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HOME RANGES OF THREE SPECIES OF CHIPMUNKS (*TAMIAS*) AS ASSESSED BY RADIOTELEMETRY AND GRID TRAPPING

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Much recent discussion in the mammal home-range literature has focused on which of the many proposed statistical and nonstatistical home-range indices provide the most reliable estimates of home range size (Hackett and Trevor-Deutsch, 1982). The standard nonstatistical measure is minimum-convex polygon (Stickel, 1954), whereas a variety of statistical indices has been proposed recently (Koepl and Hoffmann, 1985; Jennrich and Turner, 1969; Schoener, 1981). Of course, home range (sensu Burt, 1943) is a variably useful concept, depending on the behavior of the species under study, the investigator's sampling design, and the hypotheses being addressed. Home-range shape (Covich, 1976) and temporal pattern of use (Swihart et al., in press) can vary tremendously among species, causing different estimates of home-range size to vary and making interspecific comparisons ambiguous. Trap spacing and grid size, shape, and placement affect home range estimates from live trapping (Anderson et al., 1983; Van Horne, 1982), whereas statistical indices are sensitive to autocorrelation and sampling interval in methods employing more frequent monitoring, such as radiotelemetry (Swihart and Slade, 1985). Radiotelemetry generally provides better (usually larger) estimates of home-range size than grid trapping (Hackett and Trevor-Deutsch, 1982). Removing autocorrelated data or using nonstatistical indices (such as minimum-convex polygon) on data from radiotelemetry is preferable; because the latter technique is comparatively new, the bulk of data on home ranges of most species comes from grid-trapping studies. Therefore, it would be desirable to be able to obtain more reliable estimates of home-range size from grid-trapping data. In this study, I use minimum-convex polygon of telemetry locations as a standard for comparison with a modified grid-trapping home-range index for three

species of *Tamias*. These represent the first radiotelemetry-based home-range estimates reported for western chipmunks (subgenus *Neotamias*).

Chipmunks were trapped and ear-tagged on two different study sites in ponderosa pine (*Pinus ponderosa*)-Douglas fir (*Pseudotsuga menziesii*) habitat within the Roosevelt National Forest, Larimer Co., Colorado. A high-elevation site (2,740 m) consisted of one rectangular grid, 10 by 12 stations, with a trap spacing of 25 m, and a low-elevation site (2,130 m) consisted of one grid, 8 by 12 stations, with a trap spacing of 35 m. One Sherman trap (3.5 by 3.5 by 23.0 cm) was placed at each station, baited with scratch grain and sunflower seeds, and provided with cotton nesting material. Traps on both grids were examined at various times of day a minimum of 30 times during each of the summers of 1983 and 1984. *Tamias umbrinus* and *T. minimus* were present at both sites; *T. quadrivittatus* occurred only at the low-elevation site. Ten individuals of the three species were fitted with tuned-loop-collar radiotransmitters weighing ca. 3 g (L and L Electronics, Mahomet, IL). Using a three-element Yagi antenna and a frequency of 164 KHz, maximum reception range was between 100 and 200 m. Because chipmunks are diurnal and relatively conspicuous, most telemetry locations could be confirmed by direct visual observation. Therefore, the resolution of telemetry locations on the coordinate plane of the grid was often 5 m, whereas the resolution of trapping locations was always either 25 m (high-elevation site) or 35 m (low-elevation site). Each animal was radio-tracked for at least 2 days. When possible, new locations were recorded as often as every 5 min, if the animal had moved at least 10 m from its last location.

Two nonstatistical indices of home-range size, minimum-convex polygon and home-range length are presented in Table 1. To obtain home-range length from live-trapping data only, a distance of one-trap interval was added to each end of a line connecting the most widely separated grid locations. Because of the low grid resolution for live-trapping data, this amount (two-trap intervals) was added to the actual home-range length to account for a "trap detection distance." Although the amount of this adjustment is somewhat arbitrary, it is justified empirically, as this adjusted live-trapping home-range length averaged nearly 90% of telemetry home-range length (Table 1). Minimum-convex-polygon estimates from live trapping averaged less than one-sixth the size of those from telemetry. Adjusting the minimum-convex-polygon method for trap-detection distance (as for home-range length) would be computationally difficult; rather, a simpler method is proposed and evaluated empirically. The much greater number of observations plus the finer resolution obtained from radiotelemetry results in a greater number of distinct grid locations included in an animal's home-range map, which tends to increase the minimum-convex polygon. Of course, another factor contributing to underestimation of home-range size from trapping data is that some animals' home ranges may lie substantially beyond the grid. Though there may be some bias from this problem, each animal in Table 1 had a home range mostly overlapping the trapping grid.

Although home-range length is relatively well approximated by the smaller trapping sample, the actual "shape" of the range is not, in most cases appearing thinner than the true shape thus, decreasing the minimum-convex polygon. To easily quantify shape of individual ranges from telemetry data, I calculated eccentricities (E) as:

$$E = \sqrt{\lambda_1/\lambda_2},$$

where λ_1 and λ_2 are the eigenvalues of the variance-covariance matrix of X and Y coordinates. For a circular range, $E = 1$. Only one of the animals had a nearly circular home range, the average being $E = 2.5$ (Table 1). A home-range index based on elliptical area, using the adjusted home-range length from trapping as the major axis, and HRL/E as the minor axis, where HRL is the home-range length and E is the empirical average from this telemetry study, is calculated as $\pi HRL^2/4E$. This index provides smaller estimates of home-range size than telemetry minimum-convex polygon (paired *t*-test, $P = 0.003$); nonetheless, it provides much more realistic estimates of home-range size (average 72% of telemetry minimum-convex polygons than the polygons calculated directly from trapping data (average 15% of telemetry minimum-convex polygons). By using this index, more reliable estimates of home-range size could be obtained from grid-trapping records for animals with sufficient captures (>10) to estimate individual eccentricity values, or for animals with fewer captures, by using the adjusted home-range length plus an average eccentricity value from other individuals. For purposes of comparison, I used an average eccentricity value from this study (Table 1), because I assumed that most individuals in a typical live-trapping study will have insufficient numbers of captures from which to obtain realistic estimates of eccentricity values, and so a common eccentricity value, averaged from animals with sufficient captures, must be used. Using this method to calculate home ranges of 50 chipmunks from grid-trapping produced the following estimates ($\pm SE$): *T. minimus* (2.05 ± 1.28 ha, $n = 18$), *T. quadrivittatus* (1.97 ± 1.17 ha, $n = 12$), and *T. umbrinus* (1.95 ± 0.95 ha, $n = 20$). If these are assumed to be 72% of "true" home-range size (i.e., telemetry minimum-convex

TABLE 1.—Estimates of home-range size and shape for *Tamias* from radiotelemetry and live trapping.

| Animal number ¹ | Telemetry | | | Trapping | | | | $\frac{\pi \text{HRL}^{2.5}}{4E}$ |
|----------------------------|------------------------------|-----------------------------|-----------------------|----------|--|--------------------------------------|--------------------------------------|-----------------------------------|
| | Number of grid locations (n) | Minimum-convex polygon (ha) | Home-range length (m) | n | Minimum-convex polygon ² (ha) | Home-range length ^{2,3} (m) | Home-range eccentricity ⁴ | |
| M37F | 33 | 1.38 | 174 | 8 | 0.22 (0.16) | 162 (0.93) | 1.57 | 0.82 (0.59) |
| M408M | 11 | 5.42 | 408 | 5 | 1.06 (0.20) | 384 (0.93) | 2.87 | 4.63 (0.85) |
| M411M | 19 | 2.55 | 240 | 6 | 0.73 (0.29) | 230 (0.96) | 1.66 | 1.66 (0.65) |
| M414M | 20 | 1.59 | 265 | 4 | — | — | — | — |
| Q221F | 25 | 3.57 | 343 | 7 | 0.28 (0.08) | 314 (0.92) | 1.97 | 3.10 (0.87) |
| Q405F | 67 | 7.08 | 592 | 7 | 0.87 (0.12) | 375 (0.63) | 3.79 | 4.42 (0.62) |
| U280F | 62 | 5.12 | 457 | 15 | 0.92 (0.18) | 341 (0.75) | 2.66 | 3.65 (0.71) |
| U283F (1983) | 44 | 1.87 | 262 | 6 | 0.24 (0.13) | 209 (0.80) | 3.44 | 1.37 (0.73) |
| (1984) | 53 | 1.95 | 179 | 6 | 0.20 (0.10) | 201 (1.12) | 1.15 | 1.27 (0.65) |
| U410F | 40 | 5.34 | 352 | 7 | 0.66 (0.12) | 320 (0.91) | 2.90 | 3.22 (0.60) |
| U407M | 37 | 1.95 | 264 | 7 | 0.30 (0.15) | 243 (0.92) | 3.12 | 1.86 (0.95) |
| \bar{X} | | 3.44 | 321.5 | | 0.55 | 277.9 | 2.51 | 2.60 |
| SD | | +1.97 | +126.0 | | +0.33 (0.15 + 0.06) | +78.4 (0.89 + 0.13) | | +1.38 (0.72 + 0.13) |

¹ Prefix: M = *T. minimus*, Q = *T. quadricittatus*, U = *T. umbrinus*; suffix: M = male, F = female.² Numbers in parentheses = proportion of telemetry estimates (telemetry minimum-convex polygon for last column).³ A distance of two trap intervals was added to each animal's actual home-range length.⁴ From telemetry locations.⁵ The mean eccentricity from this study, $E = 2.5$, was used.

polygon, Table 1), then they should range from 2.7 to 2.8 ha; these estimates are much larger than home ranges reported previously for the genus (Table 2), primarily because the latter consist almost exclusively of live-trapping estimates. Of these, *T. striatus* apparently has smaller home ranges than its western congeners. Only one other radiotelemetry study of chipmunks is known to me (of *T. striatus*; Hackett and Trevor-Deutsch, 1982); minimum-convex-polygon estimates averaged 1.29 ha from telemetry, 0.57 ha from trapping.

Seed resources for the eastern chipmunk in deciduous forests probably are more abundant overall and less patchily distributed than for western *Tamias* inhabiting drier coniferous forests. Chipmunks are central-place foragers (Bergstrom, 1986), returning frequently to the burrow, larder-hoarding site, or hibernaculum. In a uniform habitat, optimal central-place foragers should have circular home ranges (Andersson, 1978); the generally noncircular home ranges evident for these *Tamias* may reflect the patchy distribution of their resources. Though other studies of *Tamias* have not quantified home-range shape, the eccentricities obtained in this study are similar to those of other territorial bird and mammal species for which home-range shape has been quantified (Ford, 1983). Ford (1983) also expected an inverse relationship between home-range size and eccentricity, owing to increased demands of ranging further from the center of activity. I found no such relationship, using actual minimum-convex polygon and eccentricity values derived from telemetry (Spearman's rank correlation, one-tailed test, $P > 0.05$).

Apart from optimal foraging considerations, home-range shapes in the present study may be influenced more strongly by topography (as it affects energetic demands or the distribution of preferred habitat patches). Of the eight chipmunks which had eccentricity values of roughly 2.0 or greater, seven had home ranges with major axes aligned approximately perpendicular to the major slope. The expected relationship between

TABLE 2.—Selected *Tamias* home-range estimates (in ha) from the literature, determined by live trapping and direct observation.¹

| Study | Species (sex) | \bar{X} (Range) |
|---|-----------------------|-------------------|
| Broadbrooks (1970) | <i>T. amoenus</i> (F) | 1.01 (0.45–2.08) |
| | (M) | 1.58 (0.65–3.26) |
| | <i>T. minimus</i> (F) | 0.66 (0.22–1.51) |
| | (M) | 1.23 (0.39–3.47) |
| Sheppard (1972) | <i>T. amoenus</i> (F) | 0.57 (0.07–1.11) |
| | (M) | 1.29 (0.38–2.80) |
| Chappell (1978) | <i>T. speciosus</i> | 1.27 |
| Composite from eight studies ² | <i>T. striatus</i> | 0.36 (0.04–1.26) |

¹ Other references in Bergstrom (1986).

² Cited in Bergstrom (1986).

body size and home-range size (McNab, 1963) is not apparent in interspecific comparisons from this study (no differences among species means of minimum-convex polygons, one-way analysis of variance, $P > 0.2$), but could have been masked by the effect of increased arboreality and use of vertical space by the larger species (*T. umbrinus*, 63 g; *T. quadrivittatus*, 66 g) as compared to the smallest species (*T. minimus*, 45 g; Bergstrom, 1986).

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