Boundary-strip Width for Density Estimation Based on Telemetric Locations

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Abstract: The mean maximum distance moved (MMDM) of a southern fox squirrel (*Sciurus niger niger*) population during a 12-day trapping period was compared between radiotelemetry and capture location data. MMDMs derived from capture locations averaged 51% less than MMDMs derived from telemetric locations. In addition, tests of MMDMs based on capture locations failed to detect a difference between sexes, whereas MMDMs based on telemetric locations indicated a significant difference. Density estimates of the fox squirrel population were calculated using MMDM/2 as an estimate of boundary-strip width (W) to compensate for "edge effect." A combined density estimate based on capture locations was 27% larger than the estimate based on telemetric locations. Because MMDMs derived from capture locations depend on the number of recaptures and are a function of trap spacing, W is often underestimated, resulting in positively biased density estimates. Density estimates located on $\hat{W}$ derived from telemetric locations may be less biased than estimates based on capture locations. Thus, radiotelemetry may help provide more reliable density estimates, particularly when recaptures are few.

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Many theoretical and applied ecological investigations of mammals require the estimation of population density (D). Density estimates are often based on capture-recapture data; however, knowledge of the "effective" area trapped is essential to convert an estimate of population size (N) to population density. Geographic closure, a critical assumption of both open and closed capture-recapture models (White et al. 1982), is often violated, resulting in an "edge effect." This increase in the area trapped relative to the area encompassed by the trapping grid (A) can be attributed to 2 factors: immigration, and animals whose home ranges overlap the edge of the grid (Dice 1938, Tanaka 1972). The effect of immigration can be minimized to some extent by considering the time and duration of the trapping period or by employing a study design appropriate for open populations (Otis et al. 1978). Also, because "edge effect" induced by overlap of animals' home ranges with the grid is inversely related to grid size (Tanaka 1980, White et al. 1982, Wilson and Anderson 1985), it can be minimized by using a grid which is large relative to home-range size. However, the size of a grid is frequently limited by logistic and/or monetary considerations to the point where the area of "edge effect" is not negligible. In this situation, a naive density estimate based on actual grid area, $\hat{D} = \hat{N}/A$, may have a severe positive bias. Thus, it is important to be able to estimate the actual area to which $\hat{N}$ applies so that reasonable density estimates can be obtained.

Dice (1938) was the first to propose a method to compensate for "edge effect." He suggested the addition of a boundary strip, with its width (W) defined as half the average diameter of an animal's home range, to the outer edges of the trapping grid. Wilson and Anderson (1985) suggested that W can be estimated by half the mean maximum distance moved (MMDM), i.e., the distance between the 2 locations farthest apart, as revealed by animals captured ≥2 times. Their results, based on Monte Carlo simulations, indicate that by using MMDM, density estimates can be obtained with percent relative bias <20% and fair confidence interval coverage (71%–89% actual coverage for 95% confidence intervals).

If Dice's (1938) interpretation of W was correct, determination of the "true" home-range size presents a complex problem. The use of MMDM for estimating home-range size has been proposed (Stickel 1954; Tanaka 1972, 1980); however, Wilson and Anderson (1985) used MMDM specifically to estimate W, not home-range size. Both methods are subject to problems associated with numbers of recaptures and trap spacing (Hayne 1949; Stickel 1954; Tanaka 1972, 1980; Wilson and Anderson 1985). A sufficient number of recaptures must be realized in order to provide reliable estimates of MMDM or home-range size. MMDM and home-range size as determined from trapping data also can be considered a function of trap spacing.

Many studies utilizing capture-recapture methods are conducted on small populations and/or populations with low capture probabilities (Menkens and Anderson 1988); thus, recaptures often are few. Recently, several capture-recapture population estimators have been proposed which may be appropriate for situations when recaptures are few (e.g., Gazey and Staley 1986, Menkens and Anderson 1988, Chao 1989, Minta and Mangel 1989); however, a suitable method for estimating density in these situations is presently unavailable.

To date, radiotelemetry has seldom been used as an aid in estimating density based on trapping data. Babb and Kennedy (1989) used radiotelemetry to provide information for estimating the density of a coyote (*Canis latrans*) population. Because captured coyotes were destroyed, a subpopulation of radio-equipped coyotes was utilized to determine the effective area trapped based on MMDM. However, differences between the use of MMDM derived from capture locations and from telemetric locations for estimating density have not been examined. Thus, the objective of this study was to document differences in MMDM values as derived from radiotelemetry and trapping data and their effects on density estimation using a southern fox squirrel population. In addition, advantages of estimating W based on MMDM derived from telemetric locations of a subpopulation of animals during a capture-recapture study are discussed.

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Methods

This study was conducted on a northern portion of the Piedmont National Wildlife Refuge in central Georgia. The topography is characterized by rolling hills typical of the southern Piedmont Plateau Region. Pine and mixed pine-hardwood forest with several narrow hardwood drains typify the study area. Major tree species include loblolly pine (*Pinus taeda*), oaks (*Quercus* spp.), and hickories (*Carya* spp.).

A trapping grid consisting of 144 Mosby-type box traps (Day et al. 1981) spaced 100 m apart and covering 121 ha was established. The grid was located so that it was partially bounded by natural features (e.g., a lake) to reduce "edge effect." Limited trapping was conducted in January and March 1989 to equip a subpopulation of fox squirrels with radio transmitters. Each captured squirrel was anesthetized using ketamine hydrochloride (approximately 25 mg/kg of body weight) and then fitted with a radio transmitter-collar unit (Telonics, Inc., Mesa, Ariz.) weighing approximately 40 g.

During May 1989, trapping was conducted for 12 consecutive days. Traps were baited with shelled corn and checked twice per day. Each captured squirrel was toe-clipped for individual identification; sex, weight, and capture location were recorded; and the squirrel was released at the site of capture. In addition, previously radio-equipped squirrels were monitored during the 12-day trapping period. Each squirrel was located twice per day between sunrise and sunset, just prior to each check of traps. Three compass azimuths from permanent stations were used to estimate squirrel locations. By using transmitters of known locations, telemetry error was estimated as $+0.4° \pm 4.8°$ (SD). Linear errors averaged 33.0 m $\pm$ 21.3 m.

Capture locations for squirrels captured $\geq$2 times were plotted, and the linear distance between the 2 capture sites farthest apart was calculated for each squirrel. Telemetric locations and capture locations also were plotted, and the maximum linear distance moved was determined for each of 6 male and 9 female radio-equipped squirrels. Mann-Whitney U-tests were used to compare the MMDM for each sex and each estimation method. Also, $\hat{W}$ was calculated from each MMDM value as MMDM/2. Density estimates for each method of estimating W, as well as a naive density estimate, were calculated based on population estimates derived from a Monte Carlo simulation method (Minta and Mangel 1989) using a subpopulation of radio-equipped squirrels.

Results and Discussion

During the May trapping session, 32 individual fox squirrels (14 males and 18 females) were captured 60 times. Of these, 8 males and 7 females were captured $\geq$2 times. The MMDMs calculated from capture locations for males and females (Table 1) were not different ($U = 20.5$, $P > 0.20$). Number of locations per radio-equipped squirrel averaged 20 (range 18–24). The MMDM calculated from telemetric locations of males was larger ($U = 9.0$, $P \leq 0.05$) than that of females (Table 1). In addition, MMDMs calculated from telemetric locations were larger than those calculated from capture locations (Table 1) for males ($U = 1.0, P \leq 0.01$) and females ($U = 7.0$, $P \leq 0.01$).

These results indicate that MMDM calculated from capture locations may have a negative bias in some situations. When compared to MMDMs calculated from telemetric locations, they averaged 51% less. This necessarily implies that density estimates may be positively biased when using capture locations for estimating MMDM. Wilson and Anderson's (1985) Monte Carlo simulations also found that density estimates were positively biased when using MMDM calculated from capture locations. In addition, tests of MMDMs derived from capture locations in this study failed to detect a difference between sexes.

The population of fox squirrels during the trapping period was estimated as 49 (SE = 4.0). This was partitioned into 21 males and 28 females based on the sex ratio of captured squirrels. Using calculated $\hat{W}$s (Table 1), the effective area trapped was derived for each sex and method of MMDM estimation. These areas, as well as the actual grid area, then were used to calculate the corresponding density estimates. Male and female estimates were combined into a total density estimate. Whether or not $\hat{N}$ is biased, the relationships between methods of density estimation should be constant. The estimate based on capture location data (29.7 squirrels/km^2) was 27% larger than that based on telemetric locations (21.8 squirrels/km^2). The naive density estimate (40.5 squirrels/km^2) was obviously biased.

If a measure of MMDM is useful for estimating W, as suggested by Wilson and Anderson (1985), estimates of W based on telemetric locations may be less biased than those based on capture locations. This probably stems from MMDM being a function of trap spacing. Unless traps are relatively close together, MMDM

Table 1. Mean maximum distance moved (MMDM) and boundary-strip width ($\hat{W}$) calculated from capture and telemetric locations of southern fox squirrels on the Piedmont National Wildlife Refuge, Georgia, 1989.

Sex	Location method	N	MMDM (m)	SE (MMDM)	$\hat{W}$ (m)
Male	Captures	7	259.1	65.5	129.6
	Telemetry	6	705.2	167.2	352.6
Female	Captures	8	278.4	29.8	139.2
	Telemetry	9	451.9	51.1	226.0

will tend to be underestimated, resulting in a negatively biased estimate of W and, consequently, a positively biased density estimate. In addition, the use of radiotelemetry techniques is not dependent on recaptures. Thus, radiotelemetry may prove to be a valuable aid in the estimation of density. However, it must be recognized that a reliable estimate of N is a prerequisite of a reliable estimate of D.

Many studies involve investigating habitat use as well as density estimation. Thus, the use of radiotelemetry as an aid in estimating density will have very little effect on the overall experimental design. However, if a density estimate is of primary importance, the cost of using radiotelemetry techniques may be offset by the value of the information collected.

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