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MT. GRAHAM RED SQUIRREL MONITORING PROGRAM

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INTRODUCTION

This report is a compilation, analysis, and interpretation of data collected during 1992 by the University of Arizona Mt. Graham Red Squirrel Monitoring Program. Some of the data collected during 1991 are also presented and analyzed to place the 1992 data in perspective. The Monitoring Program is required by the Mt. Graham International Observatory (MGIO) Management Plan to monitor the Mt. Graham red squirrel (Tamiasciurus hudsonicus grahamensis) populations near the MGIO and to determine the effects of construction and operation of the telescopes on the squirrel population. (All references to "squirrel" or "squirrel populations" in this report refer to the Mt. Graham red squirrel.) All of the data collected by the Monitoring Program is available for scrutiny; no part of this report may be used or reproduced in any form without permission of the Monitoring Program supervisor.

The MGIO telescope complex is being constructed near Emerald Peak in the Graham (Pinaleños) Mountains of southeast Arizona. The area surrounding the telescope sites and access road to a distance of 300 meters (m) is referred to in this document as the construction area. For comparison, the Monitoring Program also monitors squirrel population biology on two other areas of the Graham Mountains. These areas are referred to as the non-construction areas.

The border of the construction area was defined in the MGIO Management Plan as a line 300 m from the proposed telescope sites and the access road (Fig. 1). This boundary encompasses about 180 hectares (ha) from the top of Emerald Peak westward and southward to the junction of the new access road and State Highway 366 (SH366). The construction site is divided into two areas of almost equal size. The 3050 m elevation contour separates the two construction areas and approximates the boundary of two coniferous forest habitat types found on the Graham Mountains: transitional coniferous habitat (TR) and spruce/fir habitat (SF). These habitat labels are used to designate different portions of the construction and non-construction areas. The transition habitat construction area (TRC) consists of all of the western portion of the construction area, below 3050 m elevation (about 91 ha). The forest cover on the TRC area varies in species composition and dominance. The primary tree species in this area are Douglas fir (Pseudotsuga menziesii), corkbark fir (Abies lasiocarpa var. arizonica), Engelmann spruce (Picea engelmannii), ponderosa pine (Pinus ponderosa), white pine (Pinus strobiformis), and aspen (Populus tremuloides). The spruce/fir habitat construction area (SFC) is the eastern portion of the construction area, above 3050 m elevation (about 89 ha), and is primarily SF forest, dominated by Engelmann spruce and corkbark fir.

An area about 0.75 kilometers (km) east of the east boundary of the construction area was originally chosen as the non-construction area (Fig. 1). The west boundary of this area was defined as a line running north and south from the top of Hawk Peak down to an elevation of 3050 m on the south and to a hiking trail on the north. The north boundary follows this hiking trail eastward to a point below Mt. Graham, then crosses over the ridge on the NE corner of that peak and continues down the east side of the area along the 3050 m contour. The south boundary follows the 3050 m elevation contour to a point about 1 km below Mt. Graham, then crosses over Forest Road 507 (FR507) to connect to the east boundary (Fig. 1). This area (about 122 ha) is now referred to as the spruce/fir habitat non-construction area (SFN).

In September 1989, a small area (about 22 ha) of TR habitat, northwest of the TRC area, was added to compare the squirrel population on the TRC area with a population in a similar habitat (Young 1991) (Fig. 1). This area is referred to as the transition habitat non-construction area (TRN) and is adjacent to the northwest boundary of the TRC area and bordered on the west by SH366. The borders of the TRN area were not as arbitrary as were those for the TRC, SFC, and SFN areas, but were determined primarily by drawing a line at a radius of about 100 m around the known midden sites. The size of this area was increased to 25 ha in 1990 to include three new middens north of Bible Camp Road.

The four monitored areas differ in size, in the species composition of the forest cover, and in the amount of forest cover on each area. The TRC area encompasses about 48 ha of natural and manmade meadows, which are unsuitable as squirrel habitat. About 50% of the TRC area has a forest overstory while all other areas have 85-90% forest overstory. The quality of the habitat for squirrels also varies considerably (USDA Forest Service 1988). The total number of squirrels on each area, therefore, is not an accurate comparison among populations. Differences found in the measured population variables must be independent of the size and quality of the areas in order to make valid comparisons concerning the effect of construction on squirrel populations on each area.

Food resources, in particular, are an important determinant of the quality of the monitored areas as squirrel habitat. Currently we have no quantitative assessment of the food resources (primarily cone crops) available to the squirrels on each of the monitored areas. By comparing changes in populations without considering potential differences in food resources, we rely on the assumption that the monitored areas within each habitat are similar in their production of food. While this is generally a reasonable assumption, it does not allow us to distinguish between changes in population parameters caused by differences in food resources and changes caused by the construction and operation of MGIO.

The specific objective of the first phase of the monitoring program is to determine the effect of construction activities on squirrel numbers, distribution, and reproductive success. Three measures are used to determine the potential effects of construction activity on the squirrel population: 1) midden occupancy, 2) midden and squirrel distribution, and 3) reproductive success. The data on midden occupancy and distribution of middens and red squirrels are based on complete counts of the populations of each monitored area; not estimated from samples. The data on turnover of middens and reproductive success is limited because there are few marked animals.

METHODS

Red squirrels gather and cache conifer cones in a selected location that is referred to as a midden, which is easily recognized by the accumulation of cones and cone scales. Middens are excellent indicators of squirrel demographics and provide a reasonably accurate estimate of population size because red squirrels are territorial and generally solitary (C. Smith 1968; Vahle 1978). For the purposes of the Monitoring Program, a midden site is defined as an area with a 10 m radius that surrounds the primary cache site. The primary cache site and associated auxiliary cache sites are considered a single midden site for the purpose of monitoring squirrel demographics and populations.

About one-half of the squirrel middens on the monitored areas were located and classified by the USDA Forest Service (USFS), Arizona Game and Fish Department (AGFD), or University of Arizona personnel during surveys conducted prior to the initiation of the Monitoring Program in August 1989. The remaining middens were located by Monitoring Program personnel. All the monitored areas are surveyed twice a year (spring and autumn) to locate newly established middens. In addition, new middens are located as they are discovered during other monitoring activities. All known midden sites are marked with numbered metal tags and black and orange striped flagging tape.

Midden locations were taken from maps created by USFS surveys conducted from 1986-1989 and plotted on USGS 7.5 minute quadrangle topographic maps. In addition, the location of all of the middens on the TRC and TRN areas and some of the middens on the SFC area were ground-truthed by measuring distances between middens and landmarks using a 50 m tape and compass. The location of each midden, roads, and other physical features were defined as coordinates on a Cartesian grid superimposed over copies of the enlarged topographic maps. These coordinates were used to reproduce maps of the monitored areas (Appendix A) and to compute local density and nearest neighbor distances. The accuracy of mapped midden locations are estimated to be within 10 m of actual locations, based on the difference between the calculated nearest neighbor distance and the actual measured distances.

The 1992 field season began with monthly winter censuses in January, February and March. In March, the snow-depth was 250 cm at a gauge located near the beginning of the access road (about 3200 m elevation). Although there was still a considerable amount of snow on the ground in April (220 cm on 7 April at the 3200 m site), we began censusing twice monthly to locate females and assess their reproductive condition. By June most of the snow was gone from the lower elevations, but some areas of snow remained on the upper elevation areas until the summer rains began in July. Trapping and tagging of squirrels resumed in July. Censusing and trapping continued through October and a final census for the year was conducted in November.

Midden Occupancy

Most of the data on the number and distribution of the occupied middens were collected during the monthly census of each area. A census consisted of visiting each known midden site to determine occupancy. If a midden appeared to be occupied on the basis of feeding sign or caching, an attempt was made to observe the squirrel and to determine its gender, age, and reproductive condition. During winter months, visual verification often was not practical, and determinations were based on the presence and age of feeding signs, tracks, and other signs of red squirrel activity. Consequently, the winter censuses may not be as accurate as censuses taken during the rest of the year.

All middens on the monitored areas were classified as either occupied by a squirrel or unoccupied. An occupied midden was used to represent one squirrel for the purpose of describing the population. A midden was considered to be unoccupied when no squirrel was present or when the occupancy was in doubt ("N" and "P" notations in Appendix C). Therefore, the population sizes are conservative and represent the minimum number known alive (Krebs 1989). That means there may have been more squirrels on the study areas than those reported, but not fewer.

Differences in overall midden occupancy among areas and midden occupancy relative to distance from construction were compared by using census data. Three 100-m wide zones (0-100 m, 100-200 m, and 200-300 m) extending away from the access road and telescope sites were used for the distance analysis. For comparison, the occupancy of middens in similar zones the same distances from FR507 and FR669 on the SFN area were also examined.

Overwinter survival and turnover among areas were also analyzed. Overwinter survival was estimated by comparing the number of middens occupied in November 1991 with the number of those same middens that were occupied in May 1992. The estimate of overwinter survival may have been underestimated because only 11 squirrels were trapped and marked in the fall of 1991, and we had to rely on identifying most individuals by gender and age categories to determine when a resident squirrel was replaced. Midden turnover was defined as the resident squirrel in November 1991 being replaced by another squirrel. Turnover rate also may have been underestimated when an unmarked resident squirrel was replaced by another unmarked squirrel of the same gender and age category. Only middens that were occupied for at least one month and were monitored for at least three months during the year were used to measure turnover.

To facilitate the interpretation of patterns of midden occupancy, we used forest structure data provided by A. Smith (1991) that were collected at midden sites during 1989 through 1991. Within each area, we analyzed several variables (canopy coverage, foliage volume, log volume, snag density) for differences in forest structure at occupied vs. unoccupied middens and among distance zones.

Differences in the number of occupied and unoccupied middens in each area, as a result of yearly variations, overwinter survival, and distance from construction, were statistically analyzed by using likelihood ratio chi-square tests on Model II RxC contingency tables (SAS Inst. Inc. 1988:530). Tree structure at midden sites was analyzed for differences among distance zones and between occupied versus unoccupied middens by using ANOVA and protected least significant difference tests (SAS Inst. Inc. 1988:570). Midden turnover was analyzed by using the same tests. The significance level for all tests was set at $\underline{P}<0.05$.

Spatial Distribution

To describe the spatial distribution of all middens and squirrels adequately, three methods were used: crude density, local density, and nearest neighbor distance. Crude density represents the total number of middens or squirrels per unit area. No allowance was made for differences in habitat quality among the monitored areas, and statistical tests are not appropriate. However, the crude density of middens and squirrels was plotted to provide a visual representation of the actual versus potential midden occupancy.

Local density describes a population density on a local basis and allows different populations to be compared when there are uncontrolled habitat variables. Based on the location of midden sites, which are sessile, local density is similar in concept to "distance models" of neighborhood modelling used by plant ecologists to describe and compare plant populations (Czárán and Bartha, 1992). In this report, local density of *middens* represents the *total* number of occupied and unoccupied middens within 100 m of a focal midden, whereas local density of *squirrels* represents only the number of *occupied* middens (squirrels) within 100 m of a focal occupied midden. A circle with a radius of 100 m encloses 3.14 hectares, which is slightly less than the average home range of Mt. Graham red squirrels (Froehlich 1990). It is also approximately the 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) and is used to calculate an index of aggregation (Clark and Evans 1954) to compare the distribution patterns. The index of aggregation values range from 0 to 2.15, where 0 represents a completely aggregated population (i.e. all individuals are in the same place), 1 represents a randomly distributed population, and 2.15 represents a uniformly distributed population. Index values are used to compare the distribution of middens with that of squirrels both within and between areas. The values for the index of aggregation should be viewed with caution because they are calculated for a total area that is arbitrarily determined by the middens with the most extreme coordinates in an area forming a rectangle enclosing all of the middens; it uses a correction factor to correct for the lack of a boundary area (Donnelly 1978). As with local density, NND of *middens* and *squirrels* represents the NND of a midden to another midden (occupied or unoccupied) and a squirrel to another squirrel, respectively. Local density and NND were determined for each midden and squirrel from the mapped coordinates and were compared statistically among areas by using ANOVA and Student-Newman-Kuels (SNK) tests (Sokal and Rohlf 1981; Snedcor and Cochran 1980). To determine some of the local densities and NNDs of middens and squirrels on the monitored areas, it was necessary to include some off-area middens that were within 100 meters of a monitored midden in the calculations. The significance level for all tests was set at $\underline{P} \leq 0.05$.

Reproductive Activity and Success

Midden sites with resident female squirrels were visited at least twice during each 10-day field session in 1992 to collect data on lactation dates, litter emergence dates, the number of lactating females that produced litters, and litter size. These data were used to compare the reproductive success of females in different study areas and distances from construction. The reproductive status of females was determined by examining the condition of the nipples through binoculars and was recorded as "non-reproductive", "lactating", or "post-lactating". The nipples of non-reproductive females were not swollen or pigmented and were not visible through the fur. The nipples of pregnant females become swollen at the base, and if they have had previous litters, they may be darkly pigmented, but they may not be visible through the fur. Because it was not always possible to identify pregnant females at a distance, non-breeding and pregnant females are classified as "non-reproductive". Lactation was the first indication that a female had bred. The nipples of lactating females are swollen, elongated, may be pigmented, and are easily seen protruding through the fur because suckling offspring often wear away the fur around nipples. Nipples of a post-lactating female become flattened, are generally darkly pigmented, and are visible through the fur (Becker 1992).

Some natal nests, not found during regular censuses, were located by observing and following lactating females. All known natal nests were observed during visits to the respective midden sites to determine the date of litter emergence and litter size. Because the natal nests were visited at three to four day intervals, the litter emergence date was determined within less than one week. Litter size at emergence was used as a measure of reproductive success in lieu of disturbing the natal nest to obtain nestling counts. Consequently, the number of females listed as "unsuccessful" at rearing litters may be higher than the actual number of unsuccessful females because some litters were not observed at the time of emergence.

The first observed dates of lactation and litter emergence dates were used to estimate the breeding dates and to provide further data on the length of the breeding season. The gestation period of red squirrels is about 33-35 days (Ferron and Prescott 1977; Lair 1985), and the juveniles generally leave the natal nest at about 37-39 days of age (Layne 1954; Nice et al. 1956; Ferron 1980, 1981). Therefore, conception can be assumed to occur about 33 to 35 days prior to lactation and 70 to 74 days prior to emergence of the juveniles.

The number of females that lactated and the number that had litters on the construction areas were examined in relation to distance from construction. The distance of each female's midden from construction was calculated from the coordinates of the midden site and the closest point of construction activity (telescope site or access road) by the same method used to calculate nearest neighbor distances. Kruskal-Wallis tests (Sokal and Rohlf 1981) were used to test for differences in the distance to construction for female reproductive success (non-breeding, lactating, and lactating with litter emerging).

The reproductive status of male squirrels was also determined by visual assessment. As the reproductive season approaches, the testes recrudesce and descend into the scrotum, and the scrotum becomes darkly pigmented, enlarged, and highly visible. The reproductive status of males was recorded as "testes non-scrotal" (non-reproductive) or "testes scrotal" (sexually active) and was noted when ever males were observed.

Trapping and Tagging

Trapping and tagging of squirrels continued during the 1992 field season. Squirrels were trapped using Tomahawk Live-traps baited with peanut butter and/or fresh cones. Captured squirrels were handled by the Halvorson (1972) method, then fitted with numbered metal ear tags equipped with color coded plastic washers to identify individual squirrels. To minimize the risk to the squirrels, all open traps were kept under surveillance at all times, and squirrels were handled immediately after capture. Squirrels were tagged while in the "Halvorson cone" and released immediately after determining the gender of the squirrel.

RESULTS AND DISCUSSION

A census was conducted during each month of 1992, except during December when weather conditions were too severe. Three newly established midden sites were discovered in 1992, increasing the total number of middens on the monitored areas from 176 to 179 (Table 1). Because so few new middens were found, midden distribution among the four study sites in November 1992 was essentially the same as in November 1991. However, the number of squirrels decreased from 124 to 72 during the same period (Table 2, Appendix A). Squirrel populations peaked in August 1992 and then declined, whereas in 1991, squirrel populations generally continued to increase throughout the fall (Fig. 2, Appendix B). During the decline in the population, the proportion of squirrels on each area remained about the same, although a slightly greater proportion of the total population of squirrels was located in the SF habitat in November 1992 than in the previous November. The population trend observed in 1992 (in which the population was at its lowest in early spring, as a result of overwinter mortality, and was at its highest between June and August as litters emerged) is more typical of red squirrel populations than the trend observed in 1991 (Rusch and Reeder 1978).

Midden Occupancy

There were no significant differences in midden occupancy between construction and non-construction areas within either the TR or the SF habitat types in 1991 or 1992 (Table 3a). The TR habitat, however, had significantly more occupied middens in November 1991 and June 1992 than the SF habitat, (Table 3b, Appendix C). As the population declined in late 1992, the TR habitat lost more squirrels than did the SF habitat and, by November 1992, the proportion of middens occupied was similar in both habitats.

Over-winter survival (November 1991 to May 1992) of squirrels did not differ significantly between construction and non-construction areas in either the TR or SF habitats (Table 4a). There also was no difference in overwinter survival of marked squirrels on the SFC versus SFN, but the sample size was very small and statistical tests must be viewed with caution (Table 4b).

No significant differences were found in the turnover rates between construction and non-construction areas within either the TR or SF habitat (Table 5). There tended to be more turnovers in the TR than in the SF habitat, although no significant differences were found. There probably were more juveniles in the TR than in the SF habitat in the fall of 1991 (Young 1992, Appendix C), which increased the number of occupied middens in that habitat. The younger TR population also may have caused the greater turnover rates in the TR habitat, because juveniles may have had a greater tendency to vacate a midden site and be replaced by another squirrel than the older SF population (Rusch and Reeder 1978).

As a result of the population decline, midden occupancy near construction decreased between November 1991 and November 1992 in all 100-m zones on each area (TRC, SFC, and SFN). However the decreases were only significant in the second 100-m zone on all three areas and in the third 100-m zone only on the TRC area (Tables 6a,6b, and 6c). On the other hand, midden occupancy tended to increase with distance from construction, in 1992, on both the TRC and SFC areas, but the increase was significant only on the SFC area (Table 6d). Midden occupancy differed with distance from FR507 and FR669 on the SFN area, with the lowest occupancy in the second 100-m zone (Table 6e). A slight pattern of increasing midden occupancy with increasing distance from construction on the SFC area was noticed in 1990 (Young 1991), but this pattern did not appear in 1991, despite intensified construction on the SFC area, suggesting that construction activity was not the cause.

Although construction activity may have influenced the quality of some midden sites in 1992 and thus affected their potential to be occupied by a squirrel, other factors may also have influenced midden occupancy near construction. In both 1990 and 1991, middens with large local density values were more likely to be occupied than isolated middens with relatively small local density values (Young 1991, 1992), indicating that squirrels preferred to live near other squirrels. This relationship was not observed in 1992, possibly because of the declining squirrel population, which created unoccupied middens throughout the study areas. On the SFC area, however, where a significant increase in midden occupancy was found with increasing distance from construction, a significant increase in the local density of middens also was observed (Wilcoxon rank sum tests: $X^2=6.97$, df=2, $\underline{P}=0.03$). In both the TRC and the SFC areas, there are few middens in the zone closest to construction, so other squirrels may not be attracted to these areas. Thus midden occupancy around construction may be influenced by the number of nearby middens.

Forest structure variables also may influence midden occupancy. A comparison of A. Smith's (1991) structure variables at middens that were occupied and unoccupied on each area (TRC, SFC, and SFN) in 1991 and in 1992 showed that the canopy coverage, foliage volume, log volume, and snag density at occupied middens tended to be greater than at unoccupied middens. Canopy coverage was significantly greater on the TRC area at occupied middens than at unoccupied middens in both 1991 (occ $\bar{x}=91.24$, SE=1.32; unocc $\bar{x}=77.20$, SE=5.46; $\underline{F}=14.18$, df=1,20, $\underline{P}=0.001$) and 1992 (occ $\bar{x}=91.50$, SE=1.33; unocc $\bar{x}=83.90$, SE=3.78; $\underline{F}=4.15$, df=1,20, $\underline{P}=0.05$; Appendix D-1,2). The forest structure values also tend to be greatest at middens farthest from construction on each area.

No significant differences were found, but the small number of middens measured in each distance zone may have contributed to this lack of statistical significance. The occupancy patterns among distance zones on each of the areas are different each year (1990-1992), therefore it is difficult to assess the influence that the forest structure has on midden occupancy. Forest structure measurements were taken only at midden sites; no random sites were measured. Thus, there is no way to determine if the forest structure found at midden sites is unique, or is available throughout each zone. An assessment of overall habitat quality, using the same structure variables measured at midden sites, is needed to determine if some zones within each area are more limited than others in the availability of suitable midden sites.

The orientation of the slope on which middens are established, may also may affect midden occupancy. Mannan and Smith (1991) showed that more middens were established on north-facing than on south-facing slopes. The zones nearest construction are primarily on south-facing slopes, which may have caused the lower midden establishment and occupancy in these areas.

Spatial Distribution

Crude density is calculated using the total hectares within each monitored area; any addition of middens or squirrels will produce an increase in crude density and vice-versa. Because only three new middens were discovered, the *crude density of middens* remained about the same from November 1991 to November 1992 (Fig. 3, Appendix E). By November 1992, one and two new middens were discovered on the TRC and the SFC areas, respectively, resulting in the slight increase in crude density of middens on those areas. The *crude density of squirrels*, however, decreased on all areas over this same period with a larger relative decrease in the TR habitat than in the SF habitat.

Except where noted, the local density and nearest neighbor distance of middens refers to a comparison of focal middens to other middens, whereas the local density and nearest neighbor distance of squirrels refers to a comparison of squirrels to other squirrels. The *local density of middens* did not change on any area except for a slight increase on the SFC area because of the addition of one midden (Fig. 4, Appendix E-2). Even though two new middens were discovered on the TRC area, mean local density did not change on that area. The *local density of squirrels*, however, decreased on all monitored area, with the greatest decrease occurring on the TRC area. Although crude density is not directly tied to local density, if squirrels disappeared randomly, local density of squirrels would be expected to decrease. Unlike November 1991, in November 1992 there were no differences in the local densities of squirrels among areas (Table 7a,b; Appendix F).

The *nearest neighbor distance of middens* remained constant on the SFN and TRN areas, decreased slightly on the TRC area, and increased slightly on the SFC area because of the addition of three middens from November 1991 to November 1992 (Table 7a,b; Appendix E-2, G). During this period, the *nearest neighbor distance of squirrels* increased on all monitored areas, and there was no difference among any areas in November 1992 (Table 7b). Nearest neighbor distance of squirrels in 1992 were significantly longer than in

1991 on the SFN and TRC areas and almost significantly longer on the TRN ($\underline{P}$=0.056) and SFC ($\underline{P}$=0.057, paired t-test).

There were no differences in local densities or nearest neighbor distances of middens around occupied vs. unoccupied middens; there were also no differences in local density or nearest neighbor distances of squirrels around occupied vs. unoccupied middens in November 1992 (Table 8, Appendix H). In previous years, middens with large numbers of other middens and squirrels nearby were more likely to be occupied than midden sites with only a few middens nearby (Young 1991, 1992) suggesting a habitat or social influence on the distribution and spacing of squirrels. The absence of this pattern in 1992 could be the result of the overall decline in the squirrel population for the first time since 1989.

The index of aggregation values for middens and squirrels during 1991 and 1992 indicated random distributions on all areas except for the squirrels on the SFC area from November 1991 through September 1992, when these squirrels tended toward an aggregated distribution despite the random distribution of middens (Table 9, Appendix E-3). The tendency toward an aggregated distribution may be a result of selection of midden sites in preferred habitat. The squirrels on the SFC area showed an aggregated distribution in November 1991, when the population reached its peak in numbers, and remained aggregated through June 1992. However, by November 1992, the population was distributed randomly, suggesting that the loss of squirrels on the SFC area was random and not concentrated in any one area.

In general, middens and squirrels tended to be distributed randomly. Both the random and aggregated distributions contradict the findings of Gurnell (1984) that suggested a uniform distribution of individuals (n=12) in red squirrel population in Colorado. In 1991, when population sizes were relatively high, NNDs were similar to those observed by Gurnell (1984) and approximately 20 m farther than Vahle (1978). As populations declined, NNDs increased and were much farther than either Gurnell's (1984) or Vahle's (1978) distances. This difference, and the difference in spatial distribution, may be the result of the two populations being in different habitats. Gurnell's population was in a fairly uniform lodgepole pine (Pinus spp.) habitat, while the Mt. Graham population inhabits a more varied and patchier habitat. Gurnell's population also inhabited an area with less variation in slope in exposure, and only a small range of altitudes creating a relatively uniform habitat. Vahle's population inhabited mixed-conifer habitat on the White Mountains of Arizona. The Mt. Graham population inhabits various habitats in areas with slopes of all exposures and a wide range of altitudes.

The index of aggregation values are simply a measure of how middens and squirrels are distributed in relation to each other. As squirrel populations near capacity (ie. midden occupancy $\approx$ 100%) it would be expected that squirrels should be distributed in the same pattern as middens. A difference in the pattern of distribution under such conditions might indicate some effect from construction. At the lower proportion of midden occupancy that currently prevails, a difference in the distribution of squirrels versus middens could result from a number of random or selective habitat or population variables. Consequently, under the present conditions it is very difficult to interpret the spatial distribution of squirrels versus midden in a meaningful manner.

Reproductive Activity and Success

Because males are reproductively active for a longer period than females, estimates of the length of the breeding season are based on dates of first lactation and litter emergence. Scrotal males were seen from 10 March to 15 August. The dates of female reproductive activity observed in 1992 were from early April through the end of July (Table 10, Appendix I), and were similar to 1991.

Of the 82 females identified to be of breeding age in 1992, 24 were observed to have lactated, and 13 were observed to produce litters. There were no significant differences in the proportion of females that lactated or raised litters to emergence on construction and non-construction areas (Table 11). The earliest observed lactating female was on 19 May and the latest on 30 August. There were significant differences in the median dates of first lactation among all monitored areas and within the TR habitat, however, there were no differences within the SF habitat (Table 12). Although there were 23 more females on the monitored areas in 1992 than in 1991 (59 females), the overall proportion of females lactating (29%) in 1992 was lower than in the previous year (61%).

Thirteen litters were observed at the time of emergence from the natal nest; the earliest was 17 June and the latest 30 August, and the average litter size was 2.15 (range 1-3). There were no significant differences in the dates of litter emergence among the monitored areas (Table 13). Although litter size was significantly larger on the construction area compared to the non-construction area within SF habitat, this difference is probably an artifact of the small sample size and low variation in litter sizes. There were no significant differences in litter size when all the monitored areas are compared for 1992 or with the data combined for 1990-1992 (Table 14).

Reproductive success of females was also examined relative to distance from construction activity. Of the 45 females on the two construction areas in 1992, 14 were known to have lactated and five of these produced litters. Middens occupied by females on the TRC and SFC areas were an average of 215.0 m from construction (range 39.2-424.7 m). Lactating females were an average of 166.5 m from construction (range 39.2-250.7 m) and females that produced litters were an average of 252.8 m from construction (range 122.1-338.2 m) (Table 15a). There were no significant differences in the reproductive success of females relative to their distance from construction on either the TRC or SFC areas, or when the data for the two areas were combined (Tables 15a,b; Appendix J).

As in 1990 and 1991, there was no indication that construction in 1992 had any effect on the reproductive activity or success. The date of litter emergence, number of females that reared litters, and litter sizes did not differ between construction and non-construction areas or between habitats in 1991 and 1992. Lactation date was the only measure of reproductive success in which significant differences between construction and non-construction areas were found in 1991 and 1992. These differences, however, do not follow any discernable pattern from year to year. The lack of a pattern suggests that local variations in reproductive activity and success are more likely the result of local variations in food resources and/or population structure than a result of disturbance from construction.

Unrelated to potential construction effects, a difference in the timing of reproductive output has been observed between the TR and SF habitats. Although the 1992 peaks are not as distinct as in 1991, the majority of juveniles in the TR habitat emerged earlier than those in the SF habitat (Fig. 5). However, in 1992, the greatest number of juveniles in the TR habitat emerged from mid-June to August, one to two months later than the June peak seen in 1991. The later emergence dates for juveniles on the TR areas and the overall shorter breeding season in 1992 may be a reflection of a change in the population age structure in the TR habitat. There were 21 more females on the TR areas during the 1992 breeding season and only 2 more on the SF areas than in 1991. Many of these females were thought to be yearlings, born during 1991 (Young 1991). In support of the theory that the TR population was younger, the average litter sizes on the TR habitat were slightly smaller (though not significantly), in 1992 than in 1991. A tendency of younger females to breed later and have smaller litters has been seen in several other western red squirrel populations (Zirul 1970, Rusch and Reeder 1978, Becker 1992).

The later dates of litter emergence on the SF habitat relative to the TR habitat in both 1991 and 1992 may also be partially explained by the relationship between spring temperatures and the energetic costs of reproduction. Becker (1992) found that the onset of reproductive activity for red squirrels was affected by spring temperatures and the associated changes in net energy gains. With warmer spring temperatures, overall metabolic costs are reduced, allowing more energetically efficient foraging that eventually may lead to a net energy gain. Becker suggested that a positive net energy gain, along with other cues such as photoperiod and to a lesser extent, fall food availability, may initiate the reproductive cycle. The SFC and SFN populations are about 375 m higher in elevation than the TRC and TRN populations and generally have colder temperatures and later snow-melt which may explain the apparent pattern of later reproduction on these areas. Squirrels on the SF areas may take longer to accumulate the energy needed for reproduction. The age of females on the SF areas may also be important in determining the timing of reproductive activity. The breeding season was later in the SF habitat than in the TR habitat in 1991, when many of the SF females were yearlings (late breeders) (Young 1991) and, in 1992, when most of the SF females were thought to have been more than two years old (early breeders). However, any effects of age structure on the timing of reproduction appear to be overshadowed by the effects of differences in elevation.

Trapping and Tagging

Trapping and tagging of squirrels resumed for the season in July 1992. Traps were set out and pre-baited on 1 July; trapping began on 14 July and continued until 27 October. As in previous years, trapping success relative to trapping effort was very low. A total of 987 trap-days (1 trap set for 1 day = 1 trap-day) resulted in the capture and tagging of 10 squirrels (Table 16) for an average of 98.7 trap-days per capture. No squirrels were injured or appeared to suffer any adverse effects from handling. All but one of the squirrels tagged in 1992 were still on the monitored areas during the November census. Of the 21 squirrels tagged during the 1991 and 1992 field seasons, 16 were still on the monitored areas as of November 1992: eight on the TRC area and four apiece on the SFC and SFN areas (Appendix K).

The location of any marked squirrel seen outside its own midden was recorded along with other census information. This field season we recorded 13 sightings of 9 marked squirrels away from their home territory (Appendix L-1.) Squirrels were seen a maximum of 422 meters from their home midden site.

In five instances, we observed squirrels using a second nearby midden in addition to their own. In all cases, the original midden appeared to be the primary territory, with most of the caching and feeding sign. The secondary middens showed less sign of use but the squirrels were all seen caching, nest building, or displaying other territorial behaviors at the midden site (Appendix L-2).

We also documented a shift in midden ownership among three marked squirrels when one of them disappeared. Between late June and early July, the marked male at midden 169 (ear tag colors: White/none) disappeared or moved (last seen on 16 June). In early July, the marked female from midden 185 (ear tag colors: Orange/none) was seen several times in midden 169, once chasing an unmarked male from the midden twice within an hour. By the end of July, "Orange/none" was seen exclusively at midden 169. Also by the end of July, the marked male from midden 168 (Green/none) was seen more frequently in the area of midden 185. The two middens are only 14 meters apart, but "Green/none" seemed to have shifted his activity to midden 185 and was seen cleaning out a nest cavity at the midden.

GENERAL DISCUSSION

There is no definitive evidence that the construction activity on MGIO had any detrimental effect on the monitored red squirrel population in 1992. None of the population characteristics measured on the monitored populations differed between construction and non-construction areas. However, we detected subtle differences in population biology between TR and SF habitats, such as the timing of reproduction. As in past years, the small number of squirrels present on the monitored areas makes it difficult to statistically compare population characteristics.

While the population of squirrels declined from November 1991 to November 1992, for the first time since the first time since the Monitoring Program was initiated, the decline was proportionally the same on all of the monitored areas. The decrease in numbers of squirrels in 1992 probably resulted from the poor cone crops in 1991 and 1992. Other studies have used supplemental feeding and correlations with cone crop production to suggest population sizes are primarily controlled by food resources (M. Smith 1968, Sullivan and Sullivan 1982, Gurnell 1983, Gurnell 1984, Buchanan et. al. 1990, Sullivan 1990, Klenner 1991, Klenner and Krebs 1991). Mt. Graham red squirrels are undoubtedly influenced by food supply as well, and local variations in cone production have the potential to produce local changes in squirrel populations. In 1990, several species of conifers on Mt. Graham produced large cone crops, and the squirrel population increased rapidly during the following year (Young 1991). Although, cone crops were lower in 1991, the squirrel population continued to increase, but at a slower rate. In 1992, there apparently was a good crop of white-fir cones (Abies concolor), and some local populations of red squirrels, such as those near Turkey Flats, increased (C. Russworm, AGFD, pers. comm.) while squirrels in areas with no white-fir declined. Lacking a quantitative method to assess cone crops, we cannot make comparisons of the food supply among different monitored areas, and therefore cannot make any specific conclusions concerning changes in local squirrel populations relative to local food supplies. In addition to cone crop failure, other factors may have influenced the Mt. Graham red squirrel population size. Variation in weather patterns have been suggested to affect cone caches, reproduction, and squirrel survival resulting in the population decline on Mt. Graham and in other red squirrel populations (Angell 1992, Becker 1992).

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Table 1. Number and discovery status of red squirrel middens on each of the monitored areas.

Year	Area	Old	Newly Found	Newly Established	Total
1991	TRC	25	0	19	44
	TRN	17	0	6	23
	SFC	31	0	6	37
	SFN	63	1	8	72
	Total	136	1	39	176
1992	TRC	44	0	2	46
	TRN	23	0	0	23
	SFC	37	0	1	38
	SFN	72	0	0	72
	Total	176	0	3	179

Table 2. Proportion of the total area, total number of middens, and total number of squirrels found on each of the monitored areas for June and November, 1991-1992.

	Area		Jun 1991				Nov 1991				Jun 1992				Nov 1992			
			Middens		Squirrels[2]		Middens		Squirrels		Middens		Squirrels		Middens		Squirrels	
	ha	%[1]	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
TRC	91	28	26	18	15	19	44	25	38	31	44	25	31	31	46	26	20	28
TRN	25	8	18	12	10	13	23	13	19	15	23	13	15	15	23	13	9	12
SFC	89	27	34	23	19	23	37	21	24	19	37	21	19	19	38	21	15	21
SFN	122	37	68	47	36	45	72	41	43	35	72	41	34	35	72	40	28	39
Total	327		146		80		176		124		176		99		179		72	

[1]All percentages are rounded to the nearest unit.

[2]Juveniles living with their mothers are not included in the number of squirrels.

Table 3a. Number (percentage) of middens occupied within construction and non-construction areas in 1991 and 1992.

	1991		1992	
Area	June	November	June	November
TRC	15 (58)	38 (86)	31 (70)	20 (43)
TRN	10 (56)	19 (83)	15 (65)	9 (39)
X^2	0.020[1]	0.165	0.191	0.119
P	0.902	0.737	0.674	0.736
SFC	19 (56)	24 (69)	19 (51)	15 (40)
SFN	36 (53)	43 (60)	34 (39)	28 (39)
X^2	0.079	0.275	0.167	0.004
P	0.802	0.632	0.678	0.951

Table 3b. Number (percentage) of middens occupied within TR and SF habitats in 1991 and 1992.

	1991		1992	
Habitat	June	November	June	November
TR	25 (57)	57 (85)	46 (69)	29 (42)
SF	55 (54)	67 (61)	53 (49)	43 (39)
X^2	0.104[1]	11.861	6.883	0.152
P	0.755	**0.001**[2]	**0.010**[2]	0.705

[1]Likelihood-ratio chi-square tests were used to test for a difference between numbers of occupied and unoccupied middens in each habitat.
[2]Bold type indicates significant P values.

Table 4a. Over-winter survival, 1991-1992.

Area/Habitat	Number of squirrels: November 1991	Number of squirrels: May 1992	% survival	
TRC	38	26	68	$X^2=1.340$[1]
TRN	19	10	53	df=1 $\underline{P}=0.305$
SFC	24	17	71	$X^2=0.565$
SFN	43	34	79	df=1 $\underline{P}=0.453$
TR Habitat	57	36	63	$X^2=1.685$
SF Habitat	67	51	76	df=1 $\underline{P}=0.212$

[1]Results of likelihood-ratio chi-square tests for differences in numbers of squirrels surviving within and between habitats.

Table 4b. Overwinter survival of marked squirrels, 1991-1992.

Habitat/Area	Number of marked squirrels: November 1991	Number of marked squirrels: May 1992	% survival	
SFC	7	5[1]	71	$X^2=0.135$[2]
SFN	4	4	100	df=1 $\underline{P}=0.774$

[1]Two squirrels disappeared from the SFC area by the first winter census (January 1992).
[2]Results of likelihood-ratio chi-square tests for differences in numbers of marked squirrels surviving in the SF habitat.

Table 5. Number (percentage) of middens where the resident squirrel was replaced by another squirrel (turnover) during 1992.

Area/Habitat	No turnover	Turnover	
TRC	22	16 (42)	$X^2=0.027$[1] df=1
TRN	10	8 (44)	$\underline{P}=0.900$
SFC	16	9 (36)	$X^2=0.052$ df=1
SFN	32	16 (33)	$\underline{P}=0.837$
TR Habitat	32	24 (43)	$X^2=0.995$ df=1
SF Habitat	48	25 (34)	$\underline{P}=0.319$

[1]Results of likelihood ratio chi-square tests for differences in overwinter survival of squirrels within and between habitats.

Table 6a. Year-to-year differences in midden occupancy within 100 m distance zones from construction on the TRC area.

Construction 0 - 100 meters from Middens			
TRC	Occupied	Unoccupied	Total
Nov. 1991	4	2	6
Nov. 1992	1	5	6
X^2=3.256[1] df=1 P=0.128			
Construction 101 - 200 meters from Middens			
TRC	Occupied	Unoccupied	Total
Nov. 1991	13	1	14
Nov. 1992	4	10	14
X^2=13.564 df=1 **P<0.001**[2]			
Construction 201 - 300 meters from Middens			
TRC	Occupied	Unoccupied	Total
Nov. 1991	21	3	24
Nov. 1992	15	11	26
X^2=5.785 df=1 **P=0.031**[2]			

[1]Likelihood-ratio chi-square tests were used to test for differences in midden occupancy from year-to-year in each zone.
[2]Bold type indicates significant P values.

Table 6b. Year-to-year differences in midden occupancy within 100 m zones from construction on the SFC area.

SFC	Occupied	Unoccupied	Total
Construction 0 - 100 meters from Middens			
SFC	Occupied	Unoccupied	Total
Nov. 1991	3	4	7
Nov. 1992	0	7	7
X^2=4.988[1] df=1 P=0.076			
Construction 101 - 200 meters from Middens			
SFC	Occupied	Unoccupied	Total
Nov. 1991	9	2	11
Nov. 1992	4	7	11
X^2=4.915 df=1 **P=0.044**[2]			
Construction 201 - 300 meters from Middens			
SFC	Occupied	Unoccupied	Total
Nov. 1991	12	7	19
Nov. 1992	11	9	20
X^2=0.268 df=1 P=0.599			

[1]Likelihood-ratio chi-square tests were used to test for differences in midden occupancy from year-to-year in each zone.
[2]Bold type indicates significant P values.

Table 6c. Year-to-year differences in midden occupancy within 100 m zones from Forest Roads 507 and 669 on the SFN area.

FRs 507 or 669 0 - 100 meters from Middens			
SFN	Occupied	Unoccupied	Total
Nov. 1991	18	9	27
Nov. 1992	12	15	27
X^2=2.724[1] df=1 P=0.115			
FRs 507 or 669 101 - 200 meters from Middens			
SFN	Occupied	Unoccupied	Total
Nov. 1991	15	14	29
Nov. 1992	6	23	29
X^2=6.196 df=1 **P=0.011**[2]			
FRs 507 or 669 201 - 300 meters from Middens			
SFN	Occupied	Unoccupied	Total
Nov. 1991	10	2	12
Nov. 1992	9	3	12
X^2=0.254 df=1 P=0.663			

[1]Likelihood-ratio chi-square tests were used to test for differences in midden occupancy.
[2]Bold type indicates significant P values.

Table 6d. Midden occupancy in 100 m zones from construction on the TRC and SFC areas in November 1992.

	Distance (m)	Occupied	Unoccupied	Total
TRC	0-100	1 16%	5	6
	101-200	4 29%	10	14
	201-300	15 58%	11	26
	X^2=5.401[1] df=2 P=0.096			
SFC	0-100	0 0%	7	7
	101-200	4 36%	7	11
	201-300	11 55%	9	20
	X^2=9.036 df=2 **P=0.015**[2]			

[1]Results of likelihood-ratio chi-square tests for differences in midden occupancy in each zone in 1992.
[2]Bold type indicates significant P values.

Table 6e. Midden occupancy in 100 m distance zones from Forest Roads 507 and 669 on the SFN area in November 1992.

	Distance (m)	Occupied	Unoccupied	Total
SFN	0-100	12 44%	15	27
	101-200	5 19%	22	27
	201-300	9 75%	3	12
	X^2=12.036[1] df=2 **P=0.002**[2]			

[1]Results of likelihood-ratio chi-square tests for differences in midden occupancy in each zone in 1992.
[2]Bold type indicates significant P values.

Table 7a. Mean Local Densities and Nearest Neighbor Distances (NND) of middens and squirrels on the monitored areas in November 1991[1].

	Middens			Squirrels		
Area	n	Local Density (# within 100 m) $\bar{x} \pm$ SE	NND (m) $\bar{x} \pm$ SE	n	Local Density (# within 100 m) $\bar{x} \pm$ SE	NND (m) $\bar{x} \pm$ SE
TRC	44	3.9±0.37 a[1]	59.7±5.43 ab	38	3.5±0.33 a	60.2±7.75 a
TRN	23	3.0±0.36 b	53.0±3.99 a	19	2.5±0.31 b	63.1±4.84 a
SFC	37	1.8±0.25 c	77.9±7.25 c	24	1.5±0.18 c	72.7±8.58 ab
SFN	72	1.8±0.13 c	71.0±3.07 bc	43	1.1±0.14 c	88.1±4.90 b
Total	176	2.5±0.13	66.0±2.39	124	2.1±0.14	70.5±3.36

[1]Means with the same letter in each column are not statistically different.

Table 7b. Mean Local Densities and Nearest Neighbor Distances (NND) of middens and squirrels on the monitored areas in November 1992[1].

	Middens			Squirrels		
Area	n	Local Density (# within 100 m) $\bar{x} \pm$ SE	NND (m) $\bar{x} \pm$ SE	n	Local Density (# within 100 m) $\bar{x} \pm$ SE	NND (m) $\bar{x} \pm$ SE
TRC	46	3.8±0.34 a[1]	57.7±5.10 ab	20	1.3±0.18 a	81.4±6.13 a
TRN	23	3.0±0.36 b	53.2±3.99 a	9	1.3±0.47 a	97.9±16.55 a
SFC	38	1.9±0.27 c	78.3±6.96 c	15	1.2±0.28 a	126.5±25.70 a
SFN	72	1.8±0.13 c	71.0±3.07 bc	28	0.6±0.10 a	112.4±12.10 a
Total	179	2.5±0.14	66.6±2.47	72	1.0±0.11	104.9±7.7

[1]Means with the same letter in each column are not statistically different.

Table 8. Mean local densities and nearest neighbor distances (NND) of occupied and unoccupied middens, November 1992.

Focal Midden Status	n	Middens (occupied or not) Local Density $\bar{x} \pm 2xSE$	Middens (occupied or not) NND $\bar{x} \pm 2xSE$	Squirrels (occupied middens) Local Density $\bar{x} \pm 2xSE$	Squirrels (occupied middens) NND $\bar{x} \pm 2xSE$
Occupied	72	2.7±0.45	62.7±6.02	1.0±0.21	104.4±15.47
Unoccupied	107	2.5±0.40	69.2±7.20	1.1±0.21	101.8±13.92
ANOVA		$F=0.51$ $df=1, 177$ $P=0.477$	$F=1.65$ $df=1, 177$ $P=0.201$	$F=0.79$ $df=1, 177$ $P=0.375$	$F=0.06$ $df=1, 177$ $P=0.806$

Table 9. Index of aggregation of middens and squirrels on the monitored areas.

		Middens		Squirrels	
Date	Area	Index[1] Aggr.	Corrected[2] Z	Index[1] Aggr.	Corrected[2] Z
June 1991	TRC	1.067	-0.228	0.943	-1.097
	TRN	1.024	-0.622	0.703	-2.138
	SFC	1.038	-0.398	0.832	-1.884
	SFN	1.046	-0.121	1.026	-0.496
Nov 1991	TRC	0.920	-1.630	0.857	-2.193
	TRN	0.931	-1.302	1.006	-0.743
	SFC	1.016	-0.598	0.763	**-2.590**[3]
	SFN	1.031	-0.308	0.989	-0.870
June 1992	TRC	0.920	-1.630	0.942	-1.280
	TRN	0.931	-1.302	1.005	-0.753
	SFC	1.036	-0.396	0.650	**-3.119**[3]
	SFN	1.031	-0.308	1.005	-0.710
Nov 1992	TRC	0.930	-1.544	0.865	-1.695
	TRN	0.931	-1.302	1.113	-0.297
	SFC	1.035	-0.405	1.030	-0.577
	SFN	1.031	-0.308	1.018	-0.598

[1]The index ranges from 0 (aggregated) to 2.15 (uniform), 1 = random distribution.
[2]Corrected for lack of boundary area, (Donnelly, 1978). Z must be greater than 2.240 or less than -2.240 to be significant.
[3]Value indicates significant deviation from random distribution ($P < 0.05$).

Table 10. Mt. Graham Red Squirrel breeding season (range and median) based on dates of first lactation and litter emergence in 1992.

Area	By Dates of First Lactation	By Dates of Litter Emergence
TRC	14 May - 26 June 5 June	3 May - 23 May 13 May
TRN	15 April - 21 May 3 May	6 April - 25 May 1 May
SFC	10 June[1] - 8 July 24 June	31 May - 17 June 9 June
SFN	5 May - 27 July 16 June	19 April - 19 June 14 May

Table 11. Number of females that lactated and that were successful at rearing litters to emergence in 1992.

Area	Total Females		Lactating Females	Litters Emerged
TRC	28	38	9	3
TRN	10		4	3
SFC	17	44	3	2
SFN	27		8	5
Total	82		24	13

Likelihood X^2 (lactating females):
within TR habitat: $X^2=0.199$, df=1, $P=0.690$
within SF habitat: $X^2=0.826$, df=1, $P=0.350$
among all areas: $X^2=1.860$, df=3, $P=0.606$

Likelihood X^2 (litters emerged):
within TR habitat: $X^2=1.989$, df=1, $P=0.235$
within SF habitat: $X^2=0.016$, df=1, $P=0.958$
among all areas: $X^2=2.744$, df=3, $P=0.537$

Table 12. Dates of first lactation by female red squirrels on the monitored areas in 1992.

Area	n	Earliest[1]	Latest[2]	Median[3]
TRC	9	17 Jun	30 Jul	9 Jul
TRN	4	19 May	24 Jun	6 Jun
SFC	3	14 Jul	11 Aug	28 Jul
SFN	8	08 Jun	30 Aug	20 Jul

Kruskal-Wallis (X^2 approx.):
within TR Habitat: X^2=6.112, df=1, **$\underline{P}$=0.013**[4]
within SF Habitat: X^2=1.514, df=1, $\underline{P}$=0.219
among all areas: X^2=9.000, df=3, **$\underline{P}$=0.029**[4]

[1]First date a female was observed lactating
[2]Latest date a female was observed lactating
[3]Median date a female was first observed to be lactating
[4]Bold type indicates significant $\underline{P}$ values.

Table 13. Litter emergence dates from natal nests on the monitored areas, 1992.

Area	n	Earliest	Latest	Median
TRC	3	14 Jul	03 Aug	24 Jul
TRN	3	17 Jun	05 Aug	12 Jul
SFC	2	11 Aug	28 Aug	20 Aug
SFN	5	30 Jun	30 Aug	25 Jul

Kruskal-Wallis (X^2 approx.):
within TR habitat: X^2=0.429, df=1, $\underline{P}$=0.513
within SF habitat: X^2=0.000, df=1, $\underline{P}$=1.000
among all areas: X^2=3.976, df=3, $\underline{P}$=0.264

Table 14. Litter size of squirrels on the monitored areas in 1992 and all years combined (1990-1992).

	1992			All Years		
	n	$\bar{x}$	range	n	$\bar{x}$	range
TRC	3	2.33	2-3	9	2.56	2-4
TRN	3	1.67	1-3	8	2.13	1-3
SFC	2	3.00	3	7	2.14	1-3
SFN	5	2.00	2	10	1.80	1-3

Kruskal-Wallis (X^2 approx.):
within TR habitat, 1992: X^2=0.833, df=1, P=0.361
within TR habitat, all years: X^2=0.590, df=1, P=0.443
within SF habitat, 1992: X^2=6.000, df=1, **P=0.014**[1]
within SF habitat, all years: X^2=0.800, df=1, P=0.371
among all areas, 1992: X^2=4.983, df=3, P=0.173
among all areas, all years: X^2=3.706, df=3, P=0.295

[1]Bold type indicates significant P value.

Table 15a. Reproductive success of females on each construction area in 1992, relative to distance from construction.

Area	Breeding Status	n	Distance from construction $\bar{x}$	minimum	maximum
TRC	Not Breeding	17	183.7	80.0	309.3
	Lactating no litter	8	168.0	39.2	250.7
	Lactating w/ litter	3	308.1	249.8	338.2
SFC	Not Breeding	14	271.1	153.9	424.7
	Lactating no litter	1	154.5	154.5	154.5
	Lactating w/ litter	2	169.8	122.1	217.6

Kruskal-Wallis test (X^2 approx.):
within TRC: $X^2=5.198$, df=2, $\underline{P}=0.074$
within SFC: $X^2=3.224$, df=2, $\underline{P}=0.200$

Table 15b. Reproductive success of females on TRC and SFC areas combined in 1992, relative to distance from construction.

Breeding Status	n	Distance from construction $\bar{x}$	minimum	maximum
Not Breeding	31	223.2	80.0	424.7
Lactating no litter	9	166.5	39.2	250.7
Lactating w/ litter	5	252.8	122.1	338.2

Kruskal-Wallis test (X^2 approx.): $X^2=3.054$, df=2, $\underline{P}=0.217$

Table 16. Capture dates and data for red squirrels trapped in 1992. Ear tag colors and numbers are always given as "Left Ear/Right Ear".

KEY

R	Red	NS	Non-scrotal
B	Blue	S	Scrotal
O	Orange	NL	Non-lactating
G	Green	L	Lactating
W	White	A	Adult
Y	Yellow	SA	Sub-adult
-	missing	J	Juvenile

DATE	TIME	LOC	SEX	AGE	REPRO	EAR TAGS L/R	PREP TIME (min.)	HANDLE TIME (min.)	RELEASE CONDITION
19 Jul	0923	181	♂	A	NS	B/G 112/112	1	2	OK
10 Sep[1]	1320	135	♀	A	NL	R/R 114/114	1	2	OK
12 Sep[2]	0810	116	♀	A	NL	B/W 115/115	1	2	OK
12 Sep	0912	106	♀	A	NL	Y/O 116/116	1.5	2	OK
23 Sep	1412	108	♀	A	NL	G/G 117/117	2	1.5	OK
24 Sep	1220	107	♂	A	NS	W/Y 118/118	2	2	OK
08 Oct	1000	144	♀	SA	NL	O/B 119/119	3	2	OK
10 Oct	1147	103	♀	A	NL	Y/R 122/122	2	2	OK
22 Oct[3]	1520	142	♀	SA	NL	G/O 126/126	1.5	1.5	OK
27 Oct[4]	1110	109	♀	SA	NL	W/G 127/127	1.5	1.5	OK

[1]Squirrel was captured and tagged at midden 143, but was later found to be a resident of midden 135.

Table 16 (cont.)

[2]Squirrel was captured and tagged at midden 104, but was later found to be a resident of midden 116.

[3]Squirrel was captured and tagged at midden 120 then later observed at midden 142. The main midden seems to be 142, but the squirrel appears to be using both middens.

[4]Squirrel was first captured at midden 109 but escaped through the bars on the Halvorson cone. Squirrel was recaptured the next day in trap at midden 140 (approx. 30m away from the 109 trap). Midden 109 seems to be the main area, but the squirrel appears to be using both middens.

Figure 1. Maps of the areas on the Graham Mtns. monitored by the University of Arizona Red Squirrel Monitoring Program.

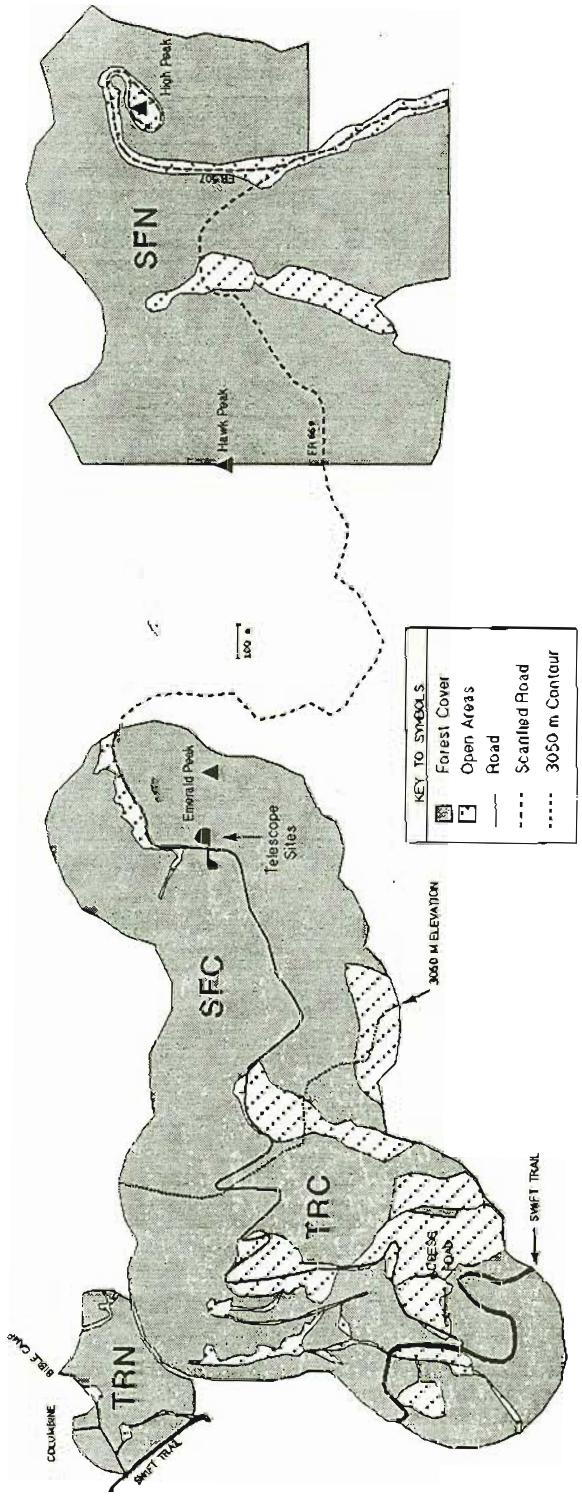


Figure 2. Red squirrel population sizes on the monitored areas, 1991-1992.

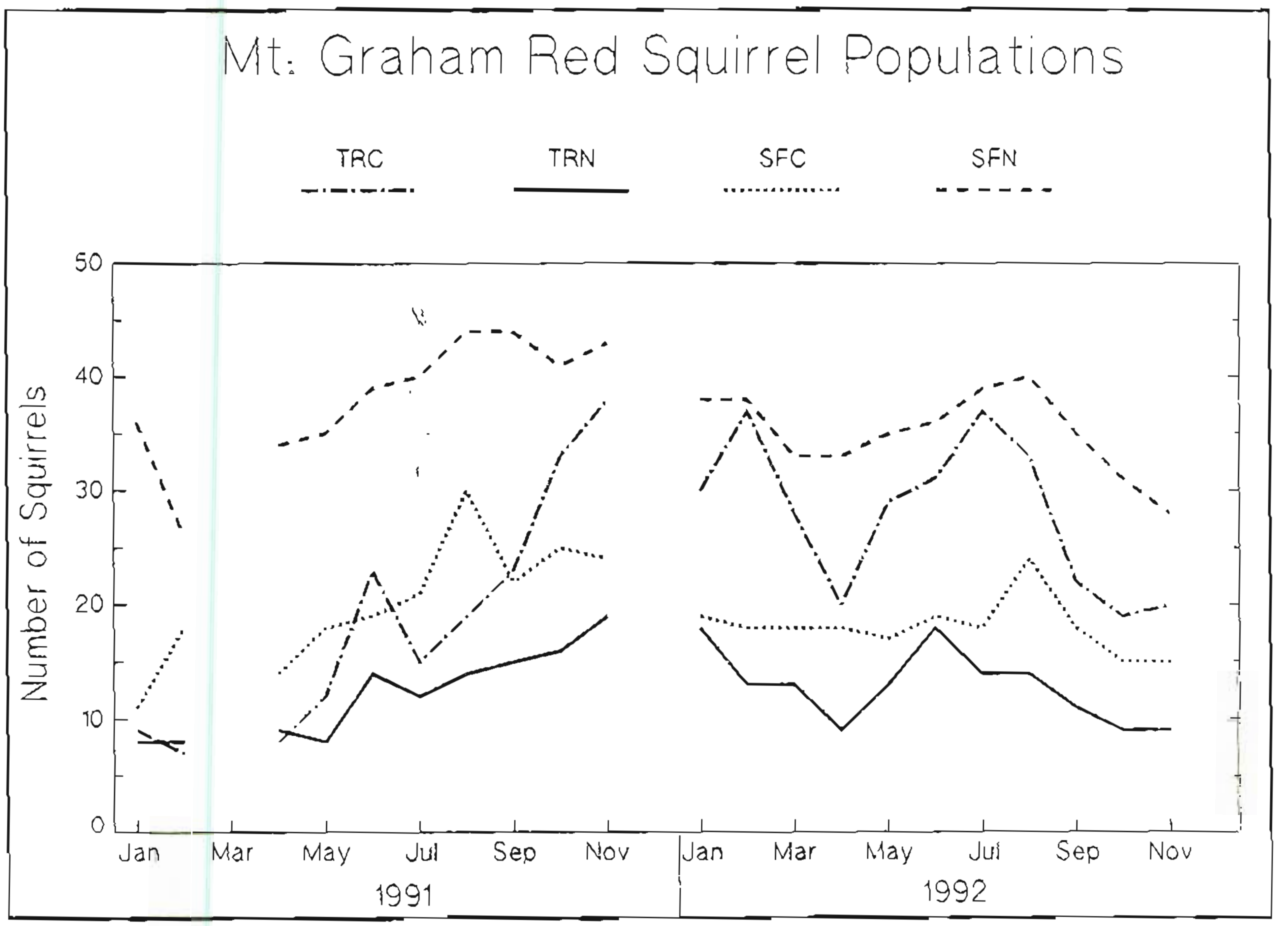


Figure 3. Crude density of middens and of squirrels for each of the monitored areas, 1991-1992.

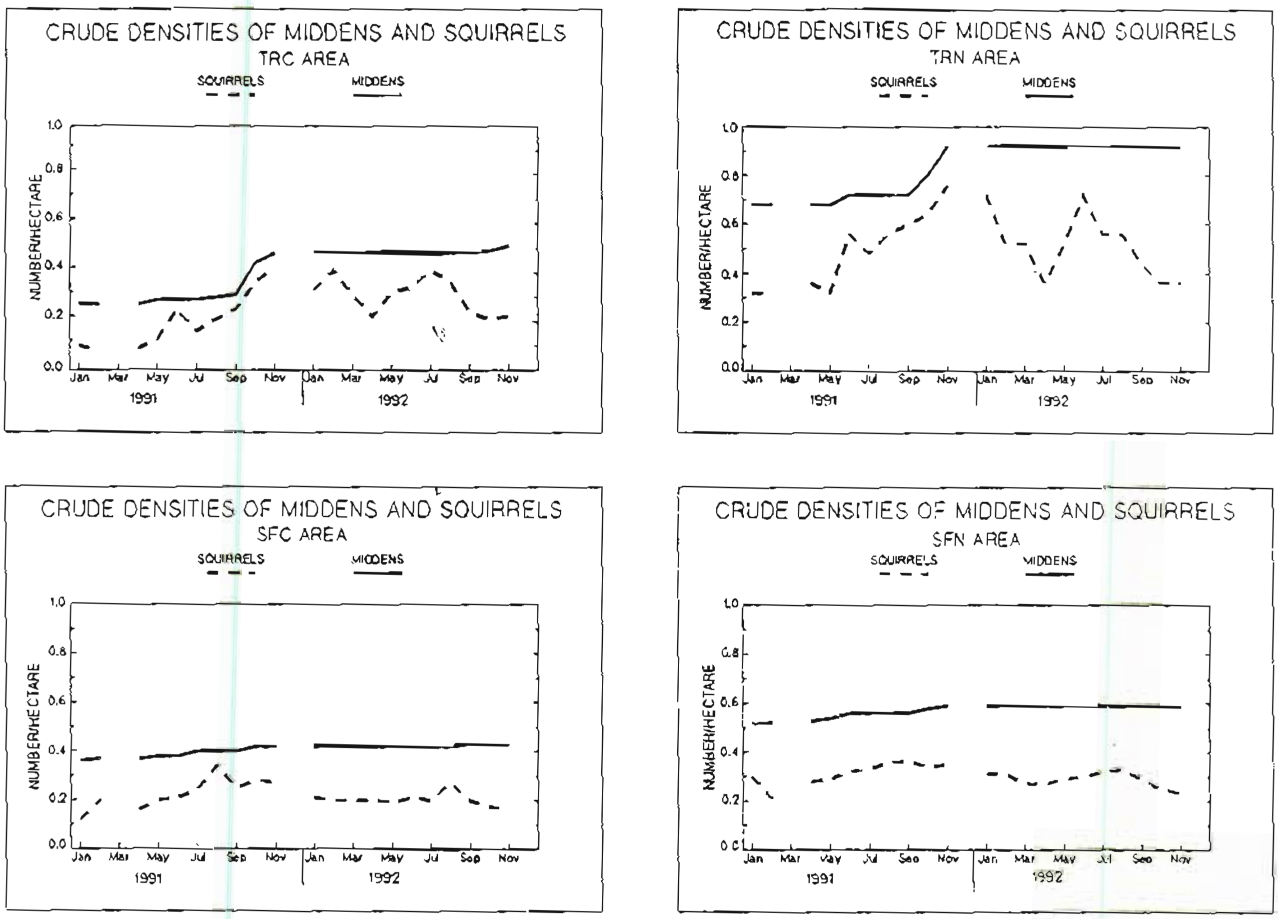


Figure 4. Local density of middens and of squirrels for each of the monitored areas, 1991-1992.

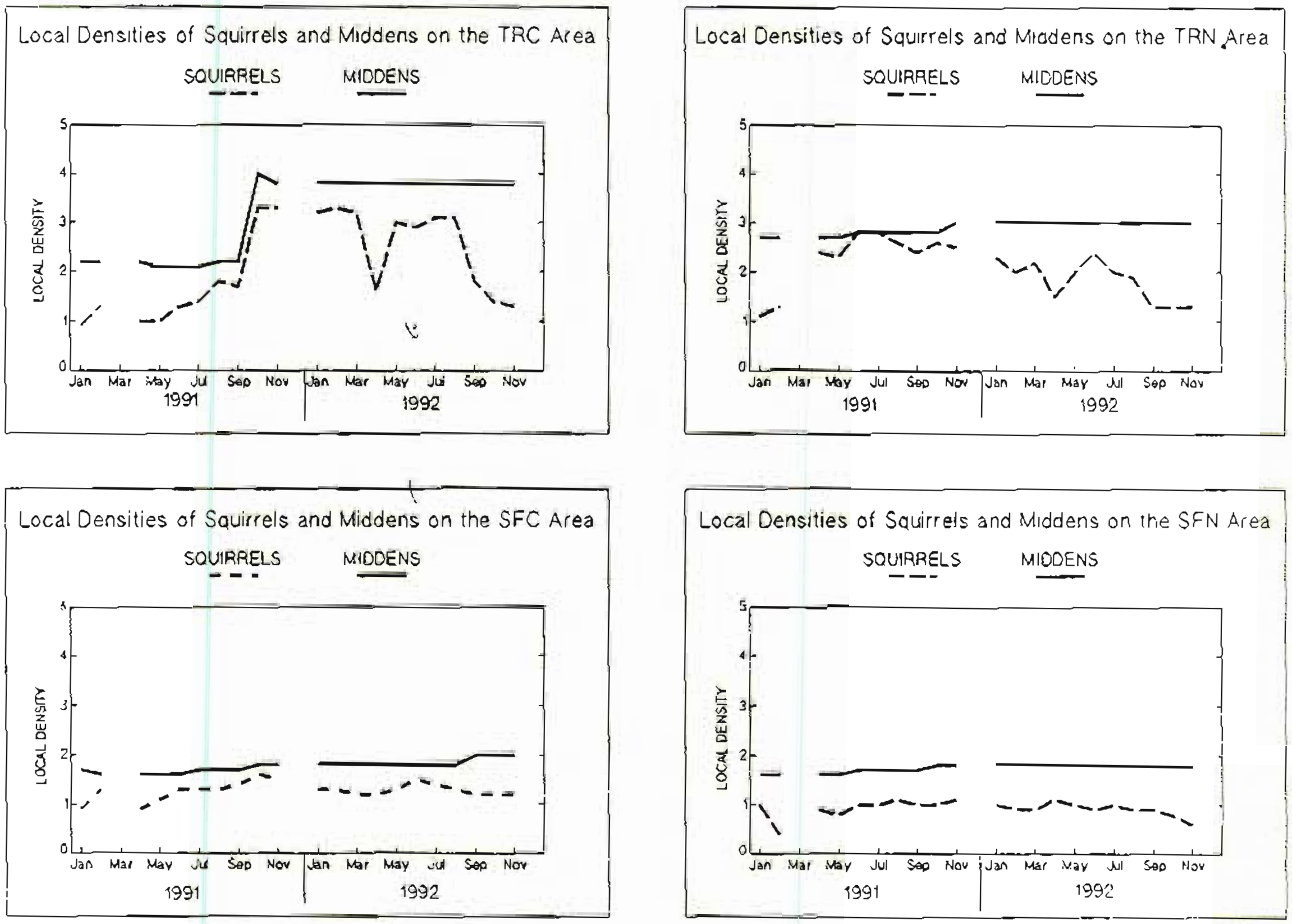
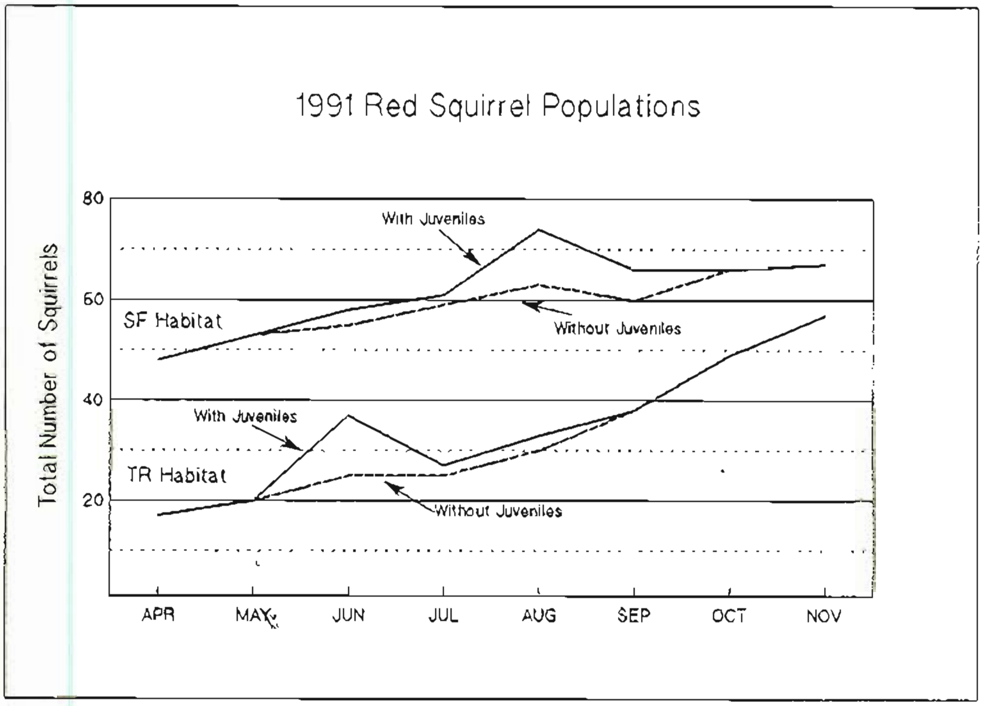
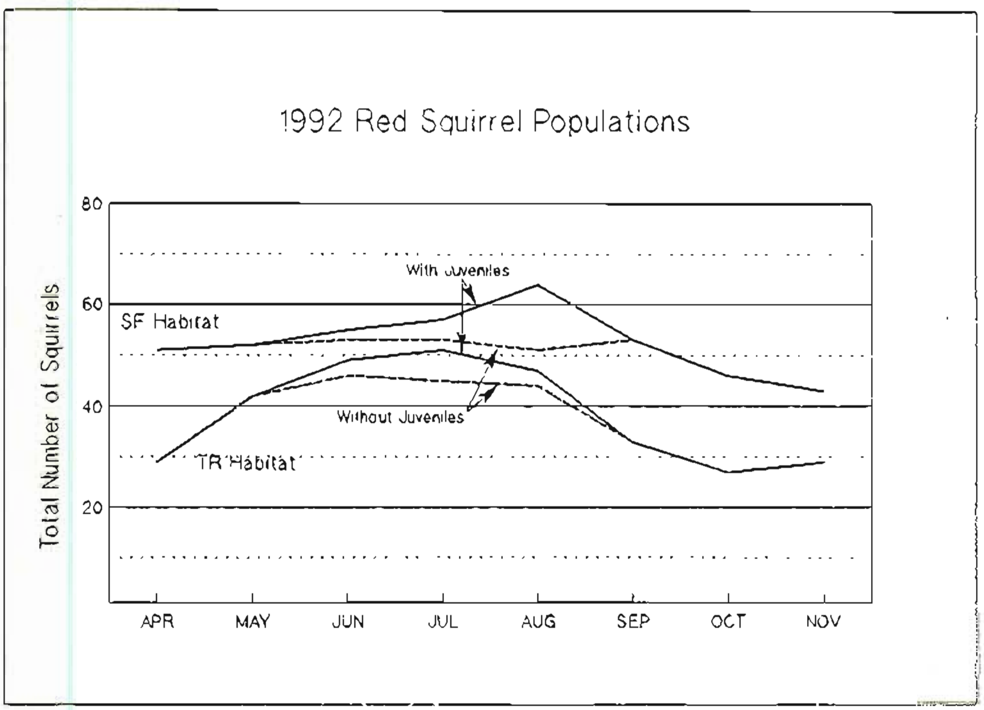


Figure 5. Red squirrel populations with and without juveniles at their mothers' midden, 1991-1992.





Appendix A. Midden Occupancy Maps

Appendix B. Red squirrel populations on the monitored areas from November 1991 - December 1992. Numbers in table cells indicate the number of squirrels living independently. Cells with "##+##" indicate the number of squirrels living independently plus the numbers of juveniles living with their mothers.

DATE	Transition Habitat		Spruce/Fir Habitat		Total
	TRC	TRN	SFC	SFN	
Nov 1991	38	19	24	43	124
Dec 1991	-[1]	-	-	-	-
Jan 1992	30	18	19	38	105
Feb 1992	37	13	18	38	106
Mar 1992	28	13	18	33	92
Apr 1992	20	9	18	33	80[2]
May 1992	29	13	17	35	94
Jun 1992	31	15 + 3	19	34 + 2	99 + 5
Jul 1992	32 + 5	13 + 1	18	35 + 4	98 + 10
Aug 1992	31 + 2	13 + 1	18 + 6	33 + 7	95 + 16
Sep 1992	22	11	18	35	86
Oct 1992	19	9	15	31	74
Nov 1992	20	9	15	28	72
Dec 1992	-	-	-	-	-

1 Data missing; census not made because of poor weather and snow conditions.

2 The May population numbers are thought to be a more accurate representation of spring midden occupancy than the April numbers. Therefore, the May numbers are used in calculating over-winter survival.

Appendix C. Occupancy records of middens on the monitored areas during 1992

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 squirrel
♂	Occupied, Adult male squirrel
J	Occupied, juvenile squirrel sex unknown
A	Abert's Squirrel using area, no red squirrel present
+	Indicates the month in which the midden was found or established.
XXX	Remains of red squirrel found
*	Squirrel is tagged
-	Missing data
♀R	Adult female, reproductive
♀L	Adult female, lactating
♀+'#'	Adult female with "#" juveniles

Transition Habitat - Contruction Area (TRC) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
101^{89}	S	S	♂	♂	♂	♂	♀L	♀L+2	♀	♀	♀	-
102^{89}	N	N	P	N	N	N	♂/♀	♀	N	N	N	-
103^{89}	Y	Y	P	♂	♂	♂	♂	♂	♀	♀*1	♀*	-
104^{89}	S	Y	Y	♀	♀	♀	♀L	♀	N	N	N	-
105^{89}	N	N	N	N	N	N	N	N	N	N	N	-
106^{89}	S	♂	Y	♂	Y	Y	♂	♂	♀*	♀*	♀*	-
107^{89}	Y	Y	♂	♂	♂	♂	♂	♂	♂*	♂*	♂*	-
108^{89}	Y	Y	Y	N	S	♀	♀	♀	♀*	♀*	♀*	-
109^{89}	S	Y	♀	♀	♀	♀	♀L	♀L	♀	♀*	♀*	-
110^{89-}	S	S	Y	N	S	♂	S	♂	♂	♂	S	-
111^{89}	N	N	N	N	N	N	N	N	N	N	N	-
112^{89-}	Y	Y	Y	♂	♂	♂	♂	♂	♂²	♂	Y	-
113^{89}	♀	S	Y	♀	♀	♀	♀L+3	♀	♀	S	S	-
114^{89}	N	P	N	N	N	N	N	N	N	N	N	-
115^{89}	Y	♂	Y	♂	♂	♂	♀L	S	♀	♀	S	-
116^{89-}	Y	Y	Y	♂	♂	♂	♂	♂	♀*	♀*	S	-
117^{89}	N	N	N	N	N	N	N	N	N	N	N	-
118^{89}	Y	Y	Y	♀	♀	♀	♂	♂	Y	♀	S	-
119^{88}	Y	S	Y	♀	♀	♀	♀	♀	♀	N	P	-
120^{89}	S	Y	Y	N	N	N	N	♀	P	N	N	-
121^{89-}	Y	S	Y	A	♀	♀	♀	♀	N	N	P	-
122^{89}	N	N	N	N	N	N	N	N	N	N	N	-
130^{90}	♀	Y	N	♀	♀	♀	P	N	N	N	N	-
131^{90-}	P	S	Y	♂	♂	♂	S	♂	♂	♂	Y	-
132^{90-}	N	Y	N	N	N	Y	♂	N	N	N	N	-
134^{91*}	N	-	N	N	N	♀L	♀L	♀L	N	N	N	-
135^{91-}	N	Y	S	♂	♀	♀	♀L	♀	♀*	♀*	S	-
136^{91*}	S	S	Y	N	Y	♂	Y	N	N	P	N	-
137^{91*}	S	S	Y	N	Y	♂	♀L	♀	P	N	N	-
138^{91-}	♀	♀	P	N	Y	♀	♀L	♀L	N	N	P	-
139^{91-}	S	♂	Y	N	Y	♂	♂	♂	♂	N	N	-
140^{91-}	♂	S	S	N	♂	♂	♂	♂	S	N	N	-
141^{91-}	Y	S	Y	N	N	N	♂	N	P	N	P	-
142^{91-}	S	Y	♀	♀	♀	♀	♀	♀	P	♀*	♀*	-

Transition Habitat - Contruction Area (TRC) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
143^{91*}	♀	♀	Y	♀	♀	♀	♀	♀	N	N	N	-
144^{91*}	S	Y	Y	N	S	♂	♂	♂	♂	♀[1]	N	-
145^{91*}	S	Y	♂	N	N	P	P	N	N	Y	Y	-
146^{91*}	Y	S	N	N	N	N	N	N	N	N	N	-
147^{91*}	♂	S	Y	♂	♂	S	♂	♂	♂	♂	S	-
148^{91*}	-	Y	-	♂	♀	♀L	♀L	♀L	S	N	P	-
149^{91*}	N	Y	-	N	N	N	N	N	N	N	N	-
300^{91*}	Y	S	Y	♀	♀	Y	♀L+2	♀	♀	Y	S	-
301^{91*}	N	S	N	N	N	N	N	N	N	N	N	-
302^{91*}	N	S	-	N	N	N	P	♀	♀	P	S[2]	-
303^{92*}	-	-	-	-	-	-	-	-	-	N	N	-
304^{92*}	-	-	-	-	-	-	-	-	-	-	S	-
# Mid	44	44	44	44	44	44	44	44	44	45	46	-
# Occ	30	37	28	20	29	31	32	31	22	19	20	-
% Occ	68	84	64	46	66	70	73	70	50	42	43	-
# Sq	30	37	28	20	29	31	32+5	31+2	22	18	20	-

1 On 10 October, a mummified red squirrel carcass was found inside an old grass nest that blew out of a tree at this midden.

2 On 11 September, a mummified red squirrel carcass was found inside an old grass nest that blew out of a tree at this midden.

Transition Habitat - Non-Construction Area (TRN) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
201^{89}	Y	Y	Y	N	P	♂	♂	♂	♂	♂	Y	-
202^{89}	S	Y	Y	♀	♀	♀L	♀L+1	♀	♀	♂	S	-
203^{89}	S	Y	Y	♀	♀L	♀L+3	♀	♂	♀	♀	S	-
204^{89}	N	N	P	N	N	P	N	N	N	N	N	-
205^{89}	Y	♂	Y	♂	♂	♂	♂	S	S	N	P	-
206^{89}	S	Y	Y	♂	♂	♂	♂	♂	♂	♂	♂	-
207^{89-}	Y	Y	N	♂	Y	Y	Y	N	N	N	N	-
208^{89-}	S	P	P	♀	♀	Y	♀	♀	♀	S	♀	-
209^{90}	S	♂	Y	♂	♂	♂	♂	♂	♂	♂	S	-
210^{90}	S	S	Y	N	Y	♂	♂	♂	♂	Y	Y	-
211^{90-}	Y	N	Y	♀	♀	♀L	♀L	♀L+1	♂	♀	Y	-
212^{90}	N	N	N	N	N	N	N	N	N	N	N	-
213^{90}	N	N	N	N	N	N	N	N	N	N	N	-
214^{90-}	Y	Y	P	N	N	N	N	N	N	N	N	-
215^{90-}	S	N	Y	N	Y	Y	P	N	N	N	N	-
216^{90-}	N	N	N	N	N	N	N	N	N	N	N	-
217^{90-}	N	N	N	N	N	N	N	N	N	N	N	-
218^{91-}	Y	Y	P	N	N	♂	P	N	N	N	N	-
219^{91-}	Y	Y	P	N	♂	N	♀	♀	N	N	P	-
400^{91-}	Y	S	♀	♀	♀L	P	N	♂	♂	♂	Y	-
401^{91-}	S	♂	Y	N	♂	♂	S	S	N	N	N	-
402^{91-}	S	N	Y	N	N	♀	P	N	N	N	N	-
403^{91-}	S	N	Y	A	P	♀	♀	S	♀	N	N	-
# Mid	23	23	23	23	23	23	23	23	23	23	23	-
# Occ	18	13	13	9	13	15	13	13	11	9	9	-
% Occ	78	57	57	39	57	65	57	57	48	39	39	-
# Sq	18	13	13	9	13	15+3	13+1	13+1	11	9	9	-

Spruce-Fir Habitat - Construction Area (SFC) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
150[87]	A	N	N	N	N	N	N	N	N	N	N	-
151[87]	N	N	-	N	N	N	N	N	♀	♀	Y	-
152[86]	N	N	N	N	N	N	N	N	N	N	N	-
153[87]	Y	Y	Y	♀	♀	♀	♀L	♀L+3	♀L	Y	N	-
154[86]	Y	Y	Y	♂	♂	♂	♂	N	N	N	N	-
156[86]	Y	♀	Y	♀	♀	♀	♀	♀	♀	♀	N	-
157[86]	N	N	N	N	N	N	N	N	N	N	N	-
158[87]	-	N	N	N	N	N	N	N	N	N	N	-
159[87]	-	N	N	N	N	N	N	N	N	N	N	-
160[86]	♂*	Y	Y	♂*	♂*	♂*	♂*	♂*	♂*	♂*	Y	-
161[86]	N	Y	Y	S	♂	♂	Y	♀	S	P	Y	-
162[86]	N	N	N	N	N	N	N	N	N	N	N	-
163[86]	N	N	N	N	N	N	N	N	N	N	N	-
164[86]	P	P	N	N	N	N	P	♀L	Y	P	N	-
165[86]	Y	S	Y	♂*	♂*	♂*	♂*/♀L	♀L+3	♀	♀	Y	-
166[86]	Y	P	Y	♂	Y	♂	S	♂	♂	P	P	-
167[87]	N	N	N	N	N	N	N	N	N	N	N	-
168[86]	Y	♂	♂	♂*	♂*	♂*	N[1]	N	N	N	N	-
169[86]	Y	S	Y	♂*	♂*	♂*	♀*	♀*	♀*	♀*	♀*	-
170[86]	N	N	-	N	N	N	N	N	N	N	N	-
171[87]	S	S	Y	♂	♂	♂	♂	♂	♀	Y	S	-
172[89]	P	♀	Y	N	♂	♂	♂	♂	♂	S	♂	-
173[87]	N	P	N	N	N	N	N	N	N	N	N	-
174[89]	Y	Y	Y	♂	S	♂	♂	♂	♂	S	S	-
175[86]	N	N	N	N	N	N	N	N	N	N	N	-
176[86]	Y	P	Y	♀	S	♂	♂	♂	N	N	N	-
177[87]	S	S	N	N	N	♀	♀	♀	♂	♀	Y	-
178[90*]	Y	Y	Y	♀	N	♀	♀	♀	N	N	N	-
179[90*]	♂	Y	♂	♂	♂	♂	♂	♂	♂	P	♂	-
180[90*]	N	N	N	N	N	N	N	N	N	N	N	-
181[90*]	Y	S	Y	♂	♂	♂	♂*	♂*	♂*	♂*	♂*	-
182[90*]	Y	Y	N	N	N	N	N	N	N	N	N	-
183[90*]	-	N	N	N	N	N	N	N	N	N	N	-
184[91*]	-	N	-	N	N	N	N	N	N	N	N	-
185[91*]	Y	♀	Y	♀*	♀*	♀*	♂*	♂*	♂*	♂*	S	-
186[91*]	Y	Y	Y	S	N	N	N	N	N	♀	Y	-
187[91*]	S	-	P	♀	♀	♀	♀	♀	S	Y	♀	-

Spruce-Fir Habitat - Construction Area (SFC) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
188[92]	-	-	-	-	-	-	-	-	♂	♂	S	-
# Mid	37	37	37	37	37	37	37	37	38	38	38	-
# Occ	19	18	18	18	17	19	18	18	18	15	15	-
% Occ	51	49	49	49	46	51	49	49	47	40	40	-
# Sq	19	18	18	18	17	19	18	18+6	18	15	15	-

1 During the month of July, the marked male at midden 169 (white/no tag) disappeared. By the end of the month, the marked female (orange/no tag) from midden 185 had moved to midden 169 and the marked male (green/no tag) from midden 168 had moved downhill to occupy midden 185.

Spruce-Fir Habitat - Non-Construction Area (SFN) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
220[90]	N	Y	S	N	♂	♂	♂	♂	S	S	Y	-
221[86]	N	N	A	N	N	N	N	N	N	N	N	-
222[86]	♂	♂	Y	♂	♂	♂	♂	♂	♂	♂	Y	-
223[86]	♀	Y	♀	♀	♀	♀L	♀L	♀	S	S	S	-
224[86]	A	A	N	N	N	N	N	N	N	N	N	-
225[87]	N	A	N	N	N	P	N	N	N	N	N	-
226[86]	N	N	N	N	N	N	N	N	N	N	N	-
227[86]	♂	Y	Y	♂	♂	Y	♂	♂	♂	S	Y	-
228[86]	S	Y	N	N	N	♀	P	S	S	♀	Y	-
229[86]	♂*	Y	♂*	♂*	♂*	♂*	♂*	♂*	♂*	♂*	♂*	-
230[86]	N	N	N	N	N	N	N	N	N	N	N	-
231[86]	S	Y	S	♂	♂	♂	P	N	Y	♀	P	-
232[86]	Y	Y	P	N	P	N	P	N	♀	S	S	-
233[87]	N	N	N	N	N	N	N	N	N	N	N	-
234[86]	N	N	N	N	N	N	N	N	N	N	N	-
235[86]	Y	Y	S	♂*	♂*	♂*	♂*	♂*	♂*	♂*	♂*	-
236[86]	Y	Y	Y	♂*	♂*	♂*	♂*	♂*	♂*	♂*	♂*	-
238[90*]	Y	S	Y	♂	♂	♂	♂	N	P	N	N	-
239[90*]	N	N	N	N	N	N	N	N	N	N	N	-
240[91]	N	N	-	N	N	N	N	N	N	N	N	-
241[86]	P	Y	S	♂	♂	P	♂	Y	S	P	Y	-
243[86]	S	Y	S	♀	Y	♀	♀L	♀L+2	♂	♀	Y	-
244[86]	S	Y	Y	♂	♂	♂	♂	♂	♂	♀	S	-
245[86]	Y	Y	♂	♂	♂	♂	♂	♂	♂	♂	♂	-
246[86]	N	N	N	N	N	N	N	N	N	N	N	-
247[86]	S	S	S	♂	Y	S	Y	♂	S	N	N	-
248[86]	-	-	-	-	-	-	-	-	N	-	-	-
249[86]	N	-	N	N	N	N	N	N	N	N	N	-
250[86]	N	N	P	N	Y	N	Y	N	P	♀	♀	-
251[88]	N	N	-	N	N	N	N	N	N	N	N	-
252[86]	S	Y	Y	N	♂	♂	♀	♀	♀	Y	S	-
253[86]	N	N	N	N	N	N	N	N	N	N	N	-
254[86]	Y	Y	P	N	N	N	N	N	S	N	P	-
255[86]	N	P	N	N	N	N	N	N	N	N	N	-
256[86]	N	N	N	N	N	N	N	N	N	N	N	-
257[86]	N	N	N	N	N	N	N	N	N	N	N	-
258[86]	Y	Y	N	N	N	N	N	N	N	N	N	-

Spruce-Fir Habitat - Non-Construction Area (SFN) Midden Occupancy 1992											
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
259^{86}	N	N	N	N	N	N	N	N	N	N	N	-
260^{87}	Y	♂	Y	♂	♂	♂	♂	♂	♂	♂	♂	-
261^{91*}	♀*	S	P	♀*	♀*	P	♀*	Y^{2}	♀*	♀*	♀*	-
262^{90}	S	Y	Y	♂	♂	♀L	♀L	♀L	Y	S	Y	-
263^{90}	S	♂	♂	♂	S	Y	♂	♂	♂	S	S	-
264^{90}	Y	♀	S	♀	♀	♀L+2	♀L+2	♀	♀	♀	S	-
265^{90*}	Y	♂	S	♂	♂	♂	S	♂	♀	Y	♂	-
266^{87}	Y	S	N	N	N	N	♂	♀	♀	Y	N	-
267^{87}	S	♂	Y	♂	♂	♂	♂	♂	♂	♂	♂	-
268^{87}	N	N	N	N	N	N	N	N	N	N	N	-
269^{87}	Y	Y	♀	♂	♂	♂	♂	♀	♀	♀	S	-
270^{87}	Y	Y	N	♂	Y	Y	♀	♀	S	♂	N	-
271^{87}	Y	P	N	♀	Y	S	♂	S	Y	N	N	-
272^{87}	Y	Y	Y	♂	♂	♂	♀	♀	Y	Y	Y	-
273^{87}	Y	S	Y	♂	♂	S	♂	♂	S	S	S	-
274^{86}	Y	Y	P	N	N	S	P	N	N	N	N	-
275^{87}	Y	♀	Y	♀	Y	♀L	♀L/♂	Y	Y	N	N	-
277^{87}	Y	Y	Y	♀	♀	♀	♀	♀	♀	S	S	-
278^{90*}	P	S	Y	♀	Y	N	N	N	N	N	N	-
279^{90*}	N	N	-	N	N	N	N	N	N	N	N	-
280^{90*}	N	N	N	N	N	N	N	N	N	N	N	-
281^{86}	N	N	N	N	N	N	N	N	N	N	N	-
282^{86}	-	N	Y	N	N	N	N	N	N	N	N	-
283^{86}	-	N	Y	N	N	N	N	N	N	N	N	-
284^{86}	Y	Y	Y	♀	Y	♀	♀L	♀L+2	♀	Y	Y	-
285^{85}	N	N	-	N	N	N	N	N	N	N	N	-
286^{86}	N	N	N	N	N	N	N	N	N	N	N	-
287^{86}	P	N	N	N	N	N	N	N	N	N	N	-
288^{91*}	Y	♂	N	♂	♂	♂	♂	♀L+2	♀	♂	♂	-
289^{91*}	S	Y	S	♂	♂	S	♀L+2	♀L+1	P	P	P	-
290^{91*}	N	N	N	N	N	N	N	N	N	N	N	-
291^{91*}	N	P	N	N	N	N	Y	N	N	N	P	-
292^{91*}	Y	-	S	♂	♂	♂	♂	♀L	S	♀	N	-
293^{91*}	N	N	N	N	N	N	N	N	N	N	N	-
294^{91*}	Y	-	S	S	N	♀	P	N	N	N	N	-
# Mid	72	72	72	72	72	72	72	72	72	72	72	-
# Occ	38	38	33	33	35	34	35	33	35	31	28	-

Spruce-Fir Habitat - Non-Construction Area (SFN) Midden Occupancy 1992												
Midden	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
% Occ	53	53	46	46	49	47	49	46	49	43	39	-
# Sq	38	38	33	33	35	34+2	35+4	33+7	35	31	28	-

Appendix D-1. Forest structure at occupied versus unoccupied middens in the TRC, SFC, and SFN in 1991 and 1992.

		Canopy coverage (% coverage)		Foliage volume (m^3)		Log volume (m^3)		Snag density (snags/ha)	
		unocc	occup	unocc	occup	unocc	occup	unocc	occup
TRC	91	77.2 (5)[1]	91.2 (17)	573.0	811.5	13.0	14.3	432.9	393.2
	92	83.9 (10)	91.5 (12)	708.6	797.9	13.3	14.6	327.8	464.2
SFC	91	89.5 (11)	86.2 (16)	499.4	512.7	11.6	12.0	494.8	499.3
	92	88.1 (18)	86.0 (9)	531.5	458.9	11.3	12.9	484.5	523.4
SFN	91	88.4 (19)	91.2 (26)	658.5	790.3	8.4	10.6	449.0	598.6
	92	89.2 (28)	91.2 (17)	716.2	765.0	9.8	9.4	491.1	608.5

1 Number of midden sites contributing to each occupancy category for each year and study area.

D-2. Tree structure values in three distance zones (0-100, 101-200, 201-300 m) from construction on the TRC, SFC, and SFN.

		Canopy coverage (% coverage)	Foliage volume (m^3)	Log volume (m^3)	Snag density (snags/ha)
TRC	0-100	82.5 (2)[1]	575.4	13.1	159.1
	101-200	87.7 (6)	723.8	14.4	281.2
	201-300	89.0 (14)	797.7	14.0	488.8
SFC	0-100	92.0 (5)	610.5	10.4	267.4
	101-200	86.3 (8)	538.4	15.6	485.4
	201-300	86.4 (14)	452.6	10.2	586.6
SFN	0-100	89.0 (21)	800.7	8.3	438.5
	101-200	88.9 (16)	721.6	10.8	549.1
	201-300	95.0 (8)	587.2	10.9	644.9

1 Number of middens sites in each zone on each area.

Appendix E.	Measures of Spatial Distribution
Table E-1.	Crude Densities a) middens, b) squirrels
Table E-2.	Local Densities and Nearest Neighbor Distances
Table E-3.	Index of Aggregation

Table E-1a. Crude Density of red squirrel middens in each of the areas under study by the Monitoring Program. The size of each area is given in hectares (ha); densities are given in middens per hectare.

DATE	TRC 91 ha	TRN 25 ha	SFC 89 ha	SFN 122 ha
Nov 1991	0.48	0.92	0.42	0.59
Dec 1991	-[1]	-	-	-
Jan 1992	0.48	0.92	0.42	0.59
Feb 1992	0.48	0.92	0.42	0.59
Mar 1992	0.48	0.92	0.42	0.59
Apr 1992	0.48	0.92	0.42	0.59
May 1992	0.48	0.92	0.42	0.59
Jun 1992	0.48	0.92	0.42	0.59
Jul 1992	0.48	0.92	0.42	0.59
Aug 1992	0.48	0.92	0.42	0.59
Sep 1992	0.48	0.92	0.43	0.59
Oct 1992	0.49	0.92	0.43	0.59
Nov 1992	0.51	0.92	0.43	0.59
Dec 1992	-	-	-	-

1 Data missing; census not made because of poor weather and snow conditions.

Table E-1b. Crude Density of red squirrels (including juveniles) in each of the areas under study by the Monitoring Program. The size of each area is given in hectares (ha); densities are given in squirrels per hectare.

DATE	TRC 91 ha	TRN 25 ha	SFC 89 ha	SFN 122 ha
Nov 1991	0.42	0.76	0.27	0.35
Dec 1991	-[1]	-	-	-
Jan 1992	0.33	0.72	0.21	0.31
Feb 1992	0.41	0.52	0.20	0.31
Mar 1992	0.31	0.52	0.20	0.27
Apr 1992	0.22	0.36	0.20	0.27
May 1992	0.32	0.52	0.19	0.29
Jun 1992	0.34	0.72	0.21	0.30
Jul 1992	0.41	0.56	0.20	0.32
Aug 1992	0.36	0.56	0.27	0.33
Sep 1992	0.24	0.44	0.20	0.29
Oct 1992	0.21	0.36	0.17	0.25
Nov 1992	0.22	0.36	0.17	0.23
Dec 1992	-	-	-	-

1 Data missing; census not made because of poor weather and snow conditions.

Table E-2. Local Densities and Nearest Neighbor Distances of middens and squirrels.

Transition Habitat - Construction Area (TRC)									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Nov 91	44	3.8	0.37	58.4	5.43	3.3	0.33	58.5	7.75
Dec 91	-	-	-	-	-	-	-	-	-
Jan 92	44	3.8	0.37	58.4	5.43	3.2	0.34	65.0	9.87
Feb 92	44	3.8	0.37	58.4	5.43	3.3	0.34	59.7	7.97
Mar 92	44	3.8	0.37	58.4	5.43	3.2	0.35	60.6	9.53
Apr 92	44	3.8	0.37	58.4	5.43	1.6	0.32	96.2	16.47
May 92	44	3.8	0.37	58.4	5.43	3.0	0.39	75.3	12.16
Jun 92	44	3.8	0.37	58.4	5.43	2.9	0.38	71.1	9.59
Jul 92	44	3.8	0.37	58.4	5.43	3.1	0.36	66.4	8.83
Aug 92	44	3.8	0.37	58.4	5.43	3.1	0.38	71.9	9.57
Sep 92	44	3.8	0.37	58.4	5.43	1.8	0.31	90.0	15.15
Oct 92	45	3.8	0.36	58.4	5.31	1.4	0.23	81.8	7.39
Nov 92	46	3.8	0.34	57.7	5.10	1.3	0.18	81.4	6.13
Dec 92	-	-	-	-	-	-	-	-	-

Transition Habitat - Non-construction Area (TRN)									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Nov 91	23	3.0	0.36	51.2	3.99	2.5	0.31	60.9	4.84
Dec 91	-	-	-	-	-	-	-	-	-
Jan 92	23	3.0	0.36	51.2	3.99	2.3	0.33	68.9	5.39
Feb 92	23	3.0	0.36	51.2	3.99	2.0	0.36	66.2	6.20
Mar 92	23	3.0	0.36	51.2	3.99	2.2	0.41	76.1	3.61
Apr 92	23	3.0	0.36	51.2	3.99	1.5	0.38	89.6	11.35
May 92	23	3.0	0.36	51.2	3.99	2.0	0.39	76.1	7.92
Jun 92	23	3.0	0.36	51.2	3.99	2.4	0.34	68.5	5.25
Jul 92	23	3.0	0.36	51.2	3.99	2.0	0.42	75.0	9.56
Aug 92	23	3.0	0.36	51.2	3.99	1.9	0.41	77.0	10.06
Sep 92	23	3.0	0.36	51.2	3.99	1.3	0.38	88.1	10.22
Oct 92	23	3.0	0.36	51.2	3.99	1.3	0.47	97.9	16.55
Nov 92	23	3.0	0.36	51.2	3.99	1.3	0.47	97.9	16.55
Dec 92	-	-	-	-	-	-	-	-	-

Spruce/Fir Habitat - Construction Area (SFC)									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Nov 91	37	1.8	0.25	77.9	7.25	1.5	0.18	72.7	8.58
Dec 91	-	-	-	-	-	-	-	-	-
Jan 92	37	1.8	0.24	77.9	7.26	1.3	0.24	82.7	13.38
Feb 92	37	1.8	0.24	77.9	7.26	1.3	0.17	81.7	15.33
Mar 92	37	1.8	0.24	77.9	7.26	1.2	0.17	75.1	12.07
Apr 92	37	1.8	0.24	77.9	7.26	1.2	0.17	71.9	12.53
May 92	37	1.8	0.24	77.9	7.26	1.3	0.17	66.1	12.39
Jun 92	37	1.8	0.24	77.9	7.26	1.5	0.21	67.3	11.09
Jul 92	37	1.8	0.24	77.9	7.26	1.4	0.22	71.9	10.92
Aug 92	37	1.8	0.24	77.9	7.26	1.3	0.21	69.7	8.63
Sep 92	38	2.0	0.28	76.8	7.14	1.2	0.22	84.6	13.73
Oct 92	38	2.0	0.28	76.8	7.14	1.2	0.27	113.7	24.00
Nov 92	38	2.0	0.28	76.8	7.14	1.2	0.28	126.4	25.70
Dec 92	-	-	-	-	-	-	-	-	-

Spruce/Fir Habitat - Non-Construction Area (SFN)									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Nov 91	72	1.8	0.13	71.0	30.6	1.1	0.14	88.1	4.90
Dec 91	-	-	-	-	-	-	-	-	-
Jan 92	72	1.8	0.13	71.0	3.07	1.0	0.14	96.1	6.13
Feb 92	72	1.8	0.13	71.0	3.07	0.9	0.17	96.6	5.65
Mar 92	72	1.8	0.13	71.0	3.07	0.9	0.13	103.7	12.24
Apr 92	72	1.8	0.13	71.0	3.07	1.1	0.13	92.8	8.01
May 92	72	1.8	0.13	71.0	3.07	1.0	0.13	104.4	10.33
Jun 92	72	1.8	0.13	71.0	3.07	0.9	0.13	100.6	10.83
Jul 92	72	1.8	0.13	71.0	3.07	1.0	0.14	103.2	10.67
Aug 92	72	1.8	0.13	71.0	3.07	0.9	0.13	107.5	11.36
Sep 92	72	1.8	0.13	71.0	3.07	0.9	0.12	98.1	6.36
Oct 92	72	1.8	0.13	71.0	3.07	0.8	0.13	106.6	10.97
Nov 92	72	1.8	0.13	71.0	3.07	0.6	0.10	112.4	12.10
Dec 92	-	-	-	-	-	-	-	-	-

All Areas Combined									
		Middens				Squirrels			
Month	# Mid	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean	Mean Number w/i 100m	Std. Error of the Mean	Mean Nearest Neighbor Dist (M)	Std. Error of the Mean
Nov 91	188	2.5	0.13	66.0	2.39	2.1	0.14	70.5	3.36
Dec 91	-	-	-	-	-	-	-	-	-
Jan 92	188	2.5	0.13	66.0	2.39	1.9	0.14	79.5	4.26
Feb 92	188	2.5	0.13	66.0	2.39	1.9	0.16	77.0	4.26
Mar 92	188	2.5	0.13	66.0	2.39	1.9	0.16	79.0	5.53
Apr 92	188	2.5	0.13	66.0	2.39	1.3	0.10	86.1	5.56
May 92	188	2.5	0.13	66.0	2.39	1.8	0.16	82.7	5.58
Jun 92	188	2.5	0.13	66.0	2.39	1.9	0.15	78.7	5.02
Jul 92	188	2.5	0.13	66.0	2.39	1.9	0.15	80.1	5.09
Aug 92	188	2.5	0.13	66.0	2.39	1.8	0.16	82.7	5.23
Sep 92	189	2.5	0.14	65.9	2.39	1.3	0.11	90.1	5.17
Oct 92	190	2.5	0.14	65.9	2.37	1.1	0.11	97.2	6.64
Nov 92	191	2.6	0.14	65.6	2.35	1.0	0.10	100.97	7.08
Dec 92	-	-	-	-	-	-	-	-	-

1 Data missing; census not made because of poor weather and snow conditions.

Table E-3. Index of aggregation of middens and squirrels. Index ranges from 0 (perfectly aggregated - i.e., all squirrels living in the same place) to 2.15 (perfectly uniform - i.e., all squirrels spaced equidistant from each other), a value of 1 is not different from random. 'Z' values < -2.24 or > 2.24 are significant ($P < 0.05$).

Month	Area	Middens		Squirrels	
		Index	Corrected Z	Index	Corrected Z
Nov 1991	TRC	0.920	-1.630	0.857	-2.193
	TRN	0.931	-1.302	1.006	-0.743
	SFC	1.016	-0.598	0.763	-2.589
	SFN	1.031	-0.308	0.989	-0.870
Jan 1992	TRC	0.920	-1.630	0.847	-2.107
	TRN	0.931	-1.302	1.107	-0.090
	SFC	1.016	-0.598	0.772	-2.289
	SFN	1.031	-0.308	1.015	-0.608
Feb 1992	TRC	0.920	-1.630	0.864	-2.109
	TRN	0.931	-1.302	0.905	-1.294
	SFC	1.016	-0.598	0.763	-2.350
	SFN	1.031	-0.308	1.046	-0.283
Mar 1992	TRC	0.920	-1.630	0.803	-2.524
	TRN	0.931	-1.302	1.040	-0.570
	SFC	1.016	-0.598	0.683	-2.828
	SFN	1.031	-0.308	1.019	-0.574
Apr 1992	TRC	0.920	-1.630	1.023	-0.597
	TRN	0.931	-1.302	1.019	-0.702
	SFC	1.016	-0.598	0.654	-3.017
	SFN	1.031	-0.308	0.913	-1.560
May 1992	TRC	0.920	-1.630	0.964	-1.069
	TRN	0.931	-1.302	1.039	-0.574
	SFC	1.016	-0.598	0.584	-3.388
	SFN	1.031	-0.308	1.057	-0.207

Month	Area	Middens		Squirrels	
		Index	Corrected Z	Index	Corrected Z
Jun 1992	TRC	0.920	-1.630	0.942	-1.280
	TRN	0.931	-1.302	1.005	-0.753
	SFC	1.016	-0.598	0.628	-3.264
	SFN	1.031	-0.308	1.005	-0.710
Jul 1992	TRC	0.920	-1.630	0.893	-1.735
	TRN	0.931	-1.302	1.024	-0.654
	SFC	1.016	-0.598	0.654	-3.019
	SFN	1.031	-0.308	1.045	-0.318
Aug 1992	TRC	0.920	-1.630	0.952	-1.191
	TRN	0.931	-1.302	1.052	-0.508
	SFC	1.016	-0.598	0.634	-3.151
	SFN	0.031	-0.308	1.057	-0.224
Sep 1992	TRC	0.920	-1.630	1.003	-0.735
	TRN	0.931	-1.302	1.107	-0.265
	SFC	1.014	-0.608	0.769	-2.263
	SFN	1.031	-0.308	0.994	-0.814
Oct 1992	TRC	0.931	-1.520	0.848	-1.785
	TRN	0.931	-1.302	1.113	-0.297
	SFC	1.014	-0.608	0.944	-1.081
	SFN	1.031	-0.308	1.016	-0.613
Nov 1992	TRC	0.930	-1.544	0.865	-1.695
	TRN	0.931	-1.302	1.113	-0.297
	SFC	1.014	-0.608	1.049	-0.460
	SFN	1.031	-0.308	1.018	-0.598

Appendix F. Results of analysis of variance and Student, Newman, Kuels - Multiple range tests on local density (LD) of middens and squirrels (occupied middens) in 1992. (output from SAS)

Local density of middens

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOC	4	TRC TRN SFC SFN

Number of observations in data set = 179

General Linear Models Procedure

Dependent Variable: LD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	133.7949644	44.5983215	15.84	0.0001
Error	175	492.7860412	2.8159202		
Corrected Total	178	626.5810056			

R-Square	C.V.	Root MSE	LD Mean
0.213532	66.30786	1.678070	2.53072626

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOC	3	133.7949644	44.5983215	15.84	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOC	3	133.7949644	44.5983215	15.84	0.0001

Student-Newman-Keuls test for variable: LD

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 175 MSE= 2.81592
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 37.94272

Number of Means	2	3	4
Critical Range	0.7603645	0.9107147	0.9993384

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	LOC
A	3.848	46	TRC
B	3.043	23	TRN
C	1.947	38	SFC
C			
C	1.833	72	SFN

Local density of squirrels

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOC	4	TRC TRN SFC SFN

Number of observations in data set = 72

General Linear Models Procedure

Dependent Variable: LD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	7.97896825	2.65965608	3.55	0.0190
Error	68	51.00714286	0.75010504		
Corrected Total	71	58.98611111			

R-Square	C.V.	Root MSE	LD Mean
0.135269	87.82844	0.866086	0.98611111

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOC	3	7.97896825	2.65965608	3.55	0.0190

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOC	3	7.97896925	2.65965608	3.55	0.0190

General Linear Models Procedure

Student-Newman-Keuls test for variable: LD

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 68 MSE= 0.750105
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 15.18072

Number of Means	2	3	4
Critical Range	0.6272975	0.7532362	0.8279389

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	LOC
A	1.333	9	TRN
A			
A	1.250	20	TRC
A			
A	1.200	15	SFC
A			
A	0.571	28	SFN

Appendix G. Results of analysis of variance and Student, Newman, Kuels - Multiple range tests on nearest neighbor distance (NN) of middens and squirrels (occupied middens) in 1992. (output from SAS)

Nearest neighbor distance of middens

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOC	4	TRC TRN SFC SFN

Number of observations in data set = 179

General Linear Models Procedure

Dependent Variable: NN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	15725.44738	5241.81579	5.15	0.0019
Error	175	177990.56686	1017.08895		
Corrected Total	178	193716.01424			

R-Square	C.V.	Root MSE	NN Mean
0.081178	47.89259	31.89183	66.5903263

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOC	3	15725.44738	5241.81579	5.15	0.0019

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOC	3	15725.44738	5241.81579	5.15	0.0019

General Linear Models Procedure

Student-Newman-Keuls test for variable: NN

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 175 MSE= 1017.089
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 37.94272

Number of Means	2	3	4
Critical Range	14.450774	17.308189	18.992489

Means with the same letter are not significantly different.

SNK Grouping		Mean	N	LOC
	A	78.340	38	SFC
	A			
B	A	70.993	72	SFN
B				
B	C	57.669	46	TRC
	C			
	C	51.236	23	TRN

Nearest neighbor distance of squirrels

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOC	4	TRC TRN SFC SFN

Number of observations in data set = 72

General Linear Models Procedure

Dependent Variable: NN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	20064.19198	6688.06399	1.61	0.1962
Error	68	283326.10137	4166.56031		
Corrected Total	71	303390.29336			

R-Square	C.V.	Root MSE	NN Mean
0.066133	61.53356	64.54890	104.900319

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOC	3	20064.19198	6688.06399	1.61	0.1962

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOC	3	20064.19198	6688.06399	1.61	0.1962

General Linear Models Procedure

Student-Newman-Keuls test for variable: NN

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 68 MSE= 4166.56
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 15.18072

Number of Means	2	3	4
Critical Range	46.752123	56.138263	61.705814

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	LOC
A	126.45	15	SFC
A			
A	112.41	28	SFN
A			
A	97.92	9	TRN
A			
A	81.36	20	TRC

Appendix H. Results of analysis of variance on midden occupancy as a function of local density (LD) and nearest neighbor distance (NN). (output from SAS)

Local density of squirrels (# occupied middens w/in 100 m) and distance to nearest neighboring squirrel (meters to nearest occupied midden) for unoccupied focal middens in November 1992.

	N	Min	Max	Mean	Std Dev
LD	107	0.0	4.0	1.1	1.1
NN	107	14.3	23.7	101.8	72.0

Local density of squirrels (# occupied middens w/in 100 m) and distance to nearest neighboring squirrel (meters to nearest occupied midden) for occupied focal middens in November 1992.

	N	Min	Max	Mean	Std Dev
LD	72	0.0	3.0	1.0	0.9
NN	72	42.4	357.1	104.4	65.7

ANOVA table for nearest neighbor distance of squirrels around middens.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
OCC	2	0 1

Number of observations in data set = 179

General Linear Models Procedure

Dependent Variable: NN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	293.9274808	293.9274808	0.06	0.8055
Error	177	855839.047951	4835.2488585		
Corrected Total	178	856132.975431			

R-Square	C.V.	Root MSE	NN Mean
0.000343	67.61674	69.53595	102.838374

Source	DF	Type I SS	Mean Square	F Value	Pr > F
OCC	1	293.9274808	293.9274808	0.06	0.8055

Source	DF	Type III SS	Mean Square	F Value	Pr > F
OCC	1	293.9274808	293.9274808	0.06	0.8055

ANOVA table for local density of squirrels around middens.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
OCC	2	0 1

Number of observations in data set = 179

General Linear Models Procedure

Dependent Variable: LD

Sourc	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.84269073	0.84269073	0.79	0.3750
Error	177	188.59865005	1.06552910		
Corrected Total	178	189.44134078			

R-Square	C.V.	Root MSE	LD Mean
0.0004448	97.76286	1.032245	1.05586592

Source	DF	Type I SS	Mean Square	F Value	Pr > F
OCC	1	0.84269073	0.84269073	0.79	0.3750

Source	DF	Type III SS	Mean Square	F Value	Pr > F
OCC	1	0.84269073	0.84269073	0.79	0.3750

Local density of middens (# middens w/in 100 m) and distance to nearest neighboring midden (meters to nearest occupied midden) for unoccupied focal middens in November 1992.

	N	Min	Max	Mean	Std Dev
LD	107	0.0	7.0	2.5	1.9
NN	107	14.3	186.7	69.2	37.1

Local density of middens (# middens w/in 100 m) and distance to nearest neighboring midden (meters to nearest occupied midden) for occupied focal middens in November 1992.

	N	Min	Max	Mean	Std Dev
LD	72	0.0	8.0	2.7	1.9
NN	72	14.3	145.7	62.7	25.6

ANOVA table for nearest neighbor distance of middens around middens.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
OCC	2	0 1

Number of observations in data set = 179

General Linear Models Procedure

Dependent Variable: NN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1784.451509	1784.451509	1.65	0.2012
Error	177	191931.562732	1084.349111		
Corrected Total	178	193716.014241			

R-Square	C.V.	Root MSE	NN Mean
0.009212	49.45104	32.92961	66.5903263

Source	DF	Type I SS	Mean Square	F Value	Pr > F
OCC	1	1784.451509	1784.451509	1.65	0.20212

Source	DF	Type III SS	Mean Square	F Value	Pr > F
OCC	1	1784.451509	1784.451509	1.65	0.20212

ANOVA table for local density of middens around middens.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
OCC	2	0 1

Number of observations in data set = 179

General Linear Models Procedure

Dependent Variable: LD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.79427142	1.79427142	0.51	0.4768
Error	177	624.78673416	3.52986855		
Corrected Total	178	626.58100559			

R-Square	C.V.	Root MSE	LD Mean
0.002864	74.23934	1.878794	2.53072626

Source	DF	Type I SS	Mean Square	F Value	Pr > F
OCC	1	1.79427142	1.79427142	0.51	0.4768

Source	DF	Type III SS	Mean Square	F Value	Pr > F
OCC	1	1.79427142	1.79427142	0.51	0.4768

Appendix I. Summary of data on reproductive success of females on the monitored areas through September 1992.

Female	Midden #	Earliest Known Lactation Date	Date Litter First Seen	Litter Size
1	101	21 Jul	3 Aug	2
2	104	16 Jul	-	-
3	109	20 Jul	-	-
4	113[1]	??	14 Jul	3
5	115	15 Jul	-	-
6	134	17 Jun	-	-
7	135	2 Jul	-	-
8	137	17 Jul	-	-
9	138	30 Jul	-	-
10	148	23 Jun	-	-
11	300	??	31 Jul	2
12	202	5 Jun	6 Jul	1
13	203	19 May	17 Jun	3
14	211	24 Jun	5 Aug	1
15	400	19 May	-	-
16	153[1]	14 Jul	11 Aug	3
17	164	11 Aug	-	-
18	165	1 Aug	28 Aug	3
19	223	8 Jun	-	-
20	243	16 Jul	30 Aug	2
21	262	22 Jun	-	-
22	264	23 Jun	30 Jun	2
23	275	22 Jun	-	-
24	284	16 Jul	30 Aug	2
25	288	??	17 Aug	2
26	289	19 Jul	19 Jul	2

Female	Midden #	Earliest Known Lactation Date	Date Litter First Seen	Litter Size
27	292	30 Aug	-	-
Average Litter Size (N=13)				2.15

[1] On 3 June, a breeding chase was seen at this midden. Five squirrels were running around the midden making buzz calls. The sex of all the squirrels was not determined, but the resident squirrel at the time was known to be female.

Appendix J. Results of Kruskal-Wallis tests (non-parametric ANOVA) on reproductive success as a function of distance from construction (output from SAS).

OBS	YEAR	MIDDEN	DIST	LITTER	LOC	SUCCESS
1	1992	102	309.31	0	1	0
2	1992	103	266.25	0	1	0
3	1992	106	190.37	0	1	0
4	1992	108	268.84	0	1	0
5	1992	116	184.95	0	1	0
6	1992	118	147.89	0	1	0
7	1992	118	147.89	0	1	0
8	1992	119	102.71	0	1	0
9	1992	120	110.22	0	1	0
10	1992	121	303.40	0	1	0
11	1992	130	108.91	0	1	0
12	1992	130	108.91	0	1	0
13	1992	138	250.67	0	1	0
14	1992	142	122.54	0	1	0
15	1992	143	79.97	0	1	0
16	1992	144	160.17	0	1	0
17	1992	302	260.10	0	1	0
18	1992	151	253.13	0	3	0
19	1992	156	180.70	0	3	0
20	1992	161	213.08	0	3	0
21	1992	169	186.25	0	3	0
22	1992	171	299.98	0	3	0
23	1992	172	308.37	0	3	0
24	1992	176	409.31	0	3	0
25	1992	177	424.73	0	3	0
26	1992	177	424.73	0	3	0
27	1992	178	167.21	0	3	0
28	1992	178	167.21	0	3	0
29	1992	185	153.86	0	3	0
30	1992	186	309.36	0	3	0
31	1992	187	297.34	0	3	0
32	1992	104	198.71	0	1	1
33	1992	109	206.31	0	1	1
34	1992	115	196.82	0	1	1
35	1992	134	39.20	0	1	1
36	1992	135	107.50	0	1	1
37	1992	137	135.54	0	1	1
38	1992	133	250.67	0	1	1
39	1992	148	159.01	0	1	1
40	1992	164	154.52	0	3	1
41	1992	101	336.56	2	1	2
42	1992	113	249.75	3	1	2
43	1992	300	338.15	2	1	2
44	1992	153	122.05	3	3	2
45	1992	165	217.58	3	3	2

KEY

DIST = Distance from nearest construction in meters
LITTER = Litter size (number of juveniles emerging from nest)
LOC = Area:
1 = TRC
2 = SFC
SUCCESS = Reproductive success category:
0 = Did not lactate
1 = lactated but did not produce litter
2 = lactated and produced litter

Distance of middens from nearest construction (meters) for all study areas combined.

SUCCESS=0

Variable	N	Minimum	Maximum	Mean	Std Dev
Distance	31	79.97	424.73	223.18	96.45

SUCCESS=1

Variable	N	Minimum	Maximum	Mean	Std Dev
Distance	9	32.90	250.67	166.48	62.12

SUCCESS=2

Variable	N	Minimum	Maximum	Mean	Std Dev
Distance	5	122.05	338.15	252.82	90.34

Appendix L-1. Sightings of Marked Squirrels outside their own midden.

ate	Time	Marked Squirrel	Location Seen	Distance from own midden	Notes
23 Sep	1145	♀116	midden 104	41m	
9 Oct	1133	♀116	25m N-NE of midden 144	67m	
?? Jun	1200	♂160	SMT site	218m	- both squirrels seen feeding on ladybugs
?? Jun	1200	♂165	SMT site	202m	- on constr. site
21 Apr	0850	♂168	midden 172	214m	
20 May	0815	♂168	midden 176	344m	- seen back at his own midden 1 hour later
29 Jul		♂168	midden 185 - py		
24May	????	♂169	midden 165	422m	- chased out by resident marked ♂
1 Aug	0800	♂181	100m N of midden 181	100m	
1 Aug	0930	♂181	midden 153	194m	
?? Jun	1130	♂229	on hiking trail	75m	
3 Jul	0900	♂235	midden 231	132m	
4 Aug	1030	♂261	midden 243	174m	
4 Aug	1050	♂261	midden 245	232m	- chased out by resident unmarked ♂
10 Apr.		♂156	midden 169		
21 Apr.		♂156	midden 169		
26 Sep		♀143	midden 135 - wt		

Appendix K. Disappearances of Marked Squirrels.

Of the 21 squirrels trapped and tagged since September of 1991, 16 are still living on the monitored areas: eight on the TRC Area (7♀/1♂), four on the SFC Area (1♀/3♂) and four on the SFN Area (1♀/3♂).

Marked squirrels disappearing in **1991**.

Midden 163 Female tagged on 8 October was last seen at her midden in November.

Midden 182 Female tagged on 2 October was last seen at her midden in November.

Marked squirrels disappearing in **1992**.

Midden 144 Female tagged on 8 October was last seen on 10 October. An adult female (post-lactating) was seen foraging in the midden along with the marked female on the 10th. After about 10 minutes the marked female began making buzz calls and chased the other female away towards midden 115. The marked female was not seen again after this day.

Midden 165 Marked male was last seen at the midden on 18 July. A lactating female had taken over the midden by the end of the month.

Midden 169 Marked male was last seen on 16 June. By July, the marked female from midden 185 had moved into this midden.

Appendix L-2. Evidence of marked squirrels using more than one midden.

Marked male at midden 181 using midden 156 (40 meters away):

12 Oct 92	1012	The marked male (blue/green) was seen foraging in midden 156 and then ran off the the west.
17 Nov 92	0850	The marked male was located after chattering in midden 181. He went to midden 156, chattered, then foraged in the trees. The squirrel next moved over to midden 180 to forage for a few minutes before returning to midden 181.

Marked female at midden 142 using midden 120 (34 meters away):

22 Oct 92	1520	Female caught at midden 120. Marked green/orange. The traps were moved to midden 142.
23 Oct 92	0750	Watched traps at this midden. Marked female (green/orange) chattered in midden then headed downhill towards midden 120 moving out of sight. About three minutes later a chatter was heard from midden 120. Later in the afternoon observers sat at both middens 120 and 142. The marked female chattered and was seen foraging in midden 120. Then about 20 minutes later the marked female chattered at midden 142 and began foraging on the ground. Most of the caching and feeding is at midden 142, but a few cones were found at midden 120.

Marked female at midden 108 using midden 139 (41 meters away):

23 Oct 92	0800	Watched traps at midden 139. Saw marked female from midden 108 (green/green) moving back and forth between the middens several times throughout the day, foraging in each area. Also the female was seen taking nesting materials to a snag located between the middens, collecting lichen and grass from both middens.

Appendix L-2 (cont.)

Marked female at midden 109 using midden 140 (37 meters away):

26 Oct 92	0800	Watched traps at this midden. Saw a sub-adult female moving back and forth between middens 109 and 140 foraging and feeding. This female was observed knocking a trap over on its side and taking a bait cone out without tripping the treadle. This female was caught later in the afternoon, but escaped through the bars on the Halvorsen cone.
27 Oct 92	0800	Back at midden 109 watching traps. Overnight almost all the locked open traps were knocked over on their sides and the bait cones removed. Also set and watched traps at midden 140 as squirrel was seen in the area yesterday. At 1050 heard something around one of the traps at midden 140 and found the trap flipped on its side and the cone removed. The trap was re-baited and set and at 1110 the female was caught in this same trap and marked.

Unmarked Female at midden 115 using midden 144 (56 meters away):

10 Oct 92	1044	At midden 144 (approx. 30m E of 115), saw marked female (orange/blue) in midden along with an unmarked adult female who was feeding on truffles. After about 10 minutes the marked female chased the adult female out of the area towards midden 115 while making low buzz calls. The marked female was not seen in midden 144 after this day.
26 Oct 92	0936	Census at midden 144. Saw an unmarked adult (post-lactating) female foraging in the midden. She then ran off towards 115, where she began barking.
17 Nov 92	1300	Census at midden 144. Saw a squirrel foraging in midden, after a few minutes it ran off towards midden 115 where it then began chattering. Most of the caching and feeding sign are at midden 115.