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Density and Distribution of White-tailed Deer (*Odocoileus virginianus*) in Cades Cove, Great Smoky Mountains National Park, Tennessee

Michael Joseph Kiningham
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To the Graduate Council:

I am submitting herewith a thesis written by Michael Joseph Kiningham entitled "Density and Distribution of White-tailed Deer (*Odocoileus virginianus*) in Cades Cove, Great Smoky Mountains National Park, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Boyd L. Dearden, James L. Byford, Paul C. Smith

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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DENSITY AND DISTRIBUTION OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) IN CADES COVE, GREAT SMOKY MOUNTAINS NATIONAL PARK, TENNESSEE

A Thesis
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Degree
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Michael Joseph Kiningham

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ABSTRACT

Three census techniques were used from June 1978 to August 1979 to estimate population densities of white-tailed deer (*Odocoileus virginianus*) in Cades Cove, Great Smoky Mountains National Park, Tennessee. Roadside counts were conducted 3 times a week; once at dawn, dusk, and dark. Drive counts were made every 3 months and a 3-week sampling interval was used to make pellet counts. Seasonal density estimates ranged from: 0.29 to 0.58 deer/ha (dark counts), 0.29 to 0.76 deer/ha (drive counts), and 0.18 to 0.47 deer/ha (pellet counts).

Adult sex ratios obtained from dawn and dark counts made during August (44.6 bucks:100 does) and November (22.0 bucks:100 does) indicated that there were more does than bucks in the population. These uneven adult sex ratios might be due to the dispersal of bucks out of Cades Cove during rut.

Fawn:doe ratios made during the summer and fall roadside counts were 27.9 fawns:100 does in 1978 and 8.4 fawns:100 does in 1979. The difference between these ratios could be the result of a delay in fawning in 1979 compared to 1978 and not an actual decrease in fawn recruitment. The similar density estimates obtained for the summer of 1978 (0.41 deer/ha) and 1979 (0.43 deer/ha) appeared to indicate that fawn recruitment in 1978 was equal to mortality and emigration among older deer in the cove.

Of the 3 census techniques used, roadside counts were determined to be the best to estimate densities of deer in the Cove. Drive counts had 2 major disadvantages compared to roadside counts: (1) they required large amounts of manpower, and (2) they generated small sample sizes in both areas sampled and deer counted. Pellet counts were difficult to conduct during periods of leaf fall and snow cover. High rates of deterioration and/or disappearance of pellet groups in open fields made pellet counts in those areas unreliable. Pellet counts should be reserved for areas where techniques utilizing direct counts are impractical.

The deer population in Cades Cove has increased since a die-off in 1971. At the present time the population might be stabilizing but, at a high density, ranging from 0.29 deer/ha to 0.58 deer/ha. As a result, disease and continued habitat degradation are probable.

Three alternatives to the present management practices of the Cove were considered: (1) the removal of deer, (2) stopping cattle grazing and hay mowing to allow for the resumption of plant succession, and (3) developing the educational and research potentials of the Cove. Adoption of the latter alternative was recommended.

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CHAPTER I

INTRODUCTION

The management of ungulate populations is a worldwide problem. Good management requires that these populations be reduced to a level that the habitat can support in good health and without impairment to the soil, vegetation, or to habitats of other animals (Leopold et al. 1963). Such management in National Parks may be idealistically desirable but pragmatically difficult to implement. This difficulty is augmented when cultural areas like Cades Cove (the Cove) in the Great Smoky Mountains National Park (the Park) are surrounded by natural or wilderness managed areas.

Although white-tailed deer (*Odocoileus virginianus*) were once common in some sections of the area now included in the Park, by the early 1930's the deer population was greatly reduced due to over-hunting and possibly disease (Komarek and Komarek 1938). The formation of the Park in 1934 provided a refuge for deer and their numbers have increased since then (National Park Service 1969).

The historical preservation of the Cove creates an area of favorable deer habitat within the Park. A sizable deer herd has been present in the Cove since the 1950's. A concern over the possible overpopulation of deer was first voiced in 1969 by the district ranger in Cades Cove

(National Park Service 1969). Two years later, a hemorrhagic disease caused a deer die-off in the Cove (Fox and Pelton 1973, Prestwood et al. 1974). The die-off caused an 84% decrease in the number of deer utilizing the Cove's fields; from an estimated 230 deer to 36 deer. By the summer of 1972, the estimated density of deer utilizing the fields in the Cove was 0.25 deer/ha (4.05 ha/deer), an estimate similar to pre-die-off density estimates. This rapid increase in the population was probably the result of deer moving into the Cove from the surrounding area (Fox and Pelton 1973). The high deer densities and the close association of deer with domestic cattle utilizing the Cove present a constant potential for disease problems in both the deer and cattle (Severinghaus and Cheatum 1956, Trainer and Hanson 1962, Prestwood et al. 1974, Anon. 1977). Habitat degradation is also a problem associated with high deer densities. Well established browse lines have been apparent in the Cove since 1971 (Fox and Pelton 1973). In order to improve the management of the Cove, baseline demographic information on the deer population is needed.

Numerous census techniques have been developed and tested for use by wildlife biologists (Overton 1971, Seber 1973, Tanner 1978). Overton (1971) described 5 general classifications of census methods: (1) direct counts, (2) indirect counts, (3) marked animals,

(4) reduction of population size and rate of capture and, (5) selective reduction or increase. At least 1 technique from each of these general classifications has been used successfully to obtain either population estimates or indices of deer.

There have been several studies on comparing various census techniques of deer (Dasmann and Taber 1955, Eberhardt 1960, Downing et al. 1965, Lewis and Safley 1966, Flynn 1976). Dasmann and Taber (1955) compared 4 census techniques: pellet counts, sample-area count, total count and Lincoln index. Of the 4 techniques, only pellet counts failed to yield similar density estimates. Eberhardt (1960) compared 3 techniques: pellet counts, the sex-age-kill method, and a combined index of field surveys. He found a high degree of correlation among all 3 techniques. However, he felt that pellet counts were too unreliable to be used as a standard by which to judge other techniques. Downing et al. (1965) compared 5 techniques: pellet counts, track counts, drive counts, strip counts, and hunter observations. They found that except for pellet counts, all of the techniques were "workable." They concluded that sample size requirements and habitat restrictions made strip counts, track counts, and drive counts impractical and recommended the use of the hunter observation index. Five techniques were compared by Lewis and Safley (1966): Lincoln index, sex-age-kill method, percent kill, minimum standing crop, and minimum fawn crop. All of these techniques indicated similar population trends and differed only in the magnitude of their estimates. The percent kill and Lincoln index were found to be the most reliable. They concluded that the percent kill technique was the most practical for use on wildlife management areas in Tennessee. Flynn (1976) found that density estimates derived from pellet counts did not compare well with estimates derived from night-lighting counts (King method), mark-reobservation (Schnabel's method) and radioactively tagged feces (Lincoln index) on 1 study area. On a second area, the same area used by Lewis and Safley (1966), Flynn (1976) found that by reducing his sampling interval for pellet counts to 4 weeks he obtained density estimates that were similar to those obtained by the percent kill method. The 1 common discovery made by all of these investigators was that certain techniques work well in some areas and not at all in other areas.

Of the many census techniques, only a few could be used in Cades Cove. The methods of reduction of population size and rate of capture and selective reduction or increase cannot be used since they are destructive sampling and involve the removal of a number of animals from the population. At the present time such methods would be contrary to Park policy. The methods involving marked animals would also be difficult to implement due to the large number of animals that would have to be marked. Standgaard (1967) estimated that at least 67% of a roe deer population needed to be marked in order to obtain reliable density estimates. Seber (1973) suggested that about 20% of a population should be marked and Downing et al. (1977) suggested that if behavior was accounted for, fewer than the 67% recommended by Standgaard (1967) needed to be marked. Regardless of whether 20% or 67% of the population was to be marked, the extra effort necessary to trap and mark deer in the Cove would make such methods impractical since alternate, less time consuming, methods are available. Thus, the 2 remaining methods are direct counts and indirect counts. Three census techniques were chosen to be tested in Cades Cove: 2 direct counts, roadside counts and drive counts and 1 indirect count, pellet counts.

The objectives of this study were threefold: (1) to test and evaluate the 3 census techniques in Cades Cove, (2) to establish baseline demographic data on the deer population in the Cove, and (3) to determine the method best suited for further monitoring of the deer population in the Cove.

CHAPTER II

STUDY AREA

General Description and Location

Cades Cove, located in the northwest corner of the Great Smoky Mountains National Park, is in Blount County, Tennessee (Fig. 1). It is a 977.2 ha valley of which 747.6 ha (76.5%) are maintained as open fields and the remaining 229.6 ha (23.5%) consists of small woodlots and wooded areas. There are 8 habitat types in the cove, of which 7 are field types. The 8 habitat types are: (1) pastures containing cows, (2) pastures containing horses, (3) hay fields, (4) pastures presently without any livestock in them, (5) "historical" areas (mowed grass around historical and interpretive structures), (6) old fields, (7) mixed use areas (areas used for both hay and livestock grazing) and (8) wooded areas (Appendix, Table A-1).

Laurel Creek Road, the only paved road into the Cove, connects the Cades Cove Loop Road with Route 73 in Townsend. The one-way Loop Road (17.7 km) circles the Cove and provides visitors in cars, on bicycles, and on foot with an easy access to the wildlife and historical sites in the Cove. Two dirt roads, Sparks Lane and Hyatt Lane, cross the Cove from north to south. Two one-way dirt roads lead out of the Park from Cades Cove: (1) Rich

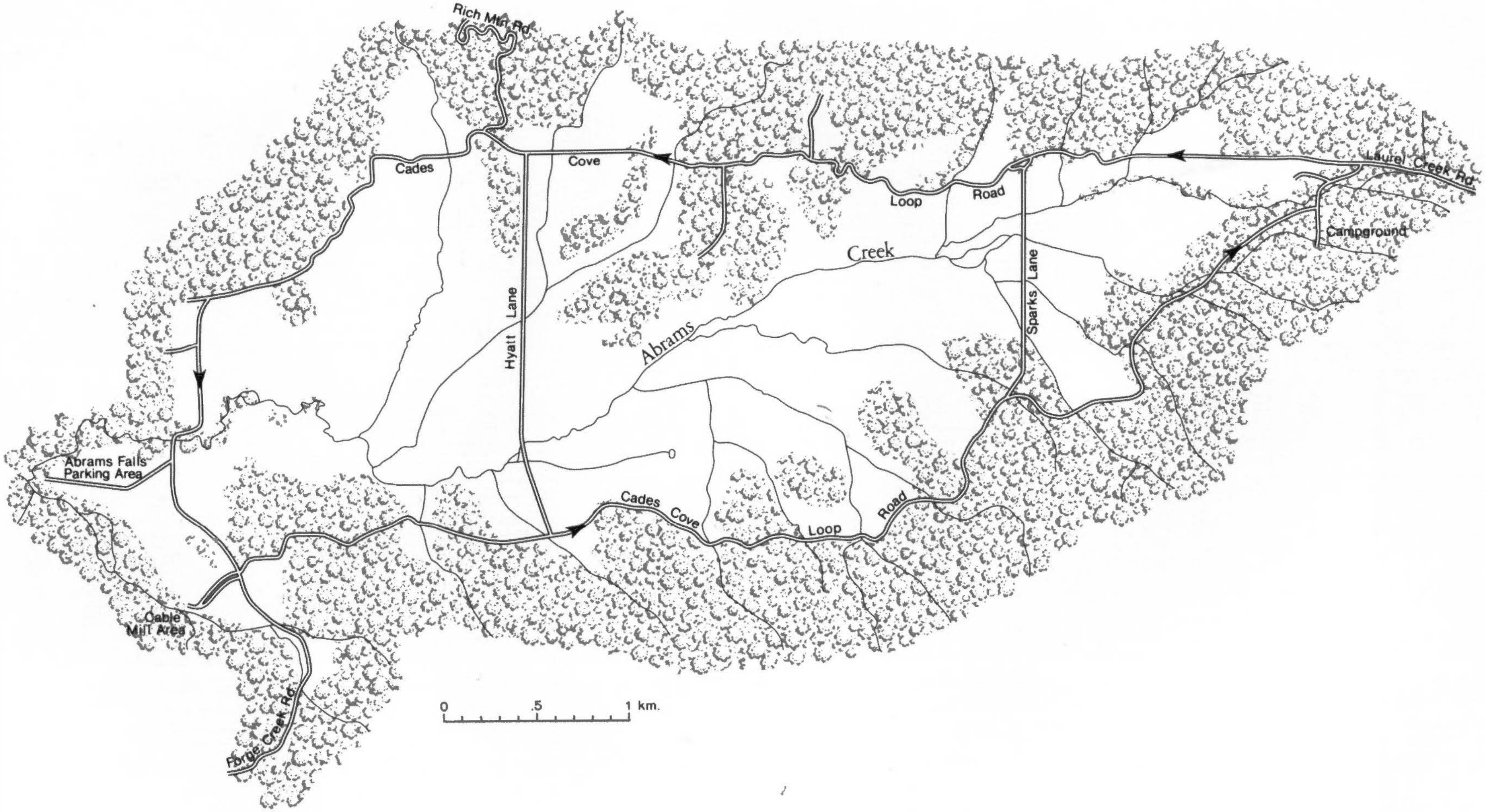

Fig. 1. Cades Cove, Great Smoky Mountains National Park, Tennessee.

Mountain Road goes from the Cades Cove Loop Road to Dry Valley near Townsend and (2) Parson's Branch Road via Forge Creek Road goes from the Cades Cove Loop Road to U.S. Highway 129 near Calderwood, Tennessee. Several trails also lead into and out of the Cove.

History and Management

As part of the Cherokee Indian nation, Cades Cove remained undeveloped until it was settled by white men in 1821. Many trees in the Cove were removed by burning and girdling and then replaced with crops and orchards. Cattle were kept in the Cove during the winter and were grazed during the summer on the mountaintop balds adjacent to the Cove. The Cove pioneer community reached a peak population of 685 people in 1850. Extensive logging occurred in and around the Cove after the turn of the century (1908-1936). The pioneer community and all logging operations were abandoned when the Cove came under the jurisdiction of the National Park Service (Park Service) with the formation of the Great Smoky Mountains National Park in 1936 (Shields 1977).

Cades Cove is currently listed in the National Register of Historic Places. Although surrounded by natural and wilderness managed areas, the Cove is managed for its historical resources, which are made up of historic sites and structures. These historic sites and structures are used to provide Park visitors with an insight into a way-of-life of the pioneer period. The old buildings and their geographic setting create a rural atmosphere and an open-air museum that greatly contributes to the historical interpretation of Cades Cove. Grazing and haying operations by Special Use Permit are used to maintain open fields and vistas (National Park Service 1969).

Physiography and Geology

Cades Cove is frequently described as a gently rolling, pastoral valley isolated by high mountains. Elevations within the Cove range from 522 m to 600 m. The Cove is a limestone "window" underlain by dolomite and limestone while the surrounding ridges are composed of older metamorphic rock. Some unique geologic formations such as caves, outcrops, sinkholes, and sag ponds are found within the Cove. Most of the Cove consists of alluvial deposits from Abrams Creek and its tributaries.

Abrams Creek enters Cades Cove as a fast-flowing mountain stream but, its flow rate decreases as it meanders throughout the flat areas of the Cove. During the year portions of Abrams Creek occasionally dry up. There are also many small swampy areas along Abrams Creek and its tributaries.

Climate

No comprehensive climatology data are available for Cades Cove; however, an indication of the Cove's climate can be gained by looking at climatology data for the Park. The Park's climate is characterized by cool temperatures and high precipitation. Precipitation and temperatures in the Park vary greatly with elevation. At low elevations, precipitation averages about 140 cm per year and well over 220 cm may occur at the highest elevations. The summer season has the greatest precipitation and the fall season has the least. The average annual temperature is 14° C at lower elevations (below 450 m) and 6° C at higher elevations (above 1900 m), with a temperature gradient of 4.07° C per 1000 m change in elevation. Monthly temperature means are usually at a high in July and a low in February (Shanks 1954, Tanner 1963, Climatography of the U.S. 1972).

Flora

The open fields in Cades Cove consist primarily of fescue (*Festuca* sp.), orchard grass (*Dactylis* sp.), timothy (*Phleum* sp.), red top grasses (*Agrostris* sp.), red and ladino clovers (*Trifolium* sp.) (National Park Service 1969). Some old farmsteads and their associated fields and orchards within the Cove are being reclaimed through natural succession. Many of these areas consist of almost pure even-age stands of white pine (*Pinus strobus*) or short leaf pine (*P. echinata*). The understory in these pine stands often contain hemlock (*Tsuga canadensis*). There are also areas of mixed hardwoods in the Cove. These areas consist of various species of oak (*Quercus* sp.), maple (*Acer* sp.), hickory (*Carya* sp.), and yellow poplar (*Liriodendron tulipifera*). Some common understory species throughout the Cove are service berry (*Amelanchier laevis*), mountain laurel (*Kalmia latifolia*), rhododendron (*Rhododendron* sp.), various species of blueberries (*Vaccinium* sp.), and huckleberries (*Gaylussacia* sp.).

Fauna

A diversity of animals inhabit Cades Cove. Of the 59 species of mammals found in the Park, many exist within the Cove (Linzey and Linzey 1971). Besides white-tailed deer, other large mammals common to the Cove include black bears (*Ursus americanus*) and European wild hogs (*Sus scrofa*). More than 200 species of birds, 23 species of snakes (including 2 poisonous), over 72 species of fish, and a wide array of salamanders inhabit the Park, and many of these occur in Cades Cove (National Park Service 1969). In addition to the wildlife, there are approximately 400 head of cattle and 45 horses in the Cove.

CHAPTER III

METHODS

Roadside Counts

The roadside count technique used in this study differs from traditional roadside count methods (King method, Frye's strip census, and Hayne's method). The technique used is actually a modification of the drive count method (Overton 1971). An imaginary drive line was projected out perpendicular to the road on both sides. As this line sweeps through both fields and wooded areas, all of the deer that pass through it were counted. The length of the imaginary drive line was variable and depended upon the visibility in the fields and wooded areas. Distances were constantly monitored during counts using known-distance landmarks in the wooded areas and fields. This method avoids the major criticism of traditional roadside counts; that the animals observed belong to a sub-population that occurs along roadsides and they are not representative of the entire population. The roadside counts conducted in the Cove sampled approximately 80% of the field area and 33% of the wooded area. This technique has been successfully used in Cades Cove by Fox and Pelton (1973).

Roadside counts are dependent on the observability of deer. Observability is related to deer activity; the more active deer are, the more likely they are to be seen. Deer tend to be crepuscular in nature; therefore, counts were conducted at dawn (1/2 hour before sunrise), dusk (1 hour before sunset), and dark (1/2 hour after sunset) every week. To prevent dawn counts from extending into daylight hours (approximately 1 hour after sunrise) and dusk counts from overlapping with dark count hours, only half of the Cove was surveyed each week. Weekly counts of the north half of the Cove (from the entrance to the Abrams Falls parking area, areas 1-47) were alternated with weekly counts of the south half (from Abrams Falls parking area to the exit, areas 48-89) (Fig. 2). The fields and wooded areas adjacent to the road were given a number for identification (Fig. 2). During each count, the following information was recorded: date, type of count (dawn, dusk or dark), half surveyed (north or south), start and end times, and general weather conditions. When deer were seen, the following information was recorded: the number of the field or wooded area in which the deer were seen, the number of deer seen, their age class and sex (male, female, young-of-the-year, unsexed), the estimated distance between the deer closest to a cow or horse if less than 300 m, and additional comments such as "fawn-at-heel," twins, group size, unusual physical abnormalities, etc.

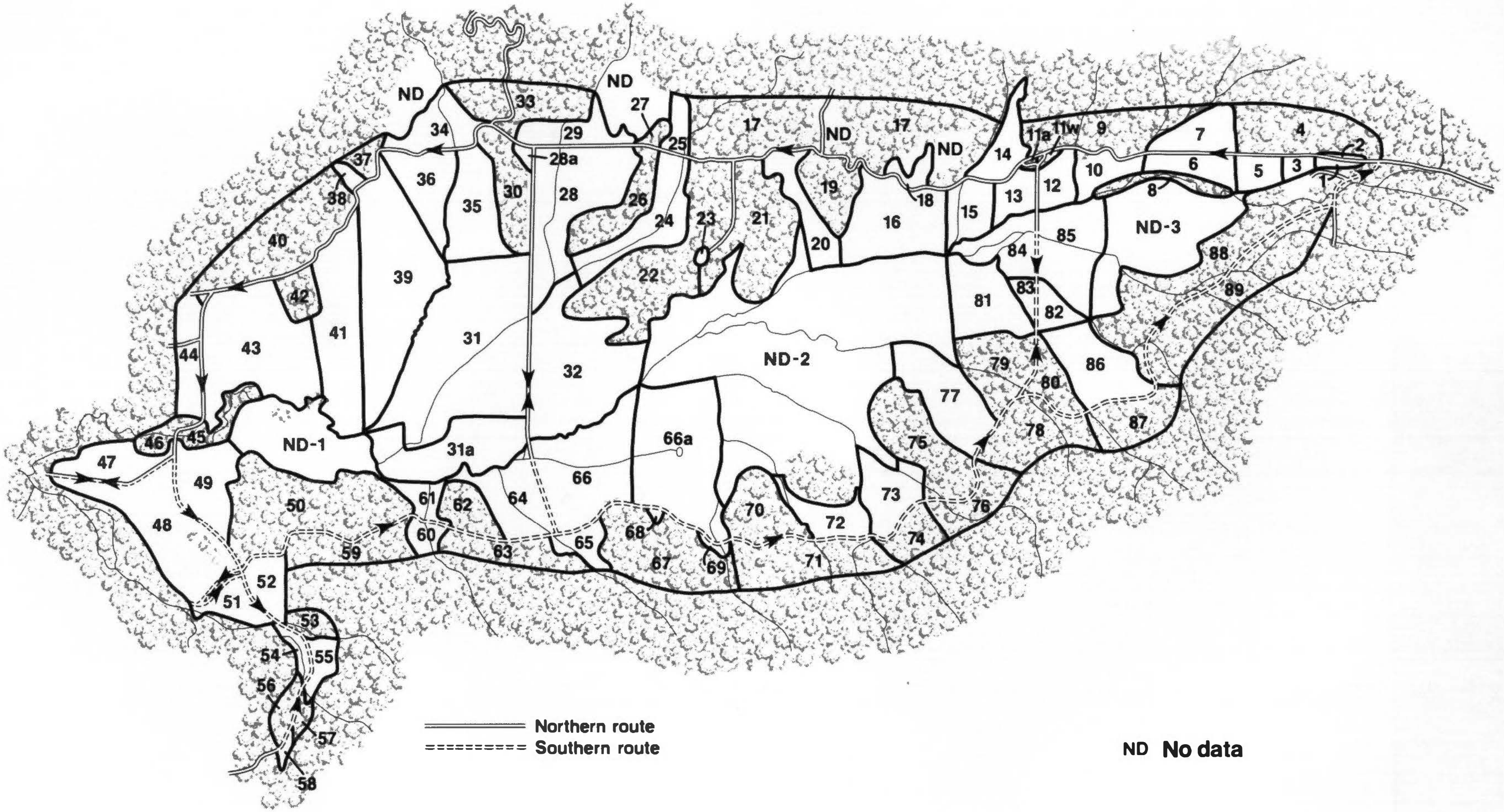

Fig. 2. Cades Cove, Great Smoky Mountains National Park, Tennessee, illustrating the route traveled during roadside counts of the north and south halves and area identification numbers.

Only antlered deer were considered to be males (bucks), only spotted deer were considered to be young-of-the-year (fawns), and unantlered deer were considered to be females (does) only if a fawn was at heel or antlered deer were prevalent. Fawns were not sexed. At least a portion of a deer's body had to be seen and it had to be positively identified as a deer in order to be counted.

The north side of the Cove that was sampled during roadside counts consisted of 46.5 ha of cow pastures, 23.1 ha of horse pastures, 166.9 ha of hay fields, 159.0 ha of fields that were used for both livestock grazing and hay, and 1.9 ha of "historical" areas (Appendix, Table A-1). The sample area on the south side consisted of 143.9 ha of cow pastures, 52.4 ha of hay fields, 6.0 ha of old fields, 10.4 ha of fields used for both livestock grazing and hay, 17.1 ha of fields used for both cattle and horse grazing, and 6.7 ha of "historical" areas (Appendix, Table A-1).

Usually counts were made using 3 people, although the number ranged from 1 to 5. When 3 people were available, 1 drove the pickup truck and recorded the data and 2 stood in the back as observers; 1 searched the right side of the road and the other the left side. At least 1 person stood in the back of the truck whenever possible. Dark counts were made using 2, hand-held spotlights equipped with sealed beam aircraft landing lights (200,000 candlepower).

A similar spotlight was mounted on the roof of the truck so that the driver could also search for deer when necessary. Distances were estimated by using known-distance landmarks in the fields and wooded areas.

Density estimates were derived by dividing the total number of deer seen by the total area surveyed. Adult sex ratios were calculated from counts made during August and November as was recommended by Michael (1970) and Downing et al. (1977). Fawn:doe counts conducted from July to October 1978 and July and August 1979 were used as an index to fawn recruitment.

Drive Counts

The procedure of the drive counts was similar to that described by Overton (1971). All drive areas were within the perimeter of the Loop Road. Both fields and wooded areas were driven for deer. The general direction of all the drives was from the Loop Road towards the interior of the Cove. Typically, open fields bounded 3 sides and the Loop Road formed the fourth side of the woodlots that were driven. These woodlots were considered to be representative of the wooded areas within the study area. Counters stood in the open fields around the woodlots and counted all of the deer that were driven out. While the counters were being positioned, 1 or 2 observers stood along the road and counted any deer that ran out of the woodlot before the drive began. The drivers, after forming a line along the road, walked through the area in a straight line and frightened deer ahead of them. Deer that turned back through the line were counted by the drivers. Counters and drivers only counted those deer which passed between them and the person to their immediate right. When possible, the sex and age class of the deer were recorded; sex and age class were determined based on the criteria used during roadside counts. Two-way radios were used to help coordinate the drivers and counters during the drives. Field areas were typically "driven" by visually scanning them from the roadside and while setting up the counters around the wooded areas; actual drive lines were usually not necessary.

Density estimates for the study area were calculated by weighting the densities obtained for the wooded areas and the fields according to their relative proportions within the study area. Fields comprised 76.5% of the study area and the remaining 23.5% consisted of small woodlots and wooded areas.

Pellet Counts

A stratified random sample of Cades Cove was used to locate 12 permanent transects for pellet counts. The transects were 610 m long and 3.05 m wide providing a sample area of 0.186 ha for each transect; a total of

2.232 ha or 0.2% of the Cove. Transect mid-lines were delineated in the wooded areas by using plastic flagging and in the fields by wooden stakes. A 1.525 m long stick was carried while making counts. This stick was used to determine the precise width of the transect by placing it perpendicular to the midline of the transect. Each transect was initially cleared of all pellet groups 3 weeks prior to making pellet counts.

Pellet groups that contained a minimum of 5 pellets were counted on each transect every 3 weeks. These pellet groups were then destroyed or marked. Neff (1968) "arbitrarily" recommended that 30 or more pellets had to be present to constitute a pellet group. For this study, the 5 pellet criterion was felt to be appropriate in light of the potentially high deterioration and/or disappearance rates of pellet groups in the Southeast (Downing et al. 1965) and Tennessee (Flynn 1976). Strewn-out or scattered pellet groups were counted if half or more of the pellets were within the transect (Robinette et al. 1958, Neff 1968).

Density estimates were derived by using the following equation:

$$\Sigma Y/(A \times D \times R) = \text{deer/ha}$$

where, ΣY = the number of pellet groups found

A = the area of the sample in ha

D = the number of days between counts

R = the defecation rate (pellet groups/day/deer)

It was assumed that all pellet groups that were on a transect were found and that deer defecate approximately 13 times a day (Neff 1968).

A deterioration and/or disappearance study of pellet groups was conducted concurrently with the pellet counts. When possible, up to 10 pellet groups (containing at least 5 pellets each) found on a transect were marked with a spray painted circle. A different color paint was used every 3 weeks. The presence or absence of a marked pellet group was recorded 3 weeks later when the transect was next surveyed. Marked pellet groups containing less than 5 pellets were considered as having deteriorated and/or disappeared.

Distribution

Temporal and spatial distribution of deer in Cades Cove was determined from the data collected using the above 3 census methods. The data from roadside counts were also analyzed with respect to deer usage of the 8 various habitat types in the Cove. Distribution maps of the roadside count data were originally made using SYMAP (Laboratory of Computer Graphics and Spatial Analysis 1975) and then manually reproduced.

Statistical Analysis

All data were analyzed by using the Statistical Analysis System (SAS) (Barr et al. 1979) unless otherwise noted. Linear models, including linear regression and analysis of variance (ANOVA) were computed using the procedure GLM of SAS. Comparisons of 2 means were made using the procedure TTEST of SAS.

Densities for the individual field and wooded areas for use by SYMAP were calculated by a FORTRAN IV program developed by A. Beauchene of The University of Tennessee Computing Center. All confidence intervals are 95% unless otherwise noted.

CHAPTER IV

RESULTS AND DISCUSSION

Roadside Counts

Density estimates. One hundred and seventy-nine roadside counts and 30,070 observations of deer were conducted between 3 July 1978 and 1 September 1979. Density estimates derived from dark counts (0.43 ± 0.04 deer/ha or 2.33 ha/deer) were significantly greater ($P < 0.05$) than those from dawn counts (0.29 ± 0.04 deer/ha or 3.45 ha/deer). Dusk counts (0.36 ± 0.04 deer/ha or 2.78 ha/deer) were lower than dark counts but not significantly ($P > 0.05$). Burst and Pelton (1978) also reported that they were able to count more deer after sunset in the Cove than dawn or dusk counts. Halloran (1943) conducted morning and evening counts of deer in Texas. His evening counts also tended to be greater than his morning counts. Thus, throughout a year deer are most likely to be observed at dusk and shortly after sunset.

Seasonal density estimates (summer: June, July, and August; fall: September, October, and November; winter: December, January, and February; spring: March, April, and May) derived from all counts were significantly different ($P < 0.001$); the highest density estimates were obtained during the spring and the lowest estimates in the winter

(Table 1). There was a significant interaction ($P < 0.002$) between the time of the count (dawn, dusk, or dark) and the season when it was made (Fig. 3).

The most accurate density estimates probably were derived from dark counts because they consistently produced the highest counts (4 out of 5 seasons) (Fig. 3). Seasonal density estimates derived from counts conducted after sunset ranged from 0.29 deer/ha (3.45 ha/deer) to 0.58 deer/ha (1.72 ha/deer) (Table 2). The use of either dawn or dusk counts would result in an obvious underestimation of the Cove's deer population.

Activity patterns. During the winter and spring the deer utilizing the Cove change their activity patterns. During the winter and spring the highest numbers of deer were observed during dusk counts and the fewest during dawn counts (Fig. 3). This pattern is contrary to that observed during the summer and the fall. Of the 3 counts made each week, dusk counts were made at the warmest time of the day during the winter. Independent of the roadside counts, large numbers of deer were observed in the middle of the day during the winter; an uncommon sight at any other time of the year. Thus during the winter, deer are apparently most active during the warmer periods of the day. These results support Ozoga and Verme (1970); they found that both the food intake and the activity of deer

Table 1. Seasonal density estimates derived from all roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Season	Sample Size (n)	Area (ha)	Number of Deer Observed	Deer/ha	(ha/Deer)
Summer 1978	24	6920.1	2035	0.29	(3.45)
Fall	42	12593.8	4721	0.37	(2.70)
Winter	33	11285.0	2648	0.23	(4.35)
Spring	39	12733.9	6391	0.50	(2.00)
Summer 1979	41	12260.7	4275	0.35	(2.86)
Total	179	55793.5	20070	0.36	(2.78)

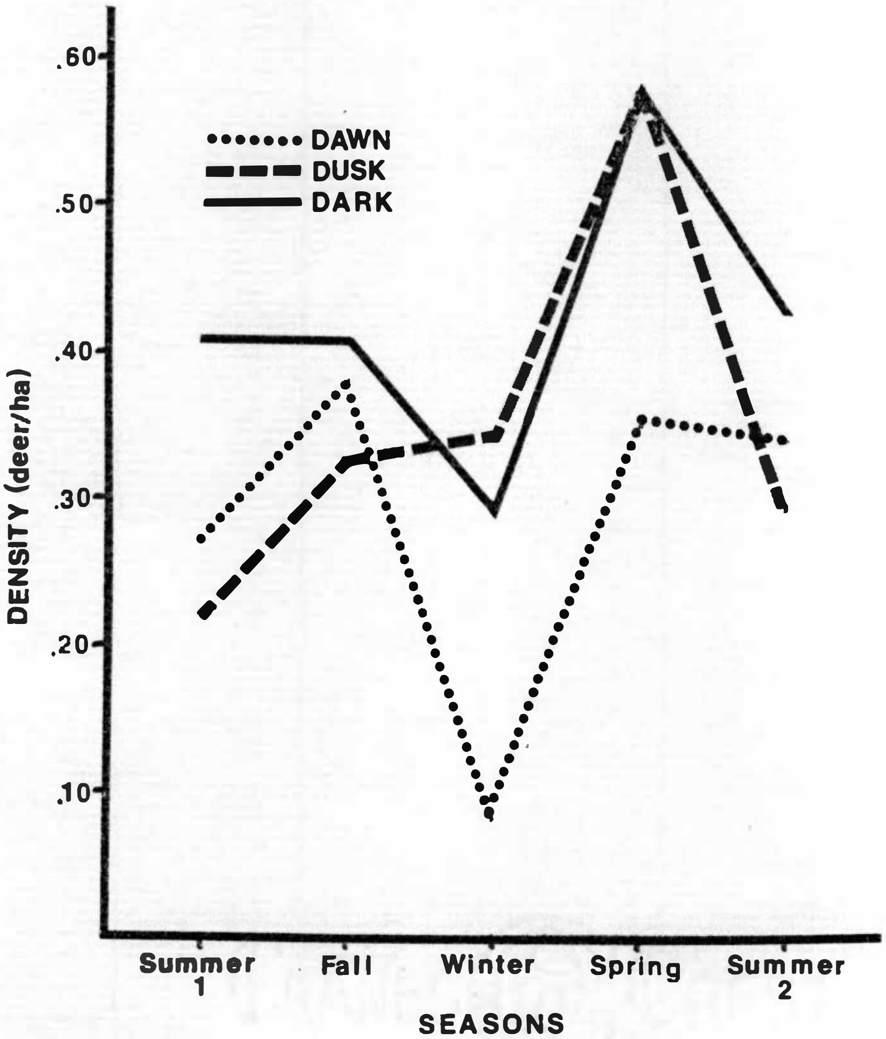

Fig. 3. Seasonal density estimates derived from dawn, dusk, and dark counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Table 2. Seasonal density estimates of deer as derived from dark counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Season	Sample Size (n)	Area (ha)	Number of Deer Observed	Deer/ha	(ha/Deer)
Summer 1978	8	2104.19	870	0.41±0.11	(2.44)
Fall	14	4243.65	1761	0.42±0.08	(2.38)
Winter	11	3416.44	993	0.29±0.09	(3.45)
Spring	13	3834.72	2232	0.58±0.08	(1.72)
Summer 1979	14	3698.38	1588	0.43±0.08	(2.33)
Total	60	17297.38	7444	0.43±0.04	(2.33)

increased during early winter and then again during the spring. As winter progressed, deer restricted their activities to the warmest part of the day. They also found that the cessation of feeding was significantly correlated with the time of sunset throughout winter. Such behavior would account for the decline in the number of deer counted after dark during the winter in the Cove since deer would become less active and more difficult to observe after sunset.

Habitat use. A significantly greater ($P < 0.001$) density estimate was derived from counts made of the north half (0.42 ± 0.03 deer/ha or 2.38 ha/deer) of the Cove than of the south half (0.26 ± 0.03 deer/ha or 3.85 ha/deer). However, when the habitat type in which the deer were seen was included in a linear model of the form: $\hat{Y} = b_0 + b_1X_1 + b_2X_2$ where, $\hat{Y}$ = density, X_1 = north or south side, and X_2 = habitat type, the side variable no longer contributed significantly ($P > 0.10$) to the model. The habitat type variable was significant ($P < 0.001$). Thus the difference in deer densities between the north and south halves was due to differences in the habitat types on each side and not a geographical difference.

The 4 largest field types (based on total area) found in the Cove were: (1) fields containing cows, (2) fields containing horses, (3) hay fields, and (4) pastures temporarily without any livestock in them.

To evaluate habitat use by deer, standard normal variate (SNV) tests for a single proportion (Hays 1973) were made using the proportions of the areas of the field types as the expected proportion of deer in each field type. The number of deer seen in fields containing cows was significantly less ($P < 0.001$) than in the other 3 field types (Table 3). Significantly fewer ($P < 0.001$) deer were seen in the wooded areas than in fields containing cows. Significantly more ($P < 0.001$) deer were seen in fields containing horses than in the other field types. Burst and Pelton (1978) also reported that deer used cow pastures less than hay fields or horse pastures. Their test results between the number of deer seen in hay fields and horse pastures were conflicting. However, they did not distinguish between pastures that actually had cattle or horses in them at the time of the count and these that did not, as was done in the present study. Of those fields that were only used for cattle or horse grazing, deer usage increased significantly ($P < 0.001$) when the livestock was not present in the field (Table 4). Relative to their usage of hay fields, deer in the Cove tended to avoid fields used by cattle and were attracted to fields used by horses. Other researchers have also reported that deer tend to avoid cattle (Kramer 1973, Hood and Inglis 1974, Suring and Vohs 1979). Hood and Inglis (1974) believed that deer avoided horses even more

Table 3. Densities of deer observed in the 4 major field types and the wooded areas during roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Field Type	Sample Size (n)	Area (ha)	Number of Deer Observed	Deer/ha	(ha/Deer)
w/cows	355	4595.0	1131	0.25	(4.00)
w/horses	138	1826.5	931	0.51	(1.96)
hay	1940	21344.7	8531	0.40	(2.50)
pasture	1735	20328.6	7978	0.39	(2.56)
wooded areas	3079	5580.5	874	0.16	(6.25)

Table 4. Density of deer observed in fields used only for horse or cattle grazing during roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Horse Pastures Only			Cow Pastures Only	
Horses			Cows	
Present	Absent		Present	Absent
86	359	Sample size (n)	272	977
467.43	1521.40	Area (ha)	3427.39	10955.13
278	1135	Number of deer observed	538	3214
0.59	0.75	Deer/ha	0.16	0.29

than cattle, but they were probably referring to horses with riders and not horses grazing in a pasture.

Suring and Vohs (1979) state that grazing by cattle can stimulate new vegetative growth and as a result, enhance the digestability and palatability of grasses and forbs for deer. In the Cove, grazing by cattle is relatively intense compared to grazing by horses. If grazing by horses also stimulates new vegetative growth, then perhaps the following can explain the differences between deer usage of horse and cattle pastures in the Cove. Cattle grazing in the Cove might be so intense that it no longer stimulates vegetative growth; it might actually stunt the growth. Since grazing by horses in the Cove is less intense, the new vegetative growth in horse pastures might attract deer. However, data on the species composition of the pastures and how deer, cattle, and horses utilize those species is needed before any definite conclusions can be made. Regardless of the cause for the difference in the usage by deer of the field types, the approximately threefold difference between cow pastures (143.9 ha on the south side vs. 46.5 ha on the north side) and hay fields (52.4 ha on the south side vs. 166.9 ha on the north side) probably accounted for the difference in density estimates for each side.

<u>Method of bounded counts</u>. Burst and Pelton (1978) used the method of bounded counts (Overton 1971) to obtain an estimated deer population of 0.52 deer/ha (1.92 ha/deer) utilizing the Cove during the summer of 1977. Their summer estimate is greater than either the 1978 or 1979 summer estimates. They may have overestimated the deer population by assuming that their sample area was representative of the whole Cove. To illustrate this point, density estimates for the summers of 1978 and 1979 were re-calculated under the following assumptions: (1) using either the north half or the south half as the sample area, (2) using the method of bounded counts to obtain density estimates, and (3) expanding the estimates for the sample areas to get a density estimate for the entire Cove as Burst and Pelton (1978) did. If the north half was the sample area in 1978 then:

$$\hat{N}_1 = 365 \text{ deer}$$

Sample area = 40% of the Cove

or, 52% of all the fields

$$\text{thus, } \hat{N}_2 = 365/0.52 = 702 \text{ deer}$$

or, 0.72 deer/ha (1.39 ha/deer)

If the south half was the sample area in 1978 then:

$$\hat{N}_1 = 92 \text{ deer}$$

Sample area = 26% of the Cove

or, 34% of all the fields

$$\text{thus, } \hat{N}_2 = 92/0.34 = 271$$

or, 0.28 deer/ha (3.57 ha/deer)

Density estimates derived this way for 1979 were also conflicting (using the north half, $\hat{N}_2$ = 0.63 deer/ha or 1.59 ha/deer; using the south half, $\hat{N}_2$ = 0.28 deer/ha or 3.57 ha/deer). Thus, which side was used as the sample area made more than a twofold difference in the density estimates for 1978 and 1979. These differences are undoubtedly due to the differential use by deer of the various habitat types and the unequal distribution of these habitat types between the north and south halves of the Cove. The proportion of the various habitat types changes in the Cove from year to year; there is no way of determining if a similar inequality existed between the study area used by Burst and Pelton (1978) and the rest of the Cove. If such an inequality did exist, then it would have caused an inaccurate estimation of the deer population.

Sex and age ratios. Male deer (bucks) were observed during every month of the year except April and May while conducting roadside counts (Table 5). Young-of-the-year (fawns) were first observed in June and most lost their spots by November (Table 5). One set of twin fawns was observed in the field numbered 44 on 13 January 1979. On 5 February, a single fawn was observed in field 44. Of all males (bucks) and females (does) observed, most were observed during dark counts (37% and 38%, respectively). Of all fawns observed, most (43%) were observed during dawn counts.

Table 5. The number of bucks and fawns observed during roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Month	Number of Bucks Observed	Number of Fawns Observed
Jul 1978	181	54
Aug	253	102
Sep	257	181
Oct	248	165
Nov	237	11
Dec	119	1
Jan 1979	56	2
Feb	16	1
Mar	13	0
Apr	0	0
May	0	0
Jun	21	7
Jul	318	33
Aug	249	96

The fewest numbers of bucks, does, and fawns were observed during dusk counts (28%, 30%, and 22%, respectively).

August was recommended by Michael (1970) and August and November were recommended by Downing et al. (1977) as the best months for determining adult sex ratios from counts. The results of dawn and dark counts (counts when the most does and bucks were observed) conducted during these months were used to calculate adult sex ratios (Table 6). The counts conducted during August may have been the most reliable since by November most fawns had lost their spots and some were probably mistakenly identified as does. However, during 1978, the change in adult sex ratios from August (45.1 bucks:100 does) to November (22.0 bucks:100 does) could have been the result of dispersal out of the Cove by bucks. Dispersal of bucks during rut has been documented in the Southeast (Downing et al. 1969, Downing and McGinnes 1975, Kammermayer and Marchinton 1975, 1976, Marchinton and Kammermayer 1980). This dispersal is believed to be in response to social pressure during rut; the number of bucks dispersing is directly related to the population density (Hawkins et al. 1971, Kammermayer and Marchinton 1976, Marchinton and Kammermayer 1980). Burst and Pelton (1978) observed a 90.9 bucks:100 does adult sex ratio in the Cove during August 1977. Frank Singer, a research wildlife biologist in the Park, reported a 32.3 bucks:100 does adult sex ratio during the fall of 1977

Table 6. Adult sex ratios as determined by dawn and dark counts conducted during August 1978 and 1979 and November 1978 in Cades Cove, Great Smoky Mountains National Park, Tennessee.

Month	Number of Bucks Observed	Number of Does Observed	Bucks:100 Does
Aug 1978	152	337	45.1
Nov 1978	158	718	22.0
Aug 1979	173	392	44.1
Total	483	1447	33.4

(pers. comm.). Again, a decrease in the buck:doe ratio during rut was observed.

The rate of reproduction could not be accurately determined since fawns are generally less observable than does (Downing et al. 1977). However, fawn:doe counts can be used as an index of the reproductive rate. Very low fawn:doe ratios were obtained for both 1978 and 1979 (Table 7). A minimum of 26 sets of twins and 2 sets of triplets (53% of all fawns observed) were observed during July and August 1978. Seven sets of twins (20% of all fawns observed) were observed during July and August 1979. These numbers are minimums because if 2 fawns were observed with 2 does, they were counted as singles even though they may have been twins.

Burst and Pelton (1978) observed a ratio of 49.5 fawns:100 does in the Cove. This ratio is higher than the ratios seen in either 1978 (27.9 fawns:100 does) or 1979 (8.4 fawns:100 does). The Cove fawn:doe ratios were also lower than those observed in Texas by Carroll and Brown (1977) (28.9, 34.6, and 47.7 fawns:100 does); a population that had known severe fawn mortality. The July fawn:doe ratios (12-22 fawns:100 does) observed by Downing et al. (1977) in Virginia were the only ratios lower than those observed in the Cove. The other Virginia ratios ranged from 38-43 fawns:100 does. The fawn:doe ratios observed in the Cove during July and August 1978 were slightly

Table 7. Fawn:doe ratios as determined by roadside counts conducted from July-October 1978 and July-August 1979 in Cades Cove, Great Smoky Mountains National Park, Tennessee.

Month	Number of Does Observed	Number of Fawns Observed	Fawns:100 Does
Jul 1978	263	33	12.5
Aug	337	77	22.7
Sep	361	136	37.7
Oct	460	151	33.3
Jul 1979	429	17	4.0
Aug	392	52	13.3
Total	2242	466	20.8

higher than those obtained by Downing et al. (1977) in Texas (8-29 fawns:100 does), whereas the ratios from July and August 1979 in the Cove were lower than those from Texas. These comparisons of fawn:doe ratios indicate that currently fawn recruitment in the Cove is poor. Although the fawn:doe ratios for the Cove were low, the number of twins and triplets observed in 1978 suggest moderate to high levels of reproduction, especially for a protected population (Burst and Pelton 1978). The few sets of twins observed in 1979 were accurately reflected by a low fawn:doe ratio.

The adult sex ratios from 1978 and 1979 and the change in adult sex ratios from 1977 to 1978 and 1979 (more does than bucks) suggest an expanding deer population. Theoretically, a skewed population in favor of females in a polygamous species should increase rates of population growth (Dasmann 1964, McCullough 1979). Density estimates from the summers of 1971 to 1979 (Fig. 4) indicate that the population has expanded since a die-off. However, the relatively low fawn:doe counts and the non-significantly different ($P > 0.10$) density estimates obtained for July and August 1978 and 1979 suggest a stable or declining population. These conflicting results could be explained as follows. The uneven adult sex ratio could be the result of the dispersal of bucks out of the Cove to areas of lower deer densities because of social pressures. This dispersal

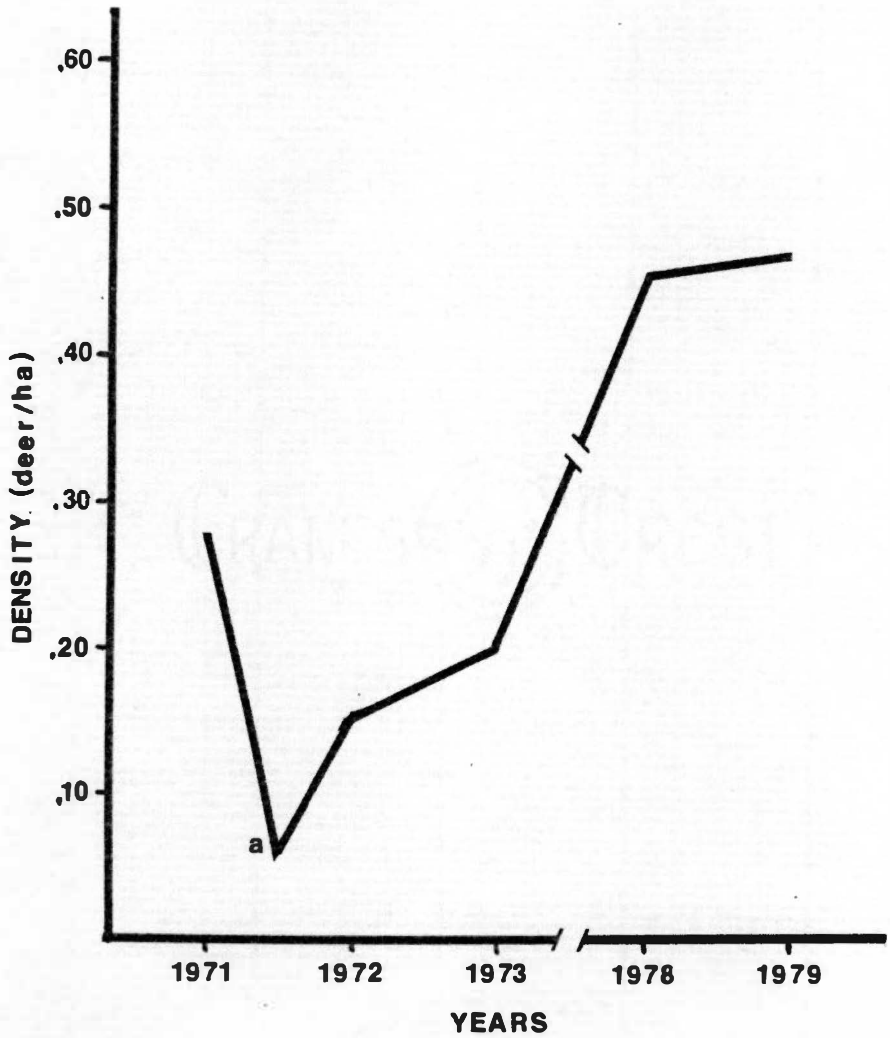

Fig. 4. Density estimates derived from dark counts of deer utilizing the fields in Cades Cove, Great Smoky Mountains National Park, Tennessee, for the summers of 1971-1979 (1971, 1972, and 1973 data from Fox and Pelton 1973).

[a]Fall, 1971, density estimate.

might initially decrease the population, but as long as the recruitment of fawns into the population during the summer is greater than the dispersal of bucks in the fall and there is low mortality, the population will continue to increase. Since mortality in the Cove is relatively low and constant (no hunting, no large predators, ample forage), in order for the population to decline, reproduction must decrease. However, as reproduction decreases and the population size declines, the dispersal of bucks will also decrease, and the population will remain relatively stable. Thus, reproduction must be reduced even more before there will be an observable difference in the population size.

Another explanation for the differences between the fawn:doe ratios obtained for 1978 and those obtained for 1979 might be that in 1979 fawns were born later than in 1978. If such a delay did occur in 1979, monthly and seasonal comparisons with 1978 should be offset accordingly. If, for example, there was a 1 month delay of the onset of fawning in 1979 compared to 1978, then July 1978 should be compared to August 1979, August 1978 to September 1979, and so on. Unfortunately, not enough data were collected during the present study to test this hypothesis. In the future, fawn:doe counts should begin in the summer after the first fawns are observed (usually late June) and continue until the majority of the fawns have shed their spotted coats (usually sometime during November).

The results of the fawn:doe counts obtained during this study and by Burst and Pelton (1978) emphasize that they are only an index and not an actual measure of the rate of reproduction. As would be expected, in 1979 when very few twins were observed, there was a corresponding increase in the number of does observed without fawns compared to 1978. The discrepancies arise when fawn-doe counts made in the Cove are compared to those made elsewhere. Fawn recruitment in 1977 (Burst and Pelton 1973) and 1978 in the Cove may have been relatively low, but it might still have exceeded or equalled mortality or emigration among older deer. As a result, there would not be a decline in the population. A decline or at least no change in the deer population would be expected for the summer of 1980 based on the summer of 1979 fawn:doe counts, if there was no delay of fawning in 1979. If such a delay did occur, no predictions can be made because not enough is known about the size of the fawn crop in 1979.

Disease. Density estimates obtained by the present study can be directly compared to those obtained by Fox and Pelton (1973) before and after a deer die-off in the Cove (Table 8). The pre-die-off period was prior to September 1971 and the post-die-off recovery period was during 1972. The deer population in the Cove has obviously increased since the die-off in 1971 (Fig. 4).

Table 8. Comparison of density estimates (deer/ha) derived from dark counts of deer utilizing the fields in Cades Cove, Great Smoky Mountains National Park, Tennessee, 1971-1979 (1971, 1972, and 1973 data from Fox and Pelton 1973).

Month	1971	1972	1973	1977[a]	1978	1979
Jan		0.08				0.17
Feb	0.93	0.18				0.25
Mar		0.26				0.72
Apr	0.38					0.76
May	0.36	0.09				0.45
Jun	0.22	0.10				0.34
Jul	0.31	0.17	0.20 (Jul–Aug)		0.39	0.66
Aug	0.30	0.18			0.51	0.46
Sep	0.09	0.29			0.55	
Oct	0.05				0.37	
Nov	0.04				0.44	
Dec	0.06				0.58	

[a]Burst and Pelton (1978) used the method of bounded counts to derive a density estimate of 0.52 deer/ha for the summer of 1977.

Since epizootics are often density-dependent (Schwabe et al. 1977) and a high density of deer is currently utilizing the Cove, the question then arises: will there be another die-off? If the pre-die-off density estimates are any indication of a threshold above which a die-off is likely, then another die-off is probable. Density estimates in the spring of 1979 and the summers of 1978 and 1979 were all greater than their corresponding density estimates prior to the die-off in 1971. No die-offs have occurred since 1971.

Eleven cattle died exhibiting lesions similar to those observed in the dead deer during the 1971 deer die-off (Fox and Pelton 1973, Prestwood et al. 1974). Cattle, as reservoirs or carriers of the disease involved in the die-off have been suspected but not verified (Prestwood et al. 1974). Perhaps, the reduction in the number of cattle grazing in the Cove from approximately 1300 head during the summer of 1971 to approximately 400 head in 1977 made the difference between a die-off in 1971 and no die-off in 1978 or 1979. Sheep also grazed in the Cove during the summer of 1971 (sheep have not grazed there since then). The sheep may also have acted as carriers or reservoirs for the disease (Bowne 1973, Prestwood et al. 1974). Deer and domestic ruminants are susceptible to many of the same diseases and parasites. When in close association, if either the deer or cattle are at high densities, the diseases and parasites common to both can be rapidly spread through their respective populations (Servinghaus and Cheatum 1956, Trainer and Hanson 1962, Bowne 1973). Therefore, despite the changes in the number of livestock grazing in the Cove, as long as a high deer density exists, the threat of a die-off remains.

Effects of weather. Several linear models were developed to investigate the relationship between weather parameters and the density of deer observed during roadside counts. Precipitation data were obtained for the entire study period; however, maximum and minimum temperatures and relative humidity were collected sporadically. None of these parameters correlated significantly ($P > 0.10$) with the estimates of density in the Cove.

Effective sample sizes. By using the equation $n = (2z\sigma/L)^2$, the sample size (n) necessary for obtaining a mean density estimate within a given confidence interval ($1-\alpha$), of a given width (L), can be determined when the population standard deviation (σ) is known (Noether 1971). The cumulative 2-tailed probability of $1-\alpha$ under a standard normal curve equals "z." Because of the large sample size ($n = 179$), a normal distribution can be assumed and the sample standard deviation of the mean density estimate derived by roadside counts can be considered as being equal to the population standard deviation (σ). The mean square error (MSE) (0.0350) from the linear model: Density = b_0 + b_1 Time + b_2 Season + b_3 Habitat type + b_4 Time x Season + b_5 Time x Habitat type + b_6 Season x Habitat type + b_7 Side x Habitat type, was used to estimate σ^2 ($\sqrt{\sigma^2} = \sigma$). This model was used because it was the model with the greatest r^2 value in which all of the variables were significant ($P < 0.01$). A sample size of n = 36 would be necessary to obtain a sample mean within a 95% confidence interval of ± 0.05 deer/ha of the true mean. In the Cove (977.2 ha), ± 0.05 deer/ha would equal about ± 50 deer. In the future, the sampling intensity for roadside counts should be adjusted accordingly. Thus, if seasonal density estimates for the Cove are desired to be within a 95% confidence interval of ± 0.05 deer/ha (50 deer), then roadside counts should be made 36 times a season or about 3 times a week. If a wider confidence interval is acceptable, then fewer counts would be necessary.

Recommendations. If roadside counts are to be used to monitor the deer population in Cades Cove, they should be conducted as follows: (1) the methodology used to make the counts in the future should be the same as used during this study so that direct comparisons can be made, (2) 3 people (an absolute minimum of 2) should be used to conduct the counts, (3) only dark counts need be made to obtain density estimates, adult sex ratios, and fawn:doe ratios, (4) dawn counts should be made from about June through October to obtain additional fawn:doe data, and (5) the initial sampling intensity should be determined using the population standard deviation ($\sigma = 0.1870$) obtained in this study.

Drive Counts

Density estimates. Drive counts were conducted every 3 months from July 1978 to July 1979. Density estimates could be calculated only for 4 dates (Table 9). There was no significant difference ($P > 0.10$, SNV test) between the July 1978 and July 1979 density estimates for both the wooded areas and the fields. The April 1979 density estimate was significantly greater ($P < 0.02$, SNV test) than the other 3 density estimates. Significantly fewer ($P < 0.02$, SNV test) deer were found in the woods during the April drive count than during the other drive counts and conversely a significantly greater ($P < 0.001$, SNV test) number of deer were found in the fields during the April drive count than during the other drive counts. More deer were also found in the fields during the January drive count than during either July drive counts ($P < 0.02$, SNV test). Thus, it appears that more deer are in the fields at midday (when the drive counts were made) in January and April than in July. These results are in agreement with the seasonal changes of activity observed during roadside counts and by Ozoga and Verme (1970).

Table 9. Density estimates derived from drive counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Date	Area (ha)		Count		Weighted Density Estimate
	Fields	Woodlots	Fields	Woodlots	Deer/ha (ha/Deer)[a]
29 Jul 1978	23.09	26.83	2	25	0.29 (3.45)
14 Oct	0.00	33.82	0	42	?
27 Jan 1979	63.97	19.08	22	21	0.52 (1.92)
7 Apr	93.77	25.77	77	14	0.76 (1.32)
26 Jul	32.36	40.14	1	49	0.31 (3.23)
Total	213.19	145.64	102	151	0.61 (1.64)

[a]See text for explanation of how the density estimates were weighted.

Age and sex ratios. Adult sex ratios obtained from the July drive counts were 100 bucks:100 does (n = 13 does) in 1978 and 76.9 bucks:100 does (n = 24 does) in 1979. The fawn:doe ratio was 8:100 does in 1978 and 25:100 does in 1979. The sample sizes for these ratios were very small and it is doubtful that any meaningful conclusions can be drawn from them.

Recommendations. Although most researchers feel that drive counts are accurate, it is usually not a preferred technique because of the amount of manpower needed for its application (Downing et al. 1965, Jeter 1965, Jenkins and Marchinton 1969, Overton 1971). In 1970, Minnesota's Department of Natural Resources began a wildlife census program using drive counts (Carter 1971). They obtained the bulk of their manpower by soliciting for volunteers at local public schools. Their results have been very similar to estimates made independently by professionals. By similarly recruiting students from The University of Tennessee, Knoxville, ample manpower was obtained for the present study at little expense. However, coordinating and motivating large groups of people can be difficult (McCullough 1979). Obtaining sufficient sample sizes and areas have also been traditional problems associated with drive counts (Overton 1971). Hosley (1956) recommended that drives should not be made on areas smaller than 50 ha.

None of the individual drive areas in the Cove were larger than 25 ha.

The number of people used to conduct drive counts ranged from 13 to 70. For the small (about 5-20 ha) woodlots that were driven approximately 20-25 people appeared to be optimal. Using 20-25 people allowed for sufficient coverage of the drive areas and maximum coordination of the people involved. Two-way radios greatly helped to coordinate drivers and counters during drive counts and they should be used whenever drive counts are made. More than 20-25 people tended to create problems in communication and were probably less efficient than when fewer people were used. The areas to be driven should have at least 3 sides bounded by roads or trails, most preferably by open fields. Manpower can and should consist primarily of volunteers so as to minimize the expense of conducting drive counts.

<u>Pellet Counts</u>

Pellet counts have been widely used to estimate densities of deer with varying success (Bennett et al. 1940, Robinette et al. 1958, Neff 1968, Overton 1971). Little emphasis has been placed on pellet counts in the Southeast because of rapid deterioration and insect damage of pellet groups (Downing et al. 1965, Overton 1971). However, Jenkins and Marchinton (1969) reported that the technique was being used successfully in the southern Appalachians and Flynn (1976) had success with the technique in East Tennessee when he reduced his sampling interval to 4 weeks. As a consequence of Flynn's (1976) work, a 3-week sampling interval for pellet counts was used in Cades Cove.

Pellet counts were conducted from 23 June 1978 to 22 December 1978 and 8 April 1979 to 24 August 1979. Several problems were encountered while making pellet counts. Pellet counts conducted in fields were unreliable because of high deterioration and/or disappearance rates (Table 10). There have been no previously published reports of pellet counts made in open fields in the Southeast. However, pellet counts have been used successfully in the North and West in clear-cuts and/or range land (Robinette et al. 1958, Neff 1968). During the period of leaf fall, pellet counts made in the wooded areas were also unsuccessful. Pellet groups could not be found in either the fields or the wooded areas during periods of snow cover. Wild hog rooting was known to have destroyed at least 1 marked pellet group, but to what extent hogs destroyed unmarked pellet groups is not known. Several wild hogs were observed in 1978 in the Cove, but none were observed during the summer of 1979 (Appendix, Table A-2). Downing et al. (1965) reported that dung beetles readily destroyed pellet groups and resulted in fewer pellet groups being found.

Table 10. Deterioration and/or disappearance of marked pellet groups after 3 weeks in Cades Cove, Great Smoky Mountains National Park, Tennessee, June 1978-August 1979.

Wooded Areas and Fields	Summer 1978	Fall	Winter	Spring	Summer 1979	Total
Wooded Areas						
Number marked	108	130	29	56	93	416
Number found	104	106	28	53	83	374
% loss	3.7	18.5	3.4	5.4	7.5	10.0
Fields						
Number marked	8	23	27	2	3	63
Number found	0	16	16	0	3	35
% loss	100	30.4	30.4	100	0	44.0

Throughout the entire study period of the present study, dung beetles were only observed twice; their effect on pellet groups was probably negligible. The Cove received an above normal amount of rainfall during the summer of 1979. Some of the pellet count transects were partially flooded during this time, and as a result, several pellet groups were probably lost.

Loss of pellet groups. The results of the deterioration and/or disappearance study indicate that in wooded areas very few pellet groups were lost over a 3-week period (Table 10). These results are maximums because the marked pellet groups were between 0 to 3 weeks old when they were originally found. Even though some marked pellet groups were not found 3 weeks after they were marked, it can only be speculated as to how many fresh pellet groups would actually have deteriorated and/or disappeared after 3 weeks. However, the results do give some indication of pellet group deterioration and/or disappearance rates. Similar monitoring of pellet group loss should be conducted while making future pellet counts.

Density estimates. The seasonal density estimates, derived from pellet counts conducted in wooded areas only, were variable and ranged from 0.18 deer/ha (5.56 ha/deer) to 0.47 deer/ha (2.13 ha/deer) (Table 11). Only the summer of 1979 density estimate was not significantly greater

Table 11. Seasonal density estimates derived from pellet counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee, June 1978-August 1979.

Season	Number of Transects	Area (ha)	Number of Pellet Groups	Deer/ha (ha/Deer)
Summer 1978	22	3.045	399	0.47$\pm$0.09 (2.13)
Fall	32	4.556	250	0.18$\pm$0.07 (5.56)
Winter	8	1.139	121	0.46$\pm$0.15 (2.17)
Spring	16	2.278	238	0.36$\pm$0.10 (2.78)
Summer 1979	32	4.416	268	0.24$\pm$0.07 (4.17)
Total	110	15.434	1276	0.38$\pm$0.04 (2.63)

($P < 0.05$) than the fall estimate. Density estimates from the summer of 1978 and winter were both significantly greater ($P < 0.01$ and $P < 0.05$, respectively) than the summer of 1979 estimate. Density estimates from the individual transects were also significantly different ($P < 0.001$). The aspect of the transect (on a north or south facing slope) was not significantly ($P > 0.10$) related to the density estimates for each transect.

Effect of rainfall. The amount of rainfall during the 3-week sample period did not relate significantly ($P > 0.10$) with the density estimate for each transect during that period. This lack of significance was probably because the greatest amount of rainfall (12.8 cm) occurred during the winter (18 November to 11 December), and the least amount of rainfall (4.0 cm) occurred during the fall. These results imply an inverse relationship between the amount of rainfall and the number of pellet groups found. But the low density estimate in the fall was probably the result of leaves covering pellet groups and not because of a lack of rainfall. Although rainfall was greatest during the winter, none of the pellet count transects were flooded as during the summer of 1979. Apparently the rainfall during the winter had little effect on pellet group deterioration and/or disappearance. Dr. Paul Smith of The University of Tennessee, Knoxville, conducted pellet counts during the summer of 1979 in the Elkmont region of the Park (a more steeply sloped area than the Cove). His counts did not appear to be adversely affected by the above normal amounts of rainfall (pers. comm.). Perhaps the actual flooding of an area is necessary before enough pellet groups are affected to lower the density estimate for that area. Other researchers have looked at the effect of rainfall on pellet groups, but due to the complex nature of such environmental factors, no definitive statements have been made (Robinette et al. 1958, Neff 1968).

Recommendations. Pellet counts for this study were conducted following many of the recommendations made by Robinette et al. (1958) and Neff (1968). In addition to their recommendations, the following suggestions should also be considered before conducting pellet counts in the future: (1) when possible, 2 people should be used to make pellet counts; (2) transects should be surveyed twice, once while going out and once while returning and the counters should switch sides on the return trip; (3) counts should not be made during periods of leaf fall or snow cover; (4) deterioration and/or disappearance rates of pellet groups should be monitored; and in the southern Appalachians, (5) a 3-week sampling interval should be used; and (6) counts should only be made in wooded areas.

Distribution of Deer

The seasonal variations in the distribution of deer from the roadside count data indicated that deer preferred some areas more than others during certain seasons, but no pattern was apparent (Figs. 5-9). Pellet groups tended to be evenly distributed along transect lines. Temporally, deer tend to spend more daylight hours in the fields during the winter and spring than during the other times of the year. This shift is probably in response to changes in temperature (Ozoga and Verme 1970).

Comparison of Techniques

The seasonal density estimates derived from the 3 techniques used (dark counts, drive counts, and pellet counts) are visually similar (Fig. 10). Because of the differences by which each density estimate was derived, none of the seasonal estimates totally parallel each other. Density estimates using dark counts were significantly greater than density estimates using pellet counts during the fall ($P < 0.003$) and the summer of 1979 ($P < 0.01$). As mentioned previously, during the fall of 1978 and the summer of 1979, leaf cover and partial flooding of transects made counts of pellet groups during these seasons unreliable. Density estimates using drive counts had such large variances that statistical comparison with dark count and pellet count estimates was meaningless.

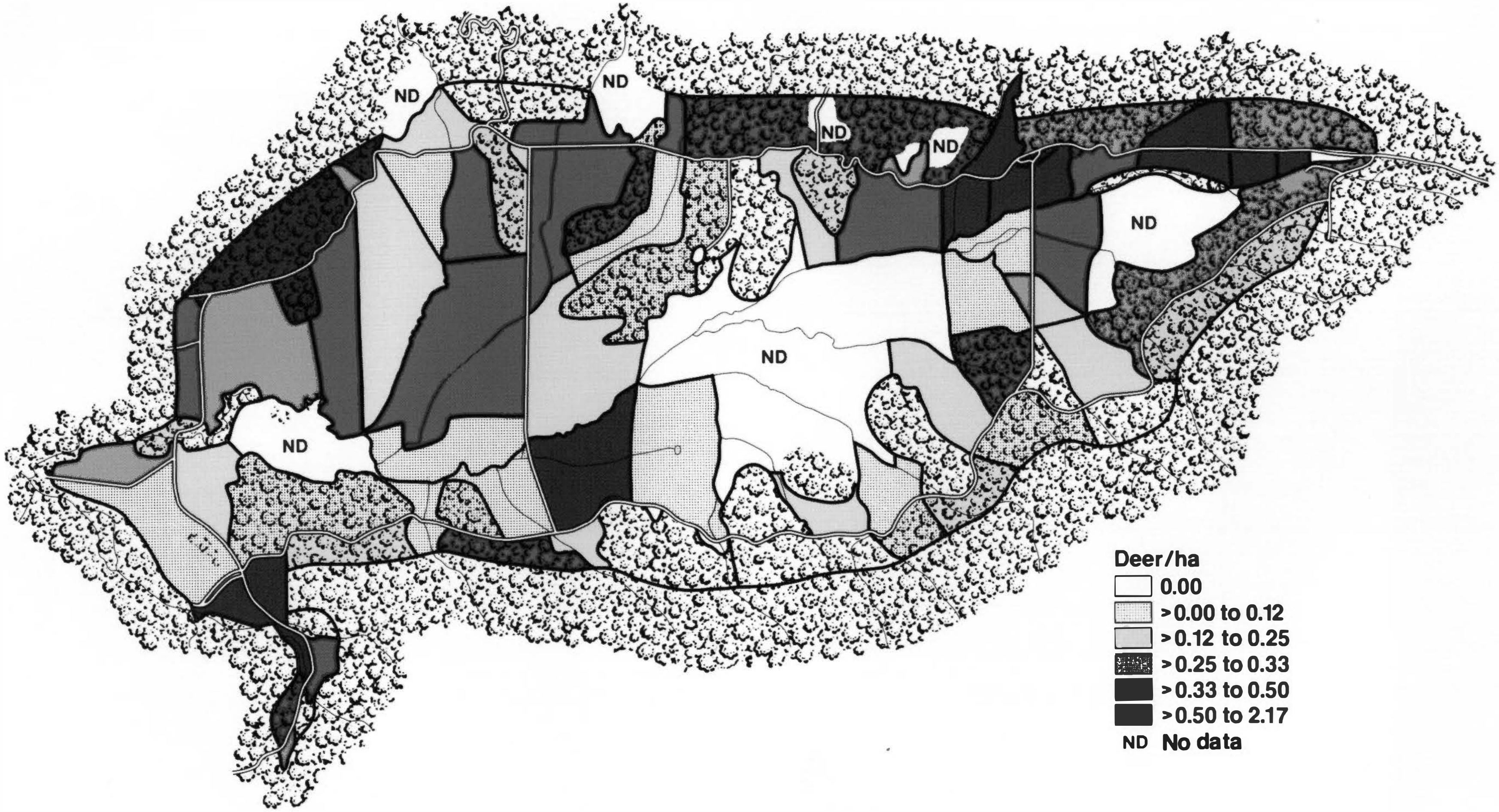

Fig. 5. Distribution of deer during the summer of 1978 as determined by roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee.

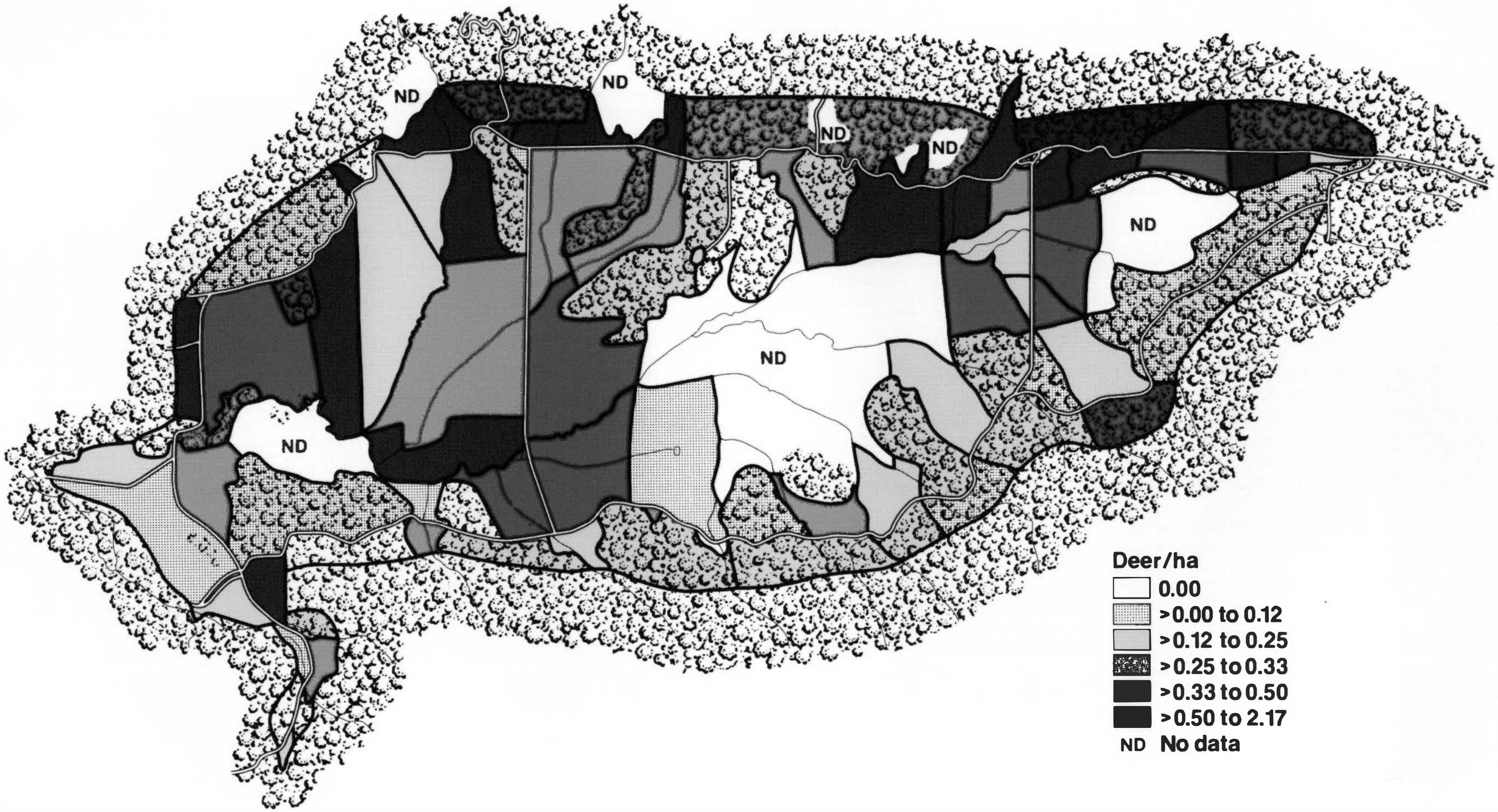

Fig. 6. Distribution of deer during the fall of 1978 as determined by roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee.

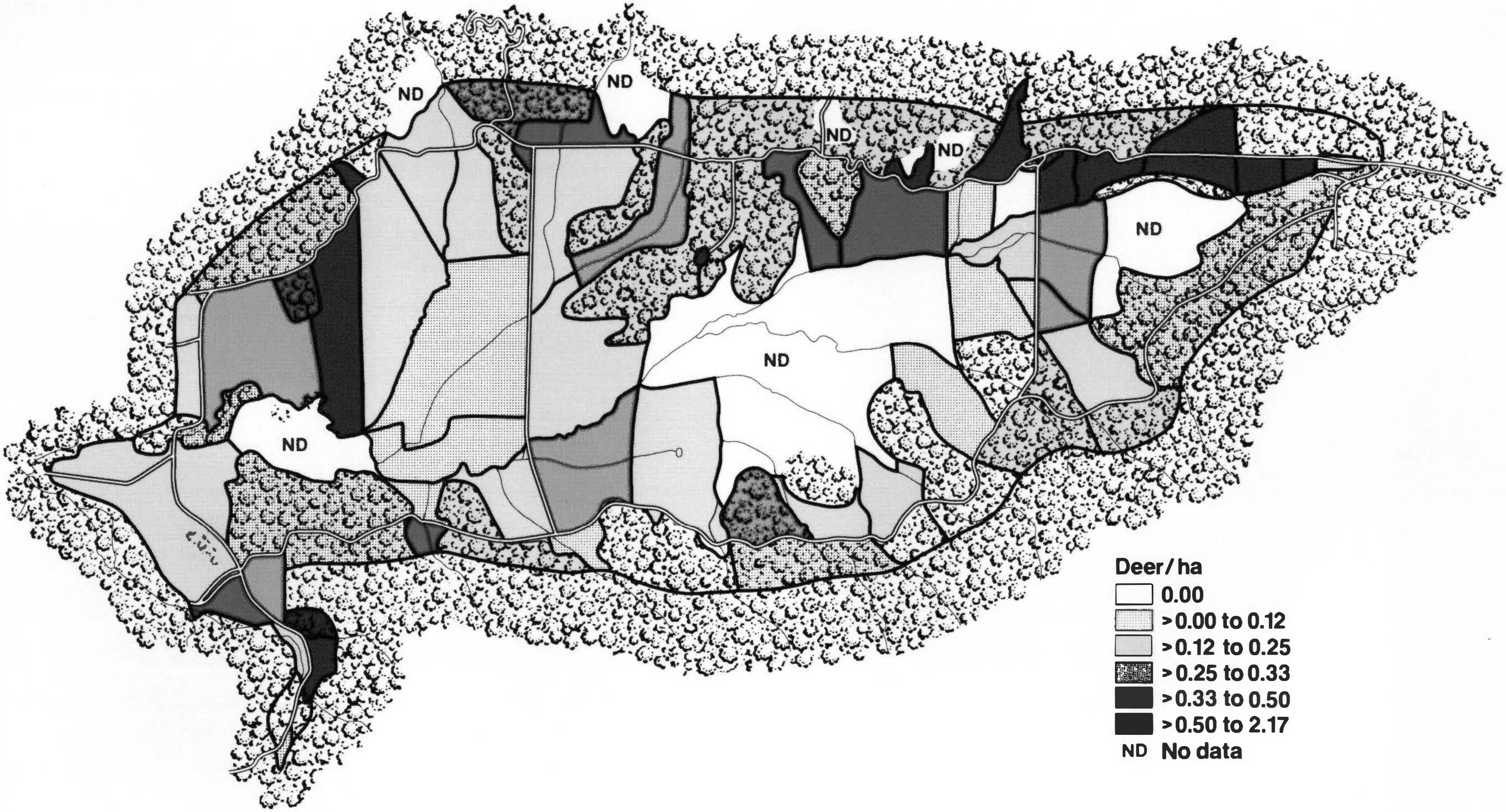

Fig. 7. Distribution of deer during the winter of 1978-1979 as determined by roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee.

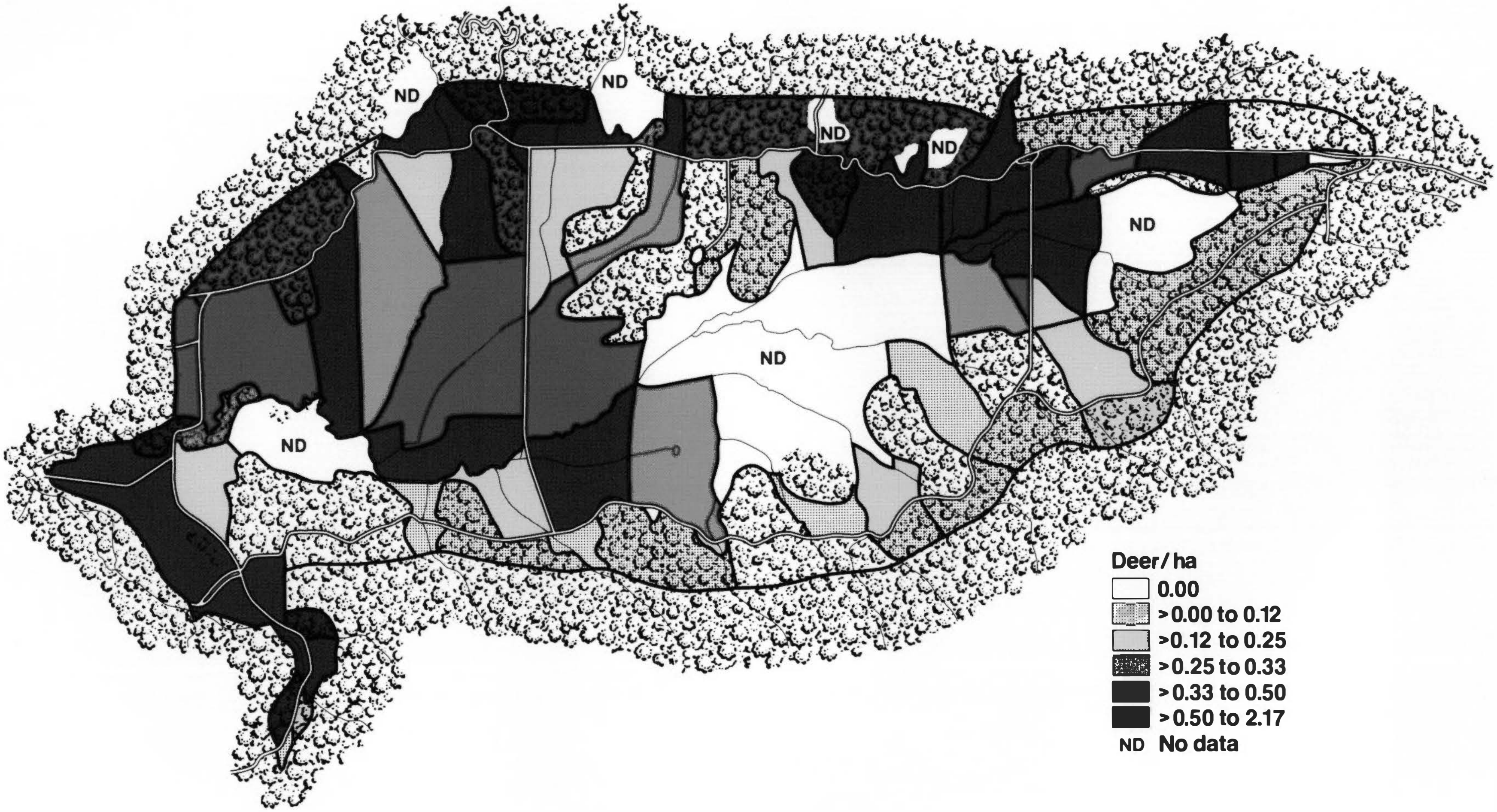

Fig. 8. Distribution of deer during the spring of 1979 as determined by roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee.

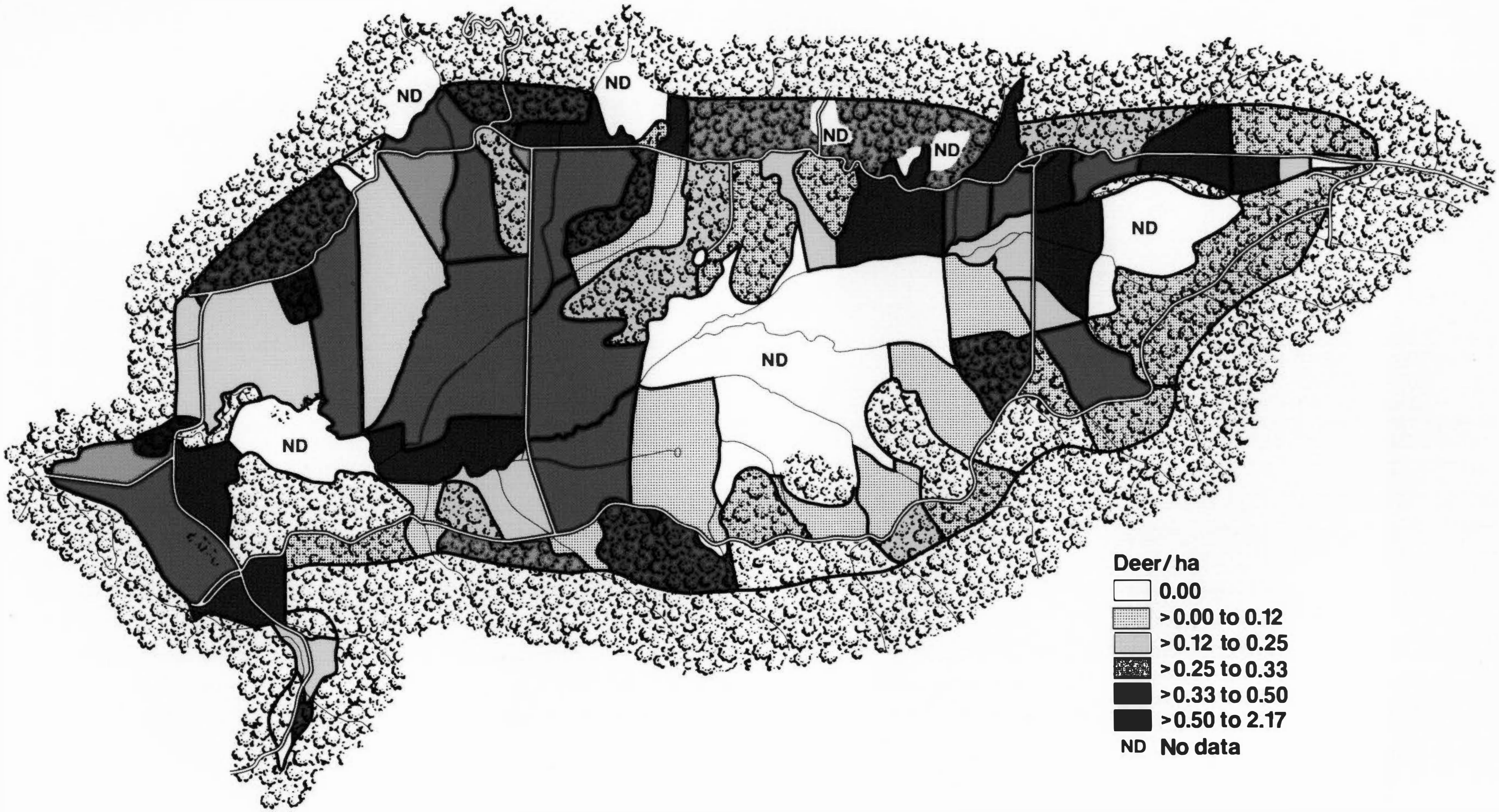

Fig. 9. Distribution of deer during the summer of 1979 as determined by roadside counts conducted in Cades Cove, Great Smoky Mountains National Park, Tennessee.

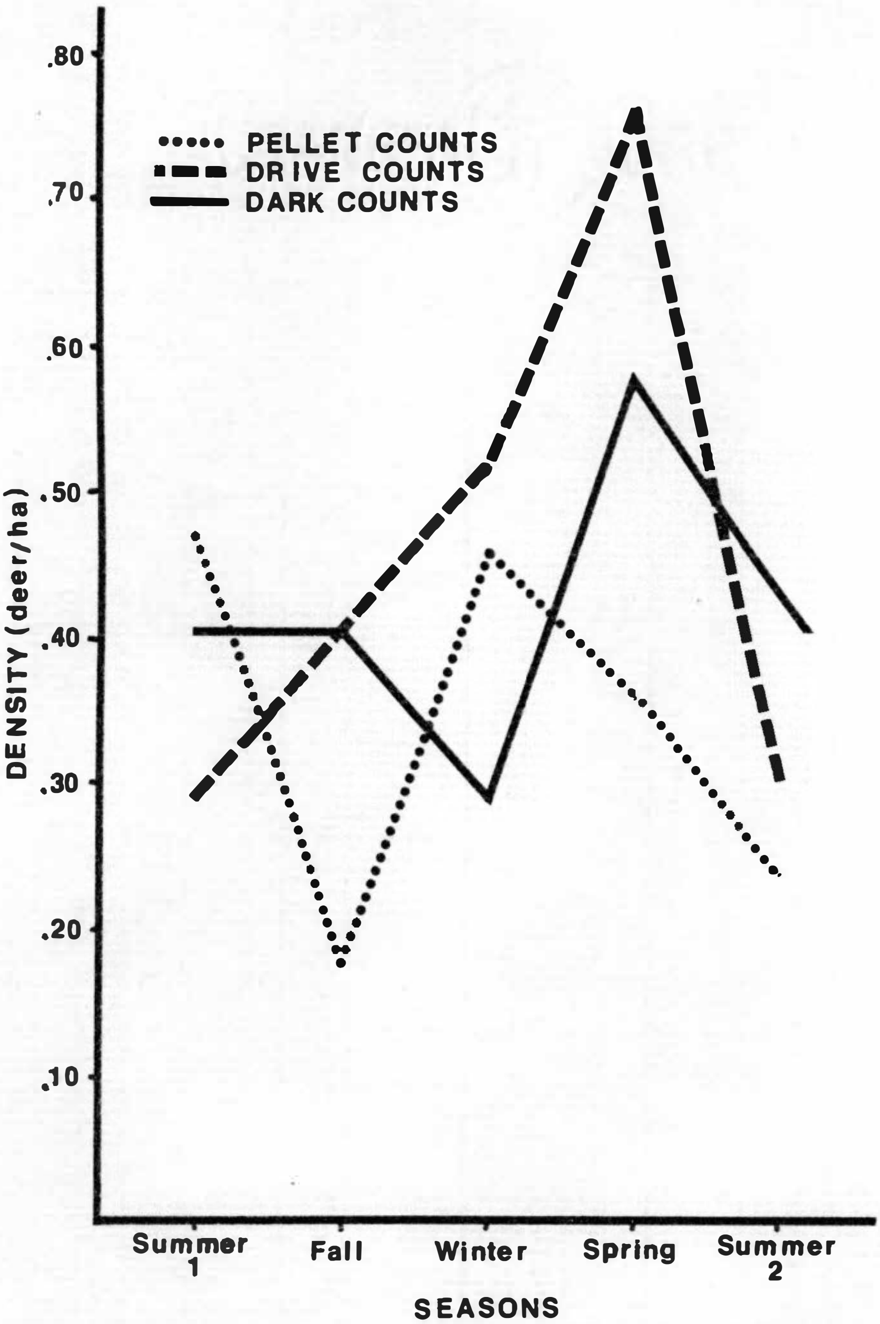

Fig. 10. Comparison of the 3 census techniques used to obtain density estimates in Cades Cove, Great Smoky Mountains National Park, Tennessee, July 1978-August 1979.

Michael (1970) suggested that direct counts are best when conducted during April. Drive counts and dark counts made in the Cove during April resulted in density estimates of 0.76 and 0.67 deer/ha (1.32 and 1.49 ha/deer), respectively. If only the fields were counted during dark counts, both techniques would result in the same estimate (0.76 deer/ha or 1.32 ha/deer). These estimates, if they are indeed a more accurate reflection of the actual population, indicate that a larger population of deer utilize the Cove than indicated by the seasonal density estimates.

All 3 census techniques used in the Cove produced density estimates that are among the highest ever reported for white-tailed deer. Most high densities of deer in the Southeast range between 0.20 and 0.30 deer/ha (5.00-3.33 ha/deer) (Marchinton 1968, Flynn 1976, Marshall and Whittington 1978, Osborne et al. 1979). Chuck Swan Wildlife Management Area, Tennessee reportedly had densities of deer as high as 0.50 deer/ha (2.00 ha/deer) during the 1950's but present densities are about 0.25 deer/ha (4.05 ha/deer) (Lewis and Safley 1966). A deer enclosure in Virginia attained densities of 0.51 to 0.57 deer/ha (1.96-1.75 ha/deer) (Downing and McGinnes 1975). Kammermayer and Marchinton (1976) reported that the Berry College Refuge in Georgia had densities as high as 0.78 deer/ha (1.28 ha/deer), but the cited reference for that estimate reported the density as being much lower; between 0.23 and 0.45 deer/ha (4.35-2.22 ha/deer) (Kammermayer and Marchinton 1975). A density of 0.75 deer/ha (1.34 ha/deer) in a refuge in Oklahoma was reported by Logan (1972). A typical description of these high density herds was that their highest densities were not sustained. Disease, habitat degradation, predation, or hunting periodically reduced the herds to more moderate levels. It should be noted that the highest densities were usually found in protected areas.

Techniques that employ direct counts have been generally considered more reliable and accurate than techniques that depend on indirect counts (Overton 1971). However, the pellet counts conducted in Cades Cove suggest that except during leaf fall and periods of snow cover, density estimates derived by them are similar to those estimates obtained from direct counts. Pellet counts have an advantage over other indirect counts such as counting scrapes, rubs, or tracks in that pellet groups are deposited every day, regardless of weather, season, or the sex of the deer. Also, pellet groups do not need to have suitable substrata to be present.

Historically, obtaining an estimate of animal abundance in an area of low population density has been a difficult task because of insufficient sample sizes. With pellet counts, the potential sample size is increased by about 13 times/day for each deer. Therefore, during certain times of the year, pellet counts might be useful in areas of low population densities.

The average man-hours needed to obtain a density estimate may determine which technique can or should be used. For this study, the number of man-hours used to obtain the density estimates varied considerably. Despite the large number of people necessary to conduct drive counts ($\bar{x}$ = 31.3 people), they were only conducted once a season and therefore required only an average of 12.5 man-hours per week. The opposite is true of roadside counts; the sampling intensity was so great that they averaged the most man-hours per week (13.5). However, since only dark counts were used to obtain the final density estimates, the average man-hours per week was only 4.5. Pellet counts required 10.6 man-hours per week.

Based on the results of this study, roadside counts are probably the best technique for obtaining estimates of deer densities in Cades Cove and areas similar to the Cove. Roadside counts offer many advantages over the other 2 techniques used: the deer herd is more constantly monitored, a minimum amount of effort and training is necessary to conduct the counts, and incidental information can be gathered such as adult sex ratios, fawn:doe counts, behavior, and physical condition of the deer. Drive counts have 2 major disadvantages compared to roadside counts: (1) they require a relatively large number of people and

(2) they tend to have small sample sizes because of the limited number of suitable areas for conducting drive counts. Pellet counts are best suited for areas where techniques utilizing direct counts are impractical; pellet counts are useful only during particular times of the year and in wooded areas of the southern Appalachians.

CHAPTER V

CONCLUSIONS

The density of the deer population utilizing the Cove has increased to a range of about 0.29 deer/ha (3.45 ha/deer) to 0.58 deer/ha (1.72 ha/deer) from a low of about 0.04 deer/ha (25.00 ha/deer) during a die-off in 1971. These high densities are possible because of a combination of factors including the protection of deer from hunting and the favorable deer habitat created by the land management of the Cove. Density estimates and fawn:doe ratios from the summers of 1978 and 1979 indicate that the population might be stabilizing at a relatively high density. At high densities, deer are vulnerable to epizootics. This vulnerability might be enhanced by the close association of deer with domestic ruminants (Servinghaus and Cheatum 1956, Trainer and Hanson 1962, Bowne 1973). High densities of deer also create a possibility of browse damage to plants; browse lines already exist in the Cove (Fox and Pelton 1973, Bratton 1979).

Internal self-regulating mechanisms have never been documented for white-tailed deer. Dispersal of bucks out of the Cove will not regulate the population size (Marchinton and Kammermayer 1980). The degradation of the forest habitat in and around the Cove because of overbrowsing by deer would probably fail to reduce the deer herd; the open fields apparently provide sufficient amounts of forage to the deer to prevent them from starving. Therefore, it is doubtful that the population in the Cove will decrease substantially by itself.

The reduction of ungulate populations in National Parks might be achieved in several ways: (1) by natural predation, (2) trapping and transplanting, (3) shooting excess animals that migrate outside of parks, and (4) shooting animals within parks (Leopold et al. 1963). Of the natural predators of deer that were once in the Park, wolves (*Canis lupus*), mountain lions (*Felis concolor*) and bobcats (*Lynx rufus*), only the bobcat remains (Linzey and Linzey 1971). At the present time, it is obvious that predation is not regulating the deer population in the Cove. Deer in the South do not migrate like deer in the North or West (Servinghaus and Cheatum 1956, Downing et al. 1969, Marchinton 1968). Some bucks might disperse out of the Cove and eventually the Park. As a result, they might get killed by hunters, but this would not regulate the population for the same reasons that simple dispersal does not. The recent public protest against the shooting of exotic species in National Parks (wild hogs in the Park and burros [*Equus asinus*] in Grand Canyon National Park) suggests that any attempt to shoot native species would face even greater public opposition. Recently the Park

Service has been testing oral anti-fertility agents on deer but without success (Matschke 1977). Thus of the above options proposed by Leopold et al. (1963), only the trapping and transplanting of deer appears to be applicable to reducing the number of deer in Cades Cove.

Burst and Pelton (1978) proposed that 25% (125 deer) of the herd in the Cove should be transplanted in order to maintain a stable population of about 0.50 deer/ha. They also recommended that the sex ratio of the deer removed be approximately equal to the observed adult sex ratio. However, fawn recruitment probably would increase with a reduction in the herd as long as there was a preponderance of does in the population (McCullough 1979). Thus, this is a temporary solution at best; more deer will probably have to be removed each year in order to maintain a stable population level. If the sex ratio was shifted to favor males, decreases in population size would result in a more rapid decrease in fawn recruitment. Therefore, if deer are removed from the Cove, it should result in an adult sex ratio that favors males. This type of management would not be preferred for a hunted deer population because it would probably result in fawn recruitment being lower than the maximum sustained yield (MSY). In the Cove, however, MSY is not a concern; the major concern is preventing the deer herd from exceeding the carrying capacity (K of the logistic equation).

Another possible way to reduce the number of deer in the Cove would be to alter the habitat in such a way to make it less favorable for deer. This goal could be accomplished by stopping most or all livestock grazing and hay mowing, thereby allowing natural succession to proceed in the open fields. Eventually, the fields would become re-forested; the Cove would become similar to the surrounding area except for small clearings around the historical places and structures (if they are to be preserved). With the elimination of the open fields, hopefully, deer would no longer concentrate in the Cove.

A final consideration would be to make the best of the "bad" situation created in the Cove. The Cove has a highly visible, free-ranging, unmanaged deer population. The favorable deer habitat in the Cove allows for relatively high densities of deer to exist. The major impacts of the concentration of deer appear to be limited to the Cove; intensive impacts of deer on vegetation apparently does not extend more than 1 km from the Cove (Bratton 1979) and during the die-off in 1971, only 2 (of 52) dead deer were found outside of the Cove, and they were within 3 km of the Cove (Fox and Pelton 1973). These conditions make the Cove an ideal area in which to investigate the complex and subtle relationships between deer and disease; deer, disease and livestock; the effects of relatively high densities of deer on vegetation; and the population dynamics of an unmanaged deer herd. This information is essential for a better understanding of white-tailed deer ecology.

Of the 3 alternatives to the present management, it is recommended that the research potentials of the Cove be developed. The other 2 alternatives involve radical changes in the management policy of the Cove and their probability of success is unknown. Scientific research is one of the purposes of National Parks (Leopold et al. 1963, Cole 1971, Houston 1971). Without research, the National Park Service would be unable to achieve its primary purpose in administering natural areas: to maintain an area's ecosystem in as nearly a pristine condition as possible (Houston 1971). The unique research that could be conducted in the Cove would ultimately benefit both Park and non-Park resource managers in their understanding of deer ecology.

In order to obtain the maximum benefit from such research in the Cove, it must not be conducted in a haphazard manner. The events immediately prior to the die-off in 1971 were recorded only by chance. If Fox and Pelton (1973) had not been conducting their counts of deer in the Cove prior to the die-off, valuable information would have been lost. Nine years have gone by since the die-off in 1971; if and when another die-off will occur is not known. Thus, long term research is necessary to study such complex and subtle phenomena.

The educational aspects of the Cove could also be expanded. The Interpretive Division could easily develop programs on deer because of their high visibility in the Cove. These programs could include discussions on the effects of deer browsing on vegetation, sex ratios, disease, and reproduction. As additional research is conducted, their results could also be incorporated into these programs.

The present study has established some baseline demographic information on the deer utilizing Cades Cove, and the techniques by which such information could be obtained. The results of the present study have probably generated more questions than they have answered. The answers to these questions can only be found through continued research.

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APPENDIX

APPENDIX

HABITAT TYPES AND WILDLIFE SIGHTINGS

Table A-1. Habitat type designations of areas surveyed during roadside counts in Cades Cove, Great Smoky Mountains National Park, Tennessee, June 1978-1 September 1979.

Area Number	Habitat Type	Area Number	Habitat Type
North Half			
1	historical	32	hay/cow pasture
2	historical	33	woods
3	horse pasture	34	hay/horse pasture
4	woods	35	hay/horse pasture
5	horse pasture	36	hay field
6	horse pasture	37	woods
7	hay field	38	hay field
8	no data	39	hay field
9	woods	40	woods
10	horse pasture	41	hay field
11	woods	42	woods
11a	woods	43	hay field
12	horse pasture	44	hay field
13	hay field	45	woods
14	hay field	46	woods
15	hay field	47	hay field
16	hay/cow pasture	South Half	
17	woods	48	hay field
18	hay field	49	hay field
19	woods	50	woods
20	hay-old field[a]	51	hay field
21	woods	52	hay field
22	woods	53	woods
23	historical	54	old field
24	cow pasture	55	old field
25	cow pasture	56	woods
26	woods	57	woods
27	woods	58	historical
28	hay/horse pasture	59	woods
28a	hay field	60	cow pasture
29	cow pasture	61	cow pasture
30	woods	62	woods
31	hay/horse pasture	63	woods
31a	cow pasture	64	cow pasture

Table A-1 (Continued)

Area Number	Habitat Type	Area Number	Habitat Type
65	historical	78	woods
66	cow pasture	79	woods
66a	cow pasture	80	woods
67	woods	81	cow pasture
68	hay field	82	cow pasture
69	historical	83	hay--old field[a]
70	woods	84	mixed use
71	woods	85	cow/horse pasture
72	cow pasture	86	cow pasture
73	cow pasture	87	woods
74	woods	88	woods
75	woods	89	woods
76	woods		
77	cow pasture		

[a]Hay field:summer, 1978 to winter, old field: spring, 1979 to summer, 1979.

Table A-2. Incidental sightings of various species of wildlife in Cades Cove, Great Smoky Mountains National Park, Tennessee, June 1978-1 September 1979.

Date	Animal(s)	Area No.[a]
1978		
19 Jun	piglet	80w roadside
22 Jun	wild hog	ND-1
	piglet	80w roadside
23 Jun	piglet	80w roadside
28 Jun	raccoon	24
	wild hog	68
	gray fox	71w
	gray fox	76w
29 Jun	gray fox	Forge Creek Rd.
	raccoon	Loop Rd.
5 Jul	turkeys (3 adults, 16 poults)	50w
7 Jul	gray fox	31
10 Jul	gray fox	80w
	bears (1 female, 2 cubs)	20
14 Jul	green heron (nest & immature)	87w
16 Jul	gray fox	86
	gray fox	88w
17 Jul	wild hog	39
19 Jul	turkeys (1 female, 2 poults)	38
21 Jul	raccoon	59w
	red fox	89w
	gray fox	16
	red fox	29
26 Jul	hogs (2 adults, 1 piglet)	86
28 Jul	gray fox	80w
	hogs (1 female, 4 piglets)	41
	raccoon	78w
	gray fox	9w
29 Jul	turkeys (3)	21w
	bear	78w
2 Aug	turkeys (2 males)	48
4 Aug	raccoon	44
	wild hog	72
	piglet	89w
	wild hog	Laurel Creek Rd.
	gray fox	30w
	raccoons (2)	21w
7 Aug	hogs (2 adults, 1 piglet)	80w
9 Aug	hogs (2 adults, 1 piglet)	85
10 Aug	raccoon	50w

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
18 Aug	wild hog	47
	red fox	28
21 Aug	fox	80w
	turkey	54
23 Aug	wild hogs (5 adults)	65
	raccoon	48
25 Aug	gray fox	72
31 Aug	red fox	26w
1 Sep	gray fox	42w
	fox	20
5 Sep	red squirrels (2)	69
8 Sep	great blue heron	ND-1
9 Sep	gray fox	73
15 Sep	turkeys (8)	7
	hogs (1 female, 2 piglets)	ND-3
	bears (2 cubs)	Rich Mtn.
16 Sep	opossum	50w
	wild hogs (2)	72
23 Sep	raccoon	64
	raccoon	48 (Cable Mill)
	turkey	73
	turkeys (2 males)	64
25 Sep	fox	28
27 Sep	turkeys (4)	7
	wild hog	48
29 Sep	turkeys (4)	64
30 Sep	raccoon	65
	raccoon	30w
	raccoons (4)	72
4 Oct	raccoons (4)	82
	turkeys (3)	66a
	turkeys (2)	77
	turkey	61
	turkeys (5)	31a
	raccoon	Laurel Creek Rd.
8 Oct	raccoon	74w
	gray fox	76w
	fox	76w
	raccoon	77
	raccoon	53w
	wild hogs (2)	Laurel Creek Rd.
14 Oct	black cat	31
	raccoons (2)	32
	gray fox	17w
	turkeys (6)	62w

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
16 Oct	turkeys (2)	61
	gray fox	Laurel Creek Rd.
	bear (w/metal ear tag)	Laurel Creek Rd.
19 Oct	red squirrels (2)	89w
	turkeys (3)	64
21 Oct	gray fox	73
	raccoon	72
	raccoons (3)	48
	raccoon	51 (in creek)
23 Oct	dogs (2)	7
25 Oct	red fox	28
	turkeys (5)	64
	turkeys (3)	66a
28 Oct	raccoon	47
	raccoon	35
	raccoon	31a
	gray fox	19w
	raccoon	25
1 Nov	turkey	64
	turkeys (4)	61
	turkeys (8)	48
3 Nov	red fox	85
	red fox	86
	raccoon	72
4 Nov	turkeys (8)	64
	turkeys (7)	61
	turkeys (9)	49
	red fox	82
10 Nov	barred owl	44
	wild hog	64
	barred owl	31
	gray fox	24
	raccoons (2)	25
	raccoon	22w
11 Nov	turkeys (21)	61
	turkeys (4 males)	64
	turkeys (9)	28
	turkey	34
	turkeys (21)	35
	wild hogs (2)	7
12 Nov	turkeys (11)	24
13 Nov	raccoon	72
15 Nov	raccoons (3)	77
	wild hog	85
	gray foxes (2)	72

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
15 Nov	raccoon	72
	raccoon	73
18 Nov	turkeys (6)	81
	turkeys (3)	64
22 Nov	turkeys (3)	24
24 Nov	red fox	31
	red fox	39
	gray fox	19w
	raccoon	17w
	raccoon	10
26 Nov	turkeys (7)	41
	turkeys (16)	24
	turkey	14
27 Nov	barred owl	80w
	turkeys (18)	64
	hawk	55
	red fox	34
30 Nov	gray foxes (2)	88w
	raccoons (2)	77
	raccoon	85
	gray fox	72
	gray fox	73
2 Dec	turkeys (3)	64
5 Dec	turkeys (4)	24
	turkeys (5)	29
	turkey	25
8 Dec	red fox	43
	wild hogs (3)	Rich Mtn.
10 Dec	red seqirrel	45
	turkeys (4)	20
11 Dec	turkeys (12)	81
	turkeys (3)	64
13 Dec	wild hogs (3)	58
	raccoons (2)	66a
	raccoon	72
15 Dec	turkeys (7)	ND-2
17 Dec	turkeys (12)	60
18 Dec	turkeys (4)	24
19 Dec	barred owl	44
	gray fox	44
	red fox	32
	raccoons (2)	31a
21 Dec	wild hog	41
	turkeys (27)	24
	raccoon	24

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
1979		
4 Jan	raccoon	79
6 Jan	turkeys (26)	73
	turkeys (14)	86
	turkeys (2)	65
	turkeys (2)	29
9 Jan	turkeys (2)	29
10 Jan	wild hogs (3)	17w
13 Jan	turkeys (9)	45w
	turkeys (8)	31a
	turkeys (9)	14
	turkey	29
15 Jan	red-tailed hawk	54
	wild hogs (4)	55
17 Jan	screech owl	67w
21 Jan	turkeys (26)	73
	turkeys (5)	12
	turkey	66
	turkey	65
23 Jan	turkeys (24)	29
	turkeys (6)	16
25 Jan	red fox	31a
27 Jan	turkey	62w
30 Jan	hawk	55
	wild hog (in trap)	54
3 Feb	red fox (carrying grouse)	48
	turkeys (27)	ND-2
5 Feb	turkeys (3)	28
7 Feb	red fox	42w
12 Feb	red fox	48
13 Feb	opossum	73
15 Feb	raccoon	64
	screech owl	89w
	opossum	71
	opossum	88w
17 Feb	ducks	66a (in pond)
	red squirrel	68
19 Feb	turkeys (12)	34
	red-tailed hawk	28
	raccoon (w/red ear tag)	28
	wild hog	31
	turkeys (22)	31
21 Feb	wild hog (w/radio collar)	5
24 Feb	bobcat	Loop Rd.
28 Feb	barred owl	12
	raccoon	

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
28 Feb	opossum	87w
	raccoons (2)	66a
	raccoon	61
1 Mar	turkeys (5)	66a
	turkeys (21)	73
	hawk	55
	turkeys (7)	31a
5 Mar	turkeys (4)	86
	turkeys (7)	ND-2
	turkeys (8)	64
9 Mar	turkeys (3)	35
	turkeys (8)	31a
	turkeys (7)	34
	hawk	16
11 Mar	turkeys (5)	31a
	grouse	22w
	turkey	16
12 Mar	wild hog	Laurel Creek Rd.
13 Mar	turkeys (3)	73
	turkeys (21)	ND-2
	turkeys (2)	49
19 Mar	turkeys (20)	81
	turkeys (6)	83
	turkey	48
	turkey	72
20 Mar	turkeys (10)	31a
	turkeys (9)	35
	turkeys (3)	29
	turkeys (6)	ND-3
22 Mar	gray fox	48
	red fox	44
25 Mar	red fox	28
27 Mar	turkeys (20)	60
	turkeys (2)	54
29 Mar	gray fox	75w
	raccoon	75w
	raccoons (2)	77
	opossum	66a
	gray fox	49
	gray foxes (2 together)	49
1 Apr	turkey	86
	turkey	77
	turkeys (2)	55
4 Apr	turkeys (2)	48
	turkeys (21 females, 5 males)	61

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
4 Apr	turkey (1 male)	60
	turkey (1 male)	73
	turkey (6 females, 5 males)	86
	turkey (flying)	37w
	turkey	44
	turkeys (22)	31a
	turkeys (2)	20
5 Apr	ruffed grouse	17w
	turkeys (7)	29
	turkeys (2)	16
7 Apr	raccoon (red)	47
	turkeys (20)	31a
	turkeys (12)	77
	red fox	39
	raccoon 34	
	red fox	25
	gray fox	20
12 Apr	turkey	ND-2
14 Apr	gray foxes (2)	89w
	gray fox	86
	red fox	84
	gray fox	77
	raccoon	77
	opossum	64
	raccoon	57w
17 Apr	turkeys (4)	31a
	turkeys (22)	32
	turkey (1 male)	24
18 Apr	gray fox	72
	gray fox	73
	gray fox	77
19 Apr	turkeys (6)	48
	turkeys (1 female, 1 male)	59w
	turkeys (3)	86
	turkey	24
21 Apr	raccoon	47
	red fox	28
	red foxes (3 pups, 1?)	30w
	raccoon	30w
24 Apr	turkeys (2 females, 1 male)	77
	turkey	72
26 Apr	turkey (1 female)	Laurel Creek Rd.
	ruffed grouse	Laurel Creek Rd.
	turkeys (8)	66a
	turkey	77

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
26 Apr	turkeys (2 males)	58
	turkey	60
	turkeys (3)	64
	red foxes (3 pups)	30w
28 Apr	fox	86
	gray fox	73
	raccoon	66a
	red fox	60
1 May	turkeys (6)	48
	turkey (1 male)	43
	red foxes (3 pups)	30w
2 May	turkey	25
	turkeys (2)	43
	turkey (1 male)	73
	turkeys (1 female, 1 male)	77
3 May	turkey	29
	raccoon	67w
	screech owl	Loop Rd.
5 May	raccoon	30w
	red fox (pup)	31
	red fox	18
	gray fox	7
	turkeys (4)	34
8 May	turkeys (2)	48
	turkey (1 male)	64
10 May	turkey (1 male)	73
12 May	red fox	66a
	bobcat	Sparks Lane
15 May	turkey	24
	turkeys (5)	7
17 May	turkeys (1 male, 1 female)	24
	turkey (1 male)	43
	turkey	64
	turkey	66a
19 May	raccoon	Laurel Creek Rd.
	red fox	31
22 May	turkey (1 male)	77
26 May	snapping turtles (3)	48
	bobcat	19w
	raccoon	72
	turkeys (6)	ND-2
29 May	red foxes (2 pups)	30w
10 Jun	bobwhites (2)	Sparks Lane
	raccoon	63w

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
15 Jun	broad-winged hawk	Laurel Creek Rd.
	fox	Laurel Creek Rd.
	turkey (1 female)	14
	red fox	19w
	raccoon	30w
	bear	48
	raccoon (blond)	88w
19 Jun	raccoon	77
	raccoon	89w
23 Jun	turkeys (3)	ND-2
24 Jun	turkey	6
26 Jun	red fox	31
28 Jun	red fox (2)	31
	red fox	35
	raccoon	34
30 Jun	turkeys (4)	72
1 Jul	turkeys (4)	64
2 Jul	bear	55
8 Jul	turkeys (5)	72
	box turtle	Laurel Creek Rd.
10 Jul	bear	16
	bobwhite	32
	fox	41
12 Jul	red fox	49
	gray fox	9w
	raccoon	17w
	red fox	31
	red fox	30w
	raccoon	33w
	red fox	36
	red fox	39
16 Jul	gray fox	Laurel Creek Rd.
18 Jul	turkeys (3 adults, 5 poults)	61
22 Jul	red fox (pup)	73
23 Jul	gray fox	Laurel Creek Rd.
	red fox	43
25 Jul	turkeys (6)	72
27 Jul	raccoon	63w
	opossum	89w
28 Jul	turkey	61
	turkeys (2)	77
2 Aug	gray fox	87w
3 Aug	turkeys (3)	73
6 Aug	turkeys (6)	73
	red fox	77

Table A-2 (Continued)

Date	Animal(s)	Area No.[a]
8 Aug	sparrow hawk	30w
	bear	Hyatt Lane
12 Aug	red fox	75w
	red fox	39
22 Aug	turkeys (3)	66a
25 Aug	raccoon	26w
	red fox	43
28 Aug	turkey	48
	bear	86
30 Aug	turkeys (4)	77

[a]The suffix "w" indicates wooded area.

VITA

Michael Joseph Kiningham was born in Summit, New Jersey on 24 June 1955. He was raised in Westfield, New Jersey, where he graduated from Westfield Senior High School in 1973. The following September he entered Bucknell University in Lewisburg, Pennsylvania and in June 1977 received a Bachelor of Arts degree with a major in Animal Behavior. He entered The University of Tennessee, Knoxville in the fall of 1977 and began his graduate studies in wildlife. He accepted a graduate research assistantship in the fall of 1978. He received a Master of Science degree in 1980. His graduate studies will continue towards a doctoral degree at Southern Illinois University, Carbondale. Mr. Kiningham is a member of Phi Kappa Phi, Gamma Sigma Delta, and The Wildlife Society.

He is married to the former Cynthia Ann Prevett of Beach Haven, New Jersey.