THE UNIVERSITY OF
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MT. GRAHAM RED SQUIRREL MONITORING PROGRAM

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Introduction:

This report is a compilation of the analysis, with minimal interpretation, of the data collected during 1990 by the University of Arizona Mt. Graham Red Squirrel Monitoring Program. The Monitoring Program is required by the MGIO Management Plan to monitor the squirrel populations near the proposed telescopes and access road in order to determine whether or not the construction and operation of the telescopes has any effect on the population. The report is divided into three sections dealing with the major aspects of research being conducted by the Monitoring Program: Population Biology and Demographics, Habitat and Microenvironment, and Behavior. The Habitat and Microenvironment data will not be complete for several years and is not analyzed in this report; only a preliminary, description of that data is presented here. Any questions concerning the data, analysis, or interpretation of the analysis should be directed to the supervisor of the Monitoring Program. All of the data collected by the program is available for scrutiny, but the University and the Monitoring Program reserve all publication rights.

Description of the Study and Control Areas:

The MGIO telescope complex is being constructed on Emerald Peak in the Graham Mountains. The area surrounding the telescope sites and access road to a distance of 300 m is referred to in this document as the Study Area. For the purpose of comparison, the Monitoring Program also monitors the population biology and behavior of squirrels on two other areas of the Grahams. These areas are referred to as the Control Areas.

The border of the Study Area was defined in the MGIO Management Plan as a line 300 m from the proposed telescope sites and the access road. This boundary encompasses a total area of approximately 180 hectares (ha) from the top of Emerald Peak westward and southward to the junction of the new access road and state highway 366. The Study area is divided into two areas of almost equal size. The Lower Study Area (LS) consists of all of the western portion of the Study Area below 3050 m elevation (approximately 91 ha.) and the Upper Study Area (US) is the eastern portion of the Study Area above 3050 m elevation (approximately 89 ha). The 3050 m elevation contour used to delineate the two areas also approximates the boundary of two coniferous forest habitat types found on the Grahams. On the LS area the forest cover is Transitional Coniferous forest (TR), varying 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 LS area encompasses a large area (approximately 48 ha) of natural and man-made meadows, which are unsuitable for red squirrel habitat. The Upper Study area is primarily Spruce-Fir forest (SF), dominated by Engelmann spruce and corkbark fir. No estimates of the amount of open meadows on the US area have been made.

An area approximately 0.75 kilometers east of the east boundary of the Study Area, on the east side of Hawk Peak and including most of Mt. Graham, was originally chosen as the Control Area. 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 the hiking trail on the north. The north boundary follows the 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 also follows the 3050 m elevation contour to a point approximately 1 km below Mt. Graham then crosses over old FR 507 to connect to the east boundary (see Map following this section). This area of approximately 122 ha is now referred to as the Upper Control Area (UC). The forest cover on the UC area is primarily spruce-fir. The area encompasses one cienega and some open meadows, however no estimate of the size of these open areas has been made.

In September of 1989 a small area of TR habitat (approximately 25 ha), north and west of the LS area, was added to the Control Area in order to provide some comparison of the behavior of squirrels in similar habitat to those on the LS area (1st Quarterly Report U of A - Mt. Graham Red Squirrel Monitoring Program, 1990). This area, referred to as the Lower Control Area (LC), is adjacent to northwest boundary of the LS area and is bordered on the west by Swift Trail (SH366). The borders of the LC area were not arbitrarily set, as were those for the LS, US, and UC areas, but were determined by drawing a line at a radius of approximately 100 m around the known middens sites. The size of the LC area was increased (from 22 to 25 ha) in 1990 with the inclusion of three new midden sites on the north side of the Bible Camp road.

Map of the Monitored Areas

Population Biology and Demographics:

Red Squirrel Populations:

General population trends

The squirrel populations on all four of the monitored areas have increased over the past year (Fig. 1). The numbers of squirrels on each of the areas remained fairly constant overwinter, from November 1989 through May 1990. The populations on all areas declined slightly from May through August. Starting in mid- to late-September the red squirrel populations on the areas began a rapid increase. A substantial increase in the Upper Control (UC) area (from 6 to 15 squirrels) was first recorded in late-September; most of the new squirrels appearing in the southeast portion of the area on the west slope of High Peak (see Maps, App. A). The population on the Upper Study (US) area also increased substantially during September, almost doubling from its lowest annual level of 3 squirrels to 5 squirrels. The increasing population on the Upper areas (primarily Subalpine Forest habitat; SF) coincided with a decrease in the populations on the Lower areas (primarily Transitional Forest habitat; TR) as juvenile squirrels in these areas disappeared from their natal areas.

The October 1990 census figures (Table 1) were recorded at the time of the USFS autumn census of the entire squirrel population. Most of the areas being monitored showed a substantial increase in October (Table 1). The UC area increased from 15 to 31 squirrels, while the US area population increased from 6 to 14 squirrels. The lower areas showed a less dramatic increase during October, the LS area going from 9 to 12 squirrels and the LC area increasing from 8 to 9 squirrels.

The increase in the squirrel populations continued through November 1990 with substantial increases being recorded on all of the monitored areas. The UC area increased from 31 to 42 squirrels, while the US area population increased from 14 to 17 squirrels, the LS area increased from 12 to 19 squirrels and the LC area increased from 9 to 14 squirrels.

By the end of November 1990 the total population on the monitored areas was 41% greater in November 1990 than in October 1990 (Fig. 1) and 280% larger than in November 1989.

Differences in the "raw" numbers of squirrels on the monitored areas were not tested statistically, on the advice of a Forest Service biometrician (R. King, pers. comm.), since each population was of a different initial size and the areas have different numbers of middens. Comparisons of proportional data (eg. density, percent midden occupancy) are better indicators of the relative change in populations of different size.

The increase in the red squirrel population observed during late 1990, particularly in the SF areas, has resulted in a more equitable distribution of squirrels throughout the monitored areas than was seen in 1989 and early 1990. This is best seen by comparing the proportion of the total number of middens on each of the areas to the proportion of the total number of squirrels on each area (Tables 2, 3, and 4). In November 1989, the red squirrel population on the monitored areas was highly skewed to the lower (TR) areas. While the LS and LC areas contained only 20% and 8%, respectively, of the total number of middens being monitored, 45% of the total red squirrel population lived on the LS area and 19% on the LC area (Table 2). This disparity continued, with little change, into 1990 (Table 3). In November 1990, after an almost 3 fold increase in the total red squirrel population on the monitored areas since November 1989, the proportion of the squirrel population living on each of the monitored areas closely matched the proportion of middens found on each area (Table 4).

Summary and discussion of changes in the squirrel populations:

1) The squirrel populations on all of the monitored areas have increased over the past year.

2) Population changes are not entirely synchronous among populations in different habitats. Populations in the SF areas increased more than those in the TR areas in 1990 (the opposite was true in 1989).

3) Within habitats there was no difference in the direction of change of squirrel populations on the Study and Control areas.

4) At the beginning of 1990, the red squirrel population on the monitored areas was disproportionately distributed. The lower (TR) areas had approximately twice the per centage of the population as might be expected from the distribution of middens. At the end of 1990, the proportion of the total monitored red squirrel population on each area at the end of 1990, was the same as the proportion of the total number of middens found on each of the areas.

Overwinter survival of individual squirrels was quite high for the winter of 1989-90, possibly owing to a large proportion of adults in the population.

Many of the new squirrels found on the monitored areas during October and November 1990 occupied newly established territories or, in the case of several squirrels on UC, re-occupied midden sites that were not previously known to the Monitoring Team.

The increase in the squirrel population on the monitored areas can no doubt be attributed solely to the large cone crop in several species of conifers, especially Engelmann spruce, during 1990. Red squirrel populations have been shown to regulated by food resources in previous studies (Brink and Dean, 1966; C. Smith, 1968; M. Smith 1968; Sullivan and Sullivan, 1982; Sullivan, 1990; Klenner and Krebs, 1991) and populations can increase very rapidly during years with heavy cone crops. The proportionately greater increase in the populations in SF habitat, compared to TR habitat is in part attributable to preponderance of spruce in this habitat, and partly to the fact that the populations in the TR habitat were already at much higher densities than those in the SF habitat. The TR habitat may have already been approaching its maximum sustainable population in some areas in early 1990, while the SF habitat was virtually vacant.

Table 1. Red squirrel populations on the monitored areas from August 1989 through November 1990.

Date	Lower Study	Upper Study	Lower Control	Upper Control	Total
Aug 1989	7	6	-	12	25
Sep 1989	11	6	6	10	33
Oct 1989	16	5	8	6	35
Nov 1989	14	6	6	5	31
Jan 1990	13	5	7	9	32
Feb 1990	13	7	7	-	32[1]
Mar 1990	10	7	6	9	32
Apr 1990	12	7	6	8	33
May 1990	10	6	7	8	31
Jun 1990	10	3	4+3J	6	23+3J
Jul 1990	6+5J	3	5+6J	6	20+11J
Aug 1990	7+2J	5	5+5J	6	23+7J
Sep 1990	9	6	8	15	38
Oct 1990	12	14	9	31	66
Nov 1990	16+3J	17	14	42	89+3J

[1] Assumes same population for UC area as in following month.

Figure 1. Graphic representation of the changes in squirrel populations on the areas monitored by the Red Squirrel Monitoring Program.

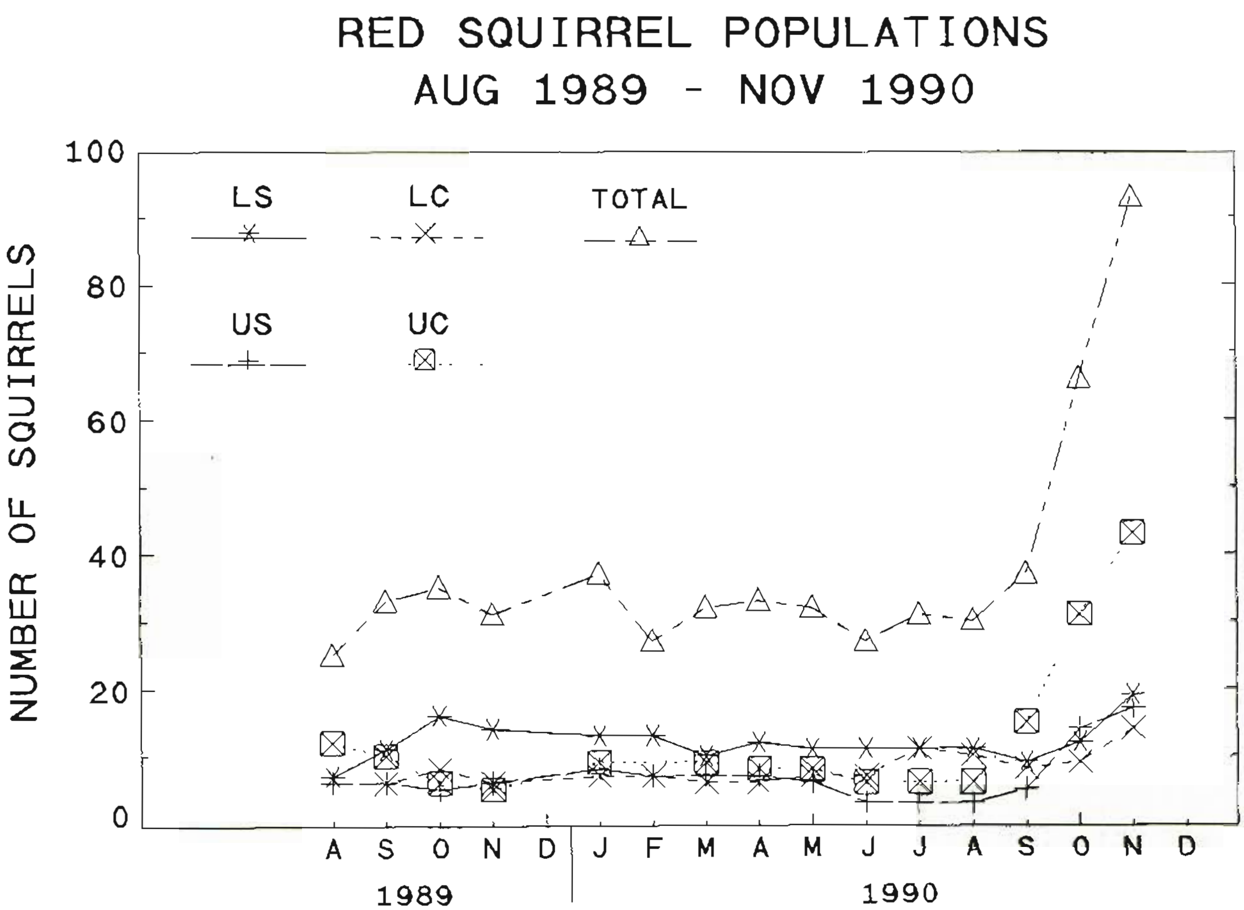


Table 2. The proportion of total number of middens and squirrels on the monitored areas, found on each of the areas, as of November 1989. (Juveniles at mothers' middens excluded)

	LS	US	LC	UC
# Middens	22	26	9	52
% of Total	20%	24%	8%	48%
# Squirrels	14	6	6	5
% of Total	45%	19%	19%	16%

Table 3. The proportion of total number of middens and squirrels on the monitored areas, found on each of the areas, as of June 1990. (Juveniles at mothers' middens excluded)

	LS	US	LC	UC
# Middens	22	27	10	52
% of Total	20%	24%	9%	47%
# Squirrels	10	3	4	6
% of Total	43%	13%	17%	26%

Table 4. The proportion of total number of middens and squirrels on the monitored areas, found on each of the areas, as of November 1990. (Juveniles at mothers' middens excluded)

	LS	US	LC	UC
# Middens	25	31	17	63
% of Total	18%	23%	13%	46%
# Squirrels	16	17	14	42
% of Total	18%	19%	16%	47%

Breeding and Reproductive Success:

We were able to gather information on the timing of reproduction events and on litter sizes for 9 females on the monitored areas in 1990 (Table 5). The earliest date when a female was observed to be lactating was 2 May (midden 209) and one female was first observed lactating as late as 28 August. Several females on the monitored areas were known to be lactating as late as September and one lactating female with a recently emerged litter (3 juveniles) was observed at midden 118 in early November.

We were unable to locate any lactating females in the SF areas during 1990. An adult female at midden 156 on US appears to have successfully reared two or three offspring, judging from the appearance of three juveniles which established territories immediately surrounding her midden in October.

Litter size, at emergence from the natal nest, ranged from 2 to 3 (mean 2.67, n=6: Table 5). This is smaller than the mean litter size reported for other red squirrel populations (Krasnowski, 1969; Davis, 1969; and see Obbard, 1988) but may represent a low reproductive effort owing to the sparse food resources on Mt. Graham for the past several years (Rusch and Reeder, 1978).

Summary and discussion of breeding and reproductive activity:

1) The reproductive season in 1990 was later than for northern populations and possibly later than in 1989 but is within the range of Colorado red squirrels (Dolbeer, 1973) and is probably normal variation.

2) Litter size in 1990 was smaller than that reported for most red squirrel populations (Obbard, 1988) but may be a result of recently poor food resources or small sample size.

3) There is insufficient data to examine for any effect of construction activity on reproductive success.

The increase in the squirrel population late in the year (Fig. 1) is consistent with and supports the small number of observations on breeding activity which indicated that the main period of breeding activity occurred in April through July (see previous reports from 1990). This is somewhat later in the year than the March to June season reported by Froehlich (1990) for 1989. The timing of breeding of the Mt. Graham population is later than that reported for red squirrels in Alaska (late-February - April, Krasnowski, 1969), and longer than for squirrels in Saskatchewan (March - May, Davis, 1969) but is within the range of dates for the onset of breeding in Colorado red squirrel populations (Dolbeer, 1973). Red squirrel populations show wide variation in the timing of reproductive activity (Obbard, 1988) much of the variation can be explained as a response to variations in weather and food resources (C. Smith, 1968; Millar, 1970; Rusch and Reeder, 1978).

The lack of data on lactating females in the SF habitat should not be taken as an indication that there was no reproductive activity in the SF habitat, but rather is a result of the initially small population size on the upper monitored areas. We identified only three adult females on the upper areas May 1990 and two of these squirrels disappeared from their middens in mid-summer.

The continued appearance of new squirrels on the monitored areas late in November suggests that some females may have produced two litters during the past summer and that a large proportion of the yearling females may have bred. Yearling female red squirrels often do not breed during their first year (D. Becker, pers. comm.) and if they do, they breed later in the year than do adult females (Kemp and Keith, 1970; Lair, 1985; D. Becker, S. Boutin, K. Larsen, pers. comm.). In northern populations red squirrels rarely have two litters per year (Kemp and Keith, 1970; Dolbeer, 1973) though it is common for squirrels in the southeast portion of their geographic range to do so (Hamilton, 1939; Layne, 1954; Lair, 1985). Froehlich (1990) reported on one female having two litters in 1989 on Mt. Graham. Douglas squirrels (Tamiasciurus douglasii) in southern British Columbia often produce two litters per year while nearby red squirrels do not (C. Smith, 1968). Supplemental feeding of both Douglas squirrels (Sullivan & Sullivan, 1982) and red squirrels (Sullivan, 1990) can increase the number of females which produce two litters per year, and may also result in yearling females breeding earlier than normal (D. Becker, pers. comm.) suggesting that food resources may limit reproductive output from year to year.

The excellent Englemann spruce cone crop during 1990 is no doubt responsible for the apparently high reproductive output, despite the lack of good food supplies in much of the SF habitat for the past four years. Red squirrel populations are regulated by food supply (Brink and Dean, 1966; C. Smith, 1968; M. Smith 1968; Sullivan and Sullivan, 1982; Sullivan, 1990; Klenner and Krebs, 1991), and apparently are able to anticipate an abundance of food with increases in reproductive effort before the maturation of a cone crop (Kemp and Keith, 1970; M. Smith, 1968).

Table 5. Lactation dates and litter size at emergence for nine adult females on the monitored areas in 1990. Midden numbers from 100 to 149 are on the LS area, numbers from 150 to 199 are on the US area, numbers from 200 to 219 are on the LC area. The litter size in parentheses was not used in the calculation of mean litter size.

LITTER	Midden #	Earliest Known Lactation Date	Litter Emerged	Litter Size
1	104	-	13 Jul	3
2	107	14 Jun	-	-
3	112	10 Jul	28 Jul	2
4	118	-	13 Nov	3
5	201	11 Jun	29 Jul	3 TRN
6	203	2 Jun	-	- TRN
7	209	2 May	18 Jun	3 TRN
8	156	28 Aug	-	(3)
9	124	-	28 Jun	2
Average			N = 6	2.67

Distribution and Density of Squirrels and Middens:

The density of red squirrel middens and of red squirrels is presented in two ways. The first method simply calculates the crude density of the middens and squirrels on each of the monitored areas by dividing the number of squirrels (or middens) by the area (in hectares: 1 ha = 2.47 acres) of each site. Because the monitored areas are all of different sizes, and contain different proportions of habitat that is suitable for red squirrels, it is desirable to analyze patterns of distribution and density in a manner which accounts for, or is not affected by these differences. One generally acceptable and common method for such comparisons is nearest neighbor analysis (Clark and Evans, 1954; Krebs, 1989). To properly use nearest neighbor analysis it is necessary to first know the precise locations of the individuals. In this case we use the middens, as a measure of centers of activity, as the location of individual squirrels. At this time we do not have the locations of the middens determined to the level of accuracy that we feel would provide the most benefit from nearest neighbor analysis. In addition, nearest neighbor analysis provides only limited information about the spacing of individuals. With highly territorial animals, such as red squirrels, it is desirable to know not only the distance to the **nearest** neighbor, but also **how many** neighbors each individual has.

As an alternative to using nearest neighbor distances, we have devised an index of the local density of the squirrels on each of the monitored areas that represents the number of middens and or squirrels that a squirrel occupying any given midden might perceive as being neighbors. The local density index is calculated as the number of middens (and new territories) or the number of squirrels within 100 meters of each midden (as measured on the midden maps). A radius of 100 m was chosen since this is the approximate distance at which human observers could hear and locate red squirrel chatters (rattle calls). The circle described around each midden by a 100 m radius encloses an area of 3.14 hectares (ha), providing a somewhat conservative approximation of the average Mt. Graham red squirrel home range (3.6 ha, from Froehlich, 1990). More accurate calculations of the local density, and nearest neighbor distances will be possible once the precise location of each midden can be surveyed and mapped.

All statistical comparisons of density were done using the local densities, no statistical comparisons were made on the crude densities.

Results:

Crude Density of Middens and Squirrels:

Despite the proportionately greater increase in squirrel populations in SF compared to TR, the crude density of squirrels in the SF areas in November (0.35 sq/ha on UC; 0.19 sq/ha on US) has remained lower than that in the TR areas (0.64 sq/ha on LC; 0.44 sq/ha on LS)(Fig. 2). The density of known middens in the SF areas was also lower than in TR (Table 6) so that the occupancy rates among areas are similar (Table 7). The US area continued to have the lowest density and occupancy of middens of all the areas monitored.

Local Density of Middens:

Differences in the **density of middens** among the four monitored areas disappear when local rather than crude density is considered (Table 8). A graph of the median number of middens within 100 m of each midden on the monitored areas (Fig. 3) makes it clear that, where red squirrel middens occur on the monitored areas, they are found at the same densities. There were no significant differences in the local density of middens among the four monitored areas during any month (Kruskal-Wallis Chi-Square Approximation, $P > 0.05$) with the exception of November 1990. In October and November several juvenile squirrels set up territories close to their mother(s) and siblings causing an increase in the local density of middens on the LC area. If those new territories are discounted the local density of middens on LC does not differ from that on the other three areas.

The local **density of squirrels** in the TR areas were significantly different from that in the SF areas for every month from September 1989 through November 1990 (Table 9; Fig. 4)(Wilcoxon 2-sample test, $P<0.05$ for all months). Further comparison of local squirrel densities, within habitats, failed to revealed any significant differences between the Lower Study and Control areas for any month (Wilcoxon 2-sample test, $P>0.05$ for all months). The Upper Study Area had significantly greater local squirrel densities than did the Upper Control Area in October and November 1989 and in April 1990 (Wilcoxon 2-sample tests, $P<0.05$), but did not differ for any other months ($P>0.05$). (Mean local densities of middens and squirrels change over time as new middens are found or established, and as midden occupancy changes).

The local density of middens and squirrels also appears to affect the pattern of re-occupancy of middens. While the median local midden density for all middens combined is 3, the median local midden density for occupied middens is 4, and that for unoccupied middens is 2. This difference is statistically significant, (Wilcoxon 2-sample test: $S=2488.5$, $Z=-3.7793$, $P>|Z|= 0.0002$, $N = 48$ unocc., 89 occ.) indicating that middens with higher local midden density values are preferred over middens with lower values. This is further illustrated by examining the frequency distribution of occupied and unoccupied middens classified by their local midden density (Fig. 5).

Summary and discussion of red squirrel densities:

1) **Red squirrel middens** (as an indicator of potential maximum population size) occurred in patches of equal local density within all of the monitored areas.

2) **Red squirrels** have occurred in lower local density in the SF areas compared to the TR areas from September 1989 through November 1990; however, the difference in density among habitat types decreased in late 1990.

3) There was no consistent, discernable difference in the local **density of squirrels** on the Study areas compared to the Control areas within habitat types. And, when differences are present, they were in the opposite direction as might be predicted if construction activity was having a detrimental effect on the squirrel populations.

4) The occupancy of a midden is apparently greatly affected by the local density of middens around that midden; middens with large local density values were more likely to be occupied than where more isolated middens.

Analysis of the local densities of middens and of squirrels has revealed an insightful and interesting comparison to the crude densities presented above. While the **crude density** of middens varies greatly within and among the habitats of the monitored areas, the **local density** of middens is remarkably consistent. This provides us with a more "level playing field" so that by using the local density rather than the crude density we are able to make direct comparisons of the distribution of squirrels and middens on the monitored areas. An important point to take from the local density index is the consistently greater local density of squirrels in the TR habitat compared to the SF habitat. The lower density of **squirrels** in SF habitat despite similar densities of **middens** may indicate that the SF habitat is lagging behind the TR habitat in its potential to support a red squirrel population.

There was no indication of any substantial amount of movements by adult squirrels from TR into SF habitat, though in the absence of marked individuals it is impossible to rule out such a possibility. Adult migration over long distances (> 1000 m) is unlikely given the generally philopatric behaviour of red squirrels (Price, et al. 1986; K. Larsen, pers. comm.) and has not been documented for any previously studied populations. Observations of the squirrels at newly occupied or newly established middens indicates that the increase in the squirrel populations on the areas was due to the recruitment of young of the year into the populations, the exact age structure of the population is impossible to determine without trapping individual squirrels.

Table 6. Density of red squirrels 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 (sq/ha); densities for the Lower Study area are based on the size given in parentheses which is an estimate of the amount of habitat on this area suitable for red squirrel habitation. Much of the LS area (approx. 48 ha) consists of open meadows, which is unsuitable for red squirrel habitation. Smaller portions of the other areas area also unsuitable for red squirrel habitation but no estimates of the suitable habitat on those areas have been made.

DATE	Lower Study Area 91 ha (43 ha)	Upper Study Area 89 ha	Lower Control Area 25 ha	Upper Control Area 122 ha
Middens/ha	0.26 (0.56)	0.34	0.77	0.52
Aug 1989	0.16	0.07	-	0.10
Sep 1989	0.26	0.07	0.27	0.08
Oct 1989	0.37	0.06	0.36	0.05
Nov 1989	0.33	0.07	0.27	0.04
Jan 1990	0.30	0.09	0.32	0.07
Feb 1990	0.30	0.08	0.27	-*
Mar 1990	0.23	0.08	0.27	0.07
Apr 1990	0.28	0.08	0.27	0.07
May 1990	0.26	0.07	0.32	0.07
Jun 1990	0.26	0.03	0.32	0.05
Jul 1990	0.26	0.03	0.50	0.05
Aug 1990	0.26	0.03	0.46	0.05
Sep 1990	0.21	0.06	0.36	0.12
Oct 1990	0.28	0.14	0.41	0.25
Nov 1990	0.44	0.19	0.64	0.35

* Data missing; census not made owing to poor weather and snow conditions.

Table 7. Per cent occupancy of middens on each of the monitored areas for each month during 1990. Only middens and territories where squirrels were visually verified were counted as occupied. Potentially occupied sites are not included.

MONTH	LOWER STUDY	LOWER CONTROL	UPPER STUDY	UPPER CONTROL
JAN	59	88	19	13
FEB	59	88	11	-
MAR	45	75	26	15
APR	55	67	26	15
MAY	50	70	22	15
JUN	45	40	11	12
JUL	27	50	11	12
AUG	32	40	15	12
SEP	39	54	22	27
OCT	52	64	45	53
NOV	64	82	55	61

Table 8. Univariate statistics for local midden density on the monitored areas in 1989 and 1990. Locations with the same superscript are not significantly different (Kruskal-Wallis test, $P > 0.05$).

DATE	Location	Number of Middens (n)	Number of middens within 100m of midden (inclusive)					
			Mean	Median	Mode	Standard Deviation	Max	Min
SEP 89	LC^a	6	2.67	3	3	0.516	3	2
	LS^a	12	2.83	3	2	1.267	5	1
	UC^a	52	2.75	3	2	0.988	5	1
	US^a	24	2.54	3	3	1.103	4	1
OCT 89	LC^a	9	2.67	3	2	1.000	4	1
	LS^a	22	2.95	3	1	1.704	6	1
	UC^a	52	2.75	3	2	0.988	5	1
	US^a	25	2.76	3	3	1.332	5	1
NOV 89	LC^a	9	2.67	3	2	1.000	4	1
	LS^a	22	2.95	3	1	1.704	6	1
	UC^a	52	2.76	3	2	1.023	5	1
	US^a	26	2.69	3	3	1.350	5	1
JAN 90	LC^a	8	2.63	3	3	0.916	4	1
	LS^a	22	3.36	3	1	2.150	7	1
	UC^a	52	2.77	3	2	1.022	5	1
	US^a	27	2.63	3	3	1.305	5	1
FEB 90	LC^a	8	2.63	3	3	0.916	4	1
	LS^a	22	3.36	3	1	2.150	7	1
	US^a	27	2.63	3	3	1.305	5	1
MAR 90	LC^a	8	2.63	3	3	0.916	4	1
	LS^a	22	3.36	3	1	2.150	7	1
	UC^a	52	2.77	3	2	1.054	5	1
	US^a	27	2.63	3	3	1.305	5	1
APR 90	LC^a	9	2.67	3	2	1.000	4	1
	LS^a	22	3.36	3	1	2.150	7	1
	UC^a	52	2.77	3	2	1.054	5	1
	US^a	27	2.63	3	3	1.305	5	1
MAY 90	LC^a	10	2.90	3	3	1.100	5	1
	LS^a	22	3.36	3	1	2.150	7	1
	UC^a	52	2.77	3	2	1.022	5	1
	US^a	27	2.63	3	3	1.305	5	1

JUN 90	LC[a]	10	2.90	3	3	1.100	5	1
	LS[a]	22	3.36	3	1	2.150	7	1
	UC[a]	52	2.73	3	3	1.073	5	1
	US[a]	27	2.63	3	3	1.305	5	1
JUL 90	LC[a]	10	2.90	3	3	1.100	5	1
	LS[a]	22	3.36	3	1	2.150	7	1
	UC[a]	52	2.73	3	3	1.073	5	1
	US[a]	27	2.63	3	3	1.305	5	1
AUG 90	LC[a]	10	2.90	3	3	1.100	5	1
	LS[a]	22	3.36	3	1	2.150	7	1
	UC[a]	52	2.73	3	3	1.073	5	1
	US[a]	27	2.63	3	3	1.305	5	1
SEP 90	LC[a]	13	3.38	4	4	1.557	6	1
	LS[a]	22	3.41	3	1	2.108	7	1
	UC[a]	56	2.88	3	3	1.070	5	1
	US[a]	27	2.74	3	3	1.318	5	1
OCT 90	LC[a]	14	3.50	4	4	1.401	6	1
	LS[a]	24	3.46	3	1	1.999	7	1
	UC[a]	58	2.86	3	3	1.089	5	1
	US[a]	31	3.06	3	3	1.289	5	1
NOV 90	LC[b]	17	4.47	4	2	2.125	8	1
	LS[a]	25	3.52	3	1	1.917	7	1
	UC[a]	64	3.20	3	3	1.262	6	1
	US[a]	31	3.13	3	4	1.360	5	1

Table 9. Univariate statistics for local squirrel density on the monitored areas in 1989 and 1990. Locations with the same superscript do not significantly differ (Kruskal-Wallis test, $P > 0.05$).

DATE	Location	Number of Middens (n)	Number of Squirrels within 100 m of midden					
			Mean	Median	Mode	Standard Deviation	Max	Min
SEP 89	LC^a	6	2.67	3.0	3	0.516	3	2
	LS^a	12	2.67	3.0	3	1.303	5	1
	UC^b	52	0.44	0.0	0	0.442	2	0
	US^b	24	0.63	1.0	1	0.625	1	0
OCT 89	LC^a	9	2.67	3.0	2	1.000	4	1
	LS^a	22	2.36	2.5	3	1.649	6	0
	UC^b	52	0.27	0.0	0	0.528	2	0
	US^c	25	0.52	1.0	1	0.510	1	0
NOV 89	LC^a	9	2.33	2.0	2	1.323	4	0
	LS^a	22	2.23	2.5	3	1.770	6	0
	UC^b	52	0.29	0.0	0	0.536	2	0
	US^c	26	0.62	1.0	1	0.496	1	0
JAN 90	LC^a	8	2.25	2.5	3	0.886	3	1
	LS^a	22	2.50	2.5	4	1.845	6	0
	UC^b	52	0.37	0.0	0	0.627	2	0
	US^b	27	0.44	0.0	0	0.506	1	0
FEB 90	LC^a	8	2.25	2.5	3	0.886	3	1
	LS^a	22	2.27	2.5	3	1.610	5	0
	US^b	27	0.37	0.0	0	0.492	1	0
MAR 90	LC^a	8	2.00	2.0	1	0.926	3	1
	LS^a	22	2.14	2.0	0	1.754	5	0
	UC^b	52	0.46	0.0	0	0.641	2	0
	US^b	27	0.67	1.0	1	0.480	1	0
APR 90	LC^a	9	1.67	1.0	1	1.118	3	0
	LS^a	22	2.18	2.0	4	1.680	5	0
	UC^b	52	0.38	0.0	0	0.491	1	0
	US^c	27	0.67	1.0	1	0.480	1	0
MAY 90	LC^a	10	2.00	2.0	2	1.155	4	0
	LS^a	22	2.09	2.0	4	1.688	5	0
	UC^b	52	0.40	0.0	0	0.495	1	0
	US^b	27	0.63	1.0	1	0.492	1	0

JUN 90	LC[a]	10	1.40	1.5	2	0.966	3	0
	LS[a]	22	2.05	2.0	0	1.721	5	0
	UC[b]	52	0.35	0.0	0	0.520	2	0
	US[b]	27	0.33	0.0	0	0.480	1	0
JUL 90	LC[a]	10	1.70	2.0	2	0.823	3	0
	LS[a]	22	1.27	1.0	0	1.386	4	0
	UC[b]	52	0.35	0.0	0	0.520	2	0
	US[b]	27	0.33	0.0	0	0.480	1	0
AUG 90	LC[a]	10	1.40	1.5	2	0.966	3	0
	LS[a]	22	1.50	0.5	0	2.041	5	0
	UC[b]	52	0.33	0.0	0	0.473	1	0
	US[b]	27	0.44	0.0	0	0.506	1	0
SEP 90	LC[a]	13	2.38	2.0	1	1.660	5	0
	LS[a]	22	1.50	1.0	0	1.596	4	0
	UC[b]	56	0.79	1.0	0	0.889	3	0
	US[b]	27	0.55	1.0	1	0.506	1	0
OCT 90	LC[a]	14	2.71	2.5	1	1.729	6	0
	LS[a]	24	2.17	1.5	1	1.949	6	0
	UC[b]	58	1.45	1.0	1	1.172	5	0
	US[b]	31	1.48	1.0	1	1.122	4	0
NOV 90	LC[a]	17	4.11	4.0	3	2.472	8	0
	LS[b]	25	2.68	2.0	2	2.135	7	0
	UC[b]	64	2.11	2.0	1	1.471	6	0
	US[b]	31	2.06	2.0	3	1.365	4	0

Figure 2. Changes in the density of squirrels on the monitored areas, from August 1989 through November 1990.

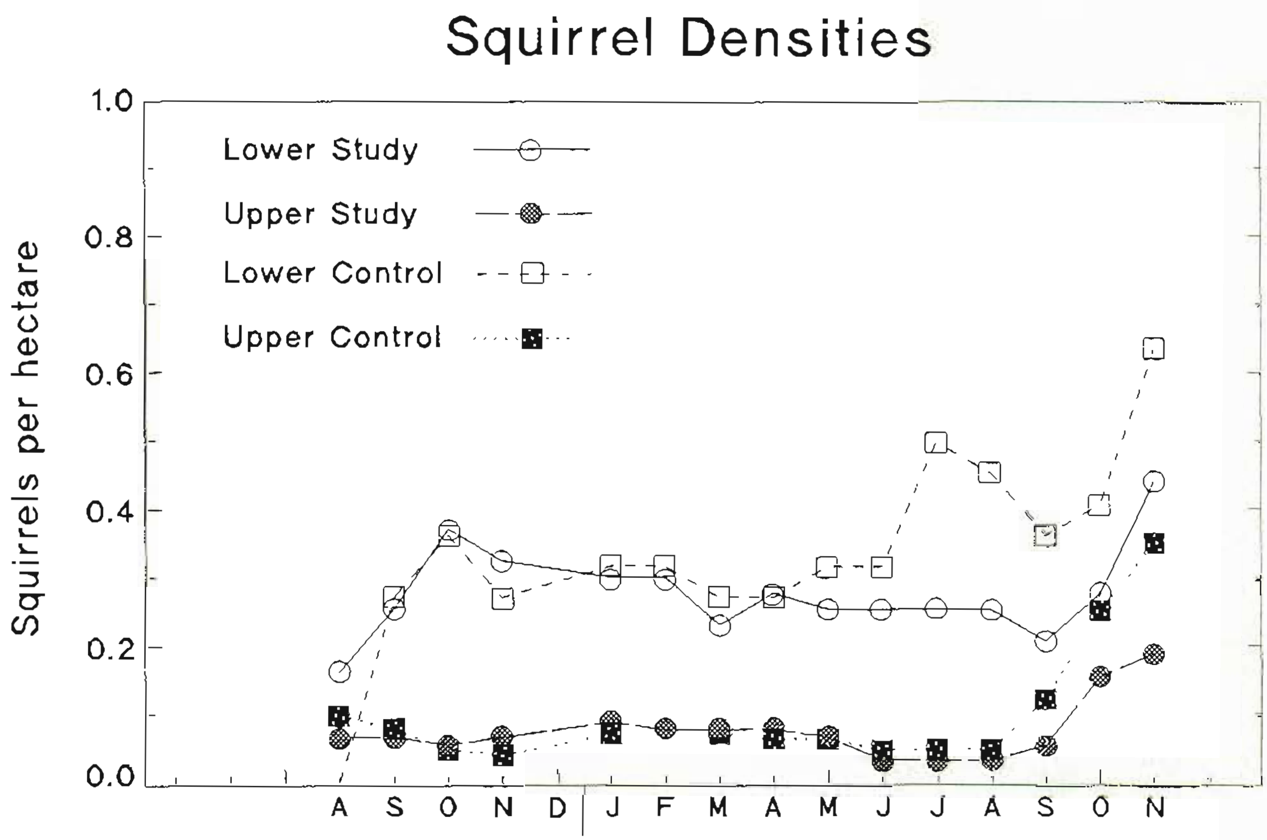


Figure 3. Median local density of red squirrel middens on each of the monitored areas from August 1989 through November 1990.

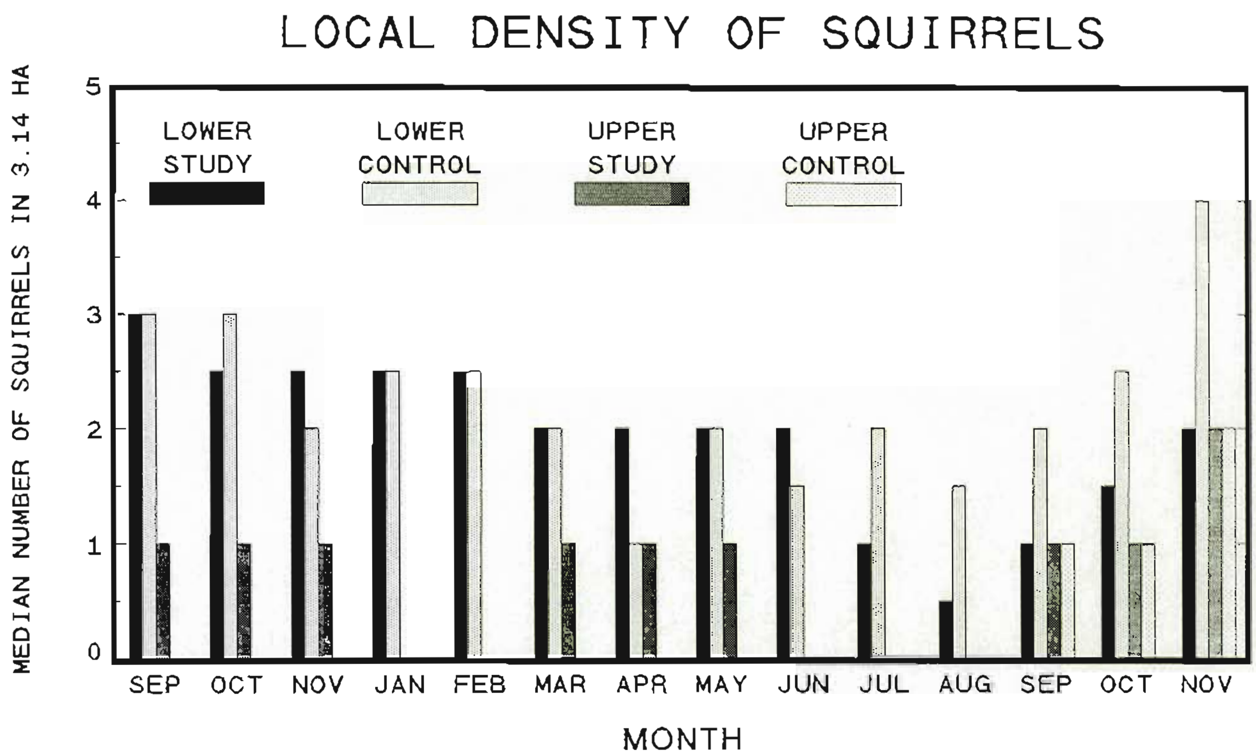


Figure 4. Median local density of red squirrels for each of the monitored areas from August 1989 through November 1990.

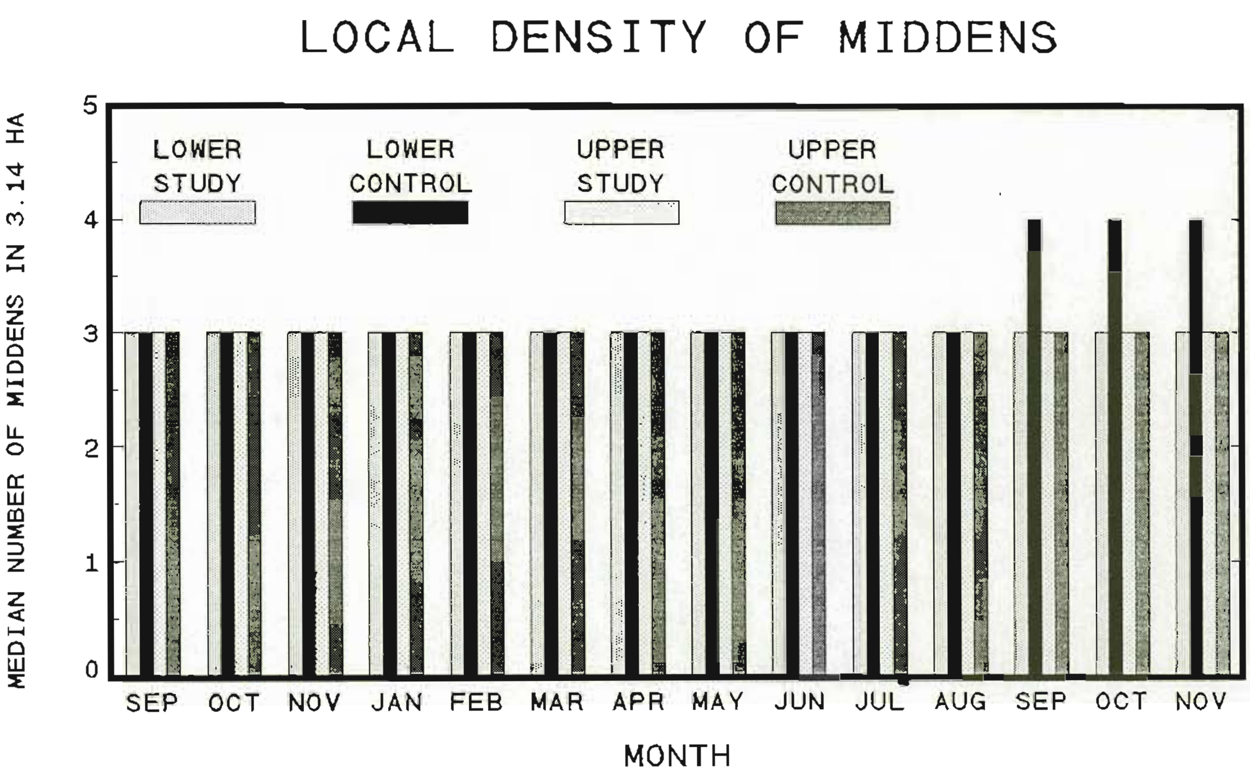
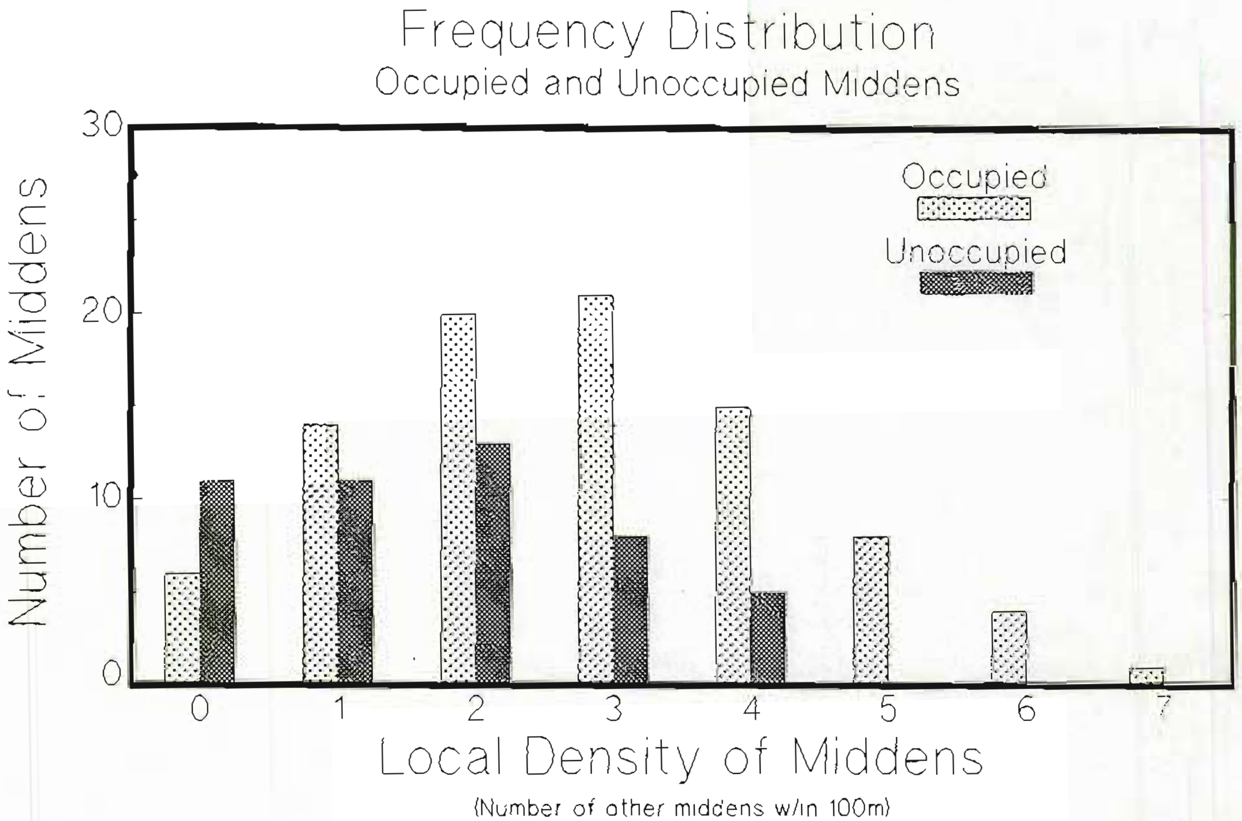


Figure 5. Frequency distribution of occupied and unoccupied middens, classified by local midden density (number of other middens within 100m).



Occupancy of Middens Near Construction:

This section tests for the potential effect of construction activity on the occupancy of squirrel middens. The analysis looks at the ratio of occupied to unoccupied middens within different distance zones from the new access road and construction sites. The occupancy of middens along sections of old FR 669 & 507 are used for comparison. The hypothesis behind the analysis is: if construction of the road has affected the quality of some middens, and thus affected the potential for these middens to be occupied by a squirrel, this effect will diminish with increasing distance from the road. If there is an effect we would expect to find a significant difference in the ratio of occupied to unoccupied middens when comparing middens in the different distance zones within the Study Area. The Control Area may not show any effect in zones extending out from FR 669 and FR 507 since there has been little or no recent construction type disturbance in that area. These roads have been in place for several decades, presumably long enough for the edge effect to stabilize and for the squirrel populations along them to adjust to new environmental conditions created by the construction of these roads. A comparison of the ratio of occupied to unoccupied middens in the zones around FR's 507 & 669 to that around the construction sites and access road should provide insight into the pattern of occupancy that might be expected to occur along previously established roadways in the Subalpine Forest region (spruce/fir) of the Grahams.

This analysis is designed to test for the effect of construction related noise and disturbances and not for the effect of the placement of the road.

The analysis was performed on the Upper Areas only, owing to the complicated nature of the position of middens on the Lower areas in relation to Swift Trail, the Bible Camp road, and the new access road. Of the 24 middens (or territories) on the Lower Study Area, 8 (33%) are closer to Swift Trail than they are to the access road and 52% of all the middens known on the Lower Study area, Lower Control area and adjacent areas are within 100m of a road.

The analysis was performed on the data from the 30-day Pre-construction period, from November 1989, and November 1990. It is possible to perform the same analysis on a monthly basis, but such frequent examination of the data would not add much insight.

Results:

The results of Type 2 (some expected values are less than 5) RXC contingency tables comparing the ratio of occupied to unoccupied middens on the Upper Study and Control Areas suggests that the two areas did not differ in the occupancy of middens during the pre-construction period nor at the end of construction in 1989 (Tables 10a & b). The comparison of occupancy for November 1990 (Table 10c) indicates a potential for a difference in the occupancy of middens within 100 m of the construction area (test is marginally non-significant, $P=0.057$).

No difference in the ratio of occupied and unoccupied middens is apparent when the occupancy of middens is examined among distance zones within each area (Tables 11 and 12).

A potential for some effect on the occupancy of middens from construction activity is shown when the change in midden occupancy from 1989 to 1990 is examined for each distance zone within areas (Tables 13 and 14). On the Upper Study area there was a significant increase in the occupancy of middens in the 201-300 m zone, but no significant increase in the occupancy of middens within 0-100 or 101-200 m from construction activity (Table 13). In contrast, all distance zones on the Upper Control area show a significant increase in the ratio of occupied to unoccupied middens (Table 14).

Summary and Discussion:

1) Midden occupancy within 100m wide zones extending from the new access road, and in comparable zones along FR 507 and 669, did not differ significantly **within** areas for any of the three time periods analyzed.

2) Midden occupancy within each distance zone did not differ significantly **between** the Upper Study and Upper Control area for any of the three time periods analyzed.

3) The year-to year change in midden occupancy showed a statistically significant difference for all distance zones on the Upper Control Area, but not on the Upper Study Area. Midden occupancy on the Upper Study Area showed a statistically significant year-to year difference only in the 201-300 m distance zone.

The resolving power of the statistical tests used is not very great because of the small number of occupied middens in August and September of 1989. The analysis is also complicated by the fact that the access road was designed to avoid midden sites and therefor the number of middens within the first distance zone (0-100m) on the Study area is much smaller than in the other zones on the Study Area or for comparative purposes, on the Control Area. There is nothing we can do to increase the sample size, although it is interesting to note that two new territories were established within this zone in winter 1990-91. The extensive firebreak along FR 507 also affects the distribution of middens within the first distance zone along that road on the Upper Control area, however FR 669 does not have an associated fire break and provides a suitable comparison for the new access road.

The disparity between the Upper Study and Upper Control areas in the change in midden occupancy between 1989 and 1990 (#3 above) suggests that immigrating squirrels may have avoided occupying middens nearest to construction in 1990.

However, this is not the only interpretation that can be applied to this data. The pattern of immigration of squirrels onto the Upper Study and Control Areas is subject to the available sources of dispersing squirrels. If the potential source of squirrels on the Study area is smaller, or farther away, from the source of squirrels for the Control Areas, that could result in the same disparity in pattern of midden occupancy that occurred between these areas in November 1990. The distribution of middens in the areas around the Upper Study and Control Areas, as shown on the 1990 Forest Service midden maps, suggests that this is in fact the cause of any differences in midden occupancy on these areas. This interpretation is further supported by the fact that the population of squirrels on the Upper Study Area continued to increase after November 1990 (4th Quarterly Report 1990).

A third potential explanation becomes apparent when the occupancy of middens is examined in relation to the local density of middens. In a previous section of this report, it is pointed out that the local density of middens appears to have some effect, or is correlated, with the occupancy status of the middens. When the median local density of middens on the monitored areas, (excluding the Upper Study Area), is examined, a pattern is evident (Unoccupied middens: median local density = 1, N = 34; Occupied middens: median local density = 4, N=72). The location of the access road, designed to avoid red squirrel middens, means that there are few middens within 100 m of the road. Furthermore, the road generally runs through areas that are less likely to have middens (south or west facing slopes: Mannan and Smith, 1991) and therefor the middens within 100 m of the access road are more widely scattered than on other areas of the mountain. In November 1990, the median local density of middens within 100 m of the road and telescope sites (median= 1, N=5) was smaller than the median local density of middens in the 101-200 m (median = 3, N=15) or the 201-300 m distance zones (median = 4, N=11). When the pattern of occupancy relative to the local density of middens is taken into consideration, it would be expected that few, if any of the middens within 100 m of the road would be occupied. One could also expect fewer of the middens in the 101-200 m zone to be occupied than in the 201-300 m zone.

Table 10. Ratio of Occupied to Unoccupied Middens at Different Distances from the New Access Road and from FR 669 & 507. Results of Randomization tests for Type 2 RXC Contingency Tables for between area comparisons in September 1989 (end of Pre-construction period; 10a), November 1989 (10b), and November 1990 (10c).

Table 10a. September 1989

Number of Middens	0-100m US	0-100m UC	101-200m US	101-200m UC	201-300m US	201-300m UC
Occupied	0	3	2	4	2	2
Unoccupied	5	19	10	13	6	5
G=	1.311		0.206		0.024	
P=	0.372		0.703		0.964	

Table 10b. November 1989.

Number of Middens	0-100m US	0-100m UC	101-200m US	101-200m UC	201-300m US	201-300m UC
Occupied	1	1	4	2	1	0
Unoccupied	4	21	7	15	9	11
G=	1.119		2.361		1.539	
P=	0.300		0.154		0.407	

Table 10c. November 1990.

Number of Middens	0-100m US	0-100m UC	101-200m US	101-200m UC	201-300m US	201-300m UC
Occupied	1	17	9	12	8	11
Unoccupied	4	7	6	10	3	1
G=	4.517		0.108		1.479	
P=	0.057		0.770		0.306	

Table 11. Ratio of Occupied to Unoccupied Middens at Different Distances from the New Access Road. Results of Randomization tests for Type 2 RXC Contingency Tables for within area, among distance zones comparisons for September 1989 (end of Pre-construction period; 11a), November 1989 (11b), and November 1990 (11c).

Table 11a. September 1989

Number of Middens	0-100m	101-200m	201-300m
Occupied	0	2	2
Unoccupied	5	10	6
G = P =		2.173 0.465	

Table 11b. November 1989

Number of Middens	0-100m	101-200m	201-300m
Occupied	1	4	1
Unoccupied	4	7	9
G = P =		2.164 0.446	

Table 11c. November 1990

Number of Middens	0-100m	101-200m	201-300m
Occupied	1	9	8
Unoccupied	4	6	3
G = P =		4.080 0.153	

Table 12. Ratio of Occupied to Unoccupied Middens at Different Distances from FR 669 & 507 on the Upper Control Area. Results of Randomization tests for Type 2 RXC Contingency Tables for within Area, among distance zones comparisons for September 1989 (end of Pre-construction period; 12a), November 1989 (12b), and November 1990 (12c).

Table 12a. September 1989

Number of Middens	0-100m	101-200m	201-300m
Occupied	3	4	2
Unoccupied	19	13	5
G = P =		1.025 0.648	

Table 12b. November 1989

Number of Middens	0-100m	101-200m	201-300m
Occupied	1	2	0
Unoccupied	21	15	11
G = P =		2.246 0.479	

Table 12c. November 1990

Number of Middens	0-100m	101-200m	201-300m
Occupied	17	12	11
Unoccupied	7	10	1
G = P =		5.673 0.072	

Table 13. Ratio of Occupied to Unoccupied Middens at Different Distances from the New Access Road (US area). Results of Randomization tests for Type 2 RXC Contingency Tables for year-to-year (November 1989 - November 1990) comparisons.

Number of Middens	0-100m 1989	0-100m 1990	101-200m 1989	101-200m 1990	201-300m 1989	201-300m 1990
Occupied	1	1	4	9	1	8
Unoccupied	4	4	7	6	9	3
G=	0.0		1.433		9.290	
P=	1.0		0.275		0.004	

Table 14. Ratio of Occupied to Unoccupied Middens at Different Distances from FR 669 & 507 (UC area). Results of Randomization tests for Type 2 RXC Contingency Tables for year-to-year (November 1989 - November 1990) comparisons.

Number of Middens	0-100m 1989	0-100m 1990	101-200m 1989	101-200m 1990	201-300m 1989	201-300m 1990
Occupied	1	17	2	12	0	11
Unoccupied	21	7	15	10	11	1
G=	24.468		8.289		24.957	
P=	<0.000		0.005		<0.000	

Habitat and Microenvironment:

A study on the microenvironmental conditions and habitat structure at red squirrel middens and in areas potentially affected by construction of the MGIO was initiated in 1990. The purpose of this portion of the Monitoring Program is to characterize microenvironmental conditions at midden sites in relation to the habitat structure and location and to attempt to determine the extent to which new forest openings (due to construction) may degrade potential squirrel habitat.

Microenvironmental data (soil temperature, soil moisture) was collected at 20 middens and along 30 transects during the summer of 1990. This year (1991) the number of midden stations will be increased to 40 and more transects will be surveyed to include the proposed alternate sites for the Columbus telescope. In addition to soil temperature and soil moisture, a pilot project will be initiated in spring 1991 to devise an index for measuring surface evaporation at the microenvironmental stations. Information on habitat structure is critical to the analysis of the microenvironmental data. The effects of habitat structure on variation in the microenvironmental variables must be known in order to accurately asses the effect of new forest openings. Data on the habitat structure at midden sites is being collected by A. Smith and is not yet available. Monitoring Program personnel will be trained by A. Smith and begin measuring habitat structure at the microenvironment transect stations in 1991. It is expected that the habitat structure data will be collected from all of the transect station by the end of 1992. The microenvironmental variables will continue to be recorded during 1991 and 1992 so that at least two full summer seasons are recorded for every station. A full analysis of this data will be conducted at the end of the data collecting period.

It is important to note that the microenvironmental study is not designed to test whether or not an "edge effect" exists. It is assumed that the edge effect exists, and the study is designed to measure the extent of such an effect with respect to environmental variables that may have a direct influence on the quality of a site to support a red squirrel midden. Since the function of a midden is to store conifer cones by providing a cool, moist substrate that preserves the seeds as a food supply for the resident squirrel, the environmental variables deemed to be most important are soil temperature, soil moisture, and surface evaporation.

Behavior:

The Monitoring program studied the behavior of red squirrels on the monitored areas in an effort to determine whether or not the noise and activity associated with the construction of the observatory has affected the behavior of the squirrels on the Study Areas. Behavioral data was collected during 2-hour observations at midden sites conducted at regular intervals during the day. Observations on the Study Areas were paired with an observation at the same time on the corresponding Control Area in similar habitat (see U of A - Red Squirrel Monitoring Program protocol for details). The observations focussed on activity at the midden site, and are comparable in theory to focal animal observations (Altmann, 1974). From these observations we were able to test for differences in some measures of daily activity patterns and time budgets of the squirrels on the Study and Control Areas as well examine for potential effects of disturbances on the behavior of squirrels.

The Monitoring Program began conducting 2-hour midden observations in April 1990 in anticipation of the start of construction. There was minimal construction activity on the mountain until October 1990 (App. B) so that most of the observations occurred during non-construction periods (Table 15). Three paired observations were conducted on most days, except when weather conditions made it impossible. The observations were regularly spaced throughout the day starting at 0700, 0800, 1000, 1100, 1300, 1400, or 1600 h depending on the season. During the summer months, (June-August) observations were conducted on an alternating schedule, starting early one day (0700, 1000, and 1300 h) and late (1000, 1300, and 1600 h) the following day. In the spring (March-May) and autumn (September-November) observations were started at 0800, 1100 and 1400 h.

Table 15. Cross tabulation showing the number of observations in relation to construction activity.

	Construction Days				Non-construction Days			
Area	LS	LC	US	UC	LS	LC	US	UC
# OBS	25	25	61	61	58	58	63	65
Hrs. OBS	50	50	122	122	116	116	126	130

Total Number of Observations 416
Total Hours Observation 832

Days with...	Observations	No Observations
Construction	37	11
No Construction	44	-

Activity patterns:

The activity patterns of the squirrels were compared by using the amount of time the squirrels spent at the observed midden sites, and the number of visits to the midden by the resident squirrel, as indices of activity. A paired t-test (Snedecor and Cochran, 1980) was used for the comparison among Study and Control Areas since it takes advantage of the paired nature of the observations to control for abiotic effects (weather, time of day, season, etc.). There was no attempt to pair observations by the sex or age of the resident squirrel at each midden.

The null hypothesis is that squirrels on the Study Areas spent the same amount of time at the midden (and conversely, the same amount of time out of the midden) as did squirrels on the Control Areas. Some aspects of the vocal behavior (# Chatters, # Squeaks, # Barks, time spent Barking) of the squirrels were also tested for differences among the monitored areas by the use of paired t-tests.

Initially, the observation data was separated into groups by habitat type (TR & SF) based on the discovery in 1989 of behavioral differences among squirrels in different habitats. An analysis of time partitioning by squirrels in different habitats (below) indicated that some behavioral differences among habitats also existed in 1990, further supporting the decision to analyze the behavior data within habitats. The data was also separated by days with or without construction activity, but not by season. Only pairs of observations in which a squirrel was present at both middens were used, to prevent biasing the data by the potential inclusion of unoccupied middens in the sample. The number of observations where a squirrel **was not observed**, did not differ among Study and Control areas during the summer or autumn (Chi^2 test, $P > 0.05$). During spring season observations we were less likely to observe a squirrel at the Study area middens than at Control Area middens (Chi^2 test, $P < 0.05$: see App. D).

The non-construction day observations were tested for differences among the Study and Control populations for the entire summer and autumn. There was no construction during the Spring or Summer seasons, only in Autumn; therefor comparisons between populations during construction were for the Autumn season only. When differences in the activity of squirrels on the TR areas were detected for non-construction days, a further analysis was made by season in order to examine this trend in more detail.

In order to further characterize the activity of red squirrels at midden sites, the average duration of visits to the midden and average interval between visits were calculated and compared among populations. Only complete visits were used in the calculations (i.e., the start and end of each visit was known). In order to increase sample sizes, all observations, not just those where a squirrel was observed at both middens, were used as a data base. The data is not paired and the small sample size, in many cases, prompted the use of non-parametric statistics (Wilcoxon Rank Sums test) for comparisons among populations.

Results:

Non-seasonal Analysis (construction and non-construction)

There were no significant differences between Study and Control populations in the TR or SF habitats in the number of visits to the midden, time spent at the midden, or measures of vocal behavior on days without construction (Tables 16a & 16b). During periods of construction, there was a statistically significant difference in the **number of chatters** per 2-hour observation by squirrels on the Lower Study Area compared to squirrels on the Lower Control Area (Table 17a). All other differences in measures of activity between the TR areas were not significantly different.

There were no significant differences in the number of visits to the midden, time spent at the midden, or in measures of vocal behavior among squirrels on the Upper Areas, during construction activity (Table 17b). The univariate statistics for the variables tested for each population are shown in Tables 18a & 18b.

Seasonal analysis (non-construction only)

Because all of the construction occurred during Autumn, this was the only season for which both, construction and non-construction observations were available. It was possible that the discrepancy in pattern of vocal behavior between the Lower Area populations (# chatters > on LS than LC during construction but not during non-construction) was due to the combination of the Summer and Autumn data for the non-construction observations. To further examine this data, the observations were separated by season and paired t-tests were performed to see if the two populations differed in vocal activity during non-construction days in Autumn (the Construction season). The data for the Upper Areas were also tested, though the small sample size ($n=8$) for non-construction observations on these areas limits the usefulness of such statistical procedures. Sample sizes for Spring in both habitats and for Summer were too small ($n<5$) to perform statistical tests. (NOTE: Since all construction took place in Autumn, the tables showing the results of paired t-tests for observations during construction days are the same for the non-seasonal and seasonal analysis, and are not repeated).

There were no statistically significant differences ($P>0.05$) in any of the measures of activity during non-construction period observations on the Lower Areas in Summer (Table 19a) or in Autumn (Table 19b). This further supports the indication from the non-seasonal analysis that there was a difference between the Lower Area populations, in the rate of chatters during construction activity.

There were no statistically significant differences in any of the measures of activity during non-construction period observations on the Upper Areas in Autumn (Table 19c).

Univariate statistics for the variables tested are given in Tables 20a, b, & c.

Duration and Interval Between Visits to a Midden

There were no significant difference in the interval between visits nor in the duration of visits for squirrels on the Study or Control Areas in either Habitat during periods of construction or non-construction in Autumn (Tables 21a,b; 22a,b). There were no differences among Study and Control populations in either Habitat in the duration or interval between visits in Summer (Tables 23a,b).

Summary and discussion of activity patterns:

1) There were no differences in the number of visits made to the midden or in the amount of time spent at the midden by squirrels on the Study or Control Areas, in either habitat, during construction or non-construction periods.

2) The vocal activity of squirrels on the Lower Areas differed in the number of chatters elicited by the resident squirrel during construction activity, but not during period without construction activity; squirrels on the LS area chattered an average of 0.69 times more per 2-hours than did squirrels on the LC area. No other measures of vocal activity differed between Study and Control populations in either the TR or SF habitat during construction or non-construction periods.

3) There were no differences among Study and Control Area squirrels in the duration or interval of visits to the midden during construction or non-construction periods.

It is reasonable to conclude from these results that there were no differences between the activity patterns of squirrels on the Study Areas and that of the squirrels on the Control Areas caused by construction activity in 1990.

The one significant difference in vocal behavior (# Chatters on Lower Areas: a difference of less than 0.5 chatters per hour) is probably not of much biological relevance. Many factors influence the rate of chattering by red squirrels; season, time of day, density of squirrels, and food supply (D. Becker, pers. comm., Pers. Obs.). The chatter (or rattle call) is primarily used for intraspecific territorial disputes (Nadler, 1973) and does not necessarily indicate an increased level of agitation caused by human activity though red squirrels will chatter at humans in their midden area (pers. obs.). The "bark" call functions as more of an indication of the level of agitation of a squirrel and no differences were found in the number of barks given or the duration of barking by squirrels on the Study and Control Areas.

Table 16a. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Lower Study and Control Areas on days with no construction. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=28	Mean	Std. Error	T	P>|T|
# visits	0.00	0.46	0.00	1.0000
Time at Midden	-8.31	8.50	-0.98	0.3367
# Chatters	0.61	0.30	2.01	0.0540
# Squeaks	-0.14	0.44	-0.33	0.7455
# Barks	-0.32	0.55	-0.58	0.5650
Time Barking	-1.94	1.07	-1.82	0.0802
# Whimpers	0.00	0.00	.	.
# Growls	0.04	0.04	1.00	0.3263

Table 16b. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Upper Study and Control Areas on days with no construction. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=15	Mean	Std. Error	T	P>|T|
# visits	-0.53	0.53	-1.00	0.3343
Time at Midden	0.04	15.92	0.00	0.9978
# Chatters	0.20	0.34	0.59	0.5667
# Squeaks	0.20	0.49	0.41	0.6893
# Barks	-0.33	0.27	-1.23	0.2377
Time Barking	0.29	1.55	0.19	0.8524
# Whimpers	0.07	0.12	0.56	0.5816
# Growls	0.00	0.00	.	.

Table 17a. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Lower Study and Control Areas on days with construction. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=16	Mean	Std. Error	T	P>|T|
# visits	-0.31	0.43	-0.73	0.4739
Time at Midden	-3.65	9.78	-0.37	0.7138
# Chatters	**0.69**	**0.30**	**2.30**	**0.0362**
# Squeaks	0.06	0.57	0.11	0.9136
# Barks	0.50	0.33	1.52	0.1495
Time Barking	0.42	1.22	0.35	0.7328
# Whimpers	0.00	0.00	.	.
# Growls	0.00	0.00	.	.

Table 17b. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Upper Study and Control Areas on days with construction. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=38	Mean	Std. Error	T	P>|T|
# visits	-0.39	0.72	-0.55	0.5884
Time at Midden	-2.98	9.06	-0.33	0.7437
# Chatters	-0.03	0.28	-0.09	0.9265
# Squeaks	0.53	0.36	1.45	0.1557
# Barks	0.13	0.29	0.45	0.6555
Time Barking	0.68	0.75	0.91	0.3695
# Whimpers	-0.03	0.03	-1.00	0.3238
# Growls	0.00	0.00	.	.

Table 18a. Univariate statistics for the variable used in paired t-tests. Only the data from observations where a squirrel was observed at each midden of a paired observation were used to construct this table. The data was not separated by season.

	Construction n=16		No Construction n=28	
	LS Area mean (st. dev.)	LC Area mean (st. dev.)	LS Area mean (st. dev.)	LC Area mean (st. dev.)
# Visits	2.31 (1.14)	2.62 (1.75)	2.21 (1.50)	2.21 (1.81)
Time @ Midden	70.19 (37.01)	73.83 (34.58)	51.94 (38.01)	60.25 (45.23)
# Chatters	0.94 (1.24)	0.25 (0.77)	0.79 (1.40)	0.18 (0.61)
# Squeaks	0.94 (1.53)	0.88 (1.45)	0.64 (1.31)	0.79 (1.79)
# Barks	1.19 (1.17)	0.69 (0.95)	1.07 (1.96)	1.39 (2.18)
Time Barking	2.24 (2.92)	1.81 (3.30)	1.74 (3.17)	3.68 (5.16)
Whimpers	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Growls	0.13 (0.50)	0.0 (0.0)	(0.04 (0.19)	0.0 (0.0)

Table 18b. Univariate statistics for the variable used in paired t-tests. Only the data from observations where a squirrel was observed at each midden of a paired observation were used to construct this table. The data was not separated by season.

	Construction n=38		No Construction n=15	
	US Area mean (st. dev.)	UC Area mean (st. dev.)	US Area mean (st. dev.)	UC Area mean (st. dev.)
# Visits	2.87 (3.00)	3.26 (3.23)	1.73 (0.80	2.27 (2.05)
Time @ Midden	68.81 (31.67)	70.54 (39.55)	57.50 (35.71)	57.46 (41.71)
# Chatters	0.47 (1.01)	0.50 (1.27)	0.40 (1.12)	0.20 (0.56)
# Squeaks	1.32 (2.11)	0.79 (1.02)	1.20 (2.93)	1.00 (1.65)
# Barks	1.26 (1.43)	1.13 (1.32)	0.47 (0.92)	0.80 (1.47)
Time Barking	2.24 (3.26)	1.56 (3.23)	2.42 (5.45)	2.13 (5.27)
Whimpers	0.0 (0.0)	0.03 (0.16)	0.13 (0.35)	0.07 (0.26)
Growls	0.0 (0.0)	0.03 (0.16)	0.0 (0.0)	0.0 (0.0)

Table 19a. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Lower Study and Control Areas on days with no construction in Summer. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=12	Mean	Std. Error	T	P>|T|
# visits	-0.25	0.63	-0.40	0.6987
Time at Midden	-1.96	9.80	-0.20	0.8452
# Chatters	0.25	0.18	1.39	0.1911
# Squeaks	-0.58	0.86	-0.68	0.5101
# Barks	0.50	0.85	0.59	0.5675
Time Barking	-1.82	1.75	-1.04	0.3204
# Whimpers	0.00	0.00	.	.
# Growls	0.08	0.08	1.00	0.3388

Table 19b. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Lower Study and Control Areas on days with no construction in Autumn. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=15	Mean	Std. Error	T	P>|T|
# visits	0.27	0.71	0.38	0.7116
Time at Midden	-15.68	13.71	-1.14	0.2718
# Chatters	0.87	0.54	1.60	0.1323
# Squeaks	-0.07	0.36	-0.19	0.8550
# Barks	-1.00	0.76	-1.32	0.2071
Time Barking	-2.16	1.46	-1.48	0.1620
# Whimpers	-	-	-	-
# Growls	-	-	-	-

Table 19c. Results of paired t-tests, on the differences (Study - Control) in some measures of activity, between squirrels on the Upper Study and Control Areas on days with no construction in Autumn. Negative mean values indicate a smaller value for squirrels on the Study Areas compared to the Control Areas. Only paired observations where a squirrel was observed at both middens were considered.

Variable N=8	Mean	Std. Error	T	P>|T|
# visits	-1.12	0.91	-1.23	0.2586
Time at Midden	6.75	25.45	0.27	0.7986
# Chatters	-0.25	0.25	-1.00	0.3506
# Squeaks	0.00	0.53	0.00	1.000
# Barks	-0.38	0.32	-1.16	0.2849
Time Barking	0.89	2.95	0.30	0.7707
# Whimpers	-	-	-	-
# Growls	-	-	-	-

Table 20a. Univariate statistics for measures of red squirrel activity used in the preceding paired t-tests. Values are for the Summer Season only.

Summer	No Construction n=12	
	LS Area mean ±st. dev.	LC Area mean ±st. dev.
# Visits	1.58 ±0.79	1.83 ±1.75
Time @ Midden	33.67 ±32.77	35.63 ±34.19
# Chatters	0.25 ±0.62	0.00 ±0.00
# Squeaks	0.50 ±1.45	1.08 ±2.35
# Barks	1.25 ±2.63	0.75 ±1.71
Time Barking	1.49 ±3.34	3.32 ±5.54
Whimpers	0.00 ±0.00	0.00 ±0.00
Growls	0.08 ±0.29	0.00 ±0.00

Table 20b. Univariate statistics for measures of red squirrel activity used in the preceding paired t-tests. Values are for the Autumn Season only.

Autumn	Construction n=16		No Construction n=15	
	LS Area mean ±st. dev.	LC Area mean ±st. dev.	LS Area mean ±st. dev.	LC Area mean ±st. dev.
# Visits	2.31 ±1.14	2.62 ±1.75	2.80 ±1.74	2.53 ±1.92
Time @ Midden	70.19 ±37.01	73.83 ±34.58	62.02 ±34.89	77.70 ±45.81
# Chatters	0.94 ±1.24	0.25 ±0.77	1.20 ±1.74	0.33 ±0.82
# Squeaks	0.94 ±1.53	0.88 ±1.45	0.53 ±0.92	0.60 ±1.30
# Barks	1.19 ±1.17	0.69 ±0.95	1.00 ±1.36	2.00 ±2.45
Time Barking	2.24 ±2.92	1.81 ±3.30	2.07 ±3.19	4.22 ±5.08
Whimpers	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
Growls	0.13 ±0.50	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00

Table 20c. Univariate statistics for measures of red squirrel activity used in the preceding paired t-tests. Values are for the Autumn Season only, as this was the only season during which construction occurred.

	Construction n=38		No Construction n=8	
	US Area mean ±st. dev.	UC Area mean ±st. dev.	US Area mean ±st. dev.	UC Area mean ±st. dev.
# Visits	2.87 ±3.00	3.26 ±3.23	1.87 ±0.83	3.00 ±2.56
Time @ Midden	68.81 ±31.67	70.54 ±39.55	74.00 ±36.27	67.25 ±44.41
# Chatters	0.47 ±1.01	0.50 ±1.27	0.00 ±0.00	0.25 ±0.71
# Squeaks	1.32 ±2.11	0.79 ±1.02	0.75 ±1.49	0.75 ±0.71
# Barks	1.26 ±1.43	1.13 ±1.32	0.75 ±1.16	1.12 ±1.73
Time Barking	2.24 ±3.26	1.56 ±3.23	4.48 ±7.00	3.58 ±7.00
Whimpers	0.00 ±0.00	0.03 ±0.16	0.00 ±0.00	0.00 ±0.00
Growls	0.00 ±0.00	0.03 ±0.16	0.00 ±0.00	0.00 ±0.00

Table 21a. Mean, standard deviation and results of Wilcoxon 2-sample tests comparing the average interval (minutes) between visits to midden by squirrels on the Lower (TR) Areas during construction and non-construction periods in Autumn.

Average Interval Between Visits to Midden				
Autumn	Construction		No Construction	
	LS	LC	LS	LC
n=	11	11	10	10
mean	15.96	16.43	23.93	17.54
st. dev.	11.69	13.16	25.71	17.69
P =	0.8438		0.5708	

Table 21b. Mean, standard deviation and results of Wilcoxon 2-sample tests comparing the average duration (minutes) of visits to midden by squirrels on the Lower (TR) Areas during construction and non-construction periods in Autumn.

Average Duration of Visits to Midden				
Autumn	Construction		No Construction	
	LS	LC	LS	LC
n=	11	12	11	11
mean	21.73	11.22	19.47	12.33
st. dev.	28.39	12.19	16.33	14.25
P =	0.1164		0.1075	

Table 22a. Mean, standard deviation and results of Wilcoxon 2-sample tests comparing the average interval (minutes) between visits to midden by squirrels on the Upper (SF) Areas during construction and non-construction periods in Autumn.

Average Interval Between Visits to Midden				
Autumn	Construction		No Construction	
	US	UC	US	UC
n=	31	28	6	4
mean	20.08	14.03	29.42	19.11
st. dev.	19.94	12.74	22.20	16.33
P =	0.3623		0.5940	

Table 22b. Mean, standard deviation and results of Wilcoxon 2-sample tests comparing the average interval (minutes) between visits to midden by squirrels on the Upper (SF) Areas during construction and non-construction periods in Autumn.

Average Duration of Visits to Midden				
Autumn	Construction		No Construction	
	US	UC	US	UC
n=	30	31	5	9
mean	19.31	15.67	20.40	13.40
st. dev.	20.22	17.08	11.48	16.55
P =	0.3121		0.5309	

Table 23a. Mean, standard deviation and results of Wilcoxon 2-sample tests comparing the average duration of visits and average interval (minutes) between visits to midden by squirrels on the Lower (TR) Areas during non-construction periods in Summer. There was no construction during Summer

Summer	Average Duration		Average Interval	
	LS	LC	LS	LC
n=	11	12	5	6
mean	12.78	21.53	26.21	21.91
st. dev.	14.39	23.56	18.78	25.65
P =	0.3557		0.5228	

Table 23b. Mean, standard deviation and results of Wilcoxon 2-sample tests comparing the average duration of visits and average interval (minutes) between visits to midden by squirrels on the Lower (TR) Areas during non-construction periods in Summer. There was no construction during Summer

Summer	Average Duration		Average Interval	
	US	UC	US	UC
n=	5	3	2	1
mean	13.44	17.00	7.00	52.00
st. dev.	8.15	13.45	7.07	.
P =	0.3682		-	

Sample sizes were too small for comparison of Spring observations.

Time budgets:

A time budget of activity is a description of the partitioning of the activity pattern into different behaviors. Comparisons of the time budgets of squirrels on the Study and Control Areas are based on the average amount of time a squirrel was observed to perform the activity during the paired, 2-hour midden observations. To facilitate the analysis it was necessary to group the behavior categories into four larger categories of similar or related activities (Table 24). These data were also analyzed by seasons to account for seasonal changes in the partitioning of time (Ferron, et al. 1986). The seasonal definitions are as follows:

Spring -	March, April, May
Summer -	June, July, August
Autumn -	September, October, November
Winter -	December, January, February

Differences in the time budgets of different age or sex classes were ignored as previous studies on the time budget of red squirrels found no significant differences among sexes even during the breeding season (Ferron, et al. 1986). Owing to some seasonal differences in the activity patterns of squirrels in different habitats (see above), and to the different nature of construction activities in the different habitats (construction activity in the TR area consisted of traffic on the access road, while there was tree removal and earth-moving in the SF area) the time budgets of squirrels were analyzed within habitats. The analysis does include some comparison of time budgets between habitats, for the autumn season. This analysis was performed to test whether differences in the behavior of squirrels in different habitats observed during autumn 1989 were still present and to justify the separation of the behavior data by habitat.

No construction or behavior study was conducted in the winter and, in 1990, all of the construction for the astrophysical development was conducted in autumn (October-November). Thus, the analysis of temporal partitioning concentrates on the autumn season. Comparison of the time budgets of squirrels on the study and control areas was done by the use of RxC contingency tables employing either Chi-square tests, Likelihood ratio (G) tests, or Fisher's exact tests depending on the size of the table and the distribution of expected values in the cells of each table (Everitt, 1977).

Results:

In autumn 1990, there was no significant difference in the amount of time budgeted into four different classes of behaviors by squirrels on the lower (TR) Study and Control Areas either during construction (G-test: DF=3, G=2.022, P=0.568; Table 25) or non-construction periods (G-test: DF=3. G=1.259, P=0.739; Table 26). Squirrels on the Upper (SF) Study and Control Areas budgeted their activities similarly during construction periods (G-test: DF=3, G=1.120, P=0.772; Table 27) but differed significantly during non-construction periods (G-test: DF=3, G=17.086, P=0.001; Table 28). During non-construction periods in autumn, squirrels on the Upper Study Area spent more time in food related activities (feeding, foraging, and caching) and less time on passive activities (grooming, basking, nest building, etc.) or out of sight than did squirrels on the Upper Control Area.

There were also some differences in time budgets among squirrels in different habitats in Autumn 1990. Squirrels in the TR areas (LC & LS) spent less time on food related activities and more time on passive activities than did their counterparts in the SF areas (UC & US) (Table 30; Chi-square test: DF=3, X^2=19.639, P=0.000).

Summary and discussion of time budgets:

1) Squirrels on the Lower Study and Control Areas partitioned their time similarly during construction and non-construction periods.

2) Squirrels on the Upper Study and Control Areas partitioned their time similarly during construction periods but dissimilarly during non-construction periods.

3) Squirrels on the Upper Study Area partitioned their time similarly during periods of construction and non-construction.

4) Squirrels in different habitats partitioned their time differently.

The pattern of temporal partitioning into different activities by squirrels on the Study and Control Areas shows no difference that can be attributed to construction activities.

The difference in the time budgets of squirrels in the SF habitat may indicate a change in the behavior of the squirrels on the Upper Control Area more than any potential effect of construction. This is supported by the comparison of the time budgets of squirrels on the Upper Study Area during construction and non-construction periods (Table 29; G-test:

DF=3, G=0.061, P=0.996), indicating that squirrels on the US area did not alter their time budgets in response to construction activity.

Differences in time budgets between squirrels in different habitats are consistent with the findings of the Monitoring Program in 1989. The greater amount of time spent on passive activities by the TR habitat squirrels may be a function of the greater local density of squirrels in these areas compared to the SF areas. The TR squirrels, having more neighbors, might be expected to spend more time at their midden, watching for intruders and protecting their food caches. Also, many of the SF squirrels were reoccupying middens, which had not been occupied for several years and probably had completely depleted food caches. The squirrels re-occupying these middens would be expected to spend more time collecting and caching food while the TR squirrels, occupying middens with some food left from previous years, would not.

Table 24. Categories of red squirrel activities used for analyzing time budgets.

1)	Food Related Activities	Feeding Foraging Caching
2)	Defensive Activities	Alert Territorial behavior w/ red squirrel Territorial behavior w/ other species Other interactions w/ other species Response to human presence Response to predator presence
3)	Passive Activities	Basking In cavity/nest Nest building Breeding Play other maintenance unusual
4)	Out of Sight	Out of sight - in midden Out of midden

Table 25. Comparison of the time budget of squirrels on the Study and Control Areas in the TR habitat in Autumn 1990 during periods with construction activities. The numbers in each cell of the table represent the average amount of time a squirrel spent in each of the four categories of activities during a 2-hour observation. Numbers in parentheses are the expected cell values.

	Control	Study	Total
Food Related	14.9 (14.4)	13.9 (14.4)	28.8
Defensive	4.0 (4.1)	4.2 (4.1)	8.2
Passive	10.2 (13.7)	17.1 (13.6)	27.3
Out of Sight	90.9 (87.8)	84.7 (87.8)	175.6
Total	120	119.9	239.9

G-test: DF=3, G=2.022, P=0.568

Table 26. Comparison of the time budget of squirrels on the Study and Control Areas in the TR habitat in Autumn 1990 during periods without construction activities. The numbers in each cell of the table represent the average amount of time a squirrel spent in each of the four categories of activities during a 2-hour observation. Numbers in parentheses are the expected cell values.

	Control	Study	Total
Food Related	16.4 (16.95)	17.5 (16.95)	33.9
Defensive	6.5 (5.7)	4.9 (5.7)	11.4
Passive	4.3 (3.1)	1.9 (3.1)	6.2
Out of Sight	92.8 (94.25)	95.7 (94.25)	188.5
Total	120	120	240

G-test: DF=3. G=1.259, P=0.739

Table 27. Comparison of the time budget of squirrels on the Study and Control Areas in the SF habitat in Autumn 1990 during periods with construction activities. The numbers in each cell of the table represent the average amount of time a squirrel spent in each of the four categories of activities during a 2-hour observation. Numbers in parentheses are the expected cell values.

	Control	Study	Total
Food Related	32.5 (29.1)	25.7 (29.1)	58.2
Defensive	3.2 (3.65)	4.1 (3.65)	7.3
Passive	4.1 (4.45)	4.8 (4.45)	8.9
Out of Sight	80.2 (82.8)	85.3 (82.7)	165.5
Total	120	119.9	239.9

G-test: DF=3, G=1.120, P=0.772

Table 28. Comparison of the time budget of squirrels on the Study and Control Areas in the SF habitat in Autumn 1990 during periods without construction activities. The numbers in each cell of the table represent the average amount of time a squirrel spent in each of the four categories of activities during a 2-hour observation. Numbers in parentheses are the expected cell values.

	Control	Study	Total
Food Related	6.1 (15.7)	25.3 (15.7)	31.4
Defensive	2.9 (3.25)	3.6 (3.25)	6.5
Passive	13.4 (9.35)	5.3 (9.35)	18.7
Out of Sight	97.6 (91.7)	85.7 (91.6)	183.3
Total	120	119.9	239.9

G-test: DF=3, G=17.086, P=0.001

Table 29. Comparison of the time budget of squirrels on the Upper Study Area in Autumn 1990 for periods with and without construction activities. The numbers in each cell of the table represent the average amount of time a squirrel spent in each of the four categories of activities during a 2-hour observation. Numbers in parentheses are the expected cell values.

	Construction	NO Construction	Total
Food Related	25.7 (25.5)	25.3 (25.5)	51
Defensive	4.1 (3.85)	3.6 (3.85)	7.7
Passive	4.8 (5.05)	5.3 (5.05)	10.1
Out of Sight	85.3 (85.5)	85.7 (85.5)	171
Total	119.9	119.9	239.8

G-test: DF=3, G=0.061, P=0.996

Table 30. Comparison of the time budget of squirrels in different habitats in Autumn 1990 during periods with construction activities. The numbers in each cell of the table represent the average amount of time a squirrel spent in each of the four categories of activities during paired 2-hour observations (one on Study and one on Control). Numbers in parentheses are the expected cell values.

	TR	SF	Total
Food Related	28.8 (43.5)	58.2 (43.5)	87
Defensive	8.2 (7.75)	7.3 (7.75)	15.5
Passive	27.3 (18.1)	8.9 (18.1)	36.2
Out of Sight	175.6 (170.55)	165.5 (170.55)	341.1
Total	239.9	239.9	479.8

Chi-square test: DF=3, $X^2=19.639$, $P<0.000$

Effect of Sudden Noise on Squirrel Behavior:

An important concern about the potential effect of construction activity is that the noise of construction could disturb the behavior of red squirrels and potentially disrupt their activity budgets. It has been suggested that such disruption, if it should occur, might interfere with reproductive activity, foraging, or other behavior and could potentially affect the survival or reproductive success of the squirrels near the construction areas.

Using data from the 2-hour midden observations, collected in 1989 and in 1990, we accumulated cases where a disturbance occurred and examined these cases for evidence that the squirrels changed their behavior coincidentally and potentially as a response to the disturbance. The instances used in this analysis had to meet the following criteria in order to be included:

1) The behavior of the squirrel before the disturbance was known for at least one minute.

2) The type and approximate location of the disturbance was noted on the observation sheet.

3) The behavior of the squirrel after the disturbance was known for at least one minute.

The disturbances were primarily auditory in nature, although some, (e.g., helicopters, road removal) also included a strong visual component. Only disturbances that were noted as being unusual, infrequent, or above background noise were included, to partially control for any acclimation of the squirrels to noise. Squirrels that are closer to the source of a recurring disturbance (i.e., roads) may become acclimated the disturbances (i.e., vehicle traffic). Disturbances could be either construction related or non-construction related (Table 31).

The behavior categories used to describe the squirrels behavior were the same as those used for all other behavior observations. Some behaviors can not occur sequentially and were not used as "Before" categories (e.g., "Enter nest" can only be followed by "Exit nest", and "Leave midden area" can only be followed by "Enter midden area". All behavior categories were possible for "After" categories. The behavior categories were further grouped into behaviors that were "passive" or "alert" behaviors, indicating whether or not these activities could represent a potential response to danger (Table 32). The "alert" category includes some behaviors that are potentially, but not necessarily, a response to perceived danger (i.e., leave midden, enter cavity, vocalize) and, thus, could give a false indication of response. The inclusion of these categories in the "alert" category may bias the analysis toward finding a response when, in fact, none occurred.

If a disturbance did have an effect on the squirrels' behavior then it could be expected that:

1) Squirrels would change their behavior at the time of the disturbance more frequently than expected by chance.

2) The change in behavior should indicate a heightened level of "awareness" (i.e., change from passive to alert).

3) Squirrels farther from the disturbances should be less likely to change their behavior than those closer to the disturbance.

All comparisons on the potential effect of disturbances on the behavior of squirrels were made by the use of Chi-square, Likelihood ratio, or Fisher's Exact tests (Everitt, 1977).

Results:

We accumulated 187 instances that met the criteria for inclusion in the analysis. In 125 cases (66.8%), no change in the behavior of the squirrel was noted for one minute after the disturbance, in 62 cases (33.2%), the squirrel changed its behavior concurrently with the disturbance.

Of the 187 cases, 164 (87%) involved construction related disturbances. Of the 62 cases when the squirrel changed its behavior, 50 (80%) of the disturbances were construction related and only 37 were on one of the Study Areas.

Some types of disturbances (voices, excavation, road removal, helicopters) tended to be associated with a change in behavior more often than expected by chance. Only two of these types of disturbances (voices and excavation) were construction related and the overall contingency table indicates that the type of disturbance was not associated with a change in behavior (Likelihood ratio Chi^2: $n=187$, $X^2=14.173$, D.F.$=11$, $P=0.213$; Table 33).

Changes in behavior also tended to be associated with certain "before" activities (Table 34). Squirrels were more likely to change their behavior if the "before" activity was an "alert" activity than if it was a "passive" activity (Chi^2 test: $n=187$, $X^2=7.145$, $P=0.008$: Table 35), however, in cases where behavior did change the "after" activity was no more likely to be "alert" than "passive" (Chi^2 test: $n=62$, $X^2=0.01$, $P=0.919$: Table 36).

Squirrels on the Study Areas were no more likely to change their behavior at the time of a disturbance than were squirrels on the Control Areas, whether it was a construction related disturbance (Chi^2 test: $n=164$, $X^2=1.208$, D.F$=1$, $P=0.272$; Table 37) or non-construction related (Fisher's Exact test: $n=23$, $P=0.722$; Table 38).

Summary and discussion of the effect of noise on squirrel behavior:

1) Loud disturbances, in general, had no visible effect on the behavior of red squirrels. In most cases the squirrels continued the activity they were involved in at the time of the disturbance.

2) In cases where the squirrel changed its behavior, the behavior following the disturbance did not indicate a tendency to become more alert.

3) There were no differences in the pattern of behavior changes at the time of disturbances among squirrels on the Study or Control areas, indicating that nearness to the disturbance did affect the outcome.

The overall pattern suggests that, in most cases, squirrels do not respond to construction noises. Many of the activity categories (feed, bask, cache cones, remain in nest, alert) used here to describe the red squirrels' behavior are typically of long duration. With the exception of 'alert', when the "before event" activity was one of these categories the squirrel was less likely to change its behavior than if the "before event" activity was one of the typically short duration categories (move, vocalize, exit nest, groom). In addition, most of the short duration activities are a prelude to changes in activity (for example a squirrel typically grooms itself after basking or eating and before leaving the midden). Consequently, these behaviors are likely to change more frequently and do not necessarily imply a reaction to perceived danger. Vocalizations are generally short in duration, although barking sessions can last for up to 45 minutes, and not all vocalizations are a response to perceived danger. Despite the inclusion of many of these short duration activities in the "alert" type behavior category this analysis still shows no relationship between the disturbances and changes in behavior.

Table 31. Disturbance categories used in the analysis of the effect of disturbances on red squirrel behavior.

Construction Related	
Tree Removal - telescope sites	Excavation - telescope sites
Hauling debris (logs, rocks, etc.)	Excavation - road
Core Drilling (telescope sites)	Impact Drilling (road)
Tree cutting - chain saw	Voices (surveying etc.)
Driving fence posts	Heavy equipment or trucks moving
Non-construction Related	
Helicopter flying overhead	Gun shots
Airplane "	Road removal (FR 507 & 669)

Table 32. Behavior Categories used in the analysis of the effect of disturbances on red squirrel behavior.

"Passive" Behaviors	
Unknown (not used in analysis)	Feed
Forage	Exit nest/cavity
Chase Abert's squirrel	Return to midden area (not chase)
Chase red squirrel	Move about in midden area
Bask (sit still, eyes closed)	Remain in cavity/nest
Cache cones	Groom
"Alert" Behaviors	
* Enter nest/cavity *	Leave midden area (not chase)
Vocalize	"Flatten" body against tree
Alert (sit still, eyes open)	

* category not used for "before" behavior.

Table 33. Frequency of the status of behavioral change for different disturbance events. Numbers in columns are Frequency of occurrence and (Expected frequency)

Event	Behavior After Event		Total
	No Change	Change	
Excavation	5 (8.02)	7 (3.98)	12
Road Removal	1 (2.01)	2 (0.99)	3
Core drilling	2 (2.01)	1 (0.99)	3
Loading Debris	10 (10.70)	6 ((5.30	16
Airplane	7 (6.68)	3 (3.32)	10
Helicopter	3 (6.02)	6 (2.98)	9
Voices	11 (12.70)	8 (6.30)	19
Chain saw	15 (14.04)	6 (6.96)	21
Vehicle traffic	59 (52.81)	20 (26.19)	79
Impact drilling	9 (7.35)	2 (3.65)	11
Gun shots	1 (0.67)	0 (0.33)	1
Driving fence post	2 (2.01)	1 (0.99)	3
TOTAL	125	62	187

Likelihood ratio Chi^2 test: D.F.=11, X^2=14.173, P=0.224

Table 34. Frequency table of the status of behavioral change for different "Before Disturbance" behavior categories. Numbers in columns are Frequency of occurrence and (Expected frequency).

	No Change	Change	Total
Feed	39 (31.42)	8 (15.58)	47
Forage	8 (9.36)	6 (4.64)	14
Bask	21 (20.05)	9 (9.95)	30
Move	6 (11.36)	11 (5.64)	17
Cache	20 (20.05)	10 (9.95)	30
Alert	9 (13.37)	11 (6.63)	20
Vocalize	3 (4.68)	4 (2.32)	7
In nest	19 (14.71)	3 (7.29)	22
TOTAL	125	62	187

Chi^2 test: D.F. = 7, X^2=23.791, P=0.001

Table 35. Frequency of change in behavior by the category of "before" activity.

	No Change	Change	Total
Alert	12 (18.05)	15 (8.95)	27
Passive	113 (106..95)	47 (53.05)	160
TOTAL	125	62	187

Chi^2 test: DF=1, X^2=7.145, P=0.008

Table 36. Frequency of type of "Before" activity to type of "After" activity for cases where squirrels changed their activity concurrently with a disturbance.

	Alert	Passive	Total
Alert	10 (10.16)	5 (4.84)	15
Passive	32 (31.84)	15 (15.16)	47
TOTAL	42	20	62

Chi^2 test: DF=1, X^2=0.010, P=0.919

Table 37. Frequency of change of behavior concurrently with a construction related disturbance by Area.

	Control	Study	Total
No Change	42 (39.93)	72 (75.07)	114
Change	14 (17.07)	36 (32.93)	50
TOTAL	56	108	164

Chi^2 test: D.F.=1, X^2=1.208, P=0.272

Table 38. Frequency of change of behavior concurrently with a non-construction related disturbance on the Control Areas and Study Areas.

	Control	Study	Total
No Change	8 (7.83)	4 (3.17)	12
Change	7 (7.17)	4 (3.83)	11
TOTAL	15	8	23

Likelihood Ratio Chi^2 test: D.F.=1, X^2=0.023, P=0.879

Appendix A. Maps of the monitored areas showing the distribution and occupancy of known midden sites.

Appendix B. Construction Log 1990

Date	Type of Construction	Obs.?	Location of Construction
22 Jun	Install gate	N	Foot of access road
25-28 Jun	Earth moving	Y	Switchbacks 3&5
26-27 Jun	Install culverts	Y	Foot of access road
11,12,17-19 Jul	Install culverts and water dips	N	Access road
28-29 Aug	Grade roadbed	Y	end of access road
30 Aug 4-5 Sep	Transplant trees	N	Telescope sites
1 Oct	Remove trees	N	telescope sites
2-5 Oct	"	Y	"
8-9 Oct	"	Y	"
10 Oct	Core drilling	Y	"
11 Oct	Tree removal, drilling	N	"
15 Oct	Clear road, Drilling	Y	Road & Telescope sites
16 Oct	Remove rock, Cut trees, Drilling	Y	Road, Maintenance site, Telescope sites
17 Oct	Drilling	Y	Telescope site
18 Oct	Tree removal	Y	"
19 Oct	Seismic "Thump" Tests	Y	Telescope Sites
20 Oct	Install culverts	Y	Road
21 Oct	"	N	"

22-24 Oct	Drill, trench, pier	Y	Road, tele. sites
25 Oct	Trenching	N	road
29-30 Oct	Culverts, excavation	Y	road, tele. sites
31 Oct	Excavate rock	Y	"
2 Nov	Excavation	N	"
5 Nov	Excavation	Y	"
13 Nov	Excavation	Y	telescope sites
14 Nov	Haul rock off sites	Y	road, tele. sites
15-17 Nov	Road excavation	Y	road
18 Nov	Haul rock	Y	Road, Tele. sites
19 Nov	Road work	Y	Road
20-21 Nov	Road work, put conduit in trench	Y	road, telescope sites
28 Nov	Fill trench cover sites for winter	Y	Telescope sites

Appendix C. Likelihood ratio tests on the likelihood of observing or not observing a red squirrel at a midden site, comparing observations on Study and Control Areas.

Fall Season, on construction days

# OBS WITH...	LC	LS
Squirrel Present	18	17
No Squirrel Present	2	1

G = 0.263 P = 0.715, not significant

Fall Season, on days with no construction

# OBS WITH...	LC	LS
Squirrel Present	18	16
No Squirrel Present	2	5

G = 1.422 P = 0.263, not significant

Fall Season, on construction days

# OBS WITH...	UC	US
Squirrel Present	48	40
No Squirrel Present	3	7

G = 2.211 P = 0.166, not significant

Fall Season, on days with no construction

# OBS WITH...	UC	US
Squirrel Present	8	10
No Squirrel Present	5	4

G = 0.297 P = 0.680, not significant

Summer Season, on days with no construction

# OBS WITH...	LC	LS
Squirrel Present	20	17
No Squirrel Present	9	9

G = 0. 080 P = 0.776, not significant

Summer Season, on days with no construction

# OBS WITH...	UC	US
Squirrel Present	4	9
No Squirrel Present	19	14

G = 2.734 P = 0.112, not significant

Spring Season, on days with no construction

# OBS WITH...	LC	LS
Squirrel Present	10	1
No Squirrel Present	5	12

G = 11.374 P = 0.004, highly significant

Spring Season, on days with no construction

# OBS WITH...	UC	US
Squirrel Present	16	7
No Squirrel Present	22	30

G = 4.840 P = 0.027, significant

The significant differences in the likelihood of observing a squirrel at the Study and Control area middens in Spring 1990 is not easily explained. In general, since there was no construction at this time, the observations in Spring were used to help confirm the occupancy of middens which were presumed to be occupied. It is possible that the results above are due to a greater number of the observations on the Study areas being conducted at middens which were presumed to be occupied but in fact were not.

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