Trends in Reproductive Performance and Condition of White-tailed Deer in Ohio[1]

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Abstract. **We compared the reproductive performance and condition of white-tailed deer (*Odocoileus virginianus*) collected in two regions of Ohio in 1996-99 with previous studies in 1962-67 (Nixon and others 1970; Nixon 1971) and 1981-83 (Stoll and Parker 1986). Statistical comparisons were limited to the 1981-83 and 1996-99 datasets because only summary data were available for 1962-67. We used uterine analysis to estimate reproductive parameters of roadkilled deer during 1982-83 and 1997-99, but ovarian analysis was used on deer obtained during fall hunting seasons in 1962-67. Pregnancy rates of fawns and yearlings declined in the farmland and hill country regions between 1982-83 and 1997-99, but no changes occurred in pregnancy rates of adult does. Fetal rates (fetuses/pregnant doe) of fawns and reproductive rates (fetuses/doe) of fawn and yearlings declined between 1982-83 and 1997-99. Body mass was collected at check stations in fall hunting seasons in the 1960s, 1981-82, and 1996-98, but antler beam and point characteristics were only measured in the 1981-82 and 1996-98 sampling periods. Mean body mass of all sex and age classes declined in the hill country, but fewer changes occurred in the farmland region. Mean antler beam diameter of yearling males declined in the hill country, but no differences were apparent in the farmland region. Reproductive performance and condition parameters were greater for deer in the farmland than in the hill country during both time periods. Declines in reproductive rates and in body condition have occurred as deer populations have increased in Ohio. Based on published sustained-yield tables (McCullough 1979; Downing and Guynn 1985), deer populations in the farmland region may currently exist at 35-40% of ecological carrying capacity, while the deer herd in the hill country may be near maximum sustained yield (MSY; 56% of ecological carrying capacity). Increased antlerless deer harvests may be required in the future to stabilize the population at MSY and maintain body condition and antler quality of deer because of a diminishing carrying capacity in southeastern Ohio.**

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INTRODUCTION

Estimates of reproductive rates are essential inputs to models for understanding the population dynamics of white-tailed deer and establishing harvest regulations (Harder 1980; Hansen and others 1996). Differences in body mass of all sex and age classes of deer and antler characteristics of bucks have been used as indexes to body condition and habitat quality (Hesselton and Sauer 1973; Severinghaus 1979; Severinghaus and Moen 1983; Rasmussen 1985).

In 1962-67, Nixon (1971) conducted the first statewide assessment of reproductive rates since white-tailed deer had become reestablished in Ohio in the 1930s. Body mass was also collected in conjunction with a study on deer diet and habitat use (Nixon and others 1970). The reproductive and condition parameters observed were typical of a deer population on a high nutritional plane and some of the highest ever reported for white-tailed deer (Nixon and others 1970; Nixon 1971). At the time, deer occupied all 88 counties and had an estimated population of 22,000 animals (Nixon 1970).

Reproductive performance and condition of deer was investigated again in 1981-83 because deer populations and harvests were 10× greater than during the 1960s study (Stoll and Parker 1986). Deer herds in southeastern Ohio increased as farms, abandoned during the depression era, reverted to forest cover in the 1970s and early 1980s (Stoll and Parker 1986). Population growth has continued and peaked at ≥500,000 animals in 1995; annual harvests have surpassed 100,000 deer since 1991 (Tonkovich 2000). The primary objective of this paper was to provide an update of deer reproductive rates and condition parameters for population modeling purposes. We also compared results of previous Ohio studies with the current data collection period (1996-99) to detect trends in reproductive performance and condition over time. Finally, we compared fawn reproductive rates of Ohio deer herds to published sustained-yield tables (McCullough 1979; Downing and Guynn 1985) to assess the position of herds in relation to carrying capacity.

METHODS

All deer examined for reproductive status and condition were assigned to 1 of 3 age classes (that is, fawn: <1 year old; yearling: 1.5 years old; adult: ≥2.5 years old) by assessing tooth replacement and wear of the lower mandible (Severinghaus 1949).

Reproductive Performance

1982-83 and 1997-99 Studies: Reproductive tracts of roadkilled deer were removed by wildlife officers in February, March, and April of 1982 and 1983 (Stoll and

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Parker 1986) and 1997, 1998, and 1999. Each uterus was examined and fetuses were counted and sexed. Reproductive tracts of fawns collected in February were excluded because fetal development was often not sufficiently advanced to reliably count and sex fetuses. Fawns generally conceived 1 month later than yearlings and adults (Nixon 1971). Age of fetuses was estimated from crown-to-rump lengths during 1997-99 and used to calculate conception dates (Armstrong 1950; Hamilton and others 1985). We defined pregnancy rate as the percentage of does sampled that were pregnant and fetal rate as the number of fetuses per pregnant doe. Reproductive rate (the number of fetuses per doe) was a combined measure of pregnancy and fetal rates and represented the deer population's actual fecundity.

Data were separated into farmland and hill country regions because of differences in land-use and deer densities in the 1982-83 and 1997-99 studies (Fig. 1). The glaciated farmland region was a 60-county area in western and northeastern Ohio that was <17% forested (Griffith and others 1993), and the predominant land use was agriculture. The unglaciated hill country region (28 counties) has rugged topography and was >55% forested (Griffith and others 1993). Deer densities were higher in the hill country than farmland regions (Stoll and Parker 1986).

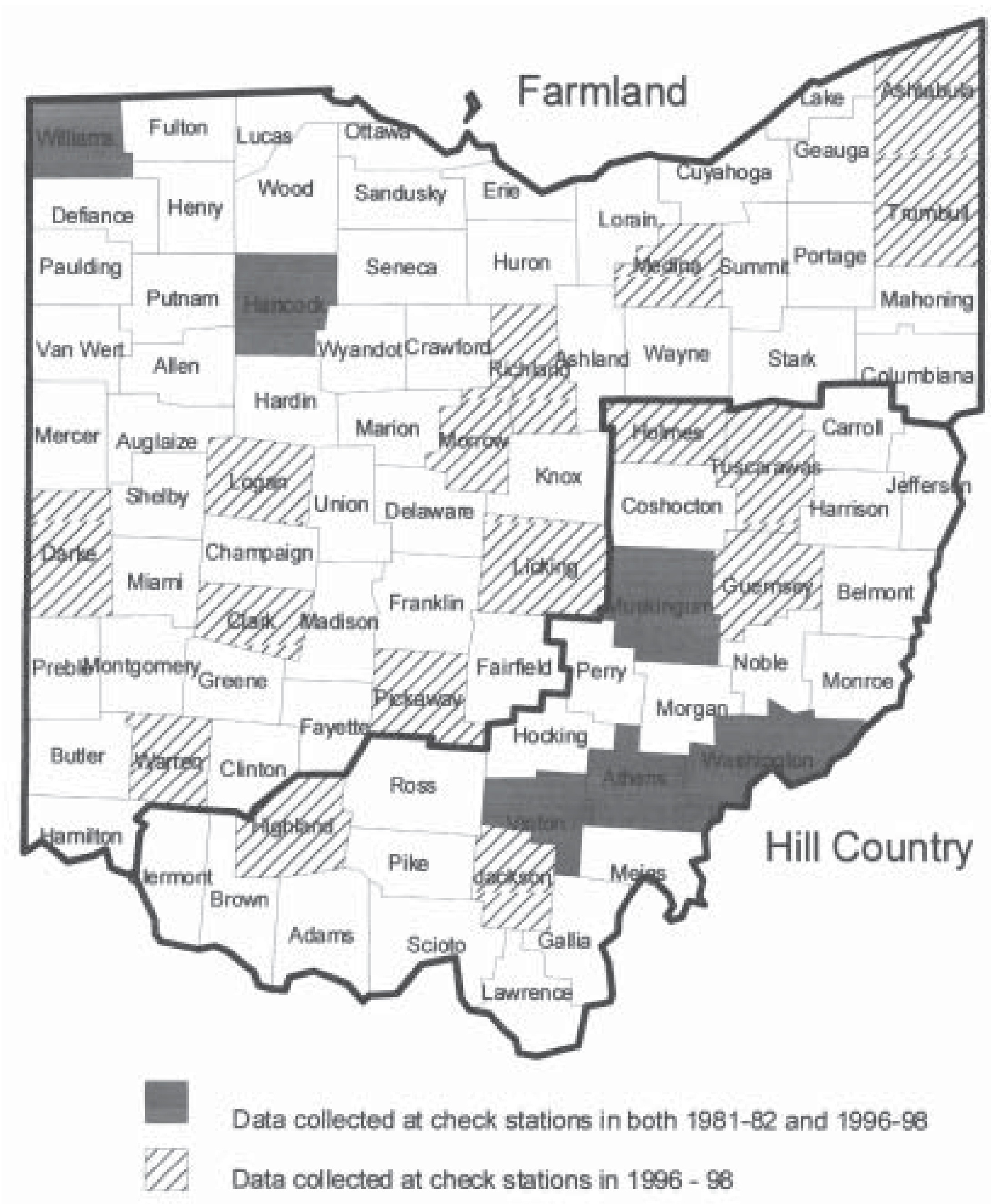

FIGURE 1. Location of Division of Wildlife deer check stations in which body mass and antler characteristics were measured during 1981-82 and 1996-98 in the farmland and hill country regions of Ohio. Statistical analyses were only conducted on data from the 6 counties sampled in both time periods.

1962-67 Study: Reproductive performance of white-tailed deer was determined by ovarian analysis of reproductive tracts collected at check stations during deer gun seasons in 1962, 1963, and 1964 and supplemented with reproductive tracts of roadkilled deer collected throughout the year in 1962-67 (Nixon 1971). Ovaries were sectioned and examined microscopically to determine ovulation rates and the number of corpora lutea/doe (Cheatum 1949). Each uterus was examined and fetuses were counted, sexed, and crown-to-rump lengths were measured to determine developmental age (Armstrong 1950). Conception dates were estimated based on fetal growth charts developed by Armstrong (1950).

Condition

1981-82 and 1996-98 Studies: Hog-dressed body mass (viscera and internal organs excluded) of all sex and age classes of deer was collected at check stations in Hancock and Williams counties in the farmland and Athens, Muskingum, Vinton, and Washington counties in the hill country region during deer gun seasons in 1981 and 1982 (Stoll and Parker 1986; Fig. 1). Sampling was expanded to include check stations in 22 counties in 1996, 1997, and 1998; 12 stations were located in the farmland and 10 stations were in the hill country region (Fig. 1). However, to make valid statistical comparisons between studies, we only used observations in 1996-98 from the 6 counties in which data were collected in 1981-82. Body mass was measured using platform or spring scales to the nearest 0.2 kg.

Antler characteristics of yearling bucks were measured at check stations during deer gun seasons in 1981-82 and 1996-98. Main antler beam diameters were measured 25 mm above the base of each antler and a mean was calculated for each buck. The total number of antler points ≥25 mm in length was also recorded. Stoll and Parker (1986) reported means, but not standard errors, for antler beam diameters and number of points measured in 1981-82; original data were unavailable for reanalysis. Consequently, we are limited to discussing trends in the means of antler beam diameters and points between the 1981-82 and 1996-98 time periods.

1962-67 Study: Field-dressed body mass (heart and liver included) of all sex and age classes of white-tailed deer was collected at check stations during deer gun seasons (Nixon and others 1970). Mass was measured and reported in pounds (Nixon and others 1970), but has been converted to kilograms for comparison with more recent studies. No antler beam data were collected during this time period.

Data Analysis

Original reproductive and condition data collected in 1962-67 were unavailable for re-analysis. As a result, statistical comparisons could not be made with the 1981-83 and 1996-99 studies. However, we did use chi-square to test for a difference in the distribution of conception dates of does ≥1.5 years old examined in 1962-67 and 1997-99 to determine if the timing of the breeding season had changed. Otherwise, we presented summary data from Nixon (1971) and Nixon and others (1970) in tables and figures along with data collected in the 2 most recent studies.

Few differences in reproductive performance or condition parameters occurred among years in either the 1981-83 or the 1996-99 study. Therefore, we combined all years of data within each study to test for differences between time periods (1981-83 vs 1996-99). We used chi-square tests of homogeneity to compare pregnancy rates, litter sizes, and sex ratios. Two-way Analysis of Variance (ANOVA) was used to test for study, region, and interaction effects in fetal rates, reproductive rates, and body mass by age class. One-way ANOVA was used to test for regional differences in antler beam diameters and number of antler points in 1996-98. All statistical tests were considered significant at $\alpha = 0.05$.

RESULTS

Reproductive Performance

A total of 897 and 395 reproductive tracts were examined in the farmland and hill country regions, respectively, during 1997-99 (samples were collected from all 88 counties). However, only 701 deer from the farmland region and 327 deer from the hill country region were included in analyses. A total of 196 farmland and 68 hill country fawns examined in February were excluded from analyses because fetal development was not sufficiently advanced for accurate fetal counts.

A total of 275 and 127 reproductive tracts were examined in the farmland and hill country regions, respectively, (75 of 88 counties), during 1982-83 (Stoll and Parker 1986). Based on sample sizes reported in Nixon's (1971) Table 1, a total of 730 reproductive tracts were examined in the 1962-67 study. However, only 434 deer had pregnancies sufficiently advanced to determine fetal rates (Nixon 1971). Most reproductive tracts were collected in eastern Ohio, but all 88 counties were represented by at least a few deer (Nixon 1971).

1982-83 vs 1997-99: Pregnancy rates of white-tailed deer fawns declined in both the farmland (68.4% vs 58.4%; $X^2_1 = 3.95$, $P = 0.047$) and the hill country regions (50.9% vs 32.4%; $X^2_1 = 4.63$, $P = 0.031$) between 1982-83 and 1997-99 (Table 1). Pregnancy rates of fawns were greater in the farmland than in the hill country region both in 1982-83 (68.4% vs 50.9%; $X^2_1 = 5.05$, $P = 0.025$) and in 1997-99 (58.4% vs 32.4%; $X^2_1 = 21.62$, $P < 0.0001$). Pregnancy rates of yearling and adult does were high in both regions and studies (>90%), but pregnancy rates of yearlings were consistently, but not significantly, lower than of adult does. A declining trend in pregnancy rates of yearling does was apparent in both the farmland (96.3% vs 90.5%; $X^2_1 = 2.92$, $P = 0.087$) and the hill country region (100% vs 94.4%; $X^2_1 = 3.40$, $P = 0.065$) between studies, but no changes occurred in pregnancy rates of adult does. Furthermore, no regional differences occurred for either yearling or adult does.

Fetal rates of fawns declined between 1982-83 and 1997-99 ($F_{1, 347} = 4.46$, $P = 0.035$) and were lower in the hill country than the farmland region ($F_{1, 347} = 3.72$, $P = 0.055$; Table 2). Fetal rates of yearling or adult does did

TABLE 1

Pregnancy rates (%) of female white-tailed deer by age class, region, and study, Ohio, 1982-83 and 1997-99.

	Farmland				Hill Country			
	1982-83		1997-99		1982-83		1979-99	
	n	%	*n*	%	*n*	%	*n*	%
Fawn	136	68.4	293	58.4	55	50.9	111	32.4
Yearling	81	96.3	157	90.5	37	100.0	72	94.4
Adult	58	96.6	251	95.2	37	97.3	144	97.2

not differ between regions or studies.

Reproductive rates of fawns declined between 1982-83 and 1997-99 ($F_{1, 629}$ = 11.42, P = 0.0008), and were lower for fawns in the hill country than in the farmland region ($F_{1, 629}$ = 22.87, P <0.0001; Table 3). There was a non-significant declining trend in reproductive rates of yearlings in both regions, driven by the declining trend in pregnancy rates, as no differences in fetal rates were observed. Reproductive rates of adult deer did not differ between the 2 study periods or between regions.

Litters size of fawns in the hill country was restricted to a single fetus in 1997-99, but 21% carried twins in the farmland region (Table 4). During the 1981-82 collection, ≤25% of fawns carried twins in both regions. Litter sizes of yearling and adult does generally ranged from 1 to 3 fetuses in all 3 studies, but <1.0% of litters had 4 or 5 fetuses in each time period. The proportion of yearling and adult does carrying triplets ranged from

TABLE 2

Mean number of fetuses per pregnant doe of white-tailed deer by age class, region, and study, Ohio, 1982-83 and 1997-99.

	Farmland						Hill Country					
	1982-83			1997-99			1982-83			1979-99		
	n	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
Fawn	93	1.25	0.05	171	1.21	0.03	28	1.21	0.08	36	1.00	0.00
Yearling	78	1.96	0.05	142	1.83	0.05	37	1.84	0.10	68	1.82	0.07
Adult	56	1.91	0.07	239	1.93	0.03	36	1.83	0.09	140	1.82	0.05

TABLE 3

Reproductive rates (mean number of fetuses per doe) of white-tailed deer by age class, region, and study, Ohio, 1962-67, 1982-83, and 1997-99.

	Statewide		Farmland						Hill Country					
	1962-67[1,2]		1982-83			1997-99			1982-83			1979-99		
	n	Mean	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
Fawn	98	1.29	136	0.85	0.06	293	0.71	0.04	55	0.62	0.09	111	0.32	0.05
Yearling	126	1.87	81	1.89	0.07	157	1.66	0.06	37	1.84	0.10	72	1.72	0.08
Adult	210	2.04	58	1.85	0.09	251	1.84	0.04	37	1.78	0.10	144	1.77	0.05

[1]Original data were unavailable for re-analysis, but are presented for comparison.

[2]Number of fetuses per doe was based on ovulation rates in 1962-67 and pregnancy rates in 1982-83 and 1997-99. This may account for the higher reproductive rates in 1962-67 period.

TABLE 4

Proportion of female white-tailed deer carrying single, twin or more fawns by age class, region, and study, Ohio, 1962-67, 1982-83, and 1997-99.

Age	Proportion of does carrying 1, 2, or ≥3 fetuses											
	Farmland				Hill Country				Statewide			
Study	*n*	1	2	≥3	*n*	1	2	≥3	*n*	1	2	≥3
Fawn												
1962-67[1]									98	71.4	28.6	0.0
1982-83	93	75.3	24.7	0.0	28	78.6	21.4	0.0				
1997-99	171	79.0	21.0	0.0	36	100.0	0.0	0.0				
Yearling												
1962-67[1]									126	23.8	65.9	10.3[2]
1982-83	78	12.8	78.2	9.0	37	27.0	62.2	10.8				
1997-99	142	23.2	71.1	5.7[3]	68	25.0	67.7	7.3				
Adult												
1962-67[1]									210	9.5	79.0	11.4[4]
1982-83	56	19.6	69.6	10.7	36	25.0	66.7	8.3				
1997-99	239	17.2	72.4	10.4	140	25.0	68.6	6.4[5]				

[1]Original data were unavailable for re-analysis, but are presented for comparison.
[2]0.8% of yearlings Statewide had 4 or more fetuses in 1962-67.
[3]0.8% of yearlings in Farmland had 4 fetuses in 1997-99.
[4]1.4% of adults Statewide had 4 or more fetuses in 1962-67.
[5]0.7% of adults in Hill Country had 4 fetuses in 1997-99.

5.7% to 11.4% among regions and studies.

Fetal sex ratios did not vary by time period, region, or age of the doe (Table 5). The proportion of male fetuses was similar between 1982-83 and 1997-99 in the farmland (50.0% vs 53.6%) and hill country regions (47.6% vs 50.4%).

1962-67 vs 1997-99 : Conception dates of does ≥1.5 years old (that is, yearling and adult deer) did not vary

TABLE 5

Fetal sex ratios (% male fetuses) of female white-tailed deer by age class, region, and study period, Ohio, 1962-67, 1982-83, and 1997-99.

Age	Farmland		Hill Country		Statewide	
Years	*n*	% males	*n*	% males	*n*	% males
Fawn						
1962-67[1]					58	63.7
1982-83	111	55.9	34	47.1		
1997-99	196	55.1	34	38.2		
Yearling						
1962-67[1]					61	64.0
1982-83	153	52.9	68	47.1		
1997-99	254	53.1	113	48.7		
Adult						
1962-67[1]					125	53.6
1982-83	105	40.0	62	48.4		
1997-99	447	53.2	248	52.8		

[1]Original data were unavailable for re-analysis, but are presented for comparison.

between the 1962-67 (Nixon 1971) and the 1997-99 studies (X^2_8 = 8.80, P = 0.36; Fig. 2). In both studies, >70% of adult does were bred between 3 – 23 November and fawned between 25 May – 14 June (based on an assumed gestation period of 200 days [Verme 1969]). Conception and parturition dates of doe fawns occurred a month later and had a wider distribution than for adult does (Nixon 1971).

Condition

A total of 1652 and 3712 deer was weighed in 1996-98 at check stations during deer gun season in the farmland and hill country regions, respectively. A total of 1116 and 1896 deer was weighed in 1981-82 in the farmland and hill country regions, respectively. A total of 370 and 303 deer was weighed in 1962-67 at check stations during deer gun season in northwest and southeastern Ohio, respectively (Nixon and others 1970). Deer in 1962-67 were checked at stations that corresponded to farmland and hill country regions in the later studies.

Antler beam diameters were measured and the number of points counted from a total of 530 and 1246 yearling males in 1996-98 in the farmland and hill country regions, respectively. Antler characteristics were recorded from a total of 356 and 2656 yearling males in 1981-82 in the farmland and hill country regions, respectively (Stoll and Parker 1986).

1981-82 vs 1996-98 : There was a significant study effect for mean body mass of all sex and age classes of deer (P <0.0001 for all tests), except for adult males ($F_{1, 1214}$ = 1.49, P = 0.222; Table 6). Deer were heavier during 1981-82 than during 1996-98, but body mass of adult males did not change between time periods. There was a significant region effect for mean body mass of all sex and age classes of deer (P <0.0001 for all tests). Deer were heavier in the farmland than in the hill country region.

Significant study x region interactions for mean body mass of female fawns, and males in the fawn, yearling, and adult age classes (P <0.0001 for all tests) indicated that body mass of these sex and age classes of deer responded somewhat differently between regions. Body mass of male and female fawns declined in the hill country, but did not change in the farmland region between 1981-82 and 1996-98 collections. Body mass of yearling males declined between studies in both regions, but the decline was of greater magnitude in the hill country region. Body mass of adult males increased in the farmland, but declined in the hill country region between studies.

Mean antler beam diameters were greater in the farmland (24.7 ± 0.16 mm [SE]) than in the hill country region (21.0 ± 0.10 mm [SE]; $F_{1, 1774}$ = 400.65, P <0.0001) in 1996-98 (Table 7). The mean number of antler points was also greater in the farmland (6.4 ± 0.08 points [SE]) than in the hill country (5.3 ± 0.06 points [SE]; $F_{1, 1774}$ = 130.34, P <0.0001) in 1996-98. Mean antler beam diameters (24.6 mm vs 23.0 mm) and mean number of antler points (6.3 vs 5.9) of yearling males were greater in the farmland than in the hill country in 1981-82 (P <0.05 for both tests as reported by Stoll and Parker [1986]). There appeared to be a decline in mean antler beam diameters (23.0 vs 21.0) and mean number of antler points (5.7 vs 5.3) between 1981-82 and 1996-98

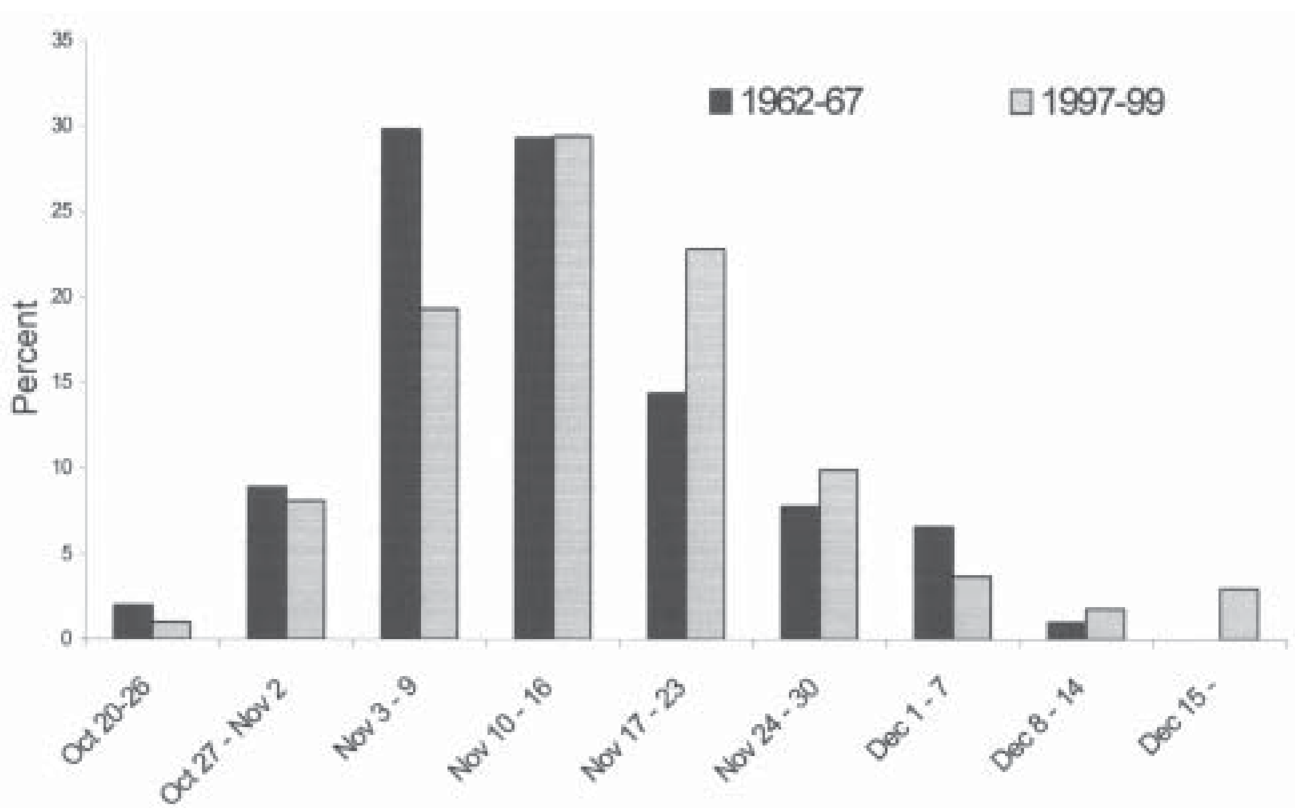

FIGURE 2. Distribution of conception dates by week for female white-tailed deer ≥1.5 years old in Ohio, 1962-67 and 1997-99.

TABLE 6

Eviscerated body mass (kg) of white-tailed deer by age, sex, and region, Ohio, 1960s, 1981-82, and 1996-98.

	Farmland Region									Hill Country Region								
	1960s[1]			1981-82			1996-98			1960s[1]			1981-82			1996-98		
	n	Mean (kg)	SE	*n*	Mean (kg)	SE	*n*	Mean (kg)	SE	*n*	Mean (kg)	SE	*n*	Mean (kg)	SE	*n*	Mean (kg)	SE
Fawn																		
Male	98	34.4	0.52	208	34.9	0.33	258	34.5	0.28	58	31.2	0.77	265	32.3	0.29	565	29.5	0.19
Female	83	32.2	0.50	206	31.4	0.34	224	30.9	0.32	62	29.1	0.60	259	29.3	0.24	510	27.2	0.18
Yearling																		
Male	51	58.7	0.99	276	57.2	0.36	531	56.1	0.28	34	51.2	1.37	502	51.8	0.23	824	48.3	0.22
Female	47	47.2	0.93	153	48.2	0.41	244	47.1	0.30	23	44.4	1.16	250	44.2	0.30	468	42.2	0.23
Adult																		
Male	45	73.3	1.83	110	68.1	0.82	199	71.0	0.61	80	66.9	1.64	337	68.3	0.48	572	62.2	0.36
Female	46	52.6	0.89	163	54.0	0.43	196	52.4	0.39	46	45.6	1.18	283	49.6	0.37	773	45.8	0.20

[1]Original data were unavailable for re-analysis, but are presented for comparison.

in the hill country, but original data were unavailable. No changes in beam diameters (24.6 vs 24.6) or number of antler points (6.3 vs 6.4) were apparent between studies in the farmland region.

DISCUSSION

Reproductive Performance

Numerous studies have established that reproductive parameters were related to the nutritional plane of white-tailed deer as influenced by habitat quality and population density (Cheatum and Severinghaus 1950; Verme 1969; Harder 1980; Ozoga and Verme 1982; Rhodes and others 1985). Fawns are more sensitive to nutritional deficiencies than older age classes of deer because of the high energetic costs associated with growth and reproduction (Ozoga and Verme 1982). Body mass may be less important than the ratio of fat:lean muscle for fawns to achieve puberty during their first breeding season in Michigan (Verme and Ozoga 1987).

Reproductive rates of fawns declined in both the hill country and farmland regions of Ohio between 1982-83 and the 1997-99 studies, but perhaps for somewhat different reasons. Lower fecundity in hill country fawns was a function of reductions in both pregnancy and fetal rates. This suggests that inadequate forage quality and/or quantity may be responsible for declining

TABLE 7

Mean antler beam diameters (mm) and number of antler points of harvested yearling male white-tailed deer by region, Ohio, 1981-82 and 1996-98.

	Farmland						Hill Country					
	Antler Beam Diameter			Antler Points			Antler Beam Diameter			Antler Points		
	n	Mean (mm)	SE	*n*	Mean (#)	SE	*n*	Mean (mm)	SE	*n*	Mean (#)	SE
1981-82[1]	356	24.6	0.21	343	6.3	-	2656	23.0	0.07	2625	5.9	-
1996-98	530	24.7	0.16	530	6.4	0.08	1246	21.0	0.10	1246	5.3	0.06

[1]Original data were unavailable for re-analysis, but are presented for comparison.

reproductive performance of fawns over time in Ohio. Forest succession has advanced to mature successional stages in the hill country (Griffith and others 1993). Habitat quality for deer in the hill country has likely declined and may have resulted in a lower carrying capacity than in previous decades. At the same time, deer densities have steadily increased in a period of conservative hunting regulations (Division of Wildlife, unpublished data). The combination of higher deer densities and reduced habitat quality in the hill country may have resulted in greater competition for limited food resources and inhibited most fawns from obtaining the fat:muscle mass ratio necessary for reproduction during their first fall.

In contrast, declines in fawn fecundity were not as great in the farmland region and were in response to declines in pregnancy rates, but not fetal rates. The lack of change in fetal rates of fawns suggests that nutrition was not limiting reproduction. Agricultural crops provide readily available sources of energy and protein in the farmland region. Declines in pregnancy rates in farmland fawns may be related to social stresses caused by high deer densities after crops have been harvested and deer are concentrated in small woodlots (Verme 1991; Hansen and others 1996). Fawns are more susceptible to social stresses that might inhibit the onset of estrus than older age classes of female deer because of their low ranking in the matrilineal social organization of white-tailed deer (Verme 1991).

Nixon (1971) reported reproductive rates of white-tailed deer during the 1960s that were much greater than in more recent Ohio studies, but his results were based on ovulation rates from counts of corpora lutea rather than actual counts of fetuses *in utero*. This method may have resulted in an overestimate of reproductive rates because shed ova and embryonic mortality were not accounted for in estimates (Stoll and Parker 1986). Nixon (1971) reported 11.5% ovum and embryonic mortality during the first 3 months of gestation in Ohio. Accounting for these differences in methodology, it is still likely that reproductive rates of fawns were greater during the 1960s than in subsequent studies, but reproductive rates of yearlings and adults may have been similar.

Reproductive rates of fawns in the farmland region of Ohio in 1997-99 (0.71 fetuses/doe) were similar or greater to fecundities observed in agricultural regions in other midwestern states in previous studies. Fecundity of fawns declined between the 1950s (0.80 fetuses/doe) and early 1980s (0.56 fetuses/doe) as deer populations rapidly increased in southern Michigan (Verme 1991). Pregnancy rates of fawns in agricultural regions of Missouri in both the early (41%) and late 1980s (31%) were lower than in the farmland region of Ohio (58%) (Hansen and others 1996). Reproductive rates of white-tailed deer are density dependent (McCullough 1979). Fecundity may be higher in agricultural regions of Ohio than in other mid-western states because aggressive antlerless deer hunting regulations have resulted in slower population growth and relatively lower deer densities.

Reproductive rates of yearling and adult does were high and only slight declines were noted for yearlings over time in Ohio. High fecundity was consistent with reproductive performance of deer herds on a high nutritional plane in other midwestern states (Roseberry and Klimstra 1970; Haugen 1975; Harder 1980; Hansen and others 1996; McCaffery and others 1998). Reproductive rates of white-tailed deer does increase with age, up through the age of 8 or 9, when slight declines in fecundity occur (Hansen and others 1996; McCaffery and others 1998). Adult deer were not separated into individual year classes in this study, but reproductive rates of yearlings were consistently lower than those of adult deer. Other studies that compared reproductive rates of yearlings and adults found no differences over time (Verme 1991; Hansen and others 1996).

We found no differences in fetal sex ratios between the 1982-83 and 1997-99 studies, by region, or by the age of the doe. Stoll and Parker (1986) reported that fetal sex ratios were equal (that is, 50:50) in all age classes of does in the hill country. Fetal sex ratios of fawn and yearling does were equal in the farmland region, but adult does only produced 40% male fetuses. Male fetuses significantly outnumbered females *in utero* in fawn and yearling does, but an equal sex ratio of fetuses was produced by adult does in Ohio during the 1960s (Nixon 1971).

Fetal sex ratios of white-tailed deer were equal in Missouri during two different time periods (Hansen and others 1996). No differences in fetal sex ratios occurred due to the age of the doe or litter size during 1978-86, but older does were more likely to have male fawns during 1989-93. They suggested this was because of a preponderance of male fawns being born by does ≥9 years old. Hansen and others (1996) reported that the date of conception affected fetal sex ratios; adult does that conceived later in fall produced more male fetuses, but few adult does bred at this time.

Verme (1983) critically reviewed published literature to synthesize results of studies regarding variations in fetal sex ratios in the genus *Odocoileus*. He concluded that the proportion of male fetuses declined with increasing maternal age of the doe and litter sizes. However, our results and those of Hansen and others (1996) do not support Verme's (1983) age-related sex ratio hypothesis. No patterns emerged in Ohio or Missouri studies in any time period and both had sample sizes greater than most studies reviewed by Verme (1983). Fetal sex ratios may not respond in a manner predicted by Verme (1983) in midwestern states where the nutritional plane of deer populations is high.

The distribution of conception dates of adult deer revealed that the timing of the rut had not changed in Ohio between the 1960s and late 1990s. This was not unexpected because deer gun season has traditionally occurred after the peak of the rut in Ohio and, therefore, adequate numbers of bucks should be available to breed does. However, the peak of conception appeared to be a week later in the late 1990s than in the study during the 1960s. Original data from the 1960s were unavailable for analysis so we can only speculate as to this apparent shift and suggest that differences in methodology or the distribution of samples may have differed between the two time periods. The timing of the rut and conception dates in Ohio was similar to dates reported in Missouri (Hansen and others 1996).

Condition

Body mass and antler quality varies with the nutritional level of the deer population (Hesselton and Sauer 1973; Severinghaus 1979; Severinghaus and Moen 1983). Nixon and others (1970) reported that field-dressed body mass of most sex and age classes of white-tailed deer was greater in northwest Ohio than in eastern counties during the 1960s. They attributed greater body mass in northwest Ohio to the higher nutritional plane available to deer provided by waste agricultural crops. This trend of heavier deer in the farmland region continued in the 1981-82 and 1996-98 study periods, but significant declines were observed in most sex and age classes between time periods in both Ohio regions. The observed declines in the farmland region were less than 2.0 kg and were likely detected because of the large sample size of deer weighed in each sex and age class; we do not attribute any biological significance to differences of this magnitude. However, body mass declines of 2.1-6.1 kg in the hill country region are consistent with declining trends in reproductive rates and antler characteristics.

Stoll and Parker (1986) reported that antler beam diameters and antler points of yearling bucks were greater in the farmland than in the hill country region during the 1981-1982 study period, and antler characteristics of yearling bucks in Ohio were greater than from deer in surrounding states. No changes occurred in antler beam diameters or points of yearling bucks in the farmland region between 1981-82 and 1996-98, presumably because of the high nutritional plane of forage available to deer. However, declines in antler characteristics of yearling bucks were observed in the hill country region and, as with most other reproductive and condition parameters, we suspect that declines were related to a rapidly increasing deer population coupled with declining habitat quality. Even so, antler beam diameters from the hill country in 1996-98 exceeded beam diameters of yearling bucks on “poor” or “fair” range, and were only slightly lower than beam diameters on “good” range, in Michigan, Minnesota, Missouri, New York, and Pennsylvania in the late 1970s and early 1980s (Table 2 in Stoll and Parker [1986]).

Ohio Deer Populations in Relation to Carrying Capacity

McCullough (1979) created a sustained-yield table based on empirical data collected during studies on the George Reserve white-tailed deer herd in southern Michigan. He demonstrated that the frequency of fawn breeding and reproductive rates declined as ecological carrying capacity was approached and that fawns failed to breed at population sizes >60% of carrying capacity (McCullough 1979). Downing and Guynn (1985) generalized McCullough’s (1979) sustained-yield table with existing data from free-ranging deer populations and incorporated reproductive rates that were somewhat lower than those observed at the George Reserve.

We used sustained-yield tables to estimate the position of Ohio deer herds in relation to ecological carrying capacity. Reproductive rates of fawns in Ohio were lower than at the George Reserve in Michigan (McCullough 1979), but similar to values incorporated into Downing and Guynn’s (1985) tables. The high reproductive rates of fawns in the farmland region of Ohio have only declined slightly over the past 15 years (0.85 fetuses/doe vs 0.71 fetuses/doe) and indicate that deer populations may currently exist at 35-40% of ecological carrying capacity (Fig. 3A). Reproductive rates of fawns in the hill country declined substantially from 0.62 fetuses/doe to 0.32 fetuses/doe between studies and indicate that the position of the deer herd in this region may currently be near maximum sustained yield (56% of ecological carrying capacity; Fig. 3B). A more rapid decline in reproductive rates and condition parameters in the hill country indicate that deer populations may be growing faster and moving closer to carrying capacity than in the farmland region.

Declines in some reproductive rates and condition parameters in Ohio were related to an exponential increase in deer populations that has occurred since the late 1970s. Regional differences in reproduction and condition are related to the high nutritional plane of deer in the farmland region and the declining habitat quality in the hill country region as forests have matured. Aggressive antlerless hunting regulations have probably kept Ohio’s deer herds from growing as rapidly as in other states and have helped maintain the high reproductive rates and body condition of all age and sex classes of deer. Increased antlerless deer harvests may be required in the future to maintain the reproductive performance and condition of deer herds in the hill country of southeastern Ohio.

The potential for deer-human conflicts will likely escalate in Ohio as deer populations increase and as human populations grow and are increasingly redistributed in suburban and rural areas. Monitoring the size of deer populations in relation to ecological carrying capacity would increase our effectiveness at managing white-tailed deer and implementing appropriate harvest management strategies. Research in New York has demonstrated a linear relationship between antler beam diameters of yearling males and reproductive rates of female deer (Severinghaus and Moen 1983). We recommend further investigation of this relationship in Ohio. Antler beam diameters are collected annually at check stations throughout the state and would be an inexpensive alternative to repeated assessments of reproductive rates.

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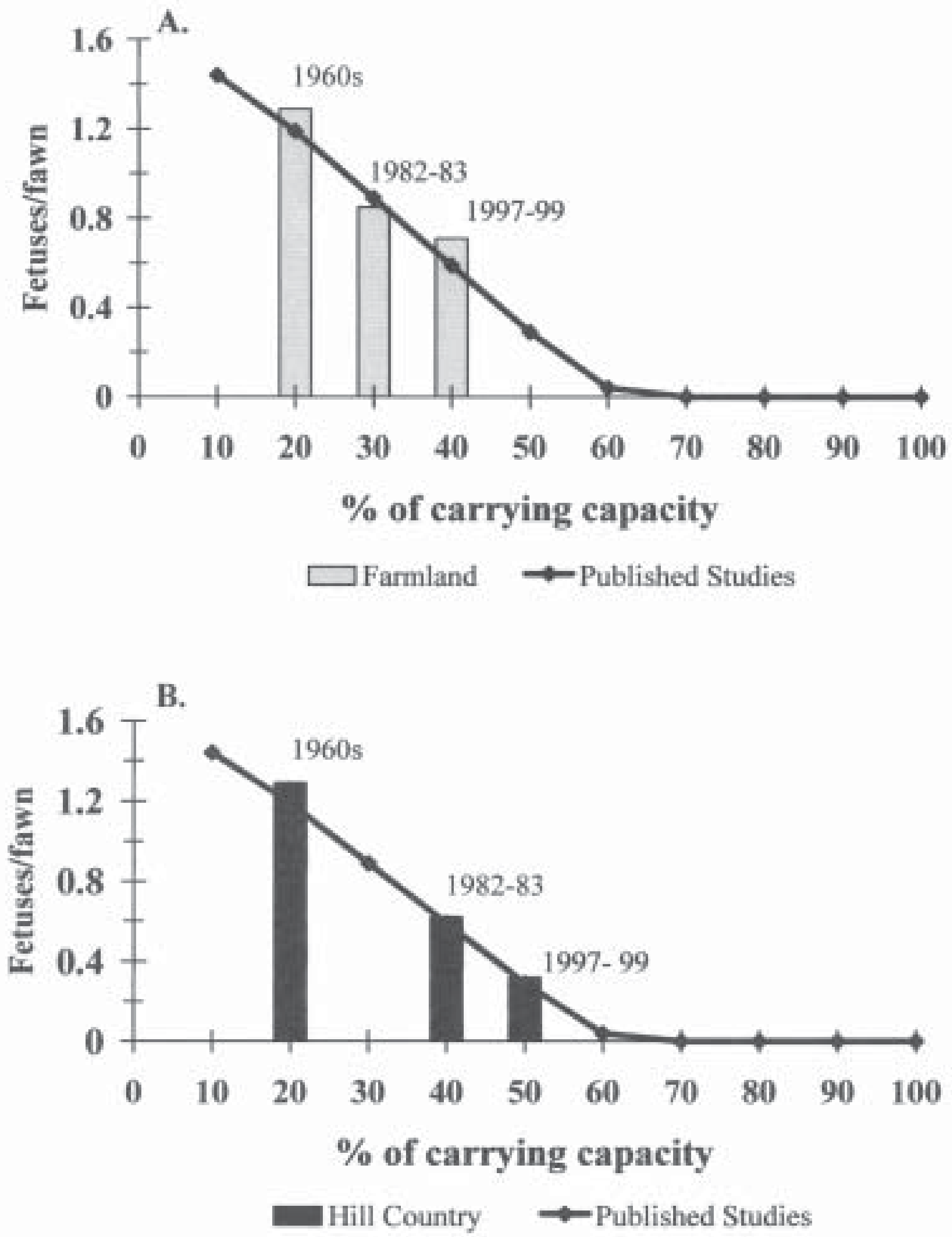

FIGURE 3. Comparison of fawn reproductive rates in different time periods in Ohio to published studies of fawn reproductive rates in relation to carrying capacity in A. the farmland region, and B. the hill country region.

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