THE UNIVERSITY OF

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MT. GRAHAM RED SQUIRREL MONITORING PROGRAM

Annual Report
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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 1999. The MGIO is located along a ridge extending westward from Hawk Peak in the Graham (Pinaleño) Mountains of southeastern Arizona. In 1999, 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 1999. The major construction activity on the LBT was the enclosure of the steel structure above the foundation.

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: February, April, May, July, August, October and November. 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. Conifer seeds, and mushrooms (epigeous or above-ground fungi) were collected at all 28 sites (Figure 1).

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 1999, all of the major features on the monitored areas were mapped using GPS, including middens, 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. No part of this report may be used or reproduced in any form without the written permission of the Monitoring Program Supervisor.

Percentages are rounded to the nearest whole number, therefore totals may be slightly more or less than 100%.

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 known midden sites are marked with numbered metal tags, and black and orange striped flagging. During censuses or other monitoring duties, new activity areas that have the potential to become new middens are often located. Feeding sign, caching and squirrels are seen at these areas. These areas are assigned a temporary number and are assessed for improved sign and the presence of a squirrel during the next quarterly census. If conditions warrant, an activity area will be upgraded to a midden and added to the regular quarterly censuses. If an activity area shows no improvement in the two quarterly censuses following initial location, it will be removed.

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 1998, seed production was estimated from 28 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 1998 crop were collected from the seed traps in June 1999. 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.

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 September. Mushrooms were collected from a total of 28 plots including the four plots added on the TRC and SFC in late 1996 (after the Clark Peak fire). 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 1999, all middens were visited at least once to determine occupancy. In addition, middens within 100 m of construction activity or the access road were censused during months of construction activity: February, April, May, July, August, October, and November. 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 1998, the number of occupied middens and the sexes of resident squirrels were determined. The December occupancy was then compared to occupancy for June 1999. 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 1999, the breeding condition of adult male and female squirrels, and litter activity was recorded when observed. By examining the squirrel's condition through binoculars, the reproductive status of a female was determined to be non-lactating, reproductive (vulva visibly swollen or appearance of pregnancy) 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 1999 field season.

Midden Mapping

Almost all middens and other physical features on the monitored areas have been mapped using GPS with an accuracy of ± 5m. 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

Red Squirrel Food Resources

1998 Conifer Seed Production

Corkbark fir seeds, on average, were again the most abundant food resource in numbers of seeds/ha on all of the monitored areas, except the SFN area where Engelmann spruce was the most abundant. This is similar to the pattern seen in1997. In the SF habitat, as in 1997, corkbark fir seeds and Engelmann spruce seeds were equally abundant, each accounting for 50% of production. But there were differences seen within the SF habitat. On the SFC area, 81% of the production was corkbark fir seeds, and on the SFN area, 96% of the production was Englemann spruce seeds. Douglas-fir seeds did not contribute at all to the production in the SF habitat. In the TR habitat, corkbark fir and Douglas-fir accounted for 81% and 15% respectively, while Engelmann spruce made up less than 5% of the crop. White pine and ponderosa pine were not represented in the samples collected from any of the plots (Table 3, Appendix A).

The 1998 Engelmann spruce crop was generally higher that the 1997 crop, but still much lower than the 1993 and 1995 crops. For corkbark fir, production was relatively high on all areas except the SFN where a very small crop was seen. The Douglas-fir production for 1998 in the TR habitat, was the third highest crop since 1993. Douglas-fir was not seen at all in the SF habitat. Overall seed production in 1998 was higher in the TR habitat than the SF habitat, following the pattern seen in recent years. (Figure 2a-c, Appendix A).

1998 Mushroom Production

Overall annual mean mushroom production in 1999 was lower than in 1998. In the TR habitat, there was greater production in 1999 compared to 1998. However, in the SF habitat, the 1999 mushroom production was almost half of that seen in 1998. (Figure 3).

As in 1998, there were no significant differences in annual production ($\bar{x}$ wet weight) between the TR and SF habitats. In contrast to past years, the 1999 mushroom production in the SF habitat was slightly smaller (though not significantly) than the TR habitat. (Table 4).

On the TRC area, three genera, *Auricularia, Cortinarius, and Lactarius* accounted for 57% of production. On the TRN area, *Clitocybe, Russula, and Auricularia* accounted for 68% of total production. *Lycoperdon, Cortinarius, and Russula* accounted for 82% of the production on the SFC area. On the SFN area, *Lycoperdon, Russula,* and *Cortinarius* accounted for 78% of the total production (Table 5). Russula, while present on all areas, was not as dominant as seen in previous years.

Energetics of Selected Food Resources in 1998

In the TR habitat, there was significantly more mean energy (MJ/ha) available from corkbark fir and Douglas-fir seeds on the TRN area than the TRC area. Energy available from Engelmann spruce was not significantly different within the TR habitat. Overall, corkbark fir in the TR habitat accounted for the largest proportion of energy available from seeds. Within the SF habitat, there was significantly more mean energy available from corkbark fir on the SFC area than the SFN area. In contrast, there was significantly more energy available from Englemann spruce on the SFN area. Douglas-fir was not represented in any of the samples. As in the TR habitat, corkbark fir accounted for the largest proportion of energy available from seeds in the SF habitat. For 1998 mushrooms, the amount of energy available was not significantly different between the four areas (Table 6). In 1998, seeds accounted for 67% of the total energy available and mushrooms accounted for 31%. This is very similar to what was seen in 1997. (Figure 4).

To compare the 1998 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 the TR habitat, the total energy available in 1998 ranged from 71 MJ/ha to 744 MJ/ha. Four of the nine plots had available energy above 300 MJ/ha. As in 1997, plot TRC-10 had the highest total energy available (744 MJ/ha) of all the monitored areas. On the SFC area, only two of the seven polygons had greater than 300 MJ/ha. On the SFN area, only one 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 1999 (Appendix B-1). In addition, the 44 middens (by Dec 99) within 100 m of the access road or construction were censused during months of construction activity (Appendix C).

From December 1998 to December 1999, the number of red squirrels on the monitored areas decreased from 134 to 102, a 24% decrease. On the TRC area, the highest number of squirrels (35) was seen in December 1999, and the lowest number was 28 squirrels seen in March. September was the month with the highest number of squirrels (29 Ad + 3Juv) on the TRN area. The lowest squirrel numbers (27) on the TRN area were seen in March. The highest numbers of squirrels (50) on the SFC area were seen in March and the lowest numbers (21) were seen in December. March again had the highest number of squirrels (29) for the SFN area, and December was also the lowest month with 18 squirrels. In general, the populations in the TR habitat remained stable or increased slightly. Populations in the SF habitat decreased, with the SFC area showing a more than 50% decrease from March to December 1999. (Figure 6, Appendix B-1,C,D,E).

Thirteen new middens were added to the monitored areas during 1999. In addition, one midden, previously removed from regular censusing because of low occupancy, became reoccupied (Table 7). Each of these new middens was identified as an activity area during the year. These areas had the potential to become new middens based on the presence of squirrel sign and a squirrel was seen at each midden. These middens were reassessed during subsequent censuses for improvement in sign and the continued presence of a squirrel. Activity areas that met the criteria were “upgraded” to new middens and added to the regular quarterly censuses (Appendix B-2). More new middens were established in the TR habitat, and the proportion of middens in the TR habitat increased slightly from June 1999 to December 1999. Even with the addition of new middens, the proportion of squirrels on each of the monitored areas did not markedly change from June to December 1999 (Table 8).

In June and December 1999, there were no significant differences in the proportion of middens occupied *within* the TR or SF habitats. However, there was a significantly greater proportion of middens occupied in the TR habitat when compared to the SF habitat, in both June and December 1999. Overall, on all of the monitored areas in 1999, the proportion of occupied middens decreased from 45% in June to 35% in December. The largest decreases were seen in the SF habitat (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 1999. On the TRC area in June, occupied middens were slightly farther (approx. 9 m) from construction than unoccupied middens. By December, this distance had increased to 15m (approx. 16 m). In June 1999, on the SFC area, occupied middens were closer to construction than occupied middens by an average of 11 m. In December, however, unoccupied middens were, on average, 5 m closer to construction than occupied middens (Table 10).

Overwinter Survival

There were no significant differences in the number of squirrels that survived the winter of 1998-1999 within or between the TR and SF habitats. Overwinter survival for the TR habitat in 1998-1999 was 70% and overwinter survival in the SF habitat was 79% (Table 11). For comparison, the average proportion of survival from the previous winter (1997-1998) was 46% in the TR habitat and 38% in the 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.

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* in the TR habitat increased on all areas between December 1998 and December 1999. In the SF habitat, the crude density of *middens* remained stable throughout the year (Figure 7, Appendix F-1a).

The crude density of *squirrels* in the TR habitat remained fairly stable or increased slightly from December 1998 to December 1999. The crude density of *squirrels* in the SF habitat, decreased slightly throughout the year. (Figure 7, Appendix F1-b, Table 7).

Local Density

The December 1999 overall mean local density ($\bar{x}$ LD) of *middens* was greater (5.2), than in December 1998 (4.9), mainly because 13 new middens were established on the monitored areas in 1999. There were significant differences in the local density of middens among the four areas. The SFN area had the lowest $\bar{x}$ LD (3.2), and the $\bar{x}$ LD on the remaining three areas (5.9 - 6.6) were similar (Table 12, Figure 8, Appendix F-2).

The $\bar{x}$ LD of *squirrels* (occupied middens) on all areas in December 1999 was 3.3, which is a slight increase from 2.9 in December 1998. There were no significant differences in the $\bar{x}$ LD of squirrels between areas in each habitat. However, the TR habitat had a significantly greater $\bar{x}$ LD than the SF habitat (Table 12, Figure 8, Appendix F-2).

Nearest Neighbor Distance

The overall $\bar{x}$ NND of *middens* increased slightly from December 1998 to December 1999. As with $\bar{x}$ LD, there were no significant differences within habitats, but the $\bar{x}$ NND in the SF habitat was significantly longer than in the TR habitat (Table 13, Figure 9, Appendix F-2).

The $\bar{x}$ NND of *squirrels* (occupied middens) in the TR habitat decreased slightly from December 1998 to December 1999. In the SF habitat, the $\bar{x}$ NND showed slight increases between December 1998 and December 1999. This increase was a reflection in the drop in squirrel numbers in the SF habitat. Again, the $\bar{x}$ NND of the areas within each habitat was not significantly different, but the $\bar{x}$ NND of squirrels in the SF habitat was significantly longer than in the TR habitat (Table 13, Figure 9, Appendix F-2).

Reproductive Activity and Success

Two breeding chases were observed in 1999. One of the breeding chases was observed in April and the other during the June census (Appendix G-1). The earliest date a scrotal male was seen was 17 February in the SFC area. Forty-two out of the fifty-three males identified during the March census were scrotal. The latest date a scrotal male was seen was 11 September on the SFC area. No scrotal males were observed during the December census (Appendix G-3b).

The earliest a lactating female was observed was 3 June in the TR habitat and the latest was on 9 September, also on the TR habitat. During the March census, 46 adult females were identified and none were lactating. By June, 29 of the 49 females identified were classified as lactating or reproductive. In September, out of 36 adult females seen, only one was lactating and

9 were post-lactating. Finally, in December, there were no lactating, post lactating, or reproductive females identified. (Appendix G-3a).

Direct evidence of 6 litters (13 juveniles) was seen during censuses or other monitoring activities. The earliest evidence of a litter was seen on 3 Jun on the TRC area. The latest evidence of a litter was seen on 11 September on the SFC area (Appendix G-2). In September, 30 squirrels were identified as young of the year. Twenty-seven squirrels were classified as young of the year in December (Appendix G-3c).

For reproductive status and age information, it must be noted that the numbers do not necessarily represent the residents of the same middens from census to census. Because the squirrels are not marked, information is provided only for a general picture of the reproductive and age status of the squirrels on the monitored areas.

Trapping and Marking

There was no trapping and marking on the monitored areas in 1999.

Marked Squirrels

There was only one marked squirrel seen on the monitored areas throughout 1999 (Appendix B-1). In addition to the ear tagged squirrel, there were 21 squirrels on or near the monitored areas in 1999 with natural identifying marks such as an ear notch or a short tail (Appendix H-1). Fifteen of these squirrels were seen during the December 1999 census.

The single remaining marked animal, a male on the SFC area, was seen for 10 of the 11 times his midden was censused in 1999. The marked male was not observed outside his home midden.

Midden Mapping

At the end of 1999, all major features on the monitored areas were mapped using GPS. The GIS database continued to be developed during 1999.

Weather Data

Weather data were collected nearly continuously in 1999 from two weather stations located at the biology camp (TR habitat) and near Emerald Peak (SF habitat). The maximum temperature recorded was 34.7°C in July at the biology camp and the minimum temperature recorded was -19.3°C in January on Emerald Peak. The maximum average monthly temperature was 13.3°C in June at the biology camp and the minimum average monthly temperature was -3.3°C in December on Emerald Peak. (Figure 10, Appendix I-1). The maximum rainfall was recorded in July, with 251.2 mm at the biology camp. There was no data for rainfall in July for the Emerald Peak station due to equipment failure. May was the driest month with 2.7 mm at the biology camp and 0 mm at the Emerald Peak station (Figure 11, Appendix I-1). Snow depth was recorded from the eight pairs of snow poles on the monitored areas. The average accumulated snow depth from November 1998 through May 1999 ranged from 0 cm to 37.7 cm (Figure 12, Appendix I-2). For comparison, average accumulated snow depths for the same period in 1997-1998 ranged from 9.0 cm to 183.4 cm, and in 1996-1997 depths ranged from 7 cm to 150.4 cm. Data on wind chill temperatures, wind direction and speed, humidity, and barometric pressure were also collected (Appendix I-1).

Insect Outbreaks on the Monitored Areas

Overview

Freezing and drought conditions in the southwest in recent years have set the stage for a series of forest insect outbreaks in the upper elevations of the Pinaleno Mountains on RSMP study areas. Since 1992, a cascade of disturbances have taken place leading to the current conditions in the SF habitat, most noticeably large areas of standing dead/dying Engelmann spruce trees.

In 1992, blowdown resulting from an ice storm provided dead timber habitat for increasing bark beetle populations. In 1996-1998, an obscure geometrid moth (*Nepytia janetae*) defoliated spruce and corkbark fir trees in the areas surrounding Hawk and High Peaks, and Emerald Cienega. By 1998, several highly destructive species of bark beetles had increased in spruce and fir trees weakened by the moth, and show no signs of abatement at this time. Engelmann spruce trees on High, Hawk and Emerald Peaks have been affected by an introduced spruce aphid (*Elatobium abietinum*), which was detected for the first time in the Pinalenos late in 1999. [March 2000 - trees as low as 2900 m elev. in mixed conifer forest on RSMP study areas were seen covered with aphids]

These outbreaks are of concern to the red squirrel because habitat is directly affected by reduced cone production in physiologically stressed trees, and by increased tree mortality. Engelmann spruce is being particularly hard-hit. At this time, Douglas-fir and white pine seem

to be relatively unaffected. Occupancy of red squirrel middens in these areas has decreased since the outbreaks began. The total number of squirrels in the SFN area has decreased from 37 in December 1997 to 18 in December of 1999. The north half of the SFN area, where the insect activity has been the greatest, has showed the largest decreases. In December 1997, there were 23 middens occupied in this area, and by December 1999, only 4 middens remained occupied (Figures 13, 14). Similar decreases in occupancy are beginning to be seen in portions of the SFC area where insect activity has occurred, in particular areas around Highwater cienega and the ridge running west from Emerald Peak.

Description of Insect Species

Janet's false hemlock looper (*Nepytia janetae*: Geometridae)

In the winter of 1996-1997, RSMP personnel first noted defoliation of Engelmann spruce and corkbark fir at Emerald Cienega. Paul Young notified USFS of the increased activity and potential impact on the Mt. Graham red squirrel in March 1998. Specimens were provided to Carl Olsen of the University of Arizona Entomology Department and identified as *N. janetae* (definitive identification made by Ron Leuschner).

This largely unknown moth was first described in 1966 and is endemic to the White and Pinaleno Mountain ranges of AZ, and the Capitan and Sacramento Mountains of NM. The moth outbreak was checked by natural disease and parasites. Some larvae turned red and died as a result of an unknown pathogen. Many larvae were killed by parasitoids including a tachinid fly, *Madremyia saundersii* (identification by Jim O'Hara, Agriculture and Agri-Food Canada), and two unidentified ichneumonid wasps.

Western balsam bark beetle (*Drycoetes confuses*: Scolytidae)

- Feeds on corkbark fir.
- Widely distributed

Spruce beetle (*Dendroctonus rufipennis*: Scolytidae)

- Feeds on spruce
- Widely distributed

Spruce aphid *(Elatobium abietinum*: Aphididae)

- attacks *Picea* spp in the Pacific Northwest, Canada, Europe and other parts of the world
- highly destructive to Engelmann spruce in the southwestern states
- Outbreaks follow mild winters

The spruce aphid was first reported in Arizona in 1988 in the White Mountains, and in the Pinaleno Mountains in 1999 by Ann Lynch of the USFS Rocky Mt. Research Station. Epidemic populations are limited by freezing weather, and it is unknown whether there are naturally occurring disease or predator checks. In the fall of 1999, RSMP personnel observed Mt. Graham red squirrels feeding on spruce aphids by gleaning them from branch tips. [During the March 2000 census, many Engelmann spruce trees at lower elevations were seen with heavy infestations of aphids.]

Miscellaneous Observations

Other insects recorded on RSMP areas include:

- few western spruce budworms (*Choristoneura occidentalis*)
- increased conifer aphid numbers in 1999 (*Cinara* spp.) on spruce and fir.
- Cooley spruce adelgids (*Adelges cooleyi*) on Engelmann spruce

In addition, increased incidence of **dwarf mistletoe** (*Arceuthobium microcarpum*) was seen on Engelmann spruce, especially in areas hit by spruce aphid. Dwarf mistletoes are the most significant tree pathogens of conifers in the southwest (FS Forest Insect and Disease Conditions in the SW Region Report 1998, see website below).

Ongoing Research

In November 1998, USFS Forest Health Office entomologists from Flagstaff (Bobbe Fitzgibbon and Jill Wilson) conducted ground surveys and set up impact plots to characterize and monitor outbreak activity, and to determine extent of defoliation by the moth and bark beetles. These surveys complement yearly aerial detection flyovers by USFS. Additional information provided by the Forest Health office can be found in yearly AZ and NM forest health reports at: http://www.for.nau.edu/usfs/r3_fpm/. The ‘97-’98 outbreak is the first documented for *N. janetae*, however it may be shown that it is part of a naturally occurring cycle.

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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, 1998.

		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	5	389.3	75.3	101.3	19.6	26.7	5.2
TRN	4	806.7	84.0	120.0	12.5	33.3	3.5
SFC	7	400.0	80.8	0.0	0.0	95.2	19.2
SFN	12	7.8	3.9	0.0	0.0	189.4	96.1
TR Habitat	9	574.8	80.5	109.6	15.3	29.6	4.1
SF Habitat	19	152.3	49.6	0.0	0.0	154.7	50.4

Table 4. Mean annual mushroom production, 1999.

Area/Habitat	n	$\bar{x}$ Wet weight (Kg/ha)	$\bar{x}$ Dry weight (Kg/ha)	$\bar{x}$ Energy content (MJ/ha)
TRC	5	39.33 ± 5.544	4.29 ± 0.773	77.20 ± 13.917
TRN	4	29.67 ± 7.381	4.15 ± 1.545	74.66 ± 27.803
SFC	7	25.60 ± 3.854	3.11 ± 0.431	56.03 ± 7.752
SFN	12	32.60 ± 6.298	3.74 ± 0.584	67.23 ± 10.517
TR Habitat	9	35.04 ± 4.528	4.23 ± 0.751	76.07 ± 13.522
SF Habitat	19	30.02 ± 4.215	3.51 ± 0.399	63.10 ± 7.190

ANOVA among all four areas:

Wet Weight	*F=0.65*	*P*= 0.5913
Dry Weight	*F=0.42*	*P*= 0.7390
Energy	*F=0.42*	*P*= 0.7390

ANOVA between SF & TR:

Wet Weight	*F=0.53*	*P=0.4738*
Dry Weight	*F=0.87*	*P=0.3607*
Energy	*F=0.87*	*P=0.3607*

Table 5. Mean annual mushroom production (wet weight Kg/ha) of selected mushroom genera known to be food resources for red squirrels, 1999. The proportions of the three 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	0.99	2.5	1.79	6.0	0.52	2.0	1.79	5.5
Auricularia	8.76	**22.3**	4.59	**15.5**	0.04	0.2	0.36	1.1
Boletus	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Clavaria	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Clitocybe	5.39	13.7	8.12	**27.4**	1.78	6.9	1.38	4.2
Cortinarius	7.95	**20.2**	4.15	14.0	2.82	**11.0**	8.17	**25.1**
Gastroid sp.	0.00	0.0	0.00	0.0	0.18	0.7	0.00	0.0
Hydnum	0.00	0.0	1.27	4.3	0.43	1.7	0.00	0.0
Lactarius	5.62	**14.3**	0.92	3.1	0.00	0.0	0.93	2.8
Leccinum	0.00	0.0	0.00	0.0	0.00	0.0	0.14	0.4
Lycoperdon	4.60	11.7	1.27	4.3	10.09	**39.4**	12.06	**37.0**
Pholiota	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Ramaria	0.27	0.7	0.00	0.0	1.66	6.5	2.56	7.8
Russula	5.41	13.8	7.57	**25.5**	8.07	**31.5**	5.13	**15.7**
Suillus	0.35	0.9	0.00	0.0	0.00	0.0	0.08	0.2
Total	39.33		29.67		25.60		32.60	

Table 6. Estimated mean energy (MJ/ha) from four primary food resources, 1998.

Area/Habitat	N	Corkbark fir	Douglas-fir	Engelmann spruce	Total Seeds	Total Mushrooms	Total Energy
				$\bar{x}$ MJ/ha ± se			
TRC	5	172.86 ± 137.764[b]	19.46 ± 11.692[a]	2.43 ± 0.858[a]	194.75 ± 133.703[b]	37.28 ± 13.952[a]	232.02 ± 129.486[b]
TRN	4	358.16 ± 109.226[a]	23.04 ±21.367[a,b]	3.03 ± 2.012[a]	384.23 ± 104.386[a]	52.36 ± 19.194[a]	436.59 ± 107.905[a]
SFC	7	177.60 ± 85.886[b]	0.00 ± 0.000[b]	8.67 ± 2.693[a]	186.27 ± 87.161[b]	117.92 ± 32.376[a]	304.18 ± 102.845[b]
SFN	12	3.45 ± 1.539[c]	0.00 ± 0.000[b]	17.24 ± 6.835[a]	20.69 ± 7.026[c]	119.52 ± 28.241[a]	140.21 ± 32.411[c]
TR Habitat	9	255.22 ± 91.214	21.05 ± 10.699	2.70 ± 0.944	278.96 ± 88.825	43.98 ± 11.068	322.94 ± 88.823
SF Habitat	19	67.61 ± 36.039	0.00 ± 0.000	14.08 ± 4.458	81.69 ± 36.144	118.93 ± 20.895	200.62 ± 45.299

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

Statistical tests were run on log transformed data.

ANOVA among all four areas (TRC, TRN, SFC, and SFN):

Corkbark fir seeds	**F=11.29**	**P=0.0001**
Douglas-fir seeds	**F=4.89**	**P=0.0086**
Engelmann spruce seeds	F=1.29	P=0.2994
Total seeds	**F=11.97**	**P=0.0001**
Total mushrooms	F=1.51	P=0.2366
Total energy	**F=10.77**	**P=0.0001**

Table 7. Number and discovery status of red squirrel middens on each of the monitored areas, 1998-1999.

		Midden Status				
Year	Area	Old	Newly Found	Newly Established	Re-Occupied[2]	Total
1998	TRC	25	0	9	1	35
	TRN	24	0	9	4	37
	SFC	101	0	4	0	105
	SFN	97	0	3	2	102
	Total	247	0	25	7	279
1999	TRC	34[1]	0	7	1	42
	TRN	38[1]	0	4	0	42
	SFC	106[1]	0	1	0	107
	SFN	96[1]	0	1	0	97
	Total	274	0	13	1	288

1 The difference in the number of middens from the end of 1998 to the beginning of 1999 reflects middens removed from regular censusing due to low occupancy after December 1998 and new middens found during the March 1999 census.

2 These are middens that were previously removed from regular censusing due to low occupancy, but have become re-occupied.

Table 8. Proportion of the total area, total number of middens, and total number of squirrels[1] found on each of the monitored areas, 1998-1999.

			Jun 1998				Dec 1998			
	Area		Middens		Squirrels[1]		Middens		Squirrels[1]	
	ha	%[2]	n	%[2]	n	%[2]	n	%[2]	n	%[2]
TRC	49.1	16	26	10	11	19	35	12	26	19
TRN	24.4	8	24	10	13	22	37	13	30	22
SFC	101.0	33	101	41	19	33	105	38	46	34
SFN	128.9	42	97	39	15	26	102	36	32	24
Total	303.4		248		58		279		134	

			Jun 1999				Dec 1999			
	Area		Middens		Squirrels[1]		Middens		Squirrels[1]	
	ha	%[2]	n	%[2]	n	%[2]	n	%[2]	n	%[2]
TRC	49.1	16	34	12	26	21	42	14	35	34
TRN	24.4	8	39	14	28	23	42	15	28	27
SFC	101.0	33	106	39	42	34	107	37	21	21
SFN	128.9	42	96	35	27	22	97	34	18	18
Total	303.4		275[3]		123		288		102	

1 Juveniles living with their mothers are not counted in the number of squirrels. Number of squirrels is equal to the number of occupied middens.

2 All percentages are rounded to the nearest whole number.

3 The difference in the number of middens from December 1998 to June 1999 reflects middens removed from regular censusing due to low occupancy after December 1998 and new middens found during 1999 censuses.

Table 9. Number and percent of available middens occupied, 1999.

	June			December		
Area/Habitat	# middens	# occupied	%	# middens	# occupied	%
TRC	34	26	76	42	35	83
TRN	39	28	72	42	28	67
SFC	106	42	40	107	21	20
SFN	96	27	28	97	18	19
TR Habitat	73	54	74	84	63	75
SF Habitat	202	69	34	204	39	19
TR + SF	275	123	45	288	102	35

Chi Square:

JUNE

within TR	X^2=0.206	df=1	*P*=0.650
within SF	X^2=2.961	df=1	*P*=0.085
between Habitats	X^2=34.382	df=1	***P*=0.001**

DECEMBER

within TR	X^2=3.111	df=1	*P*=0.078
within SF	X^2=0.038	df=1	*P*=0.846
between Habitats	X^2=81.234	df=1	***P*=0.001**

Table 10. Mean distance from construction to occupied and unoccupied middens on the TRC and SFC areas, June and December 1999.

		June		December	
Area	Midden Status	n	$\bar{x}$ ± se (m)	n	$\bar{x}$ ± se (m)
TRC	Occupied	26	215.0 ± 12.11	35	214.5 ± 10.04
	Unoccupied	8	206.5 ± 17.32	7	199.4 ± 21.04
SFC	Occupied	42	139.8 ± 10.50	21	149.7 ± 12.84
	Unoccupied	64	150.3 ± 10.61	86	144.3 ± 8.93

ANOVA:

JUNE

TRC	F = 0.13	df = 1	P = 0.7236
SFC	F = 0.45	df = 1	P = 0.5036

DECEMBER

TRC	F = 0.38	df = 1	P = 0.5411
SFC	F = 0.08	df = 1	P = 0.7780

Table 11. Overwinter survival of red squirrels on the monitored areas, 1998-1999.

Area/Habitat	Number of Squirrels Dec 1998	Number of Squirrels Surviving Jun 1999	% survival
TRC	27	21	78
TRN	29	18	61
SFC	46	38	83
SFN	32	24	75
TR Habitat	56	39	70
SF Habitat	78	62	79

Chi-square tests:

within TR	$X^2 = 0.974$	df = 1	P = 0.324
within SF	$X^2 = 0.285$	df = 1	P = 0.594
between habitats	$X^2 = 1.213$	df = 1	P = 0.271

Table 12. Mean Local Density of middens and red squirrels (occupied middens) on the monitored areas, 1998 and 1999.

	December 1998				December 1999			
	Middens		Squirrels		Middens		Squirrels	
Area/Habitat	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se
TRC	35	5.1 ± 0.40[a]	26	3.9 ± 0.41[a]	42	5.9 ± 0.37[a]	35	5.0 ± 0.41[a]
TRN	37	5.5 ± 0.31[a]	30	4.4 ± 0.29[a]	42	6.6 ± 0.28[a]	28	4.3 ± 0.28[a]
SFC	105	5.9 ± 0.24[a]	46	2.5 ± 0.21[b]	107	6.1 ± 0.25[a]	21	1.5 ± 0.25[b]
SFN	102	3.5 ± 0.17[b]	32	1.1 ± 0.19[c]	97	3.2 ± 0.17[b]	18	0.8 ± 0.17[b]
TR Habitat	72	5.3 ± 0.25	56	4.1 ± 0.24	84	6.3 ± 0.23	63	4.7 ± 0.26
SF Habitat	207	4.7 ± 0.17	78	1.9 ± 0.17	204	4.7 ± 0.18	39	1.2 ± 0.16
TOTAL [1]		279	4.9 ±	134	2.	288	5.2	1023.3 ± 0.24

ANOVA:	**1998**			**1999**		
LD of Middens						
among all areas	F=23.62	df=3	***P=0.0001***	F=39.20	df=3	***P=0.0001***
LD of Squirrels						
among all areas	F=29.05	df=3	***P=0.0001***	F=35.31	df=3	***P=0.0001***

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

1 Includes only middens on the monitored areas.

Table 13. Mean Nearest Neighbor Distance of middens and red squirrels (occupied middens) on the monitored areas, 1998 and 1999.

	December 1998				December 1999			
	Middens		Squirrels		Middens		Squirrels	
Area/Habitat	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se	n	$\bar{x}$ ± se		$\bar{x}$ ± se
TRC	35	41.4 ± 3.08[a]	26	47.1 ± 4.45[b]	42	41.0 ± 2.51[a]	35	45.4 ± 2.95[a]
TRN	37	43.0 ± 2.47[a]	30	48.4 ± 3.13[b]	42	39.8 ± 1.93[a,b]	28	48.7 ± 2.80[a]
SFC	105	42.5 ± 1.39[a]	46	64.3 ± 5.04[b]	107	44.2 ±1.41[b]	21	86.2 ± 8.59[b]
SFN	102	47.7 ± 1.92[a]	32	94.9 ± 8.94[a]	97	50.1 ± 2.08[b]	18	104.6 ± 11.11[b]
TR Habitat	72	42.2 ± 1.95	56	47.8 ± 2.64	84	40.4 ± 1.58	63	46.9 ± 2.05
SF Habitat	207	45.1 ± 1.19	78	76.9 ± 4.99	204	47.0 ± 1.25	39	94.7 ± 6.97
TOTAL [1]	279	44.3 ± 1.02	134	64.7 ± 3.34	288	45.1 ± 1.01	102	65.17 ± 3.73

ANOVA:	**1998**			**1999**		
NND of Middens						
among all areas	F=2.15	df=3	*P=0.0944*	F=5.19	df=3	***P=0.0017***
NND of Squirrels						
among all areas	F=12.75	df=3	***P=0.0001***	F=22.47	df=3	***P=0.0001***

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

1 Includes only middens on the monitored areas.

Figure 1. Map of the areas monitored by the University of Arizona Red Squirrel Monitoring Program, December 1999.

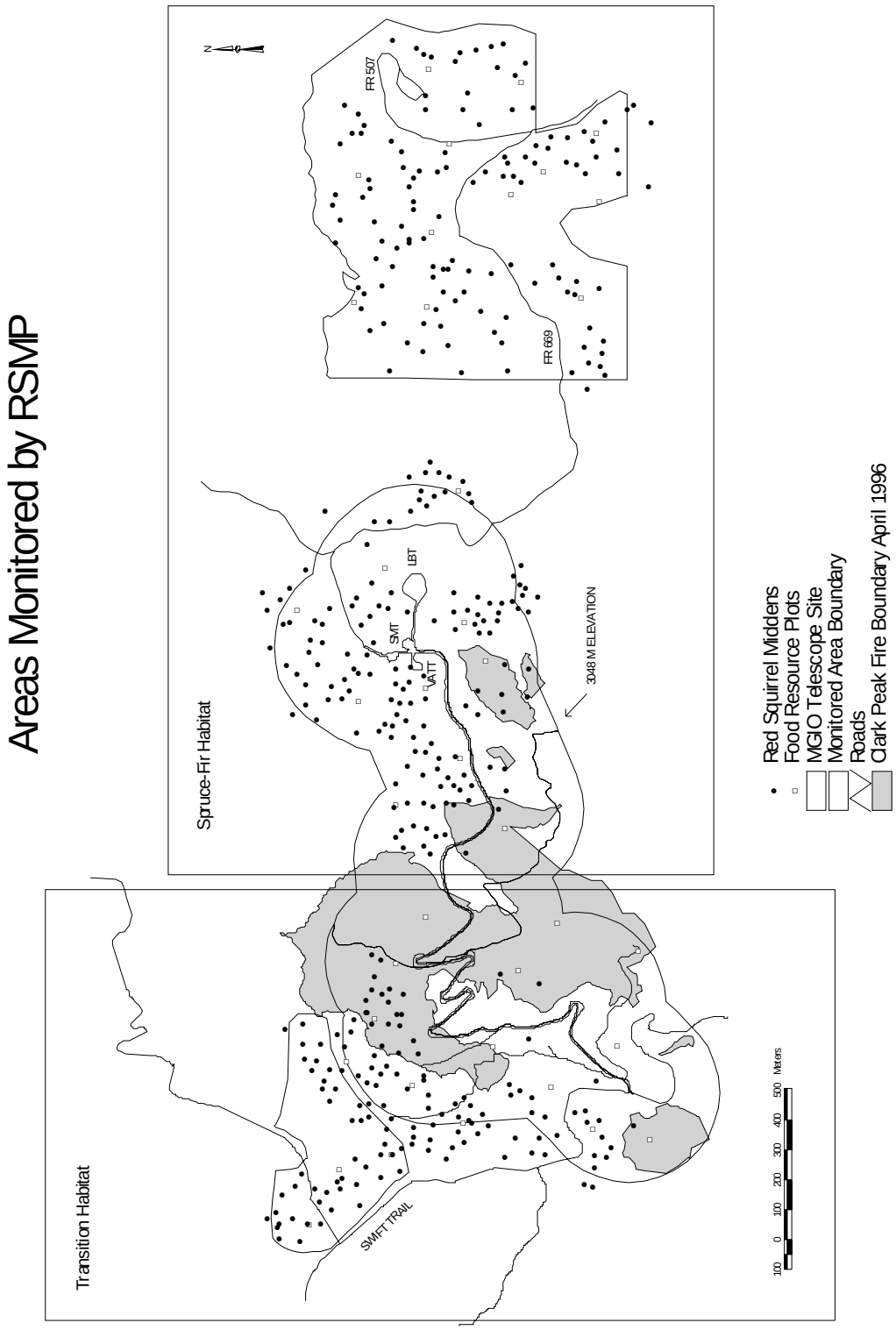


Figure 2a. Engelmann spruce seed fall, 1993-1998. Note: scales are different for figures 2a-c.

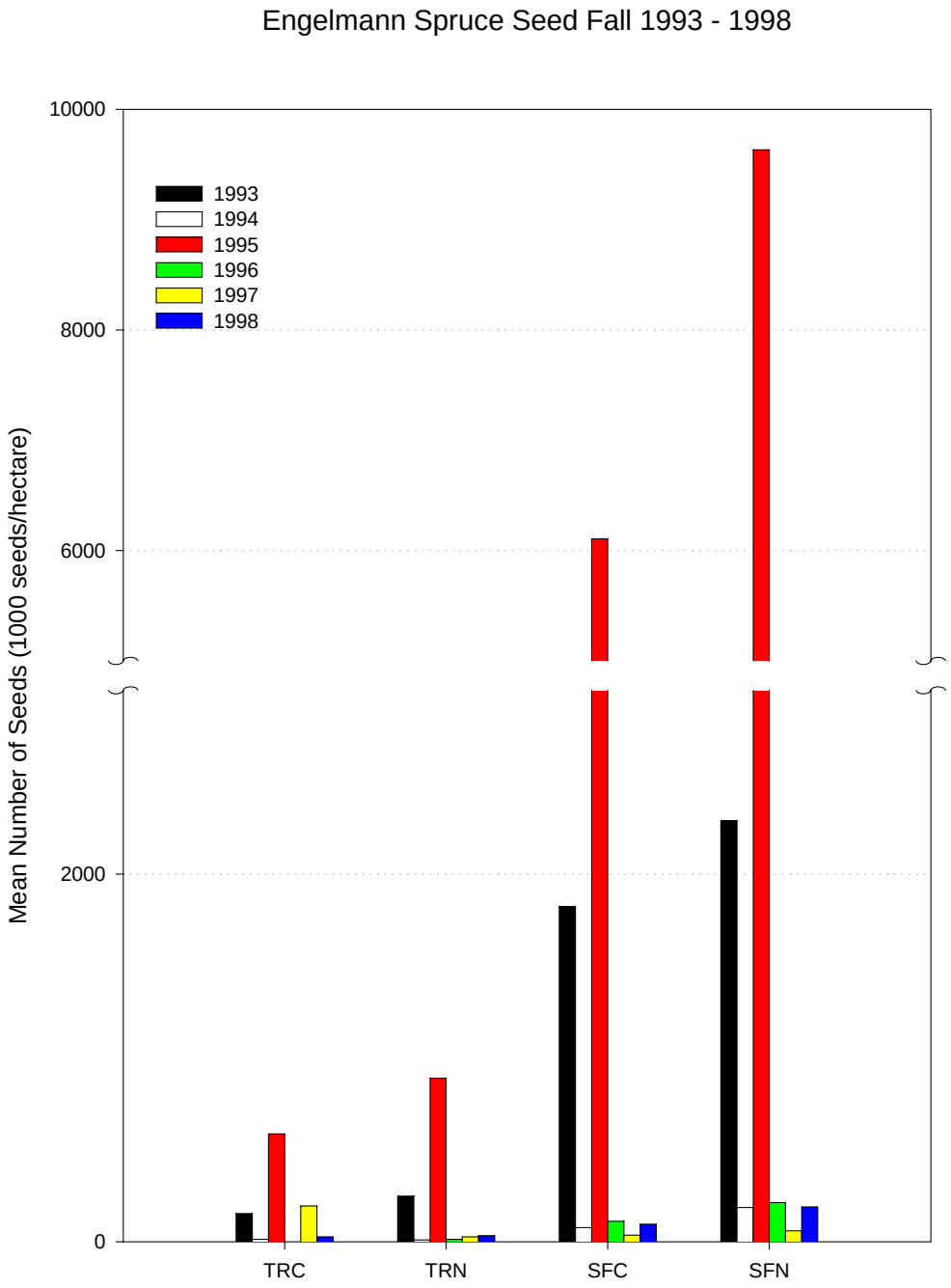


Figure 2b. Corkbark fir seed fall, 1993-1998. Note: scales are different for figures 2a-c.

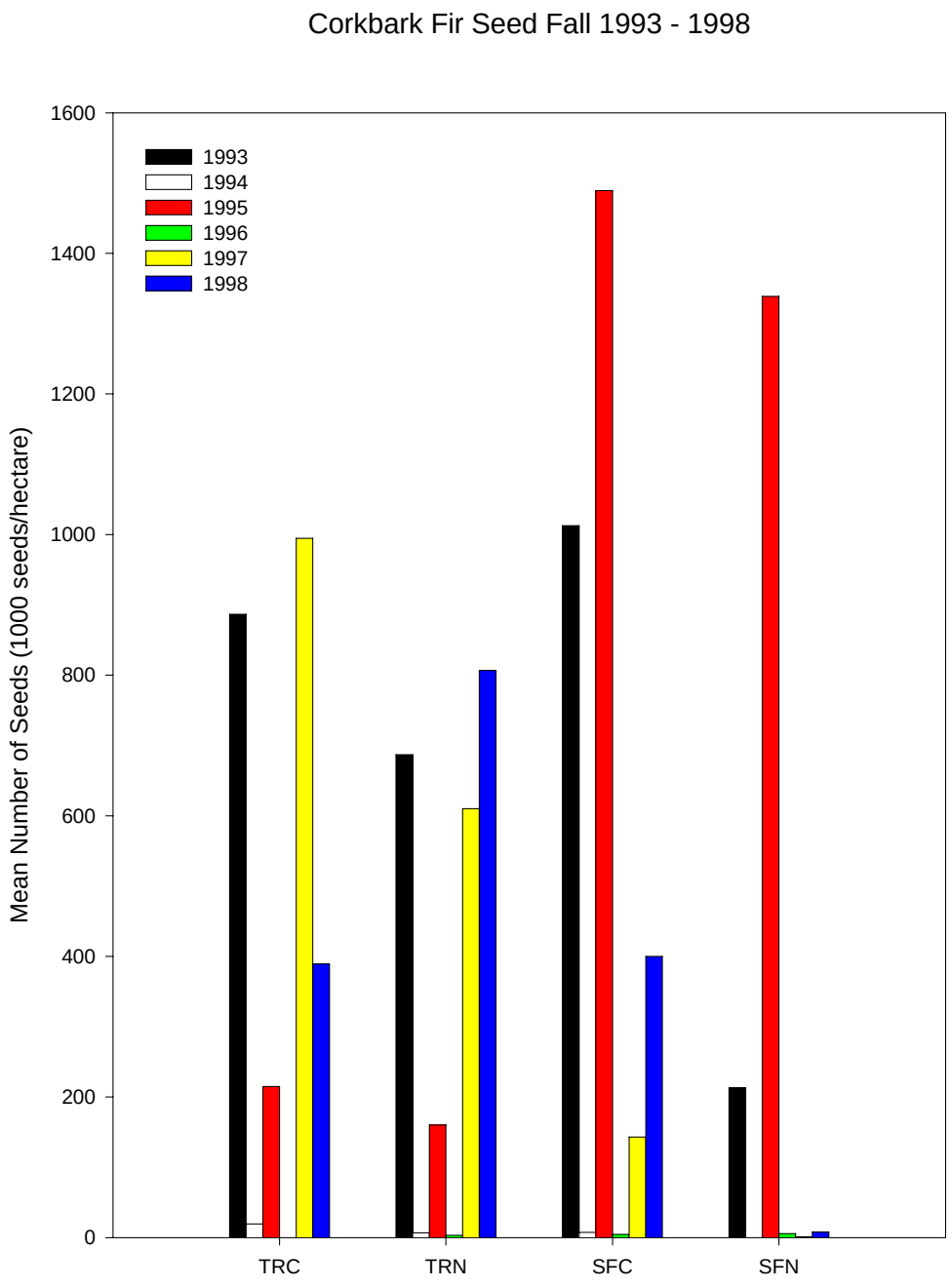


Figure 2c. Douglas-fir seed fall, 1993-1998. Note: scales are different for figures 2a-c.

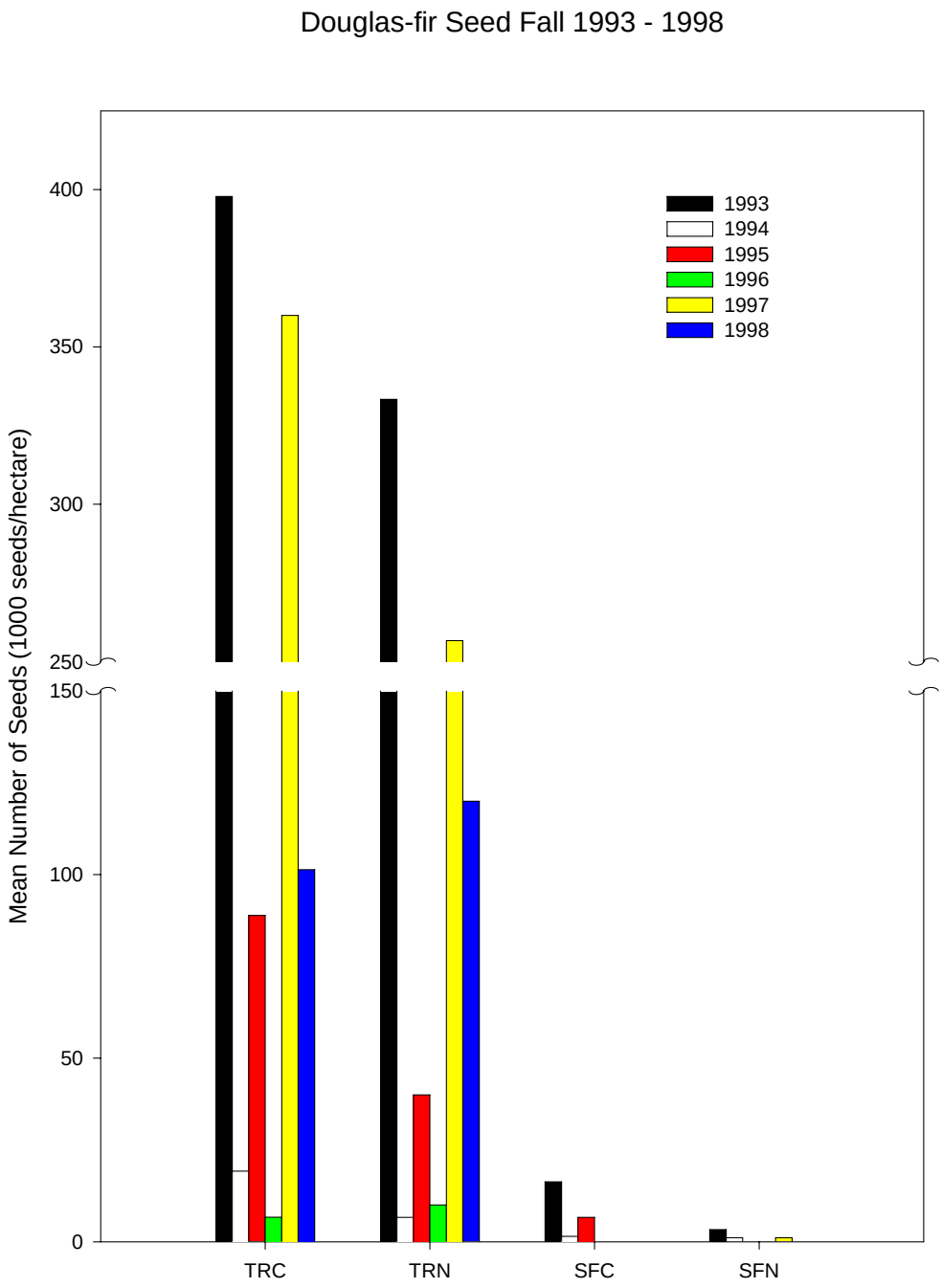


Figure 3. Mushroom crops, 1994-1999.

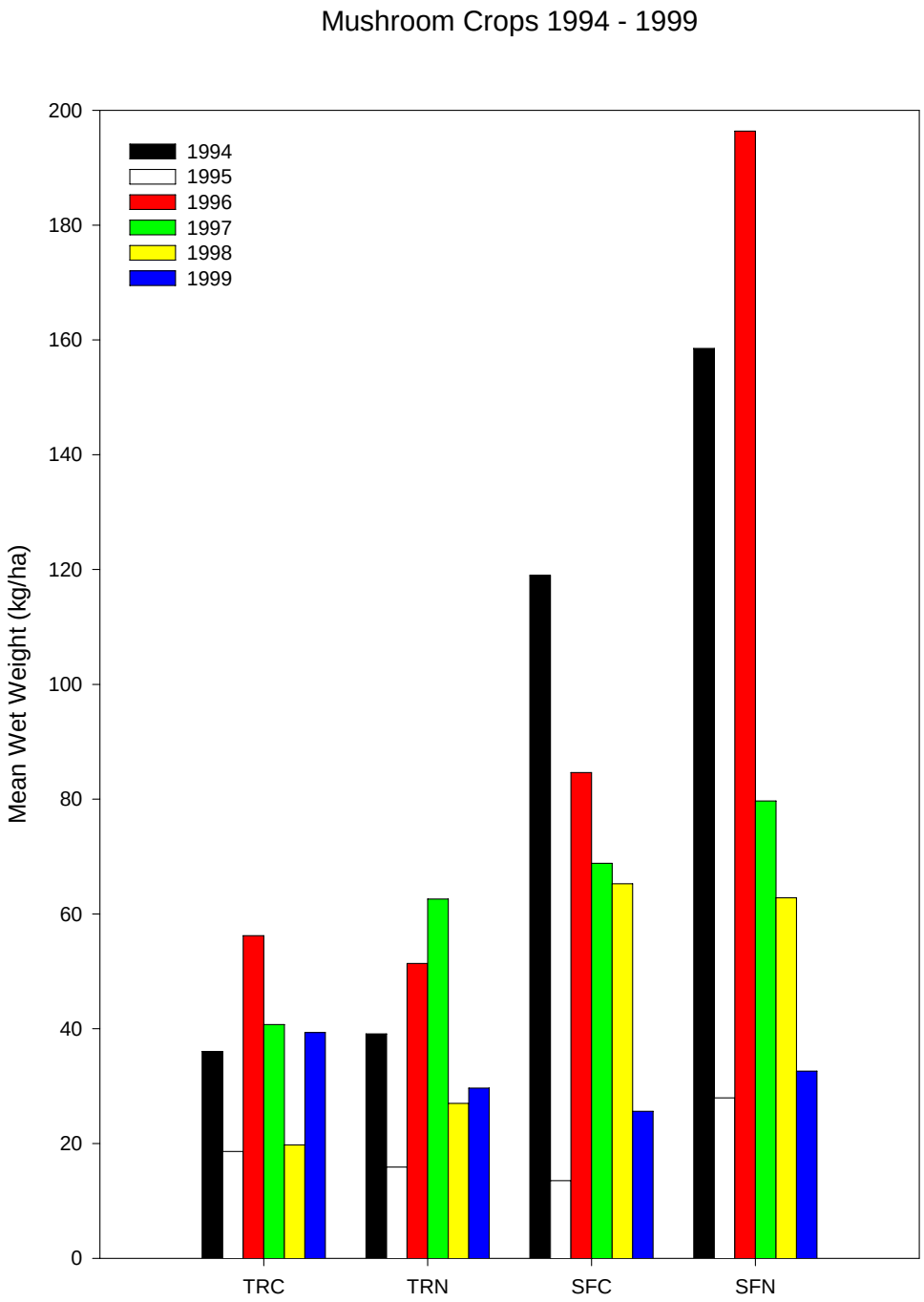


Figure 4. Energy availability on the monitored areas, 1994-1998.

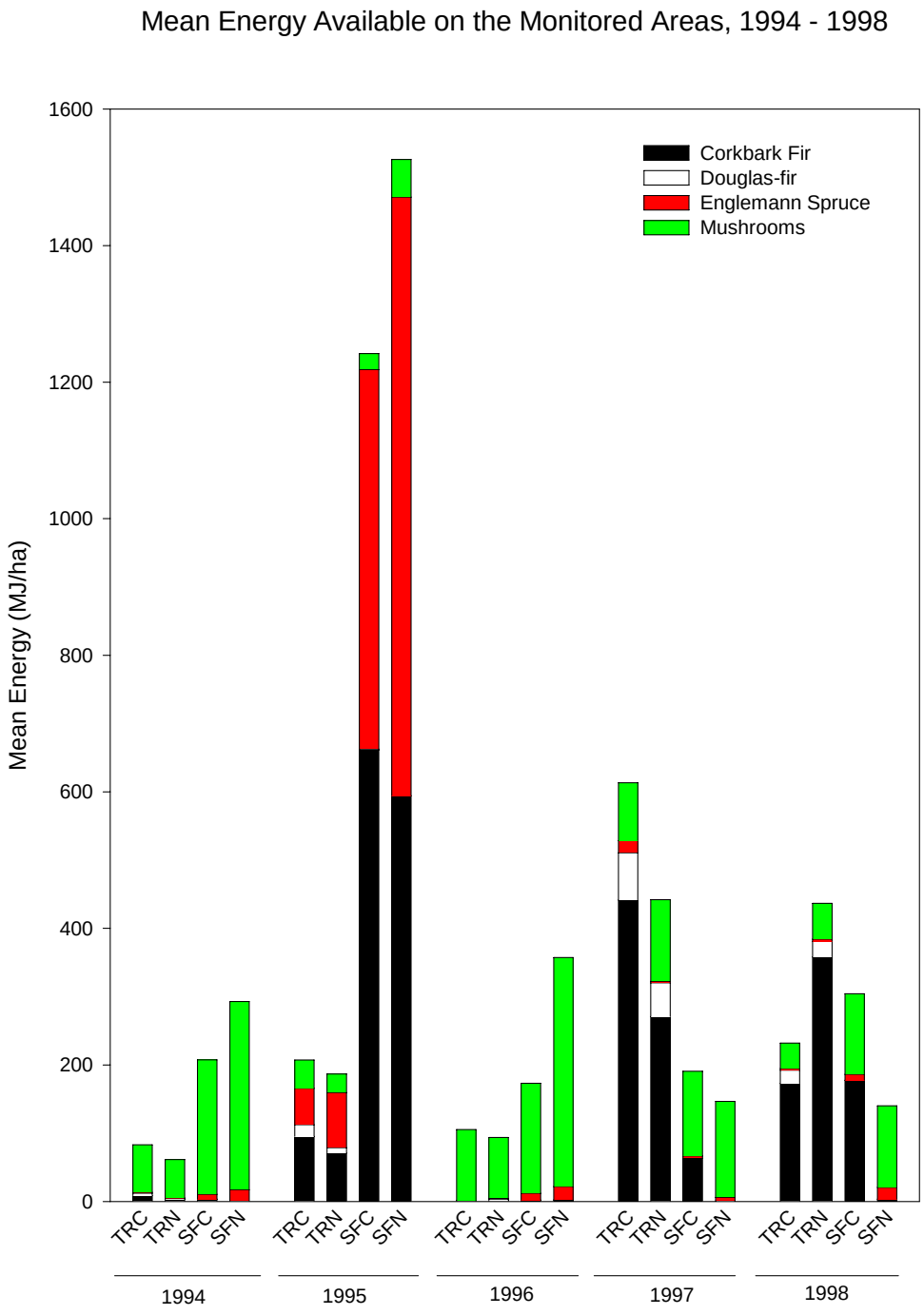


Figure 5. Distribution of total available energy from selected red squirrel food resources, 1998.

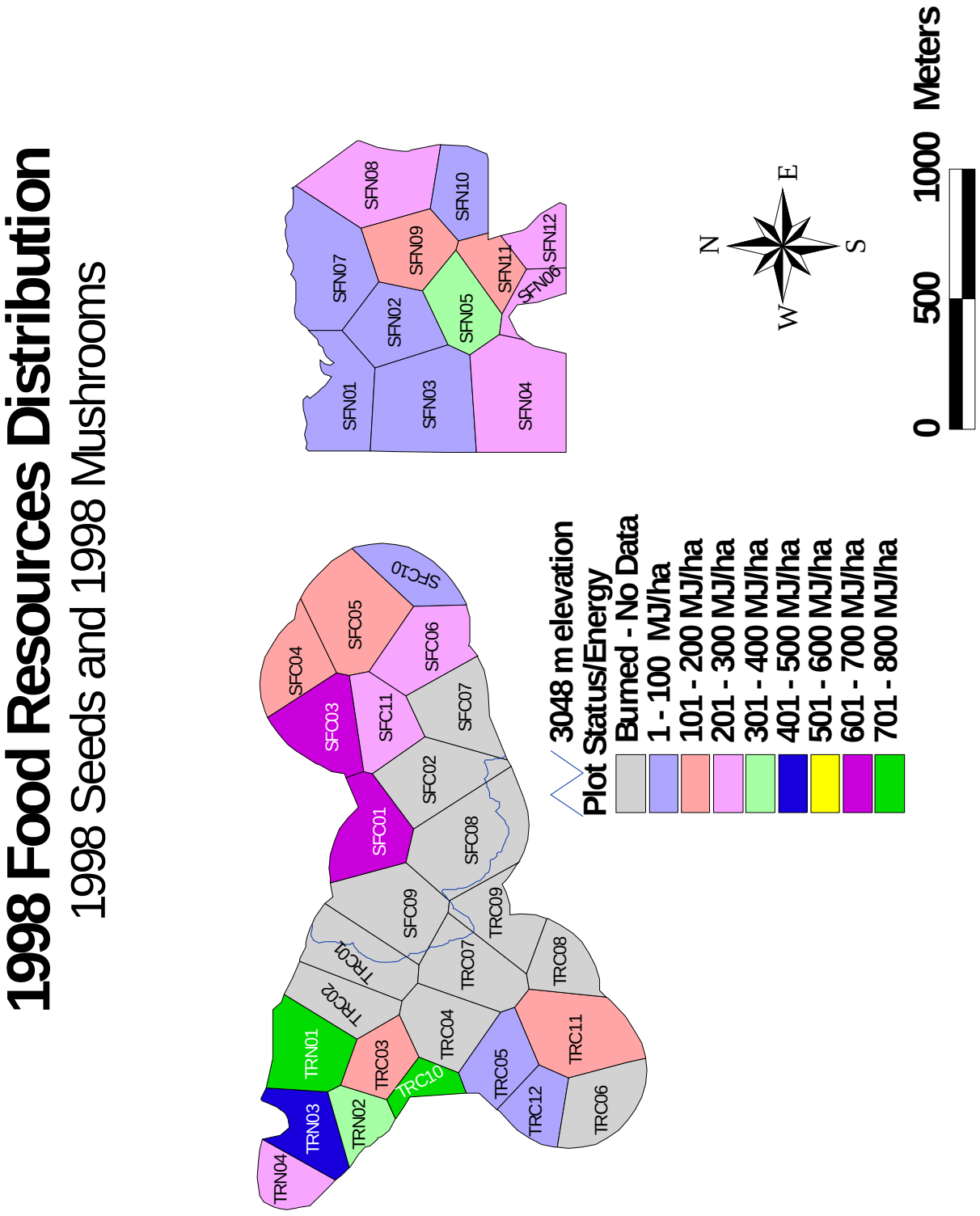


Figure 6. Red squirrel populations (including juveniles) on the monitored areas, December 1998 - December 1999.

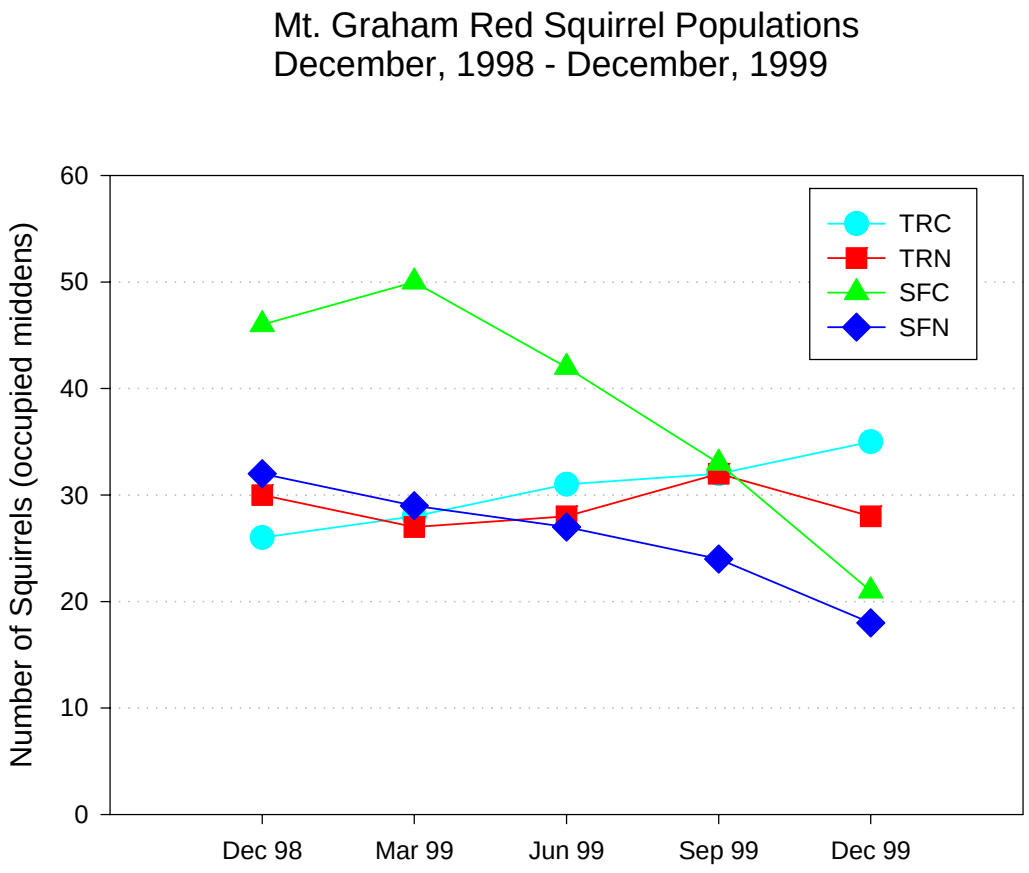


Figure 7. Crude density of middens and squirrels, 1998-1999.

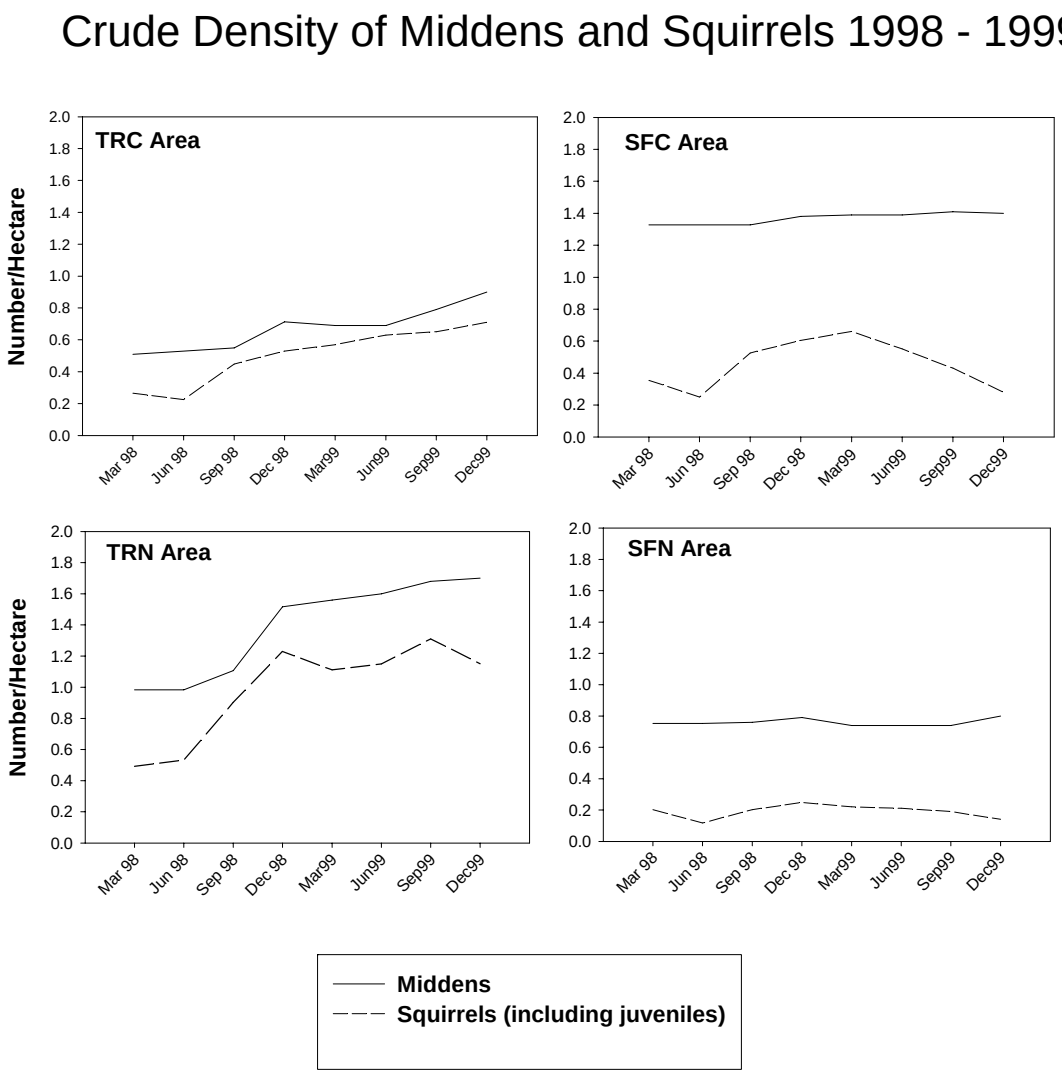


Figure 8. Local density of middens and squirrels, 1998-1999.

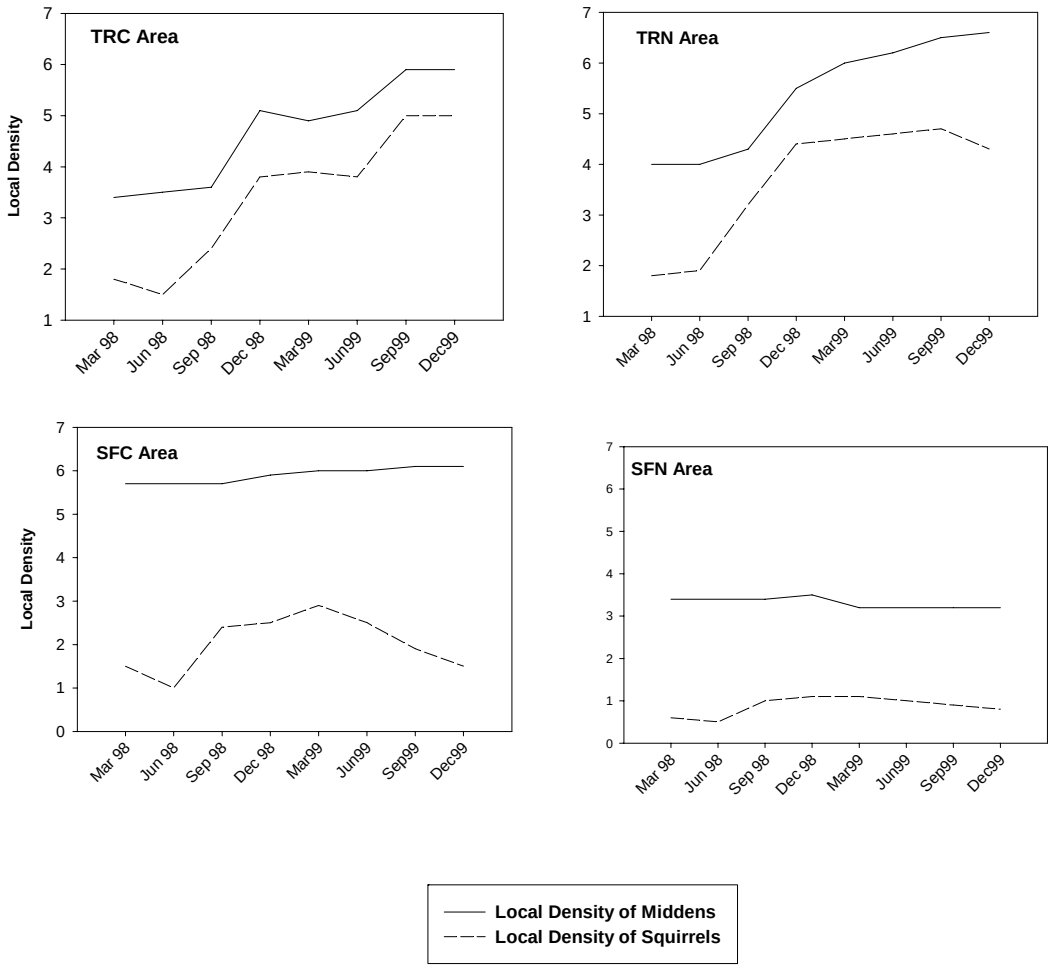


Figure 9. Nearest neighbor distance of middens and squirrels, 1998-1999.

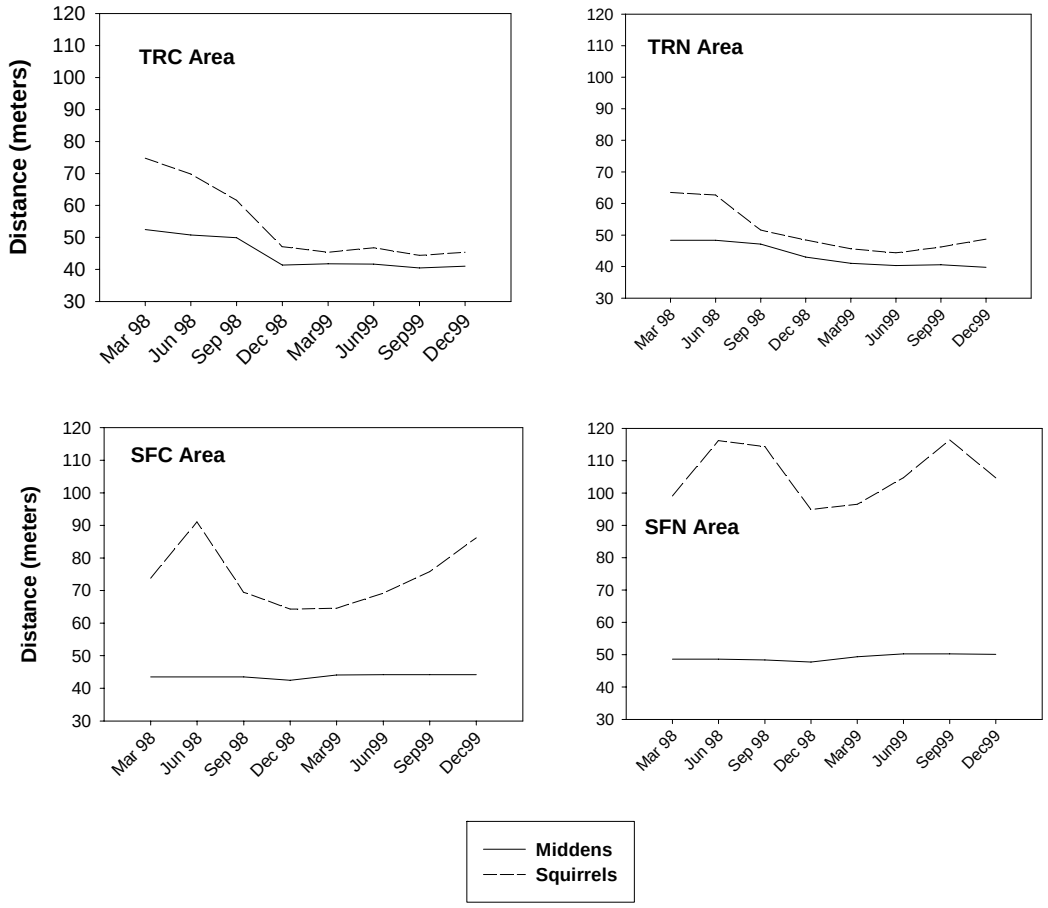


Figure 10. Monthly temperatures on the monitored areas, 1999.

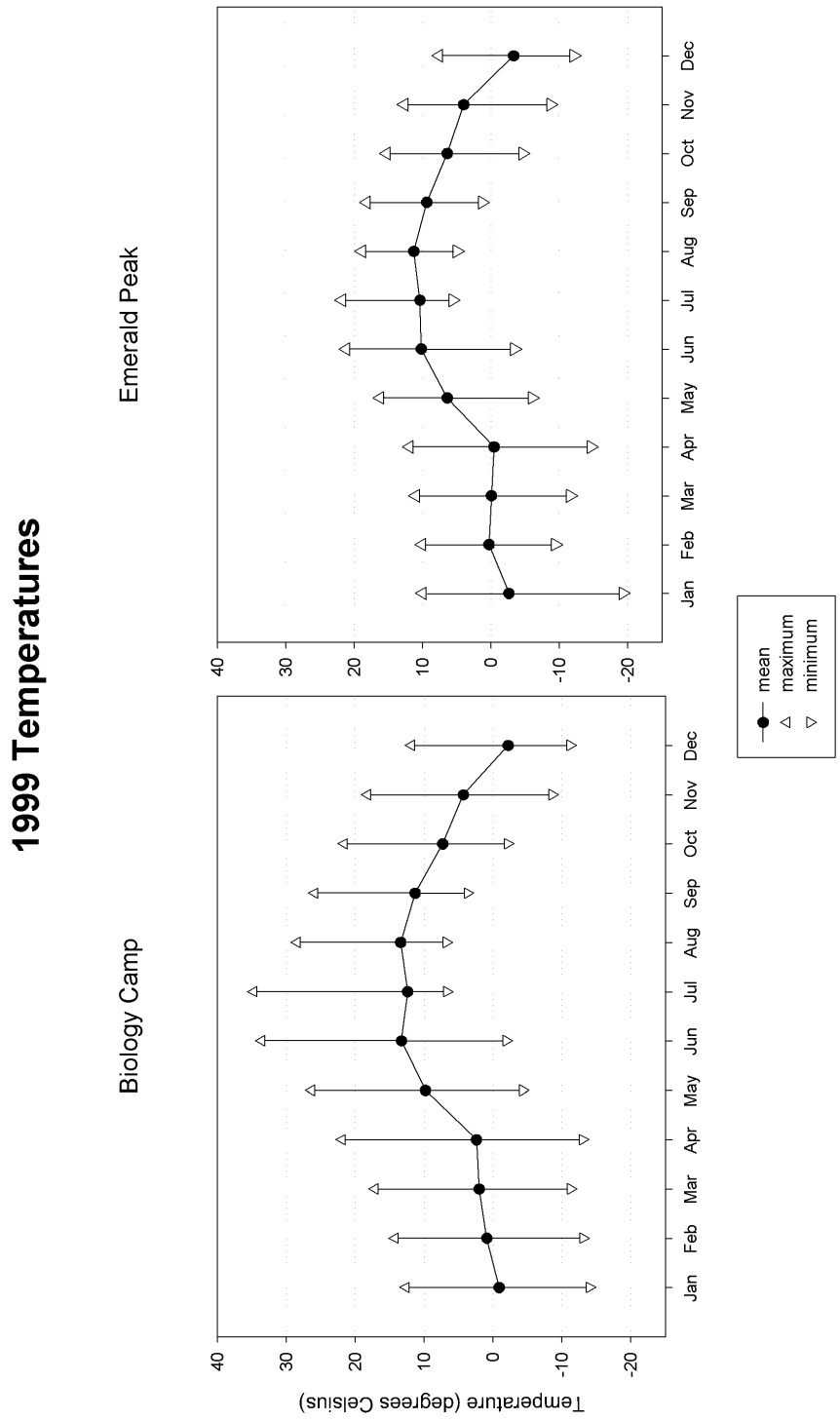


Figure 11. Total monthly precipitation as rain, 1999.

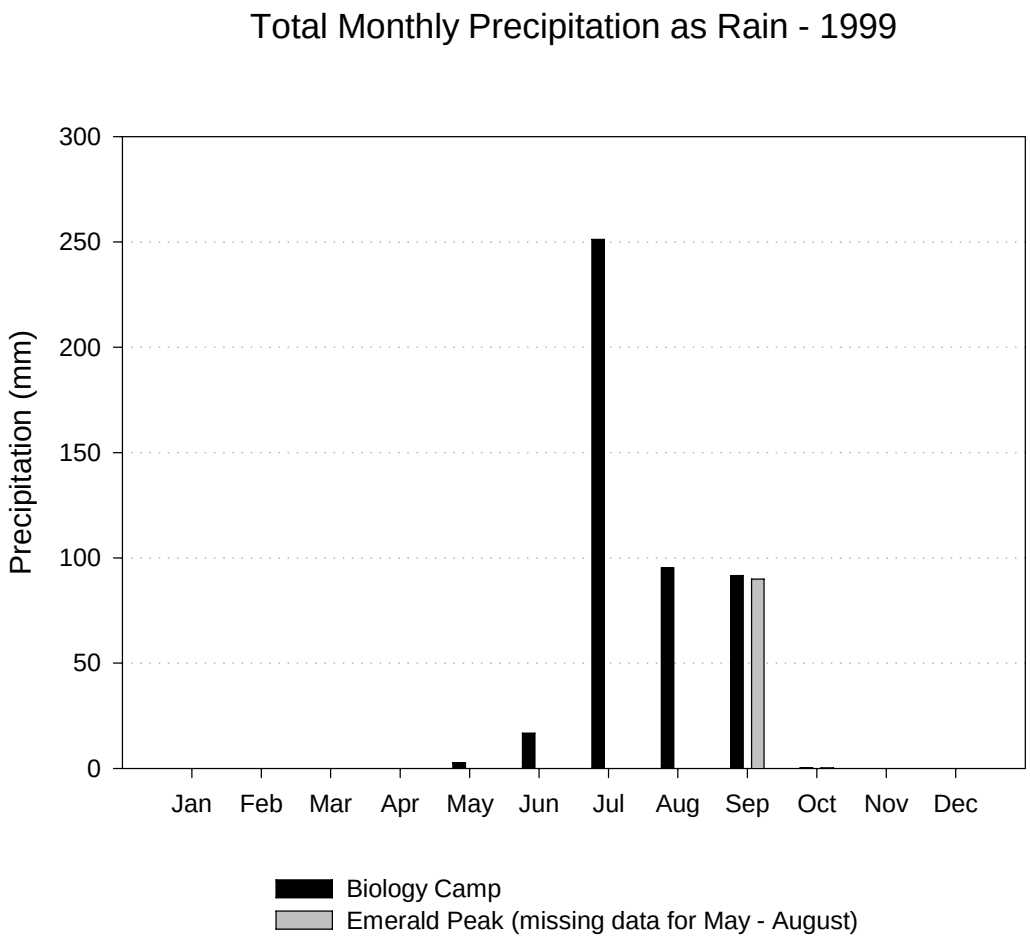


Figure 12. Accumulated snow depths, 1998-1999.

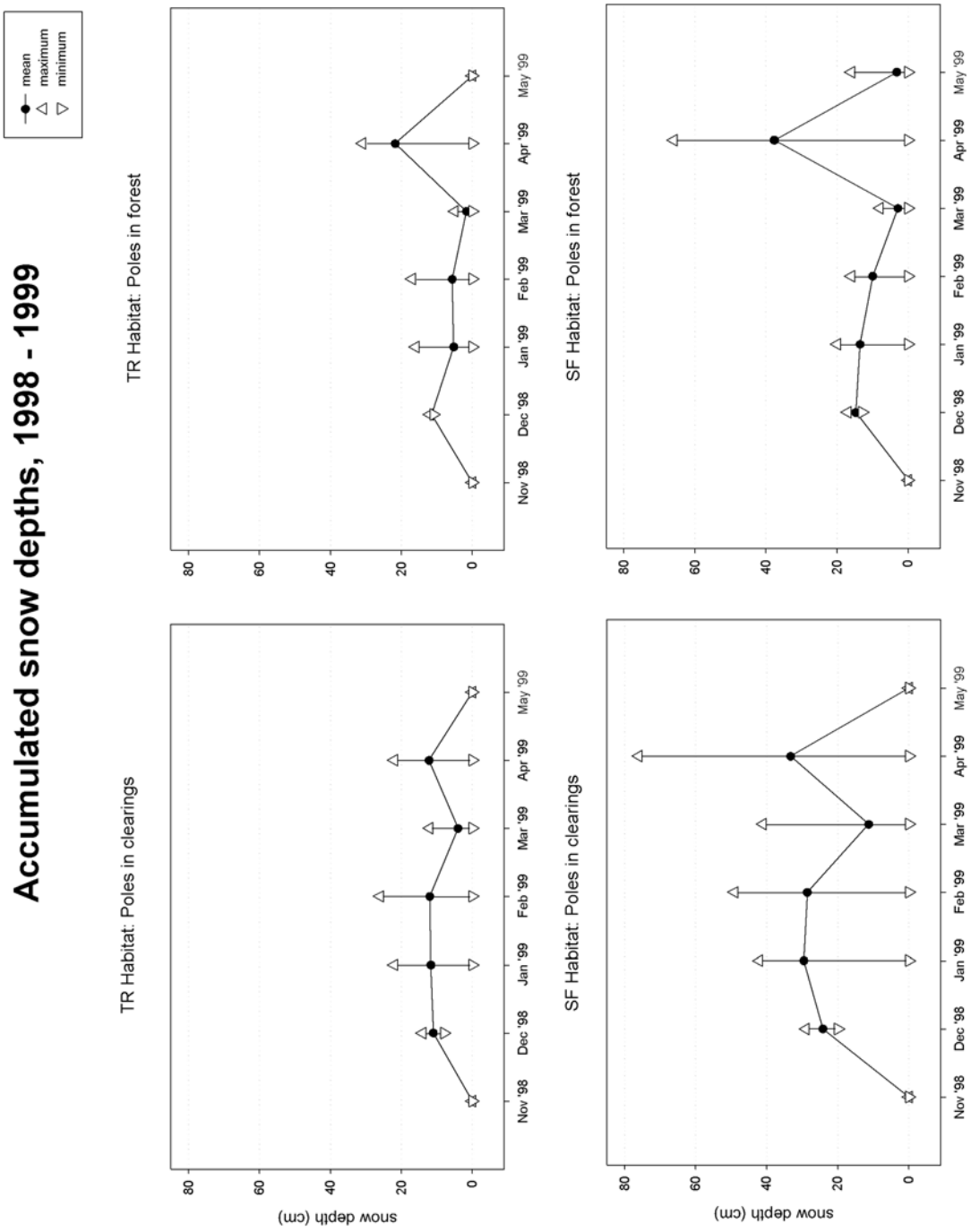


Figure 13. Estimated boundaries of the insect outbreak areas on the monitored areas, 1997 - 1999. Estimates were made by visual assessment and then plotted using ARCInfo and ARCView.

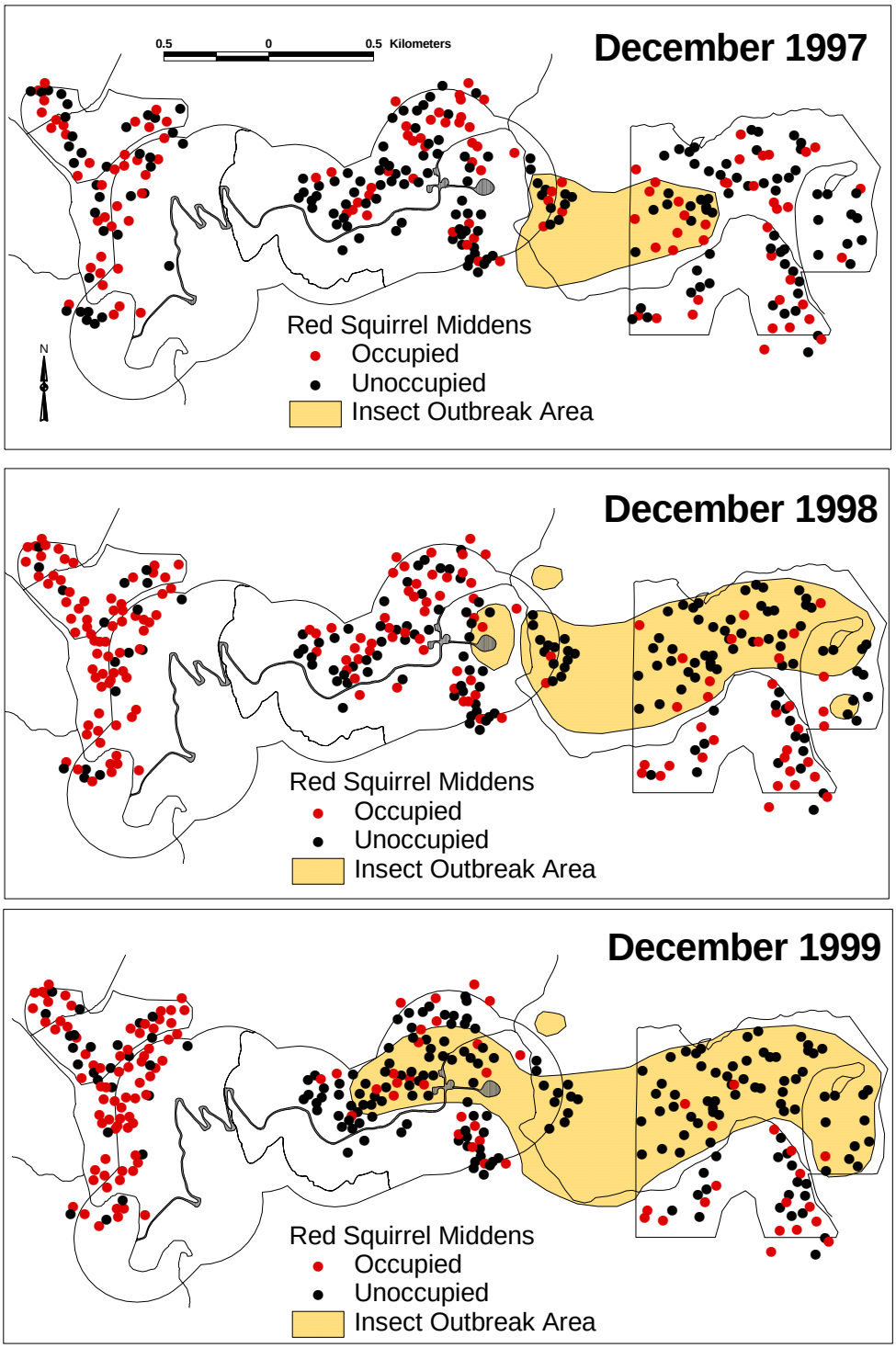
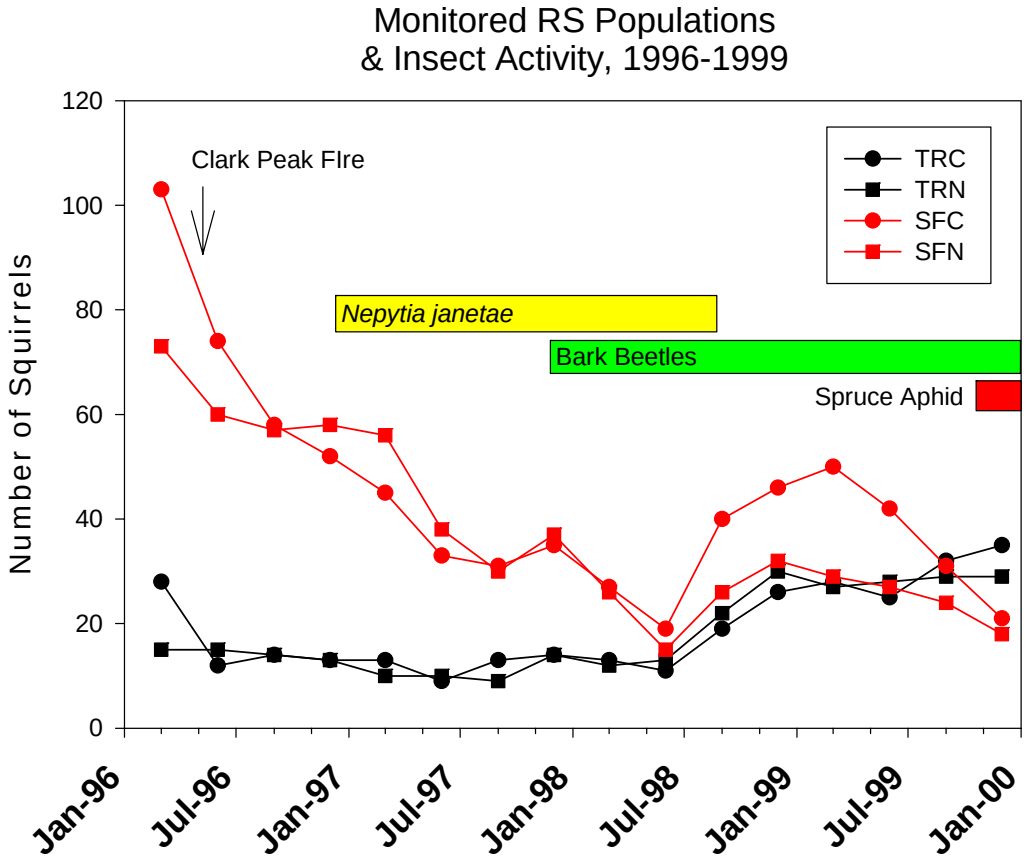


Figure 14. Red squirrel populations and insect outbreak periods on the monitored areas, 1996 - 1999.



Appendix A. Numbers, weights, and energy values for 1998 seeds and 1998 mushrooms.

A-1. Means

A-2. Medians

Appendix A-1: Mean number of seeds, weights, and energy values for 1998 seeds and 1998 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	173.3	77.0	53.3	10.2	0.0	0.0	226.7	87.2	46.4	4.8	86.8	174.0
	4	burned											
	5	40.0	17.8	0.0	0.0	53.3	4.9	93.3	22.6	25.2	2.7	48.4	71.0
	6	burned											
	7	burned											
	8	burned											
	9	burned											
	10	1626.7	722.2	13.3	2.6	26.7	2.4	1666.7	727.2	8.9	0.9	16.4	743.6
	11	53.3	23.7	333.3	64.0	13.3	1.2	400.0	88.9	12.7	1.3	24.2	113.1
	12	53.3	23.7	106.7	20.5	40.0	3.6	200.0	47.8	5.6	0.6	10.6	58.4
TRN	1	1520.0	674.9	26.7	5.1	40.0	3.6	1586.7	683.6	26.3	2.8	49.8	733.4
	2	546.7	242.7	453.3	87.0	0.0	0.0	1000.0	329.8	13.4	1.4	25.7	355.5
	3	733.3	325.6	0.0	0.0	0.0	0.0	733.3	325.6	57.4	6.0	107.4	433.0
	4	426.7	189.4	0.0	0.0	93.3	8.5	520.0	197.9	10.9	1.5	26.5	224.4
SFC	1	1280.0	568.3	0.0	0.0	200.0	18.2	1480.0	586.5	66.6	6.3	113.4	699.9
	2	burned											
SFC	3	960.0	426.2	0.0	0.0	40.0	3.6	1000.0	429.9	138.7	13.7	246.4	676.3

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
	4	226.7	100.6	0.0	0.0	106.7	9.7	333.3	110.3	32.9	3.2	57.8	168.1
	5	40.0	17.8	0.0	0.0	53.3	4.9	93.3	22.6	49.3	5.8	103.90	126.5
	6	13.3	5.9	0.0	0.0	66.7	6.1	80.0	12.0	128.4	12.2	219.30	231.20
	7	burned											
	8	burned											
	9	burned											
	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.6	10.7	10.7
	11	280.0	124.3	0.0	0.0	200.0	18.2	480.0	142.5	35.7	4.1	74.0	216.5
SFN	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	1.1	19.2	19.2
	2	0.0	0.0	0.0	0.0	20.0	1.8	20.0	1.8	10.6	1.3	22.5	24.3
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.4	3.0	53.6	53.6
	4	13.3	5.9	0.0	0.0	693.3	63.1	706.7	69.0	98.6	9.4	169.1	238.1
	5	0.0	0.0	0.0	0.0	200.0	18.2	200.0	18.2	168.9	18.3	329.5	347.7
	6	0.0	0.0	0.0	0.0	720.0	65.5	720.0	65.5	89.3	9.3	168.0	233.5
	7	13.3	5.9	0.0	0.0	0.0	0.0	13.3	5.9	3.3	0.4	8.1	14.0
	8	13.3	5.9	0.0	0.0	93.3	8.5	106.7	14.4	104.3	10.9	196.1	210.5
	9	13.3	5.9	0.0	0.0	53.3	4.9	66.7	10.8	53.9	5.4	98.0	108.8
	10	0.0	0.0	0.0	0.0	13.3	1.2	13.3	1.2	16.4	2.1	37.6	38.8
	11	0.0	0.0	0.0	0.0	306.7	27.9	306.7	27.9	69.1	7.2	129.5	157.4
	12	40.0	17.8	0.0	0.0	173.3	15.8	213.3	33.5	108.8	11.3	203.2	236.8
		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	N	# 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 $\bar{x}$	5	389.3	172.9	101.3	19.5	26.7	2.4	517.3	194.7	19.8	2.1	37.3	232.0
TRN $\bar{x}$	4	806.7	358.2	120.0	23.0	33.3	3.0	960.0	384.2	27.0	2.9	52.4	436.6

		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	N	# 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 $\bar{x}$	7	400.0	177.6	0.0	0.0	95.2	8.7	495.2	186.3	65.3	6.6	117.9	304.2
SFN $\bar{x}$	12	7.8	3.5	0.0	0.0	189.4	17.2	197.2	20.7	62.8	6.6	119.5	140.2
TR $\bar{x}$	9	574.8	255.2	109.6	21.0	29.6	2.7	714.1	279.0	23.0	2.4	44.0	322.9
SF $\bar{x}$	19	152.3	67.6	0.0	0.0	154.7	14.1	307.0	81.7	63.7	6.6	118.9	200.6

Appendix A-2: Median number of seeds, weights, and energy values for 1998 seeds and 1998 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	173.3	77.0	53.3	10.2	0.0	0.0	226.7	87.2	46.4	4.8	86.8	174.0
	4	burned											
	5	40.0	17.8	0.0	0.0	53.3	4.9	93.3	22.6	25.2	2.7	48.4	71.0
	6	burned											
	7	burned											
	8	burned											
	9	burned											
	10	1626.7	722.2	13.3	2.6	26.7	2.4	1666.7	727.2	8.9	0.9	16.4	743.6
	11	53.3	23.7	333.3	64.0	13.3	1.2	400.0	88.9	12.7	1.3	24.2	113.1
	12	53.3	23.7	106.7	20.5	40.0	3.6	200.0	47.8	5.6	0.6	10.6	58.4
TRN	1	1520.0	674.9	26.7	5.1	40.0	3.6	1586.7	683.6	26.3	2.8	49.8	733.4
	2	546.7	242.7	453.3	87.0	0.0	0.0	1000.0	329.8	13.4	1.4	25.7	355.5
	3	733.3	325.6	0.0	0.0	0.0	0.0	733.3	325.6	57.4	6.0	107.4	433.0
	4	426.7	189.4	0.0	0.0	93.3	8.5	520.0	197.9	10.9	1.5	26.5	224.4
SFC	1	1280.0	568.3	0.0	0.0	200.0	18.2	1480.0	586.5	66.6	6.3	113.4	699.9
	2	burned											
	3	960.0	426.2	0.0	0.0	40.0	3.6	1000.0	429.9	138.7	13.7	246.4	676.3
	4	226.7	100.6	0.0	0.0	106.7	9.7	333.3	110.3	32.9	3.2	57.8	168.1
	5	40.0	17.8	0.0	0.0	53.3	4.9	93.3	22.6	49.3	5.8	103.9	126.5

		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
	6	13.3	5.9	0.0	0.0	66.7	6.1	80.0	12.0	128.4	12.2	219.3	231.2
SFC	7						burned						
	8						burned						
	9						burned						
	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.6	10.7	10.7
	11	280.0	124.3	0.0	0.0	200.0	18.2	480.0	142.5	35.7	4.1	74.0	216.5
SFN	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	1.1	19.2	19.2
	2	0.0	0.0	0.0	0.0	20.0	1.8	20.0	1.8	10.6	1.2	22.5	24.3
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.4	3.0	53.6	53.6
	4	13.3	5.9	0.0	0.0	693.3	63.1	706.7	69.0	98.6	9.4	169.1	238.1
	5	0.0	0.0	0.0	0.0	200.0	18.2	200.0	18.2	168.9	18.3	329.5	347.7
	6	0.0	0.0	0.0	0.0	720.0	65.5	720.0	65.5	89.3	9.3	168.0	233.5
	7	13.3	5.9	0.0	0.0	0.0	0.0	13.3	5.9	3.3	0.4	8.1	14.0
	8	13.3	5.9	0.0	0.0	93.3	8.5	106.7	14.4	104.3	10.9	196.1	210.5
	9	13.3	5.9	0.0	0.0	53.3	4.9	66.7	10.8	53.9	5.4	98.0	108.8
	10	0.0	0.0	0.0	0.0	13.3	1.2	13.3	1.2	16.4	2.1	37.6	38.8
	11	0.0	0.0	0.0	0.0	306.7	27.9	306.7	27.9	69.1	7.2	129.5	157.4
	12	40.0	17.8	0.0	0.0	173.3	15.8	213.3	33.5	108.8	11.3	203.2	236.8

		Corkbark Fir		Douglas-fir		Englemann Spruce		Total Seeds		Total Mushrooms			Total Energy
AREA	N	# 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	5	53.3	23.7	53.3	10.2	26.7	2.4	226.7	87.2	12.7	1.3	24.2	113.1
TRN	4	640.0	284.2	13.3	2.6	20.0	1.8	866.7	327.7	19.8	2.1	38.1	394.3
SFC md	7	226.7	100.6	0.0	0.0	66.7	6.1	333.3	110.3	49.3	5.8	103.9	216.5
SFN	12	0.0	0.0	0.0	0.0	73.3	6.7	86.7	12.6	61.5	6.3	113.8	133.1
TR	9	346.7	153.9	33.3	6.4	23.3	2.1	546.7	207.4	16.3	1.7	31.2	253.7
SF	19	113.3	50.3	0.0	0.0	70.0	6.4	210.0	61.5	55.4	6.0	108.8	174.8

Appendix B. Midden occupancy records for the monitored areas, 1999.

B-1. Quarterly occupancy records

B-2. Activity area information

Appendix B-1. Midden occupancy records for the monitored areas, 1999.

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), 1999				
Midden	Mar	Jun	Sep	Dec
1101[89]	located off-area, new number - 5101			
1102[89]	S	S	♂	♂
1103[89]	♂	♂	♂	♂
1104[89]	♂	♂[NAT2]	♀	♀
1105[89]	burned in Clark Peak fire			
1106[89]	Y	♀L+3J	♀	♀
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]	removed from census - low occupancy[1]			
1112[89*]	♂	♂	♀	♀
1113[89]	♂	♂	♂	♂
1114[89]	located off-area, new number - 5114			
1115[89]	reoccupied[9]		♀	♀
1116[89*]	♂	♂	♂	♂ NAT 10
1117[89]	burned in Clark Peak fire			
1118[89]	S	♂	♂	♂
1119[88]	burned in Clark Peak fire			
1120[89]	burned in Clark Peak fire			
1121[89*]	♂[2]	♂[NAT3]	♂	♂
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*]	♀	3J	♀	♀
1132[90*]	removed from census - low occupancy[1]			
1134[91*]	removed from census - low occupancy			
1135[91*]	burned in Clark Peak fire			
1136[91*]	burned in Clark Peak fire			
1137[91*]	burned in Clark Peak fire			

Transition Construction Area (TRC), 1999				
Midden	Mar	Jun	Sep	Dec
1138[91*]	removed from census - low occupancy			
1139[91*]	burned in Clark Peak fire			
1140[91*]	burned in Clark Peak fire			
1142[91*]	burned in Clark Peak fire			
1143[91*]	burned in Clark Peak fire			
1144[91*]	♀	♀	♀	♀
1145[91*]	located off-area, new number - 5145			
1146[91*]	removed from census - low occupancy[1]			
1147[91*]	♂	♂	♂	♂ NAT 11
1148[91*]	burned in Clark Peak fire			
1149[91*]	S	♀[NAT4]	♀[NAT4]	♂
1150[91*]	located off-area, new number - 5150			
1151[91*]	♀	♀	♀	♀
1152[91*]	burned in Clark Peak fire			
1153[92*]	N	N	♀	♀
1154[92*]	♀	♀[NAT5]	♂	♂
1155[93*]	located off-area, new number - 5155			
1156[93*]	♂	S	S	S
1157[93*]	located off-area, new number - 5157			
1159[93*]	burned in Clark Peak fire			
1160[96*]	♀	♀L	♀	♀
1161[96*]	N	N	N	N
1162[96*]	N	N	S	♂
1163[98*]	S	♀	♀ NAT 7	♀ NAT 7
1164[98*]	N	N	N	N
1165[98*]	♀	♂	N	N
1166[98*]	♀	♀L	♀	♀
1167[98*]	♀	♀	♀	♀
1168[98*]	♂	♂	♂	♂
1169[98*]	♂	♂	♂[NAT 8]	♂ NAT 8

Transition Construction Area (TRC), 1999				
Midden	Mar	Jun	Sep	Dec
1170[98*]	S	N	♂	♂
1171[98*]	S	♀	P	N
1172[90*]	♂	♀	N	N
1173[99*]	♂	P	♀	♀
1174[99*]	♂	♂	♂	♂
1175[99*]	new		♀	♀
1176[99*]	new		♂	♂
1177[99*]	new		♂	♂
1178[99*]	new		♂	♂
1179[99*]	new			♀
1180	new			♂
1181	new			♀
# Mid	34	34	39	42
# Occ	28	26	32	35
% Occ	82	76	82	83
# Sq	28	25 + 6[6]	32	35

1 March 1999 - middens removed from regular censusing due to low occupancy.

2 Male at 1104 has a natural mark - short tail and notch in the right ear.

3 Male at 1121 has a natural mark - short tail.

4 Female at 1149 has a natural mark - short tail.

5 Female at 1154 has a natural mark - notch in left ear.

Appendix B-1 TRC (cont.)

6	This number represents the number of adults and juveniles OBSERVED. An adult female was not observed at 1131, but the three juveniles were too young to have dispersed from the natal midden. So the mother was certainly still around - just not observed. Therefore the number of adult squirrels on the area is more likely to be 26.
7	The female at 1163 has a natural mark - notch in left ear.
8	The male at 1169 has a natural mark - small notch in right ear.
9	Midden 1115 had been previously removed from regular censusing due to low occupancy.
10	The male at 1116 has a natural mark - short tail.
11	The male at 1147 has a natural mark - short tail.

Transition Non-Construction Area (TRN), 1999				
Midden	Mar	Jun	Sep	Dec
2201[89]	♀	P	N	N
2202[89]	N	N	N	N
2203[89]	♂	♂	♂	♂
2204[89]	N	N	♂	N
2205[89]	♂	♂	♂	♂
2206[89]	♀	♀	♀	♀
2207[89*]	N	N	P	♀
2208[89*]	S	S	♂[NAT2]	♂[NAT2]
2209[89]	N	N	N	N
2210[90]	♂	♀L	♂[NAT3]	♂[NAT3]
2211[90*]	♂	♂	♀	S
2212[90]	S	♀L	S	♂
2213[90]	removed from census - low occupancy			
2214[90*]	located on TRC, new number - 1172			
2215[90*]	♂	S	S	♂
2216[90*]	♂	♂	S	♂
2217[90*]	♀	♀L	♀	S
2218[91*]	♀	♂	♀	♂
2219[91*]	♀	♀[NAT1]	♀[NAT1]	♂
2220[91*]	N	N	♂	Y
2221[91*]	located off-area, new number - 5221			
2222[91*]	removed from census - low occupancy			
2223[91*]	♂	♂	♂	♀
2224[93*]	removed from census - low occupancy			
2225[94*]	S	S	N	N
2226[95*]	N	N	N	♀
2227[95*]	N	S	♀	♀
2228[95*]	N	N	N	N
2229[96*]	♀	♀	♀	♀
2230[96*]	N	N	S	N
2231[96*]	located off-area, new number - 5231			

Transition Non-Construction Area (TRN), 1999				
Midden	Mar	Jun	Sep	Dec
2232[96*]	located off-area, new number - 5232			
2233[96*]	N	N	N	N
2234[97*]	S	♀L	♀L	♀
2235[98*]	♀	♀L	♂	♂
2236[98*]	♀	♀L	♂	♂
2237[98*]	N	♀	♀	P
2238[98*]	♀	N	♂	N
2239[98*]	S	Y	N	N
2240[98*]	♂	S	N	N
2241[98*]	S	S	♂	♂
2242[98*]	S	♂	♂	♂
2243[98*]	S	S	N	N
2244[99*]	♂	♂	♀L + 3J	♀
2245[99*]	♂	S	P	N
2246[99*]	new	S	♀	♀
2247[99*]	new		♂	♂
2248[99*]	new		♂	♂
2249[99*]	new			♀
# Mid	38	39	41	42
# Occ	27	28	29	28
% Occ	71	72	71	67
# Sq	27	28	29 + 3J	28

Appendix B-1 TRN (cont.)

1 Female at 2219 has a natural mark - notch in the right ear.

2 Male at 2208 has a natural mark - large triangle shaped notch in left ear.

3 Male at 2210 has a natural mark - notch on top of right ear.

Spruce-Fir Construction Area (SFC), 1999				
Midden	Mar	Jun	Sep	Dec
3000[95*]	removed from census - low occupancy[1]			
3001[95*]	P	N	N	N
3002[95*]	N	N	N	N
3003[95*]	N	N	N	N
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, new number			
3008[95*]	N	N	N	N
3009[95*]	♀	♀	S	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*]	Y	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*]	♀	P	N	N
3021[96*]	burned in Clark Peak fire			
3022[96*]	♂	Y	♀	P
3023[98*]	S	♀	2J[5]	P
3024[98*]	♂	♂	P	N
3025[98*]	♀	♀	♀	S
3026[98*]	Y	S	S	P
3027[99*]	Y	P	N	N
3028[99*]	S	N	N	♀ [NAT7]
3029[99*]	♀	♀L	P	N
3030[99*]	♀	♀	N	N
3031[99*]	Y	♀	S	P
3032[99*]	new		♂[NAT6]	N

Spruce-Fir Construction Area (SFC), 1999				
Midden	Mar	Jun	Sep	Dec
3300[86]	♂	S	♀	P
3301[94*]	removed from census - low occupancy[1]			
3302[94*]	located off-area, new number - 5302			
3303[94*]	Y	♂	♂	♂
3304[94*]	N	N	N	N
3305[94*]	N	N	N	N
3306[94*]	♂	♂	Y	S
3307[94*]	N	N	N	N
3308[95*]	N	N	N	N
3309[95*]	N	N	N	N
3310[95*]	N	N	N	N
3311[95*]	N	N	N	N
3312[95*]	S	S	♂	♂
3313[95*]	located off-area, new number - 5313			
3314[95*]	N	N	N	N
3315[95*]	N	N	N	N
3316[95*]	N	N	N	N
3317[95*]	Y	S	♀	P
3318[95*]	♀	Y	P	N
3319[95*]	♀	♀L	♂	P
3320[95*]	N	N	N	N
3321[95*]	N	N	N	N
3322[95*]	Y	♀[NAT3]	N	N
3323[95*]	♂	♂	♂	S
3324[95*]	N	N	N	N
3325[95*]	N	N	N	N
3326[95*]	N	N	N	N
3327[95*]	N	N	N	N
3328[95*]	Y	N	N	N
3329[95*]	N	N	N	N
3330[95*]	S	S	N	P
3331[95*]	♀	♀	N	N
3332[95*]	N	N	N	N

Spruce-Fir Construction Area (SFC), 1999				
Midden	Mar	Jun	Sep	Dec
3333[95*]	N	N	N	N
3334[95*]	N	N	N	N
3335[95*]	N	N	N	N
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	N	N	N
3342[95*]	Y	N	N	N
3343[95*]	♀	♀	S	♀ NAT8
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]	N	N	N	N
3351[87]	S	♂	Y	S
3352[86]	removed from census - low occupancy			
3353[87]	S	♀	S	N
3354[86]	N	N	N	N
3355[95*]	♂	P	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]	Y	♂NAT4	♂NAT4	♂NAT4
3361[86]	N	N	N	N
3362[86]	♀	Y	S	S
3363[86]	N	N	N	N
3364[86]	removed from census - low occupancy[1]			
3365[86]	♂*2	♂*2	♂*2	♂*2

Spruce-Fir Construction Area (SFC), 1999				
Midden	Mar	Jun	Sep	Dec
3366[86]	♂	♂	♂	♂
3367[87]	N	N	N	N
3368[86]	♂	S	N	N
3369[86]	S	♂	S	S
3370[86]	♂	♂	Y	P
3371[87]	Y	♀	S	S
3372[89]	♂	♂	N	N
3373[87]	N	N	N	N
3374[89]	S	♀	♂	S
3375[86]	S	N	N	N
3376[86]	located off-area, new number - 5376			
3377[87]	located off-area, new number - 5377			
3378[90*]	♂	S	♀	♀
3379[90*]	N	N	N	N
3380[90*]	removed from census - low occupancy			
3381[90*]	N	N	N	N
3382[91*]	♂	S	S	S
3383[91*]	♂	♂	Y	N
3384[91*]	burned in Clark Peak fire			
3385[91*]	removed from census - low occupancy			
3386[91*]	N	N	N	N
3387[91*]	♂	Y	N	N
3388[92*]	located off-area, new number - 5388			
3389[93*]	N	N	N	N
3390[93*]	Y	S	S	♀
3391[93*]	N	N	N	N
3392[93*]	Y	♂	♀	♀
3393[93*]	S	S	P	N
3394[93*]	Y	♀	S	♀

Spruce-Fir Construction Area (SFC), 1999				
Midden	Mar	Jun	Sep	Dec
3395[94*]	removed from census - low occupancy			
3396[94*]	N	N	N	N
3397[86]	N	N	N	N
3398[86]	removed from census - low occupancy[1]			
3399[94*]	N	N	N	N
# Mid	106	106	107	107
# Occ	50	42	32	21
% Occ	47	40	30	20
# Sq	50	42	31 + 2J[5]	21

1 March 1999 - Middens removed from regular censusing due to low occupancy.

2 Marked male at midden 3365 - White (left ear)/no tag (right ear)

3 Female at 3322 has a natural mark - split left ear.

4 Male at 3360 has a natural mark - middle toe on front left foot sticks straight up.

5 Two juveniles were seen at midden 3023, but an adult female was not observed. The juveniles were probably still at the natal midden, as they did not appear to be old enough to have dispersed yet. There was likely an adult female still resident at the midden. Therefore, the actual number of red squirrels is likely to be 34.

6 Male at 3032 has a natural mark - rip in the right ear.

7 Male at 3028 has a natural mark - nick in top of right ear.

8 Female at 3343 has a natural mark - short tail.

Spruce-Fir Non Construction Area (SFN), 1999				
Midden	Mar	Jun	Sep	Dec
4000[95*]	♀	♂	♂	S
4001[95*]	N	N	N	N
4002[95*]	Y	♂	♂	♂
4003[95*]	N	N	N	N
4004[95*]	removed from census - low occupancy[1]			
4005[95*]	N	N	N	N
4006[95*]	N	N	N	N
4007[95*]	removed from census - low occupancy[1]			
4008[95*]	N	N	N	N
4009[95*]	removed from census - low occupancy[1]			
4010[95*]	♂	S	♀	♀
4011[95*]	N	N	N	N
4012[95*]	N	N	N	N
4013[96*]	N	N	N	N
4014[96*]	N	N	N	N
4015[96*]	N	N	N	N
4016[96*]	♀	♀L	♂	S
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*]	N	N	N	N
4022[98*]	♂	P	N	N
4023[98*]	♂	♂	P	N
4024[98*]	S	S	P	N
4025[99*]	new			♀
4400[89]	removed from census - low occupancy			
4401[94*]	N	N	N	N
4402[94*]	N	N	N	N
4403[94*]	N	N	N	N
4404[95*]	N	N	N	N
4405[95*]	N	N	N	N
4406[95*]	N	N	N	N

Spruce-Fir Non Construction Area (SFN), 1999				
Midden	Mar	Jun	Sep	Dec
4407[95*]	N	N	N	N
4408[95*]	N	N	N	N
4409[95*]	N	N	N	N
4410[95*]	located off-area, new number - 5410			
4411[95*]	N	N	N	N
4412[95*]	N	N	N	N
4413[95*]	located off-area, new number - 5413			
4414[95*]	N	N	N	N
4415[95*]	N	N	N	N
4416[95*]	N	N	N	N
4417[95*]	♂	♂	♂	♂
4418[95*]	N	N	N	N
4419[95*]	N	N	N	N
4420[90]	S	♂	♀	N
4421[86]	N	N	N	N
4422[86]	N	N	N	N
4423[86]	S	♀	Y	N
4424[86]	N	N	N	N
4425[87]	removed from census - low occupancy			
4426[86]	N	N	N	N
4427[86]	♂	S	♀[NAT3]	♀[NAT3]
4428[86]	N	N	N	N
4429[86]	♀	♀	♂	♂
4430[86]	N	N	N	N
4431[86]	N	N	N	N
4432[86]	N	N	N	N
4433[87]	N	N	N	N
4434[86]	removed from census - low occupancy			
4435[86]	S	♂[NAT2]	♂[NAT2]	♂[NAT2]
4436[86]	N	N	N	N
4437[95*]	N	N	N	N
4438[90*]	N	N	N	N
4439[90*]	N	N	N	N

Spruce-Fir Non Construction Area (SFN), 1999				
Midden	Mar	Jun	Sep	Dec
4440[91]	removed from census - low occupancy			
4441[86]	N	N	N	N
4442[95*]	N	N	N	N
4443[86]	P	N	N	N
4444[86]	S	Y	N	N
4445[86]	N	N	N	N
4446[86]	removed from census - low occupancy			
4447[86]	N	N	N	N
4448[86]	removed from census - low occupancy			
4449[86]	S	♂	Y	P
4450[86]	Y	S	♂	P
4451[88]	removed from census - low occupancy			
4452[86]	N	N	N	N
4453[86]	removed from census - low occupancy			
4454[86]	removed from census - low occupancy[1]			
4455[86]	removed from census - low occupancy			
4456[86]	removed from census - low occupancy			
4457[86]	N	N	N	N
4458[86]	removed from census - low occupancy			
4459[86]	removed from census - low occupancy			
4460[87]	Y	♀	S	S
4461[91*]	S	♂	S	P
4462[90]	N	N	N	N
4463[90]	N	N	N	N
4464[90]	♂	♂	Y	P
4465[90*]	N	N	N	N
4466[87]	N	N	N	N
4467[87]	♂	♂	Y	N
4468[87]	removed from census - low occupancy			
4469[87]	N	N	N	N
4470[87]	Y	♂	♂	♂
4471[87]	N	N	N	N
4472[87]	♀	♀	♀	S
4473[87]	♂	♂	♂	S

Spruce-Fir Non Construction Area (SFN), 1999				
Midden	Mar	Jun	Sep	Dec
4474[86]	S	♂	♂	♂
4475[87]	located off-area, new number - 5405			
4476[95*]	N	N	N	N
4477[87]	Y	♂	♂[NAT4]	♀
4478[90*]	removed from census - low occupancy[1]			
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]	♂	♂	♂	♂
4485[86]	removed from census - low occupancy			
4486[86]	removed from census - low occupancy			
4487[86]	located off-area, new number - 5487			
4488[91*]	removed from census - low occupancy[1]			
4489[91*]	Y	N	N	N
4490[91*]	N	N	N	N
4491[91*]	N	N	N	N
4492[91*]	♀	♀	♀	♀
4493[91*]	removed from census - low occupancy			
4494[91*]	N	N	N	N
4495[95*]	P	N	N	N
4496[93*]	S	♀	Y	♀
4497[93*]	N	N	N	N
4498[93*]	N	N	N	N
4499[93*]	N	N	N	N
# Mid	96	96	96	97
# Occ	29	27	24	18
% Occ	30	28	25	19
# Sq	29	27	24	18

Appendix B-1 SFN (cont.)

1 March 1999 - Middens removed from regular censusing due to low occupancy.

2 Male at 4435 has a natural mark - 2 notches in right ear.

3 Female at 4427 has a natural mark - short tail

4 Male at 4477 has a natural mark - small notch in the back of right ear

Off-Area Midden Occupancy, 1999				
Midden	Mar	Jun	Sep	Dec
TRC Area				
5101[89]	S	♂	♂	♂
5102[98*]	♀	♀L	N	N
5103[99*]	new			♀
5104[99*]	new			S [NAT 3]
5114[89]	removed from census - low occupancy[1]			
5118[94*]	♀	P	♂	♂
5119[89*]	♀	♀L	♀	♀
5120[89*]	removed from census - too far off area			
5121[89*]	♂	♂	♂	♂
5122[89]	♀	S	♀	♀
5123[89]	removed from census - too far off area			
5124[90*]	removed from census - too far off area			
5125[89*]	S	♂	♂	♂
5126[91]	N	N	♀	♀
5127[95*]	N	N	N	N
5145[91*]	♂	♂	N	N
5150[91*]	♂	♂	♀	♀
5155[93*]	♀	♀	♀	♀
5157[93*]	♀	♀	♀	♀
TRN Area				
5200[93*]	♂	♂	S	S
5201[99*]	♀	P	N	N
5202[99*]	new	♂	♂	♂
5221[91*]	N	♂	♂	♂
5231[96*]	♀[2]	♀	♂	♂
5232[96*]	♀	♀	♀	♀
SFC Area				
5302[94*]	removed from census - low occupancy			
5311[95*]	S	♂	♂	♂

Off-Area Midden Occupancy, 1999				
Midden	Mar	Jun	Sep	Dec
SFC Area				
5313[95*]	Y	S	♀	♀
5350[86]	S	♀L	♀	♀
5351[94*]	N	N	N	N
5352[94*]	N	N	N	N
5353[94*]	removed from census - too far off area			
5354[94*]	N	N	N	N
5355[94*]	removed from census - low occupancy[1]			
5356[94*]	N	N	N	N
5357[95*]	N	N	N	N
5358[95*]	removed from census - too far off area			
5359[95*]	S	♂	S	♂
5360[96*]	N	N	N	N
5361[96*]	N	N	N	N
5362[96*]	N	N	N	N
5376[86]	removed from census - low occupancy			
5377[87]	S	S	♀	♂
5388[92*]	removed from census - low occupancy			
SFN Area				
5405[87]	♀	♀L	S	♀
5410[95*]	N	N	N	N
5413[95*]	Y	♂	♂	♀
5475[86]	located on area - new number 4021			
5487[86]	removed from census - low occupancy			

Appendix B-1 Off Area (cont.)

1 March 1999 - Middens removed from regular censusing due to low occupancy.

2 Female at 5231 has natural mark: slight bump on nose just below eyes, lighter fur on bump. This female was seen in neighboring midden 5232 in September 1998, but appears to be resident of 5231 in March 1999.

3 Squirrel at 5104 has a natural mark - appears to have a large scar, somewhat grown back with lighter fur, on left foreleg.

Appendix B-2. New activity areas on the monitored areas in 1999 that have the potential to become new middens. Feeding sign, caching and squirrels were seen at most of these areas. These areas have been assigned a temporary number and will be assessed for improved sign and the presence of a squirrel during the next quarterly census. If conditions warrant, an activity area will then be upgraded to a midden and added to the regular quarterly censuses. If an activity area shows no improvement in the two quarterly censuses following initial location, it will be removed. See maps for location of activity areas. **Note: Shaded entries** have been upgraded to new middens. They are presented in this table for a cross-reference of midden identification numbers.

Midden	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Notes
8107	-[1]	N										Mar 1999, final check - remove
8108	-	N										Mar 1999, final check - remove
8114	-	N										Mar 1999, final check - remove
8117	N	N										Mar 1999, final check - remove
8302	N	N										Mar 1999, final check - remove
8303	-	N										Mar 1999, final check - remove
8305	-	N										Mar 1999, final check - remove
8310	-	N										Mar 1999, final check - remove
8311	-	N										Mar 1999, final check - remove
8316	-	♂										upgraded to new midden # 1173
8317	S	Y										upgraded to new midden # 3027
8318	S	S										upgraded to new midden # 3028
8405	-	N										Mar 1999, final check - remove
8406	-	N										Mar 1999, final check - remove
8407	-	N										Mar 1999, final check - remove
8409	-	N										Mar 1999, final check - remove
8411	-	♂										upgraded to new midden # 1174
8413	-	♀										upgraded to new midden # 3029

Midden	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Notes
8502	-	♀										upgraded to new midden # 5201
8504	-	♂										upgraded to new midden # 2244
8505	S	♀										upgraded to new midden # 3030
8506	♀	Y										upgraded to new midden # 3031
8607	-	♂										upgraded to new midden # 2245
8319	new	♀	-	-	S							upgraded to new midden # 2246
8412	-	N	-	-	N							Jun 1999, final check - remove
8414	-	P	-	-	N							Jun 1999, final check - remove
8501	-	N	-	-	N							Jun 1999, final check - remove
8503	-	N	-	-	N							Jun 1999, final check - remove
8507	new	♂	-	-	S							upgraded to new midden # 5202
8109	-[1]	drop	-	-	-	-	-	♀				reocc. & upgraded to new midden # 1175
8203	new	♂	-	-	P	-	-	N				Sep 1999, final check - remove
8306	new				S	♀L	♀L	♂				upgraded to new midden # 3032
8403	-	drop	-	-	-	-	-	♂				reocc. & upgraded to new midden # 1176
8414	-	P	-	-	drop	-	-	♂				reocc. & upgraded to new midden # 1177
8501	-	N	-	-	drop	-	-	♂				reocc. & upgraded to new midden # 2247
8503	-	N	-	-	drop	-	-	♂				reocc. & upgraded to new midden # 2248
8508	new	S	-	-	P	P	-	♂				upgraded to new midden # 1178
8608	new				N[2]	-	-	N				Sep 1999, final check - remove
8108	-	N									♀	reocc. & upgraded to new midden # 5103
8120	new										S	new activity area - Dec 1999
8121	new										♀	new activity area - Dec 1999
8122	new										♀	new activity area - Dec 1999

Midden	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Notes
8204	new							♀	-	-	♀	upgraded to new midden # 4025
8315	new				S	-	-	N	-	-	N	Dec 1999, final check - remove
8320	new							♀	-	-	♀	upgraded to new midden # 2249
8415	new					N	-	N	-	-	N	Dec 1999, final check - remove
8416	new							♂	-	-	S [NAT 3]	upgraded to new midden # 5104
8417	new							♀	-	-	♀	upgraded to new midden # 1179
8418	new							♀	-	-	♂	upgraded to new midden # 1180
8510	new							♀	-	-	♀	upgraded to new midden # 1181
8511	new							♀	-	-	N	check again March 2000

1 Only activity areas within 100 m of construction were checked during construction months other than the quarterly censuses (Mar, Jun, Sep, Dec).

2 This was a likely a new activity area in March 1999, but was not located until June 1999. It is a fairly established area and will be checked in September for any increased activity.

3 Squirrel at midden 5104 has a natural mark - large scar on left foreleg - partially grown back in paler fur.

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-1 for key to symbols.

Middens within 100m of construction, 1999											
Midden	Feb	Mar[1]	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1160	♀	♀	Y	Y	♀L	♀ + 2J	♀	♀	S	S	♀
1179	new										♀
3003	N	N	N	N	N	N	N	N	N	N	N
3013	N	N	N	N	N	N	N	N	N	N	N
3014	♀	Y	N	N	N	N	N	N	N	N	N
3019	N	N	N	N	N	N	N	N	N	N	N
3020	♀	♀	Y	S	P	N	N	N	N	N	N
3024	♂	♂	♂	♂	♂	Y	P	P	N	N	N
3026	♀	Y	Y	♀	S	♀	S	S	S	Y	P
3027	new	Y	Y	Y	P	N	N	N	N	N	N
3028	new	S	P	P	N	N	N	N	N	N	♀ NAT 7
3030	new	♀	♀	♀	♀	♀	Y	N	N	N	N
3031	new	Y	Y	S	♀	S	♀L	S	N	N	P
3032	new							♂NAT 6	N	P	N
3309	N	N	N	N	N	N	N	N	N	N	N
3314	N	N	N	N	N	N	N	N	N	N	N
3315	N	N	N	N	N	N	N	N	N	N	N
3319	♀	♀	♀	♀	♀L	Y	N	♂	S	♀	P
3320	N	N	N	N	N	N	N	N	N	N	N
3322	♀	Y	Y	♀ NAT 4	♀ NAT 4	Y	P	N	N	N	N
3323	♂	♂	S	♂	♂	♂	S	♂	♂	♂ NAT 8	S
3324	N	N	N	N	N	N	N	N	N	N	N
3325	N	N	N	N	N	N	N	N	N	N	N
3327	♂	N	N	N	N	N	N	N	N	N	N
3330	♀	S	Y	Y	S	♀	Y	N	S	Y	P
3334	N	N	N	N	N	N	N	N	N	N	N

Middens within 100m of construction, 1999											
Midden	Feb	Mar[1]	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3336	N	N	N	N	N	N	N	N	N	N	N
3337	N	N	N	N	N	N	N	N	N	N	N
3339	N	N	N	N	N	N	N	N	N	N	N
3340	N	N	N	N	N	N	N	N	N	N	N
3345	N	N	N	N	N	N	N	N	N	N	N
3346	N	N	N	N	N	N	N	N	N	N	N
3347	N	N	N	N	N	N	N	N	N	N	N
3350	N	N	N	N	N	N	S	N	N	N	N
3354	N	N	N	N	N	N	N	N	N	N	N
3357		removed from census - low occupancy									
3362	♀	♀	♀	♀	Y	♀	♀L	S	♀	♀	S
3363	N	N	N	N	N	N	N	N	N	N	N
3364		removed from census - low occupancy									
3365	♂*[2]	♂*[2]	♂*[2]	♂*[2]	♂*[2]	♂*[2]	♂*[2]	♂*[2]	♂*[2]	Y	♂*[2]
3368	S	♂	♂	S	S	Y	Y	N	P	N	N
3379	N	N	N	N	N	N	N	N	N	N	N
3382	♂	♂	Y	Y	S	S	S	S	♂	Y	S
3383	♂	♂	♂	♂	♂	♂[NAT5]	Y	Y	P	N	N
3385		removed from census - low occupancy									
3389	N	N	N	N	N	N	N	N	N	N	N
3391	N	N	N	N	N	N	N	N	N	N	N
# Mid[3]	38	42	42	42	42	42	42	43	43	43	44
# Occ	15	18	16	16	14	14	12	10	8	8	7
% Occ	39	43	38	38	33	33	29	23	19	19	16
# Sq	15	18	16	16	14	14+2J	12	10	8	8	7

Appendix C (cont.)

1 A complete census of all areas is conducted in Mar, Jun, Sep, and Dec (see Table 2).

2 Marked male at midden 3365 - White (left ear)/no tag (right ear)

3 The total number of middens does not include middens 3357, 3364 or 3385 (removed from censusing due to low occupancy). All middens are located on the SFC area, except for middens 1160 and 1179 which are located on the TRC area. NOTE: Midden 3025 was included in this table for the first quarter of 1999 because it was thought to be within 100m of construction. After GPS mapping, the midden is located 118m from the nearest construction and is now removed from Table 3.

4 Female at midden 3322 has a natural mark - a large rip in the left ear.

5 Male at midden 3383 has a natural mark - short tail, only a little over half length.

6 Male at midden 3032 has a natural mark - a rip in the right ear.

7 Female at midden 3028 has a natural mark - a nick in the top of her right ear.

8 Male at midden 3323 has a natural mark - a small nick in the back of the left ear.

Appendix D. Red squirrel populations (including juveniles) on the areas being monitored by the Red Squirrel Monitoring Program, from December 1998 through December 1999.

Date	TRC	TRN	SFC	SFN	TOTAL
Dec 1998	26	30	46	32	134[1]
Mar 1999	28	27	50	29	134[2]
Jun 1999	25 + 6[3]	28	42	27	122 + 6[3]
Sep 1999	32	29 +3J	31 + 2J[4]	24	116 + 5J
Dec 1999	**35**	**28**	**21**	**18**	**102**

Bold Indicates data for this quarter.

1 December 1998 - This number includes 25 new middens (upgraded activity areas).

2 March 1999 - This number includes 10 new middens (upgraded activity areas).

3 This number represents the number of adults and juveniles OBSERVED. An adult female was not observed at 1131, but the three juveniles were too young to have dispersed from the natal midden. So the mother was certainly still around - just not observed. Therefore the number of adult squirrels on the area is more likely to be 26.

4 Two juveniles were seen at midden 3023, but an adult female was not observed. The juveniles were probably still at the natal midden, as they did not appear to be old enough to have dispersed yet. There was likely an adult female still resident at the midden. Therefore, the actual number of red squirrels is likely to be 34.

Appendix E: Midden Occupancy Maps, 1999.

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

Crude Density (middens/ha) of red squirrel middens in each of the monitored areas for December 1998 through December 1999 *(Post-burn area size was used for the calculations in this table).*

DATE (post-burn area)	**TRC** (49.1 ha)	**TRN** (24.4 ha)	**SFC** (101.0 ha)	**SFN** (128.9 ha)
Dec 1998	0.71	1.52	1.38	0.79
Mar 1999	0.96	1.56	1.39	0.74
Jun 1999	0.69	1.60	1.39	0.74
Sep 1999	0.79	1.68	1.41	0.74
Dec 1999	0.90	1.70	1.40	0.80

Appendix F-1b: Crude Density of Red Squirrels

Crude Density (squirrels/ha) of red squirrels (including juveniles) in each of the monitored areas for December 1998 through December 1999 *(Post-burn area size was used for the calculations in this table).*

DATE (post-burn area)	**TRC** (49.1 ha)	**TRN** (24.4 ha)	**SFC** (101.0 ha)	**SFN** (128.9 ha)
Dec 1998	0.53	1.23	0.60	0.25
Mar 1999	0.57	1.11	0.66	.22
Jun 1999	0.63	1.15	0.55	0.21
Sep 1999	0.65	1.31	0.43	0.19
Dec 1999	0.71	1.15	0.28	0.14

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

TRC Area

	Middens					Squirrels				
Month	# Mid	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	# RS	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 98	35	5.1	0.40	41.4	3.08	26	3.8	0.41	47.1	4.45
Mar 99	34	4.9	0.37	41.8	3.06	28	3.9	0.38	45.4	3.77
Jun 99	34	5.1	0.39	41.7	3.15	26	3.8	0.42	46.8	4.33
Sep 99	39	5.9	0.4	40.5	2.74	32	5.0	0.45	44.4	3.15
Dec 99	42	5.9	0.37	41.0	2.51	35	5.0	0.41	45.4	2.95

TRN Area

	Middens					Squirrels				
Month	# Mid	Mean local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	# RS	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 98	37	5.5	0.31	43.0	2.47	30	4.4	0.29	48.4	3.12
Mar 99	38	6.0	0.29	41.0	2.56	27	4.5	0.27	45.6	2.56
Jun 99	39	6.2	0.29	40.3	2.07	28	4.6	0.27	44.3	2.39
Sep 99	41	6.5	0.29	40.6	1.98	29	4.7	0.33	46.2	2.35
Dec 99	42	6.6	0.28	39.8	1.93	28	4.3	0.28	48.7	2.80

Appendix F-2 (con't.)

SFC Area

	Middens					Squirrels				
Month	# Mid	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	# RS	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 98	105	5.9	0.24	42.5	1.39	46	2.5	0.21	64.3	5.04
Mar 99	106	6.0	0.25	44.1	1.44	50	2.9	0.20	64.6	6.12
Jun 99	106	6.0	0.25	44.2	1.43	42	2.5	0.22	69.2	6.68
Sep 99	107	6.1	0.25	44.2	1.41	32	1.9	0.22	75.8	8.78
Dec 99	107	6.1	0.25	44.2	1.41	21	1.5	0.25	86.2	8.60

SFN Area

	Middens					Squirrels				
Month	# Mid	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	# RS	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 98	102	3.5	0.17	47.7	1.92	32	1.1	0.19	94.9	8.94
Mar 99	96	3.2	0.16	49.4	2.10	29	1.1	0.21	96.5	10.06
Jun 99	96	3.2	0.17	50.3	2.09	27	1.0	0.20	104.7	10.5
Sep 99	96	3.2	0.17	50.3	2.09	24	0.9	0.22	116.4	11.88

SFN Area

	Middens					Squirrels				
Month	# Mid	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	# RS	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 99	97	3.2	0.17	50.1	2.08	18	0.8	0.17	104.6	11.11

Appendix F-2 (con't.)

All Areas Combined
(including off-area middens within 100m of middens on the monitored areas)

	Middens					Squirrels				
Month	# Mid	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	# RS	Mean Local Dens.	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Dec 98	314	4.9	0.13	44.5	0.98	157	3.0	0.17	64.0	2.97
Mar 99	308	4.9	0.14	45.4	1.03	156	3.1	0.16	63.2	3.25
Jun 99	310	4.9	0.14	45.7	1.01	145	2.9	0.18	2.9	0.18
Sep 99	318	5.1	0.15	45.5	0.99	139	3.2	0.21	67.8	3.79
Dec 99	325	5.1	0.14	45.3	0.97	126	3.3	0.22	65.2	3.29

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

DATE	MIDDEN	
15 Apr 99	3024	A male squirrel chased a female squirrel around the midden for approximately10 min. The male remained in the midden after the female left.
03 Jun 99	1171	Three squirrels, one female and two males, were observed in a breeding chase. One of the males came in from midden 1104 and left in the direction of midden 1103.

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

DATE	MIDDEN	
03 Jun 99	1131	Three very small and tentative juveniles were exploring near two of the entrances to the nest tree.
15 Jun 99	1106	Three small juveniles were climbing around on the nest snag.
18 Jun 99	3353	One large female juvenile was seen at the midden.
27 Jul 99	1160	Two juveniles were seen at the midden.
09 Sep 99	2244	Three juveniles were seen at the midden.
11 Sep 99	3023	One juvenile wandering about in a tree.

Appendix G-3. Reproductive status and age statistics by month. For each month, these numbers are based on the final resident of the middens where a squirrel was seen. Middens that were determined to be active based on sign alone and no squirrel was seen are not included. Information gathered on squirrels determined to be non-residents at a midden is also excluded. Therefore the total number of active middens for a given month may be higher than the totals of the numbers seen here. ***Information for off-area middens is included in Appendix G-3(a-c).*** Information for new activity areas is ***NOT*** included in Appendix G-3 (a-c).

Appendix G-3a. Female reproductive information

Reproductive Status	March			June			September			December		
	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.
reproductive				13								
lactating				16			1					
post-lactating							9					
non-reproductive[1]	25		6	15	1		18	13		18	18	1
unknown	15			5			8			13		

1 YOY = Young of year, squirrels that have left the maternal midden. Identified by visual cues: generally smaller size, whiter fur on underside, thinner tail, head may appear slightly large (out of proportion). Young of the year are by definition not reproductively mature.

Appendix G-3b. Male reproductive information

Reproductive Status	March			June			September			December		
	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.
scrotal	42			54			1					
non-scrotal				1			27					
non-reproductive[1]								12		26	8	1
unknown	10			4		1	20			20		

Appendix G-3c. Age information for females, males, and squirrels of unknown sex combined.

March			June			September			December		
Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.	Adult	YOY[1]	Unkn.
131		19	131	7	7	99	30	4	85	27	13

1 YOY = Young of year, squirrels that have left the maternal midden. Identified by visual cues: generally smaller size, whiter fur on underside, thinner tail, head may appear slightly large (out of proportion). Young of the year are by definition not reproductively mature.

Appendix H. Marked Squirrel Data

H-1. Squirrels with natural identifying marks.

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 using >1 midden.

Appendix H-1. Squirrels with identifying marks (natural and tagged). Only information for resident squirrels is included.

Midden	Squirrel ID	Notes
1104	Male - short tail and notch in the right ear	seen in Jun
1116	Male - short tail	seen in Dec
1121	Male - short tail	seen in Mar, Jun
1147	Male - short tail	seen in Dec
1149	Female - short tail	seen in Jun, Dec
1154	Female at has a natural mark - notch in left ear	seen in Jun
1163	Female - notch in left ear	seen in Sep, Dec
1169	Male - small notch in right ear	seen in Sep, Dec
2208	Male - large triangle shaped notch in left ear	seen in Sep, Dec
2210	Male - notch on top of right ear	seen in Sep, Dec
2219	Female - notch in the right ear	seen in Jun, Sep
3028	Male - nick in top of right ear	seen in Dec
3032	Male - rip in the right ear	seen in Dec
3322	Female - split left ear	seen in May, Jun
3343	Female - short tail	seen in Dec
3360	Male - middle toe on front left foot sticks straight up.	seen in Jun, Sep, Dec
3365	**Marked Male** - White (left ear)/no tag (right ear)	seen each month in 1999 (except Jan and Nov)
4435	Male - 2 notches in right ear	seen in Jun, Sep, Dec
4427	Female - short tail	seen in Sep, Dec
4477	Male - small notch in the back of right ear	seen in Dec

Midden	Squirrel ID	Notes
5104	Squirrel - appears to have a large scar, somewhat grown back with lighter fur, on left foreleg	seen in Dec
5231	Female - slight bump on nose just below eyes, lighter fur on bump	seen in Mar. (This female was seen in neighboring midden 5232 in September 1998, but appeared to be resident of 5231 in March 1999)

Appendix H-2. Disappearance of marked squirrels.

No marked squirrels disappeared in 1999.

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

No marked squirrels were observed oustide their midden in 1999.

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

No marked squirrels were observed moving to new middens in 1999.

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

No evidence of marked squirrels using more >1 midden in 1999.

Appendix I. Weather Data

I-1. Monthly Weather Summaries for 1999.

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

Appendix I-1. Monthly Weather Summaries for 1999.

	Month	Biology Camp	Emerald Peak
Temperature (°C) average (max; min)	January	-0.9 (12.6,-14.0)	-2.6 (10.0,-19.3)
	February	0.9 (14.2, -13.1)	0.3 (10.1, -9.4)
	March	2.0 (17.1, -11.3)	-0.06 (11, -11.6)[1]
	April	2.4 (21.9, -13.0)	-0.45 (11.9, -14.6)
	May	9.8 (26.3, -4.3)	6.4 (16.2. -6.)[3]
	June	13.3 (33.6, -1.9)	10.2 (21.2, -3.4)
	July	12.4 (34.7, 6.7)	10.4 (21.8, 5.6)
	August	13.4 (28.4, 6.8)	11.3 (18.9, 5.0)
	September	11.3 (25.9, 3.7)	9.4 (18.2, 1.3)
	October	7.3 (21.6, -2.1)	6.4 (15.3, -4.6)
	November	4.3 (18.2, -8.6)	4.0 (12.7, -8.7)
	December	-2.2 (11.8, -11.2)	-3.3 (7.6, -12.1)

	Month	Biology Camp	Emerald Peak
Wind Speed (m/sec), maximum(max. gust)	January	5.4 (19.7)	4.9 (16.1)
	February	3.6 (10.3)	4.5 (11.6)
	March	3.1 (13.9)	3.1 (11.2)[1]
	April	4.0 (13.0)	3.1 (11.6)
	May	3.6 (13.9)	3.1 (13.0)[3]
	June	0.8 (2.9)	0.5 (2.8)
	July	2.2 (8.0)	4.0 (7.6)
	August	2.2 (7.6)	2.7 (7.2)
	September	1.8 (6.3)	3.1 (6.3)
	October	2.7 (9.4)	2.7 (9.8)
	November	2.2 (8.0)	4.0 (10.3)
	December	0.9 (3.5)	0.8 (3.7)

	Month	Biology Camp	Emerald Peak
Wind, Most Common Direction	January	n/a	WNW
	February	n/a	WNW
	March	SSE	ESE [1]
	April	S	ESE
	May	S	NNW [3]
	June	N	NNW
	July	N	SE
	August	SSW	SE
	September	SSW	SE
	October	SSW	SE
	November	S	SE
	December	N	NNW

	Month	Biology Camp	Emerald Peak
Maximum Snow Depth/Rain Volume (cm/mm)	Jan (snow)	13	35
	Feb (snow)	10	32
	Mar (snow)	0	8
	Apr (snow)	31	66
	May (snow)	0	16
	May (rain)	2.7	0 [3]
	June (rain)	16.8	0
	July (rain)	251.2	n/a [4]
	Aug (rain)	95.3	44 [5]
	Sept (rain)	91.6	90.0
	Oct (rain)	0.3	0.3
	November	0.0	0.0
	December (snow melt)	4.5	5.1

	Month	Biology Camp	Emerald Peak
Relative Humidity (%) average (max; min)	January	42 (92, 12)	n/a
	February	35 (89, 6)	n/a
	March	42 (93, 15)	38.4 (88, 5)[1,2]
	April	47.4 (93, 13)	44.7 (93, 13)
	May	34.3 (88, 10)	32.2 (87, 8)[3]
	June	44.9 (93, 11)	41.6 (94, 9)
	July	87.1 (100, 21)	81.1 (97, 20)
	August	78.4 (100, 32)	74.3 (97, 33)
	September	75.5 (100, 26)	68.7 (97, 17)
	October	42.0 (90, 11)	34.3 (84, 4)
	November	34.6 (80, 7)	27.1 (87, 2)
	December	38.3 (96, 6)	35.3 (95, 1)

	Month	Biology Camp	Emerald Peak
Dew Point (°C) average (max; min)	January	-13.4 (-25.2, -3)	n/a
	February	-14.4 (-0.6, -33.6)	n/a
	March	-10.9 (2.7, -20.3)	-14.6 (-4.1, -31.6)[1,2]
	April	-9.1 (0.9, -25.8)	-13.3 (-2.3, -36.1)
	May	-6.7 (9.3, -20.8)	-10.7 (5.5, -29.6)[3]
	June	0.1 (12.4, -14.6)	-3.6 (9.3, -18.7)
	July	10.0 (16.2, -4.2)	7.5 (11.2, -9.6)
	August	9.4 (14.9, 3.7)	6.4 (11.5, -0.7)
	September	6.6 (14.2, -7.0)	3.3 (11.2, -16.1)
	October	-5.5 (6.6, -26.8)	-9.3 (1.4, -33.2)
	November	-11.0 (3.1, -33.2)	-15.2 (-1.9, -46.9)
	December	-16.4 (1.3, -35)	-20.8 (-0.7, -49.8)

n/a - data not available.

[1] New weather station installed.

[2] data missing for 1Mar 99 through 5Mar 99.

[3] data missing for 3 pm 6 May 99 through 2:30 pm 7 May 99

[4] data missing for month of July, 1999

[5] data missing for Aug 1 - noon of Aug 27, 1999

Appendix I-2. Monthly maxima, minima and averages for accumulated snow depth. Data are from snow poles in Spruce-Fir (SF) and Mixed Conifer (TR) habitats from locations in the forest (F) and in clearings (C).

Month	Hab	Loc	N[1]	Average snow depth (cm)(n)	Maximum snow depth (cm)	Minimum snow depth (cm)
Nov. 1998	TR	C	3	0	0	0
Nov. 1998	TR	F	3	0	0	0
Nov. 1998	SF	C	5	0	0	0
Nov. 1998	SF	F	5	0	0	0
Dec. 1998	TR	C	2	11	14	8
Dec. 1998	TR	F	2	11.5	12	11
Dec. 1998	SF	C	5	24.2	29	20
Dec. 1998	SF	F	5	14.8	17	13
Jan. 1999	TR	C	3	11.7	22	0
Jan. 1999	TR	F	3	5.3	16	0
Jan. 1999	SF	C	5	29.6	42	0
Jan. 1999	SF	F	5	13.6	20	0
Feb. 1999	TR	C	3	12.0	26	0
Feb. 1999	TR	F	3	5.7	17	0
Feb. 1999	SF	C	5	28.6	49	0
Feb. 1999	SF	F	5	10.0	16	0

Month	Hab	Loc	N[1]	Average snow depth (cm)(n)	Maximum snow depth (cm)	Minimum snow depth (cm)
Mar. 1999	TR	C	3	4	12	0
Mar. 1999	TR	F	3	1.7	5	0
Mar. 1999	SF	C	7	11.3	41	0
Mar. 1999	SF	F	7	2.9	8	0
Apr. 1999	TR	C	5	12.2	22	0
Apr. 1999	TR	F	5	21.8	31	0
Apr. 1999	SF	C	9	33.3	76	0
Apr. 1999	SF	F	9	37.7	66	0
May 1999	TR	C	3	0	0	0
May 1999	TR	F	3	0	0	0
May 1999	SF	C	5	0	0	0
May 1999	SF	F	5	3.2	16	0

1 There are 8 sets of snow poles (a set = 1 forest and 1 clearing) on the monitored areas: 3 in the TR habitat and 5 in the SF habitat. If the number for a given month is higher, this means some poles were read more than once during the month and all readings were included in the average.