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CONDITION AND REPRODUCTIVE PERFORMANCE OF FEMALE MULE DEER IN THE CENTRAL SIERRA NEVADA

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I determined reproductive performance in relation to age and physical condition of 58 female Rocky Mountain mule deer, *Odocoileus hemionus hemionus*, collected from the West Walker winter range in northern Mono County, California, and southwestern Douglas County, Nevada during March 1993 and March 1994. Among adult females, pregnancy and fetal rates were 86% and 1.52 fetuses/female in 1993 and 88% and 1.56 fetuses/female in 1994. Bled carcass weights, eviscerated carcass weights, and kidney fat indices of adult females were greater in 1994, indicating that deer were in better condition than in 1993. Litter category was not related to age or female body condition. The overall sex ratio of fetuses was 107 males:100 females. Reproductive potential in the West Walker deer herd was comparable to that reported for othernutritionally stressed mule deer populations. My study suggested that low productivity was in response to drought-induced changes in habitat quality.

INTRODUCTION

During 1987-1994, Rocky Mountain mule deer, *Odocoileus hemionus hemionus*, populations in the eastern Sierra Nevada, California, experienced poor fawn survival and low recruitment. For example, fall fawn ratios for the West Walker(WW) deer herd in northern Mono County averaged 26 fawns:100 females, while spring ratios averaged 20 fawns:100 females (R. Thomas, California Department of Fish and Game, pers. comm.). This low recruitment was concomitant with 7 consecutive years of drought, which subjected this deer population to repeated episodes of nutritional stress.

Nutrition is an important factor influencing productivity of deer populations (Verme 1967, McCullough 1979) because it affects the proportion of females that become pregnant, as well as ovulation rates (Sadleir 1987, Folk and Klimstra 1991). These effects are well documented for free-ranging (Morton and Cheatum 1946, Julander et al. 1961, Kucera[1] 1988) and captive deer (Verme 1965, 1967; Ozoga and Verme 1982). Research consistently has shown that deer on good quality ranges have higher rates of ovulation, conception, and pregnancy than deer on poor ranges.

An understanding of the relationships between body condition and reproductive performance of wild ungulate populations is necessary for their management

[1] Kucera, T.E. 1988. Ecology and population dynamics of mule deer in the eastern Sierra Nevada, California. Ph.D. Dissertation, University of California, Berkeley, California, USA.

(Saltz et al. 1992). Therefore, a high priority in any deer herd where fawn production is suboptimal should be to evaluate the physical condition of females during breeding and pregnancy (Connolly 1981, Saltz et al. 1992).

Body fat is the component most often associated with animal condition and can be used to index animal response to nutritional and climatic stressors (Robbins et al. 1974, Torbit et al. 1985). Various fat indices have been developed to estimate body condition, including bone marrow fat (Cheatum 1949; Riney 1955; Ransom 1965, 1967), kidney fat (Riney 1955; Ransom 1965, 1967; Batcheler and Clark 1970; Van Vuren and Coblentz 1985), and visual scoring methods (Ransom 1965, Kistner[2] 1976). I used kidney fat indices and reproductive tracts to determine the physical condition and reproductive potential of adult female mule deer collected from the WW deer herd during March 1993 and March 1994. My objectives were to (i) assess the effects of a prolonged drought, followed by an unusually severe winter, on the spring condition of female mule deer and (ii) compare the effects of an unusually severe and an unusually mild winter on deer condition and productivity. This descriptive study is intended to provide information on mule deer condition and reproduction in order to facilitate a better understanding of interactions that occur between the WW deer herd and its environment.

STUDY AREA AND METHODS

During 18-19 March 1993 and 15-16 March 1994, free-ranging female mule deer were collected from WW winter ranges in northern Mono County, California, and southwestern Douglas County, Nevada (Fig. 1). Winter range of the WW herd encompasses approximately 780 km^2 at elevations from 1,530 to 2,550 m. Dominant plant communities (following Mayer and Laudenslayer 1988) on the winter range include bitterbrush, *Purshia* sp.; sagebrush, *Artemisia* sp.; and pinyon pine, *Pinus monophylla*. Descriptions of WW herd ecology, winter range vegetation, climate, and topography have been reported by Thomas[3] (1985), Loft et al. (1989), and Taylor[4] (1993).

Deer were collected by two-person teams that shot the first identifiable adult or yearling female in each group of deer encountered, regardless of the animal's apparent body condition. Animals were shot in the head, neck, or thorax with a high-powered rifle. Carcasses were transported to a field processing station where they were weighed to the nearest kilogram (bled carcass weight, BCW) using a spring scale. External body measurements (chest girth, left hind foot length, and contour length) to the nearest centimeter were recorded. Animals were eviscerated and reproductive tracts (uterus and ovaries), right kidneys, right femurs, and lower jaws

[2] Kistner, T.P. 1976. Evaluating physical condition of deer. Oregon Department of Fish and Wildlife, Portland, Oregon, USA.

[3] Thomas, R.D. 1985. Management plan for the West Walker deer herd. California Department Fish and Game, Bishop, California, USA.

[4] Taylor, T.J. 1993. West Walker deer herd progress report 2. California Department Fish and Game, Bishop, California, USA.

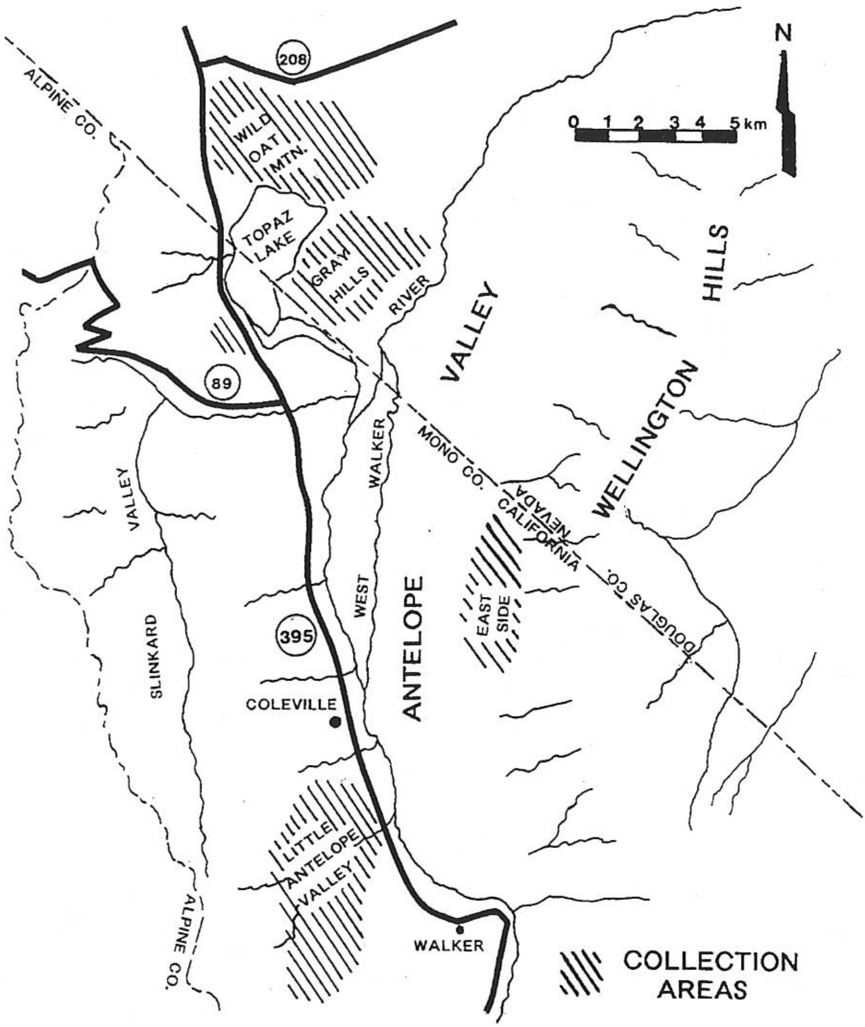

Figure 1. Locations of deer collection areas on the West Walker deer herd winter range in Mono County, California and Douglas County, Nevada, 1993-1994.

were extracted. Ages were estimated by tooth wear and replacement (Larson and Taber 1980). After field necropsies were completed, deer were weighed to the nearest kilogram to determine eviscerated carcass weights (ECW). The kidney fat index (KFI, Riney 1955) was calculated by dividing the fresh weight of kidney fat by the fresh weight of the fat-free kidney, multiplied by 100.

Ovaries were sectioned at 5-mm intervals and examined macroscopically for corpora lutea of pregnancy (CLP), which were used to estimate ovulation rates. I used a fetus scale (Forestry Suppliers Inc., Jackson, Mississippi, USA) to determine forehead-rump lengths of fetuses in order to estimate fetal age (Hudson and

Browman 1959) and conception and fawning dates. Conception date was back-calculated from estimated fetal age. Approximate date of parturition was determined by adding 204 d (Anderson 1981) to conception date. Weather data were obtained from the National Oceanic and Atmospheric Administration weather station in Coleville, California.

I used standard techniques for statistical testing with $\alpha = 0.05$. Analysis of variance was used to test for differences in mean reproductive characteristics and condition indices between years and among collection areas and to examine the relationship between "litter category" (number and sex composition of litters, i.e., single female, twin females, single male, etc.) and BCW, ECW, and KFI. Kidney fat indices were normalized by logarithmic transformation prior to analysis. I tested for deviations from the expected 1:1 sex ratio among fetuses with a binomial test (Siegel 1956); deviations from the expected distribution of sex ratios among litter categories were tested using chi-square analyses. I also used chi-square tests to examine differences in fetal sex ratio between years and among collection areas. Means and standard errors were calculated from untransformed data.

RESULTS

Deer (29 each year) were collected from three primary areas within the range that supported deer concentrations during all winters. A total of 20 deer (10 each year) were collected from Little Antelope Valley (LAV), California; 20 deer (10 each year) were collected from the east side (ES) of Antelope Valley near the base of the Wellington Hills, Nevada; and 18 deer (nine each year) were collected from the vicinity of Topaz Lake (TL), Nevada (Fig. 1).

Winter weather in 1992-93 was severe, with 180 cm of snow and average minimum temperatures of -16°C in January. In comparison, the winter of 1993-94 was mild, with 81 cm of snow and minimum temperatures averaging -6°C in January.

Pregnancy and fetal rates were similar in 1993 and 1994 and mean age (4.9 yr in 1993 and 5.2 yr in 1994) of adult females did not differ significantly between years($F = 0.227$; 1, 54 df; $P = 0.972$). Among adult females examined, 25 of 29 (86%) were pregnant in 1993and 24 of 27 (88%) were pregnant in 1994 (Table 1). Mean fetal rates of 1.52 fetuses per adult female in 1993 and 1.56 fetuses in 1994 did not differ between years ($F = 0.357$; 1, 54 df; $P = 0.553$), and mean fetal rates did not differ among collection areas($F = 0.001$; 2, 53 df; $P = 0.999$) (Table 1). Of the 29 adult femalescollected in 1993 for which ovaries were examined, 46 CLP resulted in 44 viable, implanted fetuses. Of the 27 adults collected in 1994, 45 CLP resulted in 43 viable, implanted fetuses.

Estimated breeding and parturition dates were similar in both years. Ages of fetuses in 1993 indicate that breeding occurred between 23 November and 30 December, with a median date of 6 December. In 1994, breeding occurred between 28 November and 14 December, with a median date 7 December. Predicted parturition for deer examined in 1993 ranged from mid-June to mid-July; the median was 2 July. In 1994, predicted parturition ranged from 20 June to 7 July; the median was 28 June.

Table 1. Frequency of fetuses in adult Rocky Mountain mule deer collected from the West Walker deer herd winter range in March 1993 and March 1994, Mono County, California and Douglas County, Nevada. LAV = Little Antelope Valley, ES = East Side, TL = Topaz Lake.

	No. of does with litter size of				Total no. of	Total no. of	Mean fetuses	Mean. fetuses/ pregnant
Location	0	1	2	3	fetuses	does	per doe	doe
1993								
LAV	0	4	6	0	16	10	1.60 ± 0.52	1.60 ± 0.52
ES	3	1	5	1	14	10	1.40 ± 1.07	2.00 ± 0.58
TL	1	2	6	0	14	9	1.55 ± 0.72	1.75 ± 0.46
1994								
LAV	0	2	7	0	16	9	1.77 ± 0.44	1.77 ± 0.44
ES	2	2	5	0	12	9	1.33 ± 0.86	1.71 ± 0.49
TL	1	1	7	0	15	9	1.67 ± 0.79	1.88 ± 0.35

Deer were in better condition in 1994 than in 1993 (Table 2). Mean BCW of adult females (44.5 kg in 1993 and 50.9kg in 1994) differed between years (F = 13.79; 1, 54 df; $P < 0.001$); however, mean BCW did not differ among collection areas (F = 0.170; 2, 53 df; $P = 0.193$), and year by area interaction was not significant (F = 0.360; 1, 54 df; $P = 0.700$). Eviscerated carcass weights of adult females followed a similar trend, differing between years (F = 25.57; 1, 54 df; $P < 0.001$), but not among collection areas ($F = 2.05$; 2, 53 df; $P = 0.141$); year by area interaction also was not significant (F = 0.095; 1, 54 df; $P = 0.910$). Mean KFI was significantly lower in 1993 (9.3%) than in 1994 (36.0%) (F = 29.53; 1, 54 df; $P < 0.001$), but did not differ among the three collection areas (F = 0.939; 2, 53 df; $P = 0.399$); year by area interaction was not significant (F = 0.124; 1, 54 df; $P = 0.884$).

West Walker females produced more male than female fetuses. However, the overall sex ratio of fetuses, 1.07:1.00 in favor of males (45 males:42 females), was not significantly different from unity (Z = -0.21, $P = 0.83$) (Table 3). Single fetuses were present in 12 of 49 pregnant females, 36 carried twins, and one had triplets (Table 1). Among the 12 litters of singletons, four fetuses were male and eight were female. Among the 36 sets of twins, 18 were of mixed sex, 9 were twin females, and 9 were twin males. These frequencies of sex ratio categories were not different from random expectation ($\chi^2 = 4.5$, 2 df, $P = 0.105$). Sex ratios of fetuses in 1993 and 1994 did not differ ($\chi^2 = 0.57$, 1 df, $P = 0.451$). Overall, sex ratio categories did not differ among collection areas ($\chi^2 = 5.28$, 2 df, $P = 0.072$), but in 1994 LAV and TL females produced significantly more male fetuses than did ES females ($\chi^2 = 11.3$, 2 df, $P = 0.004$) (Table 3). I found no relationship between litter category and maternal age (F = 1.55; 5, 43 df; $P = 0.208$), nor between litter category and BCW ($F = 1.61$; 5, 43 df; $P = 0.178$), ECW (F = 0.846; 5, 43 df; $P = 0.52$) and KFI (F = 1.63; 5, 43 df; $P = 0.173$).

Table 2. Mean bled carcass weight (BCW), eviscerated carcass weight (ECW), and kidney fat index (KFI) for 56 adult female Rocky Mountain mule deer collected on the West Walker deer herd winter range in March 1993 and March 1994, Mono County, California and Douglas County, Nevada. LAV = Little Antelope Valley, ES = East Side, TL = Topaz Lake.

		BCW (kg)		ECW (kg)		KFI (%)	
Location	n	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1993							
LAV	10	44.1	4.52	31.0	3.28	7.2	3.05
ES	10	42.6	5.07	30.2	2.64	9.2	5.88
TL	9	47.1	7.57	34.1	5.04	11.4	9.09
Total	29	44.5	5.90	31.7	3.97	9.3	6.38
1994							
LAV	9	49.7	3.82	35.7	2.24	45.4	27.22
ES	9	51.0	6.16	36.8	4.47	32.2	24.05
TL	9	52.1	4.39	38.6	4.08	30.4	10.72
Total	27	50.9	4.75	37.0	3.79	36.0	22.09

Table 3. Sex of fetuses from 49 adult female Rocky Mountain mule deer collected on the West Walker deer herd winter range in March 1993 and March 1994, Mono County, California and Douglas County, Nevada. LAV = Little Antelope Valley, ES = East Side, TL = Topaz Lake.

Location	Male (N)	Female (N)	% Male
1993			
LAV	7	9	43.7
ES	7	7	50.0
TL	7	7	50.0
Total	21	23	47.7
1994			
LAV	10	6	62.5
ES	2	10	16.6
TL	12	3	80.0
Total	24	19	55.8

DISCUSSION

Reproductive rates observed during this study were similar to those reported by Bischoff (1958), Jordan[5] (1967), and Kucera[1] (1988) for other central Sierra Nevada mule deer populations. I detected no significant differences in measures of reproduction between years, despite significant increases in measures of body condition in 1994. Fetal rates during this study were 1.52 fetuses/doe in 1993 and 1.56 fetuses/doe in 1994; mean KFI's increased from 9% in 1993 to 36% in 1994.

[5] Jordan, P.A. 1967. Ecology of migratory deer in the San Joaquin River drainage. Ph.D. Dissertation, University of California, Berkeley, California, USA.

ı the eastern Sierra Nevada, Taylor[6] (1991) documented reproductive rates on two ıule deer winter ranges of 1.88 and 1.93 fetuses/doe when KFI's averaged 32% and 5%, respectively. Kucera[1] (1988) found low reproductive rates 1.06-1.42 fetuses/female) among mule deer when mean KFI's averaged 10-27%; a igher reproductive rate (1.88 fetuses/female) was observed with mean KFI >60%. 'aylor[7] (1988) reported that mule deer from the CasaDiablo herd had reproductive ates of 1.74 and 1.70 fetuses/doe when KFI's averaged 41% and 37%, respectively. 'hese incongruous data suggest that KFI may not be an accurate basis for determining ıe effects of nutritional status on deer productivity when comparing disparate opulations.

I surmise that increases in deer condition during 1994 were largely due to the wet ʻinter of 1992-93, which enhanced forage production during the spring and summer f 1993, and increased forage availability during the winter of 1993-94. Kucera[1] (1988) eported large increases in forage production on two mule deer winter ranges in the astern Sierra Nevada following winters of heavy precipitation, which in turn were ıirrored by high measures of condition and reproduction. In contrast, my findings ıdicate that deer productivity in 1994 was not measurably affected by significant ıcreases in body condition. Following the winter of 1992-93, deer may have so xhausted their body reserves that they were not able to attain the threshold of body ondition necessary to enhance their reproductive potential, despite greater forage vailability during spring and summer 1993. In years of high forage availability that ɔllow extreme winters, it may not be possible for some deer to achieve enhanced eproductive performance.

The cumulative effects of drought on summer range forage production presumably ad a major influence on deer reproduction in 1993. Of 29 adult females, three were ʻithout corpora lutea and seven had one corpus luteum each for an ovulation rate of .59 CLP per female. This low ovulation rate indicated that summer ranges occupied y WW deer were of poor nutritional quality and, presumably, were inadequate to llow female deer to achieve peak body condition prior to the breeding season. Short 1981) surmised that when summer ranges provide low quality forage because of rought or other factors, the high metabolic requirements of females are not met and equirements for reproduction are not satisfied. Bertram[8] (1984) reported a pronounced ecline in reproductive potential among female mule deer collected from the North Kings herd following the dry spring, summer, and fall of 1977. Several other esearchers (Robinette et al. 1955, Swank 1958, Taberand Dasmann 1958, Julander t al. 1961) determined that summer forage nutrition influenced ovulation rates and the umber of fetuses produced per female.

Taylor, T.J. 1991. Ecology and productivity of two interstate deer herds in the eastern Sierra Nevada: East Walker-Mono Lake deer herd study. California Department of Fish and Game, Bishop, California, USA.

Taylor, T.J. 1988. The Casa Diablo deer herd: Reproduction and condition 1987-1988. Casa Diablo deer herd study. California Department of Fish and Game, Bishop, California, USA.

Bertram, R.C. 1984. The North Kings deer herd study. California Department of Fish and Game, Fresno, California, USA.

Mean KFI of 9% observed in March 1993 is similar to values reported by Kucera[1] (1988) and Anderson et al. (1972) for other nutritionally stressed mule deer populations. KFI values <15% indicate essentially no fat, and represent the point when animals begin to mobilize femur marrow fat for energy (Ransom 1965, Pojar and Reed 1974, Kie et al. 1983). Animal condition, as indexed by KFI and BCW, was lowest following the severe winter of 1992-93, when snow accumulations on primary winter ranges (1,700 m elevation) totaled 180 cm and lasted from 7 December to 3 March. This prolonged snow cover buried sources of forage and, when coupled with persistent low temperatures, resulted in widespread starvation (T.J. Taylor, unpubl. data) and decreased maternal nutrition and productivity among surviving females. Severe winters have been associated with declines in deer condition and productivity (Leach 1956, Gilbert et al. 1970, Gill 1972, Hall[9] 1973, Wallmo et al. 1977). During a severe winter, net productivity is influenced not only by deer lost to starvation, but also by the poor condition of surviving females, a situation that results in high postnatal fawn losses (Robinette 1976).

The preponderance of males produced by ES and TL deer sampled in 1994 may be the result of small sample sizes that can result in unusual sex ratios (Thomas et al. 1989). Although Robinette et al. (1957) found that mule deer on poor range produced more male fawns, my results do not suggest a male-biased sex ratio in the nutritionally stressed WW mule deer herd.

Reproductive potential in the WW deer herd during 1993 and 1994 was comparable to that reported for other nutritionally stressed mule deer populations throughout the western United States (Anderson et al. 1972, Kucera[1] 1988). This low productivity was likely in response to drought-induced changes in habitat quality, which was compounded by severe winter conditions in 1992-93. During periods of drought, the first step managers should take to maintain deer herd productivity is to increase the quality of the food supply. Therefore, I recommend management practices on WW herd winter ranges and holding areas that promote and ensure access to late season growth of succulent forage on irrigated pasture. Garrott et al. (1987) found that mule deer in northwest Colorado made extensive use of agricultural meadows during autumn; such areas provided deer with succulent forage at a time when the nutritional quality of summer and winter range vegetation was declining because of plant senescence. Hence, Garrott et al. (1987) recommended irrigation and fertilization programs designed to retain succulent forage late into the growing season and restrictions on livestock grazing to avoid competition during periods of heavy deer use. Similar pasture management on WW herd winter ranges and holding areas might enhance deer productivity by sustaining animal condition during periods of drought.

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[9] Hall, W.K. 1973. Natality and mortality of white-tailed deer in Camp Wainwright, Alberta. M.S. Thesis, University of Calgary, Alberta, Canada.

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FIGURES: Consider proportions of figures in relation to the usable page size of *California Fish and Game* (117 x 186 mm). Figures, including captions, cannot exceed this size. Figures and line-drawings should be clear, with well-defined lines and lettering. Lettering style should be the same throughout and large enough to be readable when reduced to finished size. Type figure captions on a separate page. High-quality photographs with strong contrast are acceptable and should be submitted on glossy paper. On the back and top of each figure or photograph, lightly write the figure number and senior author's last name. Be prepared to provide high-quality, scannable, original figures or graphics files on diskette with the final accepted manuscript.

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