# WESTERN GRAY SQUIRREL STUDIES AT THE GEYSERS-CALISTOGA KNOWN GEOTHERMAL RESOURCE AREA

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ABSTRACT.

Western gray squirrels (*Sciurus griseus*) were live-trapped during the spring and fall of 1978 in Lake County, California. Study areas were located in yellow pine, mixed coniferous, and knobcone pine forests. A total of 3000 trap-nights were conducted in the spring; 3945 trap-nights were conducted in the fall. Throughout the study a total of 179 squirrels were captured and examined 297 times. Catch-per-unit-effort ratios, based upon total number examined, was 0.035 in the spring and 0.049 in the fall. Squirrel abundance was greater in the fall than in the spring. Fall densities were 2.0 squirrels-per-hectare in yellow pine and knobcone pine forests, and 2.8 squirrels-per-hectare in mixed coniferous forest. These data will be used in future geothermal planning at the Geysers-Calistoga Known Geothermal Resource Area to minimize or mitigate detrimental impacts upon western gray squirrels.

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## INTRODUCTION

Geothermal development is progressing rapidly to help offset the increasing demands for energy. Pacific Gas and Electric Company (PGandE) is currently developing geothermal resources at The Geysers-Calistoga Known Geothermal Resource Area (The Geysers) of Lake and Sonoma counties. The Geysers is currently the world's largest geothermal energy producing field.

Planning and development at the Geysers has considered the growing concerns for environmental issues. PGandE has identified wildlife habitat loss as one of the major environmental issues associated with geothermal development. Geothermal energy production typically uses about 0.26 ha of wildlife habitat per megawatt produced (talk by W.C. Chouteau given at The Geysers Ecosystem Quality Workshop at Santa Rosa on October 25, 1977).

To accurately assess the wildlife impacts associated with geothermal development, PGandE has directed and conducted baseline studies on a variety of species at The Geysers (Stager 1976, Meneghin 1977, Stager 1977, Meneghin et al. 1978a, Meneghin et al. 1978b). This western gray squirrel (*Sciurus griseus*) study represents a single component of a larger study effort to quantify wildlife abundance in all major habitats of The Geysers. The objective of these studies is to develop adequate baseline data for environmental assessments. These data will also improve our ability to determine mitigation measures for geothermal impacts upon wildlife populations.

Western gray squirrels are an appropriate species to study for environmental assessments because: 1) they are an important game species, 2) they are fairly abundant, and 3) they are easily trapped. However, published literature on western gray squirrels is very limited (Swift 1977). This study presents baseline data for this species in 3 habitat types found at The Geysers.

I extend sincere appreciation to Mike Fry and Dirk Burcham for their field assistance throughout the study. I also thank Gary Meneghin for his careful review of the manuscript.

## MATERIALS AND METHODS

Western gray squirrels were live-trapped in 3 forest types of Lake County, California (Figure 1). The study areas were located in yellow pine, mixed coniferous, and knobcone pine forests. Vegetation data regarding the tree layer in the 3 habitats are presented in Table 1.

Trapping was conducted in yellow pine and mixed coniferous forests during the spring (24 April - 9 June) and fall (2 October - 10 November) of 1978. Knobcone pine forest was trapped once in the fall (11-29 September) of 1978.

Traps utilized in this study were single-door collapsible Tomahawk live-traps measuring 15 X 15 X 48 cm. Traps were placed in a grid configuration based upon a station interval of 50 m. A 10 X 10 station grid was established in yellow pine and mixed coniferous forests; knobcone pine forest was trapped with a 7 X 9 station grid.

Trapping sessions consisted of 15 trap-nights conducted during a 19-day period. Each session was preceded by a 10-day prebaiting period. Prebait stations were checked on alternating days; traps were checked daily. Stations and traps were baited with 80 gm of cracked "pick-out" walnuts.

A new procedure was developed to handle trapped squirrels without the use of drugs or anesthetizing agents. Handling equipment included a 2 cm mesh fish net (Taber and Cowan 1971), heavy leather gloves, and a small noosing device (Fry et al., unpublished manuscript in preparation). The noosing device was essentially a 50 cm long "come-along". It was made of plastic coated wire threaded through the end of a 2 cm diameter metal pipe. The handling procedure required a minimum of 2 people; however, 3 people were preferred.

TABLE 1. Species composition, density, and basal area of the tree layer in yellow pine (YP), mixed coniferous (MC), and knobcone pine (KP) forests.

| Species | Composition (percent) | | | Density (trees/ha) | | | Basal Area ($m^2$/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | YP | MC | KP | YP | MC | KP | YP | MC | KP |
| Yellow pine *Pinus ponderosa* | 80 | 26 | 0 | 323 | 92 | 0 | 33 | 9 | 0 |
| Knobcone pine *P. attenuata* | 0 | 0 | 41 | 0 | 0 | 340 | 0 | 0 | 19 |
| Sugar pine *P. lambertiana* | 5 | 0 | 0 | 20 | 0 | 0 | <1 | 0 | 0 |
| Douglas fir *Pseudotsuga menziesii* | 5 | 35 | 0 | 20 | 120 | 0 | <1 | 8 | 0 |
| Incense cedar *Libocedrus decurrens* | 0 | 6 | 0 | 0 | 21 | 0 | 0 | 3 | 0 |
| Madrone *Arbutus menziesii* | 0 | 8 | 0 | 0 | 28 | 0 | 0 | 2 | 0 |
| Black oak *Quercus kelloggii* | 7 | 25 | 0 | 28 | 88 | 0 | 4 | 11 | 0 |
| Canyon oak *Q. chrysolepis* | 1 | 0 | 49 | 4 | 0 | 417 | <1 | 0 | 64 |
| Canyon live oak *Q. wislizenii* | 0 | 0 | 2 | 0 | 0 | 17 | 0 | 0 | <1 |
| California bay *Umbellularia californica* | 0 | 0 | 7 | 0 | 0 | 60 | 0 | 0 | <1 |
| Hoary manzanita *Arctostaphylos canescens* | 2 | 0 | 1 | 8 | 0 | 9 | <1 | 0 | <1 |

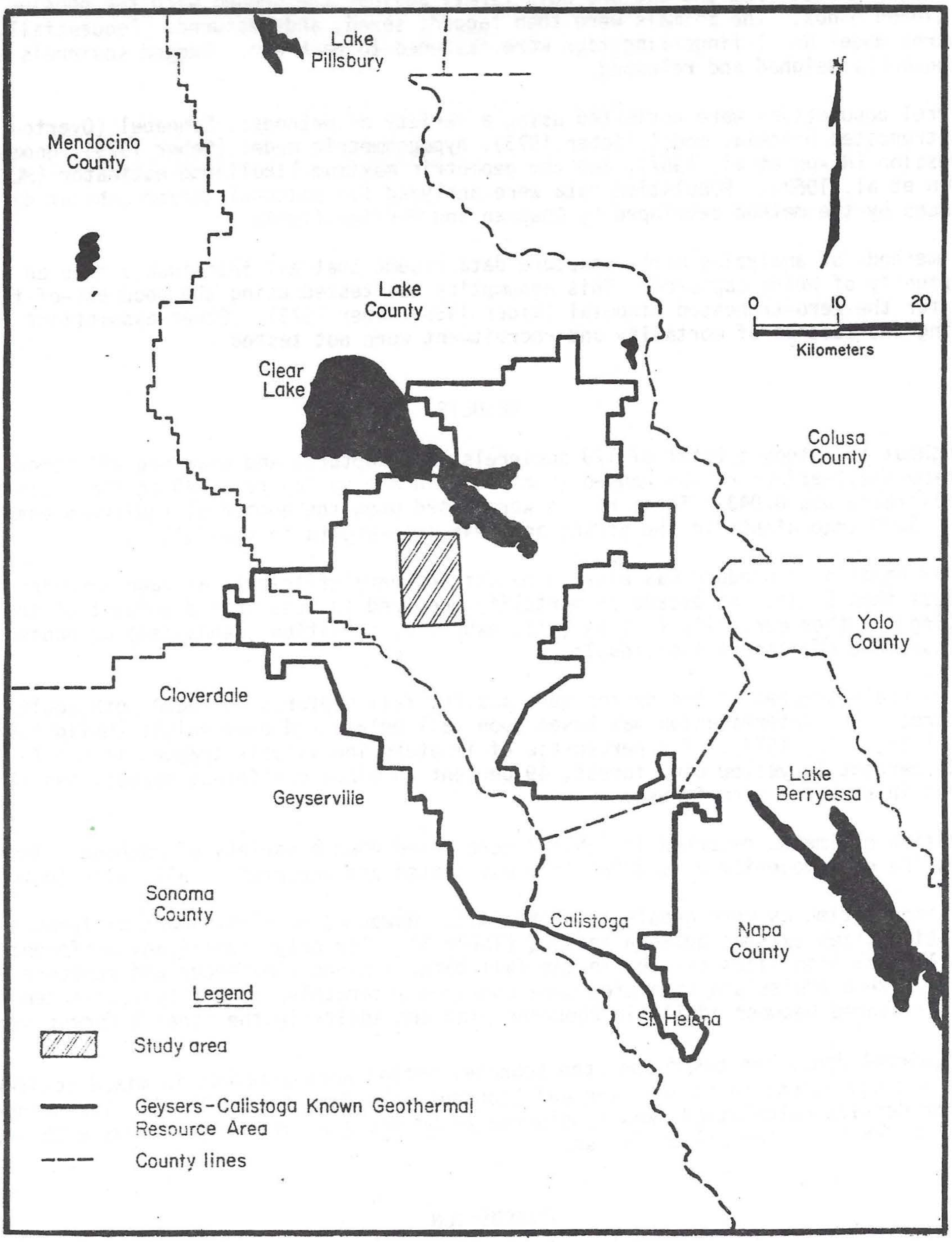


FIGURE 1. Location of The Geysers Known Geothermal Resource Area and the western gray squirrel study area.

Captured squirrels were initially transfered from the trap to the fish net bag. They were then removed from the bag and held firmly against the ground with the noosing device and gloved hands. The animals were then tagged, sexed, and measured. Sequentially numbered model No. 1 fingerling tags were fastened to each ear. Tagged squirrels were subsequently weighed and released.

Squirrel populations were estimated using a variety of methods: Schnabel (Overton 1971), zero-truncated binomial model (Seber 1973), hypogeometric model (Seber 1973), geometric regression (Nixon et al. 1967), and the geometric maximum likelihood estimator (MLE) (Nixon et al. 1967). Population data were analyzed for seasonal and/or habitat differences by the method developed by Chapman and Overton (1966).

Most methods of analyzing mark-recapture data assume that all individuals have an equal opportunity of being captured. This assumption was tested using the goodness-of-fit test for the zero-truncated binomial (Rider 1955, Seber 1973). Other assumptions regarding the absence of mortality and recruitment were not tested.

## RESULTS

Throughout the study a total of 179 squirrels were captured and examined 297 times. Catch-per-unit-effort ratios ranged from 0.035 in the spring to 0.049 in the fall; the overall ratio was 0.043. These ratios were based upon the number of squirrels examined during 3000 trap-nights in the spring and 3945 trap-nights in the fall.

The new handling procedure was easy to master and very efficient; average handling time was less than 5 min. An escape or mortality occurred in less than 3 percent of the total handlings. Other mortality factors (viz. exposure, predation, vandalism) accounted for the loss of 6 additional incividuals.

All squirrels trapped in the spring were adults; fall captures included both adults and immatures. Age determination was based upon tail pelage and body weight (Uhlig 1955, Sharp 1958, Swift 1977). The percentage of immature individuals trapped in the fall was 36 percent in yellow pine forest, 49 percent in mixed coniferous forest, and 73 percent in knobcone pine forest.

Population estimates reported in Table 2 were based upon a variety of methods. The assumption of homogenity of catchability was tested and accepted in all cases ($p > 0.05$).

Population estimates were greatest in the fall. However, no significant difference in population sizes existed between seasons (Table 3). The only significant difference in overall population sizes existed in the fall between mixed coniferous and knobcone pine forests. When adults and immatures were compared separately, significant differences were discovered between adults in knobcone pine and adults in the other 2 forest types.

Gray squirrel densities based upon the Schnabel method were greatest in mixed coniferous forest and equivalent in yellow pine and knobcone pine forests (Table 4). The trappable area for density calculations was considered to be the area of the grid plus a 25 m (one-half trap station interval) buffer strip.

## DISCUSSION

The 3 habitats studied represent 3 distinct forest types of the California Inner Coast Range. The relative value of these habitats to western gray squirrels can be established in several ways: 1) compare the quantity and quality of specific habitat parameters important to gray squirrels, or 2) compare abundance of squirrels associated with each habitat. Determining which habitat features are important to a species is an arduous task and unrealistic for the objectives of this study. Therefore, I felt that relative abundance or density estimates (where justified) were the best indicators of the relative value of each habitat to gray squirrels.

TABLE 2. Population estimates of western gray squirrels for three forest habitats of Lake County, California. All estimates were based upon 25 ha trapping grid.

| Habitat | Method<br>Schnabel | Hypo-geometric | Zero-truncated Binomial | Geometric Regression | Geometric MLE |
|---|---|---|---|---|---|
| Yellow Pine (Spring) | 45.9 | 45.0 | 45.9 | 54.8 | 82.9 |
| Yellow Pine (Fall) | 49.1 | 51.0 | 53.0 | 54.2 | 97.1 |
| Mixed Coniferous (Spring) | 61.2 | 54.0 | 54.0 | 116.1 | 100.3 |
| Mixed Coniferous (Fall) | 65.7 | 61.0 | 60.3 | 55.0 | 101.6 |
| Knobcone Pine (Fall) | 51.0 | 53.0 | 53.8 | 31.4 | 92.4 |

TABLE 3. Comparisons of populations for three forest habitats of Lake County, California. Comparisons are based upon Chapman and Overton method (1966). $H_0$= populations are not significantly different.

| Habitat | | Habitat | P | Conclusion |
|---|---|---|---|---|
| Yellow Pine-Spring* | | Yellow Pine-Fall* | 0.968 | n.s. |
| (Adults) | vs | (Adults) | 0.300 | n.s. |
| Mixed Coniferous-Spring* | vs | Mixed Coniferous-Spring* | 0.841 | n.s. |
| (Adults) | vs | (Adults) | 0.234 | n.s. |
| Yellow Pine-Spring* | vs | Mixed Coniferous-Spring* | 0.542 | n.s. |
| Yellow Pine-Fall* | vs | Mixed Coniferous-Fall* | 0.377 | n.s. |
| (Adults) | vs | (Adults) | 0.685 | n.s. |
| (Immatures) | vs | (Immatures) | 0.988 | n.s. |
| Yellow Pine-Fall* | vs | Knobcone Pine-Fall* | 0.749 | n.s. |
| (Adults) | vs | (Adults) | 0.0006 | Reject Ho |
| (Immatures) | vs | (Immatures) | 0.960 | n.s. |
| Mixed Coniferous-Fall* | vs | Knobcone Pine-Fall* | 0.017 | Reject Ho |
| (Adults) | vs | (Adults) | 0.00004 | Reject Ho |
| (Immatures) | vs | (Immatures) | 0.912 | n.s. |

*Total captures were considered (adults + immatures).

The choice of which method to use in estimating population levels is often an arbitrary decision. Hall and Stubbs (unpublished manuscript in preparation) present a detailed evaluation of the 5 methods used in this study. They concluded that the Schnabel method, while not the most robust, was adequate for these data. This method also enables us to compare our results with other studies because the Schnabel method is common in wildlife literature.

TABLE 4. Density estimates based upon the Schnabel method for three forest habitats of Lake County, California.

| Habitat | Density Estimates (Squirrels/ha) Spring | Fall |
|---|---|---|
| Yellow Pine | 1.8 | 2.0 |
| Mixed Coniferous | 2.5 | 2.8 |
| Knobcone Pine | - | 2.0 |

To my knowledge, only 2 other studies exist which report western gray squirrel densities (Asserson 1974, Schlorff 1978). Both authors reported higher densities in habitats similar to those studied here. However, I feel this discrepancy is probably a function of the methods employed rather than actual squirrel abundance. Both Asserson (1974) and Schlorff (1978) conducted fewer trap-nights over longer periods of time and on smaller grids than this study. Extended trapping periods are generally more influenced by mortality and recruitment. This influence might increase the ratio of new captures, thus inflating the density estimates.

The Chapman and Overton (1966) method of population comparison was based upon original mark-recapture data. Comparisons were totally independent of population estimates or standard errors. The method assumed that the number of recaptures was a poisson random variable. The distribution of these variables was binomial when the total number of recaptures was considered. The normal approximation was used to test the fit of the binomial.

Caution is advised when interpreting results of Chapman and Overton population comparisons. Their method is most accurate with large populations and a small probability of an individual being recaptured. However, the comparisons presented here are considered valid because the binomial model was tested and found to fit the data well( $P > 0.25$). The comparisons are probably conservatively biased if biased at all.

The only significant difference in population levels existed between adults in knobcone pine forest and adults in the other 2 habitats. The high immature/adult ratio in the knobcone pine data is obviously the reason for such a significant difference. Data from this study does not explain why the immature percentage in knobcone pine is so much higher than the other 2 habitats.

I was unable to locate comprehensive data on seasonal fluctuations in western gray squirrel abundance. Although squirrel numbers were greatest in the fall, seasonal differences were found to be insignificant in this study. The seasonal differences were probably a result of trapping new offspring in the fall. These findings correlated closely to studies on a similar species, the eastern gray squirrel (*Sciurus carolinesis*)(Flyger 1959, Barkalow et al. 1970, McDowell 1970, Bouffard and Hein 1978).

## MANAGEMENT IMPLICATIONS

Assuming that animal abundance is a good indicator of wildlife habitat value in geothermally undeveloped areas, the management implications of this study are the following: 1) mixed coniferous, yellow pine, and knobcone pine forests are important habitats for gray squirrels, 2) mixed coniferous forest has the highest habitat value for gray squirrels, and 3) density data can be used in future geothermal planning to minimize and/or mitigate for losses of gray squirrel habitat.

Data from this study will be used to determine the value of gray squirrel habitat which may be removed in future geothermal developments. Mitigation schemes will then be developed to compensate for the quantity and quality of lost gray squirrel habitat.

The current trend for mitigation at The Geysers is to improve critical habitat features in areas similar to those being impacted by new geothermal development. We feel that enhancement of unaltered habitat is the most effective means of mitigation if the enhancement potential exists.

PGandE is currently planning and implementing mitigation plans which will improve habitats for western gray squirrels. Specific habitat improvements include increasing the mast production and installing artificial nesting structures. An evaluation of the effectiveness of these measures will be based upon monitoring population responses. We feel that appropriate habitat improvements in areas adjoining new geothermal development might actually increase overall squirrel numbers.

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