Population Ecology of Deer on Chickamauga Battlefield Park, Georgia

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Abstract: Our objectives were to determine population and ecological characteristics for an unmanaged white-tailed deer (*Odocoileus virginianus*) herd on Chickamauga Battlefield National Military Park, Georgia, and to predict the potential for overpopulation in this herd in the future. We radio-collared 67 deer on the park over 4 years (1991–1994). An additional 295 deer were killed by vehicles on the park's roads, and 36 were collected for herd health analysis in August of each year (8–10 deer per year). The range of estimates for population density was 10–41 deer/km^2. The deer herd was in good nutritional condition: reproductive rates were high and kidney fat indices (KFI) closely reflected seasonal and sex-related physiological stresses ($P = 0.0001$), although the animals were never nutritionally deficient to the point that humerus marrow fat (HMF) declined ($P = 0.082$). Survival analysis revealed that hunting mortality (11.0% annually) outside the park boundary was similar to road-kill mortality (9.5% annually) within the park. Losses to poaching, disease, and accidental death were minimal. The abomasal parasite count (APC) averaged 1,195 (pooled over 4 years), thus indicating a deer herd at or near carrying capacity. A reduction in some of the present mortality factors due to increased suburbanization of the land around the park may allow the herd to exceed carrying capacity in the future.

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The National Park Service (NPS) faces a dilemma in regard to wildlife management on several historical parks and battlefields in the eastern United States (Porter et al. 1994). Many of these parks are isolated "islands" of native habitat surrounded by urban and suburban development. A lack of hunting or other natural predation can produce overabundant deer populations, which then may significantly alter native plant and animal communities in these parks (Warren 1991). Management of native deer populations generally is not allowed by NPS policy (Porter et al. 1994).

The Chickamauga Battlefield portion of Chickamauga and Chattanooga National Military Park (CHCH) was established to preserve the historical scene during the Battle of Chickamauga in September 1863. The NPS mandate at CHCH is to preserve the historical and cultural resources of the area, but also to protect native plant communities (NPS 1978). The potential ecological effects of an overabundant deer herd in this park may justify a recommendation for management of the deer herd in the future. Prior to recommending a deer management program, however, CHCH requires population and ecological data for the park's deer herd.

Our objectives were to document mortality factors, population size, and the health and nutritional condition of the Chickamauga deer herd. This study was funded by NPS Subagreement No. CA-5000-1-9017/8, McIntire-Stennis Project No. GEO-0030, and by the D. B. Warnell School of Forest Resources, University of Georgia. The ranger, maintenance, and administrative staff at CHCH assisted greatly in the conduct of field work. We thank the following additional people for their assistance and contributions: M. Ratnaswamy, L. Muller, J. Brooks, D. Wendt, J. Navarre, T. Powers, M. Tucker, V. Garner, and R. Hall.

Methods

Study Area

The study was conducted on the Chickamauga Battlefield portion of CHCH, which is located in Walker and Catoosa counties in northwestern Georgia. Deer were reintroduced to this park by the Georgia Department of Natural Resources and NPS in 1977 (J. Staub, pers. commun.). The study area encompassed 2,138 ha and was approximately square in shape. The park was located 10 km south of Chattanooga, Tennessee, in the Ridge and Valley Physiographic Region. Heavy commuter traffic to and from Chattanooga, Tennessee, occurred on U.S. Highway 27, which runs north and south through the center of the park.

The park had a diverse mosaic of vegetation communities, including fields, forests, and cedar glades (Rogers et al. 1993). The fields on the park were leased and cut for hay twice per year. The forests were dominated by pines (*Pinus* spp.), oaks (*Quercus* spp.), and hickories (*Carya* spp.) in the overstory. During the study, most of the land around the park was in established neighborhoods, with light industrial areas on the northern side. One area north of the park was owned by 1 or 2 individuals and was large enough to support deer hunting; however, it, too, was surrounded by residential subdivisions. A larger, open area on the southeastern corner of the park consisted primarily of livestock operations and large private holdings.

Deer Capture and Radio Telemetry

We captured deer during winter 1992 and 1993 using a Paxarms dart gun (Telonics, Inc., Mesa, Ariz.) firing Pneu-Dart darts (Pneu-Dart, Inc., Williamsport, Pa.), drop nets (Ramsey 1968, Silvy et al. 1990), and a corral/drive-net trap (Warren and Ford 1989). Deer were immobilized using a combination of xylazine hydrochloride (100 mg/ml) and ketamine hydrochloride (100 mg/ml). Dosages varied depending on the sex and age of individual deer. Immobilization was reversed using yohimbine hydrochloride (10 mg/ml) (Mech et al. 1985). Captured deer were fitted with radio-transmitter collars (Advanced Telemetry Systems, Inc., Isanti, Minn.) containing mortality sensors.

The status of radio-collared deer was monitored using a Telonics, Inc., TR-2 radio receiver mated with a TS-1 scanner/programmer. We monitored deer several times per day to determine their status. If mortality was indicated, we located the dead deer quickly, usually on the same day. We categorized mortality as road-kills, legal hunter-kills, or illegal poaching. Mortalities not clearly attributable to a source were investigated by necropsy.

Deer Necropsy and Nutrition

Road-killed deer were collected from the roads in the park from August 1991 to December 1994. In addition, we collected 8–10 adult deer from the park each August during 1991 through 1994 for herd health monitoring (Davidson et al. 1982). Ages of collected deer were estimated by tooth wear (Severinghaus 1949).

Fecundity and conception rates were determined for road-killed does. During the winter and spring, the number of fetuses in the uterus was counted directly. During other seasons, ovaries were fixed in 10% formalin for at least 24 hours, then washed, and examined for corpora lutea (CL) of a current or recent pregnancy (Cheatum 1949, Cheatum and Severinghaus 1950, Harder and Kirkpatrick 1994). We assumed that a doe with 1 or more CL's was pregnant (>95% probability; Harder and Kirkpatrick 1994). Conception dates were determined by back-dating the level of measured fetal development from the known date of death (Hamilton et al. 1985). An analysis of variance was used to test for differences between the mean conception dates of adult does and doe fawns.

Kidney fat index (KFI; Riney 1955) was obtained from necropsied deer and averaged for both kidneys. Humerus marrow fat (HMF) content was determined by extracting the fat from a section of bone marrow. Duplicates from each bone were analyzed as described by Warren and Kirkpatrick (1978). Humeri were used in lieu of femurs because they are simpler to remove and store, and the results are equivalent to those derived from femur marrow fat ($R^2 = 0.98$; Fuller et al. 1986). Only adult deer (≥1 year) were used for body fat information. Younger deer were not included because the primary function of bone marrow in young animals is red blood cell production, not fat storage. The rapid growth rates and high energy demands of younger deer require them to invest most available nutrition into growth, thereby allowing only minimal fat storage in bone marrow (Warren and Kirkpatrick 1982).

We divided each year into 3 nutritional seasons: 1) January–April (a period of low forage and mast availability, coupled with post-rut and pregnancy stresses); 2) May–August (a period of abundant green forage, coupled with the stresses of fawning and lactation in does); and 3) September–December (the fall season when hard mast may be available, coupled with the stresses of rut in bucks). We used analysis of variance (SAS 1985) to examine differences in KFI and HMF among seasons, sexes, years (1992 and 1993), and their interactions.

Abomasal parasite counts (APC's) were made for the stomach content of deer collected during August of each year. The analysis was done by project personnel in cooperation with the Southeastern Cooperative Wildlife Disease Study (SCWDS) (Eve and Kellogg 1977).

Population Estimation

The size of the deer herd was estimated by several techniques: spotlight surveys, mark/recapture surveys, and by extrapolation from the radio-collared sample of deer. Spotlight surveys using the modified line transect technique (Progulske and Duerre 1964, McCullough 1982) were conducted during fall and winter annually from 1992 to 1994. Two observers rode in the back of a pick-up truck and searched both sides of the road using 1-million candlepower spotlights to locate deer by reflective eye-shine. The vehicle was driven at 8–16 km/hour along a predetermined route (transect). The route included habitat types approximately in proportion to their occurrence in the park. When deer were spotted along the survey route, observers estimated the distance to the deer and took a compass bearing to the location of the deer when first seen. Visibility testing was conducted and the transect width was truncated to 100 m. This information was used to determine the width, and thus, the area of the transect. Deer densities were estimated by relating the deer counts to the area surveyed. The size of the deer population for the entire study site was estimated by multiplying the area of the study site by the density.

We also estimated the deer population size by a mark/recapture technique, where the number of marked deer seen was compared to the number of known, marked deer in the study area (Rice and Harder 1977). The survey route used for the mark/recapture survey was identical to the spotlight surveys. A series of 14 visual mark/recapture surveys was done from mid-April through mid-August 1994.

The herd also was estimated by extrapolating from the radio-collared sample of the park's deer herd, where the known number of radio-collared deer killed in the park each year was divided into the number of radio-collared deer in the park. The total known number of non-radio-collared deer killed on the roads in the park was multiplied by the quotient to derive a population estimate, or $r/R = n/N$ where r is the number of radio-collared deer killed; R is the total number of radio-collared deer; n is the total number of uncollared deer killed; and N is the total population.

Survival Analysis

Survival and cause-specific mortality rates were estimated by MICROMORT 1.3 software (Heisey and Fuller 1985) using data collected on the radio-collared deer. Mortality causes for radio-collared deer included road-kills, legal and illegal harvest, disease, accidents (not road-related), and undetermined. For analysis, if a radio signal was lost, or if we could no longer account for a deer, the animal was censored, or counted as functionally dead the day that the last signal was received (undetermined fate). Two survival intervals were examined, 1 and 3 years. Analysis was done first with deer separated by sex, and then with the sexes pooled. We used a *t*-test to analyze the 3 separate, 1-year survival intervals to determine differences between sexes. The 3-year interval was not an average of years, but rather reflected a deer's chance of surviving the entire 3-year interval. Hence, the 3-year survival interval could not be tested statistically for differences between sexes. We assumed the demography of the radio-collared deer represented the population.

Results

Deer Capture and Collections

We captured 81 deer (47 female and 34 male; 67 radio-collared and 14 ear-tagged). The initial capture effort to distribute the original 40 radio collars lasted from mid-December 1991 to mid-March 1992. Additional deer were captured during December 1992 ($N = 18$), and December 1993 ($N = 12$), and spring and summer 1993 and 1994 ($N = 11$). No capture myopathy occurred among the 67 deer that were fitted with radio collars.

A total of 295 deer was collected on roads in the park or within 1 km of its periphery during the study. An additional 36 individuals were collected each August to monitor herd-health. Poaching accounted for 22 of the recovered animals, and 16 deaths were attributed to accidents (e.g., an animal caught on a fence) or unknown causes of death. The sex ratio among collected deer was 0.6M:1.0F.

Reproductive Data

Mean conception dates of adult does (5 Dec) tended to be earlier ($P = 0.096$) than for doe fawns (17 Dec) during the study (Table 1). Fifty-five adult does (≥1 year old) and 33 doe fawns (<1 year old; Table 1) were collected between the end of January and August, when regression of the CL would make detection difficult. Fourteen (42%) of the 33 doe fawns showed evidence of a current or recent pregnancy (Table 1). Conception dates did not vary between years for adults or fawns ($P = 0.94$ and $P = 0.21$, respectively).

Nutritional Indices

Body mass was greater ($P = 0.05$) in 1992 than 1993, which may have reflected differences in consumption of acorn mast (55.8% occurrence of rumen volume in 1992 vs. 14.6% in 1993; Stromayer 1996). Deer age was not different among years, but does average >1 year older ($P < 0.001$) than bucks.

One hundred adult deer were collected for analysis of body fat condition indicators (53 deer in 1992 and 47 in 1993). A season-by-sex interaction ($P = 0.0001$) existed for the KFI (Table 2). Does had lowest KFI levels in May–August (18.7%)

Table 1. Reproductive characteristics of female white-tailed deer on Chickamauga Battlefield Park, Georgia, 1991–92—1993–94.

Breeding season (year)	Age[a]	Mean conception date[b]			*N* Corpora Lutea (*N* CL/pregnant doe)			Conception rate (% of individuals)	
		N	$\bar{x}$	SD	*N*	$\bar{x}$	SD	*N*[d]	% pregnant
1991–92	Adult	5	7 Dec	16.5	5	1.6	0.6	17	94.1
	Fawn	2	13 Dec	26.9	2	1.0	0.0	18	38.8
1992–93	Adult	3	4 Dec	15.7	3	2.0	0.0	23	91.3
	Fawn	5	11 Dec	13.2	5	1.6	0.6	11	36.4
1993–94	Adult	8	4 Dec	18.5	8	1.6	0.5	15	100.0
	Fawn	2	7 Jan	12.2	2	1.0	0.0	4	75.0
1991–94[c]	Adult	16	5 Dec	16.4	16	1.7	0.5	55	94.5
	Fawn	9	17 Dec	18.1	9	1.3	0.5	33	42.4

[a]Adult = ≥1.5 years; Fawn = <1.5 years.

[b]No significant difference was found between adult and fawn conception dates ($P = 0.096$).

[c]All years of study combined (1991 through 1994).

[d]The sample size for the conception rate data differs from the sample size for the other data sets due to different rejection criteria (no fetus required).

Table 2. Kidney (KFI) and humerus marrow fat (HMP) data sorted according to nutritional season and sex for white-tailed deer on Chickamauga Battlefield Park. Georgia, 1992–1993[a].

Nutritional season	Sex	KFI (%)[b]			HMF (%)		
		N	$\bar{x}$	SD	*N*	$\bar{x}$	SD
Jan–Apr	M	9	11.8	2.5	9	81.3	10.4
	F	19	37.9	23.1	19	87.8	19.2
May–Aug	M	8	37.7	22.3	9	87.7	10.3
	F	28	18.7	17.8	28	75.5	20.7
Sep–Dec	M	15	28.4	19.3	18	85.9	7.1
	F	17	41.1	32.1	17	88.7	6.8

[a]No difference was found between years for either KFI ($P = 0.094$), or HMF ($P = 0.57$); therefore data from both years were pooled.

[b]Season-by-sex interaction ($P = 0.0001$).

when bucks had highest KFI levels (37.7%), whereas does had higher KFI levels than bucks in both September–December (41.1% and 28.4%, respectively) and January–April (37.9% and 11.8%, respectively).

Levels of HMF exhibited the same season-by-sex interaction as KFI (Table 2), although it was only marginally significant ($P = 0.082$). Does had lowest HMF levels in May–August when bucks had highest HMF levels, whereas does had higher HMF levels than bucks in September–December and January–April. Numbers of abomasal parasites did not differ among years ($P = 0.64$), and averaged 1,195 across years.

Population Estimation

The mean population estimate from the fall/winter spotlight surveys was extremely variable, ranging from 91.5 to 392.4, and averaged 215 deer on the park

Table 3. Deer population estimation by spotlight survey in 2,138-ha Chickamauga Battlefield Park, Georgia, 1991–1994.

Year/ Month[a]	*N* deer per sighting $\bar{x}$	*N* sightings/ha *N*	SD	95% CI	Population estimate $\bar{x}$
1991 Nov	1.85	0.0884	0.013	0.048–0.130	364.2
1992 Feb	3.64	0.0113	0.003	0.002–0.021	91.5
1992 Nov	2.12	0.0832	0.012	0.045–0.120	392.4
1993 Jan	2.36	0.0364	0.014	−0.009–0.082	191.2
1993 Nov	2.08	0.0325	0.011	−0.002–0.067	150.3
1994 Jan	2.63	0.0178	0.004	0.006–0.030	103.9

[a]No significant seasonal difference was found ($P = 0.10$).

(Table 3). The mean population estimate from the visual mark/recapture surveys conducted during mid-April to mid-August 1995 was 501 deer (SD 198; 95% C.I. = 397 – 605). The deer population estimated by extrapolating from the radio-collared subset of the park's deer herd was 1,070 deer in 1992, 722 in 1993, and 989 in 1994. These estimates for the population ranged from 10–41 deer/km^2.

Survival Analysis

Males tended to have higher rates of mortality from hunting ($P = 0.09$) than females (Table 4). There were no sex-based mortality differences as a result of road-kills, poaching, or the mortality factors that make up the 'other' category. No annual variation in survival occurred (P = 0.21); therefore, survival data from the 1-year intervals were pooled. When considering the 3-year interval (Table 4), legal harvest on lands surrounding the park was the major cause of male mortality, whereas vehicle collision was the major mortality factor for females.

Table 4. Survival analysis of radio-collared deer in Chickamauga Battlefield Park, Georgia, 1992–1994.

		% Chance During Interval									
		Survive		Roadkill		Hunted		Poached		Other[a]	
Interval length	Sex	%	SD	%	SD	%	SD	%	SD	%	SD
1 Year[b]	M	63.9	13.7	8.1	7.3	17.6	9.6	1.9	3.3	8.5	7.5
	F	76.2	5.1	10.9	5.2	4.3	3.7	2.5	2.2	6.0	2.5
	Both	70.1	1.1	9.5	5.9	11.0	9.8	2.2	2.5	7.2	5.2
3 Years	M	21.6	8.5	14.4	7.7	38.4	1.1	4.8	4.7	19.2	8.6
	F	44.6	8.0	24.6	7.1	10.9	5.1	5.5	3.8	13.7	5.7
	Both	36.5	6.1	21.0	5.4	21.0	5.4	5.2	2.9	15.7	4.8

[a]The "Other" category included deer whose radio-collars malfunctioned and were censored and deer lost to non-automobile accidents, disease, or unknown causes.

[b]No differences were found between sexes or years during the 3 1-year intervals ($P = 0.21$); additionally, no differences were found between the sexes in rates of survival ($P = 0.22$), or hunting mortality ($P = 0.09$).

Since collaring and monitoring began, 14 of the radio-collared deer were known to have been killed on park roads. An equal number of radio-collared deer were killed by hunters around the park. This was a surprising fact, because only about 25% of the land around the park could be classified as rural. All of the deer killed by hunters were taken either on the fringes of, or in these rural areas. Three deer were known to have been killed by poachers. One 3-year-old buck died of a brain abscess and 1 doe was crushed by a tree during a severe winter storm in March 1993. Three missing deer were censored on the date of their last signal. Three additional deer were found dead, but had been scavenged so badly that cause of death could not be determined.

Discussion

Reproductive Data

The average number of CL per adult doe (≥2.5 years) in the Chickamauga deer herd was 1.69. In southeastern U.S. mountainous habitats, deer on adequate nutrition generally average 1.5 fawns/adult doe (Shrauder 1984). In research with captive deer, Verme (1967) found that does on a high nutritional plane averaged 1.53 and 1.78 fawns per doe for 2.5-year-old and ≥3.5-year-old does, respectively. Thus, our ovulation rate data for adult does indicate the Chickamauga deer herd was well-nourished during our study. Whereas evidence of a CL is not absolute assurance that conception occurred, a close relationship exists between maternal nutrition and neonatal mortality; when well-fed, deer average fawning losses of 7% (Verme 1962, 1963).

Overall, 42% of Chickamauga doe fawns were pregnant; they averaged 1.33 CL/pregnant doe fawn. Shrauder (1984) reported that generally only 10% of doe fawns breed, whereas Hesselton and Hesselton (1982) stated that as many as 60%-70% of doe fawns can breed when in good nutritional condition. Verme (1967) observed that doe fawns fed a high-quality diet produced an average of 1.18 fawns/doe fawn. Our reproductive data for doe fawns also suggest that Chickamauga deer were existing on a high nutritional level.

Nutritional Indices

Johns et al. (1984) determined that the most important factor determining seasonal fat cycles in both sexes in South Carolina was the timing of reproductive stresses. Interactions among sex and season for KFI at Chickamauga Battlefield Park can be interpreted in light of these stresses. Bucks had the lowest KFI in winter after the rut. Does displayed lowest KFI in late spring and early summer with the energetic stresses of fawning and lactation. The HMF index displayed the same seasonal patterns as KFI, but was less sensitive. There is a well-documented delay in the mobilization of marrow fat compared to kidney fat in white-tailed deer (Warren and Kirkpatrick 1982, Waid and Warren 1984, Harder and Kirkpatrick 1994). There is some concern that the KFI may not reliably reflect fat reserves, because deer kidney weights can fluctuate seasonally, which would change the KFI even though the amount of perirenal fat might remain constant (Batcheler and Clarke 1970, Dauphine 1975).

Nevertheless, the KFI reflected the predicted nutritional stress periods for Chickamauga deer.

The Chickamauga deer herd exhibited an average APC of 1,195 (range of 500 to 1,500), which suggests the herd was near carrying capacity (Eve and Kellogg 1977, Eve 1981, Davidson et al. 1982). A deer herd with an APC of 1,200 has a 59% probability of being overpopulated, a 36% probability of an optimal population, and only a 5% probability of being under, or suboptimally populated (W. R. Davidson, SCWDS, pers. commun.).

Population Estimation

In terms of population density, our estimates for the Chickamauga deer herd ranged from 10–41 deer/km^2. Considering the wildly variable nature of the population estimates from the different methods we used, it is impossible to choose a single, most accurate estimate for the population's density. However, Hesselton and Hesselton (1982) reported a range of 3–30 deer/km^2 for deer herds across the United States. Thus, our estimates for the Chickamauga deer herd density appear to be within the range of those for other deer herds in the United States. Furthermore, our reproductive and nutritional data indicate that the Chickamauga deer herd probably was not overpopulated during our study.

Survival Analysis

Survival analysis revealed that hunting mortality outside the park boundary was almost identical to road-kill mortality within the park, whether considered annually or over the 3-year interval (Table 4). Hesselton and Hesselton (1982) reported that road-kill mortality can equal or exceed the legal kill for deer in many states in the United States.

Does were more than twice as likely to survive over the 3-year survival interval than were bucks (Table 4). On the other hand, bucks were nearly 4 times more likely to be killed by hunters than were does (Table 4). All does taken by hunters were killed during archery season, because there were very few either-sex gun harvest days in the northern Georgia hunting region during the time of our study.

Conclusions

Chickamauga Battlefield Park has not yet begun to show evidence of habitat degradation due to overpopulation by deer (Stromayer 1996). The HMF index, an excellent indicator of long-term herd condition, was high. Fawning and reproductive rates were indicative of deer on a high nutritional plane for both adult does and doe fawns. The APC indicated a deer herd that was near carrying capacity.

Factors that appear to be limiting the Chickamauga deer herd should be considered seriously when developing future management plans. Hunting and road kills far exceed other mortality sources, and are the only 2 sources of mortality that local governments or park administrators have any hope to control. The only wildlife corridor and viable hunting area for two-thirds of the park was surrounded by subdivisions and probably will eventually become a subdivision. Future human developments around CHCH likely will further isolate the deer herd by removing wildlife corridors, which may lead to increased deer densities. Likewise, the proposed re-routing of U.S. Highway 27 around the park, with a subsequent reduction of the speed limit within the park, will cause most commuter traffic to by-pass the park. A decrease in traffic volume along with a speed limit reduction within the park will probably reduce the number of road-killed deer. A future decline in the number of hunter- and road-killed deer, which seem to have been relatively constant during the years of our study, may lead to an increasing deer population in Chickamauga Battlefield Park and concomitant destruction of the natural and historic scene in the park.

National Park Service policy mandates protection of vegetative resources (NPS 1978). Therefore, a deer management program may be necessary in the future. The park should prepare a contingency program before adverse impacts to the herd and vegetative resources occur (Cypher et al. 1985). Girard et al. (1993) warned that time-consuming legal steps may be needed to reduce a deer herd even when the reduction is founded solidly in indisputable evidence of overpopulation and range degradation. Our baseline data for this deer herd, coupled with data from future monitoring efforts, will aid in convincing the public of the justification for a deer management program in Chickamauga Battlefield Park.

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