THE UNIVERSITY OF

ARIZONA

MT. GRAHAM RED SQUIRREL MONITORING PROGRAM

Annual Report
for
1997

Submitted: 24 February 1997

Prepared by:

Paul J. Young, Supervisor
Vicki L. Greer, Biologist - Senior
Erin L. Bibles, Biologist
Nancy Ferguson, Biologist
J. Elaine Lowry, Biologist
Eric A. Point, Biologist

Table of Contents

List of Tables

List of Figures

Appendices

INTRODUCTION

The University of Arizona's Mount Graham Red Squirrel Monitoring Program continued monitoring the status of Mt. Graham red squirrels (*Tamiasciurus hudsonicus grahamensis*) near the Mount Graham International Observatory (MGIO) in 1997. The MGIO is located along a ridge extending westward from Hawk Peak in the Graham (Pinaleño) Mountains of southeastern Arizona. In 1997, the MGIO site consisted of two operating facilities, the Vatican Advanced Technology Telescope (VATT) and the Sub-Millimeter Telescope (SMT), a maintenance and generator building, and a 3.2 km access road (FR 4556). Construction continued on the Large Binocular Telescope (LBT) throughout 1997. Major construction activities included cement pouring and steelwork for the foundation and building structures.

The Monitoring Program was established in 1989 to meet the requirements of the MGIO Management Plan (USDA Forest Service 1989), with the principal goal of detecting possible effects of construction on the Mt. Graham red squirrel. Four areas encompassing 337.9 ha were defined in the vicinity of the MGIO site to monitor red squirrel populations (Figure 1). These areas include two forest habitat types: transitional (TR) or mixed conifer forest and spruce-fir (SF) forest. The TR habitat, below 3050 m elevation, is composed of Engelmann spruce (*Picea engelmannii*), corkbark fir (*Abies lasiocarpa* var. *arizonica*), Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), southwestern white pine (*P. strobiformis*) and aspen (*Populus tremuloides*). The SF habitat, above 3050 m elevation, is composed of Engelmann spruce and corkbark fir. In each habitat type, an area within 300 m of the telescope sites and access road was defined as the *construction* area. For comparison, a *non-construction* area beyond 300 m from the MGIO site or the access road was defined in each habitat. This resulted in four monitored areas: TR habitat construction (TRC) (83.6 ha), TR habitat non-construction (TRN) (24.4 ha), SF habitat construction (SFC) (101.0 ha) and SF habitat non-construction (SFN) (128.9 ha). After the Clark Peak fire in spring 1996, the amount of habitat available for use by red squirrels was reduced to 49.1 ha on the TRC area and 76.1 on the SFC area. The amount of available habitat on the TRN and SFN areas remained unchanged. The total amount of available habitat on all four monitored areas is 278.5 ha.

A census of all middens within the monitored areas was conducted in March, June, September, and December. In addition, middens within 100 m of the LBT site or the access road were censused during months of construction: April, May, July, August, and October. Census data were analyzed to determine the potential effects of construction on squirrel numbers, distribution, and density.

Efforts were continued to describe and quantify other environmental parameters that may affect squirrel populations on Mt. Graham. Food resources were measured at 28 sites distributed among the monitored areas (Figure 1). Conifer seeds were collected at 24 of the sites, and mushrooms (epigeous or above-ground fungi) were collected at all 28 sites. Measurement of habitat characteristics (such as species composition, DBH, and canopy closure) was completed at all of the food resource sites in 1997.

Weather data was collected by two computerized weather stations, one each in the TR and SF habitats. During the winter months, snow depths were recorded from eight sites throughout the monitored areas.

The Monitoring Program has developed and is maintaining a database using Global Positioning System (GPS) and Geographic Information System (GIS) applications. By the end of 1997, all but a few of the middens on the monitored areas were mapped using GPS, in addition to food resource plots, roads, trails, and MGIO boundaries.

All use of the terms *construction* or *construction areas* refers to those areas within 300 m of previous MGIO construction activity. All use of the terms *red squirrel* or *squirrel* refers to the Mt. Graham red squirrel unless otherwise noted.

METHODS

Red squirrels cache conifer cones in selected locations known as middens. Middens are easily recognized by the presence of cached cones and piles of discarded cone scales. The Monitoring Program defines a midden site as a circular area with a 10 m radius surrounding the center of the primary cache site. Because red squirrels are territorial and generally solitary, counts of occupied middens provide a reasonably accurate estimate of population size (Smith 1968; Vahle 1978).

All monitored areas are surveyed during census months to locate newly established middens. In addition, new middens are also discovered during other monitoring activities. All known midden sites are marked with numbered metal tags, and black and orange striped flagging.

All statistical analyses were conducted using standard tests found in SAS and/or SigmaStat statistical software. The significance level for all tests was $P \leq 0.05$.

Red Squirrel Food Resources

Conifer Seed Production

The Monitoring Program began collecting quantitative data in 1993 to determine the abundance of some red squirrel food resources. Conifer seeds and mushrooms were selected because they provide the majority of the red squirrels' diet and are readily sampled. In 1996, seed production was estimated from 24 seedfall plots distributed among the monitored areas (Figure 1). Three 0.25 m^2 seed traps were randomly placed within a 10 m x 10 m plot at each location. Seeds from the 1996 crop were collected from the seed traps in early June 1997. The conifer seeds contained in each trap were separated by species and individually tested (squashed) to determine the proportion of seeds that were likely to be viable. A viable seed leaves an oily spot on clean paper when squashed. This method is likely to underestimate the total number of viable seeds because some seeds may have been preyed upon within the trap. Estimates of the seedfall for each conifer species were calculated as the average number of viable seeds from all three traps on each plot. The seeds of white pine and ponderosa pine are not readily dispersed by wind due to their large size. Because of this, the crops of these species are under represented in the seed trap samples. Both of these species may be important local food supplies for red squirrels, but at present there is no reliable method for estimating the size of the crops. Since late 1996, four food resource plots were added to compensate for those destroyed in the 1996 Clark Peak fire. Three plots were added on the TRC area, and one plot was added on the SFC area. These plots were set out late in

1996 or after seeds were collected in June 1997, therefore they are not included in any analysis of 1996 seed crops.

Mushroom Production

As in previous years, mushrooms were collected from plots 1 m by 100 m (0.01 ha) at two week intervals, from June through October. Mushrooms were collected from a total of 28 plots including the four plots added on the TRC and SFC since late 1996. These plots are oriented east to west and centered on seed collection plots. Collections were restricted to genera of mushrooms used by red squirrels on Mt. Graham or in other regions (Table 1). Collected mushrooms were separated by plot and genus, and the wet weights were measured. For most genera, dry weight was calculated by multiplying the wet weight by a wet weight/dry weight ratio determined from previous samples on Mt. Graham. Dry weights were still measured for those genera with small numbers of specimens previously collected (<50).

Energetics of Selected Food Resources

The total number of viable seeds or weight of mushrooms does not provide an equitable comparison within or among areas because different species vary greatly in size, weight, and energy content. The energy content of each food type was calculated and the proportional contribution of each of the food resources was determined. The calculations were made using seed weights measured from Mt. Graham seeds and energy values from Smith (1981) (Table 2). Energy content was also used to estimate the total energy available (MJ/ha) on each area. An index of total energy available to squirrels was made by combining the total energy of conifer seeds and mushrooms from the same year. Conifer seeds and mushrooms were used to estimate total energy available because they are the primary food sources of red squirrels, they become available at about the same time of year (late summer and autumn), and they provide the majority of the stored food reserves of red squirrels. Standard statistical tests were used in all comparisons.

Because seeds for a given year are not collected and analyzed until the following spring, there is a one year delay in the presentation of seed and energy data. Consequently, the previous year's seed, mushroom, and energy data are reported in addition to the current year's mushroom data.

Population Biology

Midden Occupancy

Census data were used to determine the number and distribution of occupied middens on each monitored area. In March, June, September, and December 1997, all middens were visited at least once to determine occupancy. In addition, middens within 100m of construction activity or the access road were censused during months of construction activity: April, May, July, August, and October. If a midden appeared to be occupied on the basis of feeding sign (cone scales, dried mushrooms, and conifer clippings) or caching, every attempt was made on subsequent midden visits to observe the squirrel and to determine its sex, age, and reproductive condition. During winter months, visual verification was often not practical, and determination of occupancy, in some cases, was based on the presence and age of feeding sign, tracks, and snow tunnels.

All middens on the monitored areas were classified as either occupied, unoccupied, or questionably occupied, with an occupied midden representing one squirrel. A midden was considered to be unoccupied when there was no squirrel or squirrel sign present. A midden was considered to be questionably occupied when red squirrel sign was found but the sign was insufficient to clearly indicate occupancy. Questionably occupied middens were considered to be unoccupied when determining population size. Population size estimates are conservative and represent the minimum number known alive (Krebs 1966). Differences in midden occupancy among study areas and midden occupancy relative to distance from construction were compared using data from June and December.

Overwinter Survival

Overwinter survival was estimated for squirrels in the monitored areas. During a complete census in December 1996, the number of occupied middens and the sexes of resident squirrels were determined. The December occupancy was then compared to occupancy for June 1997. A squirrel was considered to have survived the winter if it was a resident of a midden in December and that same midden was found to be occupied by a squirrel of the same sex in June. In addition, if the midden was listed as occupied or squirrel seen, this was also counted as a survival.

Spatial Distribution

Three methods were used to describe the spatial distribution of middens and squirrels: crude density, local density, and nearest-neighbor distance. Crude density represents the total number of middens and squirrels per hectare. No allowance was made for differences in habitat quality among the monitored areas, and statistical tests are not appropriate.

Local density (LD) is a method of describing local population densities for comparisons among populations in which habitat variables are uncontrolled. For this report, LD is defined as the number of *middens* or *squirrels* within 100 m of a focal *midden* or *squirrel*. The mean LD ($\bar{x}$ LD) of *middens* (all middens, occupied and unoccupied) and *squirrels* (all occupied middens) is compared between areas and habitats. The benefit of using LD is that these measurements of density are not influenced by habitat variables, whereas crude density may include large areas not suitable as squirrel habitat, such as clearings and meadows. The LD method is adapted from distance models of neighborhood modeling used by plant ecologists to describe and compare plant populations (Czárán and Bartha 1992). A circle with a radius of 100 m encloses 3.14 hectares, which is approximately the average home range of Mt. Graham red squirrels (Froehlich 1990). It is also about the approximate maximum distance that an observer can recognize and accurately locate a squirrel "chatter" call (P. Young, pers. obs.).

Nearest neighbor distance (NND) is used to describe and compare the spatial distribution of populations and communities of plants and animals (Clark and Evans 1954, Krebs 1989). In this report, NND is the shortest distance, expressed in meters, from a focal *midden* or *squirrel* to the nearest *midden* or *squirrel*. The mean NND ($\bar{x}$ NND) of middens and squirrels was compared between areas and habitats.

Local density and NND were determined for each midden and squirrel from the mapped coordinates and compared among areas and habitats using ANOVA tests. To determine the LDs and NNDs of some of the middens and squirrels on the monitored areas, it was necessary to include some off-area middens that were within 100 m of a focal midden.

Reproductive Activity and Success

In 1997, the breeding condition of adult male and female squirrels, and litter activity was recorded when observed. By examining nipple condition through binoculars, the reproductive status of a female was determined to be non-breeding, lactating, or post-lactating. The reproductive status of male squirrels was also determined by visual assessment and was recorded as “testes non-scrotal” (non-reproductive) or “testes scrotal” (sexually active).

Trapping and Marking

There was no trapping and marking during the 1997 field season.

Midden Mapping

Almost all middens and other physical features on the monitored areas have been mapped using GPS. Universal Transverse Mercator (UTM) coordinates from the GPS files were used to compute local densities, nearest neighbor distances, and distance to construction. GPS data were collected using the Pathfinder Pro system from Trimble Navigation, Inc. Readings were taken within 5 meters of the midden center. Date, time, and location descriptions were noted in the field for later reference. Final midden locations were based on an average from a minimum of 200 three-dimensional data points. Locations were differentially corrected using base station (Federal Building, Tucson, AZ) files provided by the Forest Service. Maps were produced using PC-ARC Info and Arc-View (ESRI 1995).

Weather Data

Weather data were collected using two Davis Instruments weather stations. One station is located along the abandoned Forest Service road north of Emerald Peak on the SFC area; the other is located at the Biology Camp on the TRC area. The stations record air temperature (high, low, and average), wind speed, wind direction, and rainfall. In addition, the station at the Biology Camp records relative humidity and barometric pressure. Data were collected at 30 minute intervals. Snow depth (cm) was recorded from four snow pole pairs located in the SF habitat, one pair at the 3050 m level on the access road, and three snow pole pairs in the TR habitat. Each pair consists of a pole in a clearing or canopy opening and a second pole nearby in the forest.

RESULTS AND DISCUSSION

Red Squirrel Food Resources

1996 Conifer Seed Production

As in previous years, Engelmann spruce seeds were the most abundant food resource in numbers of seeds/ha on all of the monitored areas, except the TRC area where Douglas-fir was the most abundant. In the SF habitat, Engelmann spruce seeds, on average, accounted for 97% of the seed fall. In the TR habitat Engelmann spruce and Douglas-fir were equally abundant, each accounting for 45% of the seed fall. Filled Douglas-fir seeds were not found in any of the samples from the SF habitat. Corkbark fir seeds were, overall, the least abundant resource on all of the areas. Corkbark fir seeds, on average, accounted for 11% of the seed fall in the TR habitat, and 3% of the seed fall in the SF habitat (Table 3, Appendix A). White pine and ponderosa pine were not represented in the samples collected from any of the plots.

The 1996 conifer seed crop was the third lowest seen since data collection began in 1993. Only the overall 1994 seed crop was lower. Compared to the 1995 seed crop, the 1996 crop for all species was an order of magnitude lower. In the case of corkbark seeds in the SF habitat, the 1996 seed crop was two orders of magnitude lower than the 1995 crop.(Figure 2 a-c).

1997 Mushroom Production

Annual mean mushroom production in 1997 was, in general, lower than seen in 1996. All of the monitored areas showed a decrease (19% to 59%) in mean annual production from 1996 to 1997, with the exception of the TRN area, which showed a 22% increase in production from 1996 to 1997 (Figure 3).

In contrast to previous years, there were no significant differences in annual production ($\bar{x}$ wet weight) between the TR and SF habitats. However, as in past years, the SFN area had the greatest (though not significantly) annual mushroom production (Table 4).

On the TRC area, four genera, *Clitocybe, Cortinarius*, *Lycoperdon,* and *Russula* accounted for 67% of production. On the TRN area, *Amanita, Cortinarius*, *Lycoperdon,* and *Russula* accounted for 68% of total production. *Boletus, Leccinum, Ramaria,* and *Russula* accounted for 69% of the production on the SFC area. *Russula* and *Leccinum* were also abundant on the SFN area and the inclusion of *Cortinarius* accounts for 63% of the total productions (Table 5).

Energetics of Selected Food Resources in 1996

Between the four areas, there were no differences in the mean energy (MJ/ha) available from each type of seed or when all seeds were combined. Overall, Engelmann spruce in the SF habitat accounted for the largest proportion of energy available from seeds. For mushrooms, the SFN area had a significantly greater amount of energy available than the other three areas, which were not significantly different from each other (Table 6). In 1996, mushrooms accounted for 94 % of the total energy on all of the areas, in contrast to 1995, when seeds accounted for 95% of the total energy on the monitored areas (Figure 4).

To compare the 1996 food resources found within the monitored areas, the areas were divided into polygons enclosing each food resource plot. Boundaries between polygons were drawn along the midpoints between adjacent plots so that each area contained all the area that was closer to the sample plot than any other. In all polygons in the TR habitat, the total energy available in 1996 was relatively low, less than 200 MJ/ha. On the SFC area, total energy available was slightly greater, three of the six polygons had between 200 and 300 MJ/ha. The SFN area, as in 1994 and 1995, had the most available energy of all the areas. Five of the twelve plots had greater than 300 MJ/ha total available energy (Figure 5, Appendix A-1).

Population Biology

Midden Occupancy

Four quarterly censuses (Mar, Jun, Sep, and Dec) of all middens on or near the monitored areas were made in 1997 (Appendix B). In addition, the 36 middens within 100m of the access road or construction were censused during months of construction activity (Appendix C).

From December 1996 to December 1997, the number of red squirrels on the monitored areas dropped from 147 to 101, a 31% decrease. On the TRC area, the highest number of squirrels (15) was seen in December 1997, and the lowest number was nine adults and three juveniles seen in June. December was also the month with the highest number of squirrels on the TRN area, with 14 middens occupied. The lowest squirrel numbers (9) on the TRN area were seen in September. The number of squirrels on both the SFC and SFN areas declined throughout the year until December when slight increases were seen on both areas. There were 45 squirrels on the SFC area in March 1997 and 35 squirrels in December. On the SFN area, there were 56 squirrels in March 1997 and 37 squirrels by December (Figure 6, Appendix B,C,D,E).

There was only one new midden found on the monitored areas in 1997 (Table 7). Consequently, the distribution of middens among the areas changed very little from 1996 to 1997.

Likewise, the distribution of squirrels did not markedly change during 1997. The TRC and TRN areas had a slightly higher proportion of the total squirrels in December 1997 as compared to December 1996 (Table 8).

In June 1997, there were no significant differences in the proportion of middens occupied either within or between habitats. By December, however, a significantly greater proportion of the middens in the TR habitat were occupied in comparison to the SF habitat. The proportion of middens occupied in the SF habitat remained the same from June to December 1997 (Table 9).

The average distance to construction of occupied middens and unoccupied middens was not significantly different on either the TRC or SFC areas for June and December 1997. On the TRC area in June, occupied middens were slightly closer (approx. 10m) to construction than unoccupied middens. By December, however, unoccupied middens were slightly closer to construction (approx. 3 m). In June 1997, on the SFC area, unoccupied middens were closer to construction than occupied middens by an average of 17 m. In December, this pattern remained essentially unchanged (Table 10).

Overwinter Survival

There were no significant differences in the number of squirrels that survived the winter of 1996-1997 within or between the TR and SF habitats. Overwinter survival for the TR habitat in 1996-1997, 58% in the TR habitat, and 54% in the SF habitat was lower in comparison to the 1995-1996 survival (80% - TR habitat, 74% - SF habitat) (Table 11). However, the 1996-1997 overwinter survival was comparable to the average proportion of survival from six previous years of data collection (62% - TR habitat, 60% - SF habitat).

Overwinter survival may be overestimated because a midden may be occupied in the spring by a different squirrel of the same sex. This mortality can not be detected among unmarked squirrels. The accuracy and biological value of overwinter survival estimates can be improved by having more marked squirrels on the monitored areas.

Spatial Distribution

Crude Density

The crude density of middens and squirrels was plotted to provide a visual representation of the potential (number of middens) versus actual (number of squirrels) midden occupancy (Figure 7). The crude density of *middens* decreased slightly on all areas between December 1996 and December 1997. This decrease was due to the removal of middens from regular censusing because of historically low occupancy or because they were GPS located outside of the monitoring area boundaries (Figure 7, Appendix F-1a).

The crude density of *squirrels* decreased slightly on all areas from December 1996 to September 1997. By December 1997, however, there were slight increases in the crude density of squirrels. This is a reflection of the overall pattern in the numbers of squirrels on the monitored areas in 1997. Decreases in squirrel numbers were seen throughout the year until December when slight increases were seen on all areas (Figure 7, Appendix F1-b).

Local Density

The December 1997 mean local density ($\bar{x}$ LD) of *middens* on all areas was 4.6, almost the same (4.7) as in December 1996, despite the fact that several middens were removed from regular censusing in 1997. There were significant differences in the local density of middens among the four areas. The SFC area had the highest $\bar{x}$ LD, the TRN area had the next highest, and the TRC and SFN areas had the lowest $\bar{x}$ LD (Table 12, Figure 8, Appendix F-2).

The $\bar{x}$ LD of *squirrels* (occupied middens) on all areas in December 1997 was 1.8, which is a slight decrease from 2.2 seen in December 1996. The SFN area had a significantly lower $\bar{x}$ LD of squirrels than the other three areas, which were similar to each other (Table 12, Figure 8, Appendix F-2).

Nearest Neighbor Distance

The $\bar{x}$ NND of *middens* remained virtually unchanged from December 1996 to December 1997. The TRC area had a significantly longer $\bar{x}$ NND in December 1997 than the other three areas, which were similar to each other (Table 13, Figure 9, Appendix F-2).

The $\bar{x}$ NND of *squirrels* (occupied middens) on all areas increased from December 1996 to December 1997 on all areas except the TRC area where a slight decrease was seen. In 1997, the

SFN had a significantly longer $\bar{x}$ NND than the other three areas (Table 13, Figure 9, Appendix F-2).

Reproductive Activity and Success

Three breeding chase were observed in 1997, all in the TR habitat (Appendix G-1). The earliest date a scrotal male was seen was 5 March in the TRC area, and most of the males seen during the March census were scrotal. The latest data a scrotal male was seen was 17 July on the SFC area. None of the males seen during the September census were scrotal.

The earliest a lactating female was observed was 17 June on the TRC area and the latest was on 15 August, on the SFC area. Several females that appeared to be post lactating were seen during the September census. Evidence of 8 litters (15 juveniles) was seen during censuses or other monitoring activities. In addition, four squirrels that appeared to be young of the year were seen during the September and December censuses. The earliest evidence of a litter was seen on 17 June on the TRC area. The latest evidence of a litter was seen on 24 September also on the TRC area (Appendix G-2).

Trapping and Marking

There was no trapping and marking on the monitored areas in 1997. Trapping is planned to resume during the 1998 field season.

Marked Squirrels

There were three marked squirrels seen on the monitored areas in March 1997. A radio collar and evidence of predation were found in March at midden 3309 on the SFC area. A radio-collared male squirrel from a previous AGFD study was residing in this midden prior to March 1997. By December 1997, only one marked squirrel remained on the SFC area (Appendix B). In addition to the ear tagged squirrels, there were 13 squirrels on or near the monitored areas in 1997 with natural identifying marks such as an ear notch or a short tail (Appendix H-1). Six of these squirrels were seen during the December 1997 census.

Two marked squirrels disappeared from the monitored areas in 1997. Two of the three marked males seen during the March census were not seen anytime thereafter. (Appendix H-2).

Only one marked squirrel was observed outside his midden. The marked male from midden 3365 was seen foraging approximately 30 m from his own midden (Appendix H-3).

There was no evidence of marked squirrels moving to a new midden in 1997. There was also no evidence of marked squirrels defending more than one midden in 1997.

Midden Mapping

At the end of 1997, all but a few of the middens on the monitored areas were mapped using GPS, as well as food resource plots, roads, trails, and MGIO boundaries. The GIS database continued to be developed during 1997.

Weather Data

Weather data were collected nearly continuously in 1997 from two weather stations located at the biology camp (TR habitat) and near Emerald Peak (SF habitat). Due to several mechanical and software difficulties, there was no data collected at the biology camp station for October, November, and December. There was incomplete data for the Emerald Peak station for May and June. The maximum temperature recorded was 35.8°C in July at the biology camp and the minimum temperature recorded was -19.7°C in December on Emerald Peak. The maximum average monthly temperature was 15°C in July at the biology camp and the minimum average monthly temperature was -6.5°C in December on Emerald Peak. (Figure 10, Appendix I-1). The maximum rainfall at both stations was recorded in August, with 189.1 mm at the biology camp and 144.4 mm at Emerald Peak. June appeared to be the driest month with 2.7 mm at the biology camp and only 7.4 mm on Emerald Peak (Figure 11, Appendix I-1). Snow depth was recorded from the eight pairs of snow poles on the monitored areas. There was more snow on the monitored areas in the winter of 1996-1997 as compared to the previous winter (Figure 12, Appendix I-2). The accumulated snow depth from November 1996 through April 1997 ranged from 7.0 cm to 150.4 cm as compared to 6 cm to 40 cm during the same time period in the winter of 1995-1996. Data on wind chill temperatures, wind direction and speed, humidity, and barometric pressure were also collected (Appendix I-1).

LITERATURE CITED

Clark, P.J. and F.C. Evans. 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecol., 35:445-453.

Czárán, T. and S. Bartha. 1992. Spatiotemporal dynamic models of plant populations and communities. Trends in Ecol. and Evol., 7:38-42.

ESRI 1995. ARC View and ARC/Info Users Manuals. Environmental Systems Research Institute. Redlands, CA.

Froehlich, G.F. 1990. Habitat use and life history of the Mt. Graham red squirrel. M.S.Thesis, Univ. of Arizona, Tucson, 61 pp.

Krebs, C.J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. Ecological Monographs 36:239-273.

Krebs, C.J. 1989. Ecological Methodology. Harper and Row, New York, 654 pp.

Smith, C.C. 1968. The adaptive nature of social organization in the genus of three squirrels *Tamiasciurus*. Ecol. Monogr., 38:31-63.

Smith, C.C. 1981. The indivisible niche of *Tamiasciurus*: an example of nonpartitioning of resources. Ecol. Monogr., 51:343-363.

USDA Forest Service. 1989. Mount Graham International Observatory Management Plan. Coronado National Forest, Tucson, 38 pp.

Vahle, J.R. 1978. Red squirrel use of southwestern mixed coniferous habitat. Master's Thesis, Arizona State University, Tempe, 100 pp.

Table 1. Mushroom genera known to be food resources of red squirrels, and collected from the food resource plots.

MUSHROOM GENUS	SOURCE(S)
Amanita	Buller 1920, M.C. Smith 1968
Auricularia	Monitoring Program personal observations
Boletus	Buller 1920, C.C. Smith 1968, M.C. Smith 1968
Clavaria	M.C. Smith 1968
Clitocybe	Monitoring Program personal observations
Cortinarius	C.C. Smith 1968, Froehlich 1990, Uphoff 1990
Gastroid sp.	Monitoring Program personal observations, States 1990
Hydnum	C.C. Smith 1968, M.C. Smith 1968
Lactarius	Buller 1920, C.C. Smith 1968
Leccinum	Monitoring Program personal observations
Lycoperdon	Monitoring Program personal observations
Pholiota	C.C. Smith 1968
Ramaria	Monitoring Program personal observations
Russula	M.C. Smith 1968, C.C. Smith 1968
Suillus	C.C. Smith 1968

Table 2. Energy content of some red squirrel food resources. (Note: energy content was calculated using seed weights measured from Mt. Graham seeds and energy values from C. Smith 1981.)

Food Resource	Unit	($\bar{x}$ mg/seed)	Energy Content (kJ/unit)
Engelmann spruce	seed	3.7	0.091
Corkbark fir	seed	18.6	0.444
Douglas-fir	seed	8.7	0.192
Mushroom	mg dry weight		0.018

Table 3. Mean filled conifer seed production, 1996.

		Corkbark fir		Douglas-fir		Engelmann spruce	
Area/Habitat	n	$\bar{x}$ 1000 seeds/ha	%	$\bar{x}$ 1000 seeds/ha	%	$\bar{x}$ 1000 seeds/ha	%
TRC	2	0.0	0.0	6.7	100.0	0.0	0.0
TRN	4	3.3	12.4	10.0	37.6	13.3	50.0
SFC	6	4.4	3.8	0.0	0.0	111.1	96.2
SFN	12	5.6	2.6	0.0	0.0	213.3	97.4
TR Habitat	6	2.2	11.1	8.9	44.5	8.9	44.5
SF Habitat	18	5.2	2.8	0.0	0.0	179.3	97.2

Table 4. Mean annual mushroom production, 1997.

Area/Habitat	n	$\bar{x}$ Wet weight (Kg/ha)	$\bar{x}$ Dry weight (Kg/ha)	$\bar{x}$ Energy content (MJ/ha)
TRC	5	40.730 ± 13.8977	4.671 ± 1.6157	84.082 ± 29.0831
TRN	4	62.593 ± 8.1699	6.803 ± 0.8487	122.450 ± 15.2763
SFC	7	68.844 ± 14.2480	6.888 ± 1.4099	123.988 ± 25.3779
SFN	12	79.677 ± 15.2380	7.799 ± 1.4218	140.377 ± 25.5931
TR Habitat	9	50.447 ± 8.9179	5.619 ± 0.9927	101.135 ± 17.8685
SF Habitat	19	75.686 ± 10.7735	7.463 ± 1.0174	134.339 ± 18.3132

Wilcoxon Test between SF and TR:

Wet Weight	Z= -1.1806	*P*= 0.2378
Dry Weight	Z= -0.6395	*P*= 0.5225
Energy	Z= -0.6395	*P*= 0.5225

Table 5. Mean annual mushroom production (wet weight Kg/ha) of selected mushroom genera known to be food resources for red squirrels, 1997. The proportions of the three or four most available genera on each area are in bold.

	TRC		TRN		SFC		SFN	
Genus	$\bar{x}$ Kg/ha	%	$\bar{x}$ Kg/ha	%	$\bar{x}$ Kg/ha	%	$\bar{x}$ Kg/ha	%
Amanita	0.638	4.1	7.185	**24.5**	1.231	2.6	3.999	9.3
Auricularia	1.476	9.6	1.185	4.0	0.037	0.1	0.062	0.1
Boletus	0.000	0.0	2.046	7.0	14.113	**29.9**	0.000	0.0
Clavaria	0.000	0.0	0.000	0.0	0.000	0.0	0.949	2.2
Clitocybe	2.105	**13.6**	1.842	6.3	2.591	5.5	1.491	3.5
Cortinarius	1.621	**10.5**	4.344	**14.8**	2.985	6.3	4.933	**11.4**
Gastroid sp.	0.000	0.0	0.000	0.0	0.000	0.0	0.088	0.2
Hydnum	0.000	0.0	0.000	0.0	4.720	10.0	1.093	2.5
Lactarius	1.166	7.6	2.303	7.8	0.457	1.0	3.207	7.4
Leccinum	1.320	8.6	1.718	5.8	7.989	**16.9**	11.363	**26.3**
Lycoperdon	3.702	**24.0**	4.637	**15.8**	2.722	5.8	1.727	4.0
Pholiota	0.000	0.0	0.048	0.2	0.171	0.4	0.708	1.6
Ramaria	0.088	0.6	0.373	1.3	4.761	**10.1**	2.354	5.5
Russula	2.859	**18.5**	3.701	**12.6**	5.460	**11.6**	10.857	**25.2**
Suillus	0.455	2.9	0.000	0.0	0.000	0.0	0.320	0.7
Total	15.429		29.381		47.237		43.150	

Table 6. Estimated mean energy (MJ/ha) from four primary food resources, 1996.

Area/Habitat	N	Corkbark fir	Douglas-fir	Engelmann spruce	Total Seeds	Total Mushrooms	Total Energy
				$\bar{x}$ MJ/ha ± se			
TRC	2	0.0 ± 0.00[a]	1.3 ± 1.28[a]	0.0 ± 0.00[a]	1.3 ± 1.28[a]	104.0 ± 0.63[a]	105.2 ± 0.65[a]
TRN	4	1.5 ± 1.48[a]	1.9 ± 1.23[a]	1.2 ± 0.70[a]	4.6 ± 1.63[a]	89.2 ± 26.42[a]	93.8 ± 24.96[a]
SFC	6	2.0 ± 1.25[a]	0.0 ± 0.00[a]	10.1 ± 2.74[a]	12.1 ± 3.34[a]	161.1 ± 19.56[a]	173.2 ± 20.62[a]
SFN	12	2.5 ± 1.14[a]	0.0 ± 0.00[a]	19.4 ± 8.06[a]	21.9 ± 7.90[a]	335.4 ± 51.67[b]	357.3 ± 54.29[b]
TR Habitat	6	1.0 ± 0.99	1.7 ± 0.85	0.8 ± 0.51	3.5 ± 1.29	94.1 ± 17.00	97.6 ± 15.97
SF Habitat	18	2.3 ± 0.85	0.0 ± 0.00	16.3 ± 5.47	18.6 ± 5.41	277.3 ± 39.83	295.9 ± 41.91

a,b Means with a different letter are significantly different.

Table 7. Number and discovery status of red squirrel middens on each of the monitored areas, 1996-1997.

		Midden Status				
Year	Area	Old	Burned[1]	Newly Found	Newly Established	Total
1996	TRC	31	23	0	3	34
	TRN	28	0	0	5	33
	SFC	110[2]	10[3]	0	4[3]	113[3]
	SFN	113	0	0	8	121
	Total	282	33	0	20	301
1997[4]	TRC	27	-	0	0	27
	TRN	28	-	0	1	29
	SFC	104	-	0	0	104
	SFN	100	-	0	0	100
	Total	259	-	0	1	260

[1] This column refers to the middens that were completely burned in the Clark Peak Fire.

[2] Midden 3389 remained in the active census list even though the main area of activity (midden shift) was completely burned in the Clark Peak Fire. The main area of activity at midden 3389 had shifted ~ 15 m E of the plaque tree. The plaque tree area remained intact. The old midden site (plaque tree) is still being used by the red squirrel from 3325. Therefore, midden 3389 was included in the old midden status column instead of the burned midden column.

[3] Midden 3021 was a newly established midden in early April and was also completely burned in the Clark Peak Fire. Therefore, midden 3021 was included in the newly established column and the burned midden column.

[4] The lower numbers reflect middens removed from regular censusing due to low occupancy, located off area, and/or remnumbering.

Table 8. Proportion of the total area, total number of middens, and total number of squirrels[1] found on each of the monitored areas, 1996-1997.

			Jun 1996				Dec 1996			
	Area[2]		Middens		Squirrels		Middens		Squirrels	
	ha	%[3]	n	%	n	%	n	%	n	%
TRC	49.1	18	31[4]	11	14[4]	8	34	11	17	12
TRN	24.4	9	31	11	16	9	33	11	15	10
SFC	76.1	27	113	38	76	45	113	38	55	37
SFN	128.9	46	119	40	63	37	121	40	60	41
Total	278.5		294		169		301		147	

			Jun 1997				Dec 1997			
	Area[2]		Middens		Squirrels		Middens		Squirrels	
	ha	%	n[5]	%	n	%	n	%	n	%
TRC	49.1	18	27	10	9	10	27	10	15[6]	15
TRN	24.4	9	28	11	10	11	29	11	14	14
SFC	76.1	27	104	40	33	37	104	40	35	35
SFN	128.9	46	100	39	38	42	100	38	37	37
Total	278.5		259		90		260		101	

1 Juveniles living with their mothers are not counted in the number of squirrels.

2 The monitored area after the Clark Peak Fire.

3 All percentages are rounded to the nearest whole number.

4 The number of middens in June does not include midden 1135 which was completely burned in the Clark Peak fire. However, the number of squirrels for June does include the male seen several times in midden 1135.

5 The lower numbers reflect middens removed from regular censusing due to low occupancy, located off area, and/or remnumbering.

6 This number includes the two red squirrels observed at 1160.

Table 9. Number and percent of available middens *occupied*, 1997.

	June		December	
Area/Habitat	n	%	n	%
TRC	9	33	14[1]	52
TRN	10	36	14	48
SFC	33	32	35	34
SFN	38	38	37	37
TR Habitat	19	35	28[1]	50
SF Habitat	71	35	72	35
TR + SF	90	35	100[1]	38

Chi Square:

JUNE			
within TR	X^2=0.034	df=1	*P*=0.853
within SF	X^2=0.883	df=1	*P*=0.347
between Habitats	X^2=0.001	df=1	*P*=0.972
DECEMBER			
within TR	X^2=0.072	df=1	*P*=0.789
within SF	X^2=0.250	df=1	*P*=0.617
between Habitats	X^2=4.015	df=1	***P*=0.045**

[1] This is the number of *occupied middens* only, the actual number of *squirrels* may be higher (in December 1997, two squirrels were considered to be living at midden 1160).

Table 10. Mean distance from construction to occupied and unoccupied middens on the TRC and SFC areas, June and December 1997.

		June		December	
Area	Midden Status	n	$\bar{x}$ ±se (m)	n	$\bar{x}$ ±se (m)
TRC	Occupied	9	205.1 ± 28.12	14[1]	213.3 ± 19.66
	Unoccupied	18	215.5 ± 14.54	13	210.7 ± 18.24
SFC	Occupied	33	167.1 ± 11.95	35	165.5 ± 11.13
	Unoccupied	71	150.2 ±9.70	69	150.5 ± 10.03

ANOVA:

JUNE

TRC	F=0.13	df=1	P=0.7179
SFC	F=1.06	df=1	P=0.3050

DECEMBER

TRC	F=0.01	df=1	P=0.9220
SFC	F=0.86	df=1	P=0.3560

[1] This is the number of *occupied middens* only, the actual number of *squirrels* may be higher (in December 1997, two squirrels were considered to be living at midden 1160).

Table 11. Overwinter survival of red squirrels on the monitored areas, 1996-1997.

Area/Habitat	Number of Squirrels Fall 1996	Number of Squirrels Surviving Spring 1997	% survival
TRC	11	8	73
TRN	13	6	46
SFC	53	28	53
SFN	58	32	55
TR Habitat	24	14	58
SF Habitat	111	60	54

Fischer's Exact test:

within TR $P = 0.240$

Chi-square tests:

within SF $X^2 = 0.00321$ df = 1 $P = 0.955$

between habitats $X^2 = 0.0243$ df = 1 $P = 0.876$

Table 12. Mean Local Density of middens and red squirrels (occupied middens) on the monitored areas, 1996 and 1997.

	December 1996				December 1997			
	Middens		Squirrels		Middens		Squirrels	
Area/Habitat	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se
TRC	34	4.0 ± 0.33[b]	17	1.5 ± 0.23[b]	27	3.6 ± 0.34[c]	14[1]	1.9 ± 0.29[a]
TRN	33	4.6 ± 0.28[b]	15	2.6 ± 0.25[a]	29	4.7 ± 0.28[b]	14	2.6 ± 0.29[a]
SFC	113	5.9 ± 0.24[a]	55	3.2 ± 0.24[a]	104	6.0 ± 0.25[a]	35	2.5 ± 0.22[a]
SFN	121	3.9 ± 0.17[b]	60	1.5 ± 0.13[b]	100	3.4 ± 0.17[c]	37	0.8 ± 0.11[b]
TR Habitat	67	4.3 ± 0.22	32	2.0 ± 0.20	56	4.2 ± 0.23	28[1]	2.3 ± 0.21
SF Habitat	234	4.9 ± 0.16	115	2.3 ± 0.16	204	4.8 ± 1.30	72	1.6 ± 0.16
TOTAL	301	4.7 ± 0.13	147	2.2 ± 0.13	260	4.6 ± 0.15	100[1]	1.8 ± 0.13

ANOVA:	**1996**			**1997**		
LD of Middens						
among all areas	F=19.50	df=3	***P=0.0001***	F=29.33	df=3	***P=0.0001***
LD of Squirrels						
among all areas	F=18.25	df=3	***P=0.0001***	F=21.54	df=3	***P=0.0001***

[a,b,c] Means with the same letter(s) are not significantly different.

[1] This is the number of *occupied middens* only, the actual number of *squirrels* may be higher (in December 1997, two squirrels considered to be living at midden 1160).

Table 13. Mean Nearest Neighbor Distance of middens and red squirrels (occupied middens) on the monitored areas, 1996 and 1997.

	December 1996				December 1997			
	Middens		Squirrels		Middens		Squirrels	
Area/Habitat	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se
TRC	34	54.7 ± 5.80[a]	17	79.9 ± 7.49[a]	27	57.7 ± 7.98[a]	14[1]	76.6 ± 8.80[a,b]
TRN	33	45.9 ± 2.63[a,b]	15	51.3 ± 5.70[b]	29	45.5 ± 2.87[b]	14	61.0 ± 5.69[a,b]
SFC	113	43.3 ± 1.42[b]	55	51.9 ± 2.49[b]	104	42.3 ± 1.42[b]	35	54.9 ± 5.56[b]
SFN	121	48.5 ± 1.80[a,b]	60	72.8 ± 4.77[a]	100	50.0 ± 2.14[a,b]	37	90.4 ± 9.43[a]
TR Habitat	67	50.4 ± 3.24	32	66.5 ± 5.37	56	51.4 ± 4.16	28[1]	68.8 ± 5.36
SF Habitat	234	46.0 ± 1.17	115	62.8 ± 2.91	204	46.1 ± 1.30	72	73.2 ± 5.90
TOTAL	301	47.0 ± 1.16	147	63.6 ± 2.56	260	47.2 ± 1.36	100[1]	71.9 ± 4.49

ANOVA:	**1996**			**1997**		
NND of Middens						
among all areas	F=3.26	df=3	***P=0.0219***	F=4.58	df=3	***P=0.0038***
NND of Squirrels						
among all areas	F=7.61	df=3	***P=0.0001***	F=4.52	df=3	***P=0.0052***

[a,b] Means with the same letter(s) are not significantly different.

[1] This is the number of *occupied middens* only, the actual number of *squirrels* may be higher (in December 1997, two squirrels considered to be living at midden 1160).

Figure 1. Map of the areas monitored by the University of Arizona Red Squirrel Monitoring Program, December 1997.

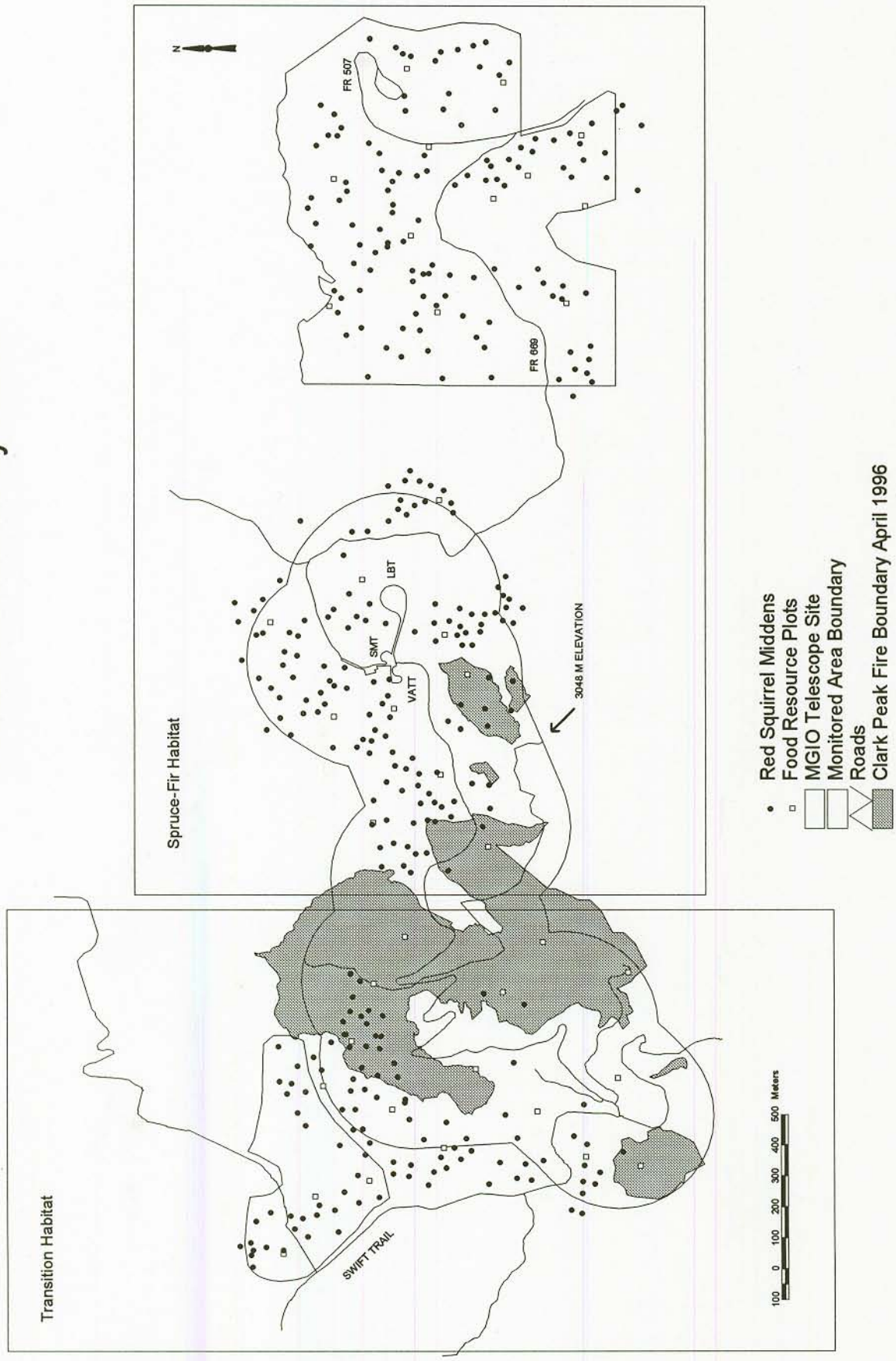


Figure 2a. Engelmann spruce seed fall, 1993-1996. Note: scales are different for figures 2a-c.

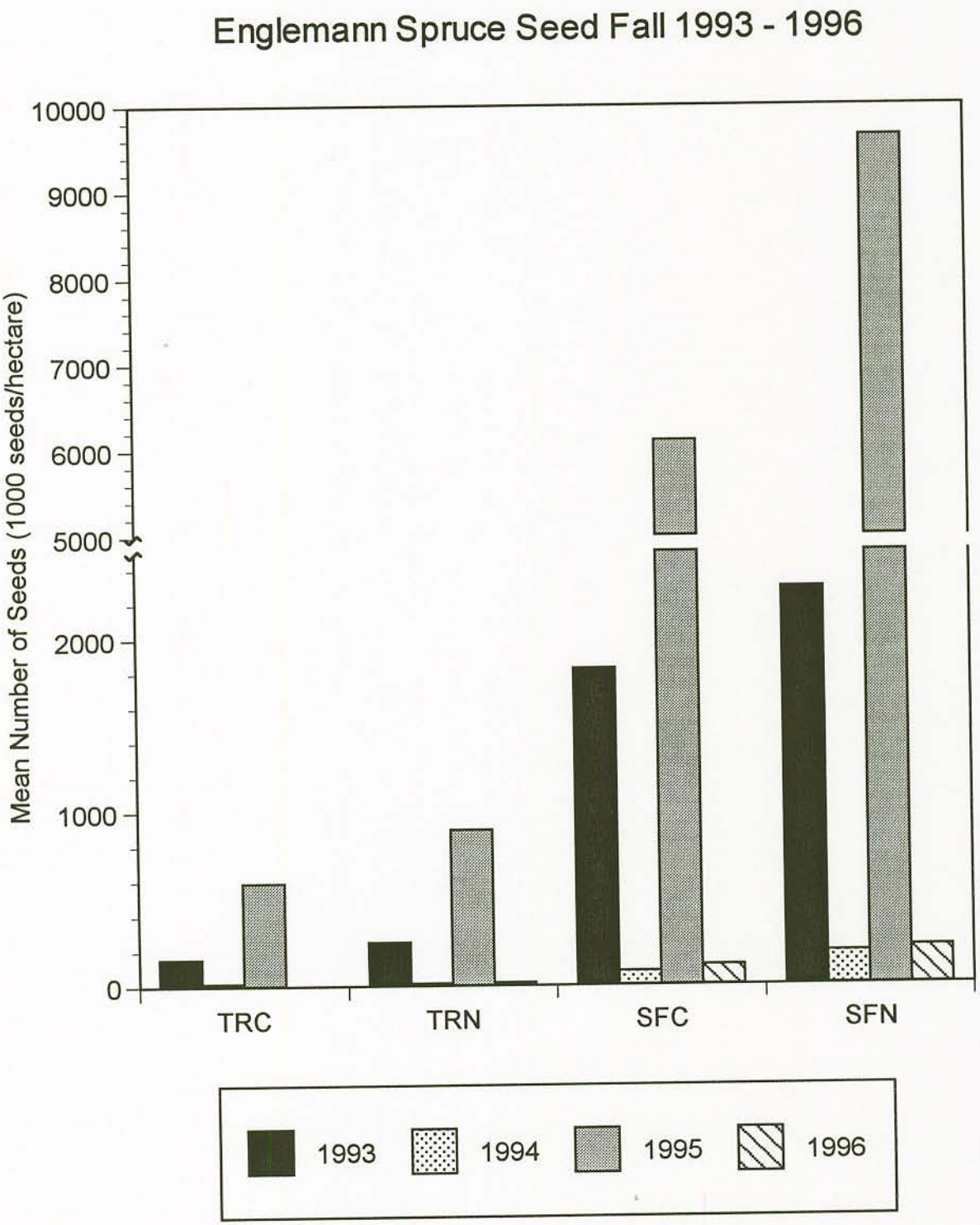


Figure 2b. Corkbark fir seed fall, 1993-1996. Note: scales are different for figures 2a-c.

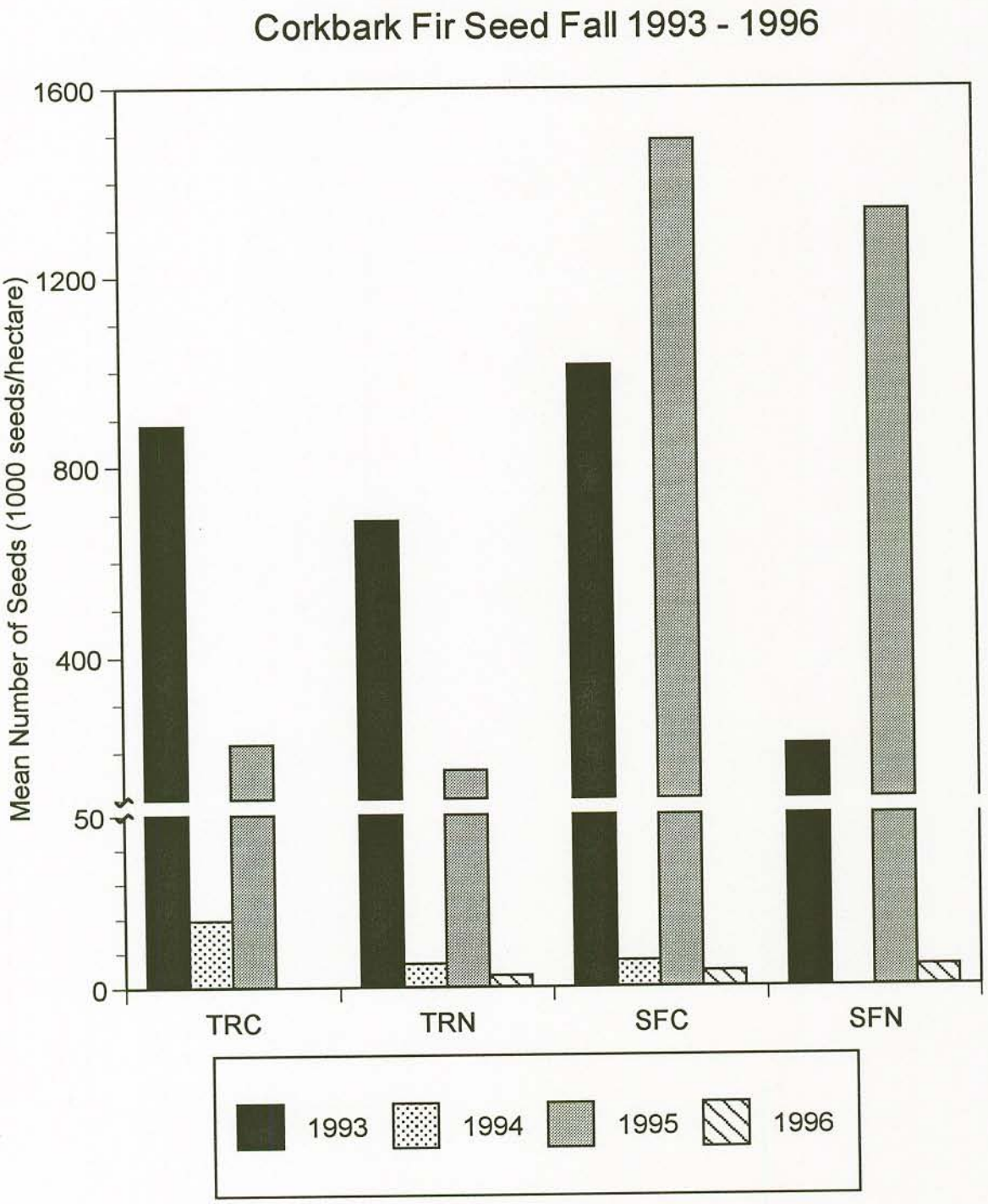


Figure 2c. Douglas-fir seed fall, 1993-1996. Note: scales are different for figures 2a-c.

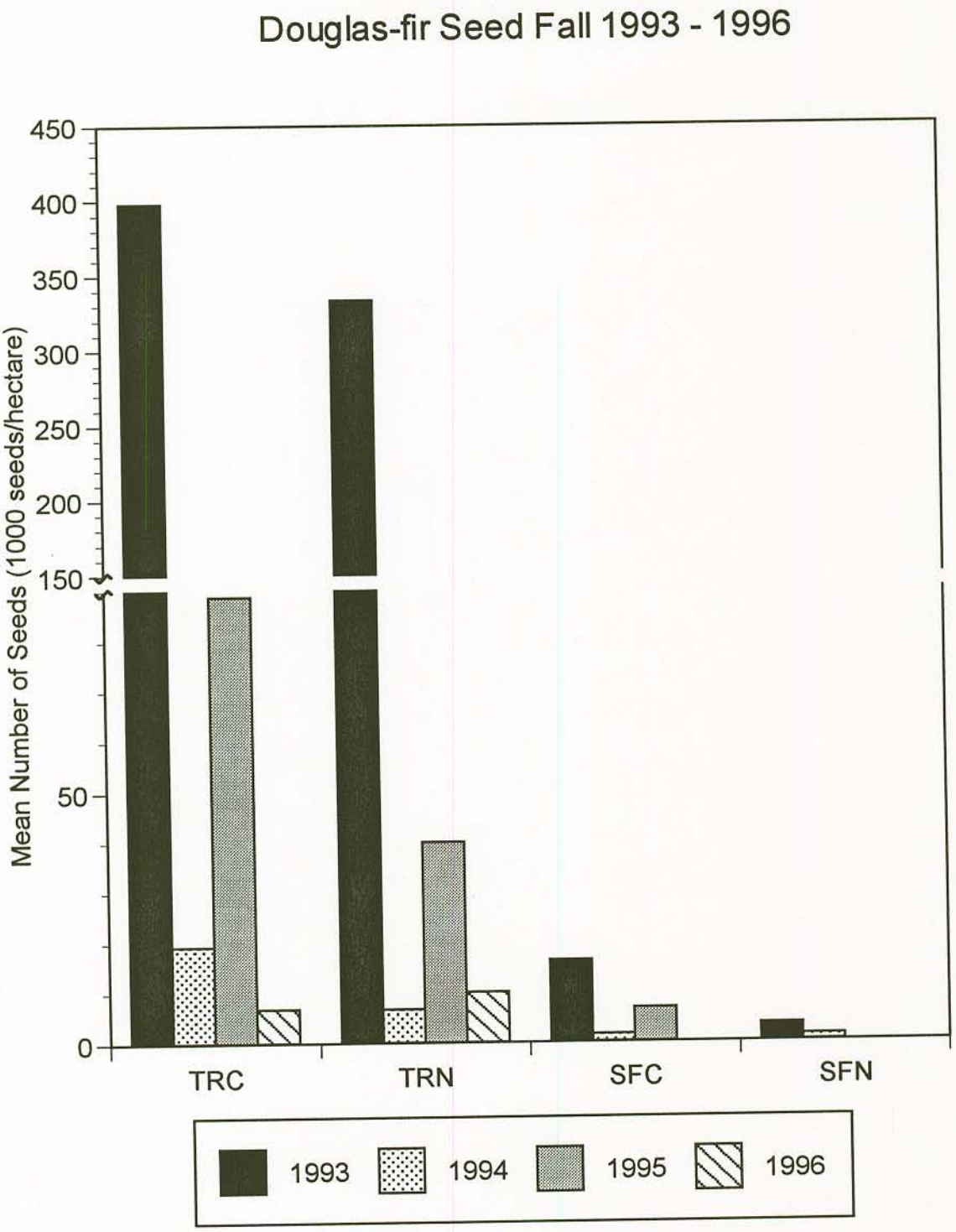


Figure 3. Mushroom crops, 1994-1997.

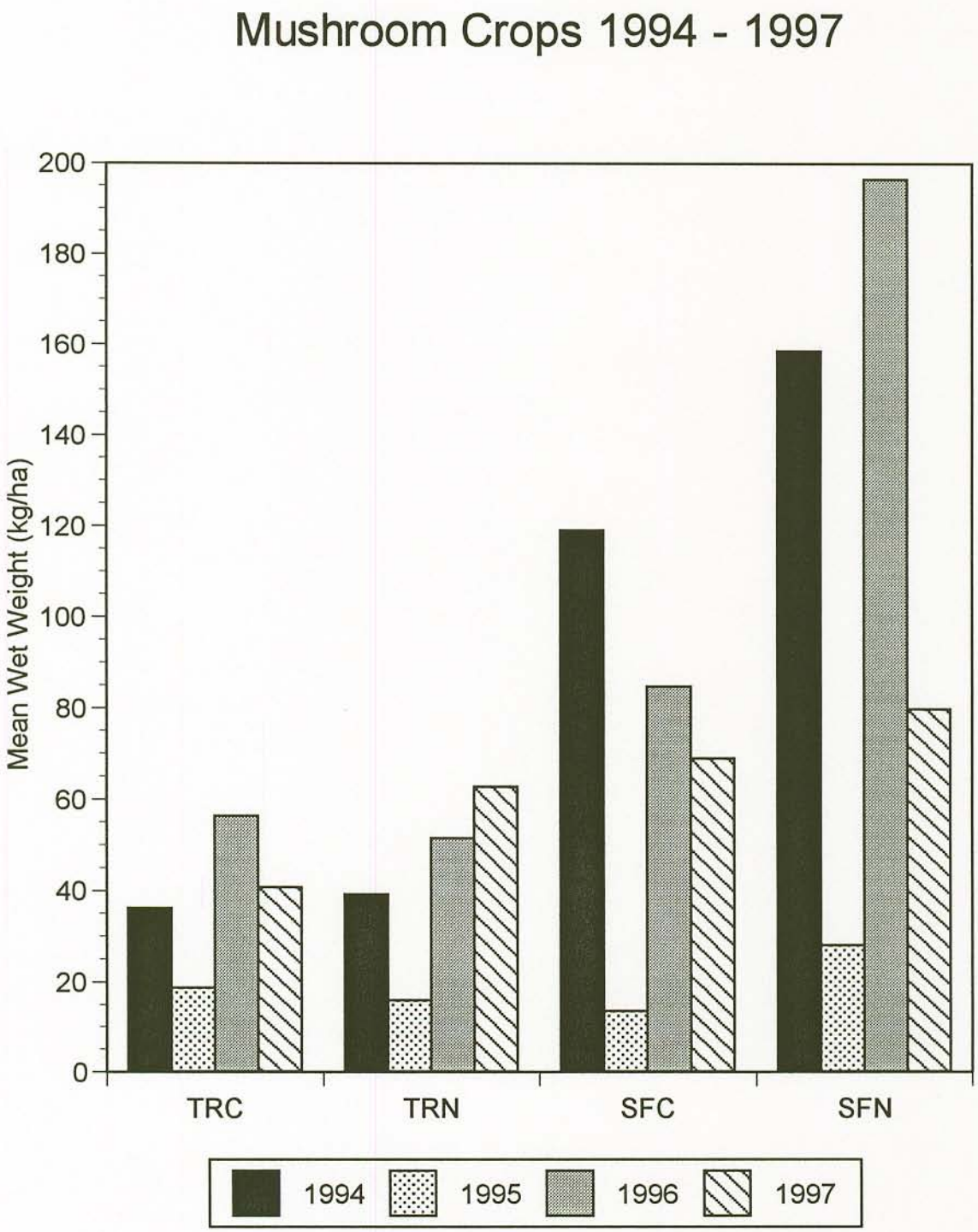


Figure 4. Energy availability on the monitored areas, 1994-1996.

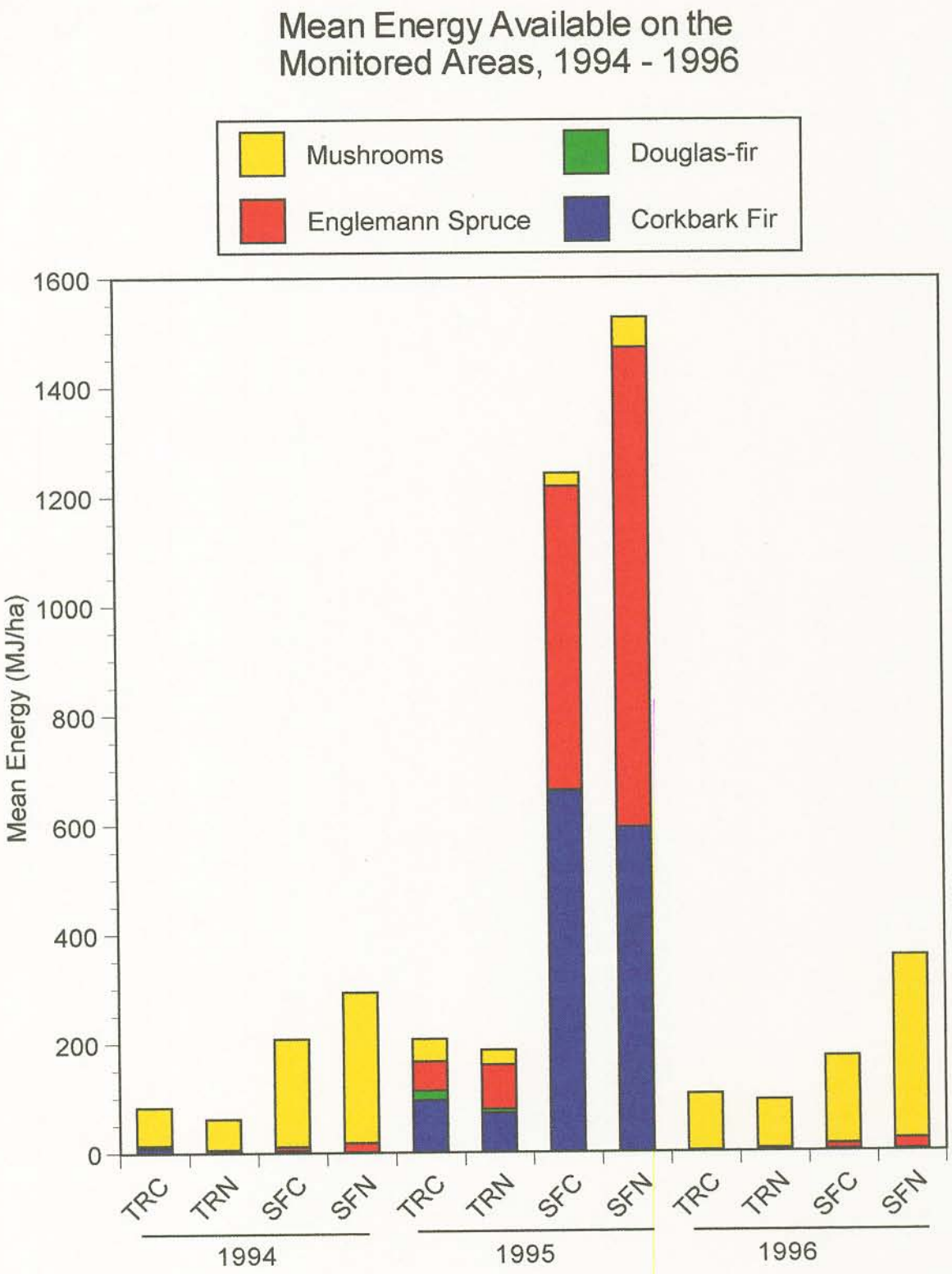


Figure 5. Distribution of total available energy from selected red squirrel food resources, 1996.

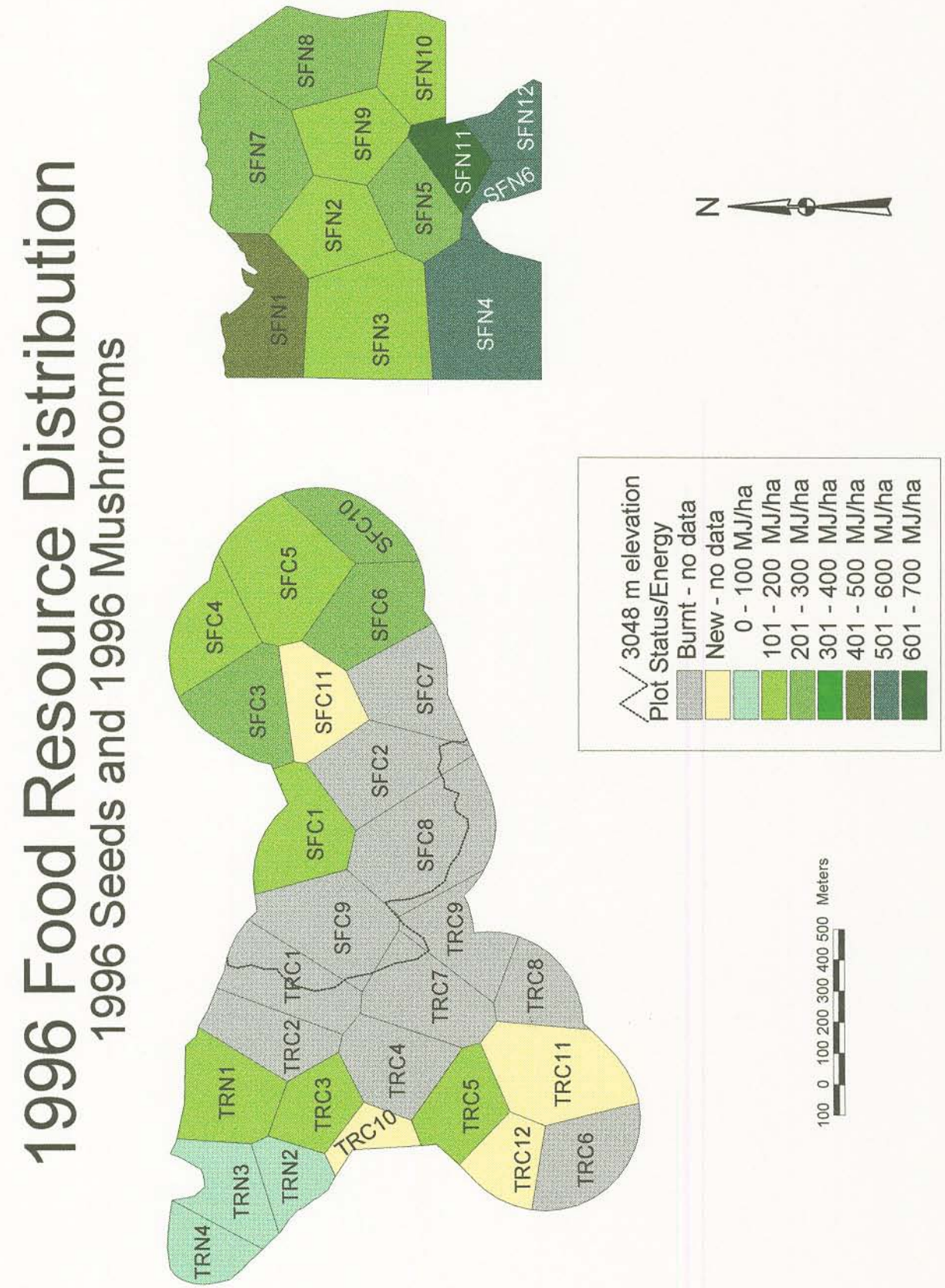


Figure 6. Red squirrel populations (including juveniles) on the monitored areas, December 1996 - December 1997.

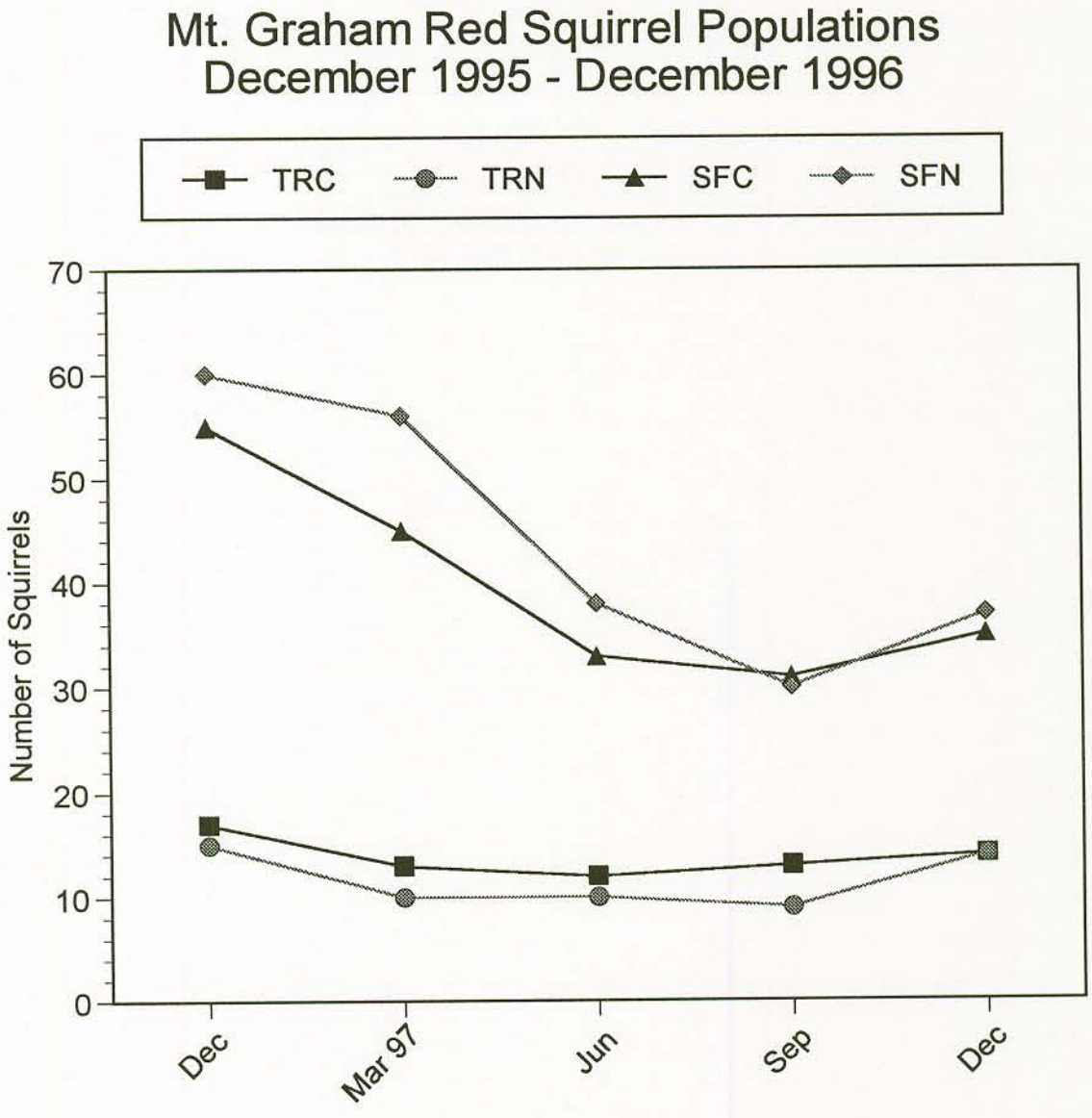


Figure 7. Crude density of middens and squirrels, 1996-1997.

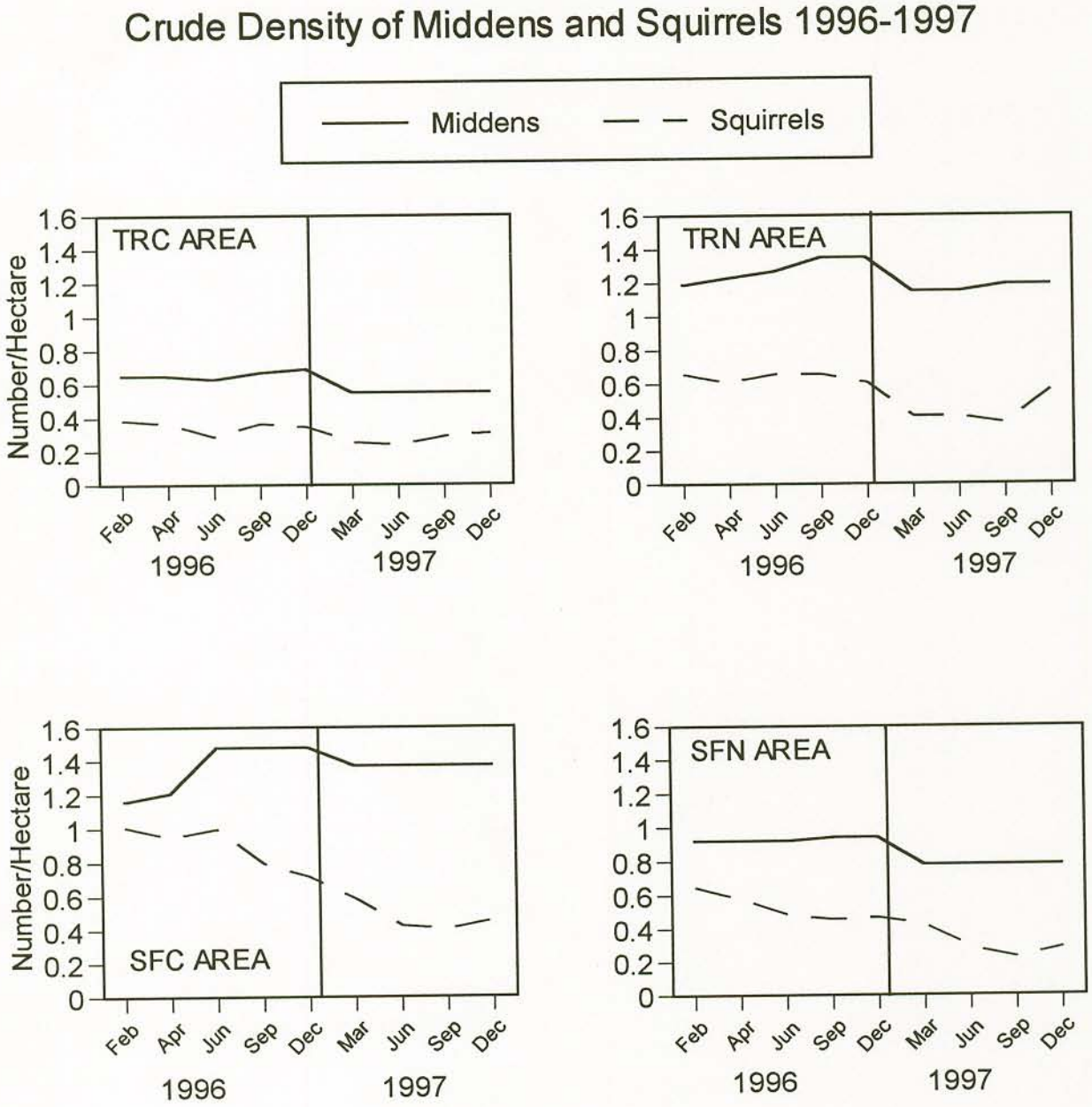


Figure 8. Local density of middens and squirrels, 1996-1997.

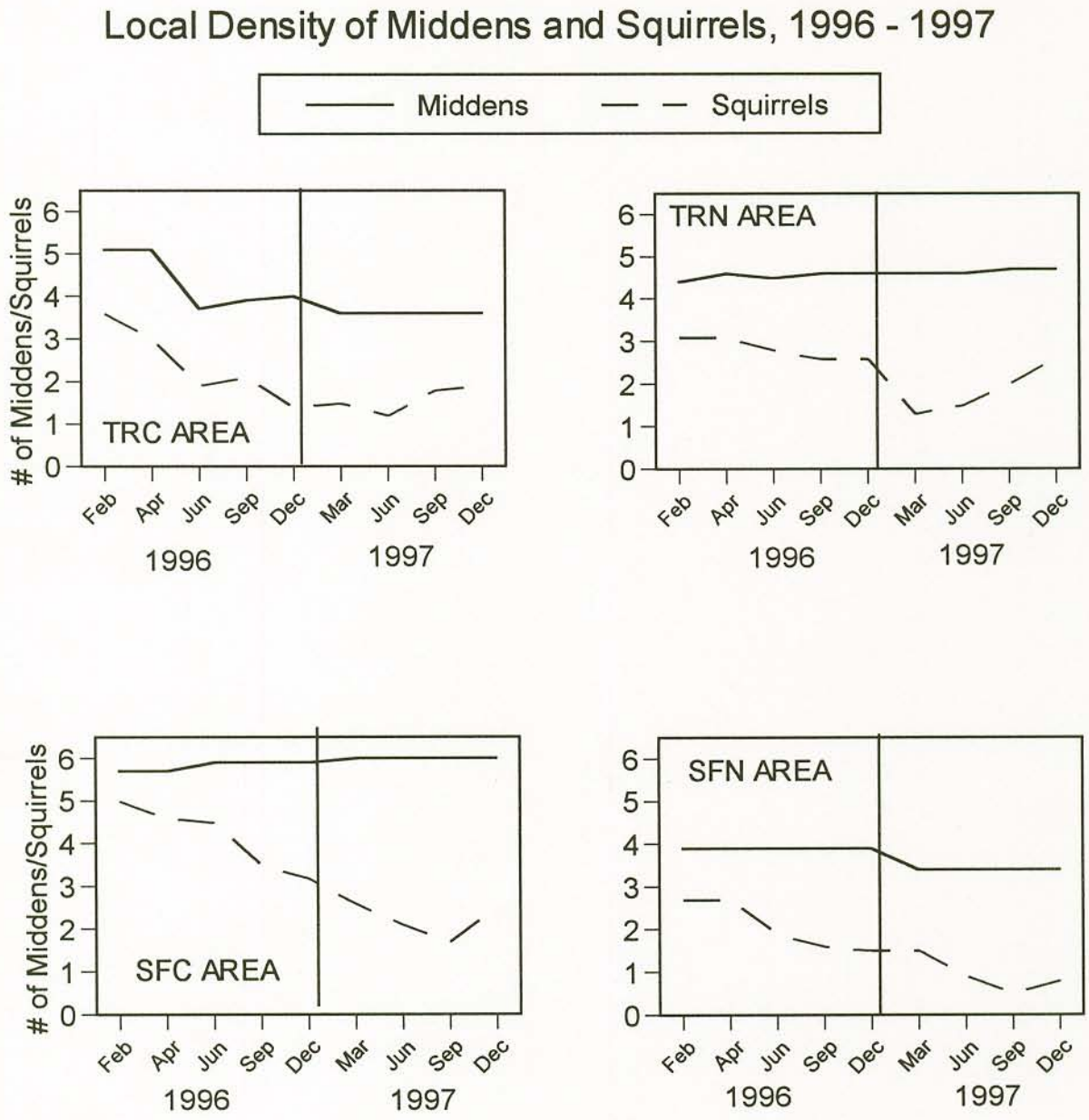


Figure 9. Nearest neighbor distance of middens and squirrels, 1996-1997.

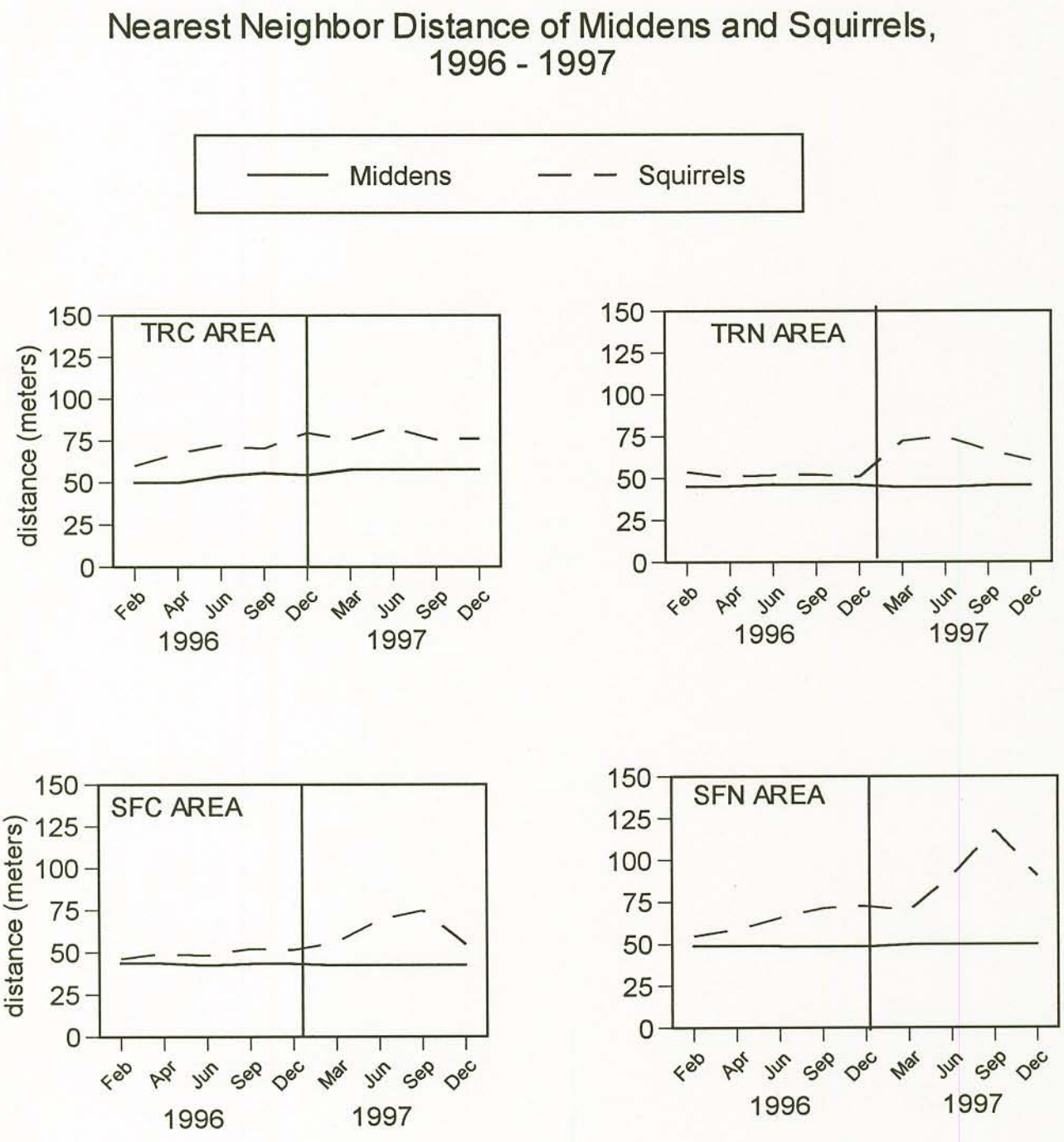


Figure 10. Monthly temperatures on the monitored areas, 1997.

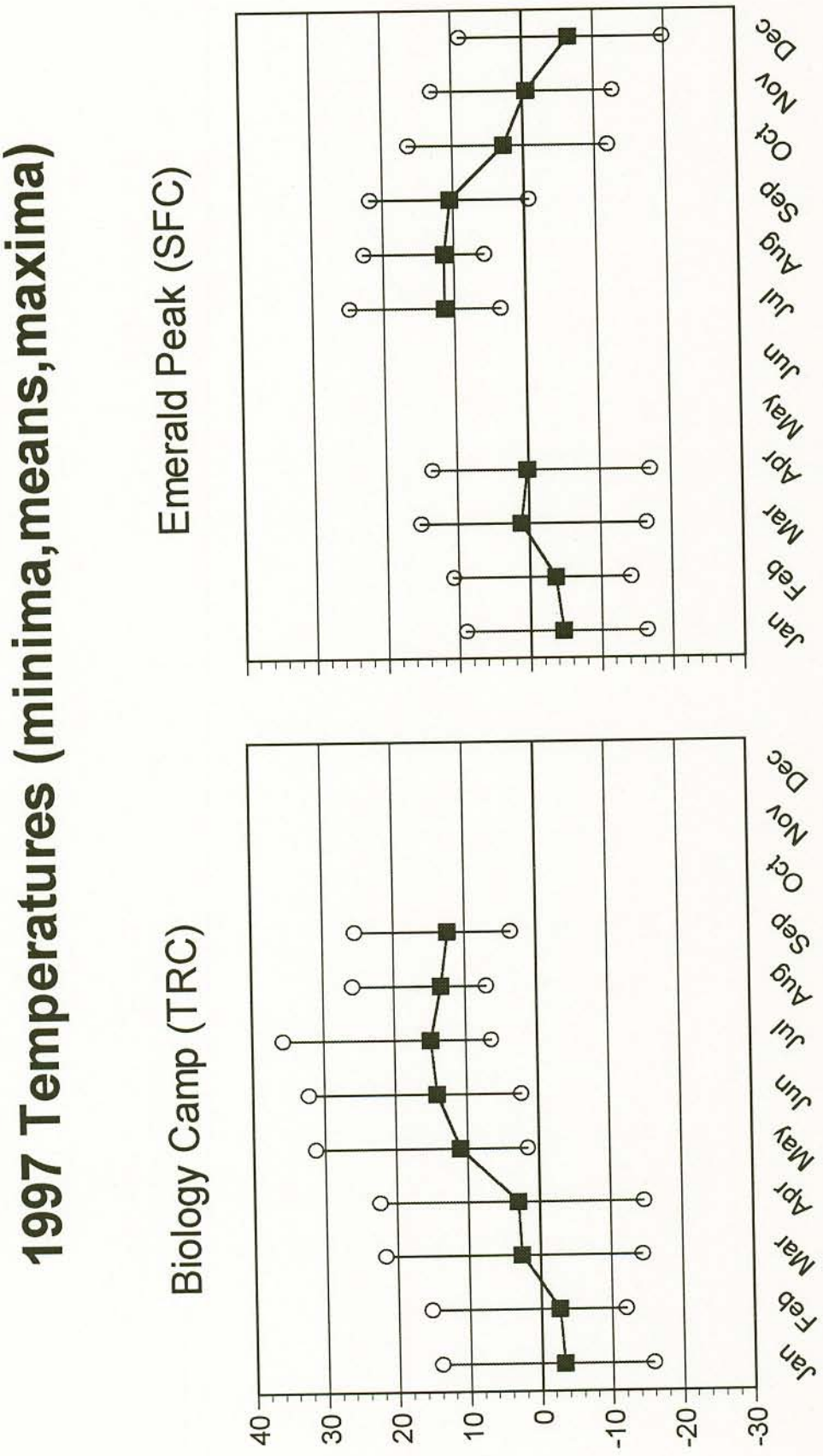


Figure 11. Total monthly precipitation as rain, 1997.

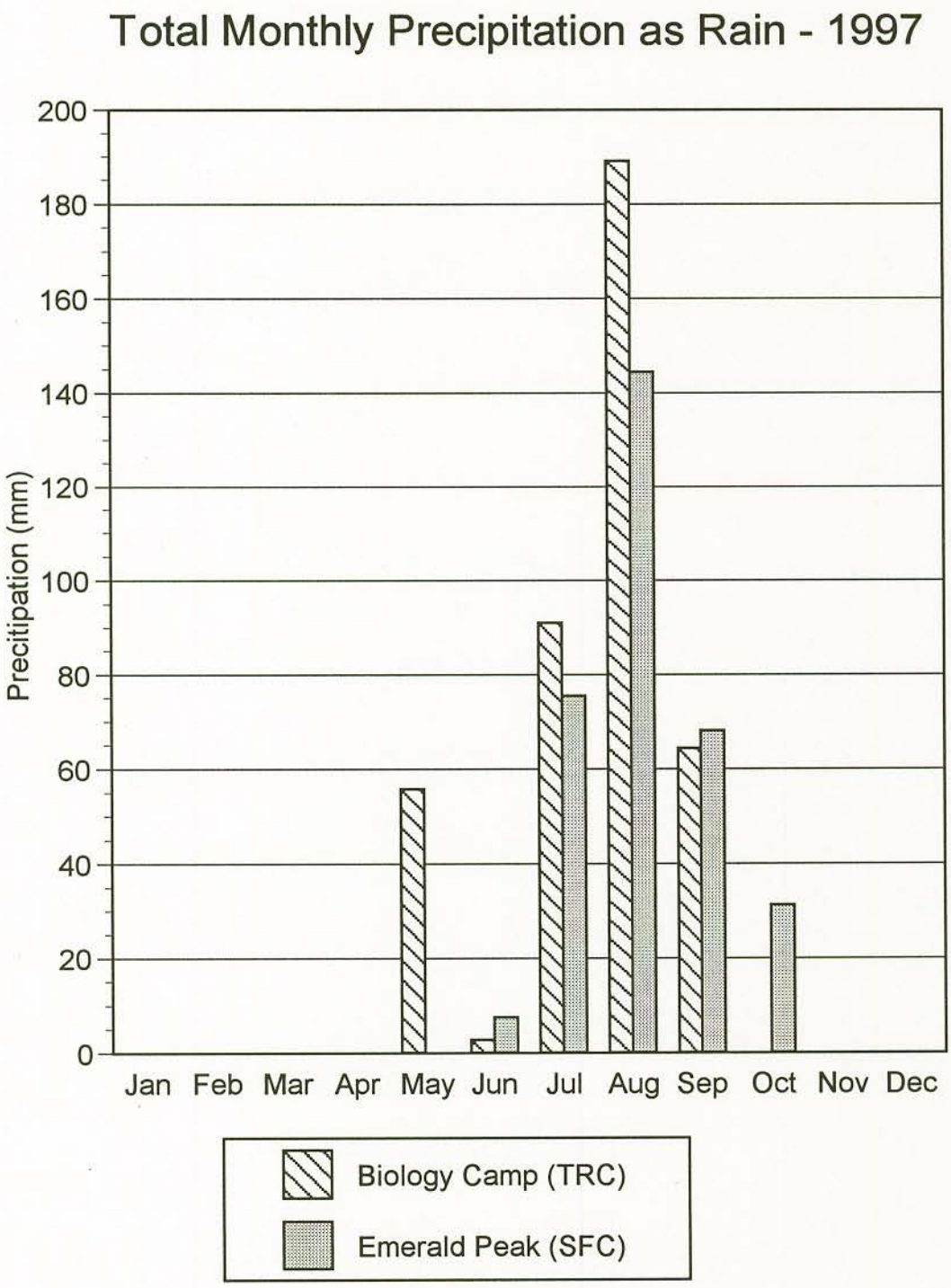
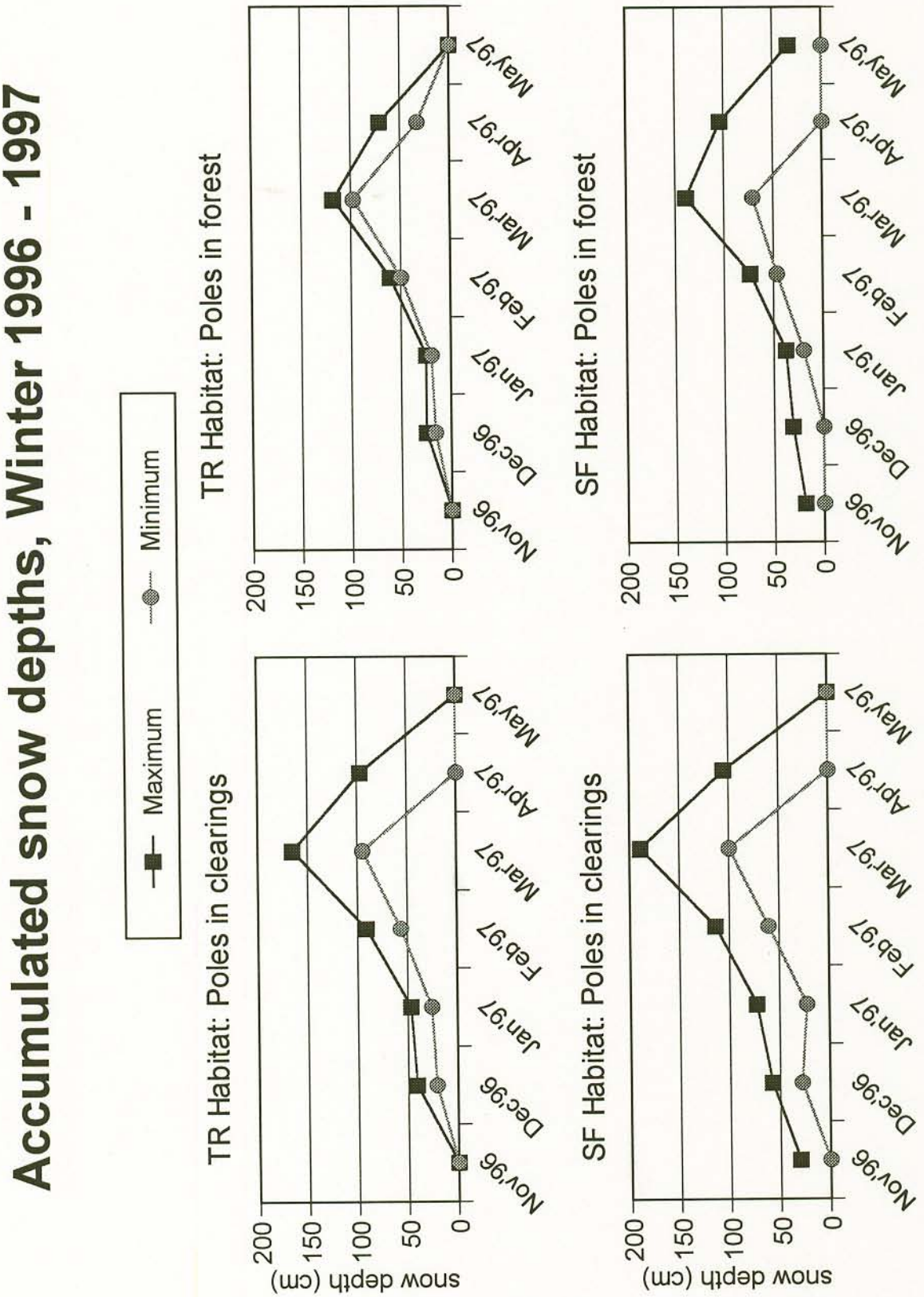


Figure 12. Accumulated snow depths, 1996-1997.



Appendix A: Numbers, weights, and energy values for 1996 seeds and 1996 mushrooms.

A-1. Means

A-2. Medians

Appendix A-1: Mean numbers, weights, and energy values for 1996 seeds and 1996 mushrooms.

		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	TRAN	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	ww Kg/ha	dw Kg/ha	MJ/ha	MJ/ha
TRC	1						burned						
	2						burned						
	3	0.0	0.0	13.3	2.6	0.0	0.0	13.3	2.6	51.50	5.70	103.3	105.9
	4						burned						
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.90	5.80	104.6	104.6
	6						burned						
	7						burned						
	8						burned						
	9						burned						
TRN	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.7	9.2	164.7	164.7
	2	0.0	0.0	26.7	5.1	26.7	2.4	53.3	7.5	28.30	3.10	56.2	63.7
	3	13.3	5.9	0.0	0.0	0.0	0.0	13.3	5.9	52.60	4.80	86.2	92.2
	4	0.0	0.0	13.3	2.6	26.7	2.4	40.0	5.0	24.90	2.80	49.6	54.6
SFC	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.00	7.60	136.4	136.4
	2						burned						
	3	13.3	5.9	0.0	0.0	213.3	19.4	226.7	25.3	91.00	10.40	187.4	212.7
	4	0.0	0.0	0.0	0.0	160.0	14.6	160.0	14.6	58.30	6.10	109.6	124.2
	5	0.0	0.0	0.0	0.0	120.0	10.9	120.0	10.9	61.10	6.20	111.4	122.4
	6	13.3	5.9	0.0	0.0	66.7	6.1	80.0	12.0	108.00	12.20	218.7	230.7

		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	TRAN	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	ww Kg/ha	dw Kg/ha	MJ/ha	MJ/ha
SFC	7						burned						
	8						burned						
	9						burned						
	10	0.0	0.0	0.0	0.0	106.7	9.7	106.7	9.7	118.30	11.30	202.9	212.6
SFN	1	13.3	5.9	0.0	0.0	173.3	15.8	186.7	21.7	254.10	23.70	425.7	447.4
	2	0.0	0.0	0.0	0.0	226.7	20.6	226.7	20.6	56.40	8.30	149.4	170.0
	3	26.7	11.8	0.0	0.0	80.0	7.3	106.7	19.1	103.30	9.70	173.7	192.8
	4	0.0	0.0	0.0	0.0	13.3	1.2	13.3	1.2	302.90	29.00	522.6	523.8
	5	0.0	0.0	0.0	0.0	240.0	21.8	240.0	21.8	131.0	13.10	236.50	258.4
	6	0.0	0.0	0.0	0.0	80.0	7.3	80.0	7.3	274.70	30.10	542.0	549.3
	7	13.3	5.9	0.0	0.0	53.3	4.9	66.7	10.8	143.6	13.60	244.70	255.4
	8	13.3	5.9	0.0	0.0	200.0	18.2	213.3	24.1	134.00	12.00	215.3	239.4
	9	0.0	0.0	0.0	0.0	160.0	14.6	160.0	14.6	101.60	9.10	163.4	178.0
	10	0.0	0.0	0.0	0.0	106.7	9.7	106.7	9.7	130.90	10.40	187.4	197.1
	11	0.0	0.0	0.0	0.0	1160.0	105.6	1160.0	105.6	375.20	32.30	580.8	686.3
	12	0.0	0.0	0.0	0.0	66.7	6.1	66.7	6.1	348.70	32.40	583.7	589.8
TRC $\bar{x}$	9	0.0	0.0	6.7	1.3	0.0	0.0	6.7	1.3	56.20	5.80	103.9	105.2
TRN $\bar{x}$	4	3.3	1.5	10.0	1.9	13.3	1.2	26.7	4.6	51.40	5.00	89.2	93.8
SFC $\bar{x}$	10	4.4	2.0	0.0	0.0	111.1	10.1	115.6	12.1	84.60	8.90	161.1	173.2
SFN $\bar{x}$	12	5.6	2.5	0.0	0.0	213.3	19.4	218.9	21.9	196.40	18.60	335.4	357.3
TR $\bar{x}$	13	2.2	1.0	8.9	1.7	8.9	0.8	20.0	3.5	53.00	5.20	94.1	97.6
SF $\bar{x}$	22	5.2	2.3	0.0	0.0	179.3	16.3	184.4	18.6	159.10	15.40	277.3	295.9

Appendix A-2: Median numbers, weights, and energy values for 1996 seeds and 1996 mushrooms.

		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	TRAN	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	ww Kg/ha	dw Kg/ha	MJ/ha	MJ/ha
TRC	1	burned											
	2	burned											
	3	0.0	0.0	13.3	2.6	0.0	0.0	13.3	2.6	51.54	5.74	103.3	105.9
	4	burned											
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.90	5.81	104.6	104.6
	6	burned											
	7	burned											
	8	burned											
	9	burned											
TRN	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.7	9.2	164.7	164.7
	2	0.0	0.0	26.7	5.1	26.7	2.4	53.3	7.5	28.30	3.12	56.2	63.7
	3	13.3	5.9	0.0	0.0	0.0	0.0	13.3	5.9	52.61	4.79	86.2	92.2
	4	0.0	0.0	13.3	2.6	26.7	2.4	40.0	5.0	24.89	2.76	49.6	54.6
SFC	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.04	7.58	136.4	136.4
	2	burned											
	3	13.3	5.9	0.0	0.0	213.3	19.4	226.7	25.3	90.97	10.41	187.4	212.7
	4	0.0	0.0	0.0	0.0	160.0	14.6	160.0	14.6	58.26	6.09	109.6	124.2
	5	0.0	0.0	0.0	0.0	120.0	10.9	120.0	10.9	61.09	6.19	111.4	122.4
	6	13.3	5.9	0.0	0.0	66.7	6.1	80.0	12.0	108.04	12.15	218.7	230.7

		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	TRAN	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	# 1000 seeds/ha	MJ/ha	ww Kg/ha	dw Kg/ha	MJ/ha	MJ/ha
SFC	7						burned						
	8						burned						
	9						burned						
	10	0.0	0.0	0.0	0.0	106.7	9.7	106.7	9.7	118.30	11.27	202.9	212.6
SFN	1	13.3	5.9	0.0	0.0	173.3	15.8	186.7	21.7	254.10	23.65	425.7	447.4
	2	0.0	0.0	0.0	0.0	226.7	20.6	226.7	20.6	56.44	8.30	149.4	170.0
	3	26.7	11.8	0.0	0.0	80.0	7.3	106.7	19.1	103.31	9.65	173.7	192.8
	4	0.0	0.0	0.0	0.0	13.3	1.2	13.3	1.2	302.85	29.03	522.6	523.8
	5	0.0	0.0	0.0	0.0	240.0	21.8	240.0	21.8	131.0	13.14	236.54	258.4
	6	0.0	0.0	0.0	0.0	80.0	7.3	80.0	7.3	274.70	30.11	542.0	549.3
	7	13.3	5.9	0.0	0.0	53.3	4.9	66.7	10.8	143.6	13.59	244.66	255.4
	8	13.3	5.9	0.0	0.0	200.0	18.2	213.3	24.1	133.99	11.96	215.3	239.4
	9	0.0	0.0	0.0	0.0	160.0	14.6	160.0	14.6	101.61	9.08	163.4	178.0
	10	0.0	0.0	0.0	0.0	106.7	9.7	106.7	9.7	130.94	10.41	187.4	197.1
	11	0.0	0.0	0.0	0.0	1160.0	105.6	1160.0	105.6	375.22	32.27	580.8	686.3
	12	0.0	0.0	0.0	0.0	66.7	6.1	66.7	6.1	348.69	32.43	583.7	589.8
TRC	9	0.0	0.0	6.7	1.3	0.0	0.0	6.7	1.3	56.22	5.78	104.0	105.2
TRN	4	0.0	0.0	6.7	1.3	13.3	1.2	26.7	5.5	40.46	3.96	71.2	77.9
SFC md	10	0.0	0.0	0.0	0.0	113.3	10.3	113.3	11.5	81.01	9.00	161.9	174.5
SFN	12	0.0	0.0	0.0	0.0	133.3	12.1	133.3	16.8	138.80	13.37	240.6	256.9
TR	13	0.0	0.0	6.7	1.3	6.7	0.6	16.7	3.4	48.34	4.87	87.6	91.6
SF	22	0.0	0.0	0.0	0.0	123.3	11.2	123.3	14.1	109.90	11.18	201.3	215.7

Appendix B. Occupancy records of middens on the monitored areas for 1997.

KEY

For Midden Numbers:

###[89*] Midden Number['Year Found' '*' following year indicates a newly established midden

For Monthly Occupancy cells:

N	Not Occupied
P	Possibly Occupied, Red Squirrel sign found but unsure of residency
Y	Occupied, Red Squirrel sign indicates resident
S	Occupied, Red Squirrel sighted
♀	Occupied, Adult female Red Squirrel
♂	Occupied, Adult male Red Squirrel
J	Occupied, Juvenile Red Squirrel sex unknown
A	Abert's Squirrel using area, no Red Squirrel present
XX	Remains of Red Squirrel found
*	Squirrel is tagged
NAT	Squirrel is naturally marked - ear notch, short tail, etc.
-	Midden not checked, no data
♀L	Adult female Red Squirrel, lactating
♀+'#'	Adult female Red Squirrel with "#" juveniles
RC	Radio-collared Red Squirrel (Arizona Game and Fish Study)

Shaded cell indicates a midden that has been renumbered or removed from censusing.

Transition Construction Area (TRC), 1997				
Midden	Mar	Jun	Sep	Dec
1101[89]	located off-area, new number - 5101			
1102[89]	N	N	S	S
1103[89]	Y	N	♂	Y
1104[89]	N	N	N	N
1105[89]	burned in Clark Peak fire			
1106[89]	♂	Y	N	S
1107[89]	burned in Clark Peak fire			
1108[89]	N	N	N	N
1109[89]	burned in Clark Peak fire			
1110[89*]	burned in Clark Peak fire			
1111[89]	N	N	N	N
1112[89*]	N	N	N	S
1113[89]	♂	♂	♂	♂
1114[89]	located off-area, new number - 5114			
1115[89]	N	N	N	N
1116[89*]	S	N	S	S
1117[89]	burned in Clark Peak fire			
1118[89]	♂	♂	♂	♂
1119[88]	burned in Clark Peak fire			
1120[89]	burned in Clark Peak fire			
1121[89*]	Y	S	2J	S
1122[89]	burned in Clark Peak fire			
1123[95*]	burned in Clark Peak fire			
1124[95*]	burned in Clark Peak fire			
1125[95*]	burned in Clark Peak fire			
1126[95*]	N	N	N	N
1130[90]	burned in Clark Peak fire			
1131[90*]	♂	♂	N	N
1132[90*]	N	N	N	N
1134[91*]	N	N	N	N
1135[91*]	burned in Clark Peak fire			
1136[91*]	burned in Clark Peak fire			

Transition Construction Area (TRC), 1997				
Midden	Mar	Jun	Sep	Dec
1137[91*]	burned in Clark Peak fire			
1138[91*]	N	N	N	N
1139[91*]	burned in Clark Peak fire			
1140[91*]	burned in Clark Peak fire			
1141[91*]	burned in Clark Peak fire			
1142[91*]	burned in Clark Peak fire			
1143[91*]	burned in Clark Peak fire			
1144[91*]	♂	N	S	S
1145[91*]	located off-area, new number - 5145			
1146[91*]	N	N	N	N
1147[91*]	♂	S	♂	S
1148[91*]	burned in Clark Peak fire			
1149[91*]	♀	♀	♀	Y
1150[91*]	located off-area, new number - 5150			
1151[91*]	removed from census - low occupancy			
1152[91*]	burned in Clark Peak fire			
1153[92*]	N	N	S	♀
1154[92*]	♀	♀L+3	N	N
1155[93*]	located off-area, new number - 5155			
1156[93*]	P	N	♀	♀
1157[93*]	located off-area, new number - 5157			
1159[93*]	burned in Clark Peak fire			
1160[96*]	S	♀	♀	2S[2]
1161[96*]	N	N	♀	N
1162[96*]	Y	N	N	N
# Mid	27	27	27	27
# Occ	13	9	13	14
% Occ	48	33	48	52
# Sq	13	9+3	14[1]	15[2]

1 This number includes the two older juveniles seen at midden 1121. An adult female was not seen at this midden, and it was not clear whether 1121 was the natal midden or the two juveniles had dispersed from another midden.

2 This number includes two squirrels seen at midden 1160 in December 1997. These two squirrels were seen together in the midden for a brief time. No positive identification as to sex or age was made (one may have been a young of the year). There was sign seen at the midden during later visits, but the squirrels were not observed.

Transition Non-Construction Area (TRN), 1997				
Midden	Mar	Jun	Sep	Dec
2201[89]	♂	Y	N	N
2202[89]	♀	P	N	Y
2203[89]	♂	♂	S	♀
2204[89]	♂	Y	S	S
2205[89]	N	Y	♂	Y
2206[89]	S	♂	♂	S
2207[89*]	N	N	N	N
2208[89*]	♂[NAT 1]	N	♂[NAT 1]	S[NAT 1]
2209[89]	N	N	P	Y
2210[90]	♂	♂	N	N
2211[90*]	N	S	S	S
2212[90]	♀	N	P	S[NAT 3]
2213[90]	removed from census - low occupancy			
2214[90*]	N	S	S	S
2215[90*]	N	N	N	N
2216[90*]	N	N	N	N
2217[90*]	N	N	N	Y
2218[91*]	N	N	N	N
2219[91*]	N	N	N	N
2220[91*]	N	N	N	N
2221[91*]	located off-area, new number - 5221			
2222[91*]	removed from census - low occupancy			
2223[91*]	♀	♀L[NAT 2]	N	N
2224[93*]	N	N	N	N
2225[94*]	N	N	N	N
2226[95*]	N	N	P	N
2227[95*]	N	N	N	Y
2228[95*]	N	N	N	N
2229[96*]	♀	Y	♀	S
2230[96*]	N	P	N	N
2231[96*]	located off-area, new number - 5231			

Transition Non-Construction Area (TRN), 1997				
Midden	Mar	Jun	Sep	Dec
2232[96*]	located off-area, new number - 5232			
2233[96*]	N	N	N	N
2234[97*]	new midden		Y	S
# Mid	28	28	29	29
# Occ	10	10	9	14
% Occ	36	36	31	48
# Sq	10	10	9	14

1 The male at midden 2208 has a natural mark - rip in the right ear.

2 The female at midden 2223 has a natural mark - rip in left ear.

3 The squirrel at midden 2212 has a natural mark - notch in left ear.

Spruce-Fir Construction Area (SFC), 1997				
Midden	Mar	Jun	Sep	Dec
3000[95*]	N	N	N	N
3001[95*]	♂	♂	♂	Y
3002[95*]	♂	N	N	N
3003[95*]	N	N	N	Y
3004[95*]	burned in Clark Peak fire			
3005[95*]	N	N	N	N
3006[95*]	N	N	N	N
3007[95*]	removed from census - too far off area			
3008[95*]	N	N	N	N
3009[95*]	N	N	N	N
3010[95*]	N	N	N	N
3011[95*]	located off-area, new number - 5311			
3012[95*]	burned in Clark Peak fire			
3013[95*]	N	N	N	N
3014[95*]	N	N	N	N
3015[95*]	burned in Clark Peak fire			
3016[95*]	burned in Clark Peak fire			
3017[95*]	burned in Clark Peak fire			
3018[95*]	burned in Clark Peak fire			
3019[96*]	N	N	N	N
3020[96*]	N	P	Y	Y
3021[96*]	burned in Clark Peak fire			
3022[96*]	N	N	N	P
3300[86]	♀	Y	♀	♀
3301[94*]	N	N	N	N
3302[94*]	located off-area, new number - 5302			
3303[94*]	Y	♂	P	S
3304[94*]	N	N	N	Y
3305[94*]	P	N	N	N
3306[94*]	♂	P	♂	S [NAT 8]
3307[94*]	N	N	N	N
3308[95*]	N	N	♀	N
3309[95*]	XX	N	N	Y

Spruce-Fir Construction Area (SFC), 1997				
Midden	Mar	Jun	Sep	Dec
3310[95*]	N	N	N	N
3311[95*]	S	♂[NAT 6]	♂	N[6]
3312[95*]	♀	♀L	S	Y
3313[95*]	located off-area, new number - 5313			
3314[95*]	N	N	N	N
3315[95*]	Y	P	N	Y
3316[95*]	♀	S	N	N
3317[95*]	♀	Y	S	Y
3318[95*]	N	N	N	N
3319[95*]	♀	♀	N	N
3320[95*]	♀[NAT 1]	N	♀	P
3321[95*]	N	N	N	N
3322[95*]	N	N	N	N
3323[95*]	♂	♂	♀	Y
3324[95*]	N	N	N	N
3325[95*]	N	N	N	N
3326[95*]	N	N	N	N
3327[95*]	N	N	N	P
3328[95*]	N	N	N	N
3329[95*]	N	N	N	N
3330[95*]	S	♀	Y	N
3331[95*]	♀	♀	S	Y
3332[95*]	N	N	N	Y
3333[95*]	N	N	P	N
3334[95*]	N	N	N	N
3335[95*]	N	N	Y	Y
3336[95*]	N	N	N	N
3337[95*]	N	N	N	N
3338[95*]	N	N	N	N
3339[95*]	N	N	N	N
3340[95*]	N	N	N	N
3341[95*]	♂	N	S	S
3342[95*]	♀	P	N	N

Spruce-Fir Construction Area (SFC), 1997				
Midden	Mar	Jun	Sep	Dec
3343[95*]	♀	N	Y	N
3344[95*]	N	N	N	N
3345[95*]	N	N	N	N
3346[95*]	N	N	N	N
3347[95*]	N	N	N	N
3348[95*]	N	N	N	N
3349[95*]	N	N	N	N
3350[87]	♂	Y	N	N
3351[87]	♂	♂	♀	S
3352[86]	removed from census - low occupancy			
3353[87]	♀	♀	♀	♀
3354[86]	N	N	N	N
3355[95*]	N	N	N	N
3356[86]	Y	S	S	♂
3357[86]	removed from census - low occupancy			
3358[87]	burned in Clark Peak fire			
3359[87]	burned in Clark Peak fire			
3360[86]	♂[*2]	P	N	♂ NAT 6
3361[86]	♂	S	N	N
3362[86]	♀	P	N	N
3363[86]	N	N	N	N
3364[86]	N	N	N	N
3365[86]	♂[*3]	♂[*3]	♂[*3]	♂[*3]
3366[86]	♂	♂NAT 7	S	S
3367[87]	♂	S	Y	S
3368[86]	S	♂	S	Y
3369[86]	♀	♀L	S	Y
3370[86]	N	N	S	Y
3371[87]	♀	♂	N	Y

Spruce-Fir Construction Area (SFC), 1997				
Midden	Mar	Jun	Sep	Dec
3372[89]	♀	♀L	♀	Y
3373[87]	♀	♂	N	Y
3374[89]	♂	♂	S	N
3375[86]	♂	♀	N	Y
3376[86]	located off-area, new number - 5376			
3377[87]	located off-area, new number - 5377			
3378[90*]	S	S	N	S
3379[90*]	♂	N	N	P
3380[90*]	N	N	N	N
3381[90*]	N	N	N	N
3382[91*]	Y	♀	S	N
3383[91*]	N	N	N	N
3384[91*]	burned in Clark Peak fire			
3385[91*]	N	N	N	N
3386[91*]	N	N	N	N
3387[91*]	♂	♂	♂	S
3388[92*]	located off-area, new number - 5388			
3389[93*]	N	N	N	N
3390[93*]	♀	♀L	♀	Y
3391[93*]	N	N	N	N
3392[93*]	♂NAT 4	N	N	N
3393[93*]	♂	S	N	N
3394[93*]	♂[*5]	Y	♀	Y

Spruce-Fir Construction Area (SFC), 1997				
Midden	Mar	Jun	Sep	Dec
3395[94*]	N	N	N	N
3396[94*]	N	N	N	N
3397[86]	Y	N	P	N
3398[86]	N	N	N	N
3399[94*]	♂	♂	Y	Y
# Mid	104	104	104	104
# Occ	45	33	31	35
% Occ	43	32	30	34
# Sq	45	33	31	35

1 Female at midden 3320 with natural mark - missing about 1/3 of her tail.

2 Marked male at midden 3360 - rip/metal (B/G)

3 Marked male at midden 3365 - W/- (W/R)

4 Male at midden 3392 with natural mark - rip in right ear.

5 Marked male at midden 3394 - rip/rip (W/O)

6 Male at midden 3311 with natural mark - middle toe of left foot sticks out straight. This male was seen in midden 3360 in December. It is presumed that this is the same male seen in September caching cones in middens 3311, 3360, and 3310; but that the natural mark went unnoticed. In September, the primary midden appeared to be 3311, but in December, while there were still tracks and feeding at and in between all three middens, there was more sign at midden 3360.

7 Male at midden 3366 with natural mark - missing 1/4 of his tail.

8 Squirrel at midden 3306 with natural mark - missing 1/3 of its tail.

Spruce-Fir Non Construction Area (SFN), 1997				
Midden	Mar	Jun	Sep	Dec
4000[95*]	♀	Y	♀	♀
4001[95*]	♀	N	N	S
4002[95*]	♀	♀L	♀	Y
4003[95*]	♀	♀	N	S
4004[95*]	N	N	N	N
4005[95*]	N	N	N	Y
4006[95*]	N	N	Y	N
4007[95*]	N	N	N	N
4008[95*]	♂	Y	N	Y
4009[95*]	N	N	N	N
4010[95*]	N	N	N	N
4011[95*]	N	N	N	N
4012[95*]	N	N	N	N
4013[96*]	♂	♂	Y	Y
4014[96*]	N	N	N	N
4015[96*]	N	N	N	N
4016[96*]	N	N	N	N
4017[96*]	N	N	N	N
4018[96*]	N	N	N	N
4019[96*]	N	N	N	N
4020[96*]	N	N	N	N
4021[96*1]	♀	Y	♀	P
4400[89]	N	N	N	N
4401[94*]	♀	N	N	N
4402[94*]	S	N	P	N
4403[94*]	N	N	N	N
4404[95*]	♀	S	S	Y
4405[95*]	S	N	N	N
4406[95*]	N	N	N	N
4407[95*]	S	N	N	N
4408[95*]	N	N	N	N
4409[95*]	♂	N	N	N
4410[95*]	located off-area, new number - 5410			
4411[95*]	N	N	N	N

Spruce-Fir Non Construction Area (SFN), 1997				
Midden	Mar	Jun	Sep	Dec
4412[95*]	♀	P	N	N
4413[95*]	located off-area, new number - 5413			
4414[95*]	N	N	N	N
4415[95*]	♀	N	N	Y
4416[95*]	♀	Y	N	♀
4417[95*]	♂	♀L	♂	♂
4418[95*]	S	N	N	N
4419[95*]	♀	N	N	Y
4420[90]	♂	Y	♂	S
4421[86]	♀	Y	N	N
4422[86]	♂	♂	S	Y
4423[86]	♂	♂	S	S
4424[86]	♂	N	N	N
4425[87]	removed from census - low occupancy			
4426[86]	N	N	N	N
4427[86]	♂	S	S	S[NAT 5]
4428[86]	Y	Y	Y	S
4429[86]	♂	♂	S	Y
4430[86]	N	N	N	N
4431[86]	♀	♂	N	N
4432[86]	♂	S	N	N
4433[87]	N	N	N	N
4434[86]	removed from census - low occupancy			
4435[86]	♂	♂[NAT 4]	♂[NAT 4]	Y
4436[86]	N	N	N	N
4437[95*]	N	N	N	N
4438[90*]	♂[NAT 2]	♂[NAT 2]	N	N
4439[90*]	N	N	N	N
4440[91]	removed from census - low occupancy			
4441[86]	N	N	N	♂
4442[95*]	N	N	N	N
4443[86]	♂	♀L	♀	S
4444[86]	♀	♀L	S	♀
4445[86]	♂	Y	S	Y

Spruce-Fir Non Construction Area (SFN), 1997				
Midden	Mar	Jun	Sep	Dec
4446[86]	removed from census - low occupancy			
4447[86]	♂	P	N	P
4448[86]	removed from census - low occupancy			
4449[86]	♂	♀	♂	Y
4450[86]	♂	N	N	N
4451[88]	removed from census - low occupancy			
4452[86]	♀	S	♀	Y
4453[86]	removed from census - low occupancy			
4454[86]	N	N	N	N
4455[86]	removed from census - low occupancy			
4456[86]	removed from census - low occupancy			
4457[86]	Y	N	N	N
4458[86]	removed from census - low occupancy			
4459[86]	removed from census - low occupancy			
4460[87]	Y	N	N	N
4461[91*]	♂	♂	S	♂
4462[90]	N	N	N	N
4463[90]	♀	Y	S	S
4464[90]	N	N	N	N
4465[90*]	♀	♀L	N	N
4466[87]	Y	S	N	N
4467[87]	♂	S	S	Y
4468[87]	removed from census - low occupancy			
4469[87]	♀	S	♀	S
4470[87]	♂[NAT 3]	♂[NAT 3]	S	S
4471[87]	♂	N	N	N
4472[87]	♀	Y	S	S
4473[87]	♀	♀L	♀	♀

Spruce-Fir Non Construction Area (SFN), 1997				
Midden	Mar	Jun	Sep	Dec
4474[86]	♂	♂	♂	Y
4475[87]	located off-area, new number - 5405			
4476[95*]	N	N	N	N
4477[87]	♂	Y	Y	S
4478[90*]	N	N	N	N
4479[90*]	removed from census - low occupancy			
4480[90*]	removed from census - low occupancy			
4481[86]	N	N	N	N
4482[86]	N	N	N	N
4483[86]	removed from census - low occupancy			
4484[86]	N	N	♂	Y
4485[86]	removed from census - low occupancy			
4486[86]	removed from census - low occupancy			
4487[86]	located off-area, new number - 5487			
4488[91*]	N	N	N	N
4489[91*]	N	N	N	N
4490[91*]	N	♀L	♀	Y
4491[91*]	N	N	N	N
4492[91*]	N	N	N	N
4493[91*]	removed from census - low occupancy			
4494[91*]	Y	P	N	Y

Spruce-Fir Non Construction Area (SFN), 1997				
Midden	Mar	Jun	Sep	Dec
4495[95*]	Y	♀	N	N
4496[93*]	N	N	N	N
4497[93*]	N	N	N	N
4498[93*]	♀	N	N	N
4499[93*]	♀	N	N	N
# Mid	100	100	100	100
# Occ	56	38	30	37
% Occ	56	38	30	37
# Sq	56	38	30	37

1 Midden 4021 was originally an off-area midden (5475), but was GPS located on the SFN area and renumbered accordingly.

2 The male at midden 4438 has a natural mark - about 1/3 of his tail is missing.

3 The male at midden 4470 has a natural mark - notch in R ear.

4 The male at midden 4435 has a natural mark - 2 rips in R ear. In September, one rip was clearly seen in the male's right ear, a second rip was possible, but not clearly seen.

5 The squirrel at midden 4427 has a natural mark - notch in R ear.

Off-Area Midden Occupancy, 1997				
Midden	Mar	Jun	Sep	Dec
TRC Area				
5101[89]	S	S	S	S
5114[89]	removed from census - low occupancy			
5118[94*]	N	N	S	S
5119[89*]	♀	Y	♀	Y
5120[89*]	removed from census - too far off area			
5121[89*]	S	♂	♀	♀
5122[89]	N	N	N	N
5123[89]	removed from census - too far off area			
5124[90*]	removed from census - too far off area			
5125[89*]	♂	♂	♂	♂
5126[91]	N	N	N	N
5127[95*]	N	N	N	N
5145[91*]	N	N	N	N
5150[91*]	♂	♂	P	N
5155[93*]	♂	♂	♀	♀
5157[93*]	♂	S	♂	S
TRN Area				
5200[93*]	♂	♀L	P	♂
5221[91*]	N	N	N	N
5231[96*]	♂	S	♀	N
5232[96*]	S	S	N	♀[NAT 2]
SFC Area				
5302[94*]	N	N	N	N
5311[95*]	♂	♂	N	S
5313[95*]	♀	N	S	S
5350[86]	♂	♀L	♀	S
5351[94*]	♀	♀L	Y	Y

Off-Area Midden Occupancy, 1997				
Midden	Mar	Jun	Sep	Dec
SFC Area				
5352[94*]	N	N	N	N
5353[94*]	removed from census - too far off area			
5354[94*]	♂	Y	Y	Y
5355[94*]	N	N	N	N
5356[94*]	N	P	P	N
5357[95*]	N	N	N	N
5358[95*]	removed from census - too far off area			
5359[95*]	♀	P	S	Y
5360[96*]	N	N	N	N
5361[96*]	♀	N	N	N
5362[96*]	N	N	N	N
5376[86]	N	N	N	N
5377[87]	♀	♀	♀/♂[1]	S
5388[92*]	N	N	N	N
SFN Area				
5405[87]	S	♂	♀	♀
5410[95*]	♀	P	N	N
5413[95*]	♀	♀L	♀	♀
5475[86]	located on area - new number 4021			
5487[86]	removed from census - low occupancy			

Bold Midden Numbers: indicate middens that were previously on-area, but have been GPS located off-area and renumbered accordingly.

1 A female squirrel was seen in midden 5377 on 25 September, and a male squirrel was seen on 27 September. The midden was definitely active (cone caching, feeding sign, and clipped cones), but it was uncertain which squirrel was the resident.

2 The female at midden 5232 has a natural mark - notch on R ear.

Appendix C. Occupancy status of middens located within 100 meters of construction (telescopes or access road). These middens are checked during months other than the quarterly full census months (Mar, Jun, Sep, Dec) in which there is construction activity. These middens are checked as an "early warning" indicator of a large population decrease in between the quarterly censuses. See Appendix B for key to symbols.

Middens within 100m of construction										
Midden	Mar[1]	Apr	May	Jun[1]	Jul	Aug	Sep[1]	Oct	Nov[6]	Dec[1]
1160	S	♀	S	♀	S	P	♀	S	-	2S[7]
3003	N	N	N	N	N	N	N	N	-	Y
3013	N	N	N	N	N	N	N	N	-	N
3014	N	N	N	N	N	N	N	N	-	N
3019	N	N	N	N	N	N	N	N	-	N
3020	N	♀	P	P	P	N	Y	Y	-	Y
3309	XX	N	N	N	N	2J	N	N	-	Y
3315	Y	S	S	P	N	N	N	N	-	Y
3319	♀	♀	♀	♀	♀	N	N	N	-	N
3320	♀[NAT2]	N	N	N	N	♀L + 2	♀	P	-	P
3322	N	N	N	N	N	N	N	N	-	N
3323	♂	N	N	♂	♂	♀L + 1	♀	S	-	Y
3324	N	N	N	N	N	N	N	N	-	N
3325	N	N	N	N	N	N	N	N	-	N
3327	N	N	N	N	N	♀L + 1	N	N	-	P
3330	S	♀	♀	♀	♀	S	Y	Y	-	N
3334	N	N	N	N	N	N	N	N	-	N
3336	N	N	N	N	N	N	N	N	-	N
3337	N	N	N	N	N	N	N	N	-	N
3340	N	N	N	N	N	N	N	N	-	N
3345	N	N	N	N	N	N	N	N	-	N
3346	N	N	N	N	N	N	N	N	-	N
3347	N	N	N	N	N	N	N	N	-	N
3350	♂	♂	♂	Y	♂	N	N	N	-	N
3354	N	N	N	N	N	N	N	N	-	N
3357		removed from census - low occupancy								
3362	♀	♀	Y	P	N	N	N	N	-	N
3363	N	N	N	N	N	N	N	N	-	N
3364	N	N	N	N	N	N	N	N	-	N
3365	♂[*3]	♂[*3]	♂[*3]	♂[*3]	♂[*3]	♂[*3]	♂[*3]	♂[*3]	-	♂[*3]
3368	S	♂	Y	♂	♀	♂	S	S	-	Y
3379	♂	♂	N	N	♂	P	N	N	-	P

Middens within 100m of construction										
Midden	Mar[1]	Apr	May	Jun[1]	Jul	Aug	Sep[1]	Oct	Nov[6]	Dec[1]
3382	Y	♂	Y	♀	Y	P	S	S	-	N
3383	N	N	N	N	N	N	N	N	-	N
3385	N	N	N	N	N	N	N	N	-	N
3389	N	N	N	N	N	♀L + 3	N	N	-	N
3391	N	N	N	N	N	N	N	N	-	N
# Mid[4]	36	36	36	36	36	36	36	36	-	36
# Occ	12	11	9	8	9	8 + 7	8	7	-	8
% Occ	33	31	25	22	25	22	22	19	-	22
# Sq	12	11	9	8	9	16[5]	8	7	-	9[7]

1 A complete census of all areas was conducted in March, June, September, and December (see Table 2). Occupancy status of middens within 100 m of construction in March, June, September, and December are presented here for comparison.

2 Naturally marked female at midden 3320 - missing about 1/3 of her tail.

3 Marked male at midden 3365 = W/- (W/R).

4 The total number of middens does not include midden 3357 (removed from censusing due to low occupancy). All middens are located on the SFC area, except for midden 1160 which is located on the TRC area.

5 This number includes the two older juveniles seen at midden 3309. It was not clear whether 3309 was the natal midden, or the two juveniles had dispersed from another midden.

6 There was no census of the middens within 100 m of construction in November. The only activity on the construction site was the winterizing of structures during the first week of November.

7 This number includes two squirrels seen at midden 1160 in December 1997. These two squirrels were seen together in the midden for a brief time. No identification as to sex or age was made. There was sign seen at the midden during later visits, but the squirrels were not observed.

Appendix D. Red squirrel populations (including juveniles) on the areas being monitored by the Red Squirrel Monitoring Program, from December 1996 through December 1997.

Date	TRC	TRN	SFC	SFN	TOTAL
Dec 1996	17	15	55	60	147
Mar 1997	13	10	45	56	124
Jun 1997	9+3	10	33	38	90+3
Sep 1997	14[1]	9	31	30	84[1]
Dec 1997	**15[2]**	**14**	**35**	**37**	**101[2]**

Bold Indicates data for this quarter.

1 This number includes the two juveniles seen at midden 1121. No adult female was observed at this midden, and it was not clear whether these two older juveniles were at their natal midden or had dispersed here from another midden.

2 This number includes two squirrels seen at midden 1160 in December 1997. These two squirrels were seen together in the midden for a brief time. No positive identification as to sex or age was made (one may have been a young of the year). There was sign seen at the midden during later visits, but the squirrels were not observed.

Appendix E. Midden occupancy Maps, 1997

Appendix F: Measures of Spatial Distribution.

F-1. Crude Density

a) middens

b) squirrels

F-2. Local density and nearest neighbor distances of middens and squirrels.

Appendix F-1a: Crude density of red squirrel middens in each of the areas under study by the Monitoring Program. The size of each area is given in hectares (ha); densities are given in middens per hectare (mid/ha).

DATE	TRC Area	TRN Area	SFC Area	SFN Area
New Areas[1]	49.1	24.4	76.1	128.9
Dec 1996	0.69	1.35	1.48	0.94
Mar 1997	0.55	1.15	1.37	0.78
Jun 1997	0.55	1.15	1.37	0.78
Sep 1997	0.55	1.19	1.37	0.78
Dec 1997	0.55	1.19	1.37	0.78

1 These new areas area the amount of habitat available for red squirrel use after the Clark Peak fire.

Appendix F-1b. Crude density of red squirrels (including juveniles) in each of the monitored areas for December 1996 through December 1997. The size of each area is given in hectares (ha); densities are given in squirrels per hectare (sq/ha).

DATE	TRC Area	TRN Area	SFC Area	SFN Area
New Areas[1]	49.1	24.4	76.1	128.9
Dec 1996	0.35	0.61	0.72	0.47
Mar 1997	0.26	0.41	0.59	0.43
Jun 1997	0.24	0.41	0.43	0.29
Sep 1997	0.29[2]	0.37	0.41	0.23
Dec 1997	0.31[3]	0.57	0.46	0.29

1 These new areas area the amount of habitat available for red squirrel use after the Clark Peak fire.

2 This number includes the two juveniles seen at midden 1121. No adult female was observed at this midden, and it was not clear whether these two older juveniles were at their natal midden or had dispersed here from another midden.

3 This number includes two squirrels seen at midden 1160 in December 1997. These two squirrels were seen together in the midden for a brief time. No positive identification as to sex or age was made (one may have been a young of the year). There was sign seen at the midden during later visits, but the squirrels were not observed.

Appendix F-2. Local Density and Nearest Neighbor Distances of *middens* and *squirrels*.

TRC Area									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 96	34	4.0	0.33	54.7	33.82	1.4	0.94	79.9	30.88
Mar 97	27	3.6	0.34	57.7	7.98	1.5	0.24	75.9	9.60
Jun 97	27	3.6	0.34	57.7	7.98	1.2	0.28	83.0	12.70
Sep 97	27	3.6	0.34	57.7	7.98	1.8	0.25	76.0	9.30
Dec 97	27	3.6	0.34	57.7	7.98	1.9	0.29	76.6	8.80

TRN Area									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 96	33	4.6	1.62	45.9	15.10	2.6	0.99	51.3	22.09
Mar 97	28	4.6	0.31	44.6	2.84	1.3	0.21	72.4	7.81
Jun 97	28	4.6	0.31	44.6	2.84	1.5	0.37	74.8	6.79
Sep 97	29	4.7	0.28	45.5	2.87	2.0	0.37	67.3	7.18
Dec 97	29	4.7	0.28	45.5	2.87	2.6	0.29	61.0	5.69

Appendix F-2 (con't.)

SFC Area									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 96	113	5.9	2.59	43.3	15.07	3.2	1.78	51.9	18.43
Mar 97	104	6.0	0.25	42.3	1.42	2.6	0.21	56.3	3.17
Jun 97	104	6.0	0.25	42.3	1.42	2.1	0.23	69.6	6.32
Sep 97	104	6.0	0.25	42.3	1.42	1.7	0.22	74.8	6.79
Dec 97	104	6.0	0.25	42.3	1.42	2.5	0.22	54.9	5.56

SFN Area									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 96	121	3.9	1.84	48.5	19.83	1.5	1.03	72.8	36.95
Mar 97	100	3.4	0.17	50.0	2.14	1.5	0.14	70.1	4.94
Jun 97	100	3.4	0.17	50.0	2.14	0.9	0.12	91.2	9.11
Sep 97	100	3.4	0.17	50.0	2.14	0.5	0.09	118.2	10.32
Dec 97	100	3.4	0.17	50.0	2.14	0.8	0.11	90.4	9.43

Appendix F-2 (con't.)

All Areas Combined									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 96	326	4.8	2.34	47.3	21.00	2.2	1.56	63.9	31.20
Mar 97	295	4.6	0.14	47.1	1.25	1.8	0.10	65.9	2.52
Jun 97	295	4.6	0.14	47.1	1.25	1.4	0.11	79.1	4.14
Sep 97	296	4.6	0.14	47.2	1.25	1.3	0.11	88.6	4.63
Dec 97	296	4.6	0.14	47.2	1.25	1.7	0.12	73.7	4.04

Appendix G. Reproductive success on the monitored areas, 1997.

G-1. Breeding chases seen on the monitored areas.

G-2. Litters seen on the monitored areas.

Appendix G-1. Breeding chases seen on the monitored areas.

DATE	MIDDEN	
4 June	1160	A non-lactating female was observed in her midden, while two males (1 scrotal and the other partially scrotal) chased each other around her midden. The female was observed chasing the scrotal male after he chattered.
17 June	1154	Two males were observed chasing each other around this female's midden. The female was observed leaving and encouraging a small juvenile female to follow her.
23 June	2223	One scrotal male was observed moving in and out of this midden. Another scrotal male entered the midden sniffing about and then a chase ensued between the two males. Female looked as if she may have been pregnant.

Appendix G-2. Litters seen on the monitored areas.

DATE	MIDDEN	
17 June	1154	17 June - a juvenile red squirrel (estimated to be about one week out of the nest) was seen at midden 1154. Two males were also seen chasing each other around this midden. The resident lactating female chased the two males out and then moved the juvenile in the direction of midden 1161. It was not known where the female moved the juvenile. 21 June - three juveniles were seen near middens 1118 and 1149 (midden 1149 is occupied by a non-lactating female and a male resides at midden 1118). The lactating female was not observed. Two squirrels chased each other through the area where the juveniles were located, but did not interact with the juveniles. 24 June - three juveniles were again seen near middens 1118 and 1149. The non-lactating female resident of midden 1149 was seen and a chatter was heard at midden 1118. A lactating female was located in a different part of the midden from the chatter. She was observed picking up a bone and caching in on the edge of midden 1118 and then heading towards the location of the juveniles. It is believed that the lactating female and the juveniles are the ones seen in midden 1154 on 17 June. The natal nest was never located.
18 Aug	3309	Two juveniles (one male) observed on a snag in the midden. They barked and went into the snag.
Aug	3320	Lactating female was observed in several territorial disputes with the adult male at 3350 in July. One observer later saw the female and two juveniles at 3350 (15 Aug). Another observer saw a juvenile in 3319 on 19 Aug. On 31 Aug, two observers watched middens 3319, 3350 and 3320. A juvenile barked west of 3350, and then chattering was heard at 3320. A new piece of pink flagging was hanging out of a cavity in a snag. Two juveniles were observed emerging from this snag. It is believed that the female and two juveniles originate from 3319 and they moved through 3350 to settle here at 3320.
19 Aug	3323	A lactating female (pink nipples) was followed from 3379 to 3354/3323 area.. She went to the tree tops and was visually lost, but she chattered.A juvenile was seen in the same tree at where the female went out of sight. This female from 3323 had been observed using 3354 and areas between there and 3379 for many months.
19 Aug	3327	A lactating or post lactating female with black nipples was observed feeding on cones and clipping cones high in tree tops near 3327 and then moved closer to 3354 and 3323. A ♂ older juvenile was seen in midden 3327 a few days earlier.

Appendix G-2 (cont.)

19 Aug	3330	An observer heard two small chirps and spotted a juvenile on a limb of a snag west of the tag tree. It was identified as young of the year based on size.
15 Aug	3389	Two juveniles were observed sitting on and Englemann spruce snag and a third was seen in a spruce tree. A lactating female entered the midden with lichen and placed it in the snag. On 19 Aug, a lactating female observed barking in her midden.
24 Sep	1121	Two juveniles (one female) were observed in the midden. One juvenile was feeding, then went higher into the tree. The second juvenile was seen only briefly, gave a bark and then disappeared.

Number of Young Observed	Number Reproductive ♀ Observed	Number Lactating ♀ Observed	Number of Post-Lactating ♀ Observed
19	4	22	6

The same female is not counted more than once in the numbers of pre-lactating, lactating and post-lactating.

Appendix H. Marked Squirrel Data

H-1. Squirrels with natural indentifying marks and radio-collared squirrels.

H-2. Disappearance of marked squirrels.

H-3. Sightings of marked squirrels outside their midden.

H-4. Movements of marked squirrels to new middens.

H-5. Evidence of marked squirrels defending >1 midden.

Appendix H-1. Squirrels with natural indentifying marks and radio-collared squirrels.

Midden	Squirrel ID	Notes
2208	♂ - rip in right ear	seen in Mar, Sep & Dec
2212	S - notch in left ear	seen in Dec
2223	♀ - rip in left ear	seen in June
3306	S - short tail	seen in Dec
3309	♂ - radio collared	found dead in March (predation)
3311	♂ - middle toe on left front foot sticks straight out	seen caching and feeding at three middens:3311, 3360, and 3310. 3311 appeared to be the primary midden in Sep, but by Dec, 3360 had more activity
3320	♀ - short tail	seen in Mar
3366	♂ - short tail	seen in Jun
3392	♂ - rip in right ear	seen in Mar
4427	S - notch in right ear	seen in Dec
4435	♂ - two rips in right ear	seen in Jun & Sep
4438	♂ - short tail	seen in Mar & Jun
4470	♂ - notch in right ear	seen in Mar & Jun
5232	♀ - notch in right ear	seen in Dec

Appendix H-2. Disappearance of marked squirrels.

Month Last Seen	Capture Location	Squirrel ID	Notes
Mar 97	3360	rip/metal ♂ (B/G)	Marked as an adult (non-scrotal) on 5 Oct 1995. Last seen on the monitored areas on 7 Mar 97 (had been living at 3360). This male was considered to be living on the area for 17 months.
Mar 97	3394	rip/rip ♂ (W/O)	Marked as an adult (non-scrotal) 6 Oct 1995. Last seen on the monitored areas on 8 March 97 (had been living at 3394). This male was considered to be living on the area for 17 months.

Appendix H-3. Sightings of marked squirrels outside their midden.

Date	Squirrel ID	Location	Distance from own midden	Notes
12 Apr 97	3365 W/- (W/R)		30 m	RS was observed feeding and foraging ~30m NW of 3365.

Appendix H-4. Movements of marked squirrels to new middens.

Movements of marked squirrels to new middens were not observed in 1997.

Appendix H-5. Evidence of marked squirrels defending >1 midden.

No evidence of marked squirrels defending more than one midden was observed in 1997.

Appendix I. Weather Data.

I-1. Monthly Weather Summaries for 1997.

I-2. Monthly maxima, mimina and averages from snow poles

Appendix I-1. Monthly Weather Summaries for 1997.

	Month	Biology Camp	Emerald Peak
Temperature (°C) average (max; min)	January	-3.2 (14.1; -15.7)	-4.6 (9.1; -16.3)
	February	-2.6 (15.4; -11.9)	-3.6 (10.8; -14.1)
	March	2.6 (21.8; -14.3)	1.2 (15.3; -16.4)
	April	3.0 (22.5; -14.6)	0.2 (13.6; -17.0)
	May	11.0 (31.4; 1.6)	7.3 (19.3; 0.0)*
	June	14.2 (32.3; 2.4)	10.1 (22.5; -1.7)*
	July	15.0 (35.8; 6.5)	11.4 (24.9; 3.6)
	August	13.4 (25.9; 7.1)	11.4 (22.8; 5.8)
	September	12.4 (25.5; 3.6)**	10.5 (21.8; -0.6)
	October	n/a**	2.8 (16.3; -11.8)
	November	n/a**	-0.5 (13.0; -12.6)
	December	n/a**	-6.5 (8.9; -19.7)
Wind Chill (°C), Minimum	January	-17.8	-24.6
	February	-13.4	-19.6
	March	-14.3	-16.4
	April	-15.0	-17.0
	May	0.9	-2.5*
	June	2.1	-1.7*
	July	6.5	3.6
	August	7.1	5.0
	September	3.6**	-0.6
	October	n/a**	-13.8
	November	n/a**	-12.6
	December	n/a**	-19.6

	Month	Biology Camp	Emerald Peak
Wind Speed (m/sec), maximum(max. gust)	January	3.1 (12.5)	4.0 (16.1)
	February	2.7 (10.3)	3.1 (11.6)
	March	2.7 (11.6)	3.6 (11.2)
	April	4.0 (12.1)	4.0 (17.0)
	May	2.7 (9.4)	2.7 (9.8)*
	June	2.7 (10.3)	1.8 (9.4)*
	July	2.2 (7.6)	3.6 (8.0)
	August	2.2 (9.8)	4.0 (9.4)
	September	1.8 (12.1)**	4.0 (10.7)
	October	n/a**	3.6 (13.0)
	November	n/a**	3.1 (10.7)
	December	n/a**	3.6 (12.5)
Wind, Most Common Direction	January	south	west northwest
	February	south	east southeast
	March	south southwest	west northwest
	April	south	west northwest
	May	south	west northwest*
	June	south	east southeast*
	July	north	north northwest
	August	north	southeast
	September	south southwest	southeast
	October	n/a**	southeast
	November	n/a**	west northwest
	December	n/a**	east southeast

	Month	Biology Camp	Emerald Peak
Total Rain (mm)	January	n/a	n/a
	February	n/a	n/a
	March	n/a	n/a
	April	n/a	n/a
	May	55.7	n/a
	June	2.7	7.4*
	July	91.0	75.4
	August	189.0	144.4
	September	64.3	68.0
	October	n/a**	31.2
	November	n/a	n/a
	December	n/a	n/a
Minimum Barometric Pressure (mbar)	January	511.7	--
	February	508.6	--
	March	513.9	--
	April	511.3	--
	May	518.2	--
	June	516.5	--
	July	524.9	--
	August	522.6	--
	September	521.3	--
	October	n/a**	--
	November	n/a**	--
	December	n/a**	--

	Month	Biology Camp	Emerald Peak
Relative Humidity (%) average (max; min)	January	69.9 (96; 17)	--
	February	51.3 (91; 11)	--
	March	44.5 (92; 14)	--
	April	53.7 (94; 19)	--
	May	47.0 (90; 11)	--
	June	36.9 (93; 10)	--
	July	53.8 (96; 11)	--
	August	77.7 (98; 33)	--
	September	73.8 (98; 35)	--
	October	n/a**	--
	November	n/a**	--
	December	n/a**	--
Dew Point (°C) average (max; min)	January	-8.5 (4.1; -23.0)	--
	February	-12.5 (-1.4; -26.7)	--
	March	-9.3 (0.0; -20.8)	--
	April	-6.6 (2.6; -18.0)	--
	May	-1.5 (8.3; -19.0)	--
	June	-2.2 (9.1; -12.7)	--
	July	3.6 (15.2; -10.0)	--
	August	9.2 (14.9; 3.7)	--
	September	7.5 (14.6; 0.6)	--
	October	n/a**	--
	November	n/a**	--
	December	n/a**	--

n/a = not available; snow still on ground.
* equipment malfunction - missing data 1530 12May97 through 0930 10Jun97.
** n/a data not available due to equipment/software malfunction.

Appendix I-2. Monthly maxima, mimina and averages from snow poles in Spruce-Fir (SF) and Transition (TR) habitats from locations in the forest (F) and in clearings (C).

Month	Habitat	Location	Avg. snow depth (cm) (# of stations)	Max. snow depth (cm)	Min. snow depth (cm)
Nov 1996	SF	C	12.7 (3)	30	0
Nov 1996	SF	F	7.0 (3)	19	0
Nov 1996	TR	C	0.0 (3)	0	0
Nov 1996	TR	F	0.0 (3)	0	0
Dec 1996	SF	C	41.6 (5)	55	28
Dec 1996	SF	F	21.8 (5)	31	0
Dec 1996	TR	C	29.2 (3)	41	21.5
Dec 1996	TR	F	19.8 (3)	25	16
Jan 1997	SF	C	49.4 (5)	73	23
Jan 1997	SF	F	28.6 (5)	38	20
Jan 1997	TR	C	33.7 (3)	47	26
Jan 1997	TR	F	21.7 (3)	25	20
Feb 1997	SF	C	88.0 (5)	114	61
Feb 1997	SF	F	65.6 (5)	74	47
Feb 1997	TR	C	71.3 (3)	91	57
Feb 1997	TR	F	53.7 (3)	61	50
Mar 1997	SF	C	150.4 (7)	189	100
Mar 1997	SF	F	119.6 (7)	139	71
Mar 1997	TR	C	132.0 (3)	165	95
Mar 1997	TR	F	107.0 (3)	118	98

Month	Habitat	Location	Avg. snow depth (cm) (# of stations)	Max. snow depth (cm)	Min. snow depth (cm)
Apr 1997	SF	C	75.2 (5)	105	0
Apr 1997	SF	F	76.6 (5)	104	0
Apr 1997	TR	C	53.3 (3)	97	0
Apr 1997	TR	F	49.7 (3)	71	33
May 1997	SF	C	0.0 (3)	0	0
May 1997	SF	F	19.7 (3)	34	0
May 1997	TR	C	n/a	n/a	n/a
May 1997	TR	F	n/a	n/a	n/a