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SECTION I:

ESTIMATING THE SNOW TRACK INDEX FOR AMERICAN MARTEN ON THE SAN JUAN NATIONAL FOREST, COLORADO

BACKGROUND

From 31 December through 22 March, 2005, 18 transects were sampled for American marten tracks on 3 ranger districts of the San Juan National Forest in southern Colorado. Ten transects were sampled on the Columbine Ranger District, 3 on the Dolores Ranger District, and 5 on the Pagosa Ranger District. Transects are the sampling units in this sampling design, and American marten tracks crossing or within 5 meters from transects are the elements measured in the design. Transects were stratified into 2 strata according to suitability of marten habitat. Randy Ghormley, USFS Enterprise Biologist stationed on the Rio Grande National Forest, summarized marten habitat availability on the San Juan National Forest and found that 88% of marten habitat is suitable and 12% marginal. Paul Morey, wildlife biologist on the Dolores Ranger District provided an evaluation of habitat around each transect by placing a 50-m buffer around each transect and using the R2 Vegetation GIS coverage to determine vegetation and structure classes within each buffer. The analysis conducted by Paul Morey showed that of the 18 transects, 2 (11%) were in marginal habitat and 16 (89%) were in suitable habitat, proportional to the availability of marten habitat strata on the forest.

ESTIMATING THE ABUNDANCE OF MARTEN WITH THE SNOW TRACK INDEX

Transects ranged in length from approximately 6 to 24 km ($\bar{x}$ = 13 km) or equivalently, 4 to 15 miles ($\bar{x}$ = 8 miles; Figure 1). Marten crossings were tallied for each 0.4 km (0.25 miles) segment of transect and summed across the length of each transect. Abundance of marten was calculated by dividing the sum of track crossings by the total length (km) of each transect. My statistical notation largely follows that of Schaeffer et al. (1996).

The estimator for the population mean (μ) for a stratified random sample is:

$$\overline{y_{st}} = \frac{1}{N}\sum_{i=1}^{L} N_i \bar{y}_i \qquad (1)$$

Where, $\overline{y_{st}}$ = mean estimator for a stratified random sample, N = number of sampling units, L = total number of strata, and, $\bar{y}_i$ = mean for stratum i computed as a simple random sample:

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

In the sampling protocol, tracks are only included in the data set when they cross the sampling unit or approach within 5 meters of the road prism on which observers travel (Ghormley 2005). Each transect is linear and the search area around each transect is ill-defined, varying from 5 meters to the exact point where tracks cross each transect, with observers making an effort to not count tracks that re-cross the transect; thus, transects, or sampling units are one-dimensional and results <u>cannot</u> be applied in a density context. The direct consequence of one-dimensional sampling units are that the an infinite number of sampling units exist on the landscape, hence obviating knowledge of *N*, or the total number of sampling units.

To compute a mean under these circumstances I modified the stratified random sampling estimator for one-dimensional sampling units. The area (*A*) of each stratum is incorporated in each estimator. This type of analysis is aided by computation of areas of each stratum in a GIS:

$$\overline{y_{st}} = \sum_{i=1}^{L} \frac{A_i}{A} \bar{y}_i \qquad (2)$$

Alternatively, if the proportionate area of each stratum is known, then that proportionate area can be included as a weight (w) for each stratum (*i*) in the computation of a mean:

$$\overline{y_{st}} = \sum_{i=1}^{L} w_i \bar{y}_i \qquad (3)$$

The variance estimator for $\bar{y}_{st}$ is:

$$\hat{V}(\bar{y}_{st}) = \frac{1}{N^2} \sum_{i=1}^{L} N_i^2 \left(\frac{N_i - n_i}{N_i} \right) \left(\frac{s_i^2}{n_i} \right) \qquad (4)$$

Where, n_i = number of sampling units in stratum *i*, and s_i^2 = sample variance for stratum *i* computed as a simple random sample

Because $\left(\frac{N_i - n_i}{N_i} \right) \geq 0.95$ for each stratum, I removed the finite population correction $\left(\frac{N_i - n_i}{N_i} \right)$ and *N* to compute the variance as follows:

$$\hat{V}(\bar{y}_{st}) = \sum_{i=1}^{L} w_i^2 \left(\frac{s_i^2}{n_i} \right) \qquad (5)$$

Standard errors (SE) are computed by taking the square root of the variance estimator above and confidence intervals are computed as $\overline{y_{st}} \pm t_{\alpha/2,\, n-1} \times$ SE.

$$SE(\overline{y}_{st}) = \sqrt{\sum_{i=1}^{L} w_i^2 \left(\frac{s_i^2}{n_i} \right)} \quad (6)$$

RESULTS AND DISCUSSION

According to the simple random sample estimator, $\bar{x}$ ± SE American marten tracks/km were 1.3 ± 1.1 for the marginal stratum, and 1.0 ± 0.3 for the suitable stratum. American Marten tracks/km based on the weighted stratified random estimator for one-dimensional sampling units was 1.1 ± 0.3 (95% CI = 0.5–1.6; Figure 2). *Please see Excel spreadsheet for calculations* (American Marten – Snow Track Index for SJNF.xls).

Because there were only 2 sampling units in marginal habitat, it would be advisable to increase the number of transects in an effort to reduce variation in estimates for this stratum. Increasing samples in 1 stratum will thus result in a need to proportionally increase the number of samples in the second stratum. Power analysis based on a set sample size provides an understanding of the number of transects needed to detect trends in American marten abundance with the snow track index (see Section II).

SECTION II:

EVALUATING THE OPTIMAL LENGTH OF SNOW TRACK TRANSECTS AND POWER ANALYSIS TO DETERMINE AN ADEQUATE NUMBER OF TRANSECTS TO MONITOR TO DETECT DECLINE IN AMERICAN MARTEN ON THE SAN JUAN NATIONAL FOREST, COLORADO

BACKGROUND

In addition to providing a revised index for American marten snow tracks, Randy Ghormley asked me to: (1) Assess the optimal length of a transect based on the existing data. I define "optimal length" as transects that are long enough to eliminate the bias of zero counts while achieving high precision, as assessed with the coefficient of variation (CV) in marten tracks; and (2) Conduct a power analysis based on the existing data to estimate the sample size needed to detect a trend based on the criteria in the protocol. In the San Juan National Forest marten protocol, the use of a snow track index is intended to provide at least 80% power to detect a 10% annual decline in marten tracks over 5 years with a 20% chance of Type I Errors ($\alpha = 0.20$; Ghormley 2005). Results from these analyses are to improve monitoring in the future.

METHODS

To more concisely organize the methods I used in this evaluation, I have listed them in bullet format. The first section details methodology used to evaluate the optimal length of transects, while the second section describes the methods used to evaluate sample size and power.

Evaluating Optimal Length of Snow Track Transects

- I defined optimal length of transects as the minimum number of miles of transect necessary to provide relatively unbiased and precise estimates of the snow track index for American marten. Bias was assessed through the proportion of times a zero index was computed and precision through the CV for 1,000 bootstrapped index estimates of American marten tracks per mile

- I pooled groups of 4 continuous 0.25-mile segments within each transect to sum to 1 mile, and deleted segments from 0.25 to 0.75 miles at the end of transects. I evaluated data only from suitable transects. Each segment was an independent observation because total counts for each segment were not related to counts from other segments

- To better understand the distribution of the data I summed the total number of 1-mile segments across all transects. I removed those 1-mile segments where the tally of marten tracks was 0 to avoid under representing larger values. I then computed the mean and standard deviation (SD) for the remaining 75 transect segments with non-zero data, and removed all values >3 SDs from the mean. I selected this cutoff value because for data that are distributed normally, 3 SDs around a mean contain 99.7% of the data (Fowler et el. 1998). The mean number of marten tracks per mile segment was 2.8 and the SD was 2.2. Three SDs above the mean index yielded a value of 9.4, thus I removed all transects of at least 9 tracks per mile. Hayward et al. (2002) followed this procedure in Russia where high numbers of track counts indicated individual Amur tigers (*Panthera tigris altaica*) had repeatedly crossed survey routes, weaving on and off the path

- To represent counts encountered on the San Juan National Forest, I used all transect segments, including those with 0 counts in bootstrapping. This sample included 122, 1-mile long transect segments representing all 16 transects in suitable habitat. I conducted 1,000 bootstrap iterations with SAS (2001) for subsamples of size 5, 10, 12, 15, and 20 to produce a new sampling distribution from the original data. The new sampling distribution was equivalent to transects 5, 10, 12, 15, 20 miles in length. I then calculated means for each 1,000 samples within each transect length category. From these means I computed SDs, CV's, and proportion of means consisting of zero counts

- I created box plots to evaluate the distribution of bootstrapped means and SDs. I plotted the mean index estimates with SDs to assess change in estimates and precision for each transect segment size. I plotted CVs for each transect length and tabulated the change in CV with each increasing segment length to provide a way to assess improvement in the marten track index with successively longer transects

Sample Size and Power

- I used Program Monitor (Gibbs 1995) to evaluate power to detect trend over time. I selected a 5-year trend analysis period because that is the period of interest outlined in the San Juan National Forest monitoring plan (Ghormley 2005). I also evaluated power based on a 10-year period, because the farther apart first and last sampling periods are, the more likely it is that trends in counts can be detected (Gibbs 1995)

- To compute power, I selected the 16 transects monitored during the winter of 2004–2005 in the suitable stratum. I only considered transects in the suitable stratum because they comprised 89% of all transects. Because Program Monitor requires non-zero data to compute power, I provided a value of 0.001 for 3 transects that did not have an index value. From these 16 transects I computed the snow track index for American marten per kilometer, which is equivalent to a mean index

- Program Monitor requires entry of SDs of mean counts from each transect to incorporate temporal variation within transects. Because each transect was only visited once during the 2004–2005 winter, I had no measure of SD and thus computed SDs as 5%, 10%, and 25% levels of the mean track index. For example the 10% SD was computed as mean index × 1.10. To incorporate spatial variation, I entered a standard value for SD of 0.10

- Power was evaluated in 10,000 iterations and based on an exponential decline. I selected the exponential model because I assumed that decline in each successive observation would be proportional to the magnitude of the current population level (Thompson et al. 1998). For the exponential model, Program Monitor generates lognormal sample counts for each survey occasion (i.e., each year of monitoring) that are log-transformed prior to the regression analysis (Gibbs 1995). Lastly, I tabulated power results according to number of years of monitoring and temporal variation level (SD of the mean track index)

RESULTS AND DISCUSSION

Evaluating Optimal Length of Snow Track Transects

Only 1 out of 1,000 bootstrapped samples for transects of 5 mile length were zero, indicating that transects of at least 5 miles in length ensure high accuracy and detectability of marten. In comparison, the 3 transects in the suitable strata with zero counts were 4.0, 6.2, and 7.2 miles in length, and ranked second, fifth, and sixth shortest, respectively, in transect length. These results indicate that short transects are most likely to yield zero counts of marten tracks.

Boxplots of bootstrapped means and SDs for each length of transect show a predictable improvement in precision as length of transects increases (Figure 3). The mean snow track index per mile was about 1.5 for bootstrapped samples of all lengths (Figure 4). The highest improvement in the CV for the mean track index occurred as transects increased from 5 to 10 miles in length (Table 1; Figure 5). The CV of the mean marten index decreased approximately 50% from transects of 5 miles in length to those of 20 miles in length.

Sample Size and Power

Power to detect a 10% decline in the American marten snow track index ranged from 0.622 to 0.653 for a 5-year monitoring effort and from 0.843 to 0.993 for a 10-year monitoring effort (Table 2). The intent of monitoring abundance of American marten on the San Juan National Forest with a snow track index is to provide at least 80% power to detect a 10% annual decline in marten tracks over 5 years (Ghormley 2005). Power of 80% or higher to detect a decline was only achieved for monitoring over 10 years, and then only primarily for a 10% decline (Table 2). Monitoring over a longer period of time such as 10 years is an option that should be considered because the farther apart first and last sampling periods are, the more likely it is that trends in counts can be detected (Gibbs 1995). However, monitoring over a 5-year period may better meet forest planning needs. Several steps can be followed to increase power to detect a 10% annual decline over 5 years (see Recommendations).

RECOMMENDATIONS

Power to detect an annual decrease of 10% over 5 years was not adequate based on the data collected during winter 2004–2005. Approaches to increase power include avoiding recording tracks from animals that weave back and forth across snow transects, monitoring over a longer time period, adding more transects, and increasing the length of some transects to reduce variation in track counts over time. My specific recommendations to increase power are:

- Train observers to avoid counting multiple tracks from individual martens that weave back and forth across the transect path. Counts of multiple tracks from the same animals cause bias in estimates and inflate variation

- Estimate variation after 2 or preferably 3 years of data collection within (temporal variation) and among (spatial variation) transects. Enter the SDs obtained by longer term monitoring in Program Monitor to counter the use of constrained levels of SD I used based on only 1 year of monitoring. More realistic estimates of temporal and spatial variation should provide a better analysis of power

- Increase the length of all transects to at least 10 miles to reduce variation in track counts and to avoid 0 counts. Currently, only 4 of 18 transects exceed 10 miles in length. Transects exceeding 10 miles could be truncated to 10 miles to reduce costs, but it is appropriate to maintain transects exceeding 10 miles if this is not logistically feasible

- Add at least 5 transects to the suitable stratum and 1 additional transect to the marginal stratum to reduce bias and improve precision

- Consider evaluating trend in 10 years. Power analysis for a decline of 10% in the marten index indicated that the present number of transects should provide adequate power to detect a trend in 10 years. Levels of temporal and spatial variation remain unclear, and these should be incorporated in the future to reassess power. However, monitoring over a 5-year period may better meet forest planning needs, so improving estimates will help in obtaining sufficient power to monitor a decline in marten snow tracks over 5 years

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Table 1. Coefficient of variation (CV), improvement (%), or the percentage difference in CV between each transect length category, and change in CV per mile (%) between each transect length category of mean American marten snow track index, San Juan National Forest, winter 2004–2005.

Transect length (mile)	CV	Improvement	Change per mile
5	52.0	--	--
10	38.9	25.2	5.0
12	35.7	8.2	4.1
15	31.4	12.2	4.1
20	26.6	15.2	3.0

Table 2. Power to detect 10%, 5%, and 3% decline in trend of the mean index of American marten tracks per mile across 5 and 10 years. Power analysis based on 16 snow transects sampled in suitable habitat on the San Juan National Forest in winter 2004–2005. The power analysis was one-tailed at alpha = 0.20, and included a trend variation (SD = 0.10) parameter to represent spatial variation, which considered the degree to which a given trend varies at random among the 16 transects. To represent temporal variation in marten counts for each transect, SDs of the mean were computed as 5%, 10%, and 25% of the mean index. Power analysis was conducted with Program Monitor (Gibbs 1995).

	Standard Deviation of the Mean Index		
Decline in trend	5%	10%	25%
5 years			
–0.10	0.653	0.649	0.622
–0.05	0.413	0.402	0.383
–0.03	0.312	0.313	0.298
10 years			
–0.10	0.993	0.861	0.843
–0.05	0.860	0.480	0.467
–0.03	0.643	0.293	0.278

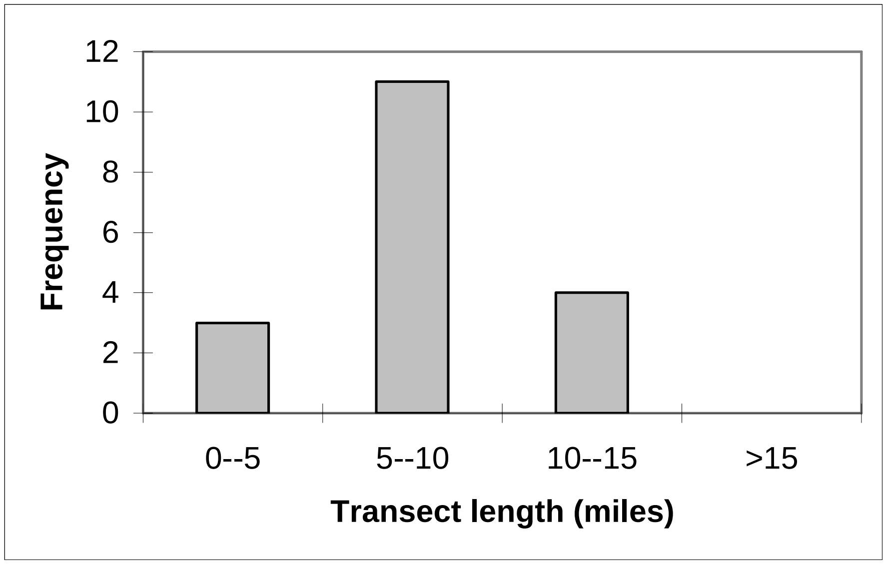

Figure 1. Frequency histogram displaying the distribution of transect lengths (miles) used to monitor American marten with a snow track index, San Juan National Forest, Colorado, winter 2004–2005.

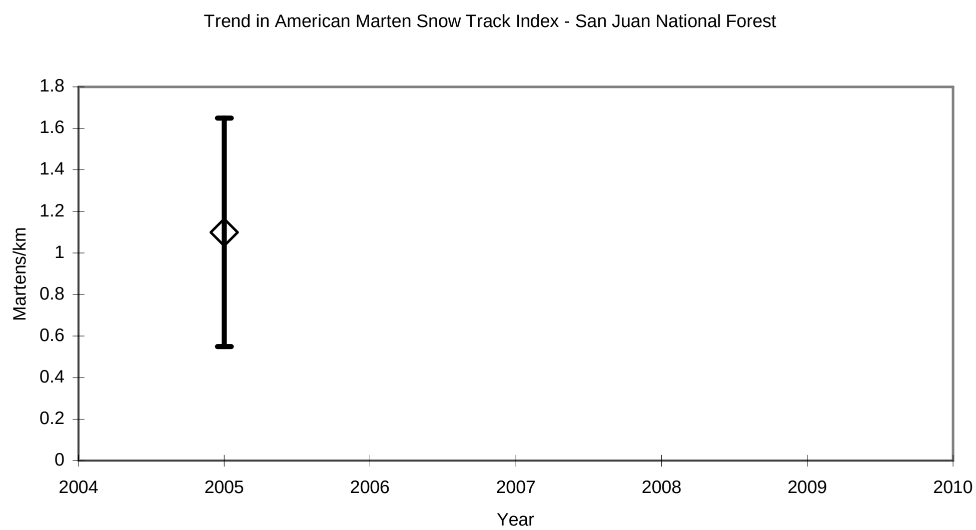

Figure 2. American marten tracks per kilometer ± 95% confidence interval, San Juan National Forest, Colorado, winter 2004–2005. This is an example of a plot that could be used to plot the annual mean index with its associated confidence intervals to depict changes over time.

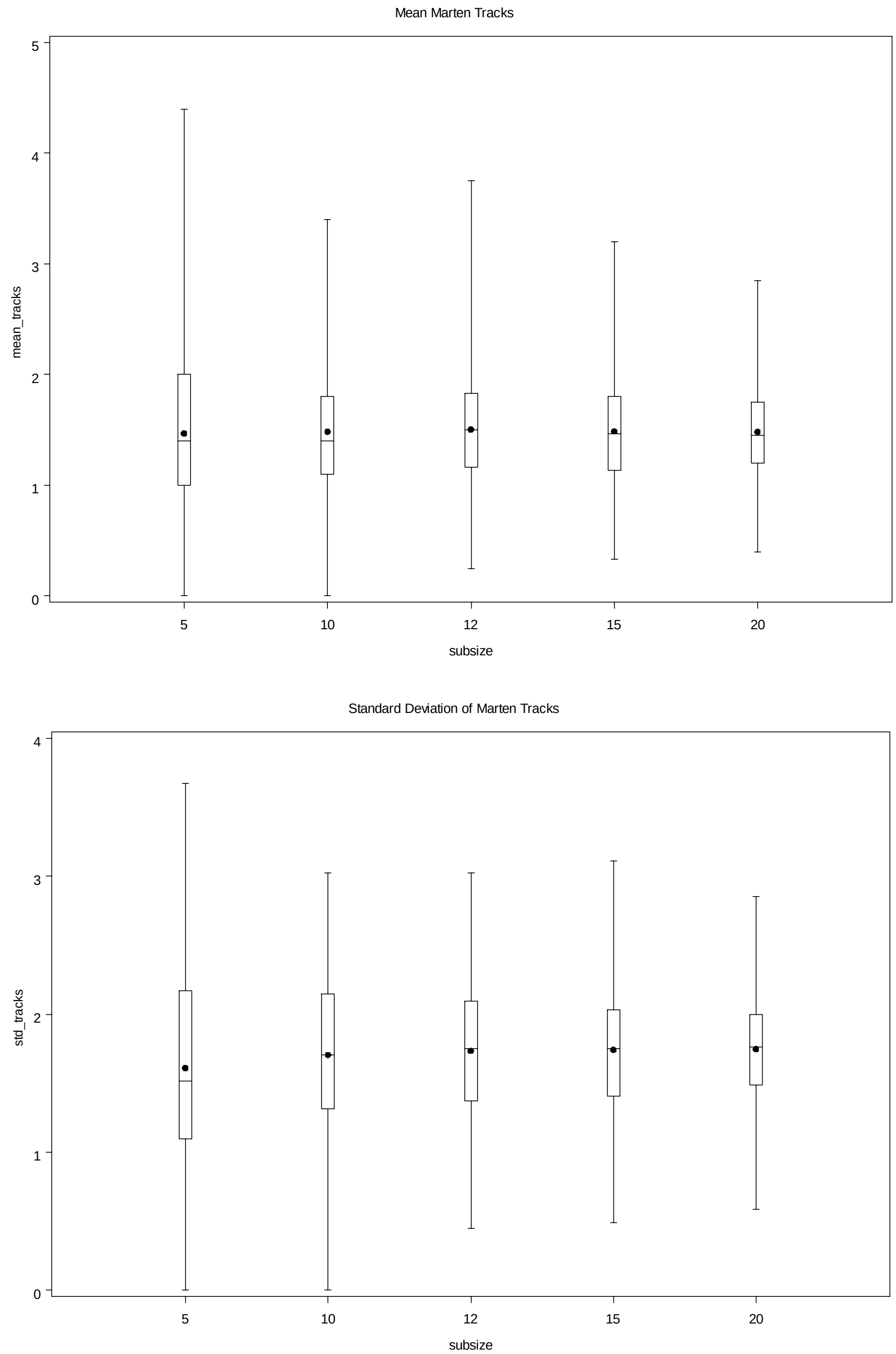

Figure 3. Box plots of means (upper) and standard deviations (lower) of an index representing American marten tracks per mile for subsamples of 5, 10, 12, 15, and 20 mile transects from 1,000 bootstrapped samples. Bootstrapping sampled with replacement from 122, 1-mile segments pooled from transects sampled on the San Juan National Forest, winter 2004–2005.

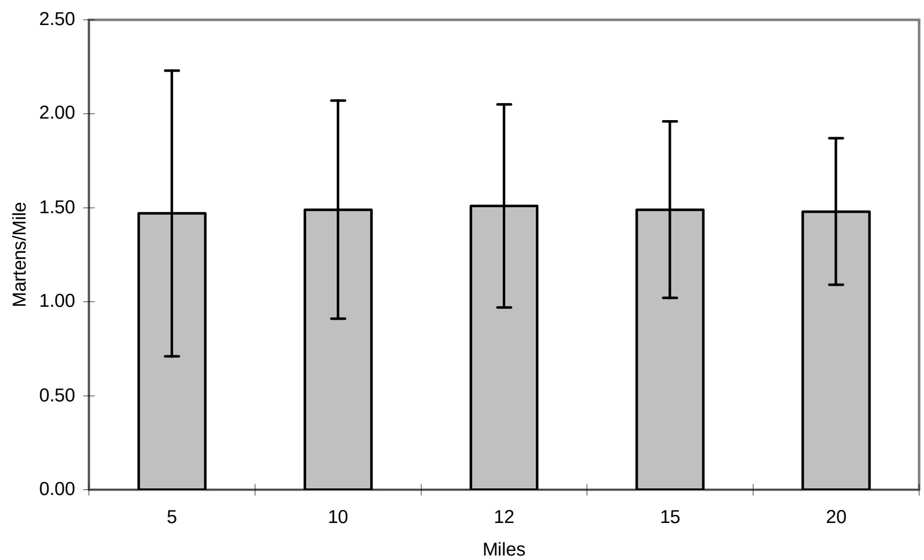

Figure 4. Mean ± SD American marten index from 1,000 bootstrapped subsamples of 5, 10, 12, 15, and 20 mile transects. Bootstrapping sampled with replacement from 122, 1-mile segments pooled from transects sampled on the San Juan National Forest, winter 2004–2005.

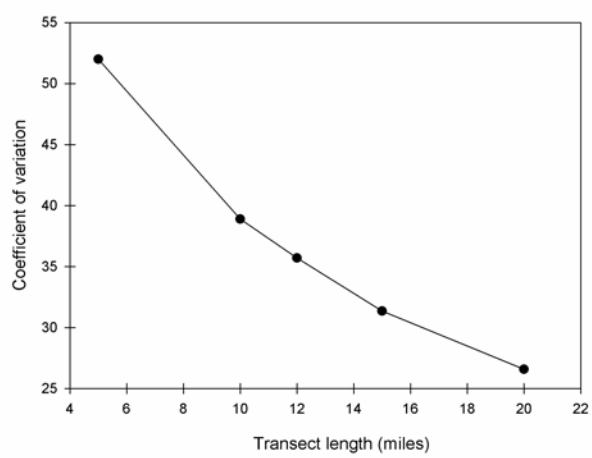

Figure 5. Coefficient of variation in mean counts of American marten snow track index from subsamples of 5, 10, 12, 15, and 20 miles derived through bootstrapped samples of 1,000 iterations, San Juan National Forest, winter 2004–2005.