

**Summer 2004 Resurveys of Kaibab Squirrel Plots on Walhalla Plateau,
Grand Canyon National Park**

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Abstract

Plots established by Dr. J.G. Hall in the early 1960s were revisited with two primary goals in mind. First, to document the presence of Kaibab squirrel activity, measured as terminal needle clusters from ponderosa pine trees and associated stripped subterminal twigs. Second to determine if there had been a change in the level of observed activity since surveys were done in 2001 and 2002. The data collected in 2004 showed no systematic change in the number of terminal needle clusters, the number of twigs, or the proportion of plots with these feeding signs in them since the surveys were re-started in 2001. The location of the feeding has shifted slightly; plots which had signs of feeding in 2001 and 2002 did not have sign in 2004 and sign was found in others in which no feeding had been evident in the previous two surveys. However, the overall level of occupancy and feeding activity (measured in this way) had not changed significantly since 2001. This led to the conclusion that there has not been a great deal of change in the abundance of squirrel feeding sign, and that these data support a view in which squirrel activity occurs in cycles which may vary spatially across the whole North Rim.

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Background

Kaibab squirrels (*Sciurus aberti kaibabensis*) inhabit the fire-adapted ponderosa pine forest on the Kaibab Plateau in northern Arizona. In addition to being the “most handsome squirrel in North America” (Hall 1981), the species has attracted the attention of biologists owing to its restricted range and habitat associations, its function as a food source for northern goshawks, and an indicator of ponderosa pine forest health. The closely related Abert squirrel (*Sciurus aberti aberti*) is found in the ponderosa forests south of the Grand Canyon and elsewhere in the western United States.

Their food habits are what tie the Kaibab squirrels to the ponderosa pine forests. The squirrels feed almost exclusively on parts of ponderosa pines or plants and fungi symbiotic with them (Hall 1981). The apparent order of preference for different parts of the tree, based on 15 years of observation on the North Rim of Grand Canyon is as follows: ovulate cones, staminate cones, apical buds, and phloem from subterminal twigs (Hall 1981). The preference order correlates with the relative caloric contents of the different parts. Fungi, especially species of the hypogeous *Gauteria* which is symbiotic with ponderosa pine on the Kaibab Plateau, are eaten seasonally. Tree parts, especially the phloem, are the most important elements in the diets of squirrels in Grand Canyon National Park (Hall 1981). Although other foods are preferred, the phloem is always there, becoming more important as other parts become unavailable.

Signs of feeding by these animals on phloem tissue are easy to spot because the process is a messy one. Squirrels feed on the phloem by taking off the ends of small branches and breaking off the current year’s needle clusters which they allow to drop to the ground. They then peel off bark from the 1-year old wood and scrape the inner bark with their teeth. The inner wood on the twig is also dropped to the ground. Terminal needle clusters and bare twigs litter the forest floor beneath trees in which squirrels have been feeding.

Human activities in the ponderosa pine forests of northern Arizona have profoundly affected its appearance and functioning. Of these activities, fire suppression has probably had the most serious impact. Without frequent, low-intensity fires to reduce fuel loads and thin seedlings and saplings, forests proceed from woodlands with open canopies and a few large individuals to dense stands with closed canopies and large numbers of relatively small individuals known as “dog hair thickets” (Covington and Moore 1994a, b).

The effects of fire suppression on the structure and vigor of ponderosa forest likely has effects which cascade up the food chain to the squirrels and the species which rely on them. The terpene and sugar chemistry of phloem in the pines explains much of the difference between feeding trees and non-feeding trees for Kaibab squirrels in Grand Canyon (Thomas 1979) and for the related Abert squirrel elsewhere (Snyder 1992). These elements of the phloem are known to respond to stress, shading, and other effects of crowding seen in fire-suppressed ponderosa pine forests (Wilkins et al. 1997). This

would lead to the expectation that the quality of phloem resources is likely declining in the forests of the Kaibab Plateau.

Walhalla Plateau study plots and feeding trees

Between 1960 and 1964, Dr. Joseph G. Hall established plots for studying the activity and feeding habits of Kaibab squirrels on the main roads and fire roads of the Walhalla Plateau on the North Rim of Grand Canyon National Park. The original 10 rectangular quarter-acre plots along fire roads E4, E4a, and E6 were supplemented with 106 circular tenth-acre plots along the same roads, plus fire roads E5 and E7 (Cape Final Road) and Cape Royal Road. The circular plots were easier to relocate and re-establish, as doing so required finding only one point (J.G. Hall, *pers. comm.*) and minimized potential problems with edge effects (see James and Shugart 1970, Krebs 1989 pp 64 - 68). In 1972, Park employee Kim Fene replaced the wooden stakes in the centers of 68 of the tenth-acre plots with 1-meter steel "T" posts, thus making them easier to relocate in the event of fire and less susceptible to disturbance by wildlife and humans.

Except for years when he was traveling, Dr. Hall visited most of these plots annually between 1961 and 1976, and assessed the level of squirrel feeding activity which had taken place during the preceding winter and spring. Each June, he counted the number of fallen terminal needle clusters within each plot. Although needle clusters may fall for many reasons (Rasmussen et al. 1975, Hall 1981), only those clusters in plots which had at least two of the bare twigs which result from Kaibab squirrel feeding were counted. Once a needle cluster was tallied, it was broken up and scattered to prevent it being counted again. The number of needle clusters in the plots was then used as an index of Kaibab squirrel activity in that plot.

All 68 plots were relocated in 1999 and 2000, in part with the assistance of Dr. Hall, and documented with photographs, written descriptions, tree measurements and coordinates from a hand-held Global Positioning System (GPS) unit (Kearsley and Hall 2004). During the relocation work in 2000, all accumulated needle clusters and feeding twigs were removed from the plots so that subsequent surveys would be assured of counting only sign from the previous winter. In 2001 and 2002, the plots were resurveyed for feeding sign. Analyses of the data on twigs and needle clusters showed that there was no measurable difference between data from 2001 and 2002 and that from the surveys 30 years earlier (Kearsley and Hall 2004).

Objectives

The three objectives of this study relate to the resurvey of plots which had been surveyed in the 1960s and 1970s and again in 2001 and 2002. The specific objectives were:

1. To relocate 68 "permanent" plots which had been surveyed for Kaibab squirrel activity on an annual basis between 1961 and 1972 and again in 2001 and 2002.
2. To assess the level of Kaibab squirrel activity in the plots during the winter and early spring by counting the abundance of terminal needle clusters associated with bare subterminal twigs in the plots.
3. To compare the levels of Kaibab squirrel activity in the years of our surveys with the range of values recorded in 2001 and 2002.

Methods

Plot relocation. The field work for this report took place during a single, 5-day trip in July of 2004. Each plot was relocated with a two-step process. First, the survey team would get close to plots by using the “Go To” feature on a handheld GPS unit (GPS II Plus, Garmin Industries, Olathe KS) while traversing the roads.. When the unit indicated that the plot was within 20m, we began looking for the roadside cairn which marked the position of pairs of plots and/or the steel “T”-post marking their centers. All 68 plots were located in this way without a problem. A map of the distribution of the plots is shown in Figure 1. Once a plot center was located, the location of the perimeter of the plot was determined by attaching a 17.95m rope to the “T”-post and walking around the edge of the circle described by that radius.

Squirrel Feeding Activity Measurements. To determine the level of squirrel winter feeding in the plots we repeated the methods used by Dr. Hall for the original surveys (Hall 1981). This involved counting all of the clipped terminal needle clusters in the plots. At the same time, the number of bare subterminal twigs were counted as well. Subterminal feeding twigs were thrown out of the plots and terminal needle clusters were broken up so that no needles remained on the twig. In the few cases where more than 200 clusters were present, many of them were simply thrown out of the plot into the surrounding forest to speed up the survey work. Following the example of the Dr. Hall’s original analyses, we used data only from plots in which at least two subterminal feeding twigs were found. Plots with one or no subterminal twigs were assigned a cluster number of zero.

Data Analysis. To determine if there were changes in the measures of squirrel activity we compared the number of terminal needle clusters in plots in 2004 to those found in 2001 and 2002 in two ways. First, for a coarse, but more general test, we tallied the number of plots on each road which had terminal needle clusters attributable to Kaibab squirrel feeding. This was converted to a proportion of all plots on that road. These data were analyzed with repeated measures ANOVA. The proportion of plots was arcsine square-root transformed before the analysis to meet assumptions of equality of variance of the ANOVA. A second ANOVA was run to test for consistent differences among roads. Second, to measure patterns on a finer scale, both the numbers of twigs and the numbers of terminal needle clusters were also analyzed with repeated measures ANOVA, after being square-root transformed. Data from plots were pooled within roads so that the road itself was the experimental unit. Again, a second ANOVA was performed to test for differences among roads.

Results

Plot occupancy. There was no statistical difference among the years 2001, 2002 and 2004 in the proportion of plots with squirrel activity. In 2004, the proportion of plots was slightly lower than in 2001, but higher than that in 2002 (Figure 2; $F_{(2,4)} = 0.808$, n.s.). Roads did not differ systematically in the proportion of occupied plots either ($F_{(5,10)} = 0.526$, n.s.).

Feeding signs. Nor was there a difference in the number of terminal needle clusters or twigs found in 2004. The number of needle clusters was intermediate to those seen in 2001 and 2002 (Figure 3; $F_{(2,4)} = 4.01$, $p > 0.10$). Similarly, the number of twigs were lower than counts in 2001 but higher than those in 2002 (Figure 4; $F_{(2,10)} = 3.95$, p

= 0.113). There were no consistent differences among the six roads over the three year period in terms of either number of clusters or number of feeding sticks ($F_{(5,10)} = 0.48$, $p = 0.783$ and $F_{(5,10)} = 1.21$; $p = 0.367$, respectively).

Discussion.

The data showed that there has not been a measurable change in the abundance of feeding sign during the three years of surveying these plots since they were cleared out of sign in 2000. There was a marginal trend towards a lower number of feeding sticks during the driest year (2002). The other two measures showed no consistent pattern of change at all.

A comparison of the behaviors of these measures by individual roads shows that while the overall numbers of signs (occupancy, clusters and sticks) has remained more or less constant, the numbers have varied widely within individual roads (Figure 5). Thus, the conclusion of a static amount of feeding activity should be tempered by including the scale at which the conclusion is made; the small amount of between-year change overall was comprised of many larger changes whose effects cancelled each other out.

Using this perspective, conclusions about changes in Kaibab squirrel populations in Grand Canyon National Park should include information about the scale at which they were drawn. Had conclusions from this study been taken from occupancy data from one or two roads, they may have included warnings of calamitous declines (E5, E6) or surges in abundance (Cape Royal, E7). By including a broader geographic range with all of the plots, the conclusion would seem to be one of a dynamic stasis, with feeding activity shifting in location, but remaining relatively constant overall. Previous reports (original citations in Hoffmeister 1971 and Hall 1981) have shown similar patterns of variability within smaller geographic areas.

The limitations of the data types collected here prevent the direct extension from these trends to trends in squirrel population sizes on the Walhalla Plateau. Many factors will affect the abundance of feeding sign from Kaibab squirrels. An abundance of subterminal twigs may actually signal a decline in the abundance of other, more preferred foods (e.g., fungi and seeds). However it would appear that these data point away from a precipitous decline in the abundance of Kaibab squirrels on the Walhalla Plateau. Data from previous work (Kearsley and Hall 2005) also show that activity has not changed a great deal from a series of surveys done in the 1960s and early 1970s.

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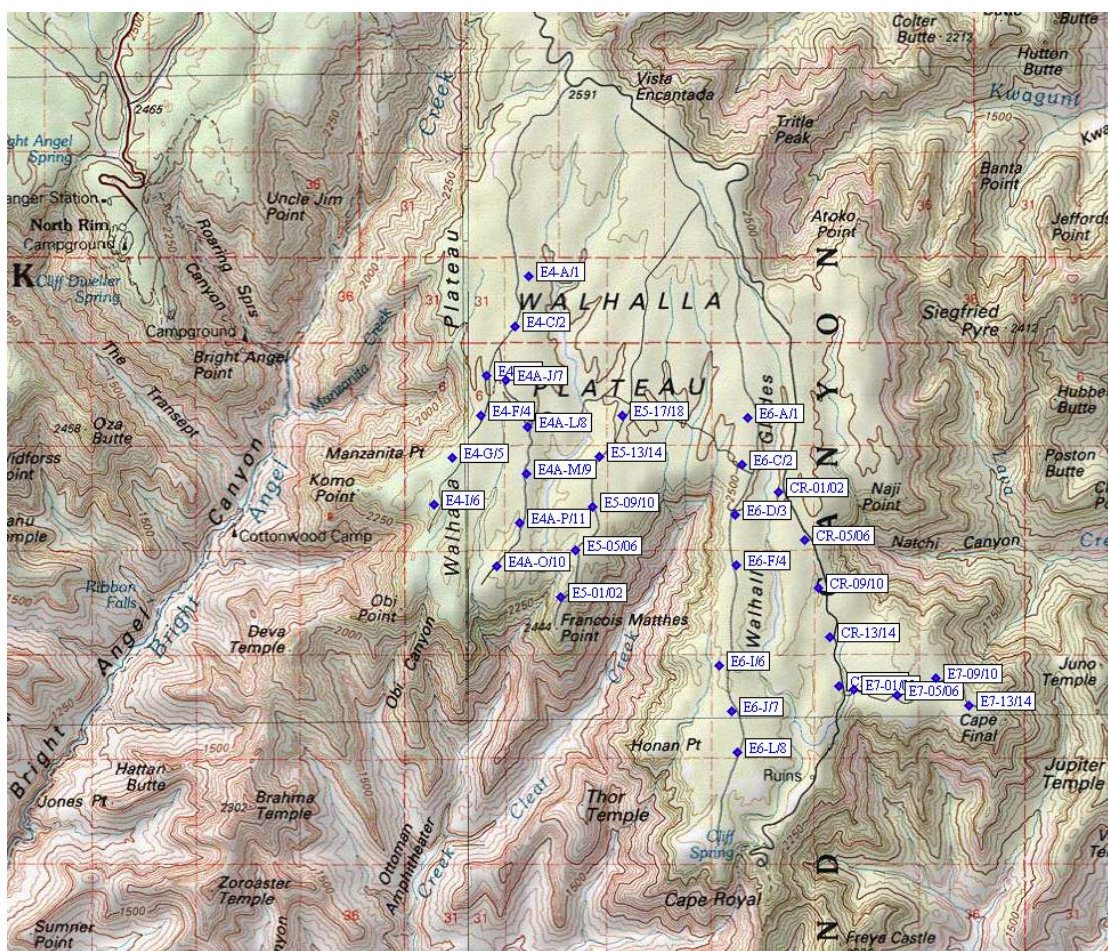


Figure 1. Study plot locations on the Walhalla Plateau. Each point represents the location of a cairn which marks the side of the road where plots are found on either side of the road.

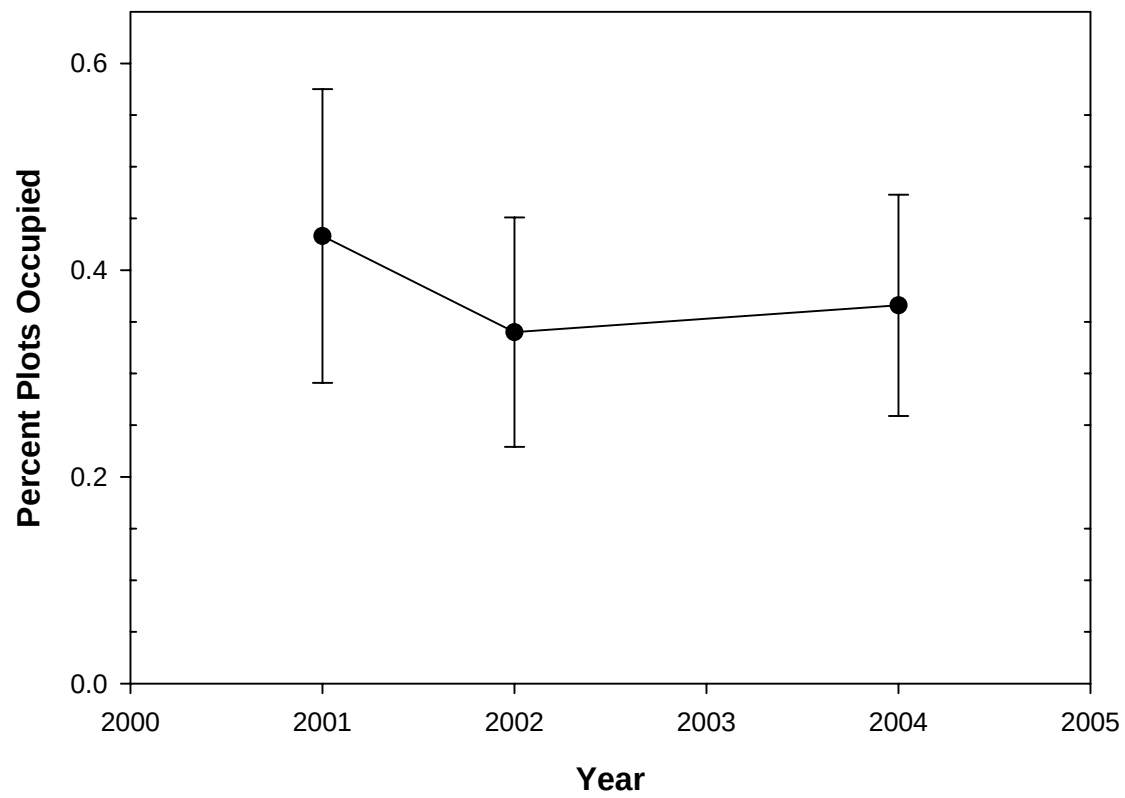


Figure 2. Percent of plots with Kaibab squirrel feeding sign in 2001 to 2004. Vertical bars represent ± 1 standard deviation. Although the graph is based on straight percentages, statistics were conducted on transformed data.

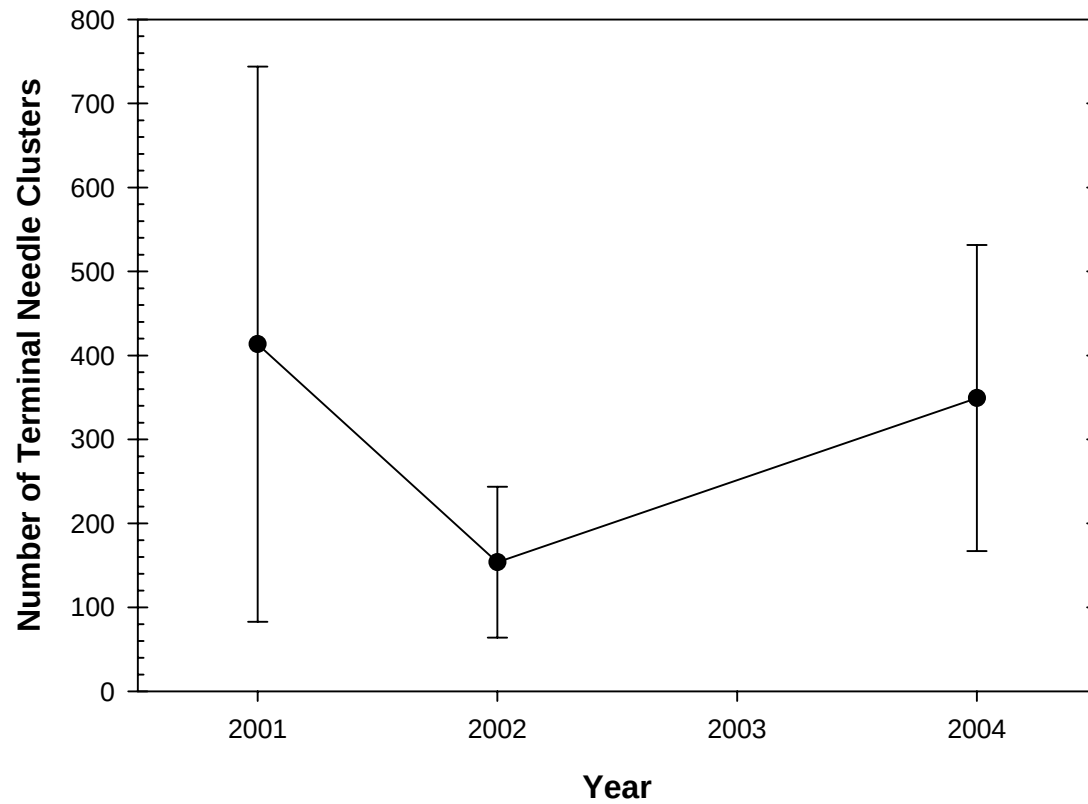


Figure 3. Number of terminal needle clusters attributed to Kaibab squirrel feeding activity per road in 2001 to 2004. Vertical bars represent ± 1 standard deviation. Although the graph is based on straight numbers, statistics were conducted on transformed data.

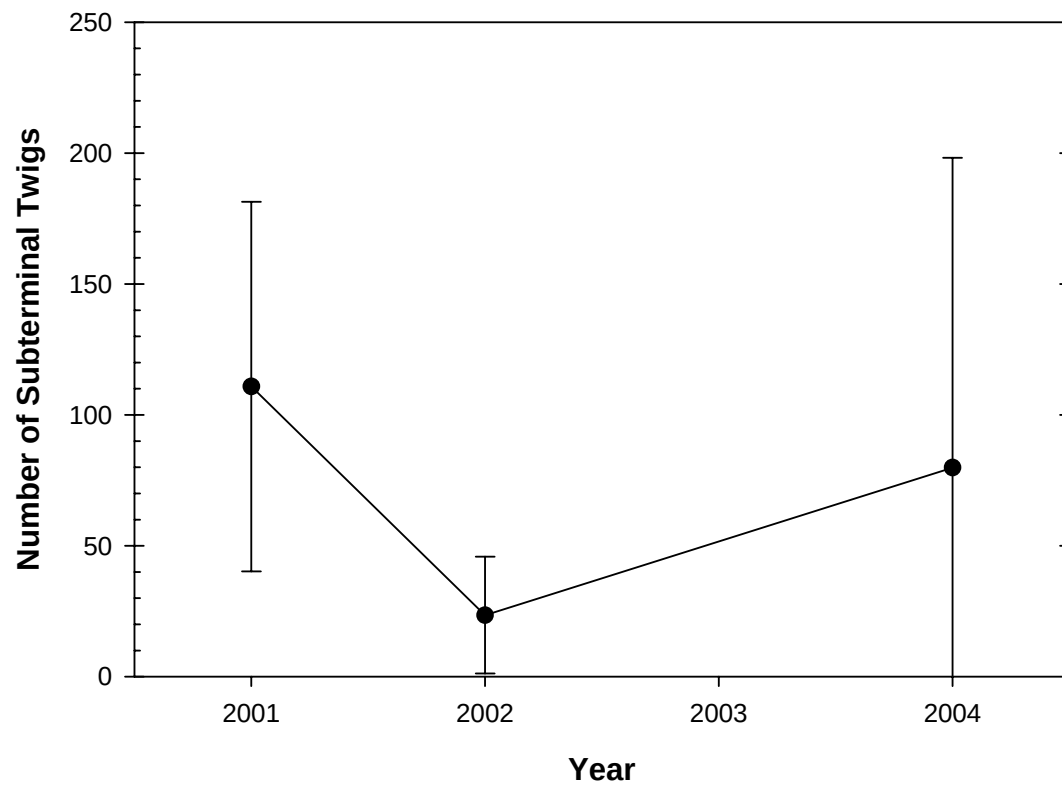


Figure 4. Number of subterminal twigs per road in 2001 to 2004. Vertical bars represent ± 1 standard deviation. Although the graph is based on straight numbers of feeding twigs encountered, statistics were conducted on transformed data.

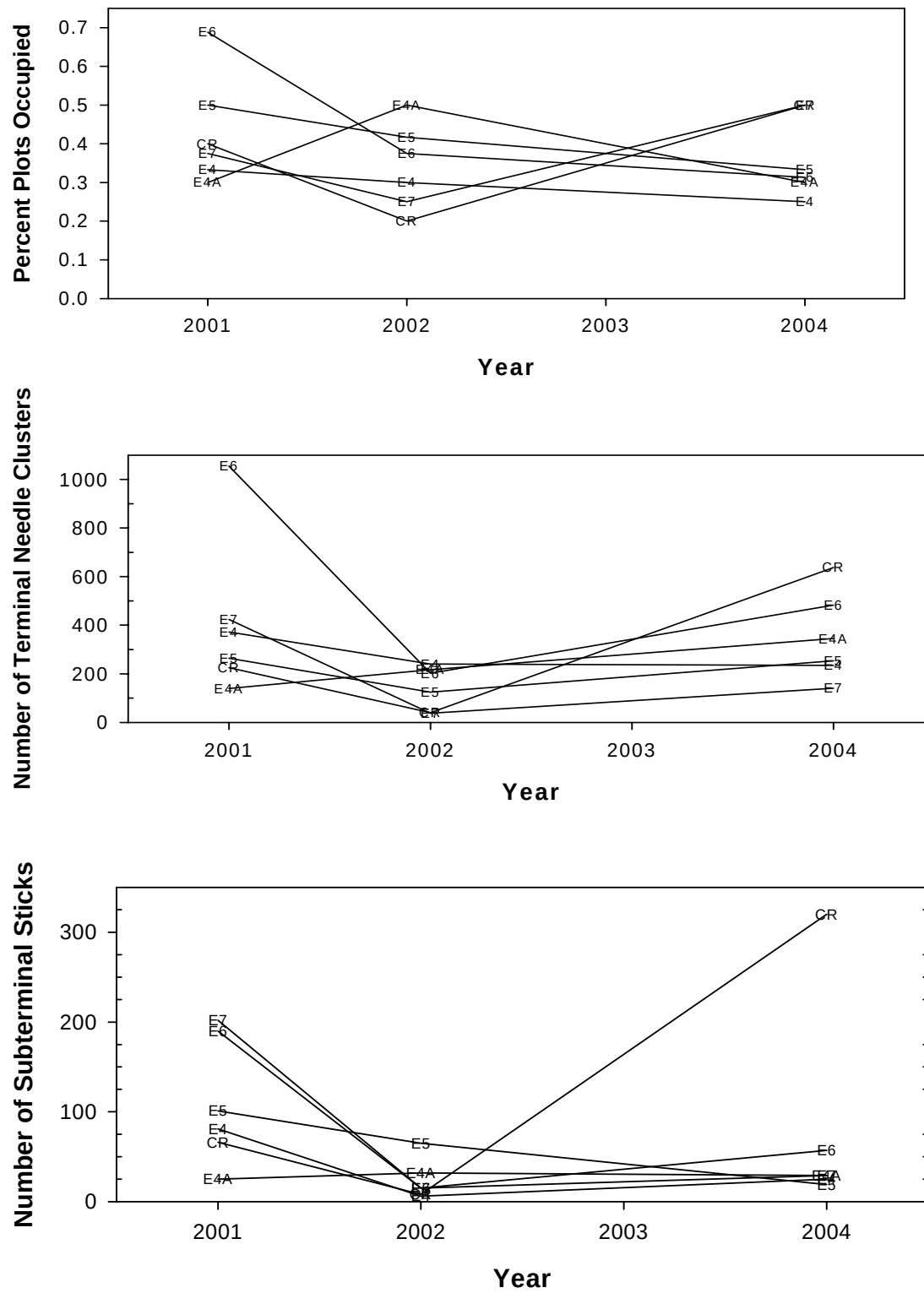


Figure 5. Changes in rates of “occupancy” (top), numbers of terminal clusters (middle) and feeding sticks (bottom) showing high variability of individual roads.