Factors Influencing Productivity of Two Mule Deer Herds in Utah

JORDAN C. PEDERSON AND K. T. HARPER

Highlight: Doe-fawn counts show that the mule deer herd on the LaSal Mountains of southeastern Utah produced over 38% more fawns per doe than the Henry Mountain herd over a 9-year period. Carcass weights of animals from the LaSal herd were generally greater for all age classes. Observed reproductive differences appear to be unrelated to the incidence of diseases, parasites, or predation. Furthermore, winter ranges are nearly equal in forage quantity and quality on the two ranges. Summer range vegetation on the LaSal Mountains, however, produced more forage of better quality than did similar community types on the Henry Mountains. LaSal summer ranges produced 2,149 kg/ha fresh weight of available forage while similar ranges on the Henrys produced only 1,314 kg/ha. Forbs account for 52% of the forage on LaSal summer ranges but only 12% of the forage on ranges of comparable elevation on the Henrys. The data suggest that the characteristics of the forage found on the summer range, especially the quantity and quality of forbs, exert important influences on productivity of these herds.

During the 1950's, Utah experienced high populations of mule deer (*Odocoileus hemionus*), and a general deterioration of habitat results. In an attempt to correct this condition, the Utah State Division of Wildlife Resources and federal land management agencies embarked on a program to reduce mule deer and livestock numbers to the carrying capacity of the range. Management tools implemented to reduce deer numbers included building access roads, issuing permits for special hunts, and extending hunting seasons. The effect of that program on herd size varied by herd unit. Some herds maintained a high reproductive rate and special controls are still being used to keep such herds in balance with their ranges. Other herds have not responded to reduced hunting pressure; production of fawns appears to be low and herd size has remained static. Because of such apparent differences in productivity, this study was initiated to quantify reproductive differences between two herds and identify factors that might be responsible for observed differences.

The LaSal and Henry Mountain deer herds were selected for their apparent differences in fawn production. Both areas are geologically similar, and each is an isolated mountain system rising from the surrounding desert. There is little movement of deer into or out of either herd unit. Research objectives were to determine: (1) fawn production for the two herds; (2) carcass weight by age-class for the herds; and (3) factors responsible for any differences observed.

Authors are wildlife biologist, Utah Division of Wildlife Resources, Springville 84663; and professor, Botany and Range Science, Brigham Young University, Provo, Utah 84602.

Vegetation data used in this study were obtained with funds provided by Federal Aid Project W-65-R and the Utah Division of Wildlife Resources. Appreciation is extended to numerous professional colleagues whose expertise helped to make this study possible.

Manuscript received August 8, 1977.

Pertinent Literature

Nutritional status of does at critical periods during the year has been found to have an effect on deer productivity. Julander et al. (1961) stated that "successful breeding depends largely upon thrifty condition of the deer at rutting time." Longhurst et al. (1952) noted: "Rate of ovulation seems to be strongly affected by the level of nutrition just prior to and during the rut."

The diet of the doe during the time of gestation has been found to have an effect upon the size of the newborn fawns (Verme 1963). Verme also found the survival of fawns to be closely related to their size at parturition. In late winter, a doe reaches her lowest nutritional ebb (Hagen 1953). Wood (1962) found that in Idaho "the primary cause of high early fawn loss . . . (was) poor doe condition during parturition." Yoakum (1965) reported that "fawns born of does that are in poor condition will often be in poor condition when dropped and handicapped for survival. Under such austere conditions fawns do not live past their first week."

After giving birth to her young, the doe has a new energy demand placed upon her, that of lactation. Verme (1962) believed that "undernourished does delay milk production or fail to produce milk." If a herd is to increase rapidly, the production of twins is essential, and, according to Yoakum (1965), "does on poor range often cannot give enough milk for twin fawns."

Deer weights show a correlation with quantity and quality of food available (Hosley 1956). The size of deer of the same age and sex will vary in response to quality and quantity of forage available to the herd during the year (Severinghaus and Cheatum 1956). According to Swank (1958), mature body size is affected by diet from birth to 5 or 6 years of age. Any shortage of food during this period will result in smaller body size. Murphy and Coates (1966) showed that a reduction of protein content in the diet reduced body weight and chest girth.

Study Areas

The study areas are located in southeastern Utah (Fig. 1). The LaSal Mountains are located east of Moab in Grand and San Juan counties. The Henry Mountains are south of Hanksville in Wayne and Garfield counties. The two areas are about 117 km apart. Both are laccolithic mountains of similar geologic age (Butler 1920; Hunt et al. 1953). Precipitation averages somewhat higher (about 10%) on the LaSals than the Henrys for comparable vegetation zones (Pederson 1970).

The LaSal herd unit encompasses approximately 221,374 ha. The highest point on the LaSals is Mount Peale at 3,876 m elevation. The Henry Mountain area includes approximately 72,886 ha; the highest point on the range is Mount Ellen at 3,500 m.

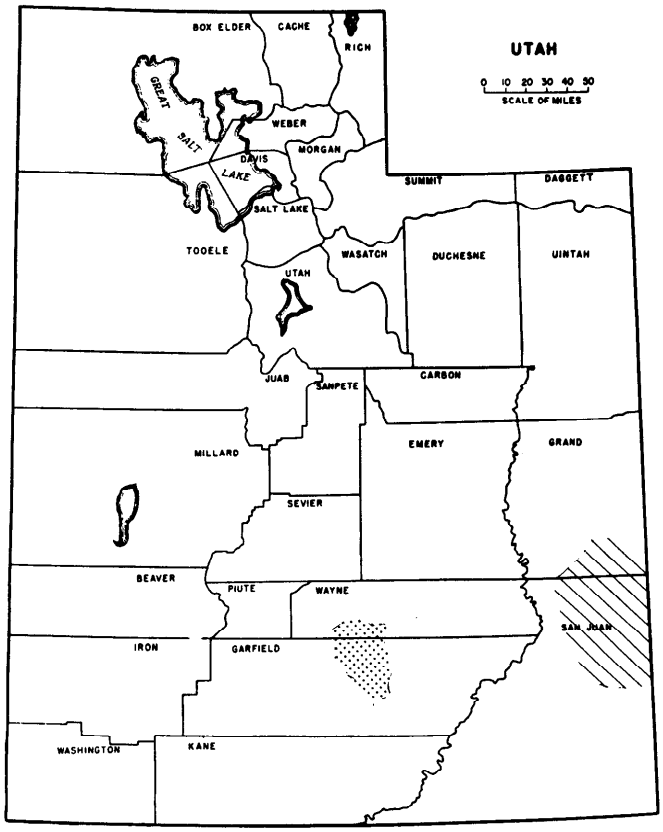

Fig. 1. *Location of study areas: outlined areas designate the Henry (left) and LaSal Mountains (right).*

Methods and Procedures

To determine population structure, hunter kills were aged by the tooth replacement and wear method (Robinette et al. 1957). Preseason sex ratio and fawn/doe counts were made over a 9-year period starting on September 15 and running to the day prior to the opening of hunting season (approximately October 20). Special attention was given to single and multiple fawns. Observations were made along the same routes each year. All counts were made by the senior author except those for the 1972–75 period on the Henrys.

Mortality was ascribed to the following causes: winter loss, predation, illegal kill, disease, and parasites. Hunter harvest was also considered, being divided into hunter kills and wounding loss. Winter loss, predator kills, and illegal kills were looked for whenever field work was conducted on an area. Nineteen deer were taken for intensive necropsy during April and May of 1968 and 1969. Blood from those animals was tested for Rocky Mountain spotted fever, tularemia, brucellosis, Q fever, and plague. Fetal counts were made on all does collected.

Hunter harvest data were obtained from the Utah Division of Wildlife Resources annual big game harvest questionnaire sent to license holders at the conclusion of each hunting season. We estimated wounding loss to be 15% of legal hunter harvest following Robinette and Olsen (1944). Deer weights were taken in hunting camps on each mountain during the regular hunts of 1967–1969.

Major vegetational studies were conducted between June and August 1967. Summer forb production was measured in July 1967–69. An average of 200 m of transect was sampled per vegetation type on each mountain range. Cover of woody plants was obtained from canopy intercept along a steel tape stretched taut along each transect. Herb and browse production were estimated in plots that paralleled the full length of each transect. Herb estimating plots were 30 cm and browse plots were 1.3 m wide. For convenience, estimates were made in 3-m segments along both herb and browse transects.

A forage palatability index (FPI) was computed for each vegetational type. A palatability rating was assigned to each species (e.g., 1=poor, 2=fair, 3=good). Ratings for all major species are reported in Pederson (1970). The rating value for each species was multiplied by the relative contribution of that species in total production. These composite values were summarized for all species in each vegetative type and divided by 100 to produce the FPI. FPI values were calculated separately for grasses, forbs, and shrubs in each vegetative type. The higher the FPI, the better the palatability of forage for that type.

During summer, 1967, a pellet-group transect (Julander et al. 1962) consisting of 100 plots, each 9.3 m^2, was examined along each vegetative transect to establish use of range types by livestock and big game. In addition, permanent pellet-group transects on winter ranges were used to help determine deer numbers and range use.

Differences between herd and range parameters on the two mountain ranges were tested for significance wherever possible. Differences were analyzed using a *t*-test designed for independent samples (Snedecor and Cochran 1967).

Results

Reproduction and Growth

Reproduction

For the 9 years of record, the average productivity of the LaSal herd was about 38% greater than that of the Henrys (Table 1). Differences between herds were consistent in all years. With about 84 fawns per 100 does, the LaSal herd is somewhat more productive than the average herd in Utah and the average herd in the Southeast Region, where the LaSal and Henry mountains occur. The Henry Mountain herd was far below average productivity for both the region and the state. Over half (52%) of the does on the Henry Mountains were judged to be barren during the period (1967–1969; only 31% were so judged on the LaSals (Pederson 1970). These figures include the yearling age-class. An average of 26% of the does on the LaSals were accompanied by twins just prior to the October hunting season

Table 1. Nine years of herd productivity as determined from doe:fawn counts taken in autumn just prior to the October hunting season. Sample size is shown in parentheses (doe/fawn).

	Fawns per 100 does									
	Year									
Herd unit	1967	1968	1969	1970	1971	1972	1973	1974	1975	Average
LaSal Mountains	(194) 96(187)	(104) 94(98)	(62) 89(55)	(151) 91(138)	(146) 75(101)	(329) 73(242)	(191) 95(183)	(280) 73(205)	(170) 75(124)	84.3
Henry Mountains	(155) 63(98)	(114) 48(55)	(134) 63(85)	(105) 61(64)	(108) 73(79)	(148) 56(84)	(94) 70(66)	(123) 53(66)	(60) 65(92)	61.3
Southeast region	83	79	77	87	84	74	71	74	79	78.6
State average	83	83	81	83	84	75	71	75	73	78.6

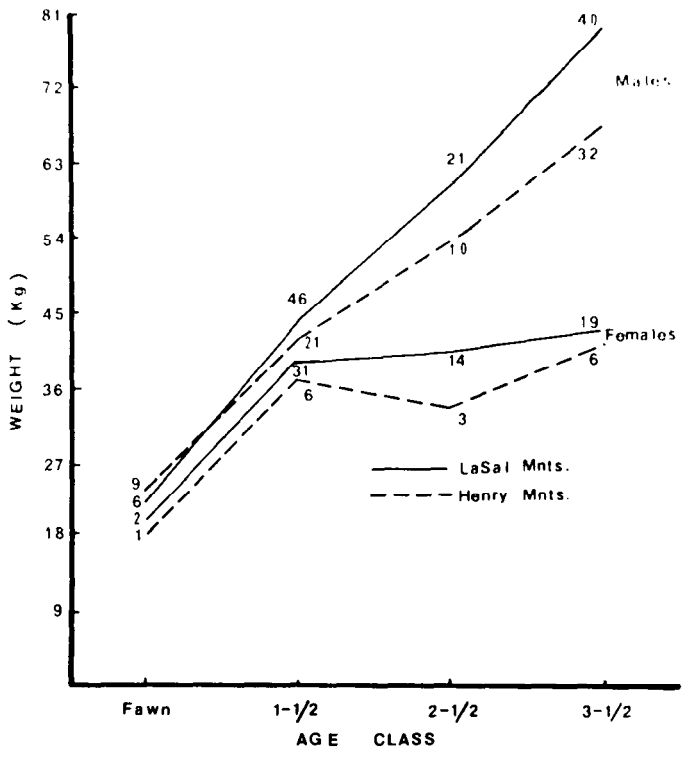

Fig. 2. *Age-eviserated body weight relationships for male and female deer of various age classes from the LaSal and Henry Mountain levels. Numbers along each curve indicate the number of animals weighed to produce the average value plotted for each sex and age class. Weights were taken during October in both areas.*

during the 1967–69 period, but only 11% of the does on the Henrys had twins during that period (Pederson 1970).

Supplementary reproduction data were obtained from does taken for necropsy. Those data show a 2.0:1 fetus/doe ratio from the LaSal Mountain herd and a 1.6:1 ratio from the Henry Mountain herd. Although the sample was small (5 does per mountain range), the trend is in the same direction as the autumn fawn/doe counts.

Body Condition

During the hunting seasons 1967–69, a total of 190 animals from the LaSal area and 82 from the Henry Mountain herd were weighed (Fig. 2). Where 6 or more weights were obtained per age-class for each herd, weight differences between herds were tested for significance. The LaSal deer were significantly heavier in the 2½ and 3½ age-classes for male animals. In the fawn and yearling age-classes, observed differences were not statistically significant.

The decline in body weight of does on the Henry Mountains (Fig. 2) between the 1½ (N = 6) and 2½ (N = 3) age-classes was unexpected and may be an artifact of a small sample. Nevertheless the majority of the does on the Henrys appear to mature their first fawn while they are in the 2½ year age-class, and poor range conditions may contribute to severely depleted body reserves of young nursing mothers. Fawns from the Henrys are almost as large as fawns from the LaSals, but it should be noted that 64% of the fawns are singles on the Henrys while singles account for only 40% of the fawns on the LaSals. LaSal does thus support more twins and still produce larger fawns on the average than Henry Mountain does.

Health and Mortality

Diseases and Parasites

A total of 19 deer (11 from the LaSals and 8 from the Henrys) were taken for detailed necropsy analysis. Blood of all animals tested negative for plague, brucellosis, tularemia, Rocky Mountain spotted fever, and Q fever. Eight parasites (5 ecto- and 3 endo-) and a nonmalignant skin tumor were observed on the animals sampled (Pederson 1970). Seven of the parasites were found on animals from both areas. Cattle lice (*Linognathus* spp.) were present on animals from the LaSal herd only. Although there are minor variations in percentage of animals infected by various parasites in the two herds, the differences do not appear to be significant.

Winter Mortality

Winter losses of deer on both areas were observed at the time vegetative transects were run, each spring when the browse transects were evaluated, and at other times as we travelled over the areas. During the years of this study, 5 possible winter losses were found on the Henrys and 7 on the LaSals. Since approximately 15 man-days per year were spent on the winter ranges of each mountain range, there is little likelihood that any major winter losses were missed.

Table 2. Harvest data (averages) for the LaSal and Henry Mountain deer herds for the period 1965–1974. Data were extracted from the Big Game Harvest Reports (1965–1974) of the Utah Division of Wildlife Resources. Animals harvested per unit area are reported in terms of area of summer range, since the limits of winter range were set by arbitrary boundary lines and not by deer use.

	Average for site	
	LaSal Mountains	Henry Mountains
No. of hunters	3.886	252
Total kill	2,554	122
% hunter success	66	48
No. hunters/km²	8.0	4.0
No. deer harvested/km²	5.2	1.9

Hunter Harvest

Harvest data (Table 2) demonstrate greater hunting pressure and greater hunter success on the LaSals as opposed to the Henry Mountains. There was almost 40% greater success per unit effort of hunters on the LaSals as opposed to the Henrys. The high hunter success on the LaSals during the period 1965–74 has been maintained despite preseason hunts, either-sex hunts, and female-only extra permits. During the same period, the Henrys have received only short season hunts, buck-only hunts and, in recent years, closed seasons and yet have shown no significant improvement in hunter harvest or fawn production.

Other Mortality Factors

Other factors affecting mortality include predation, kills by vehicles, entanglement in fences, fights, falls, and illegal kills. From extensive experience on the two mountain ranges, we do not consider any of these variables to differ significantly between ranges but quantitative data are lacking.

Vegetation

On the LaSals, 2,942 m of transect were analyzed to determine composition and production of summer range vegetation. A total of 3,883 m of transect was evaluated on the summer range of the Henry Mountains. The difference in actual length of transect was due to the greater density and number of species of

plants on the LaSals; transects there required more sampling time. A summary of the range types and their area and production on the two mountain ranges appears in Tables 3 and 4.

As shown in Table 3, the proportion of major vegetative types is quite similar on the winter ranges of the two mountain systems. The apparent difference in desert shrub vegetation is an artifact of the method of delineation of the sample area. Desert shrub vegetation extends far beyond the boundary used to delimit the Henry Mountain area.

Table 3. Aerial extent of the major vegetative complexes encountered on the LaSal and Henry Mountains.

	LaSal Mountains		Henry Mountains	
Vegetation complex	Total area (ha)	%	Total area (ha)	%
Winter range				
Desert shrub	35,510	21	8,236	12
Pinyon-juniper-sage	106,502	61	47,884	72
Mountain brush	22,948	13	8,962	13
Reseeded and agricultural	7,796	5	1,534	3
Total	172,756	100	66,616	100
Summer range				
Mountain brush	14,323	29	3,445	55
Ponderosa-mountain brush	12,277	25	1,373	22
Conifer-aspen	21,212	44	1,297	20
Rock	806	2	155	3
Total	48,618	100	6,270	100

In contrast, summer ranges differ widely in composition on these mountains. In relative terms, the mountain brush zone is larger and the conifer-aspen zone is smaller on the Henry Mountains (Table 3). The conifer-aspen zone is especially important as a source of succulent forage in the late summer in this region (Julander et al. 1961).

In respect to forage production, both winter and summer ranges are more productive on the LaSals than the Henrys (Table 4). LaSal winter and summer ranges are 23 and 64%, respectively, more productive than similar ranges on the Henry Mountains.

It should be noted too that the forb/shrub ratio differs widely on these mountains. For LaSal summer ranges, the forb/shrub ratio is about 2/1; on the Henrys the ratio is 1/6 (see Table 4). Composition of forage on the winter ranges differs far less than on the summer ranges of the two areas.

Forage palatability is another important parameter in range evaluation. Forage palatability indices are reported for winter and summer range in Table 5. Overall winter forage palatability is somewhat higher on the Henry Mountains, but the situation is reversed on summer ranges. Not only are LaSal summer ranges more productive, but their forage palatability (particularly for forbs) is superior to that of the Henrys. Pederson (1970) reported greater species diversity for the LaSals than the Henrys (270 versus 176 species). Most of the enrichment in species diversity on the LaSals is contributed by forbs.

Pederson (1970) has shown that forb production was consistently higher on LaSal summer ranges than on the Henrys in the 1967–69 growing seasons. Year to year variation in forb production on the summer ranges was positively correlated with precipitation in the growing season.

The 9-year trend for utilization of browse on four winter-range transects on each mountain (Table 6) shows browse to be utilized more heavily on the LaSal than the Henry Mountains. Although the precipitation is lower on the Henry Mountains, average twig length usually is longer than for the same species on LaSal winter ranges. This apparently indicates better species vigor on Henry Mountain ranges.

Table 4. Annual production of "available" forage in the various vegetational complexes on the two mountain ranges. Averages reported are weighted to show the value for the entire winter or summer range complex.

Vegetative complex	Forage production[1] (kg/ha)	Percent contributed by Grasses	Forbs	Shrubs
Winter range				
LaSal Mountains				
Desert shrub	675	10	14	76
Pinyon-juniper-sage	1,072	17	17	66
Mountain brush	3,328	19	18	63
Weighted average	1,300	17	17	66
Henry Mountains				
Desert shrub	407	15	2	83
Pinyon-juniper-sage	1,254	17	5	78
Mountain brush	609	28	5	67
Weighted average	1,058	18	5	77
Summer range				
LaSal Mountains				
Mountain brush	2,003	17	67	16
Ponderosa-mountain brush	1,064	23	44	33
Conifer-aspen	2,868	21	47	32
Weighted average	2,149	21	52	27
Henry Mountains				
Mountain brush	1,522	14	12	74
Ponderosa-mountain brush	1,232	16	15	69
Conifer-aspen	850	3	8	89
Weighted average	1,314	13	12	75

[1] Forage weights shown are fresh weight during the height of the growing season. Air-dry weight is approximately 40% of the figures shown.

Discussion

Our search for possible causes of the observed differences in reproductive rate between the LaSal and Henry Mountain deer herds has not offered support for hypotheses that disease, parasites, or predators are responsible. Likewise the evidence suggests that harvest rates are not responsible. Winter range differences also seem inadequate to account for the greater reproductive rate of the LaSal herd. Although Henry Mountain winter ranges are somewhat drier and less productive [about 20% less yield than on the LaSal Mountains (Table 4)], forage quality (Table 5) and plant vigor (Table 6) actually appear to be slightly better than on the LaSals. Deer use of winter ranges (Table 6) also seems to be lighter on the Henrys as opposed to the LaSals.

In contrast with the foregoing variables, summer range conditions differ markedly between these mountain ranges.

Table 5. Forage palatability indices (FPI) for the winter and summer ranges.

	Forage palatability index (FPI)[1]			
Type	Grass	Forbs	Browse	Total vegetation
LaSal Mountains				
Winter ranges	1.92	1.45	1.99	1.89
Summer ranges	1.00	1.94	1.59	1.64
Henry Mountains				
Winter ranges	1.74	1.50	1.98	1.91
Summer ranges	1.00	1.68	1.48	1.44

[1] Values reported are the average for all vegetative types. The total vegetation FPI is not a simple average of that for grasses, forbs, or shrubs, because the index is weighed by production of each group.

Table 6. Deer utilization of browse as determined from transects on winter ranges of the two study areas. Data for all transects are averaged for the 9-year period, 1967–1975. The browse species analyzed on each transect is noted in parentheses.

	% Utilization	Average twig length (cm)	Deer days use/ha
LaSal Mountain transects			
Pine Ridge (Putr)[1]	39	6.3	40
Amasa's Back (Cemo)[1]	35	6.3	37
Brumley Ridge (Cost)[1]	68	9.0	99
Melroy Ridge (Putr)[1]	34	5.5	54
Henry Mountain transects			
Horn Mountain (Cemo)[1]	16	9.7	22
Horn Mountain (Putr)[1]	20	8.3	17
Side Hill (Cemo)[1]	9	8.3	35
Bull Mountain (Putr)[1]	4	4.8	5

[1] Cemo = *Cercocarpus montanus;* Cost = *Cowania stansburiana;* Putr = *Purshia tridentata.*

Table 7. Average content (%) of nitrogen and phosphorus in five major forage species[1] in each of three plant lifeform categories on the LaSal and Henry Mountains.

	Nitrogen	Phosphorus
Grasses		
LaSal Mountain	1.50^a	0.13^{a2}
Henry Mountain	1.09^b	0.22^a
Forbs		
LaSal Mountain	1.77^a	0.18^a
Henry Mountain	1.87^a	0.19^a
Shrubs		
LaSal Mountain	2.16^a	0.19^a
Henry Mountain	1.54^b	0.19^a

[1] All of the aboveground tissue of herbs and current year growth (i.e., leaves and annual twig growth of shrubs) was taken in late July 1976.

[2] Superscript letters indicate significance of difference ($P<0.05$ or better) of averages for a specific plant lifeform nutrient element between mountain ranges. Pooled averages that differ significantly have different superscripts.

LaSal summer ranges produce over 60% more herbage per unit area on the average than Henry Mountain summer ranges (Table 4). The composition of summer range forage is dramatically different on the two mountains. Forage on the LaSal ranges is composed of over 50% forbs; the comparable figure for the Henrys is 12%. LaSal summer ranges produce 1,117 kg/ha of fresh weight forbs per year while Henry Mountain ranges produce only 158 kg/ha. Thus, LaSal summer ranges provide over seven times more forb biomass per unit area than comparable ranges on the Henrys.

As mule deer are known to feed heavily on forbs during the summer season (Kufeld et al. 1973), the striking difference in forb production on the two mountains deserves further consideration. Studies on other ranges demonstrate that forbs are good sources of nitrogen, calcium, phosphorus, potassium, carotene, and energy (Stoddart and Greaves 1942; Cook and Harris 1950; Dietz et al. 1962; Cook 1972; and Harner and Harper 1973). Chemical analysis of major grasses, forbs, and shrubs on the LaSal and Henry Mountain summer ranges substantiate those results for nitrogen and phosphorus (Table 7).

Since the vegetation of the Henrys is dominated by shrubs (Table 4), mule deer probably turn to these plants for a significant portion of their summer forage needs. Shrubs are known to be low in digestible energy (Cook 1972; Wallmo et al. 1977), and does feeding on shrubs are likely to have difficulty meeting the energy demands of daily maintenance, lactation, and weight gains required to compensate for winter losses. Cook's (1972) data suggest that stress will be most severe in late summer. Data presented by Wallmo et al. (1977) implied that mature animals that do not gain weight in the summer will not survive the winter in regions where the winter diet is dominated by shrubs. They concluded that Colorado mule deer feeding on browse in the winter experience a dietary energy deficiency which can only be compensated by the intake of more digestible herbaceous forage in the summer.

The shrub-dominated forage of the Henry Mountain summer ranges also may be deficient in protein (Table 7). A recent experimental study of the effects of dietary protein on mule deer productivity has been reported by Robinette et al. (1973). They concluded that diets that were rich in protein resulted in larger body size and a large increase in reproductive rate.

Swank (1956) concluded that mule deer populations in Arizona are largest where deer spend the summer in open ponderosa pine forests with a heavy understory of herbaceous material. Dietz et al. (1962) stated that "a general decline in the quality of summer range would almost certainly be reflected by a corresponding decline in numbers and condition in the associated deer herd."

All of the foregoing studies and data from our study area support our hypothesis that summer range conditions are related to the greater productivity of mule deer on the LaSal Mountains. Before more firm conclusions can be drawn as to the cause(s) of the reproductive differences observed, seasonal dietary studies are needed. Ideally, one would like to know the average dietary intake of a doe in each of these herds and the reproductive consequences of that diet.

Currently we have no firm evidence concerning the origin of the reproductive differences observed in autumn counts of fawns/100 does on the two mountain ranges. We are unable to say whether the observed differences arise from differentials in conception rates or from fawn mortality or both. Future studies should attempt to determine the relative importance of conception rates and fawn mortality in producing the observed differences in productivity.

If summer range condition is an influential variable controlling herd productivity, management techniques for improving forage production and quality should be developed. Much evidence suggests that the relative importance of shrubs has increased through recent decades as a consequence of natural plant succession, overgrazing, and suppression of wildfires in the Intermountain West (Harper and McNulty 1977; West and Tueller 1972; Cottam 1961). Range improvement procedures capable of increasing forbs at the expense of shrubs on summer ranges include late autumn aerial seeding of adapted forbs under aspen and oak canopies, anchor chaining of decadent aspen groves and closed oak stands to induce stand regeneration (Plummer et al. 1968), and controlled fire in areas formerly dominated by aspen but now controlled by noncommercial quality conifers (Kleinman 1973).

Literature Cited

Butler, B. S., G. F. Laughlin, V. C. Hicks, and others. 1920. The ore deposits of Utah. Professional Paper III. U.S. Geological Survey, Government Printing Office, Washington, D.C.

Coles, F. H., and J. C. Pederson. 1968. Utah big game range inventory. Utah Div. Fish Game Pub. 68-2. 120 p.

Coles, F. H., and J. C. Pederson. 1969. Utah big game range inventory. Utah Div. Fish Game Pub. 69-2. 164 p.

Cook, C. W., and L. E. Harris. 1950. The nutritive value of range forage as affected by vegetation type, site, and stage of maturity. Utah Agr. Exp. Sta. Bull. 344:1-45.

Cook, C. W. 1972. Comparative nutritive values of forbs, grasses and shrubs. p. 303-310. *In:* C. M. McKell et al. (eds.) Wildland Shrubs—Their Biology and Utilization. U.S. Dep. Agr. Forest Serv., General Tech. Rep. INT-1.

Cottam, W. P. 1961. Our renewable wild lands: a challenge. University of Utah Press, Salt Lake City. 182 p.

Dietz, D. R., R. H. Udall, and L. E. Yeager. 1962. Chemical composition and digestibility by mule deer of selected forage species, Cache La Poudre Range, Colorado. Colorado Game and Fish Dep. Tech. Pub. No. 14. 89 p.

Hagen, H. L. 1953. Nutritive values for deer of some forage plants in the Sierra Nevada. California Fish Game. 39:163-175.

Harner, R. F., and K. T. Harper. 1973. Mineral composition of grassland species of the Eastern Great Basin in relation to stand productivity. Canadian J. of Bot. 51:2037-2046.

Harper, K. T., and M. McNulty. 1977. Some ecological consequences of aspen-to-conifer succession in central Utah. Unpublished manuscript.

Hosley, N. W. 1956. Management of the white-tailed deer in its environment. p. 187-260. *In:* W. P. Taylor (ed.) The Deer of North America. Stackpole Co., Harrisburg, Penn.

Hunt, C. B., P. Averitt, and R. L. Miller. 1953. Geology and geography of the Henry Mountains region, Utah. Geol. Surv. Prof. Pap. No. 228. 234 p.

Julander, O. 1937. Utilization of browse by wildlife. Trans. N. Amer. Wildlife Conf. 2:276-287.

Julander, O., W. L. Robinette, and D. A. Jones. 1961. Relation of summer range condition to mule deer herd productivity. J. Wildlife Manage. 25:54-60.

Julander, O., R. B. Ferguson, and J. E. Dealy. 1962. Measure of annual range use by signs. p. 102-108. *In:* U.S. Dep. Agr. Misc. Pub. No. 940. 172 p.

Kleinman, L. H. 1973. Community characteristics of six burned aspen-conifer sites and their related animal use. Unpublished Masters Thesis, Brigham Young Univeristy, Provo, Utah. 46 p.

Kufeld, R. C., O. C. Wallmo, and C. Feddema. 1973. Foods of the Rocky Mountain mule deer. U.S. Forest Serv. Res. Pap. RM-111. 31 p.

Longhurst, W. M., A. S. Leopold, and R. F. Dasmann. 1952. A survey of California deer herds, their ranges and management problems. California Dep. Fish Game Bull. No. 6.

Murphy, D. A., and J. A. Coates. 1966. Effects of dietary protein on deer. Trans. N. Amer. Wildlife Conf. 31:129-139.

Pederson, J. C. 1970. Productivity of mule deer on the LaSal and Henry Mountains of Utah. Utah State Div. Fish Game Pub. 70-2. 135 p.

Plummer, A. P., D. R. Christensen, and S. B. Monsen. 1968. Restoring big-game range in Utah. Utah Div. Fish Game Pub. 68-3:1-183.

Robinette, W. L., and O. A. Olsen. 1944. Studies of the productivity of mule deer in central Utah. Trans. N. Amer. Wildl. Conf. 9:156-161.

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

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

Severinghaus, C. W., and E. L. Cheatum. 1956. Life and times of the white-tailed deer. p. 57-186. *In:* Walter P. Taylor (ed.) The Deer of North America. Stackpole Co., Harrisburg, Penn.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods, 6th ed. Iowa State University Press, Ames. 593 p.

Stoddard, L. A., and J. E. Greaves. 1942. The composition of summer range plants in Utah. Utah Agr. Exp. Sta. Bull. 305:1-22.

Swank, W. G. 1956. Protein and phosphorus content of browse plants as an influence on southwestern deer herd levels. Trans. N. Amer. Wildl. Conf. 21:141-158.

Swank, W. G. 1958. The mule deer in Arizona chaparral. Arizona Game Fish Dep. Wildl. Bull. No. 3. 109 p.

Verme, L. J. 1962. Mortality of white-tailed deer fawns in relation to nutrition. Proc. Nat. Deer Dis. Symp. 1:15-38.

Verme, J. L. 1963. Effects of nutrition on growth of white-tailed deer fawns. Trans. N. Amer. Wildl. Conf. 38:431-442.

Wallmo, O. C., L. H. Carpenter, W. L. Regelin, R. B. Gill, and D. L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30:122-127.

West, N. E., and P. T. Tueller. 1972. Special approaches to studies of competition and succession in shrub communities. p. 165-171. *In:* C. M. McKell, J. P. Blaisdell, and J. R. Goodin, (eds.) Wildland Shrubs—Their Biology and Utilization. U.S. Dep. Agr., Forest Serv., General Tech. Rep. INT-1.

Wood, R. E. 1962. A productivity study of mule deer on the Middle Fork of the Salmon River, Idaho. Idaho Fish Game Dep. Fed. Aid Proj. W133R1. 35 p.

Yoakum, J. 1966. Life and death of deer herds. p. 11-19. *In:* Univ. California Agr. Ext. Serv. Deer Seminars. Agr. Ext. Serv., Univ. of California, Eureka. 39 p.