USE OF TRACK STATIONS TO INDEX ABUNDANCE OF SCIURIDS

JOSEPH E. DRENNAN, PAUL BEIER, AND NORRIS L. DODD

Department of Forestry, Northern Arizona University, P.O. Box 15018, Flagstaff, AZ 86011-5018 (JED, PB)
Arizona Game and Fish Department, 2221 West Greenway Road, Phoenix, Arizona 85023 (NLD)

We developed rainproof track stations to index sciurid abundance. Track stations were effective at detecting presence of a species and provided a useful index of abundance in two validation efforts. In the more rigorous validation, we documented the correlation of two indices of abundance (our track index and catch-per-unit-effort, CPUE) with population size of Abert's squirrels (*Sciurus aberti*) as estimated by mark-recapture methods on eight 60-ha plots in April and August 1996. The track index (number of stations visited) was correlated highly with estimated population size in both April (r = 0.983) and August (r = 0.924). CPUE, as measured by the cumulative number of squirrels captured in the first day and first 2 days of the trapping effort, performed as well (r = 0.905 in April and r = 0.945 in August) as the track index. We also examined the correlation between these two indices for chipmunks (*Tamias*), golden-mantled ground squirrels (*Spermophilus lateralis*), rock squirrels (*S. variegatus*), and Abert's squirrels by double-sampling 30 plots (2.25 ha each) for diurnal sciurids in 1994 and 1995. The track index and CPUE were correlated highly for chipmunks (r = 0.815), golden-mantled ground squirrels (r = 0.881), rock squirrels (r = 0.868), and Abert's squirrels (r = 0.926). Similarity of regression slopes suggested that the track index was valid across seasons. Both the trap index and CPUE were less powerful statistically than mark-recapture estimates in detecting differences among plots and between seasons but did detect large differences without unacceptable Type I errors. Compared to live-trapping, track stations provided results in less time, were less expensive and easier to deploy in the field, caused no mortality to animals, and eliminated exposure of technicians to diseases transmitted by rodents.

Key words: *Sciurus aberti,* Abert's squirrel, *Tamias, Spermophilus,* abundance, population estimation, sciurid, track stations

Track stations have been used in studies of small mammals to measure home ranges (Justice, 1961), record occurrence (Raphael et al., 1986), locate mammals at low density (Boonstra et al., 1992), measure gross changes in population size (Quy et al., 1993), and provide a relative index of population size (Lord et al., 1970; Thompson et al., 1988). Indices of population size are appropriate for addressing most questions regarding differences in density and are usually less expensive than direct methods of censusing (Caughley, 1977; Dice, 1941). An index that does not require handling animals also can reduce risk to the investigator associated with handling rodents infected with Hantavirus (Mills et al., 1995), mange, and other diseases. However, visits to track stations may be an unreliable index if number of visits per animal varies greatly among individuals (Smith et al., 1994), or if visitation rate varies greatly among seasons, habitats, or other factors that might differ between plots. Although some factors can be controlled (e.g., by using the index only for comparisons within a season or habitat), the index will be unreliable if there is large variation among individual animals in visitation rate within a season or habitat.

Our objectives were to describe the design, construction, and use of inexpensive, rainproof track stations to index abundance

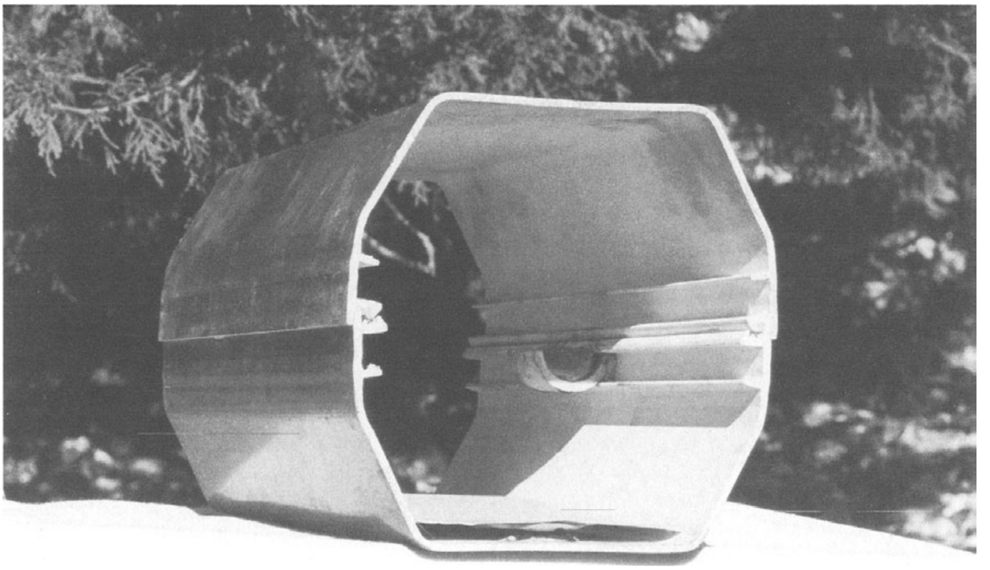

FIG. 1.—A rainproof track station (25 cm long, 12 cm high, 11 cm wide) to index abundance of sciurids.

of sciurids and compare the track-station index to both precise population estimates and an index based on catch-per-unit effort (CPUE), namely number of individuals caught in a 1–3-day trapping effort. Validations occurred during two different studies. One study indexed sciurid prey of northern goshawks (*Accipiter gentilis*) on 2.25-ha foraging sites (Beier and Drennan, 1997) and the other monitored seasonal changes in abundance of Abert's squirrels (*Sciurus aberti*) on 60-ha plots (N. L. Dodd, in litt.).

MATERIALS AND METHODS

We constructed track stations out of plastic rain gutters to form a covered tube (Fig. 1). Inside each track station, we placed an aluminum track plate. Velcro fasteners allowed the track plate to be removed for identification of tracks, simplified cleaning and preparation, and elevated the tracking surface off the base of the station so that rainwater could run off without disturbing the tracking surface. We installed a bait shelf made from a halved 2-cm diameter PVC pipe inside the station midway between each end.

We prepared track plates in the field by removing them from the housing, cleaning them with a dry cloth, and applying a mixture of blue carpenter's chalk and alcohol with a garden-type mist sprayer (Orloff et al., 1993). A ratio of one-part chalk to two-parts alcohol worked best under most ambient conditions and dried within 15 min. Thin mixtures did not cover track plates uniformly, and thick mixtures sometimes failed to record tracks of light-weight small mammals (e.g., *Peromyscus maniculatus*). Mass of diurnal sciurids that we studied caused their tracks to register adequately on track plates that were prepared with thin or thick mixtures. We inserted track plates and bait (a mixture of peanut butter and oatmeal) into the stations prior to deploying them in the field.

We made a reference collection of tracks by live trapping all target species and releasing them through a runway of six track stations placed end to end. In the first and third track station, we inserted chalked aluminum track plates; the remaining four stations contained clear contact paper with the sticky side facing up. As each animal passed through the runway, its footprints transferred chalk impressions onto the contact paper. We removed the contact paper and placed these onto unlined white sheets of notebook paper with the sticky side face down. Preserved tracks on contact paper were retained as a permanent reference.

Track index and CPUE for Abert's squirrels.—To test the validity of the track station index of abundance, we conducted two sampling efforts in pine (*Pinus*) forests surrounding Flagstaff, Arizona. We used capture-recapture techniques to estimate the number of Abert's squirrels on eight 60-ha plots on two occasions in 1996: 9–20 April and 30 July–12 August. These plots were trapped with 49-cm Tomahawk traps ($n = 144$), spaced 70 m apart in a 12- by 12-trap grid. Each plot was pre-baited with raw unshelled peanuts for a minimum of 1 day preceding trapping. Trapped Abert's squirrels were immobilized for handling using Metofane® (Pitman-Moore, Mundelein, IL) following Patton et al. (1976) and Pederson et al. (1987). Individuals of all other species were released immediately. Most smaller sciurids could escape from traps, precluding estimates of population size. Plots were trapped for ≥ 6 days; trapping continued for 12 days or until the standard error was ≤ 10% of the population estimate, whichever came first. Estimates of population size were derived using the program CAPTURE (Rexstad and Burnham, 1991; White et al., 1978). This program adjusted for effect of edge, tested for population closure and for behavioral responses of squirrels to capture, and selected the most appropriate model for each data set.

Immediately following the live trapping effort, we distributed track stations on the interior 100 stations of the trap grid. Track stations were placed on the plot by 0800 h and retrieved at ca. 1800 h on the following day. After retrieving track stations, we recorded the number of stations with Abert's squirrel tracks. We did not attempt to determine if more than one animal visited a single station. We computed the correlation coefficient between population estimates and the track-station index and with the cumulative number of squirrels captured on the first 1 or 2 days of trapping. We used analysis of covariance (ANCOVA, with the population estimate as covariate) by season to test for differences in slopes of regression lines.

We used multiple pairwise comparisons to test for differences in abundance of squirrels among the eight plots in April and August 1996. We compared patterns of abundance based on mark-recapture estimates with the patterns revealed by track index and CPUE for the first day's trapping effort. We similarly evaluated the power of both indices to statistically detect temporal changes (April–August) in estimated population size on each plot. In these analyses, differences between estimated population sizes were judged significant if there was no overlap between the 95% *CI* provided by the program CAPTURE. Differences in the track index and CPUE were evaluated relative to the null hypothesis that both samples were drawn from a binomial distribution with the expected value equal to the mean of the two observations and $n = 100$ (track stations) or 144 (CPUE).

Track index and CPUE for diurnal sciurids.—We sampled 30 plots (2.25-ha) for diurnal sciurids with both track stations and live traps. Fifteen of these plots were sampled during 24 May–10 June 1994, and 15 plots were sampled during 31 July–9 August 1995. These plots were laid out in grids of 10 by 10 with 15 m between stations. Track stations were placed on the plot by 0800 h and retrieved at ca. 1800 h on the same day. For each species, total number of stations with tracks was recorded as the track index for that species. Occasionally, stations recorded tracks of more than one species.

When retrieving track stations, we placed 100 live traps on the same grid. In 1994, we trapped for 3 days and used three different models of traps: 30-cm long Sherman live traps ($n = 20$ per plot), 38-cm Sherman live traps ($n = 50$), and 49 by 18 by 18-cm Tomahawks ($n = 30$). In 1995, we used only the large Sherman live traps ($n = 80$) and Tomahawks ($n = 20$) and trapped for 1 day following the track stations. To minimize time spent on the plot on the first day of trapping, we placed live traps (closed) out the previous evening. We opened live traps at ca. 0700 h and closed them at ca. 1700 h. We checked traps at 1200 h and after closing at 1700 h and marked, tallied, and released new captures and released recaptured animals.

For each species, we determined the correlation coefficient between number of stations with tracks and number of individuals trapped on the following day (1995), or the cumulative number of individuals captured on 1, 2, or 3 days (1994). We used analysis of covariance (ANCOVA, with

TABLE 1.—*Population estimates for Abert's squirrels (*Sciurus aberti*) on eight plots (60-ha) sampled in April and August 1996 near Flagstaff, Arizona. Population estimates were correlated with number of track stations visited in the 2 days following the trapping effort (April—*r = 0.983, P < 0.00005*; August—*r = 0.924, P < 0.00005*) and to the number of Abert's squirrels captured on the first day (April—*r = 0.915, P = 0.0014*; August—*r = 0.931, P = 0.0008*) and first 2 days (April—*r = 0.905, P < 0.002*; August—*r = 0.945, P = 0.0004*) of live trapping.*

Date and plot name	Population estimate	Standard error (% of estimate)	Number of track stations visited	Number of Abert's squirrels caught in first 1 day	2 days
April 1996					
Pumphouse	45	0.80 (2%)	62	16	30
Marshall Mesa	33	0.80 (2%)	40	10	16
Clints Well	22	4.92 (22%)	26	2	2
Fort Tuthill	18	1.44 (8%)	28	4	6
Parks	18	0.54 (3%)	20	7	11
Long Valley	15	0.85 (6%)	15	6	9
Mormon Lake	11	1.05 (9%)	7	1	4
Gash Flat	8	0.83 (10%)	8	0	1
August 1996					
Pumphouse	58	1.58 (3%)	76	34	38
Marshall Mesa	40	2.02 (5%)	51	13	23
Clints Well	22	2.76 (13%)	23	6	10
Fort Tuthill	41	3.34 (8%)	35	25	33
Parks	29	0.59 (2%)	51	15	22
Long Valley	13	0.84 (6%)	10	2	3
Mormon Lake	16	0.73 (5%)	6	10	13
Gash Flat	15	1.24 (8%)	10	1	2

CPUE as covariate) by season-species combination to test for differences in slopes of regression lines among species or seasons. All *P*-values are for two-tailed tests.

RESULTS

Track stations were lightweight, inexpensive, rainproof, and caused no mortality for study animals. One hundred track stations weighed 35 kg compared to 45 kg for 100 38-cm Sherman live traps and 116 kg for 100 49-cm Tomahawks. Cost of materials was $1.41 per station, excluding the cost of carpenter's chalk, isopropyl alcohol, and bait materials. Track plates were protected adequately from rain by the gutter tubes. Six days of mild rain during the sampling period did not disturb the tracking surface in any of the track stations to the point that tracks could not be identified. Mortality in the track stations (6,200 track-station days) was zero. Mortality in live traps (25,872 traps days) was 35 out of 1,410 captures, or ca. 2.5% of total captures, despite midday trap checks.

Track index and CPUE index for Abert's squirrels.—In April 1996, we recorded 428 captures of Abert's squirrels, including 161 different squirrels (74 females, 83 males, 4 unknown) during 10,368 trap days on eight plots. Five plots were trapped for 8 days, and one each for 9, 11, and 12 days. In August 1996, we recorded 587 captures, including 232 different squirrels (103 females, 126 males, and 3 unknown) during 9,504 trap days on the same eight plots. Two plots were trapped for 6 days, two for 7 days, and one each for 8, 9, 11, and 12 days.

Program CAPTURE estimated that population size of Abert's squirrels on the eight plots ranged from 8 to 45 squirrels per plot in April (Table 1). Seven plots met the target level of precision (*SE* averaging 6% of the estimate); the eighth plot had a *SE* of

22% of the estimate after 12 days of trapping. The track index (number of stations visited by Abert's squirrels in 2 days) was correlated highly with the population estimate (Table 1). CPUE, as measured by the number of animals caught in the first 1 or 2 days of trapping, also was correlated highly with the population estimate (Table 1).

In August, population estimates ranged from 13 to 58 squirrels per plot (Table 1). Once again, seven plots had acceptable levels of *SE* (averaging 5%), and the eighth plot had a *SE* of 12.5% after 12 days. Both the track index and CPUE were correlated highly with population estimates (Table 1).

As expected given their high correlations with numbers of animals, the two indices also were correlated highly with each other in both April ($r = 0.896$, $P < 0.001$) and August ($r = 0.821$, $P = 0.012$). Regression lines did not differ in slope between April and August for both the track index (Fig. 2; ANCOVA, $F = 1.45$, $d.f. = 1, 13$, $P = 0.25$) and CPUE (Fig. 2; $F = 2.08$, $d.f. = 1, 13$, $P = 0.17$).

Mark-recapture estimates revealed that numbers of squirrels differed significantly among the eight plots and six of the eight plots showed significant increases between April and August (Table 2). The track index and CPUE were about as powerful as mark-recapture estimates in detecting differences among plots but considerably less powerful than mark-recapture estimates in detecting differences between seasons (Table 2). The two indices were about equally powerful when compared to each other.

Type I errors are more serious than loss of power. There were two discrepancies between mark-recapture estimates and indices over rank order of the eight plots (both in August, one for each index), and additional cases (four for each index) in which indices suggested differences between plots not evident in mark-recapture estimates (Table 2). If mark-recapture estimates were accurate, these were Type I errors. Thus for each index, there were five discrepancies out of the

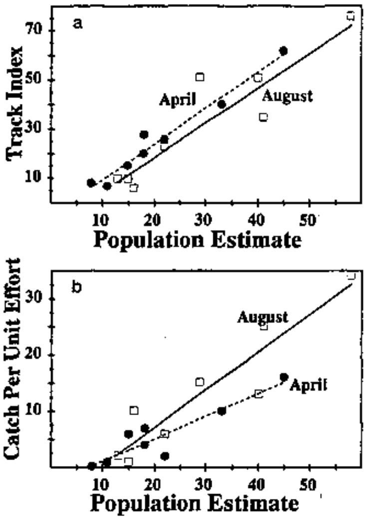

FIG. 2.—a) Relationship between number of track stations visited by Abert's squirrels (*Sciurus aberti*) in 2 days and estimated population size of Abert's squirrels (based on a 6- to 12-day mark-recapture effort) on 60-ha plots (n = eight per line) in northern Arizona during April 1996 (dashed line, circles) and August 1996 (solid line, squares). There were no differences between slopes. b) Relationship between number of Abert's squirrels caught in the first day of the trapping effort and estimated population size on the same plots; slopes did not differ.

64 contrasts between pairs of plots which suggested that inferences based on indices may have had Type I error rates approaching 8%.

Track index and CPUE for diurnal sciurids.—In 1994 and 1995, six species of small mammals were recorded in track stations and caught in live traps: golden-mantled ground squirrels (*Spermophilus lateralis*), rock squirrels (*S. variegatus*), grey-neck chipmunk (*Tamias cinereicollis*), cliff chipmunks (*T. dorsalis*), Abert's squirrel, and red squirrels (*Tamiasciurus hudsonicus*). Golden-mantled ground squirrels were the most frequently recorded species in both track stations (59% of stations with tracks) and live traps (60% of trapped individuals), followed by chipmunks (30% of tracks, 35% of live captures). Abert's and rock squirrels accounted for < 10% of sta-

TABLE 2.—*Differences in numbers of Abert's squirrels (*Sciurus aberti*) on eight plots in northern Arizona during April and August 1996 and differences between months within plots. Statistical significance of differences was assessed by mark–recapture estimates (M–R), the track index (Tracks), and catch-per-unit-effort (CPUE) on the first day of trapping.*

	Differences among plots in April numbers[a]			Differences among plots in August numbers[a]			Significance of change from April to August		
Plot name	M–R[b]	Tracks[c]	CPUE[c]	M–R[b]	Tracks[c]	CPUE[c]	M–R[bd]	Tracks[c]	CPUE[c]
Pumphouse	A	A	A	A	A	A	*	0.02	0.002
Fort Tuthill	C	C	B	B	C	AB	*	0.20	0.00001
Marshall	B	B	AB	B	B	CD	*	0.07	0.41
Parks	C	CD	B	C	B	BC	*	0.0005	0.04
Clints Well	BCD	C	BC	D	D	DE	>0.05	0.53	0.10
Mormon Lake	D	E	C	DE	E	CD	*	0.71	0.002
Gash Flat	D	E	C	DE	E	F	*	0.52	0.23
Long Valley	CD	DE	B	E	E	EF	>0.05	0.20	0.10

[a] Estimates with the same letter do not differ at $P < 0.05$. For each method, the eight plots are rank-ordered by letter, with A indicating highest abundance.

[b] Differences between estimated population sizes were judged significant if there was no overlap between the 95% *CI* provided by program CAPTURE.

[c] Two-tailed *t*-test of the null hypothesis that both samples were drawn from the same binomial distribution with expected value equal to the mean of the two samples.

[d] No exact test possible; * indicates $P < 0.05$.

tions with tracks and live captures. Red squirrels were tracked and trapped on only one plot in 1994 and none in 1995.

For each species, number of stations with tracks was correlated highly with the number of animals caught ($r = 0.662$–0.955, Table 3). Slopes did not differ among six regressions involving four species and two time periods (ANCOVA, $F = 0.87$, $d.f. = 5, 83$, $P = 0.51$). Track stations recorded presence of a species on seven plots where live trapping on the following day did not.

TABLE 3.—*Correlation coefficients (*r*) between number of track stations visited and cumulative number of individuals live trapped on the following days (1–3 days in June 1994; 1 day in August 1995) near Flagstaff, Arizona. Fifteen plots (2.25-ha each) were doubled-sampled each year. Except as noted, all* r*-values were significant at* P < 0.0007*, and slopes did not differ among the six single-year regression lines.*

		r between track stations and			Number of plots	
Species	Year	1 day of trapping	2 days of trapping	3 days of trapping	With tracks but no captures on the following day	With captures but no tracks on the previous day
Tamias	1994	0.889	0.938	0.955	3	1
	1995	0.776			1	0
	both	0.815			4	1
Spermophilus lateralis	1994	0.839	0.754[a]	0.662[b]	1	1
	1995	0.840			0	0
	both	0.881			1	1
Spermophilus variegatus	1994	0.868	0.868	0.856	1	0
Sciurus aberti	1995	0.926			1	0

[a] $P = 0.001$.

[b] $P = 0.007$.

Conversely, on two plots, a species was detected by live trapping but not detected by track stations.

DISCUSSION

In both April and August 1996, the track index and CPUE were correlated highly with mark-recapture estimates of abundance of Abert's squirrels. Patterns of abundance across the eight plots in April and August 1996 were generally similar regardless of whether inferences were made with mark-recapture estimates, track index, or CPUE (Table 2). Differences among the three methods generally reflected lower power of the indices compared to mark-recapture estimates. The track index and CPUE also were less sensitive than mark-recapture estimates in assessing differences in abundance of squirrels between seasons (Table 2). Given budget constraints and lower costs of the track index, a researcher might find this acceptable, especially if loss of power can be offset by increasing numbers of plots or track stations per plot. If budget constraints force a choice between CPUE and the track index, the track index would be favored on the basis of lower cost and similar power.

In addition to lower power, the track index and CPUE may have actual rates of Type I errors larger than the "acceptable" 5%. This conclusion, however, depends on the absolute "correctness" of inferences based on mark-recapture estimates. Given biases in estimates produced by program CAPTURE (Pollock et al., 1990), some of the observed discrepancies between methods in our experiment were probably due to false inferences from mark-recapture estimators. The true rate of Type I errors probably lies between 5% and 8% for our data. Overall, we believe that the track index and CPUE provide reliable indices of abundance, although they are substantially less powerful than mark-recapture estimators.

The most probable reason that track counts and CPUE were correlated with each other was because both were correlated highly with numbers of Abert's squirrels in 1996. This is supported by correlations between index values and population estimates, which were higher (r = 0.905–0.983) than correlations between the two indices (r = 0.821–0.896). The two indices of abundance also were correlated highly for all sciurid species sampled in 1994 and 1995. We therefore believe that both the track index and CPUE are valid for within-species comparisons for chipmunks, golden-mantled ground squirrels, rock squirrels, and Abert's squirrels, despite the lack of conclusive data for species other than Abert's squirrels.

We sampled in different months and years because we expected that the relationship between track counts and live captures might vary seasonally and perhaps also with year. Because slopes of the regressions were similar across all time periods and indices detected changes over time in Abert's squirrels (albeit with less power than mark-recapture estimators), we concluded that track counts were a reliable index of seasonal change within a species. Although the similarity among slopes of the regression lines across species suggested that these indices also might allow inference about differences in abundance between species, we do not feel this is justified by our limited study.

Compared to mark-recapture efforts, track stations were less expensive, less labor-intensive, easier to deploy in the field, and safer for the animals studied. For example, in April 1996, an average of 15 person-days were needed to estimate population size of one species on each plot using capture-recapture trapping. In contrast, track stations yielded indices for four species in one person-day. Track stations caused no mortality for study animals and therefore may be appropriate for studies of sensitive populations or for the prey base of a sensitive species.

On seven plots, we detected species that were not detected on the following day by live traps. On only two plots, we captured a species that we had not recorded in track stations on the previous day (Table 3). Thus, track stations were more effective at detecting presence of species than live traps. We believe that animals may be less wary of track stations because the tubular design allows them to see through stations.

One of the primary reasons that we developed track stations was to reduce risk of exposure to diseases transmitted by rodents. Known Hantaviruses have been found in the urine, droppings, and saliva of some rodents. Because the virus may be rendered harmless after a few minutes of contact with sunlight, track stations posed little risk, whereas live traps require direct handling of individual rodents. Current guidelines for working in potentially infected areas include wearing protective clothing and a respirator (Center for Disease Control and Prevention, 1993; Mills et al., 1995). Cost of this equipment and discomfort and inconvenience of wearing it in the field further favor use of track stations when appropriate.

Acknowledgments

We thank D. Boughter, S. Wood, D. Martinez, K. Bostwick, M. Zimmerman, C. O'Brian, B. Jones, C. Austin, D. Russell, A. Freeman, and N. Csaszar for field work on the goshawk plots, and individuals from the Arizona Game and Fish Department, the Coconino National Forest, and the Student Chapter of The Wildlife Society at Northern Arizona University for work on the Abert's squirrel plots. The United States Forest Service Rocky Mountain Station provided mammal traps. The work on Abert's squirrels was funded by the Federal Aid in Wildlife Restoration Act. We are especially indebted to S. Orloff, whose suggestions led to the design of the track stations.

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Submitted 9 January 1996. Accepted 19 May 1997.

Associate Editor was Edward J. Heske.