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Snowshoe Hare Pellet Density Plots:

An Evaluation of Sample Size, Subsampling, and Power to Monitor Trends in Snowshoe Hare on the Medicine Bow National Forest, Wyoming

Introduction

Sampling designs involve substantial costs in time and funds to obtain data necessary to accurately (unbiased and precise) estimate population parameters. Two fundamental issues related to sampling include the number of total samples to collect and the number of subsamples collected at each sampling location. Limiting the number of subsamples collected when it is determined that additional subsamples do not improve estimates can improve sampling efficiency. In general, increasing the number of sampling units should be emphasized over increasing the number of subsamples when site estimates are relatively precise. Increasing the number of sites will yield more accurate estimates and improve power.

As part of its revised Forest Plan, the Medicine Bow National Forest (MBNF) has selected the snowshoe hare (*Lepus americanus*) as a management indicator species. A common index used to monitor abundance of hares involves counting fecal pellets in fixed plots to obtain a pellet/plot index (Krebs et al. 2001). This index will be used to monitor trend in snowshoe hare abundance over on the MBNF as part of Forest Plan monitoring. Melissa Miller, Routt National Forest (RNF), began the monitoring effort on the MBNF in summer 2004 when she counted hare pellets on 46 sites in the Snowy Range and 34 on the Sierra Madres. Experience from this effort and Melissa's hare sampling on the Routt National Forest provide insights into the logistics and the sampling efficiency of monitoring using pellet counts. Joe Doerr, White River National Forest (WRNF), provided an additional data set of pellet counts from 19 sites collected in lodgepole pine (*Pinus contorta*) in summer 2004 on the WRNF (Doerr 2004). The WRNF sites consisted of 20 subsamples per site.

My objectives in this review were 2-fold: (1) evaluate subsample size necessary to provide relatively unbiased (through proportion of 0 mean counts) and precise (through the coefficient of variation [CV] of mean counts) estimates of snowshoe hare pellet counts at sample sites, and (2) evaluate how many sites need to be sampled to provide good estimates in the array of forest types available. Recommendations from this analysis are intended to aid the MBNF in developing a monitoring protocol to monitor changes in trend of snowshoe hare on the forest.

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 subsample size, while the second section describes the methods used to evaluate sample size and power.

Subsample evaluation

- In 2004, Joe Doerr established 20, 15" × 20' (300 in^2) rectangular plots at 19 sites in lodgepole pine (primarily mature stands) on 5 ranger districts (Aspen-Soris, Blanco, Dillon, Eagle, and Holy Cross) of the WRNF. The first sampling year included pellet counts above and below forest duff. Following initial counts, duff and pellets are cleared to aid counting in subsequent years (Miller 2005). I assume that counts in the first year are relative to high or low densities of hares and should be correlated with counts in following years.

- I removed the highest mean count, because it was 3.5-times greater than the second highest mean count, largely influencing results. For the remaining 18 sites I tabulated the mean, CV, and proportion of each count consisting of zeros.

- I then created a box plot of mean hare pellet counts to locate the lower quartile (25% percentile), median (50% percentile), and upper quartile of mean snowshoe hare pellet counts. From this box plot and a summary of means and CV for each site I was able to evaluate the distribution of these data to determine sites with low, medium, and high counts of snowshoe hare pellets.

- After determining the quartiles and median I identified the sites most closely representing these three values. I then selected one site nearest the quartiles and median with the lowest CV and proportion of zero counts to control precision and accuracy of the sample data included in bootstrapping.

- I conducted 1,000 bootstrap iterations with SAS (2001) for subsamples of size 3, 5, 10, 15, and 20 to produce a new sampling distribution from the original data. I then calculated means for each 1,000 samples within a subsample size category. From these means I computed a standard deviation (SD) of the mean count, CV's, and proportion of means consisting of zero counts. Box plots were created to evaluate the distribution of bootstrapped means and SDs.

Sample size and power evaluation

- I used program Monitor (Gibbs 1995) to evaluate power to detect trend over time. I selected a 10-year trend analysis period because recent evidence indicates snowshoe hare in the southern boreal forest may cycle with a 7-year period between peaks (Malloy 2000). An additional reason to monitor trend at 10-year versus shorter intervals is because the farther apart first and last sampling periods are, the more likely it is that trends in counts can be detected (Gibbs 1995).

- Sample sizes considered in power analyses were 15 and 18. The sample size of 18 included all lodgepole pine sites, while the sample size of 15 was derived by randomly removing 3 sites.

- To evaluate the effect of subsample size and sample size on power, I used subsample sizes of 5, 10, and 20 in concert with sample sizes of 15 and 18. Means and SD's for subsamples of size 5 and 10 were derived through 1,000 bootstrapped iterations for each of the 18 sites. The SD for each bootstrapped sample was computed as the square root of (∑sample variances/1,000). Means and SD's for subsamples of size 20 were obtained from a summary of the raw data (i.e., average and SD of 20 plots per site).

- To evaluate the influence of trend on power analysis I included trend variation (SD = 0.10), which considered the degree to which a given trend varies at random among the 15 or 18 monitoring sites. The power analysis was one-tailed with a Type I error rate set at alpha = 0.20.

- I compared mean pellet counts from the RNF in aspen (*Populus tremuloides*), lodgepole pine, and spruce-fir cover types (Miller 2005) to delineate strata based on very low, low, moderate, and high mean hare pellet counts. Miller's (2005) work indicates that in the southern boreal forest, spruce-fir cover types tend to have highest hare pellet counts, with larger lodgepole pine having moderate mean pellet counts and aspen having lower mean pellet counts than the coniferous cover types. Pellet counts in small (2.54–12.69 cm dbh) spruce-fir tend to have very low counts, and pellet counts in small lodgepole pine tend to be higher than in aspen, but lower than in larger lodgepole pine.

- Pat Dolan provided me with a summary of available forest cover types on the MBNF. Based on the information for pellet counts on the RNF, I delineated 4 sampling strata for the MBNF. Strata are (1) medium aspen (12.7–22.85 cm) (2) small lodgepole pine, (3) medium, large (22.86–40.63 cm), and very large (>40.64 cm) lodgepole pine, and (4) medium, large, and very large spruce-fir.

- Results from the power analysis were used to determine what subsampling size and sample size would yield the highest probability to detect a decrease of 10% in hare pellet counts over a 10-year period.

Results

Subsample evaluation

- I selected the Mitchell Creek site on the Holy Cross Ranger District for the upper quartile; the Swan Mountain site on the Dillon Ranger District as the median; and, the Frey Gulch site on the Dillon Ranger District as the lower quartile.
- As expected, proportion of mean zero counts decreased with increasing subsample size (Figure 1). At a subsample size of 3, there were only 1 and 9 zero mean counts out of

1,000 bootstrapped samples in upper quartile and median sites, respectively. Mean zero counts for the lower quartile at a subsample size of 3 was 42 out of 100 (Figure 1).

- Coefficients of variation in mean counts decreased with increasing subsample size (Figure 2). The steepest declines occurred as subsample sizes increased in the lower quartile (Table 1, Figure 2). Successive improvement in reducing CV's was maximized at 10 subsamples, especially in the upper quartile, because improvements dramatically tapered off following a subsample size of 10 (Table 1).

- Distribution of means and SDs, visualized through the size of the inter-quartile range (i.e., range = 25–75%) was approximately stabilized at 10 subsamples, while the average of each mean and SD distribution (dots on box plots) were nearly equal for each level of subsampling for subsamples of 3, 5, 10, 15, and 20 iterated through 1,000 bootstraps (Figures 3, 4, and 5).

- Outliers in the distribution of each bootstrapped data set, visualized through whiskers on box plots, increased as pellet counts from which bootstraps were drawn decreased (Figures 3, 4, and 5).

- Proportion of mean zero counts for all 18 sites indicates that subsamples of size 5 and 10 rapidly increase in sites with decreasing pellets/plot (Figure 6).

- Power to detect a 10% decline in trend was about 84% for subsamples of size 5, 10, and 20 when power was evaluated for 15 sites over 5 years, and only increased about 5% when 3 additional sites were monitored over 10 years (Table 2).

- Medium, large, and very large lodgepole pine dominated the available snowshoe hare habitat on the MBNF, followed by spruce-fir, small lodgepole pine, and medium aspen (Table 3).

Discussion and Recommendations

Subsampling did not appreciably reduce bias or improve precision when subsample size was greater than 10. Sampling at least 15 sites in mature lodgepole pine sites with 5, 10, or 20 subsamples per cover type provides assurance that 10% declines in hare abundance can be detected with a high degree of power, or the probability of detecting a true significant difference (10% decline) in hare abundance. Stratification assists in reducing variation, yielding more precise estimates. In this case, stratification is based on 4 cover types and a final estimate of hare pellet densities will include summing the variation in each stratum, providing a reduction in the size of standard errors.

I recommend that biologists subsample no less than 10 plots in very low- and low-density sites and 5 plots in sites predicted to have moderate-to-high hare pellet densities. It may be a good idea to increase subsamples to 15 in aspen and small lodgepole pine and to 10 in moderate, large, and very large lodgepole pine and spruce fir if the time to collect data at additional plots is less efficient than moving to additional sites to collect samples. Biologists should keep in mind that in areas where hare abundance is expected to be low (e.g., aspen sites) that subsampling 15 or 20 plots will reduce within site variation and zero counts. However, as was seen with an increase of 3 plots (18 versus 15), increasing the number of sites sampled should improve estimates more than increasing the number of subsamples per site. I provide recommendations for allocation of 45 sampling sites or sampling units among the 4 strata (Table 3). Number of recommended sampling sites is greater for areas with a larger proportion of the total area (e.g., medium, large, and very large lodgepole pine and spruce-fir). This should ensure sampling from the range of variability in hare pellet counts inherent in a larger landscape. Following the results of our analysis, I recommend higher subsampling in areas with lower hare abundance, and lower subsampling in areas with higher hare abundance. An additional benefit of Melissa Miller's work on the MBNF is that 80 potential sampling sites were established in 2004. I would encourage the MBNF to consider the feasibility of using at least a portion of these sampling sites to evaluate trend in abundance of hare with pellet plot counts.

Literature Cited

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Malloy, J. C. 2000. Snowshoe hare, *Lepus americanus*, fecal pellet fluctuations in western Montana. Canadian Field-Naturalist 114:409–412.

Miller, M. A. 2005. Snowshoe hare habitat relationships in successional stages of spruce-fir, lodgepole pine, and aspen cover types in Northwest Colorado. Masters Thesis (*in preparation*), Colorado State University, Fort Collins, Colorado, USA.

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Table 1. Successive improvement (% difference between previous coefficient of variation [CV]) in CV's of mean snowshoe hare pellet density relative to an increase in subsample size, White River National Forest, 2004.

	Representative stand		
Subsample	Lower quartile[a]	Median[b]	Upper quartile[c]
3	--	--	--
5	23.3	20.30	10.2
10	26.8	13.75	8.6
15	10.2	6.15	3.4
20	6.8	5.93	3.1

[a]Data are from the Frey Gulch site on the Dillon Ranger District.

[b]Data are from the Swan Mountain site on the Dillon Ranger District.

[c]Data are from the Mitchell Creek stand on the Holy Cross Ranger District.

Table 2. Power to detect a 10% decrease in mean snowshoe hare pellet counts in 10 years with 5, 10, or 20 subsamples per monitoring site. Power analysis based on 15 or 18 monitoring sites sampled in lodgepole pine on the White River National Forest in 2004. The power analysis was one-tailed at alpha = 0.20, and included a trend variation (SD = 0.10), which considered the degree to which a given trend varies at random among the 15 or 18 monitoring sites.

	Subsample size[a]		
	5	10	20
15 sites			
-0.10	0.841	0.847	0.837
-0.05	0.470	0.469	0.466
0.00	0.241	0.237	0.243
18 sites			
-0.10	0.878	0.875	0.879
-0.05	0.490	0.504	0.486
0.00	0.256	0.250	0.251

[a]Means and SDs included in power analyses for subsample sizes of 5 and 10 represent bootstrapped subsamples, whereas, means and SDs from samples of size 20 are from raw data.

Table 3. Summary of cover type and size categories placed in strata, Medicine Bow National Forest, Wyoming. Recommendations are based on 45 sampling sites allocated among the 4 strata.

Cover type	Code	Tree[a] size class	Acres available	% total acres	Proportional allocation to sites	Recommendations	
						Number of sites	Subsamples per/site
Aspen	TAA	M	39979	6	3	5	10
Lodgepole Pine	TLP	S	44708	7	3	10	10
Lodgepole Pine	TLP	M, L, V	398355	61	28	15	5
Spruce fir	TSF	M, L, V	165016	25	11	15	5
Total			648058	100	45	45	

[a]Tree size classes at diameter breast height (dbh) are S, small (2.54–12.69 cm); M, medium (12.7–22.85 cm); L, large (22.86–40.63 cm); and V, very large (>40.64 cm).

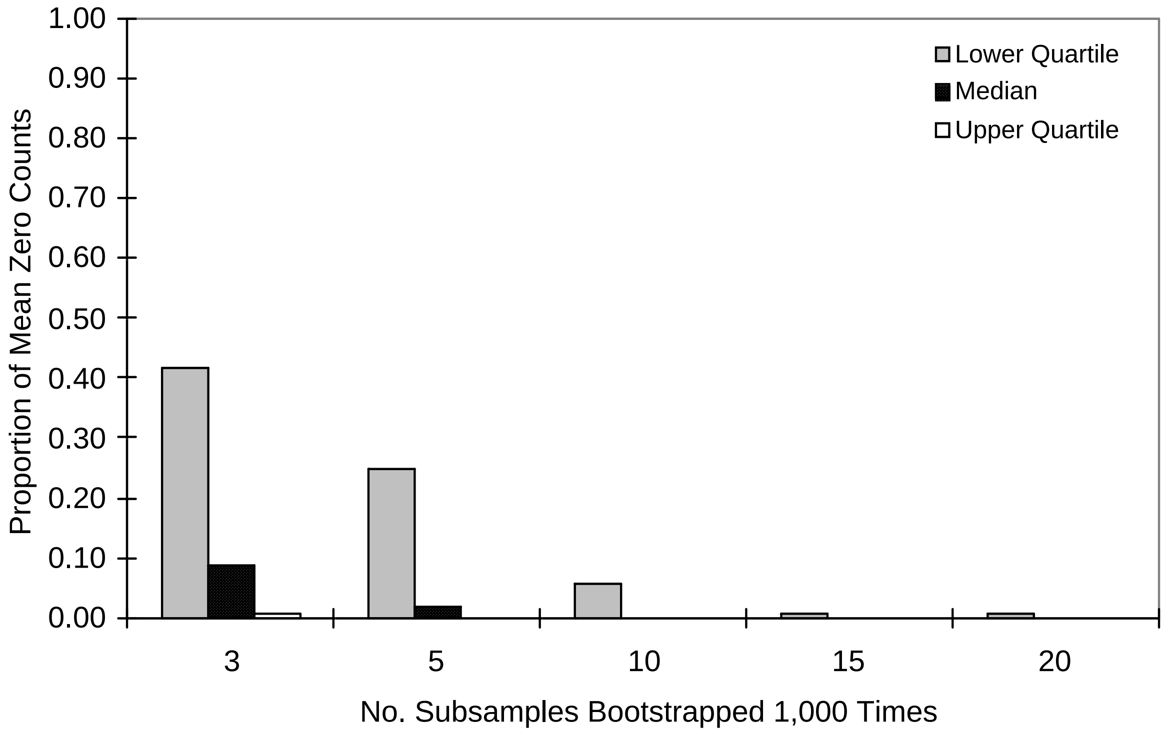

Figure 1. Proportion of mean zero counts of snowshoe hare pellet densities in subsamples of 3, 5, 10, 15, 20 derived through bootstrap samples of 1,000 iterations, White River National Forest, 2004.

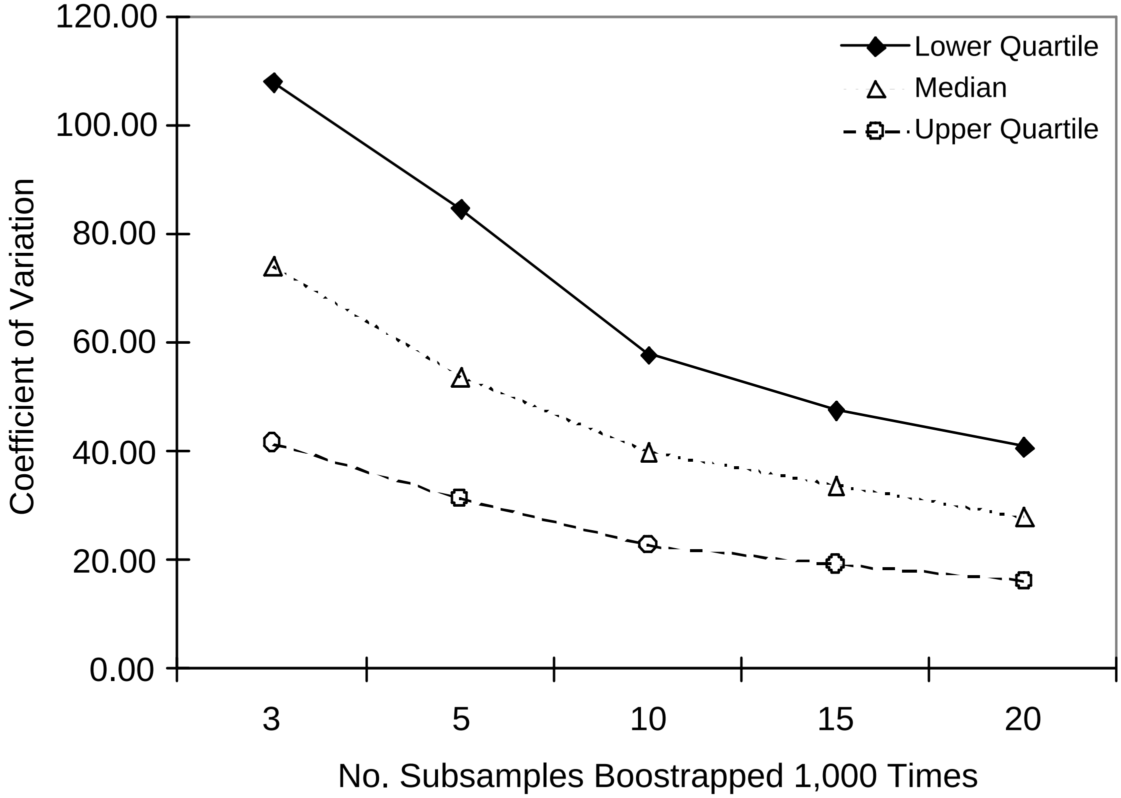

Figure 2. Coefficient of variation in mean counts of snowshoe hare pellet densities from subsamples of 3, 5, 10, 15, and 20 derived through bootstrap samples of 1,000 iterations, White River National Forest, 2004.

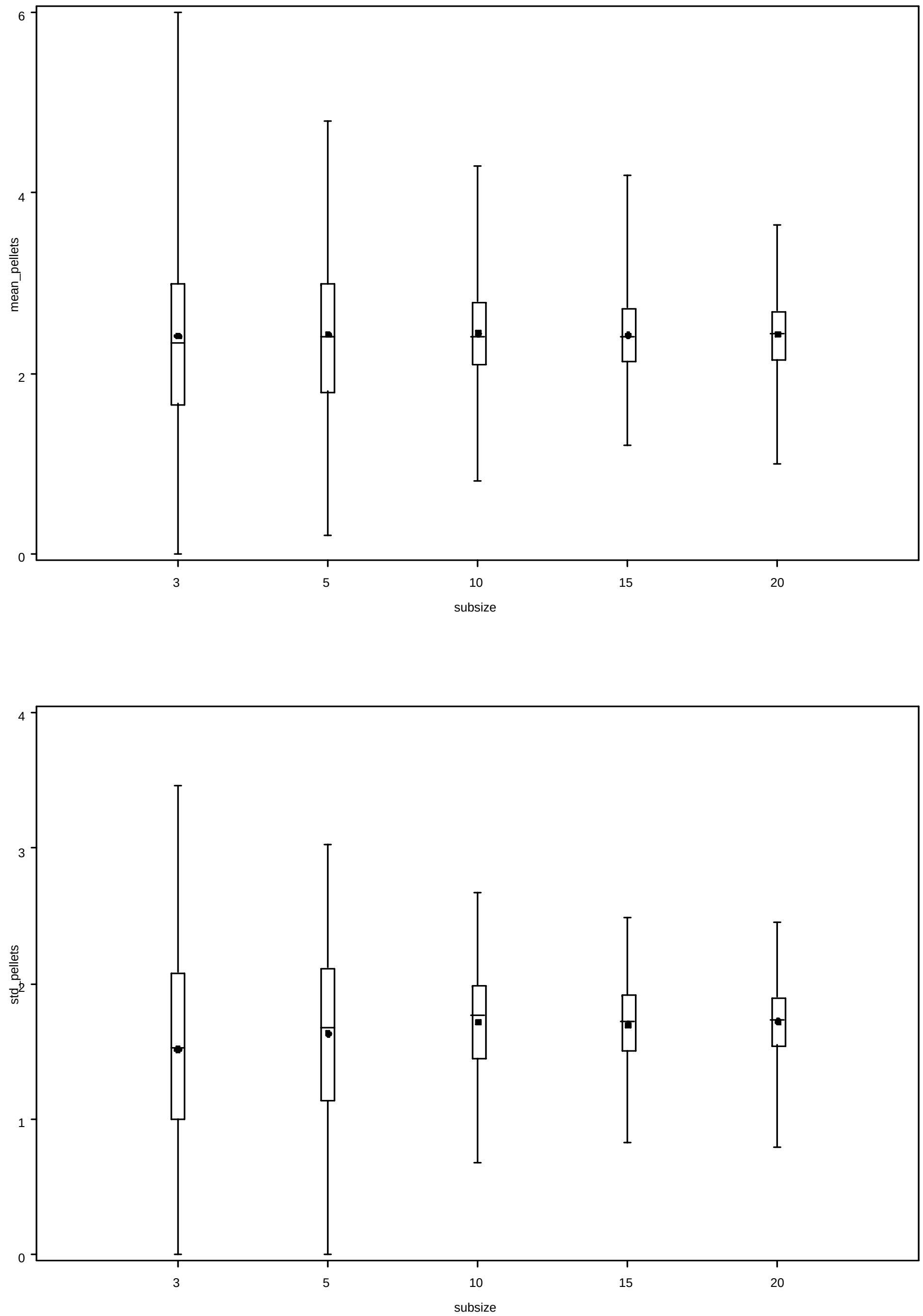

Figure 3. Box plots of means (upper) and standard deviations (lower) for subsamples of 3, 5, 10, 15, and 20 from 1,000 bootstrapped samples from the Mitchell Creek site, Holy Cross Ranger District, White River National Forest, 2004. This site is representative of lodgepole pine sites from the upper quartile of mean snowshoe hare pellet counts. For comparison, the mean for 20 plots was 2.5 pellets/plot and the standard deviation was 1.8 pellets/plot.

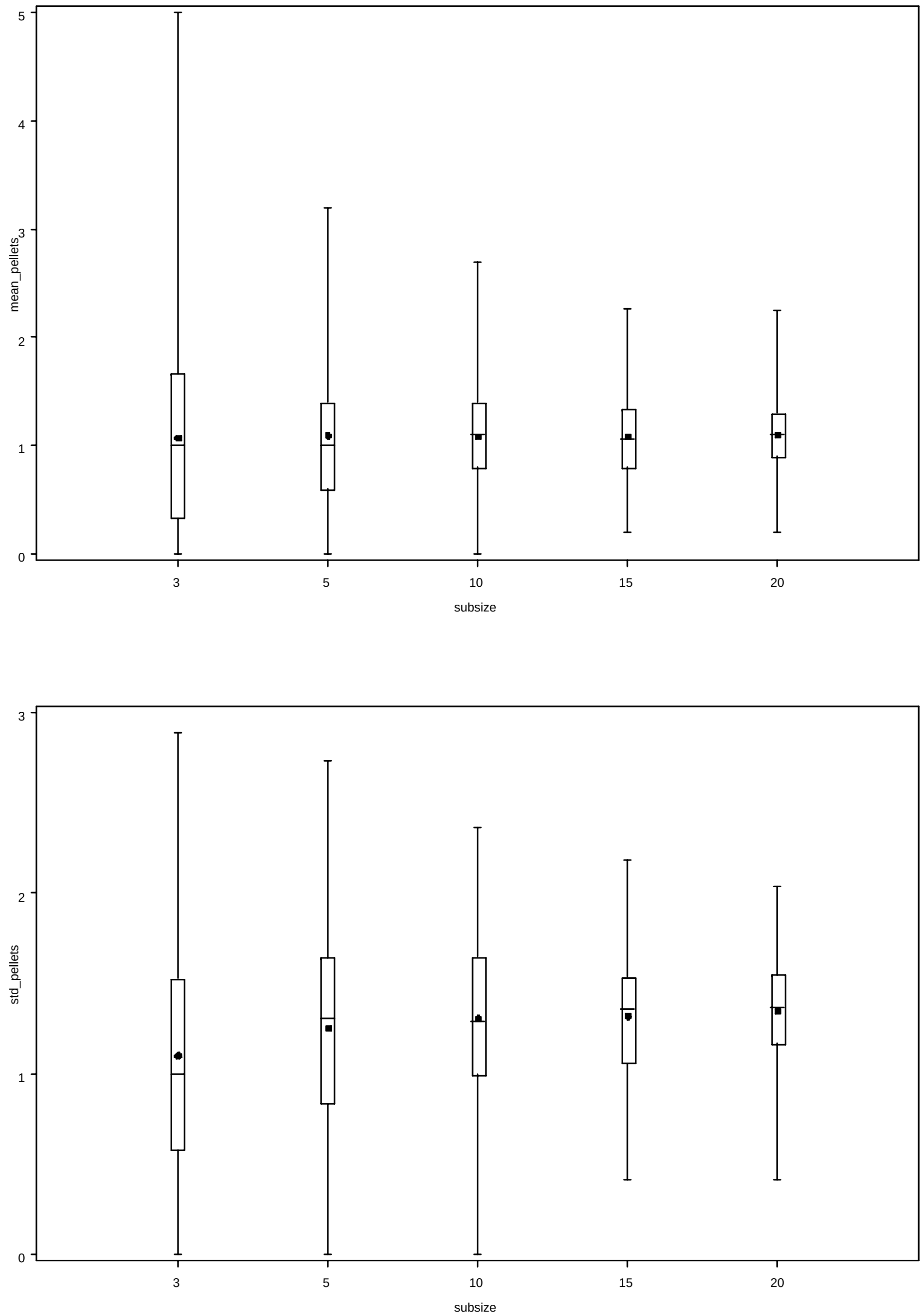

Figure 4. Box plots of means (upper) and standard deviations (lower) for subsamples of 3, 5, 10, 15, and 20 from 1,000 bootstrapped samples from the Swan Mountain site, Dillon Ranger District, White River National Forest, 2004. This site is representative of lodgepole pine sites from the median of mean snowshoe hare pellet counts. For comparison, the mean for 20 plots was 1.1 pellets/plot and the standard deviation was 1.4 pellets/plot.

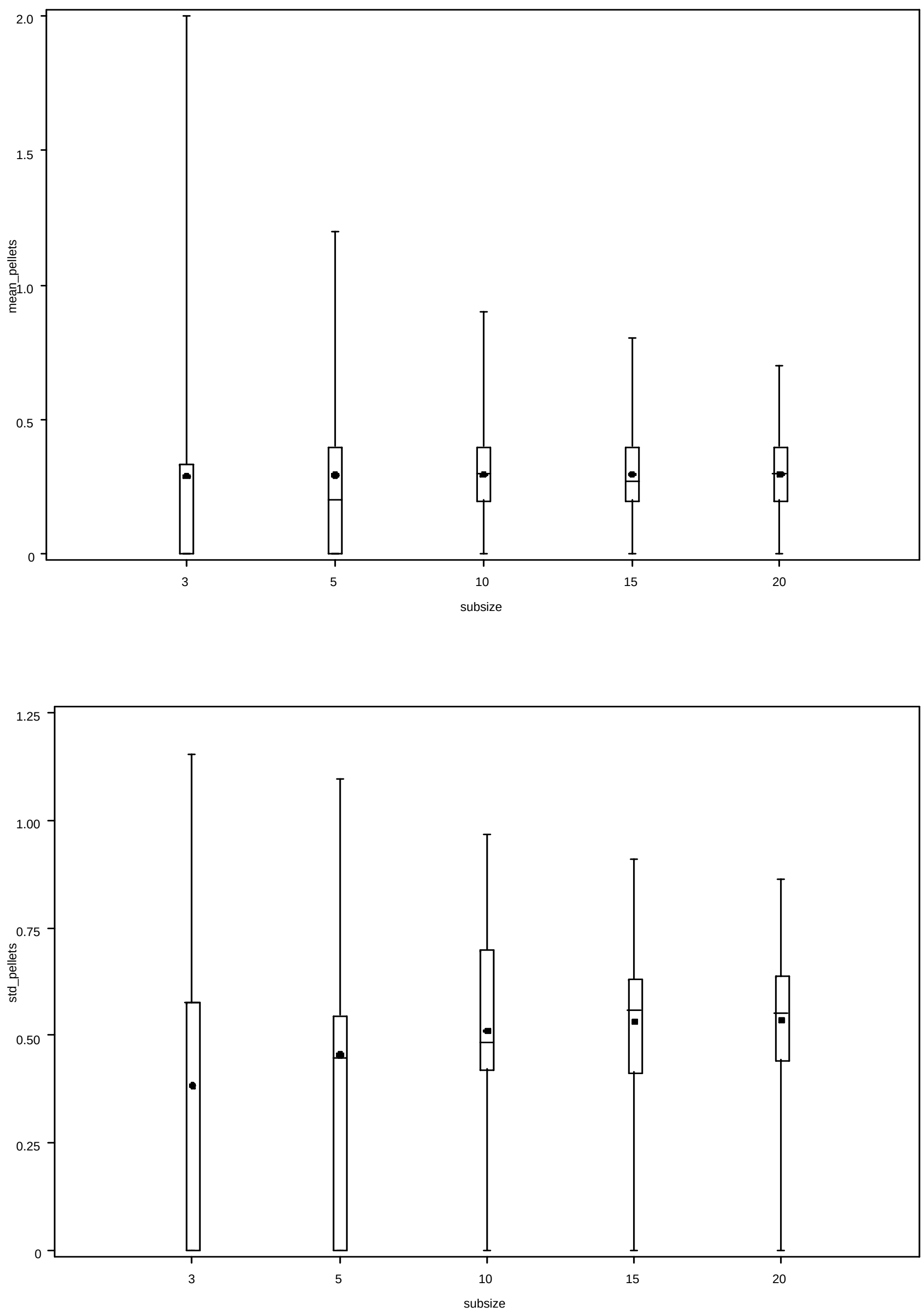

Figure 5. Box plots of means (upper) and standard deviations (lower) for subsamples of 3, 5, 10, 15, and 20 from 1,000 bootstrapped samples from the Frey Gulch site, Dillon Ranger District, White River National Forest, 2004. This site is representative of lodgepole pine sites from the lower quartile of mean snowshoe hare pellet counts. For comparison, the mean for 20 plots was 0.3 pellets/plot and the standard deviation was 0.6 pellets/plot.

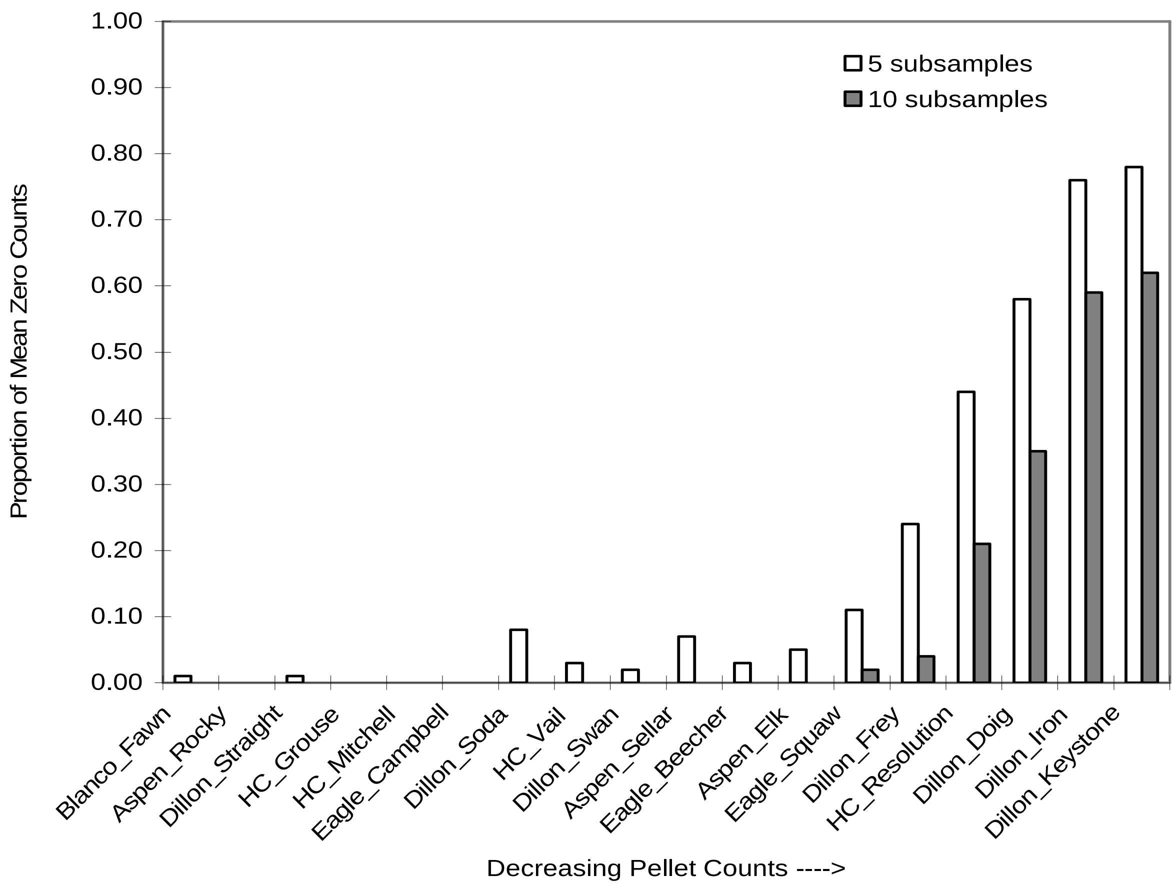

Figure 6. Proportion of mean zero counts of snowshoe hare pellet densities in subsamples of 5 and 10 derived through bootstrap samples of 1,000 iterations, White River National Forest, 2004.