share the same letter are not significantly different ($p > 0.1$) according to Z-test.

Table 15. Minimum and maximum fawn summer (June-Sept.) survival rates (var) on Pinon Canyon Maneuver Site, Colorado, 1983-1988.

Year	N	Radio days	Number of mortalities	Maximum survival rate	Maximum 95% CI ^a	Minimum survival rate	Minimum 95% CI
1983	7	416	3(2) ^b	0.4135(0.0444)ab ^c	0.1516-1.0000	0.2287(0.0228)	0.0623-0.8278
1984	17	867	11	0.2106(0.0098)a	0.0836-0.5270	0.2106(0.0098)	0.0836-0.5270
1986	8	560	2(1)	0.6463(0.0398)ab	0.3524-1.0000	0.5193(0.0386)	0.2468-1.0000
1987	13	951	3	0.6801(0.0229)b	0.4394-1.0000	0.6801(0.0229)	0.4394-1.0000
1988	19	1144	8(2)	0.4248(0.0165)ab	0.2344-0.7677	0.3426(0.0134)	0.1761-0.6643

^aConfidence interval

^bMortalities in parenthesis indicate transmitters that failed; used in determining minimum survival.

^cMaximum rates that share the same letter are not significantly different (experiment-wise $\alpha = 0.1$) according to pairwise Z-tests.

Table 16. Buck: doe and fawn: doe ratios from quadrat surveys of mule deer on the Pinon Canyon Maneuver Site, Colorado, June 1983-Dec. 1988.

Survey Date	Bucks	Does	Fawns	Bucks:100 Does	Fawns:100 Does
August 1983 ^a	15	24	7	63:100a ^b	30:100a
December 1983 ^a	16	26	7	60:100a	27:100a
August 1984 ^a	21	17	5	123:100a	29:100a
November 1984 ^a	18	36	14	50:100a	39:100a
August 1987	47	50	22	94:100a	44:100a
December 1987	30	54	14	56:100a	26:100a
August 1988	23	35	7	66:100a	20:100a
December 1988 ^c	30	58	24	52:100a	41:100a

^aData from Gerlach (1987)

^bRatios within the same column and survey season that share the same letter are similar (experiment-wise $\alpha = 0.1$) according to pairwise Z-tests.

^cData from Canestorp, M. (unpubl. data)

Population Estimation

Density, and unadjusted and adjusted (using observability index) population estimates were determined from quadrat censuses (Table 17). Unadjusted population estimates were compared using the 90% confidence intervals. Only estimates obtained during the same seasons were compared due to differences in deer sightability among seasons. Two estimates were considered statistically similar if the point estimate of one fell within the confidence interval of the other (Figure 4). Among late summer surveys, the August 1983, 1984, and 1988 estimates were similar but the August 1987 estimate was greater than all 3 of these. In late fall, November 1984 was similar to December 1988 which was similar to December 1987. However, the December 1987 estimate was greater than both the December 1983 and November 1984 estimates. Furthermore, November 1984 was greater than December 1983. Finite rates of increase calculated from individual quadrat survey estimates compared within seasons were used to generate mean rates of increase for 3 periods: premaneuver (1983-1984), transition (1984-1987), and maneuver (1987-1988). The mean rates of increase from population estimates for the pre-maneuver, transition, and maneuver periods were 1.08, 1.22, and 0.82, respectively. The August 1988 estimate was lower than expected possibly because of a decrease in fawn survival observed in radio-collared fawns and fawn:doe ratios during the summer of 1988. Also, the earlier survey date for the August 1988 surveys may have resulted in a lower estimate. The younger age of fawns implies less activity by does and fawns (Trainer et al.), as well as solitary behavior (Stephenson, unpubl. data), resulting in lower observability. As a result the observed rate of increase for the 1987-88 period was quite low. Rates of increase calculated using age specific birth and death rates illustrated similar trends: 1.00 (premaneuver), 1.22 (transition), and 1.09 (maneuver).

Table 17. Density estimates with 90% CI's and unadjusted and adjusted population estimates for mule deer on Pinon Canyon Maneuver Site, Colorado, using quadrat censuses.

Survey date	Density (deer/km ²)	95% CI (deer/km ²)	Unadjusted population	Adjusted population ^a
June 1983 ^b	0.82	0.54-1.10	422	620
August 1983 ^b	0.68	0.50-0.85	350	515
December 1983 ^b	0.63	0.46-0.79	324	476
May 1984 ^b	0.65	0.48-0.82	337	496
August 1984 ^b	0.62	0.40-0.84	320	470
November 1984 ^b	0.87	0.79-0.96	452	665
August 1987	1.24	0.88-1.59	638	938
December 1987	1.43	1.00-1.87	738	1085
March 1988	1.63	1.17-2.10	842	1238
August 1988	0.69	0.42-0.95	354	520
December 1988 ^c	1.16	0.65-1.67	601	884

^aAdjusted estimate = unadjusted estimate/observability index
(observability index = 0.68)

^bData from Gerlach (1987)

^cData from Canestorp, M. (unpubl. data)

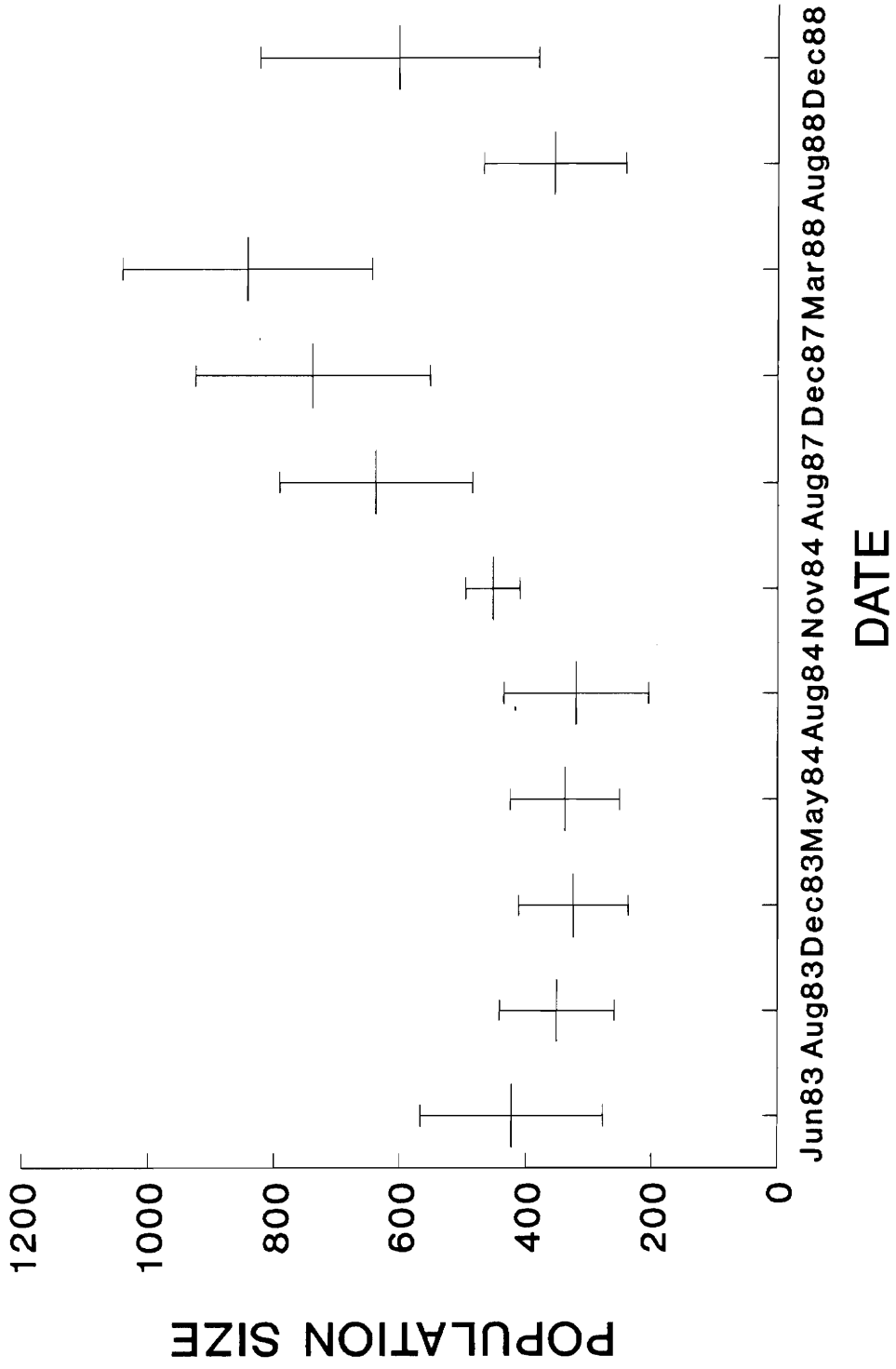


Figure 4. Unadjusted population estimates with 90% CI's from quadrat censuses on PCMS.

DISCUSSION

There was no evidence that military training was the proximate cause of adult or fawn mortality. Buck survival decreased slightly during the second phase of the study (1986-88) but this was due largely to increased hunting pressure and buck harvest (Chapter 4). Changing ownership of the property from private to public and shifting the rifle season to coincide with the rut during 1986-88 contributed to the increased harvest. However, the conservative number of permits (30 buck and 5 doe) annually issued to hunters on PCMS should not significantly reduce the population.

Fawn recruitment on PCMS continues to be limited by coyote predation as suggested by Gerlach (1987). Although fawn survival is low, adult survival continues to be high. To date there has been no evidence of does abandoning fawns as a result of military disturbance during the summer fawning season. Several does with fawns have failed to leave postpartum fawns even when tanks and armored personnel carriers approached to within 100m of the hidden, bedded deer. One doe even gave birth within 300-500 m of an active tank road. However, both of her fawns were killed by coyotes within 5 to 40 days postpartum. Military training may reduce fawn survival by increasing opportunities for coyote predation through increased flushing rates. This is of particular concern if foot-soldier training is increased (Chapter 1). Large numbers of foot soldiers could flush a significant number of fawns and increase their risk of predation. Trainer et al. (1981) noted that less active fawns were less subject to coyote predation.

In similar disturbance studies, changes in movement and activity were detected, but survival was not significantly reduced. Freddy et al. (1986) found that although mule deer disturbed by snowmobiles increased activity, mortality did not increase and disturbed females produced fawns. Similarly, winter survival did not differ between disturbed and undisturbed elk calves exposed to simulated mining activity even though traditional calf-rearing areas

were abandoned (Kuck et al. 1985). Pregnancy rates did not decline following initiation of military use of PCMS in 1985.

The PCMS deer population, as determined using quadrat censuses, remained stable during the 2-year baseline study (Gerlach 1987) but increased during 1984-87. However, estimates during the second half of 1988 indicate that the population may be declining, possibly in response to sustained military disturbance. Precipitation during this period was above average (Shaw and Diersing 1989) which likely benefitted deer production by providing succulent forage.

Two important confounding factors existed on PCMS during the period 1983-88 that make it difficult to assess the effect of military training on mule deer demographics. First, extensive cattle grazing occurred prior to acquisition of PCMS and continued through most of Gerlach's (1987) baseline study. Secondly, coyote control was conducted on the western half of the parcel during 1987 and 1988 as part of an experiment to monitor coyote population response to control and as a management action to improve pronghorn fawn survival.

The removal of cattle from PCMS just prior to training may have enabled the site to support more deer. Cattle may affect not only available forage for deer but also hiding cover for fawns. More importantly, Lonner and Mackie (1983) note that social interactions between big game and cattle may result in the exclusion of big game from cattle ranges. Compton et al. (1988) found that a negative relationship existed between cattle and white-tailed deer use of riparian areas in Montana.

Coyote control on half of the site during the disturbance phase of this study also may have allowed the deer population to perform better under disturbance (maneuver) conditions. Stout (1982) found that coyote control on Fort Sill, Oklahoma, resulted in a 154% increase in fawn recruitment. Thus, in contrast to the potential for training to reduce the PCMS deer population, the removal of cattle and coyotes may have been a benefit to the deer. This may in part explain why no immediate decline in the population was detected. However, trends in population estimates indicate that although deer numbers increased during the transition

phase (1984-87), they may now be declining below the 1987 peak population (Figure 4). A slowing in the rate of increase also was seen using age specific mortality and natality.

Small sample sizes in most phases of the demographics data resulted in low levels of precision for many of the estimates. As a result, it was difficult to detect statistical differences among annual estimates of survival, reproduction, and density. White (1983) notes that Type II errors are more likely when small samples are used in survival analysis. In a similar disturbance study Garrott and White (1984) radio-collared 85 new mule deer in each of 2 subpopulations each year; however, the expected development of an oil shale site did not occur.

Another factor that may mask a decline in deer exposed to maneuver conditions is the fact that deer densities were highest in the off-limits areas of PCMS. Thus, even if deer are declining in maneuver areas, this may not be detected using census data due to the high densities observed in off-limits areas.

LITERATURE CITED

- Barrett, M. W., J. W. Nolan, and L. D. Roy. 1982. Evaluation of a hand-held net-gun to capture large mammals. *Wildl. Soc. Bull.* 10:108-114.
- Clover, R. B. 1956. Single-gate deer trap. *Calif. Fish and Game* 42:199-201.
- Compton, B. B., R. J. Mackie, and G. L. Dusek. 1988. Factors influencing distribution of white-tailed deer in riparian habitats. *J. Wildl. Manage.* 52:544-548.
- Freddy, D. J., W. M. Bronaugh, and M. C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. *Wildl. Soc. Bull.* 14:63-68.

- Garrott, R. A. and G. C. White. 1984. Methodology for assessing the impacts of oil shale development on the Piceance Basin mule deer herd. *Thorne Ecol. Inst. Tech. Publ.* 14:228-231.
- Gerlach, T. P. 1987. Population ecology of mule deer on Pinon Canyon Maneuver Site, Colorado. unpubl. M. S. Thesis, Virginia Polytechnic Inst. and St. Univ. 61 pp.
- Gill, R. B. 1969. A quadrat count system for estimating big game populations. *Colo. Div. Game, Fish and Parks Game Inf. Leaflet*. 76. 2pp.
- Heisey, D. M. and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. *J. Wildl. Manage.* 49:668-674.
- Kendeigh, S. C. 1961. *Animal Ecology*. Prentice-Hall, New Jersey. 468 pp.
- Kirkpatrick, R. L. 1980. Physiological indices in wildlife management. Pages 99-112 *in* ed. S. D. Schemnitz. *Wildlife Management Techniques Manual*. The Wildlife Society, Washington, D. C.
- Kuck, L., G. L. Hompland, and E. H. Merrill. 1985. Elk calf response to simulated mine disturbance in southeast Idaho. *J. Wildl. Manage.* 49:751-757.
- Lonner, T. N. and R. J. Mackie. 1983. On the nature of competition between big game and livestock. Pages 53-58 *in* B. F. Roche', Jr. and D. M. Baumgartner, eds. *Forestland grazing, proceedings of a symposium*. Coop. Ext. Serv., Washington St. Univ., Pullman.
- Mech, L. D. 1983. *Handbook of animal radio-tracking*. University of Minnesota Press, Minneapolis. 107 pp.
- Ramsey, C. W. 1968. A drop-net deer trap. *J. Wildl. Manage.* 32:187-190.
- Robinette, W. L., P. A. Jones, G. Rogers, and J. S. Gashwiler. 1957. Notes on tooth development and wear for Rocky Mountain mule deer. *J. Wildl. Manage.* 21:134-153.
- , C. H. Baer, R. E. Pilmore, and C. E. Knittle. 1973. Effects of nutritional change on captive mule deer. *J. Wildl. Manage.* 37:312-326.
- Shaw, R. B. and V. E. Diersing. 1989. Impact of 2 years of tracked vehicular training on the vegetation at the U. S. Army's Pinon Canyon Maneuver Site, Colorado. *J. Environ. Quality* (In Press).

- Stout, G. G. 1982. Effects of coyote reduction on white-tailed deer productivity on Fort Sill, Oklahoma. *Wildl. Soc. Bull.* 10:329-332.
- Trainer, D. E., J. C. Remos, T. P. Kistner, W. C. Lightfoot, and D. E. Towerill. 1981. Mortality of mule deer fawns in southeastern Oregon, 1968-1979. *Oregon Wildl. Res. Report No.* 10. 113pp.
- Trent, T. T. and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. *J. Wildl. Manage.* 38:459-472.
- U. S. Dept. of Army. 1980. Draft: Environmental impact statement for acquisition of training land in Huerfano, Las Animas, and Pueblo counties, Colorado. Fort Carson, Colorado.
- White, G. C. 1983. Numerical estimation of survival rates from band-recovery and biotelemetry data. *J. Wildl. Manage.* 47:716-728.

CHAPTER 3

A COMPARISON OF LINE TRANSECT SAMPLING AND QUADRAT SAMPLING FOR ESTIMATING MULE DEER DENSITY

INTRODUCTION

Pellet-group counts (Neff 1968), track counts (Salwasser 1976), change-in-ratio estimates (Hanson 1963), quadrat sampling (Gill 1969), strip census (Robinette et al. 1977), aerial mark-recapture (Bartmann et al. 1987), and aerial line transects (White et al. 1989) have been used to assess mule deer (*Odocoileus hemionus*) density and abundance. Often a technique is required that can accurately and efficiently assess mule deer densities for management purposes on low density areas. Population size or trend are of interest both in assessing deer response to human disturbance and managing harvests. Bartmann et al. (1986) demonstrated

that deer observability does not approach 100% in surveys in pinyon-juniper forests. Strip sampling also assumes 100% observability and therefore is undesirable in pinyon-juniper habitat where detectability drops off rapidly as distance from the line of flight increases (G. C. White, pers. commun.). Alternatively, line transect sampling does not assume that all animals in the surveyed area will be sighted; however applicability of the methodology for estimating deer density in low deer density pinyon-juniper habitat has not been tested.

We conducted both aerial line transect and quadrat sampling on the Pinon Canyon Maneuver Site (PCMS) in southeastern Colorado during 1987-1988. The objectives of this study were to (1) compare mule deer density estimates on the PCMS obtained using 2 aerial census techniques, line transect and quadrat sampling, (2) evaluate practical application of using line transect sampling versus quadrat sampling in the field, and (3) determine the validity of the assumptions of both techniques.

STUDY AREA

Research was conducted on the U.S. Army's 1,040 km² Pinon Canyon Maneuver Site along the Purgatorie River in Las Animas Co., Colorado, about 64 km NE Trinidad. The site consisted of open prairie bordered by deep canyons to the east and south and limestone breaks to the north, northwest, and southwest. Elevation ranged from 1,310 to 1,740 m. The climate was semiarid with mean temperatures of -1 C in January and 23 C in July. Average annual precipitation ranged from 26 to 38 cm. Five major vegetation types found on the area included grassland, shrub-grassland, upland pinyon-juniper (*Pinus edulis- Juniperus monosperma*) woodland, canyon juniper woodland, and canyon shrub (Anderson 1988).

METHODS

Line transect sampling

Line transect surveys (Anderson et al. 1979, Burnham et al. 1980) (Figure 5) were flown using a military UH-1 helicopter with a pilot, copilot, navigator, and 2 observers. The helicopter flew 25 to 35 m above ground level at speeds from 55-80 km/hr. Surveys were conducted 8 hours per day, beginning at about 0800 hours. Navigation was conducted using U. S. Geological Survey 1:24,000 topographic maps and the helicopter's path was continually monitored using topographic features.

Transect lines (61) were placed parallel with the general direction of canyons and ridges when possible to increase observability and at 1 km intervals following a systematic-random sampling scheme. The PCMS was not stratified by habitat type or deer density for transect surveys because of the low number of deer observations (Burnham et al. 1980).

Observer accuracy in estimating perpendicular distance from the line to the deer was aided by placing markers on the ground at known perpendicular distances to a predetermined line of flight; the line was then flown multiple times, before the survey was conducted.

Line transect data were evaluated using program TRANSECT (Laake et al. 1979). Multiple deer observed as a group were entered into the program as individual observations, then the calculated density estimates were multiplied by the mean group size (Burnham et al. 1980). Perpendicular distance data were entered into the program as grouped data. The 5 intervals selected were 0-100, 101-200, 201-300, 301-400, and 401-500 meters. The effective transect width was truncated at 500 m since observability was found to be zero beyond this distance. Data were analyzed using all 5 available TRANSECT estimators; a non-parametric linear model (Fourier Series), 2 simple parametric models (Negative Exponential and Half-normal), and 2 generalized parametric models (Exponential Polynomial and Exponential

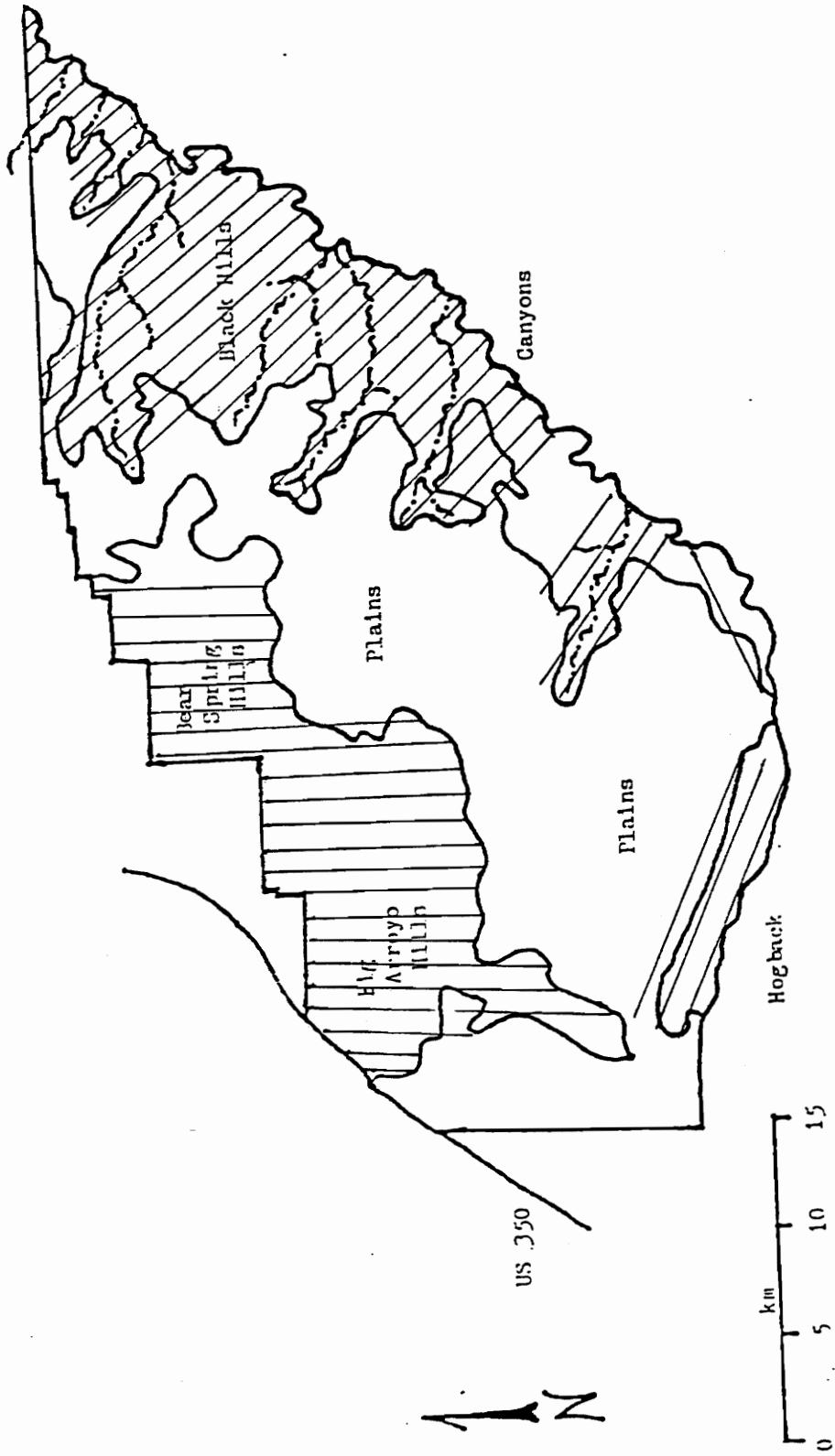


Figure 5. Sixty-one systematic-random line transects censused by helicopter on PCMS.

Power Series). The most appropriate density estimate for a given survey was selected using the Chi-square goodness-of-fit test to select the model that best fit the distance data. Model fit was considered the highest criteria in selecting the most appropriate estimator.

Quadrat sampling

Thirty-seven 2.6 km² quadrats (Figure 3) were selected for censusing following a stratified random sampling technique (Gerlach 1987). Based on preliminary relative density estimates, PCMS was stratified into low and high deer density areas. Of a possible 199 2.6 km² quadrats, 12 and 25 were randomly selected in low and high deer density areas, respectively, based on the proportion of deer habitat those areas composed. Random selection of quadrats occurred once at the beginning of the study and the same 37 quadrats were flown throughout the study. Surveys were flown using a military UH-1 helicopter with a pilot, copilot, navigator, and 2 observers. The helicopter flew 25 to 35 m above ground at a speed of 55-80 km/hr. Although quadrat boundaries were not marked permanently, they were easily identified using U. S. Geological Survey 1:24,000 topographic maps. The perimeter of each quadrat was flown first upon reaching it. The helicopter then proceeded from one side of the quadrat to the other following a series of parallel lines at 200 m intervals; canyons and ridges were followed to increase observability. Movement of deer within a quadrat was noted to avoid double counting. Density and population estimates were calculated according to Gill (1969). Quadrat and line transect surveys were conducted during the same week but at least 2 days separated surveys over a given portion of the study area.

The proportion of radio-collared deer sighted during helicopter telemetry trials was used to estimate observability during quadrat surveys. Telemetry was conducted following completion of surveys. Radio-marked deer were located visually or a definite locational fix was obtained using standard aerial telemetry technique (Mech 1983). Search patterns were

similar (i.e. contours were followed) for both quadrat surveys and telemetry flights, except that more passes were made for telemetry flights. This observability estimate represents maximum observability.

RESULTS

Line Transect

Four line transect surveys were conducted between August 1987 and August 1988 on the PCMS (Figure 6). On average, 10 hours of air time were required to fly the 536 km of transects. Sixty-one individual transects of varying length provided complete coverage of the PCMS "deer" habitat; the grassland vegetation type was not surveyed for deer (Figure 5). Density estimates ranged from 0.21 to 3.3 deer/km². Only the March and August 1988 survey results were similar (see 95% CI, Figure 6). The perpendicular distance data did not consistently fit one of the 5 available TRANSECT estimators. The Exponential Power Series model was selected for the August 1987 data set ($P=0.599$). The December 1987 ($P=0.986$) and March 1988 ($P=0.138$) data sets fit the Negative Exponential model the best. Finally, the Exponential Polynomial model was selected for the August 1988 data set ($P=0.816$).

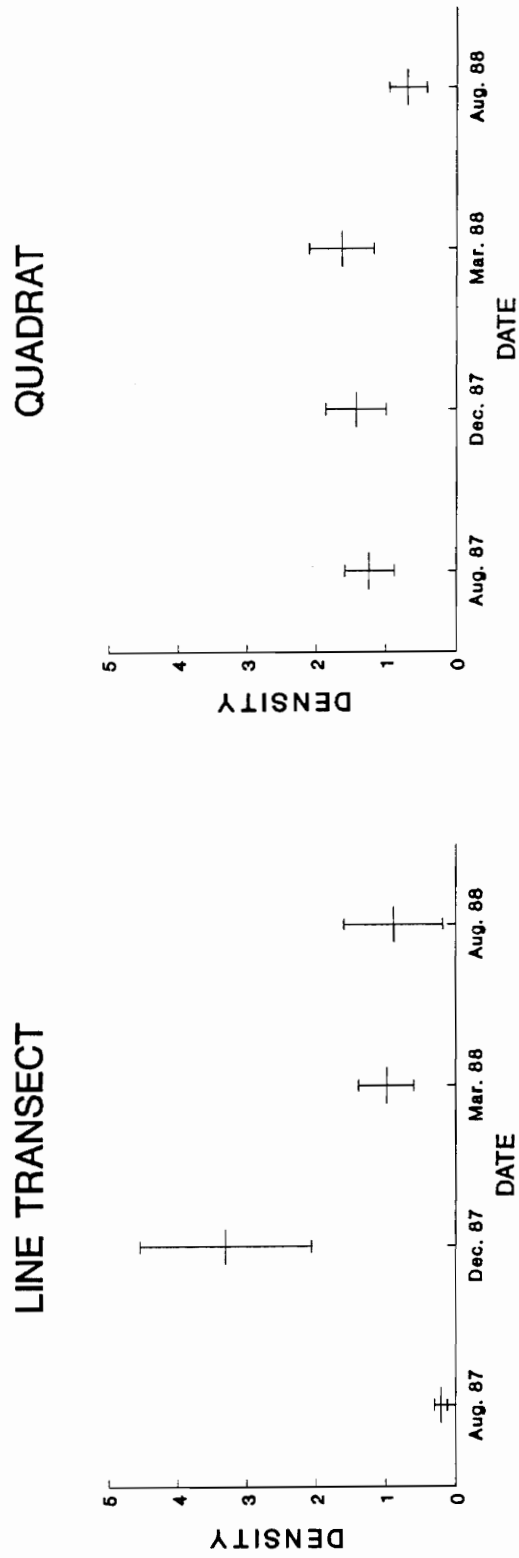


Figure 6. Density estimates (deer/km²) with 95% CI's from line transect surveys and quadrat surveys of mule deer on PCMS.

Quadrat

Each survey of 37 quadrats required about 16 hours to complete. Four quadrat surveys, timed to coincide with line transect surveys, yielded variable density estimates ranging from 0.69 to 1.63 deer/km² (Figure 6). However, only the August 1988 survey estimate was statistically different, based on 95% CI's (Figure 6), from the other surveys.

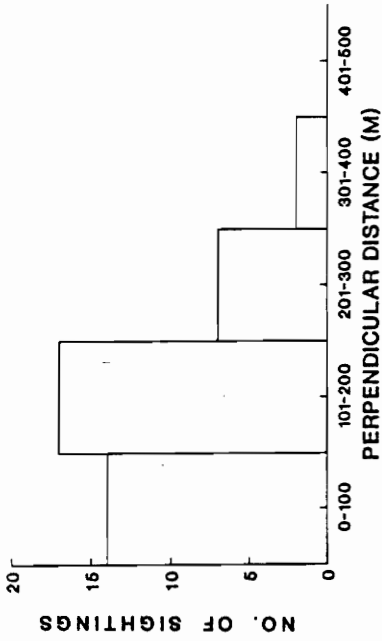
DISCUSSION

Line Transect

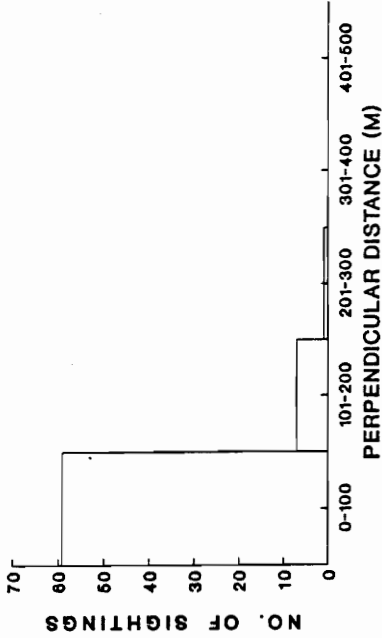
The variation in transect density estimates did not follow an observed pattern that might be explained by changes in sightability (due to deer behavior or weather) or population numbers. Survival and movements of radio-collared deer on PCMS do not support such drastic population fluctuations (Chapters 1 & 2).

The selection of the negative exponential model to describe the data implies that sightability drops off very rapidly with increasing distance from the line of flight. However, the perpendicular distance distributions (Figure 7) were not similar among surveys. Different distributions of sighting distance influence detection function shape and resulting density estimates. Variation among perpendicular distance distributions results in variation among density estimates. Variation in density estimates (CV = 100%) was higher than the variation in the number of animals observed among surveys (CV = 50%).

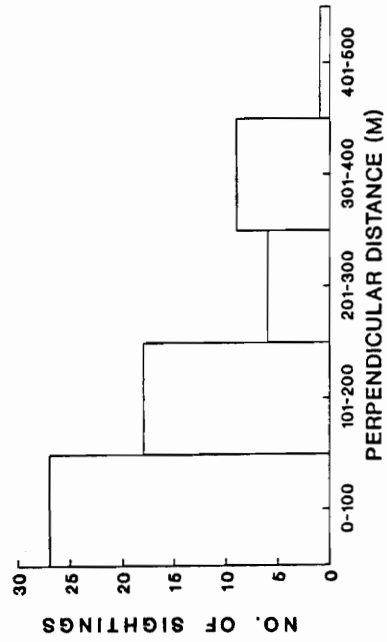
AUGUST 87



DECEMBER 87



MARCH 88



AUGUST 88

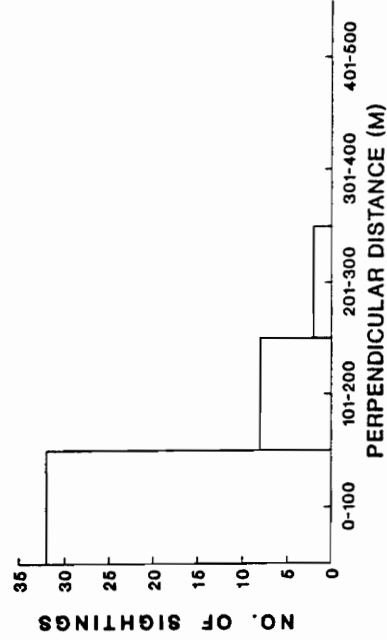


Figure 7. Perpendicular distance distributions for line transect surveys on PCMS.

Reliable density estimates are dependent upon 4 critical assumptions (Burnham et al. 1980), which are of particular concern for aerial surveys of mule deer in rugged habitats. In conducting the line transect surveys on the PCMS, the 3 most critical of these appear to be violated.

Assumption 1--ANIMALS DIRECTLY ON THE LINE WILL NEVER BE MISSED. The extremely rugged terrain on PCMS over which much of the survey was conducted decreased sightability. Though the lines were oriented parallel with the canyons when possible, the canyons were not straight and observability in perpendicular side canyons was low. Observability in shadowy, deep, narrow canyons was low relative to more open, level habitat types as indicated by telemetry flights. Pollock and Kendall (1987) and White et al. (1989) noted that the assumption of 100% visibility on the line may not be justified.

Assumption 2--ANIMALS ARE FIXED AT THE INITIAL SIGHTING POSITION; THEY DO NOT MOVE BEFORE BEING DETECTED. Practically all deer sighted during surveys were sighted after they flushed. If the deer are sighted upon initial flushing, the detection function is unlikely to be biased especially if data are grouped for the analysis. However, for the August 1987 survey there appeared to be significant movement away from the line (Figure 7). Observers were positioned to view to the side rather than forward, and deer may have moved away from the line before being detected.

Assumption 3--PERPENDICULAR DISTANCES ARE MEASURED ACCURATELY. This assumption is of particular concern because distances of deer from the helicopter were estimated. Variation in perpendicular distance distributions among surveys probably can, in large part, be explained by differences in the ability of observers to estimate distances. It is unlikely that the variation in true distances to animals actually fluctuated as much as the data indicate. The recorded variation led to widely varying detection functions that produced widely varying estimates. Observer distance estimation may have been biased high during the August 1987 survey. Grouping data after collection was used to compensate for variation in distance estimation among surveys, however, the August 1987 survey data show a

distribution with a peak in detection 101-200 m from the line. The violation of this critical assumption hampered the effectiveness of this technique.

Assumption 4--SIGHTINGS ARE INDEPENDENT EVENTS. Although many deer were sighted in groups rather than as individuals, groups were considered single observations for program TRANSECT. Since the helicopter did not leave the line to more closely examine deer groups, the possibility of flushing other groups while flying off the line was not a concern. Thus, the problem of one sighting leading to a second was minimal.

Quadrat

The coefficient of variation (CV = 33%) was less than for transect estimates (CV = 100%). Gregarious behavior and snow covered ground, which increase mule deer observability (Ackerman and Garton 1986), explain the greater estimates obtained during winter months. The decreased estimate observed for August 1988 correlates with a decrease in fawn survival observed in radio-collared fawns and fawn:doe ratios during the summer of 1988 (Chapter 2). Also, the earlier survey date for the August 1988 surveys may have resulted in a lower estimate. The younger age of fawns implies less activity by does and fawns (Trainer et al. 1981), as well as solitary behavior (Stephenson, unpubl. data), resulting in lower observability

Quadrat sampling also requires that certain assumptions be met to achieve reliable estimates. The 4 most important will be discussed here.

Assumption 1--ALL ANIMALS PRESENT WITHIN A QUADRAT WILL BE SIGHTED. Bartmann et al. (1986) found that in pinyon-juniper woodland an average of only 60 to 68% of all deer were observed. On PCMS, deer were rarely seen unless they flushed; this may become a significant problem if deer habituate to extensive military helicopter traffic present

on a regular basis. Mule deer appear to habituate to extensive helicopter traffic in other areas in eastern Colorado (S. Emmons, Fort Carson DEH, pers. commun.).

Forty-three of 63 radio-collared deer were observed during telemetry flights, indicating that under optimal sighting conditions observation efficiency was 68% and in most cases likely would be less. Observability on quadrat surveys is likely to be less than on telemetry flights as considerable effort is expended when locating radio-collared deer known to be directly below the helicopter. Furthermore, Ackerman and Garton (1986) found that group size and activity level significantly affected observability.

Assumption 2--QUADRAT BOUNDARIES ARE EASILY IDENTIFIED. Although quadrats were not marked, the perimeter was located easily due to the diversity of the topography on the PCMS, which aided in finding boundaries.

Assumption 3--ANIMALS DO NOT MOVE IN OR OUT OF THE QUADRAT BEFORE BEING SIGHTED. The perimeter of each quadrat was flown first upon reaching it to classify any deer near the boundary as in or out. Due to the low deer densities on PCMS, most search time was spent scanning a quadrat and not pursuing individual groups to identify sex and age.

Assumption 4--MULTIPLE REGISTRATIONS OF THE SAME ANIMAL ARE AVOIDED. Quadrats were searched systematically and the direction of moving deer was noted to avoid recounting previously sighted deer. This assumption was less likely to be violated on PCMS compared to high deer density areas because it is less difficult to keep track of a small number of deer.

CONCLUSIONS

The factors that appear to separate the 2 survey techniques are the validity of the assumptions for each procedure and the reliability of the density estimates. For a census

technique to be valuable as a population management tool it must illustrate trends in population density. The number of surveys conducted in this study was low, yet the extreme variability that resulted using line transect sampling under these aerial survey conditions is apparent. Therefore, the consistent, reliable nature of quadrat sampling was preferred. Quadrat sampling provided more precise density estimates than line transect sampling (see 95% CI's), (Figure 6).

The extreme variability in the density estimates using line transect sampling were in response to the detection functions and in turn the range in perpendicular distance distributions. These unequal distributions were assumed to result from inaccurate perpendicular sighting distances. Data were grouped to reduce some of the variability, but this did not compensate for the extreme variation. Application of line transect sampling to quail populations in Texas was not biased by this inability to accurately measure distances because transects were walked (Guthery 1988).

There is a need for a better distance estimation approach, with less dependence on observer ability, if line transect sampling is to produce reliable estimates from aerial surveys. Although we were not able to use the same observers on all occasions, which may in part explain the wide variation in distance estimation among surveys, I believe this is more representative of conditions that would exist for a management agency over time. Samuel et al. (1987) found that use of different observers did not have a significant effect on sightability among quadrat surveys.

Although some of the concerns raised with line transect sampling are applicable to aerial surveys on many areas, other problems were more specific to conditions on PCMS. Aside from the problem of accurately estimating perpendicular distances, more specific drawbacks with line transect sampling arose in response to habitat and population sampling. The low density of deer on the area precluded obtaining large sample sizes of observations; thus the area could not be stratified by density. If larger sample sizes had been obtainable, more precise estimates of density might be achieved. The topography of PCMS requires that a census technique follow the contours to provide greater sightability; this is not possible

using straight line surveys. However, on other sites where the terrain is more gradual or level, transect sampling would be more effective with less of a decline in sightability.

A future concern for any aerial survey technique on an area exposed to extensive helicopter use such as PCMS is that deer may habituate to the frequent helicopter traffic such that they fail to flush. In this case, quadrat surveys would still be preferred because of the more intensive search technique. Also, as previously noted, a sightability correction could be used to adjust density estimates.

LITERATURE CITED

- Ackerman, B. B. and E. O. Garton. 1986. Mule deer sightability. Job Progress Report W-160-R-13. Idaho Dept. Fish & Game. 14pp.
- Anderson, D. R., J. L. Laake, B. R. Crain, and K. P. Burnham. 1979. Guidelines for line transect sampling of biological populations. *J. Wildl. Manage.* 43:70-78.
- Anderson, E. M. 1988. Effects of male removal on spatial distribution of bobcats. *J. Mamm.* 69:637-641.
- Bartmann, R. M., L. H. Carpenter, R. A. Garrott, D. C. Bowden. 1986. Accuracy of helicopter counts of mule deer in pinon- juniper woodland. *Wildl. Soc. Bull.* 14:356-363.
- _____, R. M., G. C. White, L. H. Carpenter, and R. A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. *J. Wildl. Manage.* 51:41-46.
- Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72. 202pp.
- Gerlach, T. P. 1987. Population ecology of mule deer on Pinon Canyon Maneuver Site, Colorado. unpubl. M. S. Thesis, Virginia Polytechnic Inst. and St. Univ. 61 pp.

- Gill, R. B. 1969. A quadrat count system for estimating game populations. Colo. Div. Game, Fish and Parks Game Inf. Leaflet. 76. 2pp.
- Guthery, F. S. 1988. Line transect sampling of bobwhite density on rangeland: evaluation and recommendations. Wildl. Soc. Bull. 16:193-203.
- Hanson, W. R. 1963. Calculation of productivity, survival, and abundance of selected vertebrates from sex and age ratios. Wildl. Monogr. no. 9. 60pp.
- Laake, J. L., K. P. Burnham, and D. R. Anderson. 1979. User's manual for program TRANSECT. Utah St. Univ. Press, Logan, Utah. 26pp.
- Mech, L. D. 1983. Handbook of animal radio-tracking. University of Minnesota Press, Minneapolis. 107 pp.
- Neff, D. J. 1968. The pellet-group technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32:597-614.
- Pollock, K. H. and W. L. Kendall. 1987. Visibility bias in aerial surveys: a review of estimation procedures. J. Wildl. Manage. 51:502-510.
- Robinette, W. L., N. V. Hancock, and D. A. Jones. 1977. The Oak Creek mule deer herd in Utah. Resource Publication 77-15. Salt Lake City: Utah Division of Wildlife. 148pp.
- Salwasser, H. 1976. Man, deer, and time on the Devil's Garden. Proc. West. Assoc. Game and Fish Commissioners 56:295-318.
- Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. J. Wildl. Manage. 51:622-630.
- Trainer, D. E., J. C. Remos, T. P. Kistner, W. C. Lightfoot, and D. E. Towerill. 1981. Mortality of mule deer fawns in southeastern Oregon, 1968-1979. Oregon Wildl. Res. Report No. 10. 113pp.
- White, G. C., R. M. Bartmann, L. H. Carpenter, and R. A. Garrott. 1989. Evaluation of aerial line transects for estimating mule deer densities. J. Wildl. Manage. 53:625-635.

CHAPTER 4

MANAGEMENT RECOMMENDATIONS FOR MULE DEER ON THE PINON CANYON MANEUVER SITE, COLORADO

INTRODUCTION

The Pinon Canyon Maneuver Site (PCMS) has been identified as an area with high potential for trophy deer management. It is one of the few parcels of public land in the state where the probability of a hunter harvesting a nice quality (trophy) buck is high (1987 statistics on hunter success: PCMS = 81%, statewide = 31%; buck:doe ratio: PCMS = 60:100, statewide = 25:100). For the purposes of this management plan, a trophy buck is defined as one scoring at least 150 points or better by Boone & Crockett standards. A high quality hunt is defined by the following attributes: (1) a hunter has a 70% probability of harvesting a deer (assumes the season is held during the rut), (2) at least 50% of harvested deer are trophy bucks, and (3) hunter density does not exceed 1/8 km² of deer habitat (400 km²). If this quality

experience is to be maintained, proper habitat management, minimization of disturbance, population monitoring, and harvest management are essential.

HABITAT

We recommend that mule deer habitat be maintained under conditions similar to those existing in 1983 when the U. S. Army purchased the site. This assumes the military is under no responsibility to improve the land above conditions existing at time of purchase. At present it does not appear that the military maneuvers pose an extensive threat to much of the mule deer habitat on the PCMS. Although the grassland/ pinyon-juniper interface is used extensively for bivouac, it accounts for a low percentage of the high deer density pinyon-juniper habitat on the PCMS. The majority of the high deer density habitat (Figure 8) is not only identified as off-limits to tracked and wheeled vehicles (i.e.-soil protection areas and canyons) but much of it is physically restrictive to mechanized land-based training (i.e.-canyons). However, there is concern that the amount of grassland pinyon-juniper interface (primarily low deer density habitat) used by the military will continue to deepen and expand with each new maneuver, especially if forest is destroyed in the process forcing the existing forest perimeter back from the original perimeter. Thus, considerable effort must be made to revegetate disturbed areas as rapidly as possible with plant species that are valuable as forage and cover to reduce the expansion of disturbed areas and to reduce erosion. Undisturbed (off limits) deer habitat on the other hand may be in better condition under military management (no grazing) than it was as ranchland (extensive grazing), both in terms of available forage and hiding cover for newborn fawns.

Trends in condition indices (kidney fat index, body weight, and antler score/age) obtained from harvested deer (Table 18), could be used as an indicator of shifts in habitat

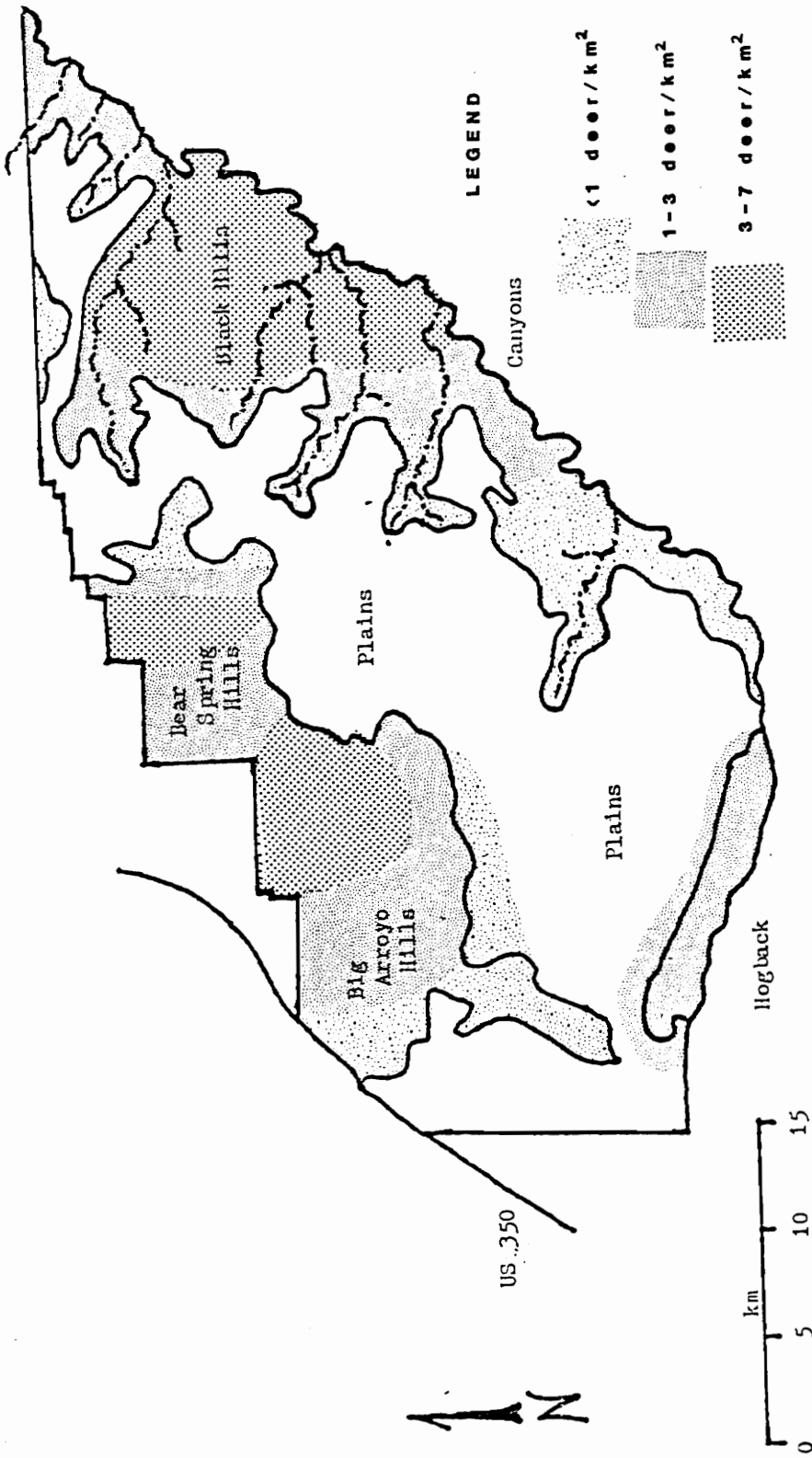


Figure 8. Mule deer distribution and density on PCMS.

quality and quantity. However, confounding factors such as deer density and weather must be considered in assessing causality if a decline in condition occurs.

DISTURBANCE

Much of the pinyon-juniper habitat is off-limits to land-based vehicular traffic, but helicopters use areas in close proximity to training sectors extensively. Deer in areas frequented by helicopter traffic have responded by moving 2 to 12 linear kilometers beyond their home ranges to escape the disturbance. This disturbance could negatively impact deer in severe winters and does during late gestation and lactation. However, deer may eventually habituate to helicopter traffic as they have at Fort Carson, Colorado (Steve Emmons, pers. commun.) and continue to use disturbed areas as long as suitable habitat exists.

We recommend military disturbance in deer habitat be prevented in June and July to reduce fawn mortality from accidents, abandonment, vulnerability to predation, and depletion of energy reserves from excessive movement. The majority of fawning occurs during 20 June - 20 August on PCMS. We further recommend that land-based traffic and helicopter traffic in particular be reduced during periods of deep snow.

POPULATION MONITORING

To effectively manage the mule deer population, population size or trend must be known. We have used line transect and quadrat surveys for this purpose (Chapter 3). A military UH-1 (Huey) helicopter was used to fly either the 37 randomly selected 2.6 km² quadrats or the 535.6 km of line transects. Results indicate there is less variability involved in conducting the

Table 18. Hunting season (rifle) data for the Pinon Canyon Maneuver Site, Colorado, 1983-1988.

Year	Antlered deer				Antlerless deer					
	No. of permits	No. of hunters	No. harvested	Hunter success	Success (w/ no shows)	No. of permits	No. of hunters	No. harvested	Hunter success	Success (w/ no shows)
1983	NA	13 ^a	4	NA	NA	NA	^a	1	NA	NA
1984	NA	NA	5	NA	NA	NA	NA	0	NA	NA
1985	NA	37 ^a	11 ^b	30%	NA	NA	^a	^b	NA	NA
1986	39	34	27	82%	68%	5	5	4	80%	80%
1987	30	25	22	88%	73%	5	4	3	75%	60%
1988	30	30 ^c	21 ^c	70%	70%	5	5	3	60%	60%

^aProportion of buck vs. doe hunting unknown
^bProportion of bucks vs. does harvested unknown
^cIn addition, 16 archery hunters harvested 4 deer

Additional harvest data (1987 Season)		Antlered deer	Antlerless deer
Bucks with ≥ 4 points on 1 side		20 (91%)	NA
Mean kidney fat index (n)		90.3% (15)	37.6% (3)
Mean eviscerated body weight (n)		189 lbs. (20)	80 lbs. (2 does)
Mean age in years (n)		5.7 (17)	8 (2 does)

quadrat survey (Chapter 3). Because the magnitude of error appears to be greatest for the line transect census, we recommend using the quadrat survey to census the mule deer population. In addition, the quadrat census technique is more effective in obtaining accurate composition counts because groups of deer are pursued upon being sighted. Helicopter air time can be used more efficiently if a fuel truck accompanies the aircraft to PCMS. Use of a fuel truck on site deletes shuttle time to airports and reduces the air time needed to conduct the quadrat survey from 16 hours to 12 hours.

Aerial surveys also are used to perform composition counts, thus they must be timed properly. Fawn:doe and buck:doe ratios should be determined after the period of greatest fawn mortality but while fawns and bucks can still be differentiated from does. Because most fawn mortality occurs during the summer (Chapter 2), and bucks lose their antlers in late winter, fall is the optimal time to conduct a survey. A second survey should be conducted in spring following winter mortality but prior to the birth pulse to estimate mean population level. The spring survey should be conducted late enough that it encompasses any delayed mortality occurring as a result of severe weather stress or late spring "green up".

We recommend establishment of an effective hunter check station. If hunters are informed that the information will be used to optimize the hunting experience, they tend to be quite cooperative upon arrival and departure. Hunters must be contacted before entering the field, if complete data are to be collected. The following information should be collected:

- (1) Collect incisor teeth. Collected to accurately age harvested deer to determine whether the trophy age classes are being maintained (Figure 9). This technique is subject to less error than tooth wear aging (Connolly 1981).
- (2) Measure antlers. Use the Boone and Crocket method (Nesbitt and Parker 1977), which enables the quality of the buck population and the trophy standards to be monitored. A decrease in size and quality would indicate either the proportion of trophy bucks is declining or their ability to grow large antlers is declining. Either could result from a decrease in the forage base, nutrient supply, or increased stress.
- (3) Weight. Used as an index to condition.
- (4) Collect kidneys with associated fat. Used as an index to animal condition (Kirkpatrick 1980).. If harvest continues to occur during or after the rut, the condition of bucks could be a good index for the entire population because this segment of the population would likely be in the worst condition due to physiological demands of rutting. However, while one could assume that bucks in good condition reflect the condition of the rest of the population, one could not conclude that the remainder of the population is in poor condition just because bucks are in poor condition during the rut. Condition also could be used to assess the proximity of the population to its carrying capacity. Because the

- condition of deer is related to the forage base, condition should reflect population density and forage availability, but other possible influences must not be ruled out.
- (5) Collect rumen samples. Used to detect changes in diet which may be related to changes in habitat quality and range condition. Utilization of species introduced during revegetation efforts also could be assessed. If any of the above data exhibit a new trend, further sampling outside of the hunting season may be desired to quantify disturbance related impacts.
 - (6) Location of harvest. Used to disperse hunters in the future and monitor harvest pressure.
 - (7) Hunter effort and success should be calculated.
 - (8) Hunters should be asked to complete a questionnaire designed to assess hunt quality.

Information on hunter success, buck size, and condition could be used to confirm the results of aerial surveys, particularly since there is concern that deer may habituate to helicopter traffic and alter their flushing behavior. It must be emphasized that trends, as opposed to individual year shifts, in survey and harvest data should be the impetus for management decisions. The relationship among population estimates, condition indices, and age structures must be considered in conjunction with military training, habitat, and weather data in determining population trends.

PRODUCTIVITY AND PREDATOR CONTROL

The PCMS mule deer population appears to be increasing based on the high reproductive rates, lack of excessive fawn mortality, and high adult survival. The implied rate of increase under such conditions is currently supported by census results (mean finite rate of increase = 1.07). Therefore, predator control is not recommended at this time. However, if future military disturbance appears to be directly or indirectly depressing the population (i.e., additive mortality), predator control or a reduction in harvest are options to reduce excessive mortality.

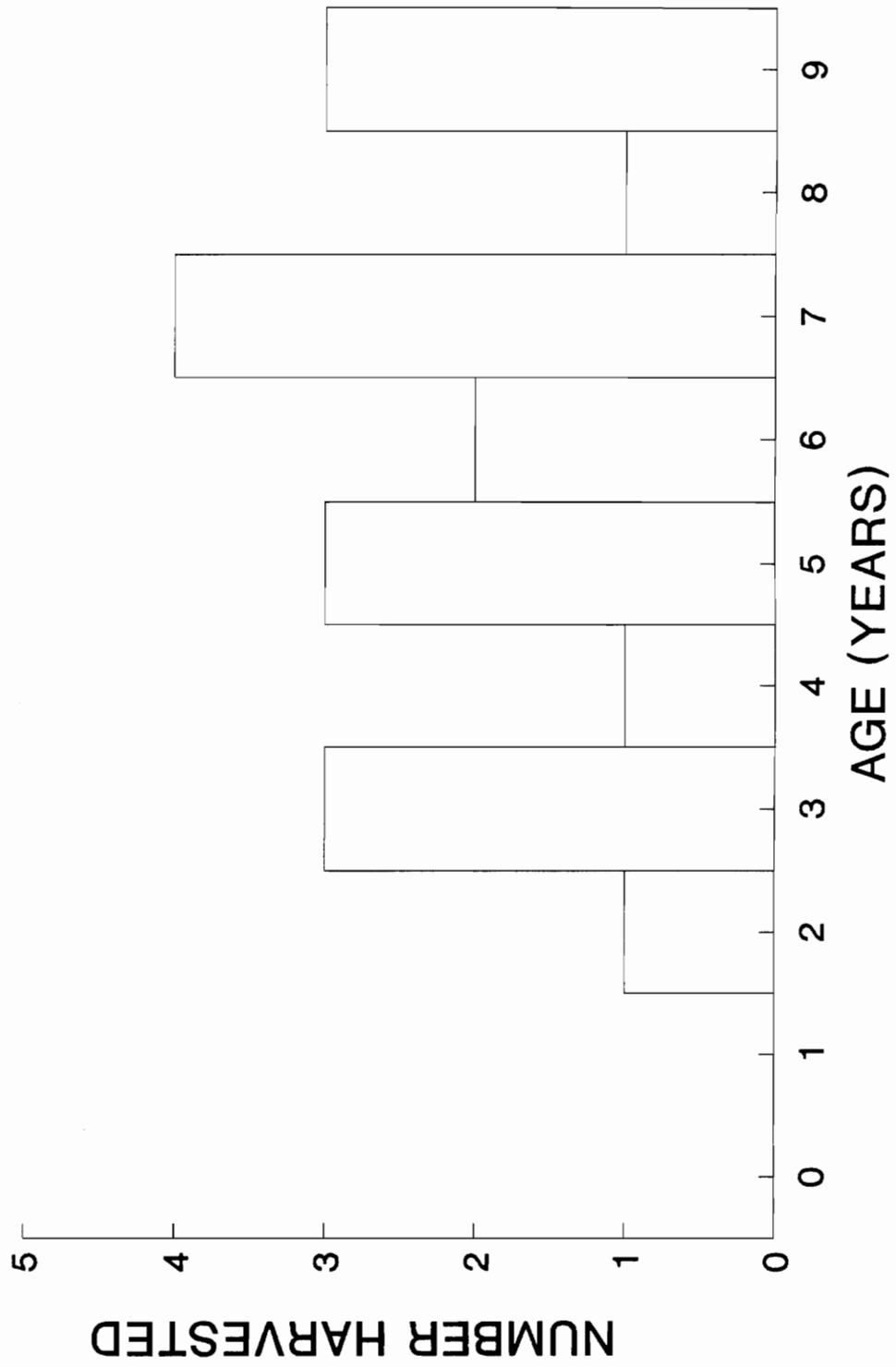


Figure 9. Age structure of mule deer harvested during the 1987 rifle season on PCMS.

HARVEST

With the goal of harvest management to produce trophy-sized bucks, a conservative approach should be taken in setting harvest quotas. This coordinates with wise management of a population subject to disturbance. The number of bucks harvested each year should not exceed the proportion of prime-age and old-age classes in the population to insure that primarily bucks of harvestable age are taken. In addition, because the population appears to be below carrying capacity (animal condition good and minimal evidence of browsing), as well as increasing (mean rate of increase = 1.07), it is unproductive to harvest does. Approximately 15-20% of the antlered population could be harvested each year; thus actual numbers of deer harvested should be adjusted yearly. POP-II simulations (Bartholow 1987) may be used to model the population and predict the effects of numerous harvest rates.

POP-II enables the manager to consider the effects of changes in demographic parameters over time. The program requests the user to input a number of values based on pre-existing knowledge about the population under consideration, as well as possible guesses on future environmental conditions. These variables are then used to model the population in future years. POP-II models a population over biological years (Bio-year). A bio-year begins with the birth pulse in June and ends just prior to the birth pulse of the following year. POP-II simulations must be used cautiously because mortality rates, harvest rates, and reproductive rates may vary unpredictably from year to year.

We recommend antler point restrictions not be implemented. Under a 3-4 point minimum restriction, the harvest of young bucks (1-2 years) would be decreased and more hunting pressure would be placed on the middle age classes (3-5 years). This would increase the average age of harvest and reduce the number of bucks that reach the trophy age classes (6-9 years). Middle-aged bucks would come under greater harvest pressure rather than distributing the harvest pressure over all age classes (Wolfe 1985). In addition, the majority of hunters on this area already appear to be imposing their own antler size restrictions.

LITERATURE CITED

- Bartholow, J. 1987. POP-II System Documentation. IBM-PC Version 6.7, Fossil Creek Software, 57pp.
- Connolly, G. E. 1981. Assessing populations. Pages 287-345 in ed. O. C. Wallmo. Mule and Black-Tailed Deer of North America. Wildlife Management Institute, Washington, D. C.
- Kirkpatrick, R. L. 1980. Physiological indices in wildlife management. Pages 99-112 in ed. S. D. Schemnitz. Wildlife Management Techniques Manual. The Wildlife Society, Washington, D. C.
- Nesbitt, W. H. and J. S. Parker. 1977. North American Big Game. The Boone and Crockett Club and The National Rifle Association of America, Washington, D.C.
- Wolfe, G. J. 1985. Population dynamics of the Vermejo Park elk herd, with special reference to trophy management. Colo. St. Univ., Ft. Collins. Ph.D. Diss. 161 pp.

Vita

Thomas Robert Stephenson was born in Blacksburg, Virginia on 25 June 1964. In 1982, he graduated from Blacksburg High School in Blacksburg, Virginia. He attended Wake Forest University in Winston-Salem, North Carolina between 1982 and 1984 as a biology major. After transferring to Colorado State University in Fort Collins in 1984, he received a Bachelor of Science degree in Wildlife Biology in 1986. While an undergraduate at Colorado State, he worked on a bobcat research project for the Colorado Cooperative Wildlife Research Unit. He began his graduate research with Virginia Polytechnic Institute and State University in June 1986. His research focused on the behavioral and demographic responses of mule deer to military activity in southeast Colorado. In November 1989, he completed the requirements for a Master of Science degree in Fisheries and Wildlife Science.



Thomas R. Stephenson