CHANGES IN TRACKING TUBE USE BY SMALL MAMMALS OVER TIME

VILIS O. NAMS* AND ELIZABETH A. GILLIS
Department of Environmental Sciences, Nova Scotia Agricultural College, Box 550, Truro, Nova Scotia, B2N 5E3, Canada

Tracking tubes offer an efficient alternative to live-trapping for studies that require very large sample sizes. However, it is necessary to know how small mammals change in their tendency to enter tracking tubes with time. We measured this change in response in a region of boreal forest in northern Nova Scotia, Canada, in 1994–1998. Over 4 weeks, small mammals increased in their tendency to enter tubes, with no difference in response among species. Thus, when designing studies using tracking tubes, one needs to adjust for differences in duration—one cannot simply calculate a tracks/tube-night measure. We show how to statistically remove the effect of duration.

Key words: footprints, mice, population indices, shrews, small mammals, technique, tracking tubes, tracking tunnels, voles

In the last decade, mammalogists have become interested in studying how mammals use space at different spatial scales (e.g., Hanley and Barnard 1999; Jorgensen and Demarais 1999; Powell 1994; Stapp 1997). These studies require many samples over large areas. Furthermore, because population densities change with time, the sampling should be done in a short period of time. The prime limitation is thus lack of efficiency. For example, Jorgensen and Demarais (1999), in a study of habitat selection of small rodents at 2 spatial scales, used 48 trapping grids of 90 traps each for a total of 4,320 trap sites! This is difficult to do with traditional time and labor-intensive capture-recapture methods, where it can take several days to tend 200 live traps. Density indices, being much easier and faster to use (but less accurate), can allow studies that are not possible with live trapping.

One such useful density index uses animal tracks or footprints recorded on paper placed inside tubes or tunnels (Glennon et al. 2002; King and Edgar 1977; Merriam 1990; van Apeldoorn et al. 1993). The proportion of tubes with animal tracks (the “track index”), or the number of tracks per tube, can then be calculated. A key advantage of tracking tubes is that they do not need to be checked daily (Mabee 1998).

The sampling period must be chosen carefully, however, because both sensitivity and precision vary with the proportion of tubes with tracks. Sampling periods should be neither too short nor too long. A shorter sampling period generally gives a lower track index, which increases the sensitivity of the index to changes in the underlying population. For example, if over an x-day sampling period 10% of the tubes have tracks, and subsequently the underlying population doubles, then the track index almost doubles. However, if 90% of the tubes have tracks, then the track index can only increase minimally (Fig. 1, Appendix I). On the other hand, a longer sampling period generally gives more tubes with tracks, which increases the relative precision. For example, with 100 tubes, if 10% of the tubes have tracks, then the SE is almost 30% of the mean, but
if 90% of the tubes have tracks, then the SE is only 4% of the mean (Fig. 1). Ideally, a sampling period should provide an intermediate proportion to balance precision and sensitivity.

It is difficult to choose an ideal sampling period because animal densities vary with habitat, time, and other factors. One possibility is to increase the duration of the sampling period when animal densities are low, to increase precision, and decrease the duration of the sampling period when densities are high to increase sensitivity to detecting underlying population changes. To make these adjustments it is necessary to know how animals respond to tracking tubes with time, so that the track index can be adjusted to take into account the sampling period.

Animals can respond in several ways to tracking tubes through time: response can decrease because they find no reward in using the tubes; response can increase because of initial wariness of a new item appearing in their home range; or response might not change with time (constant catch per unit effort). The latter assumption is made when adjusting for sampling period by calculating the numbers of tracks per tube night (or when snap trapping, by calculating the numbers of animals per trap night). This assumption has not been previously tested. The purpose of our study was to describe improvements we made on the technique of trapping tubes, to present results of tests of the assumption of a constant catch per unit effort per time, and to show how to use this information to standardize density indices.

**Materials and Methods**

**Tracking tubes.**—The basic technique involves using some type of tube or tunnel containing paper and a substance to mark the footprints. We refined the techniques first described by Merriam (1990) for use with small mammals. We used the same diameter (3.75 cm) plastic tubes, but to minimize wetting of the paper from rain, we modified the tubes by extending the length to 35 cm and cutting slits 3 cm from the end, just under half-way through the tube (Fig. 2a). Water entering the modified tubes thus runs along the bottom and out of the slit before going onto the paper. With these tubes, papers usually
remain dry if the tubes are placed on a level surface. We placed a strip of white recycled photocoppy paper (28 × 7 cm) inside each tube. In the center of the paper, we attached a 6 × 6-cm square of waxed butcher paper with a smear of powdered carbon black and oil on it.

We tested various ratios of carbon black to vegetable corn oil, linseed oil, and mineral oil. We chose a 1:2.5 weight ratio of carbon black to heavy mineral oil, applied to all but the very edges of the waxed side of the butcher paper. We attached the butcher paper using a glue stick instead of staples to prevent the oil from soaking through the staple holes. We applied a liberal amount of the mixture (determined by testing with domestic lab mice) and waited one day after putting the mixture on the paper before running the mice over it. We found it best to store the tubes horizontally so that the mixture does not run off. The mixture tends to dry out, so we replaced the paper after 1–2 weeks in the field (depending on temperature and humidity). To carry prepared papers in the field, we devised tracking-paper holders (Fig. 2b). Each holder holds two pieces of tracking paper placed back-to-back, and easily can be made with corrugated cardboard and a glue gun.

**Sampling Design.**—We placed 39 sets of tubes in different forested habitats at various times during the spring and summer, over three years of study in an area of boreal forest in northern Nova Scotia, Canada. Tube placement and spatial setup were determined by the needs of other research; however, sets were placed at least several km apart and thus we treated each set as an independent replicate. Different sites were chosen for each set of tubes, even from one year to the next. We sampled from June to August, setting 2–6 sets per month, using 77 and 121 tubes per set in 1994 and 1996, and 80 tubes per set in 1998. We checked each set several times over 4-week periods, using different time intervals for each set; the time of each check was set to be the midpoint of the sampling interval. At each check we noted the presence or absence of tracks of each type of small mammal and replaced those paper strips that had tracks.

**Analysis.**—We grouped the species into 4 main categories: small shrews (Sorex palustris, S. cinereus, S. hoyi, S. arcticus, S. fumeus), short-tailed shrew (Blarina brevicauda), mice (Peromyscus maniculatus and P. leucopus), and voles (Clethrionomys gapperi, with some Microtus pennsylvanicus). We could identify footprints of Blarina brevicauda, Clethrionomys gapperi, Microtus pennsylvanicus, Peromyscus, and Sorex. We could not differentiate between P. maniculatus and P. leucopus, but previous live-trapping showed that P. leucopus is rare in our area, and so the “mice” group mostly represented P. maniculatus. We combined C. gapperi and M. pennsylvanicus because M. pennsylvanicus was also rare. We currently have no way to differentiate among footprints of the 5 Sorex species.

Our null hypothesis was that for each set, the likelihood that small mammals entered traps remained constant over the 4-week sampling period. Because the length of each sampling period varied, we standardized the track index. It is incorrect to divide the proportion of tubes with tracks by the number of days because some animals might visit the same tracking tube repeatedly. We derived an estimate for the proportion of tubes entered during one day (p<sub>t</sub>) of sampling (Appendix II):

\[ p_t = 1 - (1 - p_0)^{1/t} \]  

(1)

where p<sub>t</sub> represents the proportion of tubes that contained tracks over time t.

Because effects of various factors on population densities are more likely to be multiplicative than additive, we log-transformed p<sub>t</sub> estimates before further analysis, allowing us to use additive parametric models. This transformation also resulted in residuals that were normally distributed with homogenous variances.

Our aim was to measure the change in animals’ responses to tracking tubes through time. However, changes in log(p<sub>t</sub>) through time also could be affected by fluctuations in animal densities throughout the season, and thus we removed these seasonal effects as follows. We first isolated the effects of changes in animal densities by analyzing mean log(p<sub>t</sub>) over each replicate (i.e., combining the various time periods). A preliminary analysis showed that populations of each species responded differently over time, and thus we conducted this analysis for each species.

We fitted a linear model of log(p<sub>t</sub>) versus Year (a categorical measure) and time of year (Date: a continuous measure of time throughout 1 year), with interactive and 2nd-degree higher-order terms. Variables for this model were selected...
TABLE 1.—Analysis of long-term changes in track indices by species with time, from northern Nova Scotia, Canada, during the summers of 1994, 1996, and 1998. A manual stepwise regression was carried out, removing nonsignificant terms.

| Species | Effect | d.f. | F    | P-level |
|---------|--------|------|------|---------|
| Sorex   | Date\(^a\) | 1    | 8.20 | 0.006   |
|         | Date\(^b\) | 1    | 4.06 | 0.051   |
|         | Year\(^b\) | 2    | 1.58 | 0.22    |
|         | Year × Date | 2    | 1.01 | 0.37    |
|         | Year × Date\(^b\) | 2    | 0.78 | 0.47    |
| Voles   | Year | 2    | 1.81 | 0.18    |
|         | Date | 1    | 2.11 | 0.16    |
|         | Year × Date | 2    | 8.22 | 0.001   |
|         | Year × Date | 1    | 0.02 | 0.87    |
|         | Year × Date\(^b\) | 2    | 1.16 | 0.33    |
| Mice    | Year | 2    | 10.6 | 0.001   |
|         | Date | 1    | 1.99 | 0.17    |
|         | Date\(^b\) | 1    | 2.18 | 0.15    |
|         | Year × Date | 2    | 0.66 | 0.52    |
|         | Year × Date\(^b\) | 2    | 0.66 | 0.52    |
| Blarina | Year | 2    | 3.54 | 0.040   |
|         | Date | 1    | 4.24 | 0.047   |
|         | Year × Date | 2    | 5.93 | 0.006   |
|         | Year × Date\(^b\) | 1    | 0.03 | 0.86    |
|         | Year × Date\(^b\) | 2    | 0.52 | 0.60    |

\(^a\) Date represents a continuous measure of time throughout 1 year.
\(^b\) Year represents a categorical measure of year.

if they were significant at \(P < 0.05\), or if a higher-order interaction was significant—for example, if the interaction of Year × Date was significant, then Year × Date, Year, and Date were all included. This model was fitted for data among replicates. We then used the model to estimate predicted log\((p_1)\) values within each replicate. These predicted values represented the variation in log\((p_1)\) due only to changes in animal density throughout the year, and deviations of the observed values from the predicted values represented log\((p_1)\) with the effects of changes in animal density removed. These deviations were used in the final analyses.

The deviations were used to test the null hypothesis that, for each set of tubes, the likelihood that animals entered tracking tubes remained constant over the 4-week sampling period. Testing for a curvilinear response was done by including a Time\(^2\) term in the analysis. Terms for species and replicates also were included, as were interactions of all of these. Note that the sampling design has various Time values within each replicate, and 4 species at each Time; thus the individual values could not be treated simply as independent estimates, and a mixed-model form of a general linear model was used to ensure that the appropriate error terms were used for each test.

**RESULTS**

*Sorex* track indices increased throughout the summer (Table 1), with the increase leveling off (Date\(^2\), \(P = 0.051\)), but there were no differences (\(P = 0.22\)) among the 3 years of the study. Track indices for voles and *Blarina* increased linearly throughout each summer, and the increase differed among years (Year × Date, voles: \(P = 0.001\), *Blarina*: \(P = 0.006\)). Mice track indices differed among years (Year, \(P = \ldots\)
TABLE 2.—Analysis of changes in track indices \[\log(p_1)\], for all species, within sets of tubes. Data were gathered from northern Nova Scotia, Canada, during the summers of 1994, 1996, and 1998. The long-term effects of population increases through time were removed from \[\log(p_1)\] before this analysis. A manual stepwise regression was carried out, removing the nonsignificant terms.

| Effect               | df. | \(f\) | P-level |
|----------------------|-----|-------|---------|
| Included in model    |     |       |         |
| Time                 | 1   | 18.3  | 0.001   |
| Species\(^b\)       | 3   | 10.5  | 0.001   |
| Replicate\(^c\)     | 38  | 3.54  | 0.001   |
| Species \times Replicate | 114 | 3.77  | 0.001   |
| Not included in model|     |       |         |
| Time\(^2\)          | 1   | 0.01  | 0.90    |
| Species \times Time  | 3   | 0.91  | 0.43    |
| Species \times Time\(^2\) | 3   | 0.93  | 0.43    |

\(^a\) Time represents time throughout the sampling period of 1 set.
\(^b\) Species represents the 4 species groupings: small shrews (Sorex palustris, S. cinereus, S. hoyi, S. arcticus, S. fumeus), the short-tailed shrew (Blarina brevicauda), mice (Peromyscus maniculatus and P. leucopus), and voles (Clethrionomys gapperi and Microtus pennsylvanicus).
\(^c\) Replicate represents differences among sets of tubes.

0.001), with no significant changes within a year. These relationships were used to remove the effects of time of year from our measure of track index.

Small mammals increased in their propensity to enter tubes with time (Table 2, \(P < 0.001\)) and this response did not level off over the 4-week period (Time\(^2\), \(P = 0.90\), Fig. 3). They were about 1.5 times as likely to enter the tubes after 4 weeks than at the start of each set. Although species differed in their overall track indices among sets of tubes (Species \times Replicate, \(P < 0.001\)), they did not differ in their response to tubes over time (Species \times Time, \(P = 0.43\)).

**DISCUSSION**

We have shown that small mammals become more likely to enter tracking tubes over time. Perhaps this happens because the animals were initially wary and avoided the tubes—individual *Microtus townsendii* tend to avoid the odor of newly set out live traps (Boonstra and Krebs 1976).

Tracking tubes should not be set for different time intervals and then standardized simply by calculating tracks per tube night. Ignoring the effects of time and assuming equal capture rates would bias tracking indices by 50% over a period of 4 weeks (Fig. 3). We offer 5 alternatives.

First, adjust for the effect of time, as we have done in our analysis. The tracking tubes need to be examined more than once during each sampling period. This procedure only has to be done often enough to calculate a time adjustment factor. We found that all species groupings responded similarly to the tubes with time, meaning...
that a separate adjustment does not need to be calculated for each species.

Second, run all the tracking tubes for the same time intervals, as is done for density indices for many small mammals, such as snap-trapping (e.g., Redpath et al. 1995). This procedure is most useful when there are no large differences in mammal density.

Third, vary the sampling period, but only by a few days. The change in animals’ response was significant only over several weeks—for example, over 4 weeks, animals increase in their likelihood to enter tracking tubes by about 50%, whereas over 1 day, animals increase in their likelihood to enter tracking tubes by about 5% (Fig. 3).

Fourth, only compare tubes that have the same time interval. For example, one of us (VON) is studying the relationship between habitat use and spatial scale. Each tracking tube setup contains pairs of tubes set different distances apart. The analyses compare the relationship between the tubes of each pair (that are set out for the same time interval) and are not affected by differences among pairs (which can be set out for different time intervals).

Fifth, “prebait” the tracking tubes. When live-trapping, biologists often leave baited traps open for a period of time before using them (Boonstra and Krebs 1976) to allow animals time to familiarize themselves with the traps. Similarly, one could set tubes out for a period of time before putting new papers in them for data collection. Prebaiting should be done for long enough to allow the response of small mammals to level off. Our experiments show that this happens at longer than 4 weeks, and thus more work is needed to determine at which time interval the response levels off.

With an adjustment for the effects of sampling period, tracking tubes can be a useful technique for studying spatial aspects of small mammal distribution patterns. One person can potentially sample several thousand data points at a time. The sampling period for each set can be varied to produce intermediate values of track counts, ensuring high precision and sensitivity.

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Appendix i

Sensitivity of track index

Suppose with n animals in the population, proportion p of the tracking tubes have tracks. It is of interest to know how p changes when animal density changes.
At \( n \) animals, \( q = 1 - p \) of the tubes did not contain tracks. When there are \( K \) times as many animals, then \((1 - p)^K\) of the tubes will not contain tracks. Therefore if \( n \) increases to \( nK \), then \( p \) will increase to \( p_K \), where

\[
p_K = 1 - q^{1/K}
\]  

(2)

As a proportion of the initial value, \( p \) will increase by:

\[
\frac{p_K - p}{p} = q - q^K
\]

(3)

We can standardize this by the increase in \( n \)—i.e., by dividing by \( K-1 \) (for example, the population increases by 50\% when \( K = 1.5 \)), and combining it with equation (3), to get an estimate of the sensitivity of the proportion of tracks to changes in underlying animal population:

\[
\text{Sensitivity} = \frac{p_K - p}{p(K - 1)} = \frac{q - q^K}{p(K - 1)}
\]

(4)

This also measures accuracy of the change in \( p \) as an estimator of change in population density—if \( p \) changes proportionally the same amount as does the population, then this measure should be 1.

**Appendix II**

**Standardization of track index for 1 night of sampling**

The following gives a derivation for and estimate of the proportion of tubes entered during 1 day of sampling. If animals enter tubes randomly, then over \( t \) number of days, the proportion of tubes entered by animals is given by

\[
p_t = 1 - (1 - p_t)^t
\]

(5)

with \( p_t \) being the probability of a tube being entered in one night. We estimate \( p_t \) by:

\[
p_t = \frac{m}{M}
\]

(6)

where \( m \) is the number of tubes with tracks, and \( M \) is the total number of tubes. The number of tubes with tracks is distributed binomially, with

\[
P(m | M, p_t) = \binom{M}{m} p_t^m (1 - p_t)^{M - m}
\]

(7)

We calculate the likelihood function \( L \) for \( p_t \) by substituting equation (5) into (7). To calculate the likelihood estimate, we take the partial derivative of \( \ln(L) \) with respect to \( p_t \), and simplify, getting:

\[
\frac{\partial \ln(L)}{\partial p_t} = \frac{m + M[(1 - p_t)^t - 1]}{[(1 - p_t)^t - 1](1 - p_t)^{M - m}}
\]

(8)

We maximize it by letting it equal 0 and solving for \( p_t \), getting

\[
p_t = 1 - \left( \frac{M - m}{M} \right)^{1/t}
\]

(9)

Finally, combining equations (9) and (6) we get that

\[
p_t = 1 - (1 - p_t)^{1/t}
\]

(10)