et calculator, thus eliminating computer simulation. Finally, the fact that the encounter relationship (eq. 6) based on data from one hunting area (Crab Orchard National Wildlife Refuge, Illinois) results in a model that predicts harvest from another hunting area (Cary Estate, New York) indicates that both the binomial and the queuing models are general. Studies from different habitats and various deer and hunter population sizes, in which relationships similar to eq. (6) could be established, would reveal if both models are as general as indicated.

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THE RELATIONSHIP BETWEEN WHITE-TAILED DEER TRACK COUNTS AND PELLET-GROUP SURVEYS

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Wildlife managers have long recognized the need for an efficient means of estimating white-tailed deer (*Odocoileus virginianus*) populations. Counting tracks of deer crossing dirt roads has been investigated as one possibility. Downing et al. (1965) concluded that track counts could detect a 20% change in a deer population in a 3-km^2 enclosure. Tyson (1959) reported a 1.6:1 ratio of tracks per km of road to deer per km^2, a ratio later confirmed by Daniel and Frels (1971). Harlow and Downing (1967) evaluated the published data and could not confirm or refute the 1.6:1 ratio. Bennett et al. (1980) showed a correlation between pellet-group surveys and track-count data ($r = 0.78$, $P < 0.01$), and track counts and the buck kill ($r = 0.84$–0.94, $P < 0.01$). W. A. Creed (pers. commun.) demonstrated a correlation ($r = 0.85$, $P < 0.05$) between track counts and the buck kill in Wisconsin. Track counts have been used in Poland, with varying results, as an index to populations of red deer (*Cervus elaphus*), wild pig (*Sus scrofa*), roe deer (*Capreolus capreolus*), and moose (*Alces alces*) (Pucek et al. 1975, Dzieciolowski 1976). The objective of our research was to examine the relationship between deer track counts and pellet-group survey data.

STUDY AREA

The Bearville Study Area (BSA) covers 839 km^2 in northeastern Itasca County, in north-central Minnesota. The topography is undulating to strongly rolling. The dominant soil type is the sandy, well-

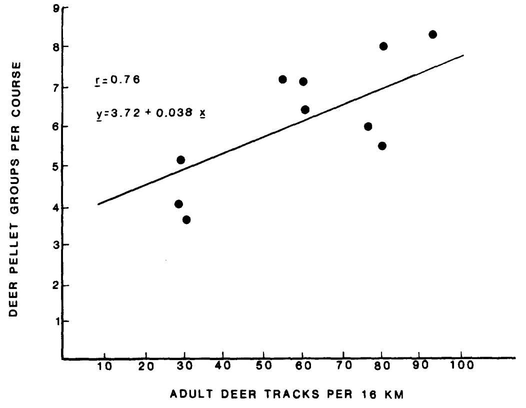

Fig. 1. The relationship of white-tailed deer track counts and pellet-group surveys, Bearville Study Area, Minnesota.

drained, light-colored soils of the Prairie River Plain (Univ. Minn. 1971). However, there are also substantial areas of silty, loamy, and clay soils, with organic soils dominant in lowland areas.

The area was logged for pine and sporadically burned by wildfire between 1900 and 1930. Upland forests presently consist of mature quaking aspen (*Populus tremuloides*)–paper birch (*Betula papyrifera*) and jack pine (*Pinus banksiana*)–red pine (*P. resinosa*) stands managed primarily for pulpwood. Lowland areas are dominated by mixed or pure stands of black spruce (*Picea mariana*), northern white cedar (*Thuja occidentalis*), and tamarack larch (*Larix laricina*).

Monitoring of radio-collared deer showed that there were no extensive seasonal movements to or from the BSA (Kohn and Mooty 1971, Waddell 1973, Pierce 1975).

METHODS

The occurrence of deer pellet groups on the study area from 1968 through 1977 was determined following Ryel (1971). Track counts were conducted on dirt roads within the BSA during these same years. Track-count routes were selected based on (1) location in representative deer range, (2) availability of suitable dirt roads, and (3) relation of a given route to other routes. The counts were made on 16-km segments of roads between 1 July and 15 August. An earlier study (Kohn and Mooty 1971) indicated that BSA deer neither avoided nor preferred roadsides during this period. Open areas such as roadsides are attractive feeding grounds for deer in the spring and fall (McCaffery and Creed 1969). Therefore, track counts made at these times would not be comparable to midsummer counts.

The road surface was prepared the day before counting by grading with a steel frame drag. Dragging erased old tracks and disturbed the surface enough so that new tracks were visible. Some counts were also made on days after a light rain if the shower obliterated old tracks, or after the road had been maintained by a road grader. Elapsed time from road preparation to track counting ranged from 18 to 24 hours. Counts were not made during periods of unstable weather, i.e., approaching storms or cold fronts. Petraborg and Idstrom (1972) found that track counts were higher than usual after rains of 1–3 days; unseasonably cool temperatures tend to reduce deer activity (Progulske and Duerre 1964).

Counts were made on one side of the road by an observer in a slowly moving vehicle. Tracks of adult deer and fawns were recorded separately. Only tracks of adult deer were used to compare the data with spring pellet-group survey results. All track-count routes were conducted one–three times each summer during the 10-year study.

Each count on a route was the sampling unit. The total number of adult tracks per 16-km route was used in analyzing the results. Track and pellet-group surveys were compared using Bartlett's three-group

Table 1. White-tailed deer track-count and pellet-group survey data for the Bearville Study Area, Minnesota.

Year	Track-count routes, N	Total track counts, N	Tracks/16 km[a] $\bar{x}$	Tracks/16 km[a] 95% CI	Pellet-group survey courses[b], N	Pellet groups/course[a] $\bar{x}$	Pellet groups/course[a] 95% CI
1968	2	4	56.2	0–158.2	75	7.2 A	5.6–8.8
1969	2	6	28.0	0–60	150	5.1 AB	3.6–6.6
1970	3	8	31.4	0–175.4	175	3.6 B	3.1–4.1
1971	4	10	27.9 A	21.9–33.9	176	4.0 C	3.4–4.6
1972	4	9	77.5 A	41.5–113.5	200	5.8 C	5.1–6.5
1973	3	5	57.0	0–121	100	5.8	4.6–7.0
1974	4	9	81.3	40.3–122.3	100	5.4	4.4–6.4
1975	4	9	60.8	25.8–95.8	100	7.0	4.7–9.3
1976	4	7	81.6	50.6–112.6	100	7.9	6.4–9.4
1977	4	8	94.5	35.5–153.5	65	8.2	6.1–10.3

[a] Columnar values with same letter differ ($P < 0.05$). Test applied only between adjacent values.
[b] Data for 1968–71 based on random sampling and for 1972–77 from stratified sampling with optimum allocation.

method for model II regression (Sokal and Rohlf 1969). Population changes between years were tested using the Student-Newman-Keuls test (Steel and Torrie 1960). We used a balanced design, mixed model analysis of variance (BMD program BMD08V, Dixon 1974) to estimate route, count within route, and kilometer within count variance components. These variance components were used to determine the amount of effort required to achieve desired levels of precision using track counts.

Eight duplicate counts were made to determine inter-observer reliability. Two observers in separate vehicles made independent counts on a particular route within 2 hours.

RESULTS AND DISCUSSION

Track counts of adult deer per 16-km of road were correlated with results of pellet-group surveys ($r = 0.76$, $P = 0.011$) (Fig. 1, Table 1). Confidence limits for track counts ranged from ±22 to ±460% vs. ±14 to ±33% for the pellet-group surveys (Table 1). Because of their higher variability, track counts are less sensitive than the pellet-group survey for detecting changes in population trends, assuming both methods are equally correlated with the true population levels. There were three significant between-year changes in pellet-group survey results and only one for track-count results (Table 1).

It required approximately 50 man-days of effort per year to complete pellet-group surveys yielding a precision of ±20% of the mean. The ANOVA indicated that for a fixed level of effort, precision for track counts was increased by reducing the number of replications within routes and increasing the total number of routes. For the most efficient design, each route would only be surveyed once. Precision of ±20% could be achieved with 19 man-days if 19 unique routes are counted. However, a sufficient number of routes will often not be present in the area of interest. Such was true in our study, where four or fewer unique routes were surveyed each summer. Increasing the amount of replication will increase the precision, but gains will not be rapid. For example, with five routes, going from one replication/route to 10 increases the precision from ±39% to ±33.3%, little reward for a 10-fold increase of effort. Calculations were also made for hypothetical 8-km-long routes on the assumption that more short routes

Table 2. Calculated sample sizes and man-days of effort for estimating the mean number of white-tailed deer tracks at different levels of precision.

Route length, km	Repetitions/ route, N	Routes, N	Precision, 95% CI[a]	Man-days[b]
8	1	10	±39.0	10[c]
16	1	5	±39.0	10[d]
8	5	10	±32.5	50
16	5	5	±34.0	50
8	10	10	±31.6	100
16	10	5	±33.3	100

[a] Expressed as a percent of the mean.
[b] Includes the actual time to prepare and count the route.
[c] Includes ½ day for preparation and counting of each route.
[d] Includes 1 day for preparation and counting of each route.

could be found in an area. Little saving in work effort was observed (Table 2). We recognize that the confidence limits for track counts and pellet-group surveys may not be comparable, and conclusive statements require knowledge of their relation to actual population size.

Our limited experience with duplicate counts ($N = 8$) yielded a difference of 0.4% in total tracks observed. A paired t test (Snedecor and Cochran 1967) of these data indicated no difference ($P > 0.05$) between observers.

CONCLUSIONS

1. A significant linear correlation existed between midsummer track counts of adult deer and spring pellet-group surveys.
2. Variability in the number of tracks among counts and routes resulted in large confidence intervals for track-count data.
3. Calculations indicated that track-count variability would be reduced by counting more routes vs. repeat counts on the same routes.
4. Whether track counts can achieve the same or better precision than a pellet-group survey in an area depends on the number of routes that can be sampled.
5. Route length (e.g., 8 vs. 16 km) had little influence on precision or effort.

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EFFECTS OF TIMBER HARVESTING ON UNGULATES IN NORTHERN MAINE

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Commercial timber harvesting produces widespread changes in successional plant communities in northern forests and, thus, is a major factor affecting the abundance and distribution of moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*). Knowledge of the effects of timber harvesting on moose and deer will aid in the development of plans to manage ungulate resources in forests. I studied the effects of commercial clear-cutting and partial stand harvesting on moose and white-tailed deer in northern Maine during three winters (1974–77). My objectives were to determine overall use and cover-type preferences by moose and deer in relation to browse availability within two harvested areas and an undisturbed forest. I also assessed seasonal shifts in use of cover types by moose and deer during winter with respect to forest management practices.

STUDY AREA

The study area is in north-central Maine in Piscataquis County, near the eastern shore of Moosehead Lake. Detailed descriptions of the three forests examined and their cover types were presented by Soutiere (1979). Major cover types included softwoods (75–100% conifer crown cover), hardwoods (75–100% hardwood crown cover), mixed softwood-hardwood stands (softwood-dominated, 50–74% conifer crown cover), and mixed hardwood-softwood stands (hardwood-dominated, 25–49% conifer crown cover).

The undisturbed forest comprised 13.9 km^2 in 1974, but ongoing timber harvesting reduced the forest to 5.5 km^2 by 1977. Undisturbed forest stands were primarily even-aged. Red spruces (*Picea rubens*) were 60–200 years old and balsam firs

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