Estimation of tassel-eared squirrel abundance at selected sites within the Lakeside Ranger District, Apache-Sitgreaves National Forest

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INTRODUCTION

Abert's squirrels are forest dwelling, arboreal mammals endemic to ponderosa pine forests. Although they have been documented using both mixed-conifer and spruce-fir forests (Hutton et. al 2003), they are thought to be primarily dependent on ponderosa pine ecosystems to maintain stable populations (Keith 1965). Several researchers have hypothesized that the foraging and seed caching activities of Abert's squirrels benefit ponderosa pine forests by facilitating increasing precipitation absorption, nutrient turnover, and root inoculation by fungal spores (States and Gaud 1997, States and Wettstein 1998, Allred and Gaud 1999). In addition, Abert's squirrels are a primary food source for northern goshawks, a sensitive species in Arizona, and are particularly important during winter months (Reynolds et al. 1992, Drennan and Beier 2003). Large scale thinning and burning operations are commonly being used in forests in the Southwest United States. We are only beginning to understand the effects of large scale forest restoration activities on this ponderosa pine specialist. In a recent study, Dodd et al. (2003) estimated density, survival and recruitment of Abert's squirrels in north-central Arizona. Their data indicated that recruitment was both positively and strongly associated with the number of interlocking canopy trees and August fungal content in feces. In addition, the August fungal content in feces was positively related to basal area. Forest treatment prescriptions generally propose reducing basal area and canopy cover for a number of reasons ranging from reducing wildfire severity to promoting forest health. These alterations will likely substantially decrease the number of interlocking canopy trees, and may disturb the diversity and abundance of the fungal communities, with the potential to negatively affect squirrel populations (Dodd et al. 2003).

Our objective was to estimate Abert's squirrel density in several selected sites in the Lakeside Ranger District in western Arizona. We will compare estimates obtained in 2007 to surveys completed in previous years by US Forest Service personnel in 2004 – 2006. Density estimates calculated in 2007 can serve as a benchmark to compare to surveys conducted in subsequent years to determine the effects of various forest management practices to the abundance of tassel-eared squirrels.

STUDY SITES AND METHODS

We sampled squirrel index in 3 different locations on the Lakeside Ranger District. Ten plots were surveyed at the Blue Ridge site, which is located on the Apache-Sitgreaves National Forest just northeast of Pinetop, Arizona (Figure 1). Twenty-four plots were surveyed at the Los Burros site, which is located in the Apache-Sitgreaves National Forest north of McNary, Arizona (Figure 2). Ten plots were surveyed at the Show Low South site, which is located in the Apache National Forest southwest of Show Low, Arizona (Figure 3). Plot locations were provided by the US Forest Service and corresponded to locations previously surveyed by Forest Service personnel. Each plot consisted of 8 survey transects, each 543 meters long consisting of 32 survey points. The feed sign plots encompassed an area of 27 ha (66 acres), and consisted of 256 individual survey points. All surveys conducted in 2007 were completed in May, those occurring in 2004 through 2006 also occasionally occurred in early June. We followed protocols

established by Dodd (1998) to use feeding sign index to estimate spring squirrel densities (See Appendix A). The observers traveled along each transect and recorded presence or absence of squirrel sign within a one square meter plot every 17 meters. Squirrel sign consisted of terminal branch clippings, peeled twigs, ovulate cone cores or cobs, staminate cones or flowers, apical buds, or hypogeous fungi digs.

RESULTS

Squirrel density estimates for 2007 were relatively low, ranging from 0.01 to 0.21 squirrels per hectare (Blue Ridge 0.01 – 0.12 sq/ha; Los Burros 0.01 – 0.21 sq/ha; Show Low South 0.01 – 0.04 sq/ha; Tables 1 – 3). Although there was variation in the density estimates between plots, none of these differences were significantly different (Figures 4 – 6). There were also no significant differences or consistent patterns seen in specific plots from 2004 through 2007 (Figures 7 – 9). Squirrel numbers have been shown to fluctuate dramatically between years (Keith 1965, Patton et al. 1985) and within years (Dodd et al. 2003). Low population estimates may be attributed to current drought conditions on the Mogollon Plateau, which have persisted without significant change since the mid-1990's.

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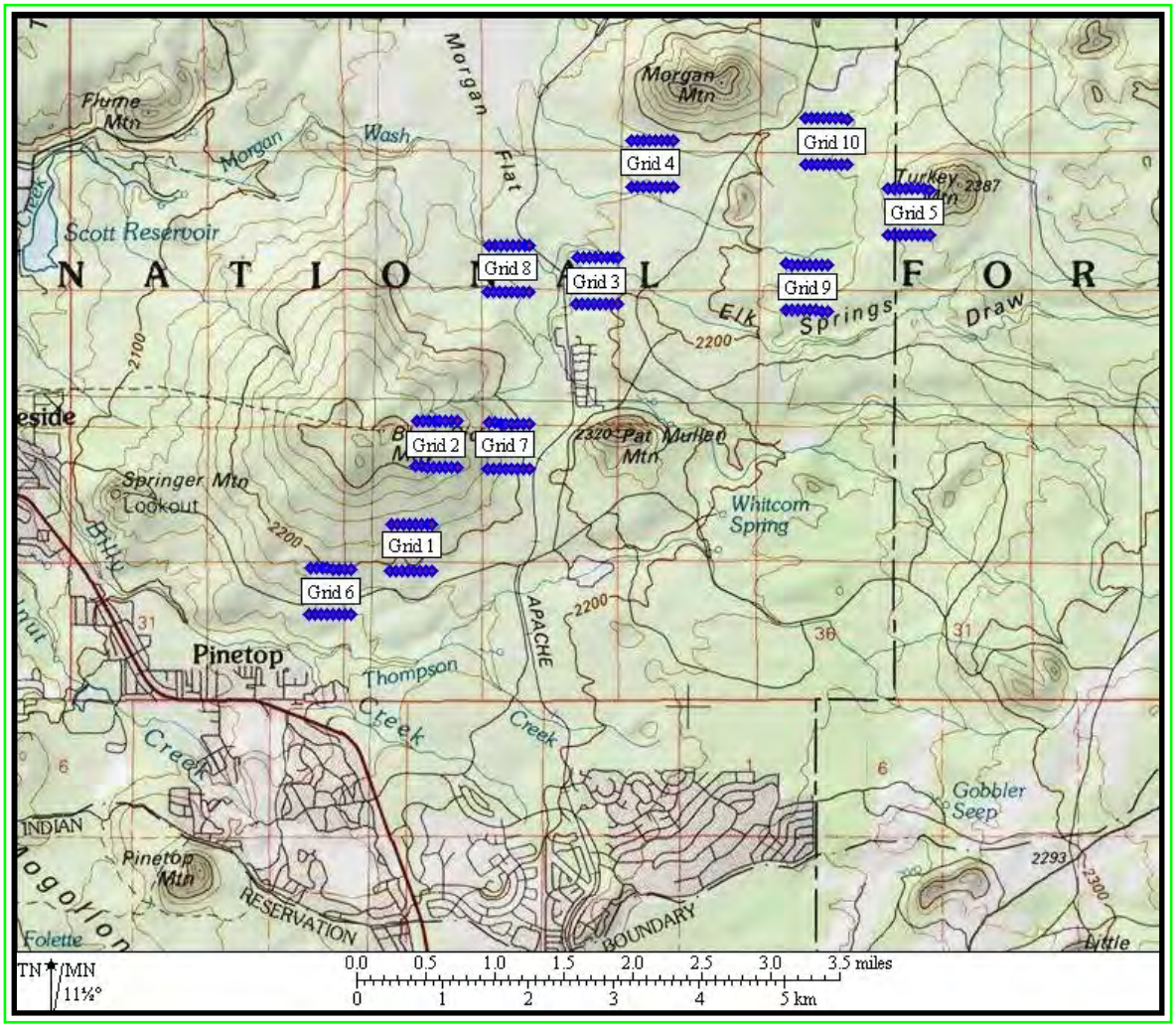


Figure 1. Location of Blue Ridge tassel-eared squirrel feeding sign index plots (1 - 10) in the Lakeside Ranger District. Surveys were conducted during May and June 2004 – 2007.

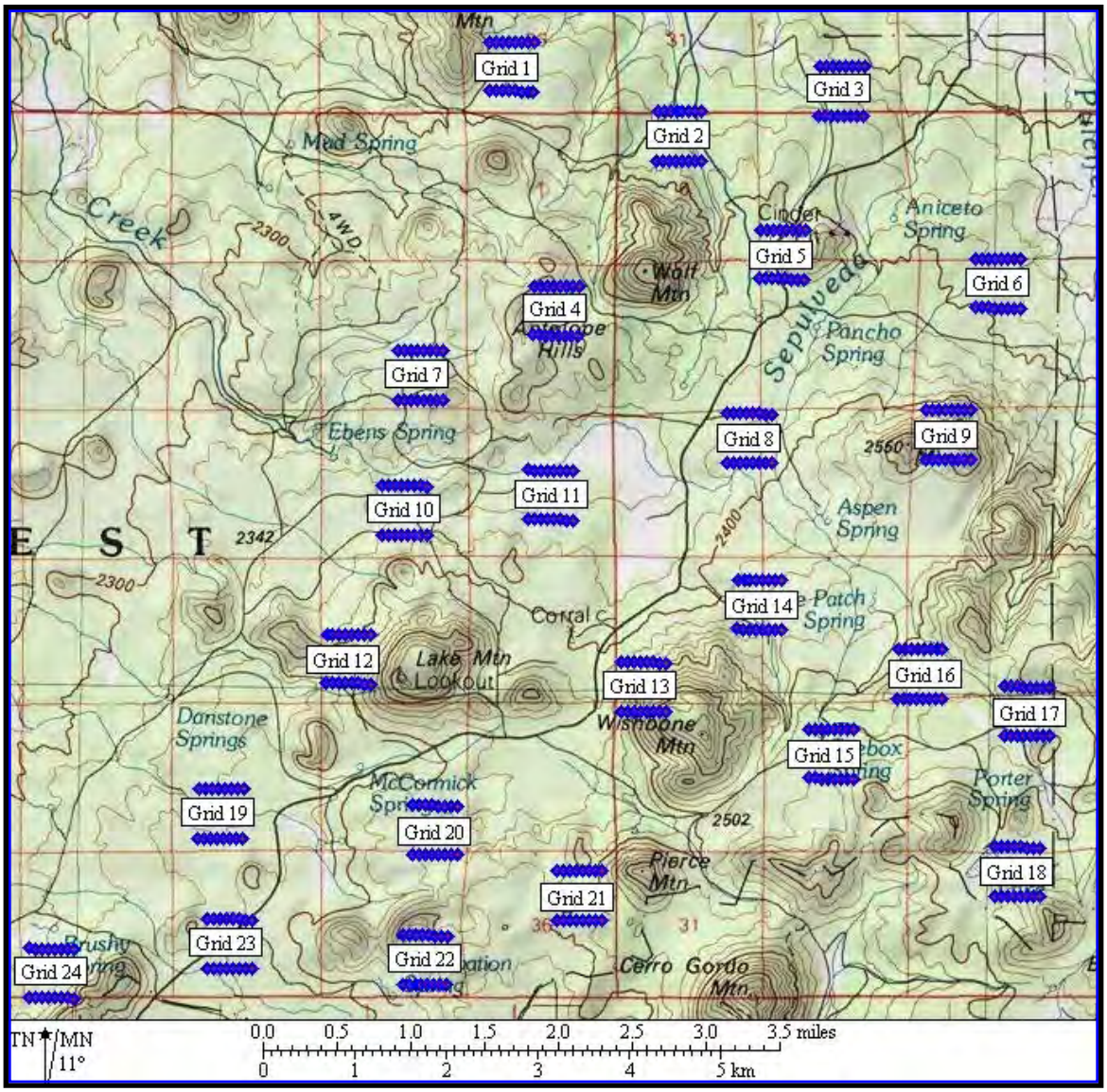


Figure 2. Location of Los Burros tassel-eared squirrel feeding sign index plots (1 - 24) in the Lakeside Ranger District. Surveys were conducted during May and June of 2005 – 2007.

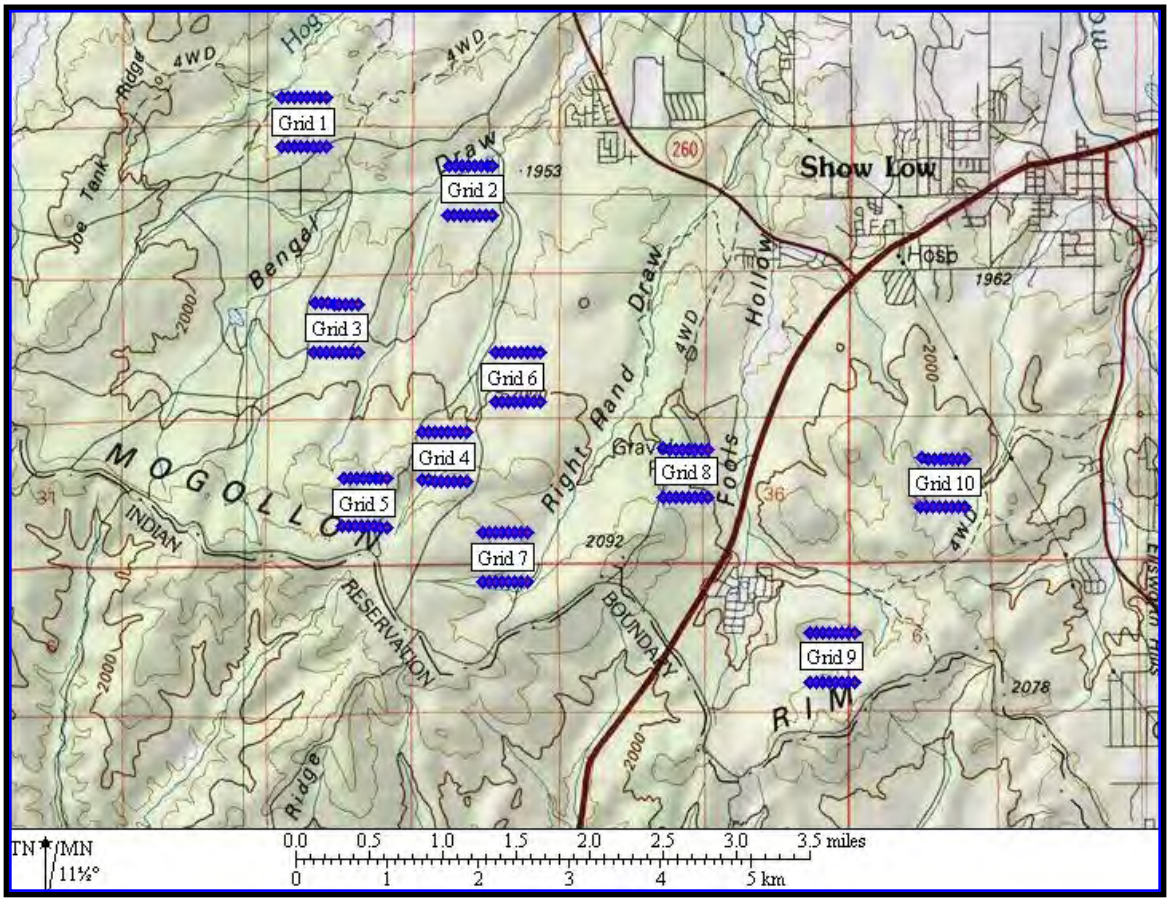


Figure 3. Location of Show Low South tassel-eared squirrel feeding sign index plots (1 - 10) in the Lakeside Ranger District. Surveys were conducted during May and June 2004 – 2007.

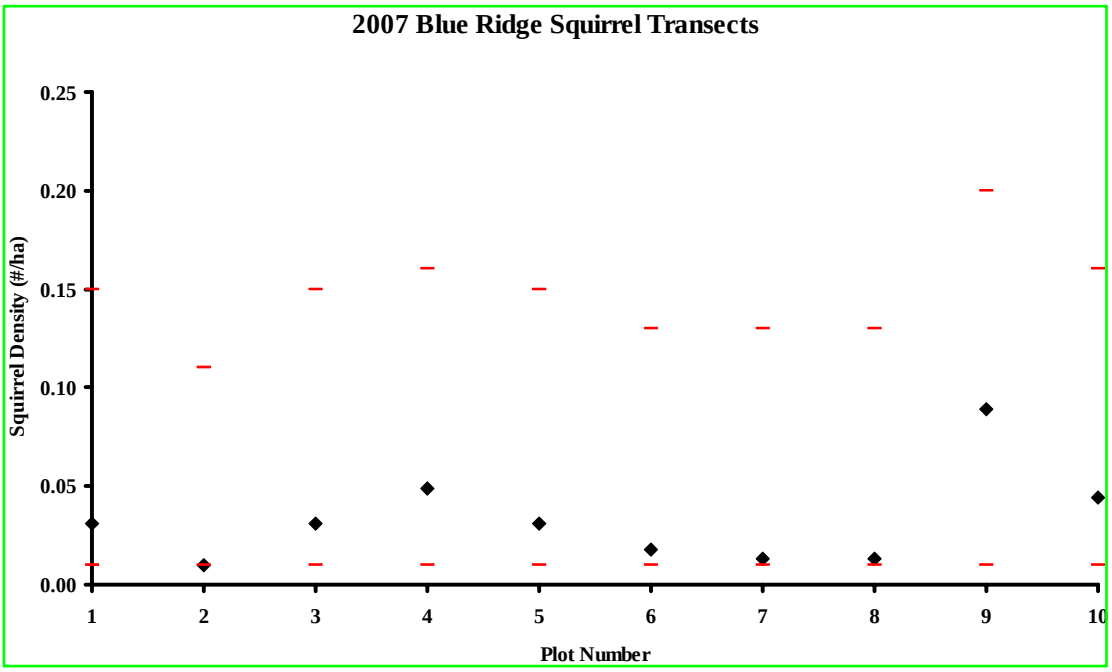


Figure 4. Graph of regression analysis for squirrel density at the Blue Ridge study sites during spring 2007. Red bars indicate upper and lower 90% prediction intervals.

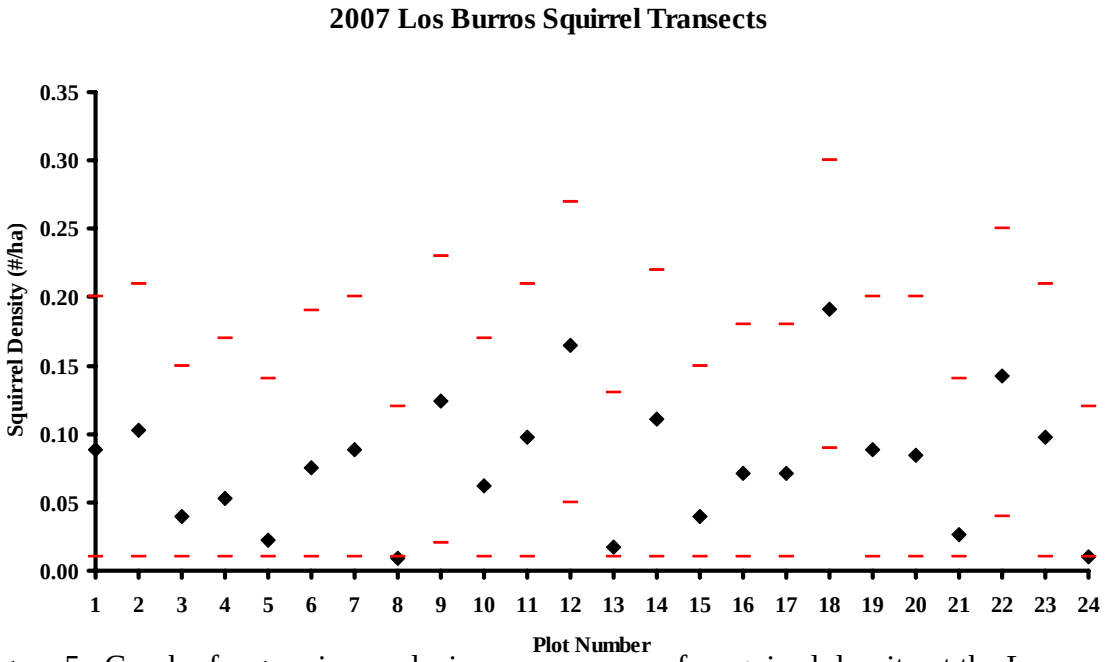


Figure 5. Graph of regression analysis for squirrel density at the Los Burros study sites during spring 2007. Red bars indicate upper and lower 90% prediction intervals.

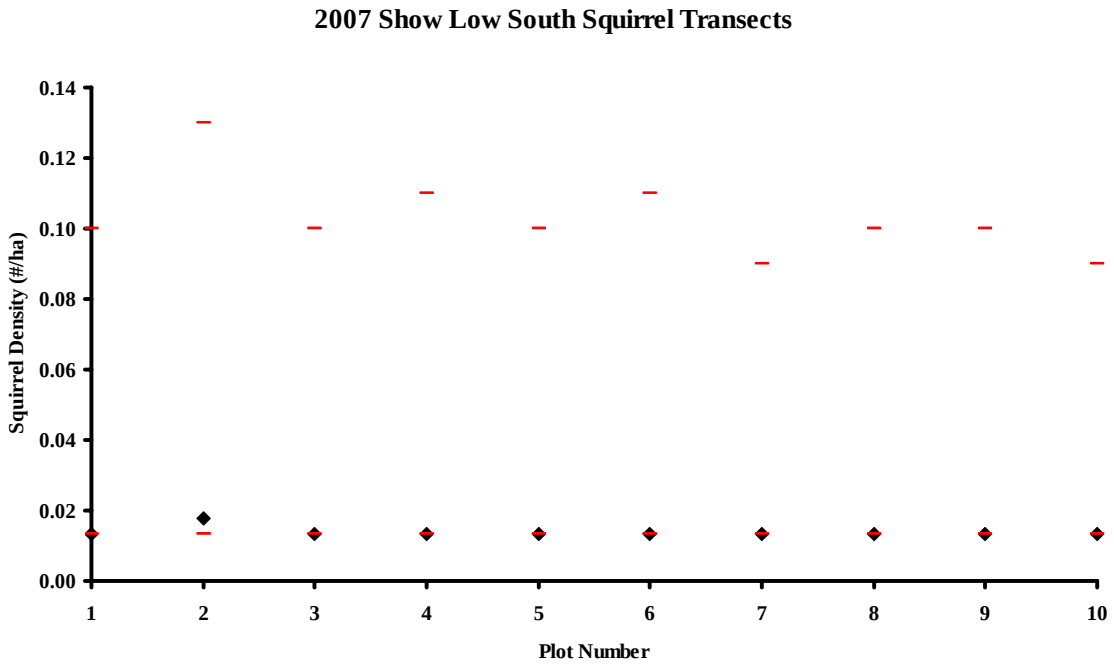


Figure 6. Graph of regression analysis for squirrel density at the Show Low South study sites during spring 2007. Red bars indicate upper and lower 90% prediction intervals.

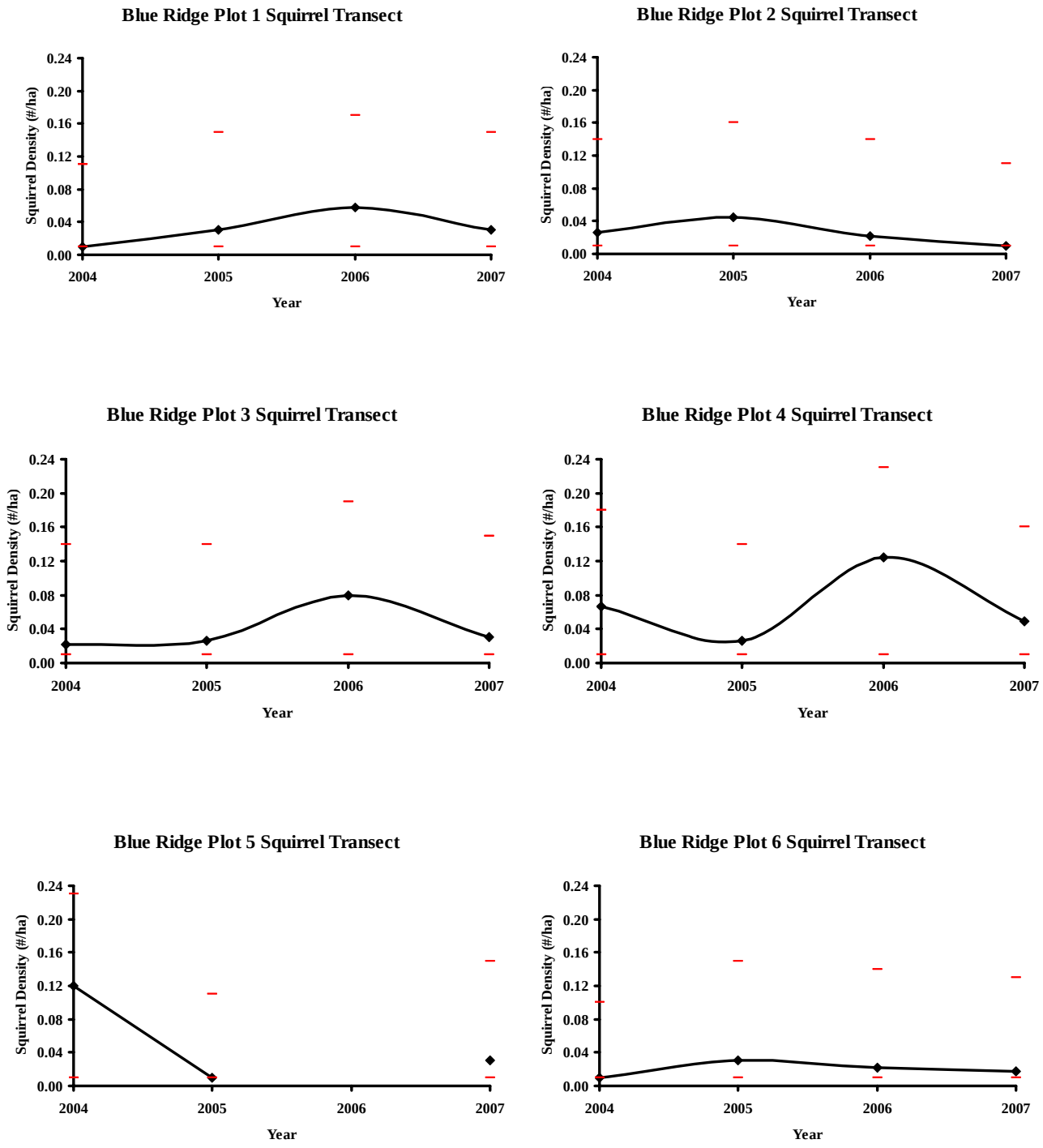
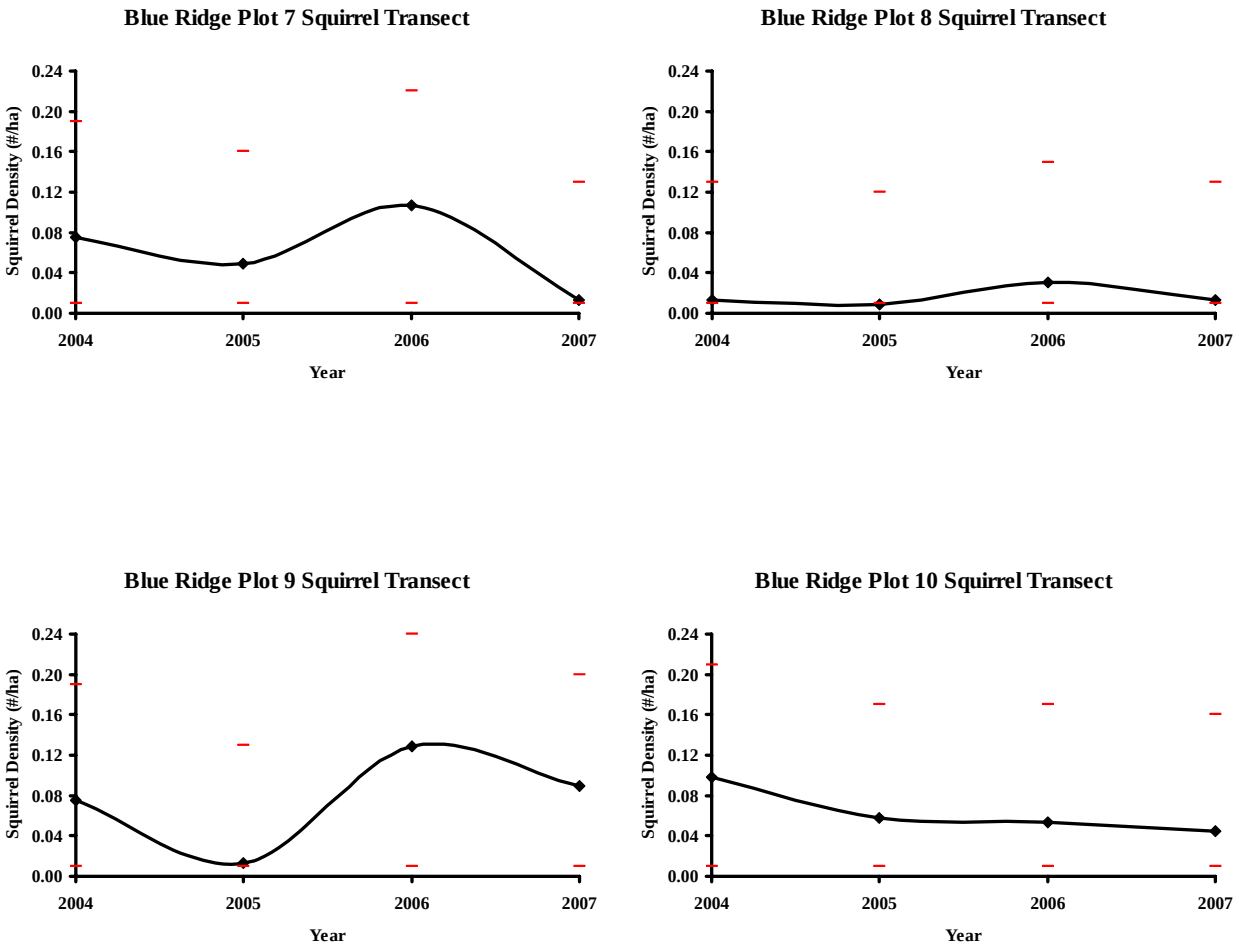


Figure 7. Graph of regression analysis for squirrel density at the Blue Ridge study site during spring 2004 – 2007. Red bars indicate upper and lower 90% prediction intervals.



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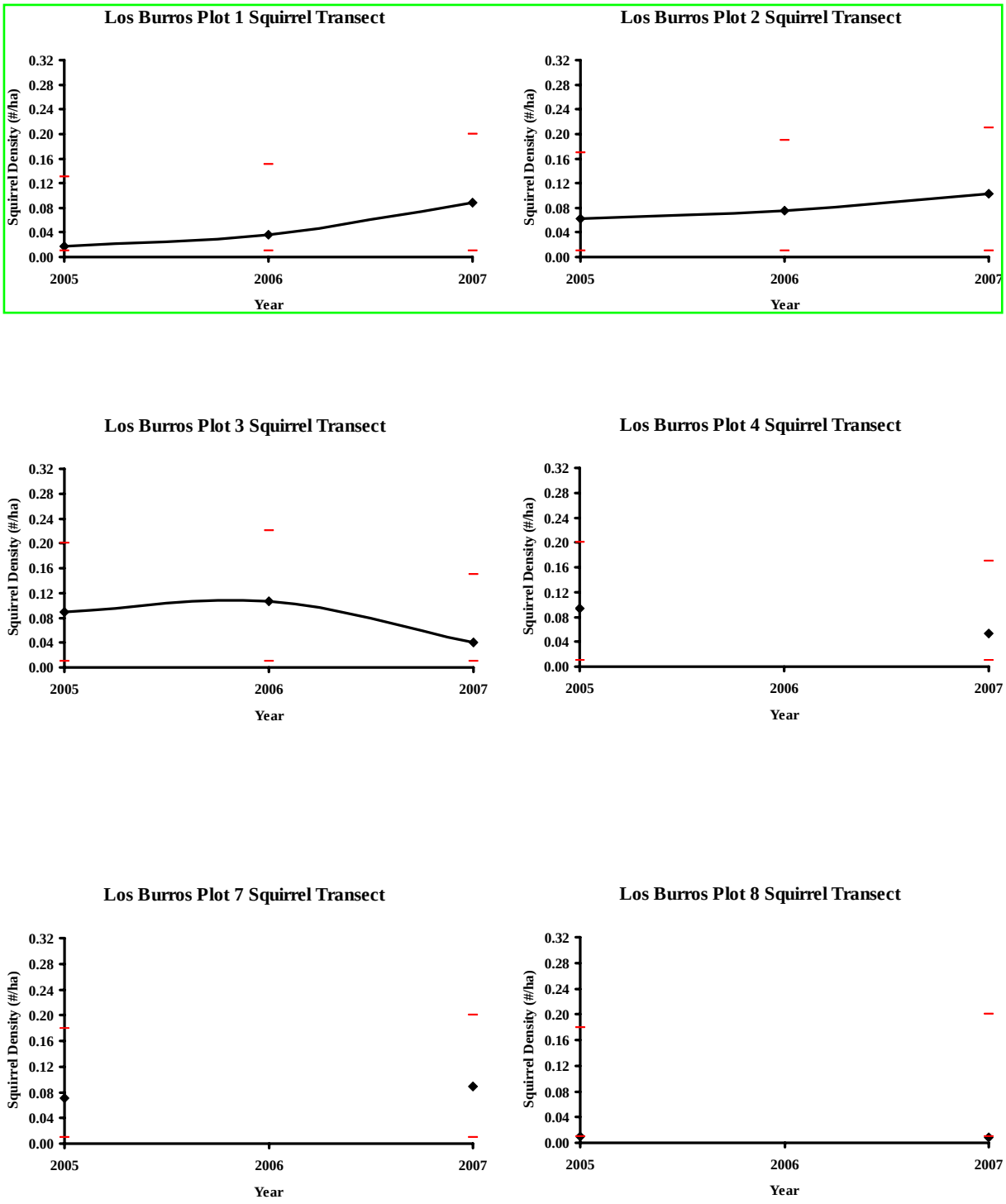


Figure 8. Graph of regression analysis for squirrel density at the Los Burros study site during spring 2005 – 2007. Red bars indicate upper and lower 90% prediction intervals.

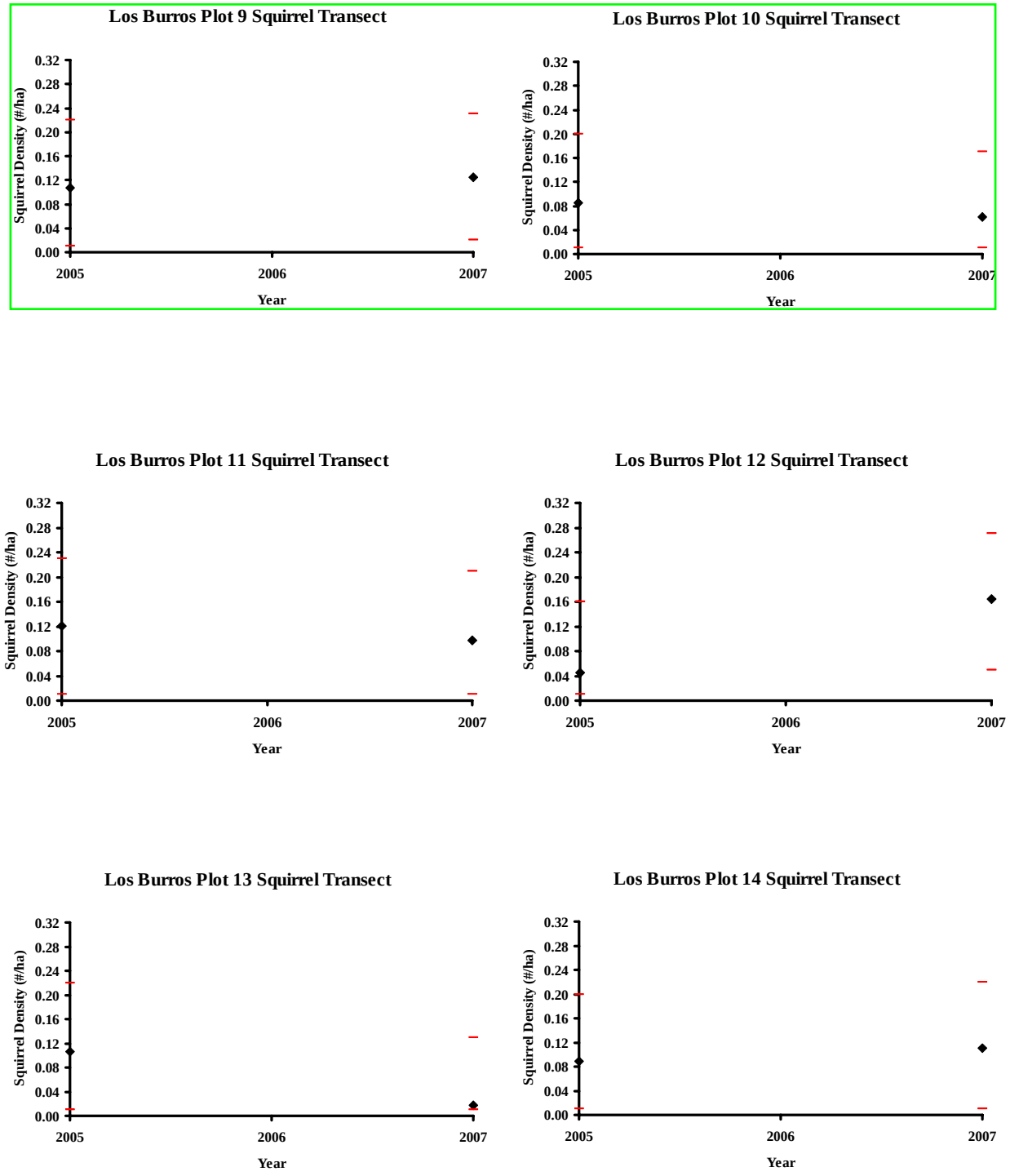


Figure 8 (continued). Graph of regression analysis for squirrel density at the Los Burros study site during spring 2005 – 2007. Red bars indicate upper and lower 90% prediction intervals.

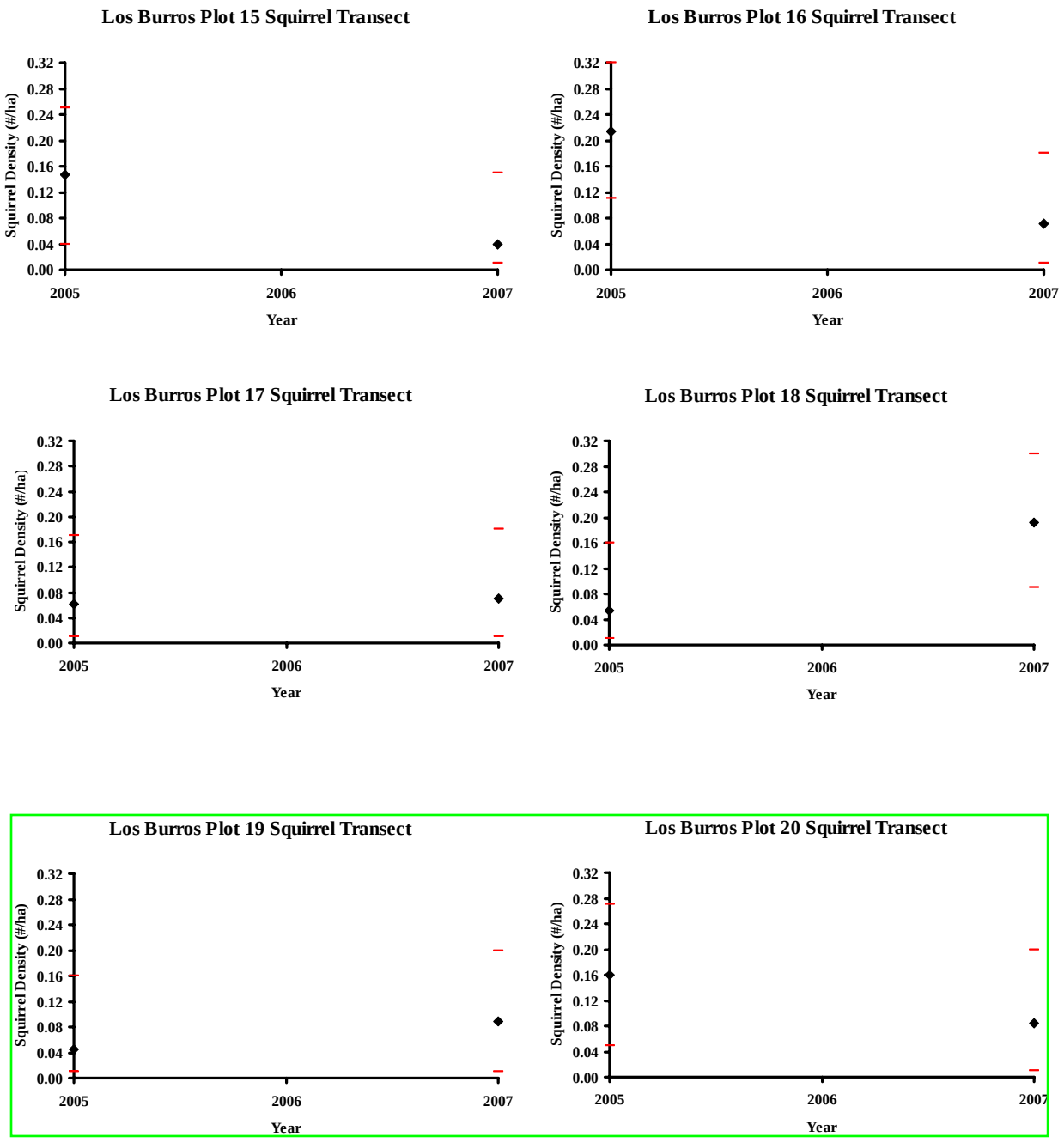


Figure 8 (continued). Graph of regression analysis for squirrel density at the Los Burros study site during spring 2005 – 2007. Red bars indicate upper and lower 90% prediction intervals.

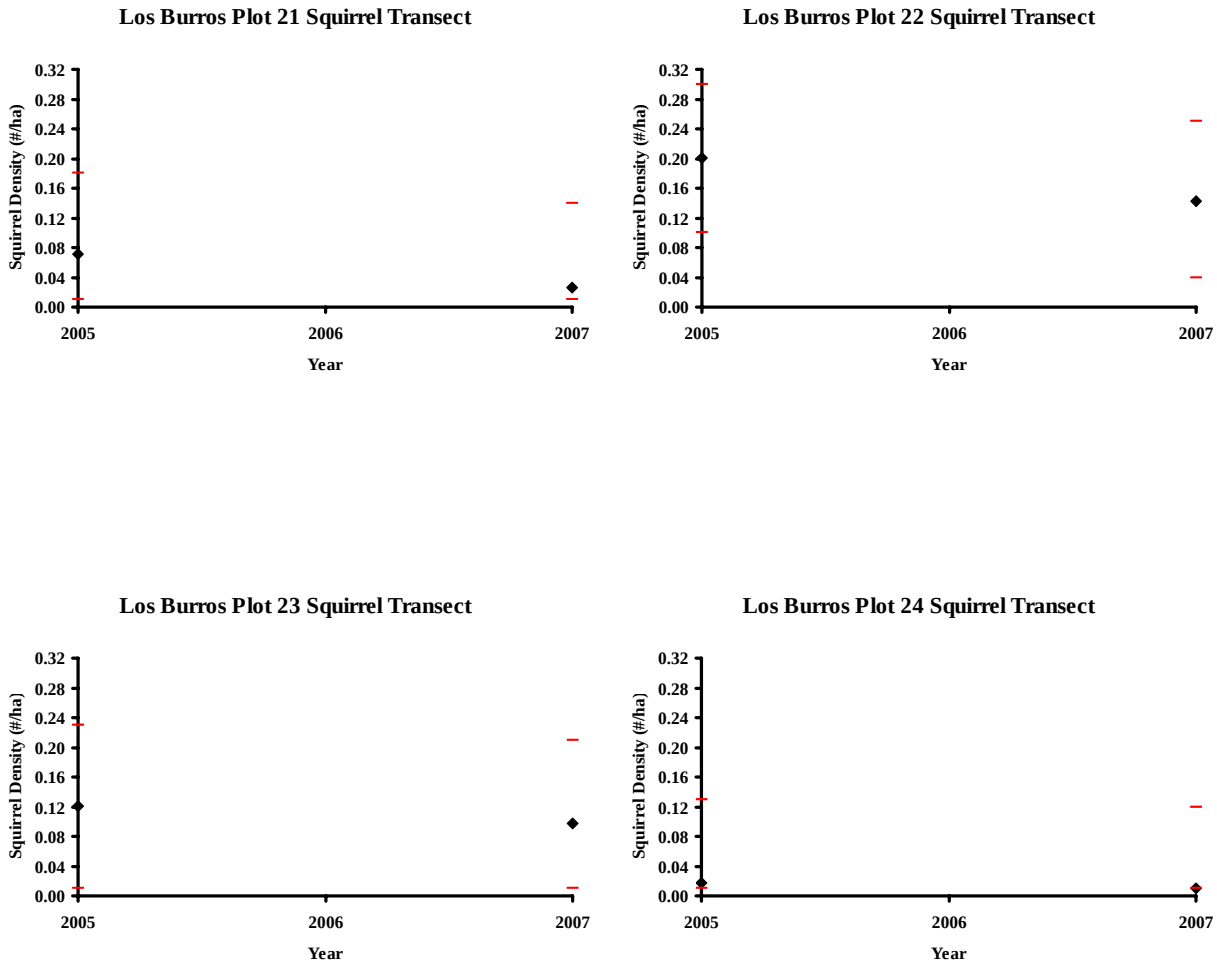


Figure 8 (continued). Graph of regression analysis for squirrel density at the Los Burros study site during spring 2005 – 2007. Red bars indicate upper and lower 90% prediction intervals.

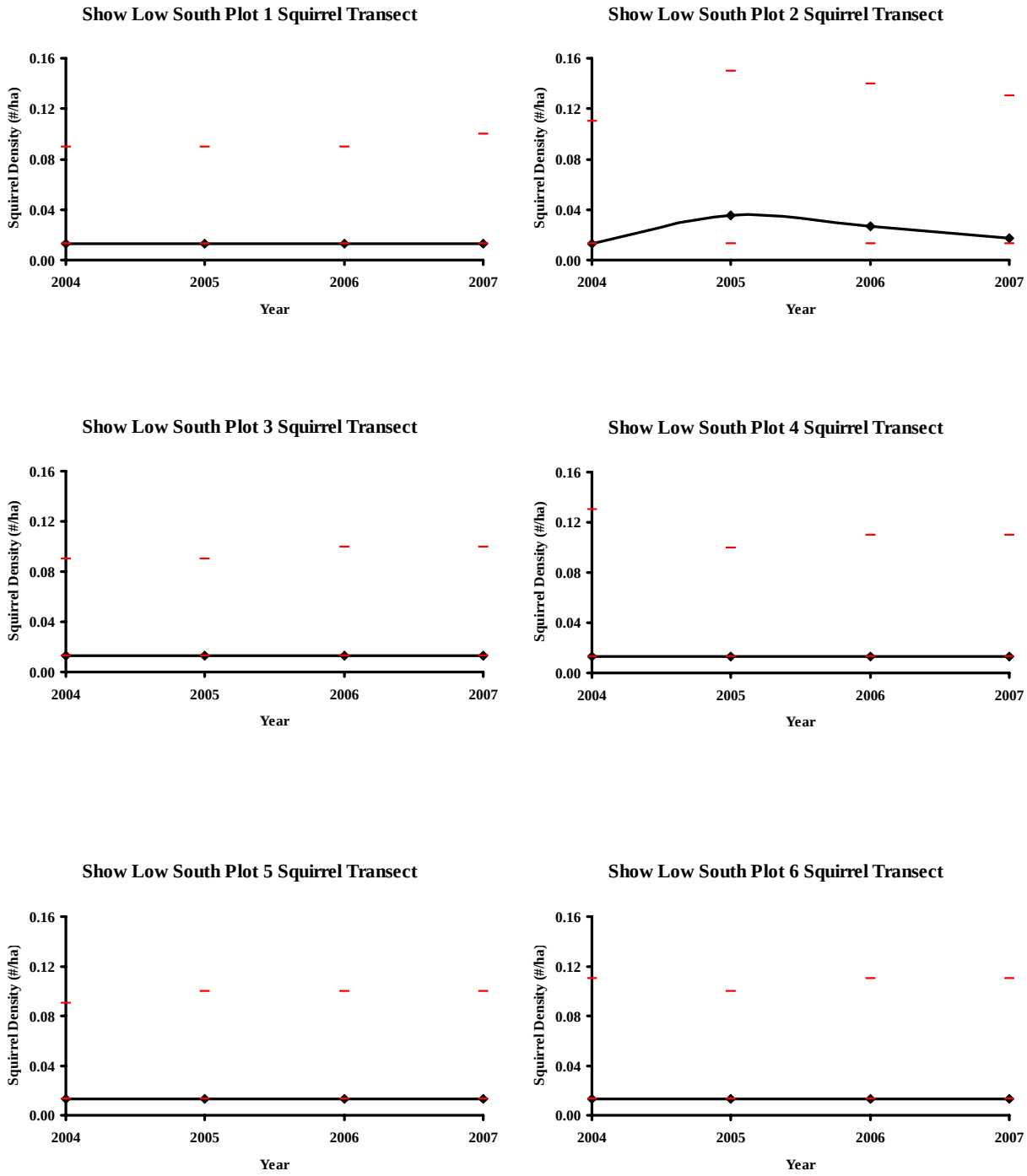


Figure 9. Graph of regression analysis for squirrel density at the Show Low South study site during spring 2004 – 2007. Red bars indicate upper and lower 90% prediction intervals.

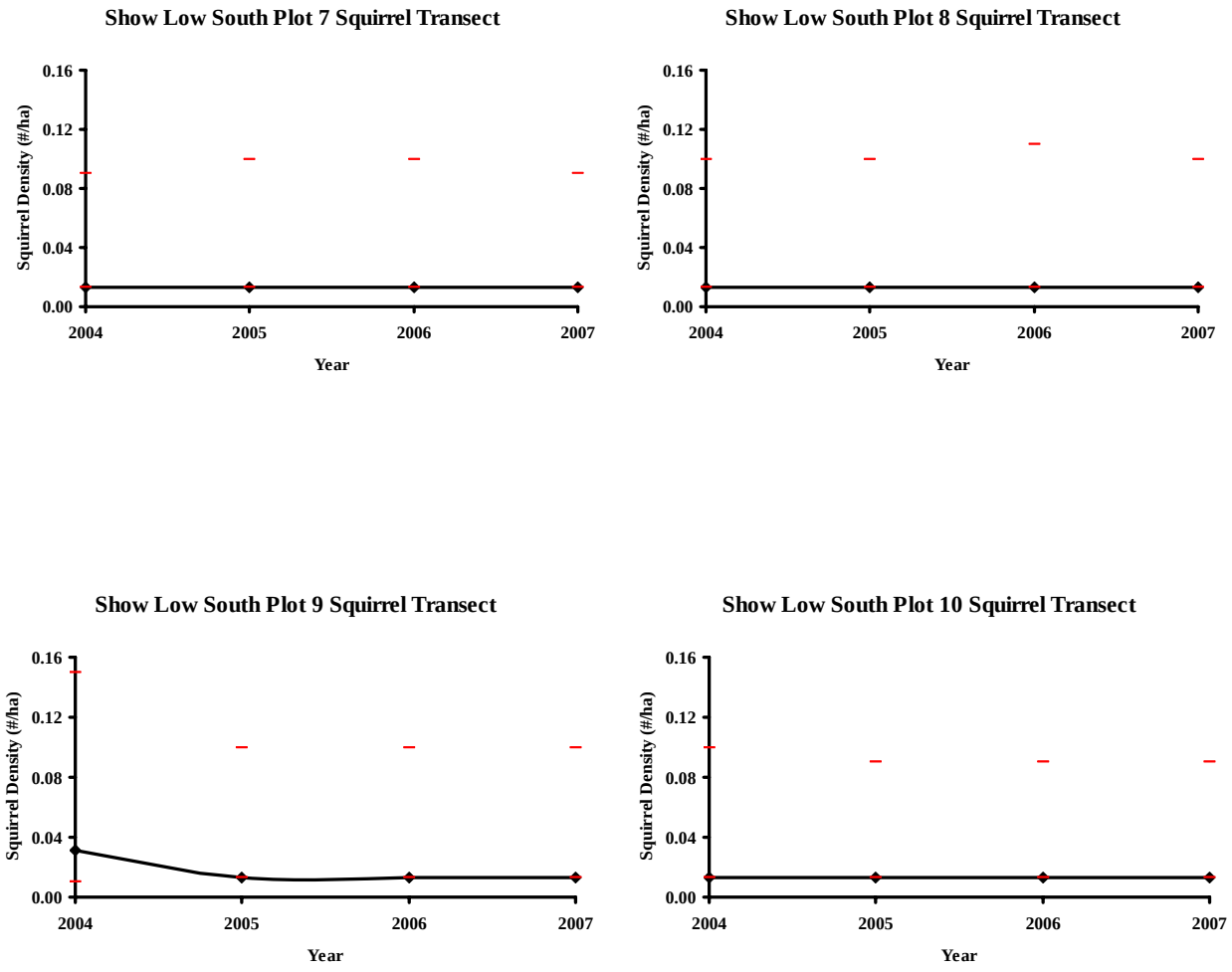


Figure 9 (continued). Graph of regression analysis for squirrel density at the Show Low South study site during spring 2004 – 2007. Red bars indicate upper and lower 90% prediction intervals.

Table 1. Results of regression analysis used to predict squirrel density at the Blue Ridge study site during spring 2004 – 2007.

Blue Ridge Tassel-Eared Squirrel Survey Results

					90% Prediction Interval	
Grid #	**Plots Sampled**	**Sign Hits**	**%**	**Density (#/ha)**	**Lower**	**Upper**
2004						
1	256	4	1.6	0.01	0.01	0.11
2	256	12	4.7	0.03	0.01	0.14
3	256	11	4.3	0.02	0.01	0.14
4	256	21	8.2	0.07	0.01	0.18
5	256	33	12.9	0.12	0.01	0.23
6	256	1	0.4	0.01	0.01	0.10
7	256	23	9.0	0.08	0.01	0.19
8	256	9	3.5	0.01	0.01	0.13
9	256	23	9.0	0.08	0.01	0.19
10	256	28	10.9	0.10	0.01	0.21
2005						
1	256	13	5.078	0.03	0.01	0.15
2	256	16	6.25	0.04	0.01	0.16
3	256	12	4.688	0.03	0.01	0.14
4	256	12	4.688	0.03	0.01	0.14
5	256	5	1.953	0.01	0.01	0.11
6	256	13	5.078	0.03	0.01	0.15
7	256	17	6.641	0.05	0.01	0.16
8	256	8	3.125	0.01	0.01	0.12
9	256	9	3.516	0.01	0.01	0.13
10	256	19	7.422	0.06	0.01	0.17
2006						
1	256	19	7.4	0.06	0.01	0.17
2	256	11	4.3	0.02	0.01	0.14
3	256	24	9.4	0.08	0.01	0.19
4	256	34	13.3	0.12	0.02	0.23
6	256	11	4.3	0.02	0.01	0.14
7	256	30	11.7	0.11	0.01	0.22
8	256	13	5.1	0.03	0.01	0.15
9	256	35	13.7	0.13	0.02	0.24
10	256	18	7.0	0.05	0.01	0.17
2007						
1	256	13	5.1	0.03	0.01	0.15
2	256	6	2.3	0.01	0.01	0.12
3	256	13	5.1	0.03	0.01	0.15
4	256	17	6.6	0.05	0.01	0.16
5	256	13	5.1	0.03	0.01	0.15
6	256	10	3.9	0.02	0.01	0.13
7	256	9	3.5	0.01	0.01	0.13
8	256	9	3.5	0.01	0.01	0.13
9	256	26	10.2	0.09	0.01	0.20
10	256	16	6.3	0.04	0.01	0.16

Table 2. Results of regression analysis used to predict squirrel density at the Los Burros study site during spring 2004 – 2007.

Los Burros Tassel-Eared Squirrel Survey Results

Grid #	Plots Sampled	Sign Hits	%	Density (#/ha)	90% Prediction Interval Lower	Upper
2005						
1	256	10	3.9	0.02	0.01	0.13
2	256	20	7.8	0.06	0.01	0.17
3	256	26	10.2	0.09	0.01	0.20
4	256	27	10.5	0.09	0.01	0.20
5LB	256	30	11.7	0.11	0.01	0.22
6	256	14	5.5	0.04	0.01	0.15
7	256	22	8.6	0.07	0.01	0.18
8	256	5	2.0	0.01	0.01	0.11
9	256	30	11.7	0.11	0.01	0.22
10LB	256	25	9.8	0.08	0.01	0.20
11	256	33	12.9	0.12	0.01	0.23
12	256	16	6.3	0.04	0.01	0.16
13	256	30	11.7	0.11	0.01	0.22
14	256	26	10.2	0.09	0.01	0.20
15	256	39	15.2	0.15	0.04	0.25
16	256	54	21.1	0.21	0.11	0.32
17	256	20	7.8	0.06	0.01	0.17
18	256	18	7.0	0.05	0.01	0.17
19	256	16	6.3	0.04	0.01	0.16
20	256	42	16.4	0.16	0.06	0.27
21	256	22	8.6	0.07	0.01	0.18
22	256	51	19.9	0.20	0.10	0.30
23	256	33	12.9	0.12	0.01	0.23
24	256	10	3.9	0.02	0.01	0.13
2006						
1	256	14	5.5	0.04	0.01	0.15
2	256	23	9.0	0.08	0.01	0.19
3	256	30	11.7	0.11	0.01	0.22
5LB	256	16	6.3	0.04	0.01	0.16
6	256	22	8.6	0.07	0.01	0.18
2007						
1	256	26	10.2	0.09	0.01	0.20
2	256	29	11.3	0.10	0.01	0.21
3	256	15	5.9	0.04	0.01	0.15
4	256	18	7.0	0.05	0.01	0.17
5LB	256	11	4.3	0.02	0.01	0.14
6	256	23	9.0	0.08	0.01	0.19
7	256	26	10.2	0.09	0.01	0.20
8	256	8	3.1	0.01	0.01	0.12
9	256	34	13.3	0.12	0.02	0.23
10LB	256	20	7.8	0.06	0.01	0.17
11	256	28	10.9	0.10	0.01	0.21
12	256	43	16.8	0.16	0.06	0.27
13	256	10	3.9	0.02	0.01	0.13

Table2 (cont)

14	256	31	12.1	0.11	0.01	0.22
15	256	15	5.9	0.04	0.01	0.15
16	256	22	8.6	0.07	0.01	0.18
17	256	22	8.6	0.07	0.01	0.18
18	256	49	19.1	0.19	0.09	0.30
19	256	26	10.2	0.09	0.01	0.20
20	256	25	9.8	0.08	0.01	0.20
21	256	12	4.7	0.03	0.01	0.14
22	256	38	14.8	0.14	0.04	0.25
23	256	28	10.9	0.10	0.01	0.21
24	256	7	2.7	0.01	0.01	0.12

Table 3. Results of regression analysis used to predict squirrel density at the Show Low South study site during spring 2004 – 2007.

Show Low South Tassel-Eared Squirrel Survey Results

					90% Prediction Interval	
Grid #	**Plots Sampled**	**Sign Hits**	**%**	**Density (#/ha)**	**Lower**	**Upper**
2004						
1	256	0	0.0	0.01	0.01	0.09
2	256	5	2.0	0.01	0.01	0.11
3	256	0	0.0	0.01	0.01	0.09
4	256	9	3.5	0.01	0.01	0.13
5	256	0	0.0	0.01	0.01	0.09
6	256	5	2.0	0.01	0.01	0.11
7	256	0	0.0	0.01	0.01	0.09
8	256	3	1.2	0.01	0.01	0.10
9	256	13	5.1	0.03	0.01	0.15
10	256	3	1.2	0.01	0.01	0.10
2005						
1	256	0	0.0	0.01	0.01	0.09
2	256	14	5.5	0.04	0.01	0.15
3	256	5	2.0	0.01	0.01	0.11
4	256	1	0.4	0.01	0.01	0.10
5	256	1	0.4	0.01	0.01	0.10
6	256	3	1.2	0.01	0.01	0.10
7	256	2	0.8	0.01	0.01	0.10
8	256	2	0.8	0.01	0.01	0.10
9	256	1	0.4	0.01	0.01	0.10
10	256	0	0.0	0.01	0.01	0.09
2006						
1	256	0	0.0	0.01	0.01	0.09
2	256	12	4.7	0.03	0.01	0.14
3	256	1	0.4	0.01	0.01	0.10
4	256	4	1.6	0.01	0.01	0.11
5	256	3	1.2	0.01	0.01	0.10
6	256	4	1.6	0.01	0.01	0.11
7	256	1	0.4	0.01	0.01	0.10
8	256	4	1.6	0.01	0.01	0.11

Table 3 (cont)

9	256	2	0.8	0.01	0.01	0.10
10	256	0	0.0	0.01	0.01	0.09
2007						
1	256	1	0.4	0.01	0.01	0.10
2	256	10	3.9	0.02	0.01	0.13
3	256	2	0.8	0.01	0.01	0.10
4	256	6	2.3	0.01	0.01	0.12
5	256	2	0.8	0.01	0.01	0.10
6	256	4	1.6	0.01	0.01	0.11
7	256	0	0.0	0.01	0.01	0.09
8	256	3	1.2	0.01	0.01	0.10
9	256	2	0.8	0.01	0.01	0.10
10	256	0	0.0	0.01	0.01	0.09

Appendix A.

Protocols established by Dodd (1989) to predict tassel-eared squirrel density using feeding sign counts.

GUIDELINES FOR APPLYING A TASSEL-EARED SQUIRREL FEEDING SIGN INDEX TO ESTIMATE SPRING DENSITY

Sampling Design

Utilization of the tassel-eared squirrel feeding sign density index technique is predicated upon applying the same general design used by Dodd et al. (1998). This design includes 64 "intervals", each 70 m in length. The intervals may be oriented either in a grid (e.g., 8 X 8) or transect design, depending on configuration of habitat to be sampled. The 8 X 8 grid design requires a minimum area of 24 ha. Within each interval, 4 1-m^2 plots are spaced an even distance apart, or approximately 17.5 m (at 0, 17.5, 35.0, and 52.5 m along each interval), for a total of 256 m^2 sampling plots. At the end of each transect line (if a grid design is employed), the 17.5, 35.0, and 52.5 m plots are spaced between lines.

Sampling Criteria

Timing of index counts.--The spring period was the only season that Dodd et al. (1998) were able to establish consistent relationships from year to year between squirrel feeding sign and density, partly owing to the consistent limiting nature of food resources at this time. As such, feeding sign counts should be conducted only during the period mid-March through late-May.

Conducting index counts.--Index counts should be accomplished with a 1 m2 plot frame constructed of wire, small steel rod, or other rigid material, preferably with an open front to facilitate placement under small trees, shrubs, etc. The distance between plots is paced off (observers will need to calibrate pacing required for 17.5 m) and the plot frame is placed on the ground just beyond the observer's feet. Feeding sign frequency of occurrence is determined by determining presence ("1" on the form) or absence ("0" on the form) on each plot. Feeding sign presence is recorded for any sign that falls within any part of the sampling frame; the entire feeding sign item need not fall within the sampling plot.

Feeding Sign Criteria

It is important to the accuracy of the density index technique to assess presence/absence of only relatively fresh feeding sign, sign reflective of squirrel feeding during the spring period. The following criteria serve as guidelines to determining whether to consider squirrel feeding sign as fresh and present on sampling plots. Rasmussen et al. (1975)

provide an excellent guide to differentiating tassel-eared squirrel feeding sign from that of other species.

Terminal clippings.--The most prevalent evidence of spring feeding by tassel-eared squirrels is ponderosa pine terminal needle clusters, or clippings. Any intact clippings exhibiting green coloration are recorded as present. Older clips from early spring may be faded and only exhibit green on the undersides; such clippings are counted as present. Do not count the larger nest clippings, on which the terminal clipping is still attached to the limb. Clippings from fall and early winter, or from the previous year are generally discolored and dark (from snow coverage), and the clusters easily disintegrate when picked up.

Peeled Twigs.--The peeled ponderosa pine twigs from which squirrels have removed the inner bark are typically bright and whitish when fresh, appearing similar to a pencil. They quickly become discolored in the spring and summer. Twigs that are predominately bright or whitish should be counted as present on the sampling plots.

Ovulate Cone Cores/Cobs.--Considerable spring feeding on mature ponderosa pine ovulate cones has been documented, probably from scatterhoarded pinecones. After tassel-eared squirrels have removed the scales from ponderosa pine ovulate cones, the appearance is that of a corn cob (Brown 1984). When fresh, these cone cores have a consistent bright yellow to reddish coloration. With age, cone cores become dark and devoid of bright coloration. With increasing age, cone cores exhibit oxidation on the side resting on the ground/litter surface, and take on a “two-tone” appearance. Only cones exhibiting bright yellow to reddish coloration should be counted as present when conducting index counts.

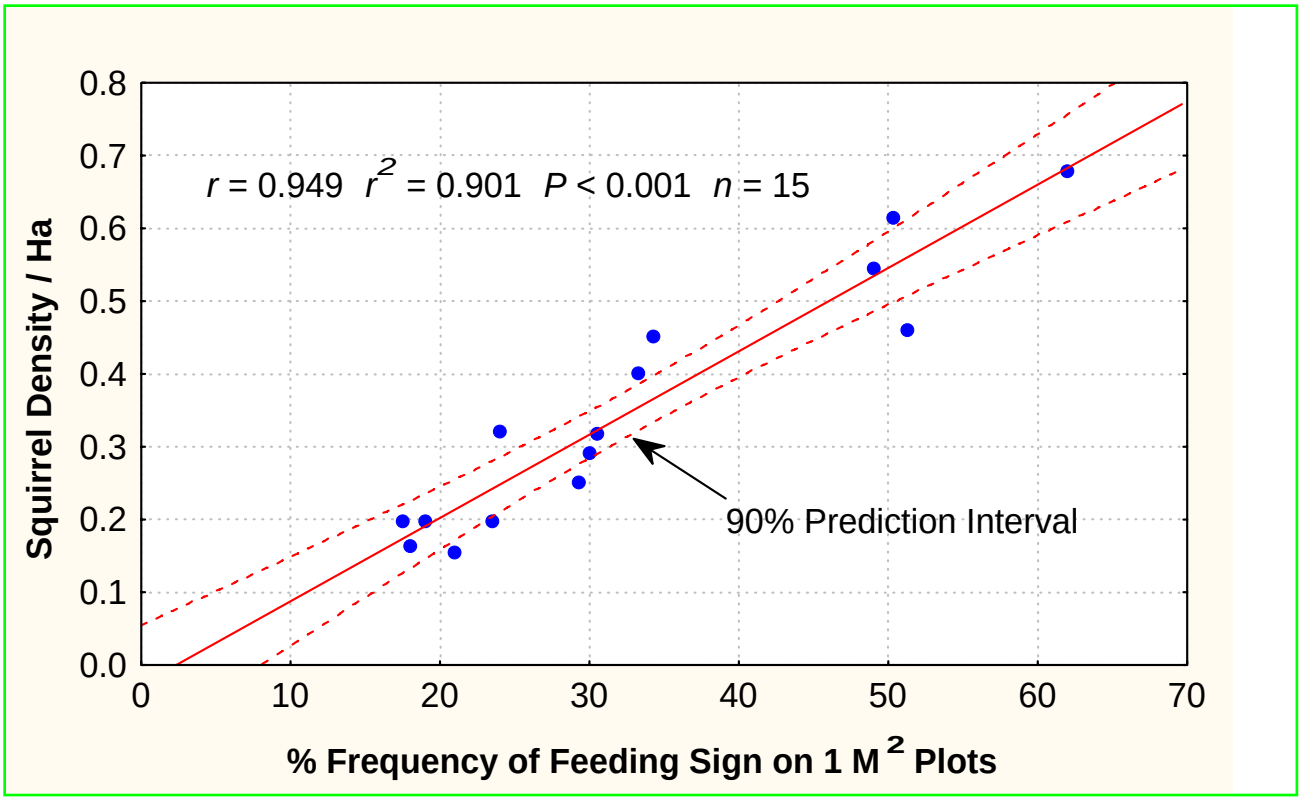
Staminate cones/flowers.--Squirrels feed on the male, pollen-producing cones/flowers in late-spring. Evidence of feeding on the staminate cones is typically limited, but any sign noted should be counted during feeding index counts.

Apical buds.--In the spring, squirrels will feed on ponderosa pine apical buds, which often have an appearance similar to terminal clippings, only smaller. These should be recorded as present when noted as they are fed upon by squirrels only during the spring and early summer. Apical bud feeding sign from the previous year will not persist.

Hypogeous fungi digs.--Depending on the amount of winter moisture and temperature, squirrels may begin feeding on mycelium and fruiting bodies of hypogeous fungi, of “truffles” during the spring. Fungi digs are persistent evidence of feeding by squirrels, and may be from 3-15 cm in depth. Some digs are shallow (<3 cm in depth), and may be attributable to other rodents, or are “exploratory” in nature; these shallow digs or pits are not counted as squirrel feeding sign during index counts. Also, relatively fresh digs counted during index counts are those that exhibit fresh digging, are not covered with litter, or have not been partially filler with soil.

Analyzing Index Count Data and Estimating Density

Following index counts, feeding sign frequency of occurrence at each sample site is computed as a percentage of the 256 m^2 plots exhibiting fresh sign. Tassel-eared squirrel density is estimated using the feeding sign index regression model curve, plotting percentage of plots with feeding sign against density; the regression equation may also be used to calculate density. The model curve also includes a 90% prediction interval band around the density estimate, appropriate for management-level monitoring and decision making. The prediction interval band reflects the statistical power and accuracy of the regression model, as non-overlapping intervals denote significantly different densities between or among sample sites. Density estimates and prediction intervals may also be computed using the regression module in STATISTICA©, SPSS©, or other statistical computer programs. Data to generate such regression models will be provided upon request.


r = 0.949 r2 = 0.901 P < 0.001 n = 15
90% Prediction Interval
Squirrel Density / Ha
% Frequency of Feeding Sign on 1 M2 Plots
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10
20
30
40
50
60
70

Appendix B.

Data sheet for measuring feeding sign through index counts used in the Lakeside Ranger District May of 2007.

2007 Region 1 Tassel-Eared Squirrel Density Estimation Index Counts

Study Site_____ Grid Number: _____

Line Number:_____ Sample Plot (circle) A B C D E F G H

Observer_____ Date_____

Start: UTM E_____ UTM N_____

END: UTM E_____ UTM N_____

Plot #	Index Hit (Circle)		Comments
1	Y	N	
2	Y	N	
3	Y	N	
4	Y	N	
5	Y	N	
6	Y	N	
7	Y	N	
8	Y	N	
9	Y	N	
10	Y	N	
11	Y	N	
12	Y	N	
13	Y	N	
14	Y	N	
15	Y	N	
16	Y	N	
17	Y	N	
18	Y	N	
19	Y	N	
20	Y	N	
21	Y	N	
22	Y	N	
23	Y	N	
24	Y	N	
25	Y	N	
26	Y	N	
27	Y	N	
28	Y	N	
29	Y	N	
30	Y	N	
31	Y	N	
32	Y	N	