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The health of any wildlife population is a function of the quality of habitat, and the primary resource affecting habitat quality is often food. The balance between food availability and requirements is reflected in the nutritional condition of individuals within the population. Consequently, biologists routinely monitor condition indices such as body weight, fat reserves, blood chemistry, and reproductive rates as a means of assessing changes in habitat quality (Harder and Kirkpatrick, 1993). When food is limited, body weights and fat reserves decline, and reproductive performance, e.g. age of puberty, ovulation rate, birth weight, and recruitment of offspring, is negatively affected. To improve the nutritional status of game populations, wildlife managers can (1) increase the amount of food available to each individual by using harvests to reduce population size and intra-specific competition, or (2) increase the food resource through habitat manipulation (Caughley and Sinclair, 1994). Of these two options, the former is often preferred because it is easier and less costly.

This paper reports the results of a study conducted from 1991 to 1995 to assess the nutritional condition of white-tailed deer (*Odocoileus virginianus*) on Ft. Chaffee military base in western Arkansas. A baseline survey was conducted in 1991 because hunters and wildlife managers expressed concerns that resident deer were poorly nourished, as indicated by low body weights and poor antler development. We continued to monitor the nutritional condition of this population over the next 4 years to investigate whether nutritional indices improved after managers reduced the density of the population by increasing harvests and increased the quantity and quality of the food by improving habitat. The specific objectives were to (1) evaluate the age-structure of deer harvested between 1991 and 1995, (2) quantify the nutritional condition of the population before and during this deer management program, (3) survey the prevalence of common diseases in the population, and (4) estimate reproductive rates and the timing of reproduction.

Study Area.--This study was conducted on Ft. Chaffee, a 29,000 ha army base in western Arkansas. Prior to 1990, the Arkansas Game and Fish Commission (AGFC) had primary responsibility for wildlife management on the base. That responsibility shifted to the Department of Army (DoA) in 1990.

The topography of the area is diverse, ranging from low floodplains to gently sloping terraces, to hills with peaks near 300 m elevation. The climate is one of mild winters and warm summers. Mean rainfall is 107 cm with much of the precipitation falling in the spring. Winter is the driest month, but significant droughts often occur in July and August. Evaporation rates during these months can be as high as 1 cm per day (Cox et al., 1975). Soils in the valleys and low terraces are poorly drained, acidic, and low in natural fertility with a shallow fragipan that restricts the penetration of roots and slows the percolation of water. Hilltops and slopes contain soils which are well-drained, but shallow, droughty, and stony with low to moderate fertility (Cox et al., 1975).

Much of the land comprising Ft. Chaffee was cleared and used for pasture and hay crops during the first 4 decades of this century. Intensive farming and overgrazing severely depleted soil fertility by the time Ft. Chatfee was established in 1940. Much of this land has reverted to trees, particularly drought-tolerant oaks (*Quercus* spp.), hickories (*Carya* spp.), and pines (*Pinus* spp.) on the hills and ridges. Ash (*Fraxinus* spp.), maple (*Acer* spp.), and cottonwood (*Populus deltoides*) dominate bottomland forests. Forage and browse species are abundant, but are likely of poor quality. Summer droughts and a year-round schedule of military activities lead to frequent fires, creating a mosaic of open, early-successional fields interspersed with the forests (Sturdy et al., 1991).

Beginning in 1990, the DoA initiated an active program of habitat improvement for deer. Approximately 11,000 ha were scheduled for prescribed burning on a 3-year rotation (3,600 ha/yr) to improve soil fertility and maintain early-successional communities. Habitat was further improved by planting 80 ha of supplemental food plots each year in 0.25-0.5 ha plots. These contained mixes of clover, wheat, millet, milo, and lespedeza. In addition, all areas of pronounced soil disturbance due to military activities were re-seeded to legumes and grasses as conditions permitted (Sturdy et al. 1991).

The first managed deer hunt on Ft. Chaffee occurred in 1961 when the AGFC acquired a license to manage the wildlife resources. Initially, deer seasons on the base coincided with statewide seasons and were "antlered bucks only" hunts. These hunts are believed to have contributed to a sex ratio skewed heavily towards females by the late 1980's. The primary evidence for this is that adult females outnumbered adult males in annual spotlight counts by approximately 7 to 1 in 1990 and 1991 (unpubl. data, Environmental Branch, Ft. Chaffee). The perceived need to balance sex ratios in the herd led to limited "either-sex" hunts during 1988-1990, during which hunters using muzzleloaders were allowed to harvest females as well as males. Either-sex hunts were expanded to include all hunters using rifles or muzzleloaders in 1991.

Harvesting Deer and Condition Assessment.--Ft. Chaffee was divided into 12 compartments, and hunters were assigned to these compartments to distribute hunting pressure evenly across the area. All hunters were required to check harvested deer at a check station throughout the 5-year study. Deer were sexed, aged by tooth wear and replacement (Severinghaus, 1949), and weighed on a platform scale to determine body weight. Antler dimensions were measured on all antlered males, including number of tines greater than 2.5 cm in length, circumference of the main beam 2.5 cm above its base, and antler spread measured at the widest point of the rack.

During the 1991 and 1995 deer seasons, hunters were asked to bring antlerless deer in whole. These deer were weighed (whole carcass weight), eviscerated, and reweighed (dressed weight). Fresh blood (40 ml) was collected from randomly-selected deer by severing the aorta, drained into clean vials, and centrifuged at 2,000 RPMs for 10 minutes. Serum was decanted into vials, frozen, and transported to a diagnostic laboratory for serum chemistry analyses, including blood urea nitrogen (BUN), glucose, total protein, albumin, albumin/ globulin ratio, calcium, phosphorus, cholesterol, and triglycerides. In addition, a 5-10 ml serum sample from each deer was sent frozen to the Southeastern Cooperative Wildlife Disease Study Laboratory (SCWDS) at the University of Georgia for antibody screening. These samples were tested for 7 common diseases of deer including brucellosis, bovine viral diarrhea (BVD) virus, infectious bovine rhinotracheitus virus, parainfluenza 3 virus, epizootic hemorrhagic disease (EHD) virus serotypes I and II and leptospirosis.

Both kidneys and adhering kidney fit were removed and weighed for determination of the kidney fat index (KFI). KFI is the ratio of the weight of trimmed kidney fat divided by the weight of the kidneys multiplied by 100 (Riney, 1955; Warren and Kirkpatrick, 1982).

Female reproductive tracts (ovaries, oviducts, uterus and cervix) were removed from female carcasses and fixed in 10% formalin (Golley, 1957). In the laboratory, ovaries were thinly sliced using a scalpel. All corpora albicantia (CA) and corpora lutea (CL) were counted in both ovaries (Teer et al., 1965). CL larger than 3 mm in diameter were recorded as CL of pregnancy (CLP), whereas CL smaller than 3 mm were considered accessory CL (Mansell, 1971). The presence of one or more CLP was evidence of current pregnancy, whereas CA's were evidence of pregnancy and ovulation rates in the previous year (Woolf and Harder, 1979). Each uterus was opened and drained into a dissecting tray for examination. Macroscopic embryos were counted, measured and sexed (if sufficiently developed). The age of each embryo was estimated using crown-rump length (Harnilton et al., 1985). These ages could be used to back date embryos to the conception date.

All data were analyzed using the SAS statistical package (SAS Institute 1987). Differences in body weights for each sex-age class and differences in antler measurements among years were tested using ANOVA with Tukey's mean comparison test to find differences of means. Differences in mean serum values, ovulation rates, and KFI's between the 1991 and 1995 samples were tested using two-sample t-tests. The x^2 contingency test was used to test for differences in the frequency of yearling males with branched versus unbranched antlers. All tests were conducted at $\alpha = 0.05$.

Age-structure of Harvested Deer.--Hunters harvested 2,627 deer during the 5-year study (Table 1). The largest harvest was in 1991 when 736 deer were taken. The total number of hunters participating ranged from 3,136 to 3,617 during the first 4 years. Hunter success during this period varied from 20.3% to 13.5%. In 1995 the number of permits was reduced to 2,370; only 265 deer were harvested, and hunter success fell to 11.2%.

Adult females comprised the largest percent of the harvest throughout the study, and the percent of total harvest that was adult female varied little (35-39%) each year (Table 1). The large harvest of this class was consistent with the management goal of reducing the proportion of adult females in the population and balancing the sex ratio. Concurrently, the proportion of adult males in the harvest rose steadily from 13% in 1991 to 19% in 1995. The ratio of adult females to adult males in the harvest during this period dropped from 2.9:1 to 1.9: 1, suggesting that liberalizing the harvest of females was leading to a more balanced sex ratio. The proportion of fawns harvested remained quite constant (10-15% females; 11-14% males) across all years, suggesting that the increased harvest of females did not

Table 1. Number of deer in each sex-age class harvested during the firearm deer seasons on Fort Chaffee, AR, 1991-95.

Class	1991	1992	1993	1994	1995	Total
Female fawn	77 (11%)	74 (12%)	65 (15%)	57 (10%)	29 (11%)	302 (12%)
Female yearling	74 (10%)	49 (8%)	26 (6%)	47 (8%)	24 (9%)	220 (8%)
Female adult	265 (36%)	241 (37%)	158 (37%)	215 (39%)	92 (35%)	971 (37%)
Male fawn	105 (14%)	81 (13%)	61 (14%)	72 (13%)	30 (11%)	349 (13%)
Male yearling	122 (17%)	101 (16%)	47 (11%)	80 (14%)	41 (16%)	39 (15%)
Male adult	93 (13%)	100 (16%)	66 (16%)	86 (15%)	49 (19%)	394 (13%)
Total Harvest	736	646	423	557	265	2,627

affect the proportion of fawns in the population.

Although hunters periodically expressed the opinion that the harvest of females was too heavy, this view is not supported by the high, consistent proportion of adult females in the harvest over this 5-year period. We speculate that the fewer number of deer harvested and lower hunter success in 1995 were due to the low number of permits issued, not overharvest. This is supported by the high positive correlation ($r = 0.925$; $P<0.05$) between the number of permits issued and hunter success rates.

Nutritional Condition of Deer.--Body weight is one of the oldest methods of directly assessing the nutritional status of deer and indirectly assessing habitat quality (Park and Day, 1942; Severinhaus, 1955). Weight is often the only index of condition available to wildlife managers and can be a good indicator of temporal changes in habitat quality if weights are collected in the same season and corrected for age and sex (Brown, 1984; Dinkines et al., 1991).

Deer harvested on Ft. Chaffee in 1991 were lighter than their counterparts in the Arkansas Ozark Mountains and on Holla Bend National Wildlife Refuge, located about 100 km east of Ft. Chaffee (Table 2; Torgerson and Porath, 1984; Nelson, 1991). Deer on Holla Bend were generally 2-25% heavier than those on Ft. Chaffee. However, Holla Bend provides a favorable nutritional environment with cropfields covering about 50% of the area. Consequently, these deer were expected to be heavier. In contrast, deer in the Ozarks occupy ranges with infertile soils and less agriculture, and these deer are among the lightest in the Midwest oak-hickory forest region (Torgerson and Porath, 1984).

The low body weights among Ft. Chaffee deer were reason for concern. Eve (1981) citing data from Oklahoma, Texas, and Kentucky suggested that chronically overpopulated deer herds "approach a minimal survival weight, and this weight is often in the vicinity of 65-75 pounds for field dressed yearling or older bucks." Yearling males on Ft. Chaffee averaged 76.5 lbs. in 1991 and had averaged 71.6 lbs. in 1989 (unpubl. data, Environmental Branch, Ft. Chalfee). The low body weights recorded in 1991 were particularly worrisome because that year had been mild with ample precipitation and above average acorn production (J. Sturdy, DoA. Ft. Chaffee, pers. comm.). The chronic low body weights among resident deer were thought to result from (1) high deer densities, (2) soils and forage that are low in nutrients, and (3) the relative scarcity of crops, which provide high quality, supplemental foods throughout most of the region.

Body weights of yearling and adult males increased from 1991 to 1995 after intensive harvesting and habitat management began (Table 3). Fawns also tended to be heavier, except in 1994, a drought year when the weights for fawns and all females were low. The weights of juvenile and adult females did not change during the 5-year period. The energy demands of gestation and lactation through spring and summer may limit growth and fattening in mature females. Further, mature females had been more comparable in weight to other deer in the region before intensive management began.

Antler Dimensions.--Antler growth in males is affected by age, nutrition, and genetics (Smith et al., 1983; Ullrey, 1983). Antler dimensions can be useful indicators of habitat quality. Males inhabiting good habitat with good quality food produce more tines and larger main beams (French et al., 1956; Cowan and Long, 1962). Gore (1984) and Scribner

Table 2. Comparison of eviscerated body weights of deer harvested on Fort Chaffee in 1991 with the weights of deer in other regional populations.

	Fort Chaffee			Arkansas Ozarks[1]			Holla Bend NWR[2]		
Age-class	N	Mean	SE	N	Mean	SE	N	Mean	SE
Female fawn	77	43	0.7	35	43	--	69	44	0.6
Female yearling	74	69	0.7	26	77	--	48	76	0.8
Female adult	264	79	0.4	47	80	--	101	87	0.9
Male fawn	103	47	0.6	35	50	--	74	50	0.7
Male yearling	121	77	0.7	202	87	--	52	98	1.1
Male adult	93	98	1.3	32	104	--	58	123	2.2

[1]Adapted from Torgerson and Porath, 1984.

[2]Data reported in Nelson, 1991

Table 3. Mean dressed weight of deer in each age-class on Fort Chaffee, 1991-95. Standard errors are shown in parentheses.

	FEMALE			MALE		
Year	Fawn[A]	Yearling[B]	Adult[C]	Fawn[D]	Yearling[C]	Adult[E]
1991	43 (0.7)[a,b]	69 (0.7)[a]	79 (0.4)[a]	47 (0.6)[b]	77 (0.7)[b]	98 (1.3)[b]
1992	45 (0.9)[a]	70 (0.6)[a]	79 (0.6)[a]	52 (0.9)[a]	79 (1.0)[a,b]	98 (1.4)[a,b]
1993	45 (1.0)[a]	70 (1.6)[a]	79 (0.6)[a]	49 (1.2)[a,b]	81 (1.3)[a,b]	104 (1.8)[a]
1994	41 (0.8)[b]	68 (1.1)[a]	78 (0.5)[a]	47 (1.1)[b]	79 (0.9)[a,b]	103 (1.2)[a,b]
1995	45 (0.9)[a]	69 (0.9)[a]	80 (0.9)[a]	50 (1.1)[a]	81 (1.2)[a]	104 (2.1)[a,b]

Mean weights for classes followed by different capital letters at $\alpha=0.05$ across all years.
Within columns, means followed by different trivial lettes at $\alpha=0.05$.
No interactions between age-class and year were found.

et al. (1984) reported that white-tailed deer, especially yearlings, have a much greater tendency to produce small "spike" antlers (no tines) in poor quality habitats.

In 1991, 69% of the yearling males harvested on Ft. Chaffee had spike antlers. Torgerson and Porath (1984) listed the typical percentage of spikes among yearlings in Arkansas and surrounding states as 17-33%. Eve (1981) reported that "studies of Oklahoma deer showed that 70 to 100% of yearlings on chronically overpopulated ranges had spike antlers, while at lower densities on other areas spike bucks comprised only 0 to 18% of the yearling buck class." Beam diameters among Ft. Chaffee yearlings harvested in 1991 averaged 15.4 mm, significantly smaller than average diameter of 19-20 mm for most deer in Arkansas, Missouri, and Oklahoma (Torgerson and Porath, 1984).

The proportion of yearling males with spike antlers decreased from 69% in 1991 to 63% in 1992 to 53% over the last 3 years of the study. We believe that this trend toward fewer spike bucks is an indication of healthier deer. Among adult males, the mean number of tines (7) did not differ significantly among years. However, the mean beam diameter did increase significantly from 19 mm in 1991 to 31 mm in 1995 ($t = 5.1$; $P < 0.05$).

Stored Fat and Blood Chemistry.--Fat reserves and blood parameters have been found to be useful indicators of nutritional status in deer. Blood chemistry often reflects the individual's short-term nutritional balance (days, weeks), whereas fat deposits indicate energy balance over longer periods (months) (Brown, 1984). Mech and Delgiudice (1985) reported that when white-tailed deer fatten, they first deposit fat in the bone marrow, then around the kidneys, then throughout the abdominal region, and finally on the back and rump. Stored fat is generally utilized in reverse order. Consequently, kidney fat (usually expressed as KFI) has been shown to be a useful indicator of energy balance over the middle ranges of nutritional condition (Ransom, 1965; Stockle et al., 1978).

We measured KFI's only in the adult and yearling female classes to assess changes in body fat. These classes were selected because they are the classes least affected by the timing of the hunting season. Fawns tend to put most energy into growth, and generally have low KFI's even on high planes of nutrition. During the fall mating season, the energy reserves of mature males are rapidly depleted as the season progresses. Consequently, adult and yearling females appear to be the best indicators of annual changes in fat reserves. The mean KFI of females harvested on Ft. Chaffee was relatively high (120) in 1991 and increased significantly to 290 in 1995 ($t = 6.05$; $P < 0.01$), suggesting higher levels of body fat and net energy in 1995.

Biologists began using blood serum chemistry to predict dietary protein and energy in deer during the 1970's (Brown, 1984). Serum composition reflects relatively short-term (hours to weeks) dietary intake. BUN (blood urea nitrogen) is positively correlated with dietary protein and is a good indicator of protein intake (Seal et al., 1972; Seal et al., 1978; Warren et al., 1982). Dietary energy is best measured by NEFA (nonesterified fatty acids), triglycerides, calcium, phosphorus, and cholesterol (DeCalestra et al., 1975; Seal et al., 1978; Warren et al., 1982). NEFA is usually considered to be the preferred indicator of dietary energy when collected from live deer, but triglyceride concentration is indicative of dietary energy and remains unchanged for several hours after death (Dinkines et al., 1991). We did not measure NEFA, but did evaluate triglycerides, calcium, phosphorus, and cholesterol levels in Ft. Chaffee deer.

Serum characteristics were analyzed in 36 adult female deer harvested in 1991 (Table 4). Mean BUN concentrations were low (13.4 mg/dl) and below values found in other regional populations. Dinkines et al. (1991) reported that deer occupying good habitat in Oklahoma had average BUN concentrations of 25 mg/dl, whereas those on poor range averaged 16.6 mg/dl. Low BUN levels suggests that dietary protein levels may be low for deer at Ft. Chaffee. In contrast, triglyceride, calcium, and phosphorus levels were high, indicating high dietary energy levels during the fall of 1991. Acorn production had been good in western Arkansas, and deer had fed heavily on them. We believe that the carbohydrates and fats supplied by these acorns contributed to a high energy plane and substantial fat reserves seen in these deer.

Serum levels were generally higher in 1995 after 4 years of herd reduction and habitat improvements (Table 4). Mean concentrations of BUN, total protein albumin, albumin:globulin ratio, phosphorus, and triglycerides were higher in 40 adult females harvested in 1995, although these differences were not significant ($P = 0.06 - 0.52$). Higher kidney fat levels, and higher concentrations of BUN, triglyc-

Table 4. Mean values for blood serum parameters measured in white-tailed deer harvested on Ft. Chaffee, AR in 1991 and 1995.

Blood Serum Parameter	1991	1995
Blood Urea Nitrogen (mg/dl)	14.1	14.5
Total Protein (g/dl)	6.9	7.5
Albumin (g/dl)	2.6	3.7
Albumin/globulin ratio	0.61	0.97
Phosphorus (mg/dl)	13.1	14.3
Triglycerides (mg/dl)	128	146
Calcium (mg/dl)	10.7	8.5
Cholesterol (mg/dl)	56	57

Table 5. Age-specific pregnancy and ovulation rates for female white-tailed deer on Fort Chaffee, AR in 1991 and 1995.

	1991			1995		
Class	N	% Breeding	$\overline{X}$ ova[1]	N	% Breeding	$\overline{X}$ ova[1]
Fawn	54	17	1.00	16	25	1.00
Yearling	33	98	1.26	16	100	1.50
Adult	138	99	1.87	93	100	2.22

[1] Mean number of ova/breeding female

erides, and total protein in the blood serum of harvested females indicate that the nutritional plane of the Ft. Chaffee deer herd was higher in 1995 than in 1991.

Reproduction.--The beginning of the breeding season on Ft. Chaffee was estimated by back-aging fetuses to the dates of conception. Earliest conception occurred on October 7, but significant numbers of adult and yearling females did not breed until after October 29. The peak of breeding occurred between November 8-20. Fawns bred later than older deer; of 36 female fawns examined, only 2 (6%) had CLP before January. A previous study conducted on Holla Bend NWR showed that the peak of breeding occurred during mid- to late-November (Nelson, 1991), coinciding with the period when peak numbers of spermatozoa were found in the reproductive tracts of adult males (Nelson and Johnson 1990).

Over the past 30 years, substantial evidence has accumulated to indicate that nutrition is the primary determinant of reproductive performance in deer (Verme, 1969; Woolf and Harder, 1979). Dietary energy intake and not protein intake influences ovulation rates (Murphy and Coates, 1966). Studies have shown that does on higher nutritional planes 6 to 8 weeks before breeding produce significantly more offspring. Richter and Labisky (1985) found that a doe's productivity was linked to its nutritional plane but was also affected by deer density. Nutrition appears to have its greatest effect on the percentage of fawns breeding and the ovulation rates of adult does (Harder, 1980).

The percentage of female fawns breeding was low (17%) in 1991, but rose to 25% in 1995 (Table 5). Harder (1980) reported that approximately 48% of fawns bred in the Missouri Ozarks, and 56% bred in the agricultural region of that state. Only 24% of fawns bred statewide in Tennessee (Torgerson and Porath, 1984), and 27% bred on Holla Bend NWR in Arkansas (Nelson, 1991).

A high percentage of adult females breed in most deer populations, and the Ft. Chaffee population was no exception. Nearly all yearling and adult females had bred in 1991 and 1995 (Table 5). However, ovulation rates were higher in 1995 in yearlings ($t = 11.5$; $P < 0.05$) and adults ($t = 7.16$; $P < 0.05$) than in 1991. The higher reproductive rates found in 1995 appear to be further evidence that the deer population was in improved condition.

Table 6. Percent prevalence of disease found in harvested deer on Fort Chaffee. Sample size was 40 deer in 1991 and 16 deer in 1995.

	Percent prevalence	
Disease	1991	1995
Bluetongue virus	0	0
Bovine viral diarrhea virus	0	0
Brucellosis	0	0
Epizootic hemorrhagic disease virus	10	18
Infectious bovine rhinotracheitis virus	0	0
Leptospira	8	6
Parainfluenza 3 virus	15	18

Prevalence of Disease.--Blood serum from 40 deer was screened for 7 common diseases of deer in 1991, and 16 deer were screened in 1995 (Table 6). The presence of antibodies to Parainfluenza 3 virus, EHD virus (serotype II), and Leptospira in individual deer indicated that these diseases were present in the population, but at relatively low prevalences. EHD is the most important endemic infectious disease afflicting deer in the U.S (Nettles and Stallknecht, 1992). Fischer et al. (1995) reported that more than 14,000 deer in a relatively small region of Missouri died due to hemorrhagic disease between August and October 1988. Population immunity to particular serotypes can vary greatly, and immunity to one serotype does not provide immunity for the others (Stallknecht et al., 1991). The prevalence of EHD in Ft. Chaftee deer was higher than in deer tested in the Arkansas Ozarks (0%), but lower than in deer tested in southeastern Arkansas (57%; D. Stallknecht, SCWDS, pers. comm.).

Nearly all of the indicators of herd health that were measured during this study suggested that the nutritional condition and reproductive rates of Ft. Chaffee deer improved from 1991 to 1995. Although body weights showed few significant trends, fat levels were higher, the percentage of spike bucks was lower, and blood parameters suggested that dietary energy and protein were higher in 1995. Finally, reproductive rates were higher in 1995 as indicated by more fawns breeding, and higher ovulation rates among yearlings and adults. While it is difficult to prove causality, it appears likely that the improved condition of the herd was due largely to a management program that reduced deer density and improved habitat. Wildlife is a product of the land. The inherent limitations on habitat quality imposed by relatively infertile soils and periodic droughts mean that the Ft. Chaffee deer population may never reach a high nutritional plane relative to others in the region. However, a management program which maintains the population at or below current levels and leads to a balanced sex ratio should provide a healthy population and high reproductive rates.

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