USE OF THE PELLET COUNT TECHNIQUE FOR DETERMINING DENSITIES OF DEER IN THE SOUTHERN APPALACHIANS[1]

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Abstract: Pellet counts were conducted to estimate population densities of white-tailed deer *(Odocoileus virginianus)* on 3 areas in the southern Appalachian Mountains of east Tennessee: (1) the Department of Energy's Oak Ridge Reservation (2) Chuck Swan Wildlife Management Area, and (3) Cades Cove, Great Smoky Mountains National Park. A different sampling interval was used on each area: 3 months, 2 month, and 3 weeks, respectively. Density estimates derived from pellet counts were compared to those derived from 2 mark-recapture techniques and 1 line transect technique on the Reservation; 1 mark-recapture and 1 line transect technique at Chuck Swan; and 2 plot sampling techniques at Cades Cove. The results indicated that the use of a 3-week to 1-month sampling interval for pellet counts appeared to be appropriate in the southern Appalachians.

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Numerous techniques for estimating population densities of wildlife have been developed and tested (Overton 1971, Seber 1973). One of these is the pellet count technique; this procedure has been used to estimate population densities for many species including deer and other large ungulates (Neff 1968), rabbits (Cochran and Stains 1961), and other small mammals (Emlen et al. 1957). The pellet count technique has received its most widespread use and has been well documented for estimating population densities of deer. However, little emphasis has been placed on pellet counts in the Southeast as a result of rapid deterioration and insect damage of pellet groups (Downing et al. 1965, Overton 1971). Many technical problems have also been associated with the pellet count technique (Robinette et al. 1958, Neff 1968). These problems range from determining a defecation rate to the size and shape of the sample plots. The objectives of the present study were twofold: (1) to determine if a relatively simple methodology for conducting pellet counts could be used to obtain density estimates similar to those derived from other techniques, and (2) to investigate the effects of different sampling intervals on the density estimates derived from pellet counts.

STUDY AREAS

The study was conducted on 3 different areas in the southern Appalachian Mountains of east Tennessee: (1) the Department of Energy's Oak Ridge Reservation (the Reservation), (2) Chuck Swan Wildlife Management Area (Chuck Swan), and (3) Cades Cove, Great Smoky Mountains National Park (Cades Cove). The Reservation and Chuck Swan are physiographically similar, with alternating ridges and V-shaped valleys. The major forest

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associations on these 2 areas are mixed hardwoods and pine plantations. The study area on the Reservation was 3,504 ha and 10,049 ha at Chuck Swan. Cades Cove is a broad, relatively flat valley surrounded by steep mountains. The study area of Cades Cove was 977 ha in the lower portion of the valley. Pastures and hayfields comprise 76.5 percent (748 ha) of the valley floor and the remaining 23.5 percent (230 ha) consists of small woodlots and wooded areas.

All 3 areas have similar climates. The average annual precipitation is about 140 cm. The summer season tends to have the greatest precipitation and the fall season the least. The average annual temperature is about 14 C. Monthly temperature means are usually at a high in July and a low in February (United States Department of Commerce 1977).

The Chuck Swan area, formerly known as Central Peninsula, was used as a "control" area; the area has one of the most closely monitored deer herds in the Southeast (Lewis and Safley 1966) with more than 40 years of accumulated data.

METHODS

Pellet counts

A stratified random sample of each study area was used to locate permanent transects for pellet counts. Fourteen, 16, and 12 transects were established on the Reservation, Chuck Swan, and Cades Cove, respectively. The transects were 610 m (2000 ft) long and 3 (10 ft) wide providing a sample area of 0.186 ha for each transect. Transect mid-lines were delineated by using plastic flagging at 15-35 m intervals. By measuring 1.5 m perpendicular to the mid-line of the transect, its precise width could be determined. This width was easily measured in the field by carrying a walking stick of the appropriate length. Each transect was cleared of all pellet groups 1 month prior to making pellet counts at Chuck Swan and 3 weeks before making counts at Cades Cove. On the Reservation, an initial 4-month sampling interval was assumed (from the cessation of leaf fall in October until the first counts were made in January). Thereafter, a known 4-month interval was used.

Pellet groups that contained a minimum of 5 pellets were counted. These pellet groups were then destroyed or marked. Neff (1968) "arbitrarily" recommended that 30 or more pellets be present to constitute a pellet group. The 5-pellet criterion was believed to be appropriate in light of the potential for rapid deterioration and/or disappearance of pellet groups in the Southeast (Downing et al. 1965). Scattered pellet groups were counted if half or more of the pellets were within the transect (Robinette et al. 1958, Neff 1968); this methodology requires a relatively small amount of training and supervision of the personnel conducting the pellet counts.

Density estimates were obtained by using the equation described by Overton (1971). It was assumed that all pellet groups on a transect were found and that deer defecate approximately 13 times a day (Eberhardt and Van Etten 1956).

A deterioration and/or disappearance study of pellet groups was conducted at Chuck Swan and Cades Cove. When possible, up to 10 pellet groups (containing at least 5 pellets each) naturally occurring on a transect were marked with a spray painted circle; the presence or absence of these groups were recorded with the transects were next surveyed. Marked pellet groups containing less than 5 pellets were considered as having deteriorated and/or disappeared.

Mark-recapture I

The Schnabel technique (Schnabel 1938) was used to estimate deer densities from mark-reobservation ("recapture") data collected on the Reservation. Seven deer (approximately 10 percent of the population) were marked with 10 cm-wide thermoplastic collars. The collars had 10 cm reflective numerals on each side. Data were collected throughout the study period. Schnabel's binomial model, as described by Seber (1973), was used to obtain density estimates.

Mark-recapture II

Zinc-65 was used as a feces tag as described by Pelton and Marcum (1975). Seven of 10 captured deer from the Reservation were injected intramuscularly with 60 microcuries of Zn-65 in an isotonic saline solution. Thirty-two pellet groups were collected from the Reservation for scintillation analysis. The Lincoln index (Overton 1971) was used to derive density estimates, using the number of observations of marked deer and the total number of pellet groups found as the number of observations of all deer.

Roadside line transects

The King technique (Howe 1954) was used to derive density estimates of deer on the Reservation and at Chuck Swan. Deer were counted while driving along roads (transect lines) after dark. Hand held spotlights (200,000 candle power, sealed beam aircraft landing lights) were used to search for deer. The King technique uses a doubled average of all flushing distances (the perpendicular distance between the deer and the transect line) and the total length of the transect line to calculate the area populated by the deer observed (Howe 1954).

Plot sampling I

The drive count procedure used at Cades Cove was similar to that described by Overton (1971). Density estimates were calculated by weighing the densities obtained for the wooded areas and the fields according to their relative proportions within the study area.

Plot sampling II

The large open fields and woodlots of Cades Cove coupled with the general lack of fear exhibited by deer toward humans and automobiles enabled us to treat roadside counts as plot samples rather than line transects. The technique used was actually a modification of the drive count technique (Overton 1971). An imaginary drive line was projected out perpendicular to the road on both sides. As this line swept through both fields and wooded areas, all of the deer that passed through it were counted. Counts were conducted ½ hour after sunset using hand-held spotlights. Density estimates were derived by dividing the total number of deer observed by the total area surveyed. This technique was used successfully in Cades Cove prior to the present study (Fox and Pelton 1973).

Data were collected from January through September 1975 on the Reservation, from July through September 1975 at Chuck Swan, and the summers of 1978 and 1979 (June through August) at Cades Cove.

RESULTS AND DISCUSSION

The results of the deterioration and/or disappearance studies show that there was a 3.7 percent (n=108) loss of marked pellet groups over a 3-week period in 1978 and a 7.5 percent (n=93) loss in 1979. A 12.7 percent (n=646) loss occurred after 1 month at Chuck Swan and 19.7 percent (n=381) were lost after 2 months. The actual rate of deterioration and/or disappearance of fresh pellet groups could not be determined because, the precise ages of the marked pellet groups were not known. However, these results do give an indication that pellet group deterioration and/or disappearance rates were not excessively high.

Dung beetles and other insects did not appear to be involved in the deterioration and/or disappearance of pellet groups at either Chuck Swan or Cades Cove: only once were any seen on or near pellet groups in these areas. After a few heavy rains, earthworms were found in some pellet groups. Whether the earthworms eventually destroyed the pellet groups is unknown. Wild hog (*Sus scrofa*) rooting in the Cades Cove study area destroyed at least 1 marked pellet group and they may have destroyed other pellet groups as well.

The effect of vegetative growth was also monitored by using marked pellet groups. At both Chuck Swan and Cades Cove, such growth did not greatly reduce our ability to find pellet groups. However, on the Reservation, where marked pellet groups were not used, thick ground cover may have prevented the finding of some pellet groups.

Patric and Bernhardt (1960) concluded that pellet groups in Adirondack forests persist for long periods. Some groups remained evident for as long as 2.5 years and in many areas pellet groups 1.5 years old looked very similar to groups only 6 months old. Van Etten and Bennett (1965) determined that pellet groups in Michigan deposited on dry, closed hardwood sites demonstrated a lower rate of deterioration than those deposited on closed, swampy sites. Moisture and heavy rains appear to be the primary factors in determining the rate of pellet group deterioration. Wallmo et al. (1962) reported that heavy rains had a significant effect on the persistence of pellet groups. They lost as high as 91 percent of all marked groups after 4 heavy rains on their study area in Texas.

Density estimates of deer derived from all the techniques used on the Reservation were relatively low, moderately high at Chuck Swan, and relatively high at Cades Cove (Table 1).

The density estimate derived from pellet counts made at Chuck Swan using a 1-month sampling interval was nearly identical to the Tennessee Wildlife Resources Agency's (TWRA) percent kill estimate. At Cades Cove, the density estimate derived from pellet counts was higher in 1978 than those derived from either drive or roadside counts (plot sampling) but lower in 1979 (Table 1). In 1979, Cades Cove received an above normal amount of rainfall and some of the pellet count transects were partially flooded during this time. Several pellet groups were probably lost because of the flooding, thereby resulting in an underestimation of the density of deer. Density estimates derived from roadside counts (plot sampling) made after sunset were believed to most accurately reflect the actual density of deer utilizing Cades Cove (Kinningham 1980).

The roadside line transects conducted at Chuck Swan yielded a density estimate 1.9 times lower than the density estimate derived by TWRA using the percent kill technique. The percent kill technique was reported to be the most practical technique for estimating densities of deer at Chuck Swan (Lewis and Safley 1966). Based upon the results from Chuck Swan, it could be assumed that the density estimate using the roadside-line transect density estimate for the Reservation was also low by approximately one-half since both areas had similar physiographic features and habitats. If this assumption is indeed true, the corrected density estimate derived from roadside-line transect for the Reservation is 0.017 deer/ha (58.48 ha/deer). Thus, the density estimates derived from the various techniques used on each area compared fairly well except for the estimate from pellet counts made on the Reservation. The potential for relatively large losses of pellet groups during the 4-month sampling interval used on the Reservation probably resulted in the low density estimate.

Seven of 10 deer captured on the Reservation were injected with Zn-65; 3 of 32 pellet groups collected were radioactive. Pellet counts were conducted 3 times on both the Reservation and Chuck Swan. As a result of these small sample sizes, statistical comparisons between the density estimates obtained for the Reservation and Chuck Swan were meaningless. At Cades Cove, the estimate derived by pellet counts in 1979 were significantly less ($P < 0.01$) than the roadside count (plot sampling) estimate. No meaningful statistical comparisons could be made with drive count estimates for Cades Cove because of their small sample sizes (1978: 3 drives, 49 ha; 1979: 6 drives, 72 ha).

Although the confidence intervals around the density estimates for the Reservation were large (probably due to the small sample sizes), the 2 estimates based upon mark-recapture techniques were believed to be representative of the deer density on the Reservation. This conclusion is based not only on the estimates themselves but also on the

Table I. Comparison of density estimates (deer/ha) with 95 percent confidence intervals obtained for the Department of Energy's Oak Ridge Reservation (the Reservation), Chuck Swan Wildlife Management Area (Chuck Swan), and Cades Cove, Great Smoky Mountains National Park (Cades Cove).

Technique	The Reservation 1975	Chuck Swan 1975	Cades Cove 1978	Cades Cove 1970
Pellet count	0.009[1]	0.232[1]	0.470 $\pm$ 0.090	0.29 $\pm$ 0.070
	(106.17 ha/deer)	(4.31 ha/deer)	(2.13 ha/deer)	(4.17 ha/deer)
Mark-recapture	0.020 $\pm$ 0.011			
(Schnabel technique)	(50.78 ha/deer)			
Roadside line transects	0.009 $\pm$ 0.002	0.128 $\pm$ 0.061		
(King technique)	(113.02 ha/deer)	(7.97 ha/deer)		
Mark-recapture II	0.021 $\pm$ 0.016			
(Lincoln index)	(46.72 ha/deer)			
Percent kill		0.247[1]		
		(4.05 ha/deer)		
Plot sampling I			0.290[1]	0.310[1]
(Drive count)			(3.45 ha/deer)	(3.23 ha/deer)
Plot sampling II			0.410 $\pm$ 0.110	0.430 $\pm$ 0.080
(Roadside count)			(2.44 ha/deer)	(2.33 ha/deer)

[1]Confidence intervals not available for these estimates.

lack of visible browsing, especially on strawberry bush *(Euonymus americanus)* which is considered a preferred food for deer, yet is found in abundance on the Reservation.

CONCLUSIONS

Historically, obtaining an estimate of animal abundance in an area of low population density has been a difficult task because of insufficient sample sizes. Theoretically, with pellet counts, the potential sample size is increased by about 13 times/day for each deer. Thus, the low density estimate derived from pellet counts made on the Reservation appears to be the consequence of a long sampling interval relative to the deterioration and/or disappearance rate obtained for the area rather than a failure of the technique itself in areas of low deer density.

None of the study areas had known deer population densities. However, the deer population at Chuck Swan has been intensively studied since 1937 when deer were originally restocked there (Lewis and Safley 1966). The density estimate from pellet counts conducted at Chuck Swan was similar to TWRA's percent kill estimate. Thus, although the actual accuracy of the density estimates derived from pellet counts is not known, when an appropriate sampling interval is used, such estimates are comparable to density estimates derived from other techniques now available.

Direct count techniques have traditionally been considered more reliable than techniques that depend on indirect counts of feces, tracks, scrapes, and rubs. However, the results of the pellet counts from Chuck Swan and Cades Cove indicate that indirect counts may be as reliable as techniques utilizing direct counts. Pellet counts have an advantage over other indirect counts in that pellet groups are deposited every day, regardless of weather, season, or sex of the deer. Also, pellet groups do not need to have suitable substrata in order to be present.

It is evident that deterioration and/or disappearance of pellet groups in the southern Appalachians would invalidate the use of pellet counts only if counts are based on long sampling intervals. A short interval of 3 weeks to 1 month appears to be appropriate based on the results of the present study. Additional monitoring of deterioration and/or disappearance rates of pellet groups should be conducted on each study area concurrently with pellet counts so that researchers can better evaluate their results.

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) deterioration and/or disappearance rates of pellet groups should be monitored; and (4) in the southern Appalachians, a 3-week to 1-month sampling interval is recommended.

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