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THE USE OF LINE TRANSECTS TO EVALUATE THE ABUNDANCE OF DIURNAL MAMMALIAN PREY

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ABSTRACT.—While studying the foraging behavior of accipiters in northern New Mexico, chipmunk abundance was evaluated with a line transect technique. This is a timely, cost-effective method for providing quantitative estimates of the abundance of diurnal small mammal prey in different habitats. The limitations and general applicability of this method to raptor prey studies are discussed.

Many feeding ecology studies of diurnal raptors suffer from difficulties in assessing prey abundance in foraging areas. Fitzner et al. (1977) described techniques for determining densities of raptor prey species, emphasizing procedures that would provide quantitative data for comparisons of prey exploitation rates and prey densities. Methods traditionally used for collecting these data are time-consuming and labor-intensive. Other problems with these methods have been widely addressed, and no unified approach toward obtaining comprehensive and systematic estimates of small mammal density or population size has been developed (Otis et al. 1978). Most density estimation methods also sample relatively small areas (<10 ha) and are not practical for determining animal abundance in large foraging areas used by raptors (>100 ha for many species). In addition, precise quantitative density estimates may not be necessary to answer many of the questions addressed in raptor studies.

Many studies have attempted to estimate animal abundance by counting all individuals in a known area (Hayne 1949; Krebs 1966; Hirst 1969; Emlen 1971; Franzreb 1981). However, most of these methods were not designed to sample chipmunks (*Tamias* sp.) or other diurnal small mammals which are common raptor prey. In addition, species and habitat comparisons may not be possible because the sample area sizes and the relationship between indices of abundance and absolute abundance are difficult to assess (Burnham et al. 1980). Because of these difficulties, many recent papers have suggested that enumeration methods are not sound and should not be used to evaluate animal abundance (Burnham et al. 1981, 1985; Jolly and Dickson 1983; Smith and Brisbin 1984; Montgomery 1987).

We have been studying the foraging behavior of a population of Cooper's Hawks (*Accipiter cooperii*) nesting in northern New Mexico. Cooper's Hawks feed primarily on medium-sized passerines, woodpeckers, and chipmunks (Kennedy 1985). To evaluate foraging areas, sampling methods were needed that were suitable for sampling prey populations over large areas in a timely, cost-effective manner and would provide results appropriate for comparisons.

To determine chipmunk abundance in Cooper's Hawk foraging areas, we modified the line transect method of Burnham et al. (1980, 1981). Burnham et al. (1980) have shown that line transect sampling is practical, relatively inexpensive, and efficient for calculating density estimates, particularly when a study area is stratified by some feature such as habitat. Despite the potential usefulness of line transect sampling, it has been infrequently used (Burnham et al. 1980). In this paper we describe our application of this method and evaluate its usefulness in quantifying the abundance of diurnal small mammals in different habitats.

STUDY AREA

The study was conducted in the Jemez Mountains in north-central New Mexico. The study area and the Cooper's Hawk nesting habitat are described in detail in Kennedy (1988).

METHODS

For comparison of prey abundance between foraging areas, 2 habitats commonly used by Cooper's Hawks (as determined from radio-tracking data) were examined: mesa tops and canyon bottoms. Mesa tops are dominated by pinyon-juniper (*Pinus edulis-Juniperus* sp.) woodland and Gambel oak (*Quercus gambelii*). Canyon bottoms are characterized by large ponderosa pine (*Pinus ponderosa*), scattered Douglas fir (*Pseudotsuga menzesii*), cottonwood (*Populus* sp.), and numerous shrub species.

During 1986, prey populations in foraging areas of 5 nesting pairs of Cooper's Hawks were sampled. Transects of varying lengths (1.61-3.22 km) were established in mesa top and canyon bottom habitats. Transect lengths were determined by the amount of homogeneous habitat [from vegetation maps (Allen 1989)] available for sampling in each foraging area. Transects were run for 3 sampling periods in 1986 which were designed to coincide with the late incubation/early nesting period (late May–early June), late nestling/early fledgling dependency period (late June–July), and late fledgling dependency period (August–early September).

During 1988, transects varying from 2.90–3.70 km in length were established in mesa top and canyon bottom habitats near 2 Cooper's Hawk nest sites. In 1988, transects were run during the first and third sampling periods. Total transect lengths established in each habitat for 1986 and 1988 are shown in Table 1.

An observer walked along each transect at a continuous pace of about 1.6 km/hr, alternating between slow walking and brief pauses to look and listen. All chipmunks seen or heard along the transect were counted. The type of detection (auditory or visual) was noted with each observation. In the canyon bottom habitat, estimates of the perpendicular distance from the observer to each detection (Burnham et al. 1980) were recorded within each of four distance categories: 0–7.6 m, 7.7–15.2 m, 15.3–22.9 m, and 23.0–30.5 m. In the mesa top habitat, which had more vegetative cover, distances could not be accurately estimated beyond 23 m so only the first three distance categories were used. Efforts were made not to count individuals more than once. When an observed individual fled, the escape route was monitored to ensure against duplication in counts.

Only 1 transect was traversed each day. Sampling guidelines established for breeding bird transects (Emlen 1971) were followed. One observer conducted all censuses to avoid multi-observer biases (Faanes and Bystrak 1981). Transect counts were conducted only on days with no precipitation, moderate cloud cover (<50%) and low wind speeds (<1 m/sec) (Newman 1959; Robbins 1981). Transects were run for approximately 2 hr and were traversed from 0800–1100 (Verner and Ritter 1986).

Chipmunk densities for each sampling period within each habitat were calculated using the exponential polynomial estimator in program TRANSECT (Burnham et al. 1980). Computation of the Shapiro-Wilk statistic (W) indicated that the density data were a random sample from a normal distribution (W = 0.95, P = 0.74). Differences in chipmunk density between habitats were evaluated for the data using a paired *t*-test. All statistics were computed with the SAS Statistical Program (SAS 1985a, 1985b).

RESULTS

Table 1 shows estimates of chipmunk density within each habitat calculated using the line transect method. Significantly more chipmunks were counted in the canyon bottom habitat than in the mesa top habitat during all sampling periods ($t = 3.37$, P = 0.02).

DISCUSSION

Our results indicate that this line transect method is suitable for evaluating chipmunk abundance within different habitats. However, this method has limitations; these and the assumptions addressed by Burnham et al. (1981) should be considered before

Table 1. Estimates of chipmunk densities in mesa top and canyon bottom habitats in Cooper's Hawk hunting areas.

	Habitat			
	Mesa Top		Canyon Bottom	
Sampling Period	Transect Length (km)	Density (#/ha) (SE)	Transect Length (km)	Density (#/ha) (SE)
1986				
1	12.87	0.45 (0.34)	7.24	2.69 (0.87)
2	14.48	1.82 (0.64)	18.02	1.98 (0.47)
3	11.26	1.32 (0.61)	23.02	2.60 (0.48)
1988				
1	9.33	0.79 (0.52)	10.14	4.32 (0.94)
3	9.33	0.90 (0.55)	9.66	3.14 (0.82)
Average density (SE)		1.09 (0.25)		2.78 (0.37)

this method is used to sample prey populations in raptor studies.

Four basic assumptions in line transect sampling were recognized by Burnham et al. (1981): (1) animals directly on or very near to the line will always be detected; (2) there is no movement of animals in response to the observer and none are counted more than once during a given walking of the line; (3) all distance data are recorded without measurement error; and (4) sightings of different individuals are statistically independent events. We violated assumptions 1 and 2. However, Burnham et al. (1981) indicate that the robustness of the TRANSECT estimators allows for moderate violations of these assumptions.

Habitat type influences the level of survey accuracy because more detectability problems occur in dense, heavily vegetated habitat than in open, sparsely vegetated habitat. The screening effect of dense vegetation can result in variable detectability of animals near the transect line (violation of assumption 1). Thus, we recommend the line transect method be used primarily in relatively open habitats where the observer can see clearly in all directions to catch quick movements of individuals.

In addition to limited visibility in dense habitat, the observer makes more noise walking through thick vegetation. As a consequence, individuals may be frightened and move away from the center line, thus

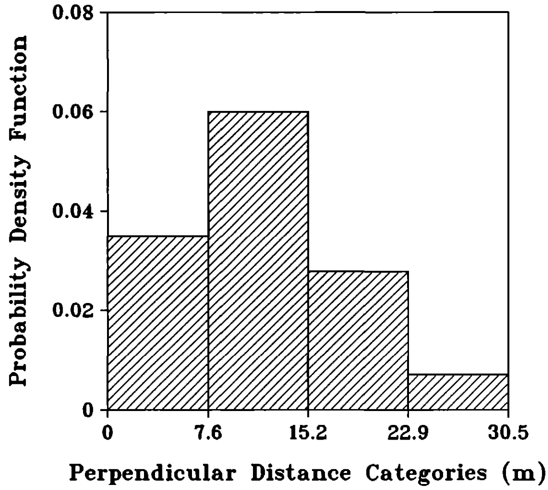

Figure 1. A frequency histogram of chipmunk perpendicular distance data collected in the mesa top habitat during sampling period 1 in 1986.

escaping detection. Undetected nonrandom movement as a result of lower visibility or reaction to the observer is the problem most frequently encountered in applying line transect sampling methods to wildlife populations (Burnham et al. 1981). Such nonrandom movement tends to increase the perpendicular distance of the animal from the line or cause it to be missed. If the animal is spotted, it would be at a point farther from the line than its original position; this violates assumption 2 (Burnham et al. 1980).

The characteristic pattern one can expect to see in the data histogram generated by TRANSECT if evasive movement occurs is shown in Figure 1, a representative frequency histogram of the chipmunk distance data collected in this study. Tests of the robustness of various estimators to animal movement (Burnham et al. 1980) revealed that the exponential polynomial estimator is substantially more robust to movement than other estimators, thus we used it to calculate chipmunk densities.

Due to the movement response of chipmunks to the observer, we do not recommend measuring the exact perpendicular distance to each individual from the transect line. Additional observer movements resulting from these measurements would increase evasive responses of the sample animals and introduce additional errors into the density estimates. Assigning individuals to distance categories during sampling eliminates this problem and the ability to take distance data as grouped greatly extends the applicability of the line transect procedure (Burnham et al. 1981). Density estimates can be calculated from grouped distance data and assumption 3 is not violated if there is no error in category assignment (Burnham et al. 1980).

Minimizing the number of observers and training them in distance estimation in each habitat prior to sampling will improve estimator accuracy. The number of distance categories should be as large as possible to improve estimator accuracy but not so large that distance estimation errors are introduced.

Although we used this line transect method only to assess chipmunk abundance, the method is suitable for surveying other small, diurnal mammals. When we began this study, we attempted to record all species of diurnal mammals encountered on each transect. To improve consistency of the methodology and thus density estimates (Temple 1981), we recommend that each survey be conducted for 1 or 2 species at a time. Obtaining simultaneous counts for calculating density estimates on gregarious ground-dwelling small mammals [chipmunks or Golden-mantled Ground Squirrels (*Spermophilus lateralis*)] is not difficult. This may be more difficult for less detectable mammals such as Rock Squirrels (*S. variegatus*) which may have a greater flushing distance, and consequently a lower probability of detection along the transect line. To obtain suitable counts for more reclusive species, these species should be surveyed separately. In addition, line length and/or the number of distance categories may need to be increased.

This technique is also suitable for arboreal mammals such as Abert's Squirrels (*Sciurus aberti*) or Red Squirrels (*Tamiasciurus hudsonicus*). Surveying the trees and the ground simultaneously is difficult; therefore, we recommend that arboreal species be surveyed at a different time than ground-dwelling species.

In summary, our results indicate that within certain limitations, this line transect method can be useful for evaluating prey populations in raptor foraging areas.

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