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EVALUATION OF THREE INDICES FOR ESTIMATING RED SQUIRREL *TAMIASCIURUS HUDSONICUS* RELATIVE ABUNDANCE

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ABSTRACT—Three indices, bait station visitations, elicited call counts, and total squirrel counts, were used for determining red squirrel (*Tamiasciurus hudsonicus*) relative abundance. Each index was recorded three times per season (summer, fall, winter, and spring) from June 1996 to May 1997 along a 1.5 km transect at each of two sites, Falls Branch and Grassy Gap, in the Cherokee National Forest in eastern Tennessee. Response rates for bait stations and elicited call counts were considered too low to be useful in detecting seasonal or annual trends in red squirrel populations. Forty-five red squirrels were counted during total counts at Falls Branch, and 14 were counted at Grassy Gap during the study. Total counts reflected a higher density of red squirrels at Falls Branch, which was in agreement with mark-recapture data. Total counts appear to be a useful technique for estimating relative abundance of red squirrels.

Wildlife managers need reliable indices to monitor seasonal and annual trends in wildlife populations. While relative abundance indices do not provide estimates of actual population densities, they often reflect trends in population size. Such techniques frequently satisfy the needs of managers and require fewer resources than those required for absolute abundance indices such as mark-recapture studies (Caughley, 1977; Lint et al., 1995).

Caughley (1977) and Call (1986) summarized many techniques for estimating relative abundance of wildlife populations. Several methods of estimating relative abundance of arboreal herbivores have been reported, some of which have been utilized to assess trends in red squirrel (*Tamiasciurus hudsonicus*) populations (Thompson et al., 1989; Carey and Witt, 1991). However, these methods have primarily relied on snow tracking, which may not always be possible at southern latitudes. Also, Davis and Winstead (1980) noted that the relationship of an index to population size may vary regionally. While red squirrels have been the subject of numerous investigations in northern boreal forests (Kemp and Keith, 1970; Rusch and Reeder, 1978; Price et al., 1990; Larsen and Boutin, 1995; Larsen et al., 1997), studies in the southeastern portion of their range are lacking. At present, little management information is available relating to this species in the southeastern United States.

The purpose of this study was to examine three indices of relative abundance for assessing population trends of red squirrels in the southern Appalachians. Indices were compared with population density estimates from a mark-recapture study to assess their ability to accurately reflect population trends.

METHODS

The study was conducted in the Tellico Ranger District of the Cherokee National Forest in Monroe County, Tennessee, from June 1996 to May 1997. Two study sites were selected, Grassy Gap (1040 m elevation) and Falls Branch (1220 m elevation). Both sites were mature forest, predominantly eastern hemlock (*Tsuga canadensis*) and Carolina silverbell (*Halesia carolina*), with lesser proportions of oak (*Quercus* sp.) and hickory (*Carya* sp.)

Prior to initiation of this study, a mark-recapture study was conducted at both sites to estimate population density (Stevens and Kennedy, 1999). Near the completion of the study, another mark-recapture study was conducted at Falls Branch. A 50 trap (15 × 15 × 61 cm Tomahawk live trap, Tomahawk Live Trap Co., Tomahawk, Wisconsin) trapping grid was established at each site. Trapping was conducted for 14 days (not consecutively) at each site, and population density estimates were obtained using a modified Lincoln-Peterson index (Menkins and Anderson, 1988) or direct enumeration.

A 1.5 km transect was established at each site. Three relative abundance indices, bait station visitations, elicited call counts, and total squirrel counts, were measured along each transect. All indices were recorded three times each season (summer, June–August; fall, September–November; winter, December–February; spring, March–May) with a minimum of two weeks between successive sampling. Counts were conducted within three h after sunrise when squirrels were reported to be most active (Pauls, 1978). Counts were not conducted on days with rain, snow, or moderate to heavy winds, all of which have been reported to adversely affect squirrel activity (Steele, 1998). All counts were conducted by the author to minimize observer bias.

Bait stations (n = 10) were established at 150 m intervals along each transect. Stations consisted of a 25 × 36 cm plywood platform mounted 1.5–2.0 m high in a tree >30 cm in diameter. An aluminum plate was attached to the platform, and a chalk tracking surface was applied to the plate (Orloff et al., 1993). Stations were baited with raw peanuts within three hours after sunrise and checked after 24 h for presence of tracks. Peanuts were chosen as bait because smaller baits were rapidly consumed

TABLE 1. Number of red squirrels counted during total counts (counts of all squirrels seen or heard) at two sites in eastern Tennessee. Counts were conducted 3 times each season.

Site	Summer	Fall	Winter	Spring	Total
Falls Branch	10	26**	9	0	45*
Grassy Gap	5	4	3	2	14

* Differs from Grassy Gap value, $P = 0.05$.
** Differs from other Falls Branch values, $P = 0.05$.

by birds. Stations were reset if precipitation affected the tracking surface.

Elicited call counts were conducted by playing three tape-recorded red squirrel rattle (territorial) calls (Lair, 1990) at ten stations placed at 150 m intervals along the transect. All vocal responses by red squirrels were counted within a ten second interval after each call.

Total counts were counts of all squirrels seen or heard giving any call (Lair, 1990) as the transect was walked at a slow, but continuous, steady pace. Locations of squirrels along the transect and estimated distance from the transect were recorded to minimize the possibility of recording the same animal twice. Squirrels responding to elicited calls were not counted.

The nonparametric Kruskal-Wallis test was used to test for differences in mean response rates of indices among seasons. The Mann-Whitney *U*-test was used to determine differences in mean response rates of indices between sites. In all cases, significance was declared at $P < 0.05$. Statistical analyses were performed on SAS statistical software (SAS Institute, Inc., 1985).

RESULTS

Population density was estimated at 1.5 red squirrels/ha at Falls Branch and 0.1 red squirrels/ha at Grassy Gap prior to the initiation of the study. During spring 1997, near the end of the study, no red squirrels were captured during the 14 days of trapping at Falls Branch and the density was estimated at 0.0 red squirrels/ha.

During the 12 month study, 45 red squirrels were counted during total counts at Falls Branch and 14 were counted at Grassy Gap (Table 1). This difference was marginally statistically significant ($P = 0.05$). More squirrels were counted during fall than in other seasons at Falls Branch ($P = 0.05$). There was no statistical difference among seasons at Grassy Gap. During fall, there was a marginally significant difference between sites, with more squirrels counted at Falls Branch than at Grassy Gap ($P = 0.06$). However, no statistical differences between sites were detected during other seasons.

Seventy-one percent of all squirrels counted during total counts over all sites were heard calling, and 29% were observed visually. Ninety percent of all calls recorded were bark calls, and 10% were rattle calls (Lair, 1990).

Response rates for bait stations and elicited call counts were relatively low compared to total counts. During the entire study, three bait stations recorded red squirrel visits at Falls Branch, and three bait stations recorded red squirrel visits at Grassy Gap. Visitation rate was 2.5% at both sites. One elicited call count was recorded at each site, during fall at Falls Branch and during summer at Grassy Gap.

DISCUSSION

In this study, responses to elicited call counts and bait stations were too low to be useful in detecting trends in red squirrel populations. The low response by red squirrels to tape-recorded calls was surprising. Tape-recorded calls have been utilized by researchers in several studies to elicit responses from red squirrels (Price et al., 1990, Price, 1994). Price (1994) found that rattle calls were given in response to 80–95% of tape-recorded rattle calls in a western Canadian spruce (*Picea sp.*) forest when the call was played from within a squirrel's territory and in response to approximately 50% of calls played outside a squirrel's territory. Although red squirrels were often heard calling during this study, they responded to <1% of all tape-recorded calls. Red squirrel vocalizations are primarily given in territorial disputes and other aggressive situations (Smith, 1978; Lair, 1990). Layne (1954), Kemp and Keith (1970), and Rusch and Reeder (1978) found that red squirrels inhabiting primarily deciduous habitats, where spruce, fir (*Abies sp.*), or pine (*Pinus sp.*) cones could not be hoarded, did not defend exclusive territories. Non-territorial red squirrels may vocalize less than territorial squirrels and may be less inclined to respond to conspecific vocalizations. However, it is not known if red squirrels in this study were territorial. More than one squirrel was occasionally observed in the same tree with no obvious sign of aggression, but many agonistic encounters also were noted. This area of red squirrel ecology requires more research.

Visitation rates at bait stations were identical at both sites, and thus failed to reflect differences in population size between the sites at the beginning of the study as shown by mark-recapture. This rate of visitation also was probably too low to detect trends in red squirrel populations. Roughton and Sweeny (1982) theorized that scent-station visitation rates must be >40% to detect significant trends in population size. Response to bait stations may have improved significantly if stations remained active for longer than 24 h, giving squirrels a greater opportunity to find them. Also, a different bait may have been more effective than peanuts. Peanut butter and sunflower seeds proved to be an effective trap bait for red squirrels (Stevens and Kennedy, 1999), but was rapidly consumed by non-target species, especially birds, when applied to bait stations. Drennan et al. (1998) recently used a technique similar to bait stations which they found accurately determined relative abundances for Abert's squirrels (*Sciurus aberti*) and other diurnal sciurids.

Total counts were the only index found to be useful in this study. Total counts reflected the higher density of red squirrels at Falls Branch at the beginning of the study and the decline of the Falls Branch population by the end of the study. More squirrels were counted at Falls Branch than at Grassy Gap during all seasons except spring. Because the greatest number of squirrels was counted during fall, and because this was the only season where differences between sites approached statistical significance, fall is recommended for conduction of total red squirrel counts in the southern Appalachians. Annual total counts during fall may prove useful for monitoring annual trends in population size as well as for comparing differences in population size between sites. Recently, Bayne and Hobson (1997) used total counts at fixed plots to determine relative abundance of red squir-

rels at several sites in Saskatchewan and found the technique satisfactory.

The ratio of squirrels counted during total counts between the sites (3.2:1) and the ratio from the initial mark-recapture study between the sites (10.7:1) were not in agreement. However, ratios of total counts from yearly data may not be indicative of population trends, as the population at Falls Branch declined significantly by the end of the study. Trends revealed by both mark-recapture and total counts were consistent, which indicates that total counts were an accurate index of relative population size.

Total counts have several practical advantages over other methods of relative abundance estimation. They take less time to conduct than bait stations and elicited call counts. They also require no special equipment or expense other than labor. Red squirrel calls are easily identified. Also, red squirrels exhibit little fear of observers (Price and Boutin, 1992) and are thus easily spotted and counted. For these reasons, total counts are recommended as a useful method for estimating relative abundance of red squirrels in the southern Appalachians.

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