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STATUS OF THE FLORA AND FAUNA ON THE NEVADA TEST SITE, 1994

Compiled By
Richard B. Hunter

September 1995

Work Performed Under
Contract No. DE-AC08-94NV11432

Prepared by
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STATUS OF THE FLORA AND FAUNA ON THE NEVADA TEST SITE, 1994

Results of Continuing Basic Environmental Monitoring January through December 1994

Compiled By
Richard B. Hunter

September 1995

Work Performed Under Contract No. DE-AC08-9411432

Prepared for the
United States Department of Energy
Nevada Operations Office

Prepared by
Reynolds Electrical & Engineering Co., Inc.
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LIST OF ACRONYMS AND EXPRESSIONS

ASD	Analytical Services Department
BECAMP	Basic Environmental Compliance and Monitoring Program
BYU	Brigham Young University
CDC	Centers for Disease Control
DAF	Device Assembly Facility
DOE	Department of Energy
GPS	Global Positioning System
GZ	Ground Zero
IBP	International Biological Program
KW	Kruskal-Wallis
MWU	Mann-Whitney U Test
NAEG	Nevada Applied Ecology Group
NDOW	Nevada Department of Wildlife
NKMRT	Newman-Keuls Multiple Range Test
NOAA	National Oceanic and Atmospheric Administration
NTS	Nevada Test Site
PMR	Pahute Mesa Road
RADEX	Radiation Exclusion
SVL	Snout-to-vent length
se	Standard Error
TH	Tippipah Highway
UCLA	University of California, Los Angeles
UGTA	Under Ground Test Area Operable Unit
WSNSO	Weather Service Nuclear Support Office

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EXECUTIVE SUMMARY

This is the final progress report of a Department of Energy (DOE), Nevada Operations Office (NV), program to monitor the ecology of the Nevada Test Site (NTS). The eight-year Basic Environmental Compliance and Monitoring Program (BECAMP) included meeting goals of understanding the spatial and temporal changes of plants and animals on the NTS, and determining the effects of DOE operations on those plants and animals. Determination of the changes was addressed through monitoring the most common plant and animal species at undisturbed (baseline) plots located in the major NTS valleys and mesas. One plot in Yucca Flat, the site of most nuclear weapons tests, was monitored annually, while other baseline plots were censused on a three- or four-year cycle. Effects of DOE operations were examined at sites of major disturbances, related to both DOE operations and natural disturbance mechanisms, censused on a three-year cycle. This report concentrates on work completed in 1994.

Changes in baseline conditions on the NTS from 1993 to 1994 were largely related to rainfall. Calendar year rainfall at BJY in Yucca Flat declined from an unusually high 245 mm in 1993 to 127 mm in 1994. Winter rainfall (September through April) declined from 263 to 87 mm. Populations of winter annual plants, small mammals, and lizards are correlated with winter rainfall, hence those populations declined significantly during 1994.

Winter annuals germinated only sparsely, as density in Yucca Flat fell from $1762/m^2$ in 1993 to $112/m^2$ in 1994. Biomass declined from 18.1 to 1.6 g/m^2. Shrubs shrank slightly as total live volume declined from 192 to 183 $liters/m^2$. Density of perennial plants declined more than volume, as seedlings which germinated in 1992 and 1993 died. Density of small mammals increased slightly (50 to 53/ha) as a result of excellent reproduction in 1993. However, mean weight of small mammals declined, especially in adult females, indicating reproduction was poorer in 1994. Similarly, adult lizards increased in density (18 to 54/ha) because of good reproduction in 1993, but juveniles declined (154 to 21/ha) as reproduction was reduced in 1994.

Although overall population fluctuations could be correlated with rainfall, individual species' populations sometimes failed to follow the trend. In particular, the kangaroo rat (*Dipodomys microps*) increased more than other species, and the little pocket mouse *(Perognathus longimembris*) remained in low densities following a 1991-1992 decline. The introduced annual grass (*Bromus tectorum*) continued to spread below 5000 feet, though it remained at low density in comparison to its dominant congener, *Bromus rubens*.

Hantavirus infection in rodents was monitored at townsites and widespread natural areas on the NTS. Carriers of the Muerto Canyon virus were limited to the deer mouse, (*Peromyscus* *maniculatus*), of which 4 of 31 tested positive for antibodies. The deer mouse is most common at higher elevations on the NTS.

The small horse population on the NTS declined 14% to 56 animals in 1994. Foal survival has been negligible for several years and the decline was attributed to mountain lion predation. Deer sighting rates in 1994 were only 50% of the 1993 level. The drop in deer numbers may be related to the closing and drying of several man-made ponds on Pahute Mesa, associated with the continuing moratorium on weapons testing.

Raptor populations in the spring of 1994 were somewhat higher than in the spring of 1993. Perhaps this is related to the increased abundance of small mammals. Both raptors and ravens appeared to benefit from man-made structures, using them for perching, shade, and nest sites.

Disturbance studies were conducted at eight sites - four areas blasted by above-ground nuclear weapons tests in the 1950s, the Sedan below-ground cratering test, a drill pad on Pahute Mesa, a revegetated waste-cleanup site, and a rodent-denuded area. Regardless of mechanism of disturbance, density of winter annuals was greater (mean 23 times) and biomass was greater (mean 31 times) wherever shrubs had been removed and their live volume remained low. On the T4 blast area and the revegetated site, where shrub live volume exceeded 90% of control values, winter annual densities and biomass were not different from controls. Perennial plant populations remained much reduced on several blast areas, and recovery there was slower than on burned areas and roadsides. Reasons for the slow recovery were unknown, but hypotheses relating to ecological imbalances and competition, rather than physical conditions, appeared most plausible.

Small mammal densities on the blast areas were equivalent to controls. However, there were fewer species on the blast areas, which were dominated by the kangaroo rat *(Dipodomys merriami)*. The lower diversity on the blast areas was hypothesized to be due to the reduced shrub cover. Densities of *D. merriami* were always greater on the blast areas, but those of other species were reduced.

Lizard populations on the blast areas were dynamic. In spring, densities were similar to those on control plots, but in summer they were reduced, with juveniles reduced more than adults. Lizards were generally larger on the blast areas, but survival from spring to summer was reduced. The reduced lizard survival was also tentatively associated with the absence of shrub cover.

A study of plant species composition along paved roadsides confirmed that roadsides differ significantly from nearby undisturbed locations. This was not due solely to removal of species by roadside maintenance activities, but included the addition of species that survive better under roadside conditions.

Measurement of tritium in four fresh horse feces confirmed the presence of low, innocuous levels found in one sample in 1993. Tritium concentrations in grass samples collected from within the horse range suggested grass, rather than drinking water, may be the source of the tritium.

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STATUS OF REPTILES ON THE NEVADA TEST SITE, 1994
AND SUMMARY OF WORK 1987 - 1994

by

Bruce Woodward

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ABSTRACT

This report summarizes reptile studies performed by the Basic Environmental Compliance and Monitoring Program (BECAMP) on the Nevada Test Site (NTS) from 1987 to 1994. These studies were designed to assess Department of Energy (DOE) impacts on reptiles, monitor changes in lizard populations over time, and evaluate lizard sampling techniques. Reptile studies concentrated on lizards, in particular the abundant *Uta stansburiana* (uta). The NTS lizard work took place at both largely undisturbed baseline sites, which are well removed from DOE projects, and at disturbed sites proximal to DOE projects and at their nearby controls.

Baseline studies revealed sizeable temporal fluctuations in lizard densities, lizard body sizes, and reproductive characteristics. Populations crashed and returned to high levels over two to three years. On most baseline plots, there was neither a consistent increase nor decrease in uta density over this study. Instead, numbers rose and fell rapidly and inconsistently implying no long-term indirect impacts of DOE activities on lizard populations. There was some suggestion that these patterns may be driven by rainfall. There also was tremendous spatial variation in uta traits across the largely undisturbed baseline sites. Basin bottoms tended to contain many fewer uta relative to foothills areas. These differences suggest that future sampling approaches should involve widely dispersed and numerous sample sites in order to fully represent the range of uta populations.

Results at disturbed sites revealed sizeable direct effects of DOE activities. Comparisons of burned, blasted, cratered, graded, or paved areas with their appropriate control areas revealed sizeable negative effects of DOE activities on lizards. All of these activities removed the perennial vegetation, a major component of lizard habitat, suggesting that habitat removal is the proximal mechanism involved. At some sites, like the above-ground blast sites and the below-ground blast sites that breached the surface, effects on lizards may also have been caused by release of radioactive material. The majority of these DOE activities took place at least 10 years ago and many greater than 20 years ago, yet uta have still not recovered. This is probably because the habitat itself has not recovered. At present, the spatial extent of these effects on the NTS is not known.

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INTRODUCTION

This report reviews reptile studies performed at the NTS in 1994 and summarizes reptile studies performed over the history of this program (1987 - 1994). Reptile studies fall into three general classes: those designed to monitor long-term trends in populations, those designed to look for direct impacts of DOE projects, and those designed to assess sampling techniques. Long-term trends were assessed on baseline plots that are well removed from DOE activities. These baseline studies were designed to assess indirect impacts of DOE actions. Direct impacts of DOE activities were assessed with disturbance studies by comparing reptile traits on study plots proximal to DOE disturbances to those from nearby control areas. Technique evaluation involved both new studies in 1994 and comparisons of extant data sets.

Environmental studies have a long history at the NTS. Studies have examined both causal mechanisms that could influence population size and population itself. Studies of causal mechanisms have included examination of direct effects of radiation on animal survival and reproduction (Turner et al. 1969, Medica et al. 1973, French et al. 1974, Turner, 1975) - two factors with direct connections to fluctuations in population size. Examination of causal factors is important because this approach yields information about what causes change and, thus, is central to remediation efforts. In 1994, population monitoring occurred at baseline sites in largely undisturbed areas and in highly disturbed areas. Sampling has gone on long enough that tentative conclusions can be drawn about natural population variation, recovery rates from disturbances, and the efficiency of our sampling approach.

Reptile studies on the NTS focus on *Uta stansburiana* (the side-blotched lizard or uta) because these lizards are widespread and occur at high enough densities that conclusions can be drawn from their study (Tinkle 1967, Vitt 1991). Other lizard species, especially *Cnemidophorus tigris* (whiptails), are sometimes common enough for analysis. In most areas of the NTS, other lizard species occur at low densities and can be analyzed only in species counts or counts of number of all lizards present. Snakes are too infrequently encountered for any kind of quantitative analysis. Tortoises have been studied by BECAMP since 1987. Most of this work has related to tortoise natural history and, in large part, is a continuation of studies initiated in 1963 by researchers at the University of California, Los Angeles (UCLA).

Population fluctuation is the norm in nature with stasis as an unusual event (Cole 1954). Three purported causal factors have shared center stage in studies of what drives population fluctuations: abiotic factors (usually weather), competition, and predation. All three can be important factors causing population fluctuations, and there is some evidence that all may influence uta populations on the NTS (Turner et al. 1973). Human activities are another set of factors that can influence natural populations (Appelberg et al. 1993, Meyers 1994). Human activities are likely to influence reptiles either by directly killing them (for example, by running over them) or by modifying the habitat. Modifying the habitat influences how individuals deal with competitors, predators, or the physical environment. Many DOE projects include activities that remove shrubs and, thus, are likely to modify lizard habitats.

Population fluctuations are expected to be large in desert systems because abiotic factors like weather, prey carrying capacities, and populations of competitors and predators all typically fluctuate greatly (Polis 1991, Woodward and Mitchell 1991, Vitt 1991). Historically, abiotic factors have been envisioned as dominating desert systems (Polis 1991). Recent viewpoints on this have shifted to a more coequal balance between abiotic and biotic factors (Woodward and Mitchell 1991).

Uta populations have fluctuated tremendously on the NTS over the years (Woodward 1994, see Results and Discussion section of this report). In this report, the long-term patterns on the NTS were examined in an attempt to determine whether DOE activities have had significant impacts on reptiles.

METHODS

Lizards were sampled at several sites in spring and summer of 1994 and at many sites from 1987 to 1994 (Figure 1-1) to assess population sizes and the condition of individual lizards. These data were used to estimate whether past or present human activities were influencing lizard populations. In 1994, lizard studies took place at three baseline plots and several sites influenced by human disturbance. Baseline sites have minimal direct disturbance but were not protected from region-wide effects such as fallout or invasion by exotic species. Disturbed sites are more directly impacted by DOE activities. The disturbed sites included three tower blast sites and their controls, three sites at various distances from Sedan Crater (an underground blast that breached the surface), and a largely nonvegetated plot and its control near Mercury. In addition, multiple-year and multiple-site comparisons of lizard traits were made to examine temporal and spatial variation in these traits and test for trends. Finally, experiments, observations, and statistical tests were conducted to evaluate the current sampling approach.

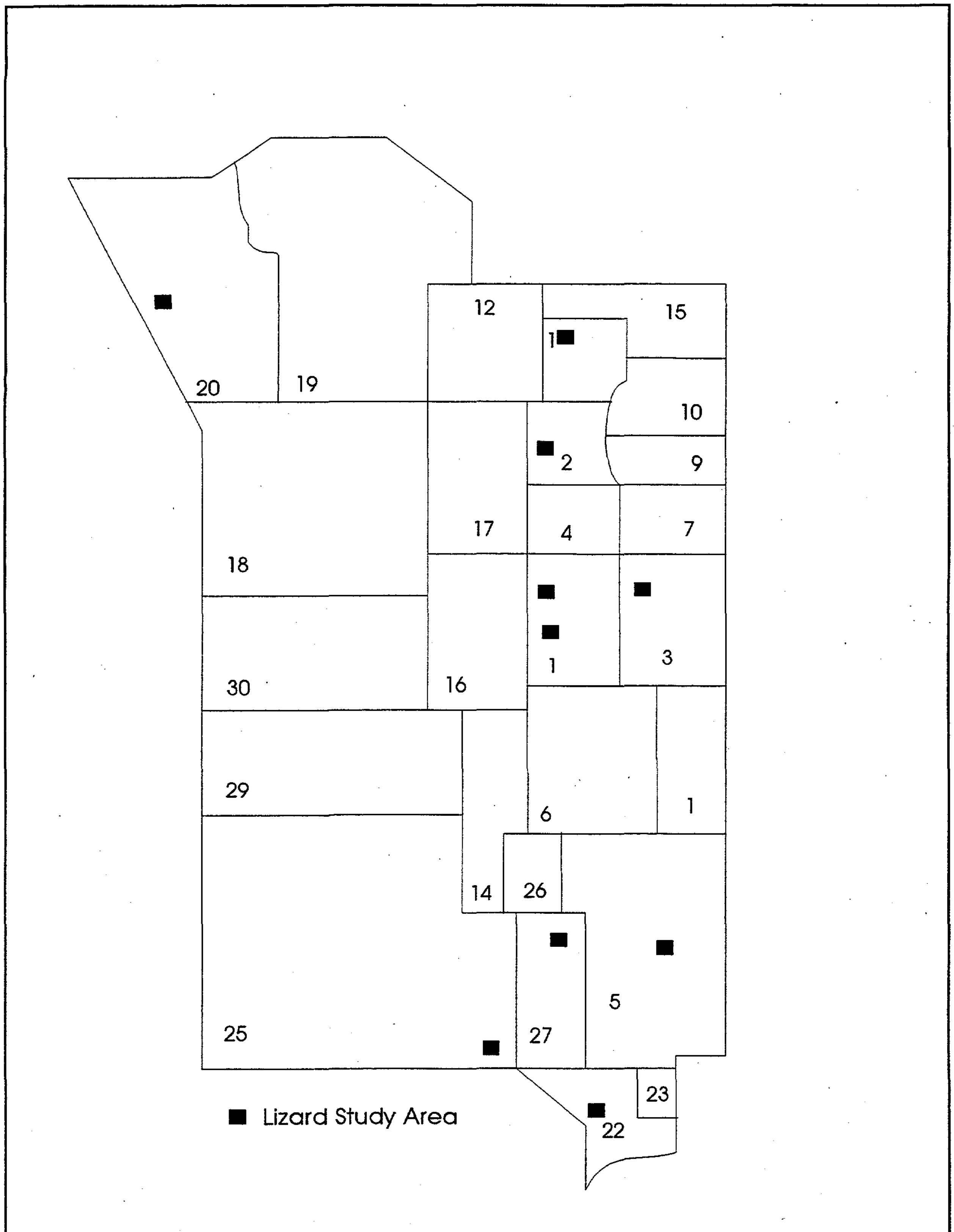

Figure 1-1. Distribution of lizard sampling areas on the NTS in 1994.

Lizards were sampled in the spring to assess the size of the overwintering population and in the summer to assess spring to summer survival and reproduction. Lizard snout-to-vent length (SVL) and weight were used to reflect recent growth and indicate how harsh local conditions have been. Age and juvenile to adult or hatchling to adult ratios reflect the age composition of the population and were used to assess the recent survival and reproduction of the population. Sex ratios were also examined.

Both transect and plot techniques were used to estimate lizard abundances in 1994. Transect studies involved walking a predetermined route and recording the number of each species seen along subsections of the route. This approach was quick and allowed the study of species that are either difficult to catch, wander widely, or have low densities. Its disadvantage is that numbers of relatively sedentary species, like horned lizards (*Phyrnosoma platyrhinos*), tend to be underestimated. The plot-approach employs mark-recapture techniques in a specified area. Transect and plot techniques were used in several areas in 1994.

Unless otherwise noted below on each transect, three investigators walked abreast and recorded the number of lizards seen per species per 50 m of a 15-m wide transect (Hunter and Medica 1989). Ten to twenty-five transect sections were examined at each location. Surveys were performed in the morning over temperatures favorable to the focal species. Counts/50 m were recorded for each species, and the number of species along with the total number of individual lizards seen per 50 m were calculated. Values were converted to numbers/ha. On alternate days, investigators started from opposite ends of transects to sample each transect both early and late. In 1994 on any given day, all transects in an area were walked, and then the first transect was sampled again. A one-way ANOVA was used to contrast counts for the first transect examined each day with its repeat collected later that day. This analysis allowed us to ask if lizard activity changed over the sampling period. Finally, a runs test was performed to determine if uta counts or total lizard counts (pooled across species) changed over each day of the sampling period. Nonparametric analyses were used when parametric assumptions could not be met.

Density estimates were made during plot studies via a mark-recapture program as discussed in Hunter and Medica (1989). Our plots are relatively small and thus contain few individuals of most species (whiptails [*Cnemidophorus tigris*], zebratails [Callisaurus draconoides], horned lizards [Phrynosoma platyrhinos], leopard lizards [*Gambelia wislizenii*]). Uta have low vagilities and occur at high densities and are well suited to plot studies. Lizards were marked short term with paint and long term by toe clipping. A sizeable sampling effort (usually four or five days with three to five people) was spent at each study site (single or multiple plots).

Investigators started from opposite ends of the plot(s) on alternate days so each area was sampled both early and late in the morning.

Seber's (1982) mark-recapture estimation program was used to generate a mean $\pm$ 2 standard error (se) estimate for lizard densities. Where sample sizes were sufficient, density estimates were generated for juveniles (individuals < 1 year old in spring) and adults in spring, hatchlings (individuals hatched that summer) and adults (all nonhatchlings) in the summer, and all uta age classes pooled (estimated in both spring and summer). Simulation studies (Menkens and Anderson 1988) suggest standard errors or confidence intervals for these estimators may be underestimates (too narrow). The mean estimate does appear to be quite close to the actual mean in simulation studies. A conservative approach was taken by reporting $\overline{x} \pm 2$ se, using caution when interpreting the estimate of variation, and using mean values in analyses. The actual number of lizards caught per plot across control and disturbed areas were compared with chi-square tests or, in some cases, across years for data from within one plot. Fisher Exact Probability tests were used when sample sizes were inadequate for chi-square tests.

Lizards captured during plot studies were measured from snout to vent to the nearest 0.5 mm and weighed to the nearest 0.05 g. Individuals were sexed, and females were palpated to estimate number of eggs per clutch. Ages were estimated by comparing SVLs and weights to those of individuals from the same plot which were marked shortly after hatching. The mean plus or minus two standard errors is reported for all results.

BASELINE STUDIES

Lizard populations were monitored in baseline study areas to assess long-term changes in lizard populations. The baseline lizard plots were 105 x 105 m (1.10 ha) and were walked twice each morning. Different people walked each area during the first and second passes. In 1994, baseline study areas were examined on Yucca Flat, Frenchman Flat, and Pahute Mesa. Correlations were performed between the year of sample and the estimated lizard density to test for consistent long-term increases or decreases in lizard densities. To look at lizard species composition, the proportion each species contributed to the total number of lizards present was computed on each plot. Lizard weights, SVLs, and ages were compared across years with Kruskal-Wallis (KW) tests. Sex ratio or age class ratios (juvenile to adult in spring, hatchling to adult in summer) were compared across years with chi-square tests.

Yucca Flat Study Area (YUF001)

Five 500-m lizard transects were walked on three consecutive days in 1993 and from 21 to 23 June in 1994 to allow comparisons between years. The number of lizards per species were compared across years and across days within years with a two-way ANOVA.

Lizard sampling was performed on the 1.1 ha plot for five days in spring from 4 to 12 April, and for five days in summer from 1 to 5 August. A correlation was performed to test for a relationship between mean summer density estimate and year of the study. Precipitation regimes on this site were estimated from a rain gauge located 5.6 km away. Total annual rainfall was correlated with estimated number of side-blotched lizards present each summer (1988-1994) to test for rainfall effects on population size. Uta SVL, weight, and age were compared between 1993 and 1994 with Mann-Whitney U (MWU) tests. These parameters were also compared across all years of the study with a Kruskal-Wallis test.

Frenchman Flat Study Area (FRF001)

Lizard transects were walked for three days in 1991 and from 14 to 16 June 1994. In both years, five 500-m transects were walked during early morning. The number of lizards per species, the total number of species, and the total number of lizards (pooled across species) were recorded per 50 m of transect. A two-way ANOVA was used to compare across years and across days within years. Data on lizard numbers were collected via the plot sampling technique for four days in the spring from 14 to 17 March and four days in the summer from 18 to 21 July . Uta SVL, weight, and age were compared across all years of the study with a Kruskal-Wallis test. Sex and age compositions were compared across years with chi-square tests.

Pahute Mesa (PAM001)

This plot was sampled for five days in the summer. A correlation was performed between the mean summer density estimate and the year of study to determine if density remained constant across years. Uta SVL, weight, and age were compared between 1993 and 1994 with MWU tests. These parameters were also compared across all years of the study with a Kruskal-Wallis test.

DISTURBANCES

Disturbance studies are designed to assess direct DOE impacts on the environment, by comparing impacted areas with nearby controls. Impacts examined in past years include fires, land grading, cratering, land cleared by aboveground nuclear blasts, and paving. Lizard populations were studied at three tower test sites (where above-ground nuclear devices were detonated on towers), and also at their associated control plots in 1994. These plots were 75 x 75 m or 0.5025 ha. The T1 tower blast site (YUF009) and control area (YUF010) plots were simultaneously sampled for four days from 13 to 18 April 1994 and for four days from 22 to 25 August. The T2 blast site (YUF014) and control area (YUF015) were searched for lizards for four days from 26 April to 2 May 1994 and for four days from 29 August to 1 September. The T3 blast site (YUF013), control area (YUF012), and T3 revegetated site (YUF011) were searched for lizards for four days from 19 to 25 April and for five days from 15 to 19 August. Because of the temporal staggering of these studies, the tower test sites were analyzed as three separate studies. In each study, the tower site was compared to its control to assess potential impacts of aboveground testing of nuclear devices.

The second disturbance type examined in 1994 was "a rodent denuded area" (Hunter 1995) and its nearby control. These large shrubless areas occur in several places on the NTS and do not appear to occur off of it, suggesting that they may in some way be associated with DOE activities. Lizard populations were surveyed on the rodent denuded plot (MER002) and control plot (MER003) (each 75 x 75 m) from 7 to 10 March 1994 and from 11 to 14 July 1994 to determine how these sites influence lizard populations.

The third disturbance type examined in 1994 was Sedan Crater, an area where a shallow atomic blast was allowed to breach the surface as part of a project designed to examine the feasibility of using nuclear devices to create canals. This blast threw dirt for thousands of meters around the crater. Lizard populations were simultaneously studied on plots at 457 m (YUF016), 1067 m (YUF017), and 1600 m (YUF018) from ground zero (GZ) at Sedan Crater for four days from 3 to 6 May in the spring, and for four days from 8 to 11 August in summer. Comparisons of lizard populations were made across the three plots to determine if impacts occurred and if they were reduced at farther distances from the explosion.

In each disturbance study, characteristics of lizards on disturbed areas were compared with those of lizards on a nearby control area. Lizard SVL, weight, and ages were compared with Mann-Whitney U tests or Kruskal-Wallis nonparametric analysis of variance tests. Lizard age-class distributions were compared between disturbance and control plots with chi-square tests. The number of lizards seen were compared across plots with chi-square tests. Density estimates were also compared by looking for overlap in the variance estimates around the mean. Finally, the sex ratio was compared between the control and disturbed areas with chi-square tests.

TECHNIQUE EVALUATION

To broaden the examination of potential human impacts on the biota of the NTS, experiments were intergrated to examine lizard preferences for certain plant types or physical structures. This was done to determine if DOE impacts on vegetation or physical structures might impact lizard distributions. An experiment was performed to assess how time of sample collection can influence the number of lizards seen and thus density estimates. In addition, lizard characteristics were compared across traditional BECAMP study sites to ask questions about spatial variability in lizard traits. In particular, a basin-bottom site in Yucca Flat (YUF001) was compared to another basin-bottom site in Frenchman Flat (FRF001), and these basin-bottom sites were compared to foothill sites in Frenchman Flat (FRF0013) and Yucca Flat (YUF003).

Lizard Preference Tests

Lizard abundance varies from place to place and year to year (Woodward 1994). One potential contributor to this variation is shifts in vegetation if lizards exhibit preferences for certain plant species over others. Shifts in vegetation can arise naturally or as a consequence of human activities (Woodward 1994). Hunter and Medica (1992) suggest that fires, grading, above-ground nuclear blasts, and road construction are all human impacts with potential to remove vegetation from large areas of the NTS. To determine if shifts in plant species composition could influence lizard abundances, four choice tests were performed in which lizards could choose between two choices. In each experiment, a metal enclosure was placed around two shrubs separated by 3 to 5 m. Three or four pairs of test shrubs were used as potential choices in different trials in each experiment, so that results would likely reflect lizard response to the specified "choice" and not just the characteristics of the two shrubs in any one trial. Four choices were offered to lizards: *Ambrosia dumosa* versus *Krameria parvifolia*, *Ambrosia* versus *Larrea tridentata*, *Ambrosia* with a rock versus *Ambrosia* without a rock, and large versus small *Ambrosia* clumps. In the first three comparisons, the two shrubs differed by less than 20% in coverage. In each trial of each experiment, one *Uta* was released in the enclosure equidistant from its two choices. The following morning (or subsequent mornings) the lizard was scored as having made a choice if it was under a shrub or within 30 cm of it. Each lizard was scored only once, and 20 to 24 lizards were observed in each experiment. A sign test was used to assess preference.

Diel Sampling Effects

Lizards were surveyed in two enclosures (approximately 4 x 5 m) from 12 May to 7 June 1994. The number of lizards present per enclosure was changed daily and ranged from 0 to 7 *Uta stansburiana*. Typically only 1 of the 3 observers knew the actual count. Observers walked around and through the enclosure as if searching for lizards in the wild. Lizards were counted twice each day in each enclosure, representing the beginning (0809 $\pm$ 5.4 minutes, $\overline{x} \pm 2$ se) and towards the end (0918 $\pm$ 25.6 minutes) of a typical lizard sampling period. Data were analyzed with a three-way ANOVA with investigator, time of sample, and enclosure as factors. Correlations were performed between counts across observers in each enclosure at similar times.

Population Fluctuations

The magnitude of population fluctuations were examined by studying the history of population size at baseline plots on Yucca Flat and Pahute Mesa. Year to year fluctuations were examined in light of the maximum observed fluctuation at a site by computing an index of relative population turnover. This was defined as the ratio of year to year change/maximum change in population size at a site over the study period. This index was used to examine the relative change in population size across years and across sites.

Spatial Variation in Lizard Traits

Historically, lizard sampling at the NTS has occurred at only a few study sites, and comparisons have not been made between sites farther than 2 km apart. Because of this, spatial variation in lizard traits is largely unknown. Traits of lizards were compared from the center of Yucca Flat and Frenchman Flat and from the foothills that ring these flat areas. Comparisons were made with Mann-Whitney U tests or chi-square tests, both across drainage basins and from basin-bottom to foothills within each basin. These comparisons allowed assessment of the relative magnitudes of variation across important spatial scales. Because of the sampling protocol used (only a single study site is examined at one time), some of the differences revealed in these comparisons could be due to differences in sampling date. The significance of this problem is described in the discussion section, and some alternative approaches are presented there as well.

Tortoise Studies

Tortoise studies in 1994 concentrated on capturing and measuring marked tortoises in the three enclosures in Rock Valley to examine tortoise growth rates. Methods followed those described in Woodward (1994).

RESULTS

BASELINE STUDIES

Yucca Flat Study Area (YUF001)

About equal numbers of uta were seen along transects in 1993 (2.6 $\pm$ 0.52/ha) and 1994 (4.06 $\pm$ 1.14/ha, $F_{1,296} = 3.39$, $P = 0.067$). Whiptails were more commonly observed in 1993 (26.1 $\pm$ 3.1/ha) relative to 1994 (2.4 $\pm$ 1.0/ha, $F_{1,296} = 218.7$, $P < 0.0001$). The total number of lizards (pooled across species) seen along the transects also was higher in 1993 (31.2 $\pm$ 20.7/ha) than in 1994 (6.5 $\pm$ 2.1/ha, $F_{1,296} = 164.6$, $P < 0.0001$). The number of lizard species seen per transect section was higher in 1993 (1.1 $\pm$ 0.1/50 m) than in 1994 (0.4 $\pm$ 0.1/50 m, $F_{1,296} = 87.9$, $P < 0.0001$), implying a more diverse local lizard assemblage in this area in 1993.

This plot was sampled in spring and summer. Uta, horned lizards, and whiptails were seen in the spring; however, only uta were abundant enough to allow generation of a density estimate. The estimate for the entire uta population was 118.3 $\pm$ 17.2/ha. Adult density was estimated as 46.2 $\pm$ 7.8/ha, while juveniles (individuals < 1 yr old) were estimated at 79.9 $\pm$ 18.6/ha. The number of juveniles caught did not change from 1993 to 1994 ($X^2 = 0.03$, 1 d.f., $P = 0.87$), while there were significantly more adults caught in 1994 relative to 1993 ($X^2 = 11.95$, 1 d.f., $P < 0.0001$).

Sex ratios did not differ across years in the spring ($X^2 = 2.32$, 7 d.f., $P = 0.89$, Figure 1-2). The ratio of juveniles to adults varied greatly across years (juveniles ranged from 4 to 79% of the population, $X^2 = 92.9$, 7 d.f., $P < 0.001$, Figure 1-3). There were fewer juveniles per adult in 1994 relative to 1993 ($X^2 = 7.77$, 1 d.f., $P = 0.008$, Figure 1-3). Multi-year comparisons of uta SVL (KW = 25.6, 6 d.f., $P < 0.0001$, Figure 1-4), weight (KW = 67.5, 6 d.f., $P < 0.0001$, Figure 1-4), and age (KW = 72.3, 6 d.f., $P < 0.0001$, Figure 1-4) suggested that these parameters vary greatly from year to year.

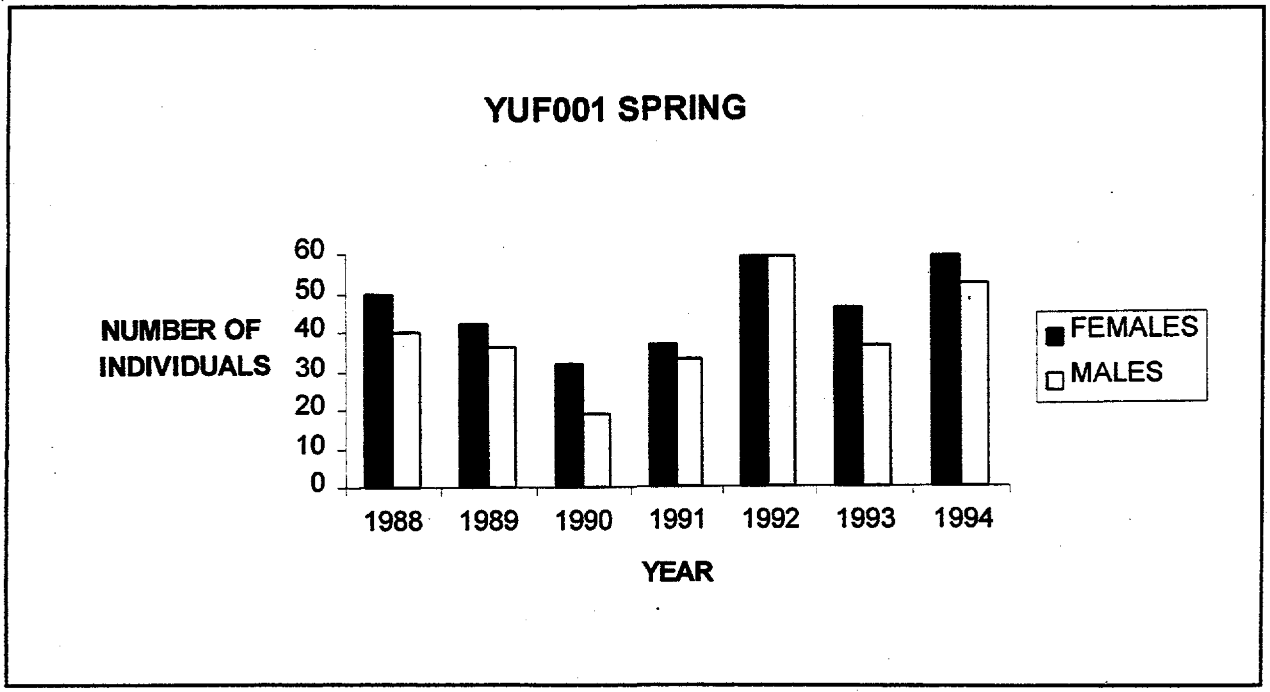

Figure 1-2. Sex ratio of uta population in spring at YUF001 on Yucca Flat from 1988 to 1994.

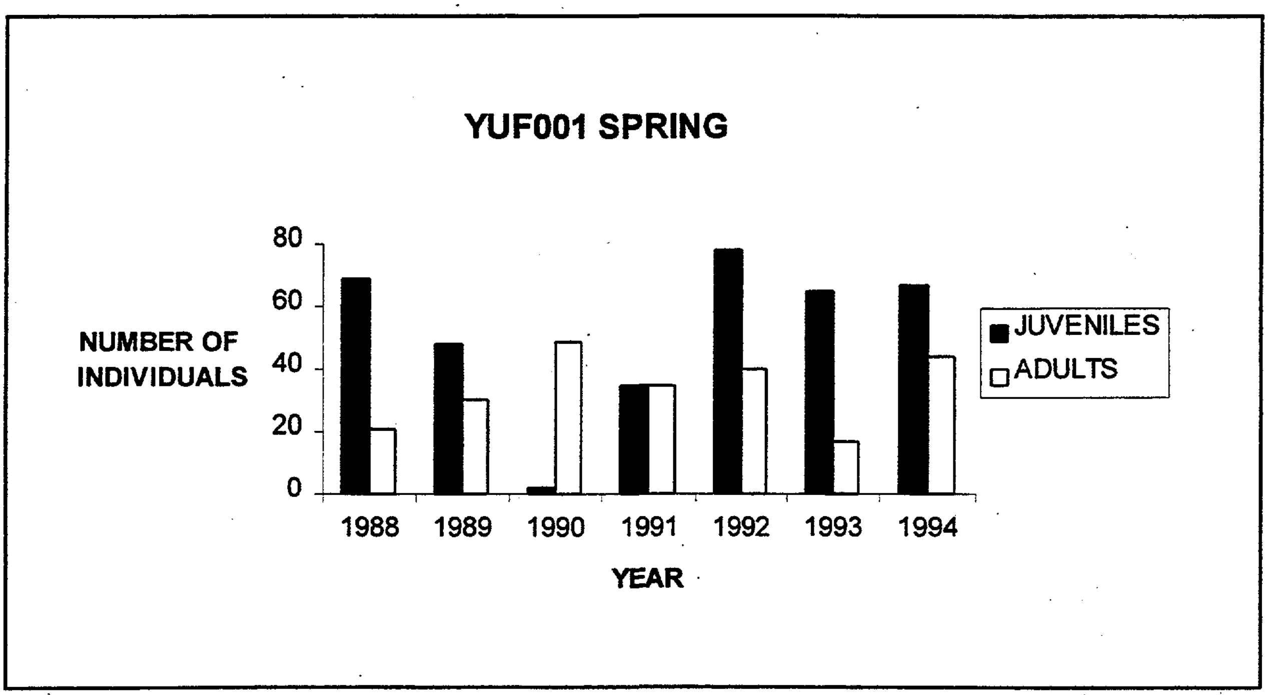

Figure 1-3. Age class composition of a uta population in spring at YUF001 onYucca Flat from 1988 to 1994.

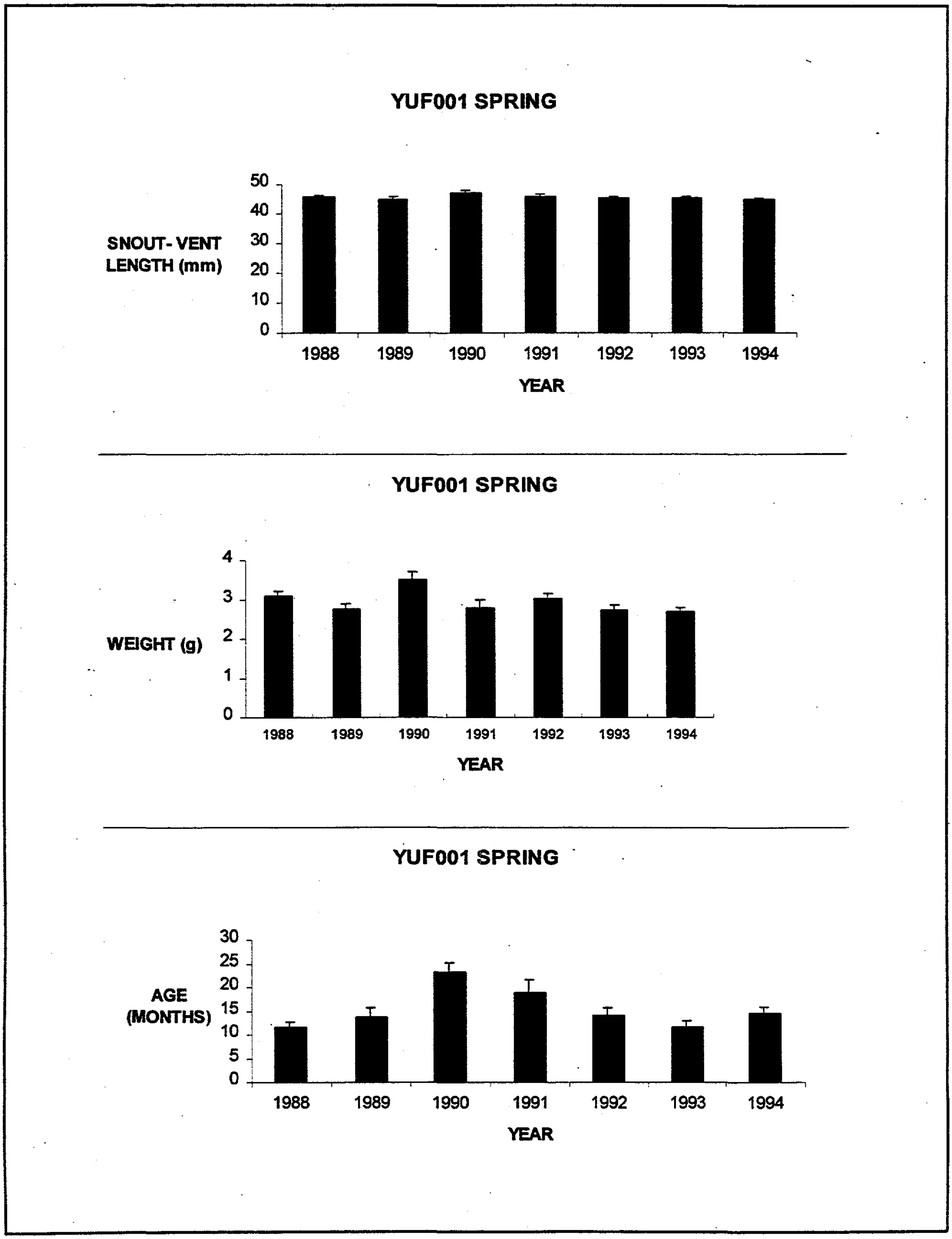

Figure 1-4. Uta SVLs, weights, and ages from plot YUF001 on Yucca Flat from 1988 to 1994.

Uta, horned lizards, leopard lizards, and whiptails were seen on YUF001 in the summer; however, only uta were abundant enough for analysis. The lizard fauna on YUF001 is composed primarily of uta. In plot surveys (which probably underestimate the number of whiptails and leopard lizards) 85 - 95% of the sampled lizards were uta, a pattern that was quite stable across years. Adult uta (57.9 ± 8.3/ha) appeared to greatly outnumber hatchlings (20.9 ± 6.7/ha) on this plot. The overall density estimate for uta (all ages pooled) was 91.3 ± 14.6/ha. The number of adults caught in 1994 was greater than that in 1993 ($X^2 = 17.0$, 1 d.f., $P < 0.0001$) whereas the number of hatchlings caught in 1994 was markedly less than in 1993 ($X^2 = 86.4$, 1 d.f., $P < 0.00001$).

There were no consistent trends in summer densities across years (adult plus hatchling estimates pooled, $r = 0.183$, 6 d.f., $P > .50$, Figure 1-5). In a similar manner, uta densities also did not correlate with total yearly rainfall across years ($r = 0.581$, 6 d.f., $P = 0.13$, Figure 1-6). Summer sex ratios also did not differ across years ($X^2 = 4.87$, 7 d.f., $P = 0.68$, Figure 1-7). The hatchlings' proportion in the population did shift greatly from year to year ($X^2 = 211.68$, 7 d.f., $P < 0.0001$, Figure 1-8). In 1994, there were far fewer hatchlings per adult relative to 1993 ($X^2 = 89.1$, 1 d.f., $P < 0.00001$, Figure 1-8). Multiyear comparisons of uta SVL (KW = 61.7, 7 d.f., $P < 0.0001$, Figure 1-9), weight (KW = 52.4, 7 d.f., $P < 0.0001$, Figure 1-9), and age (KW = 166.5, 7 d.f., $P < 0.0001$, Figure 1-9) suggested that these parameters differ across years.

Frenchman Flat Study Area (FRF001)

This plot was sampled in spring and summer. In spring, uta and horned lizards were seen; however, only uta were abundant enough for analysis. Juvenile density was high in the spring (26.3 ± 22.9/ha), while adult uta density was low (7.3 ± 0.0/ha). The pooled density estimate for uta of all ages was 28.5 ± 13.6/ha. Multiyear comparisons suggest no difference in sex ratios across years ($X^2 = 1.53$, 2 d.f., $P = 0.47$, Figure 1-10). The ratio of juveniles to adults differed across years ($X^2 = 14.29$, 2 d.f., $P < 0.001$, Figure 1-10) with juveniles common in 1988 but relatively uncommon in subsequent samples. Multiyear comparisons of uta SVL (KW = 8.65, 2 d.f., $P = 0.81$, Figure 1-11), weight (KW = 8.55, 2 d.f., $P = 0.014$, Figure 1-11) and age (KW = 18.15, 2 d.f., $P < 0.001$, Figure 1-11) suggested that these parameters differed across years.

In summer, uta, horned toads, leopard lizards, zebra-tails, whiptails, and geckos (*Coleonyx variegatus)* were seen. Uta dominated this plot and were abundant enough for analysis. Adult uta densities were relatively low (10.9 ± 0.0/ha). Hatchling uta estimates appeared to

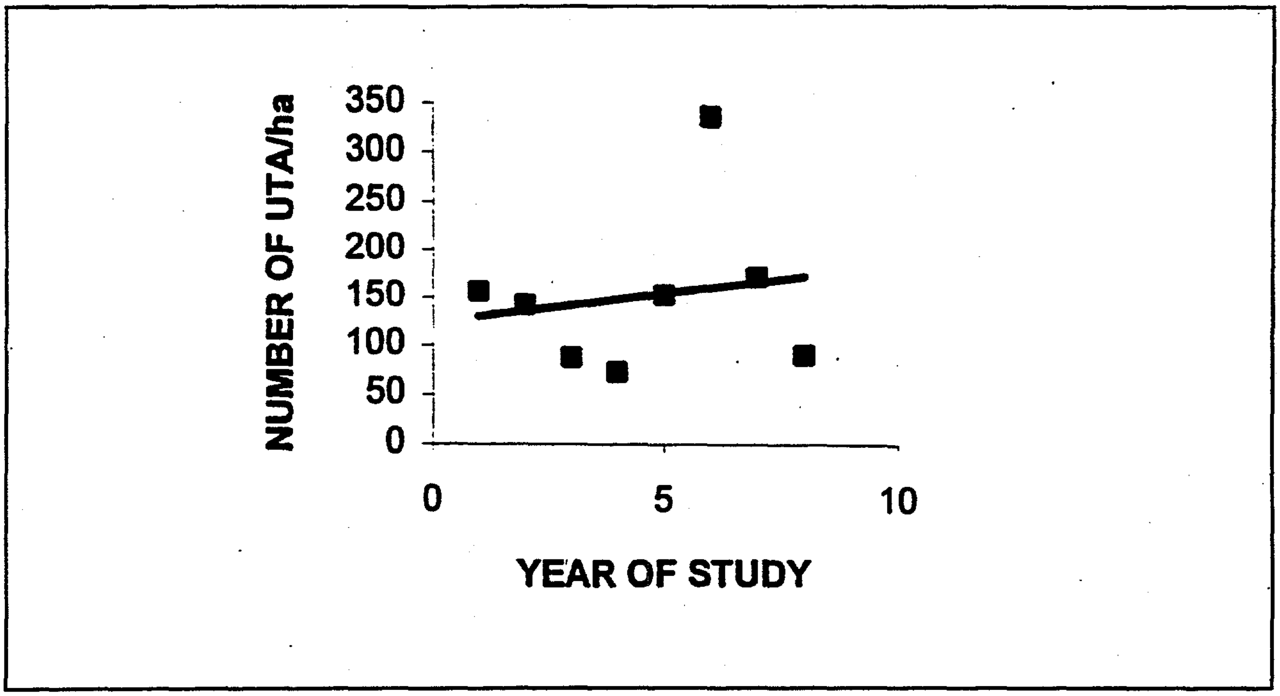

Figure 1-5. Relationship between uta density estimate in summer (adults plus hatchlings pooled) and year of study from 1987 to 1994.

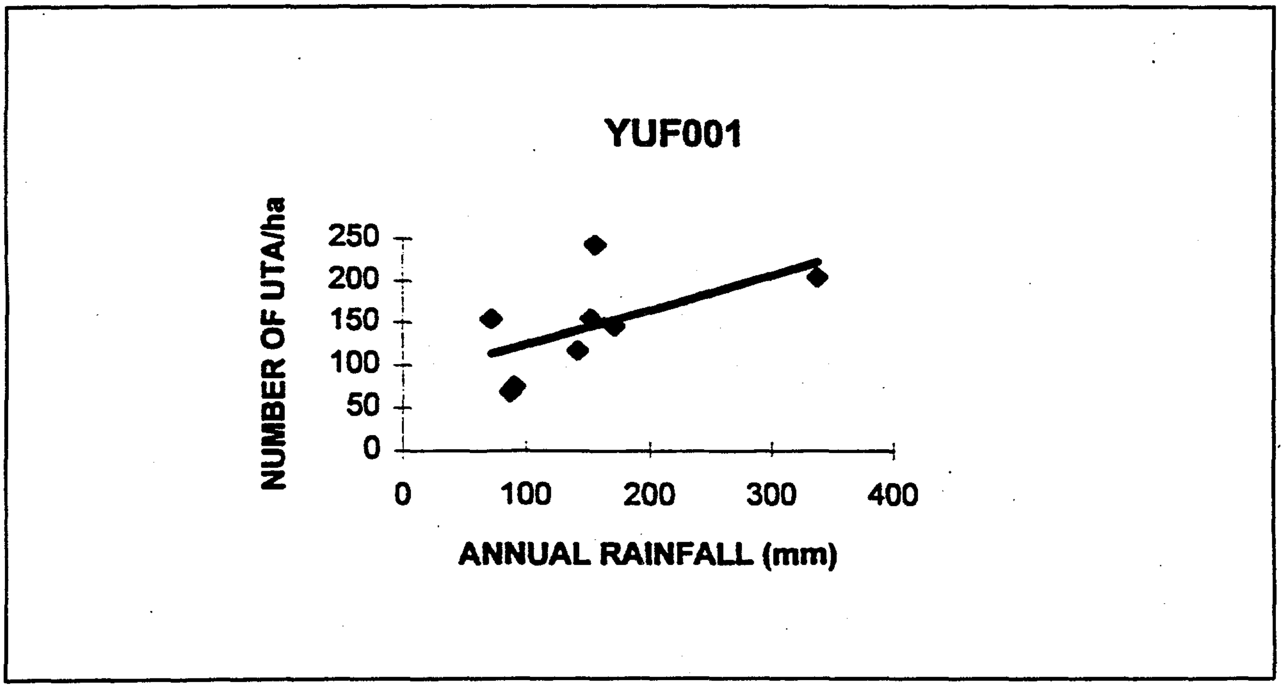

Figure 1-6. Relationship between annual rainfall and uta density estimate in summer (adults plus hatchlings pooled) from 1987 to 1994.

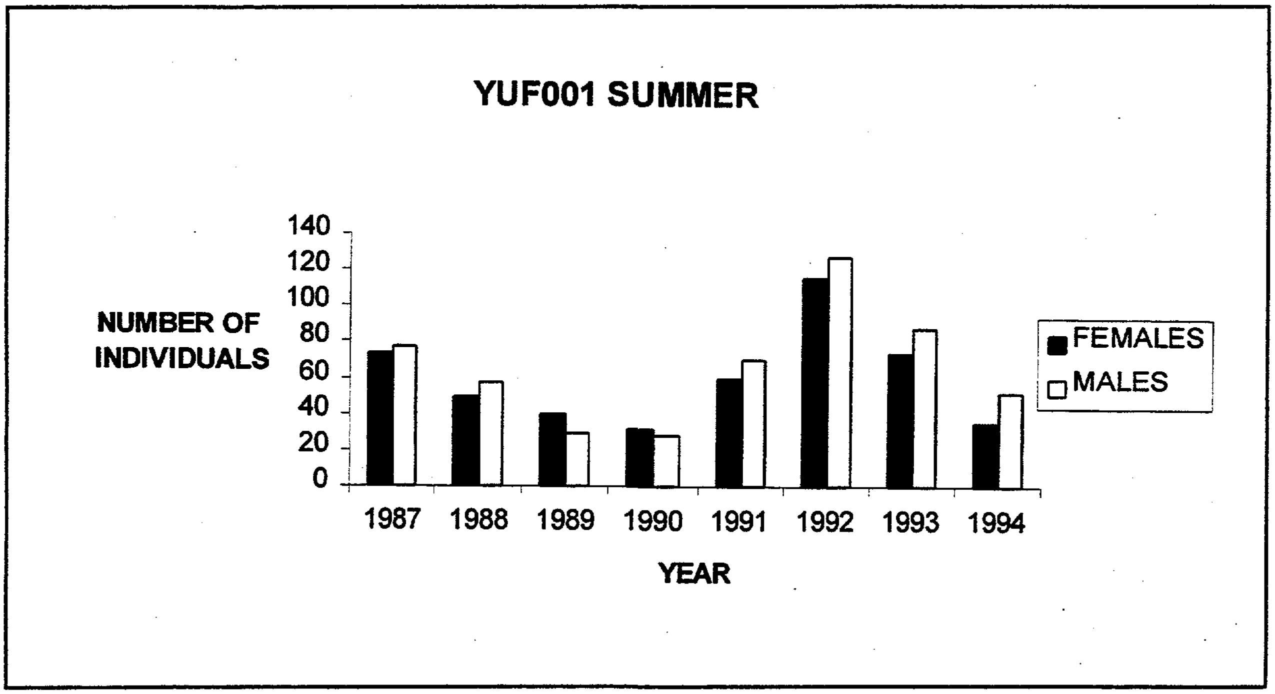

Figure 1-7. Sex ratios of uta populations present in summer on YUF001 on Yucca Flat from 1987 to 1994.

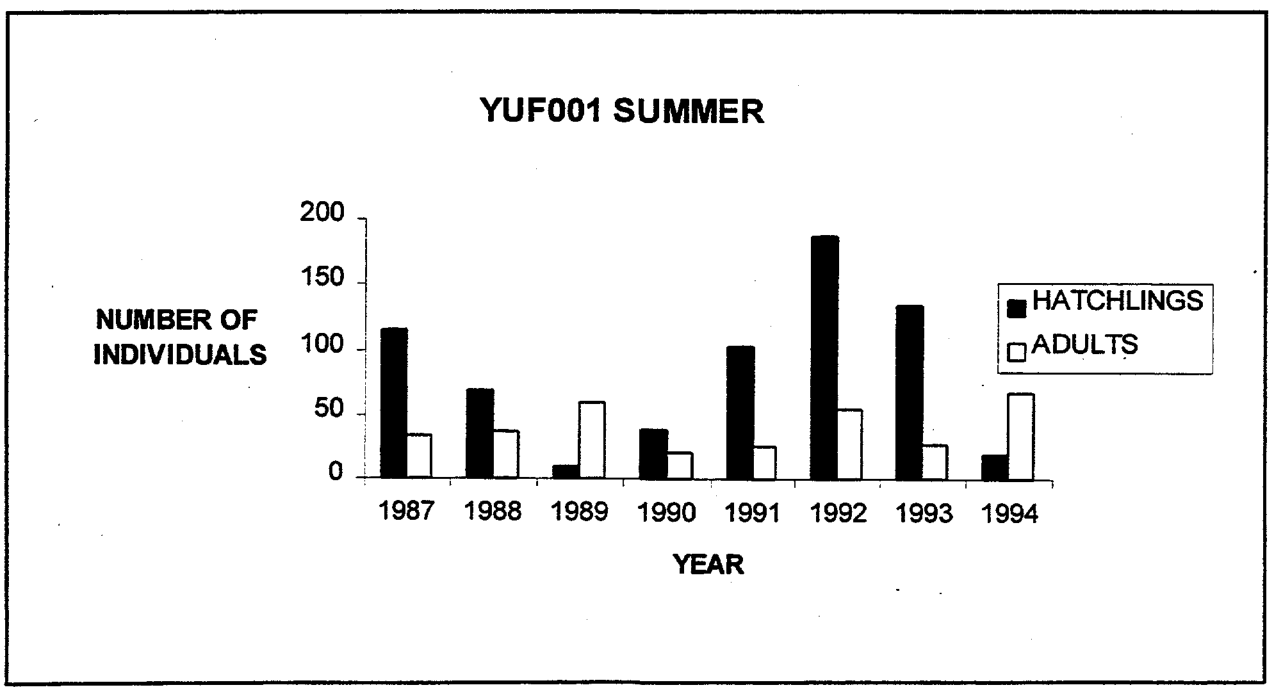

Figure 1-8. Age class composition of a uta population present in summer on YUF001 on Yucca Flat from 1987 to 1994.

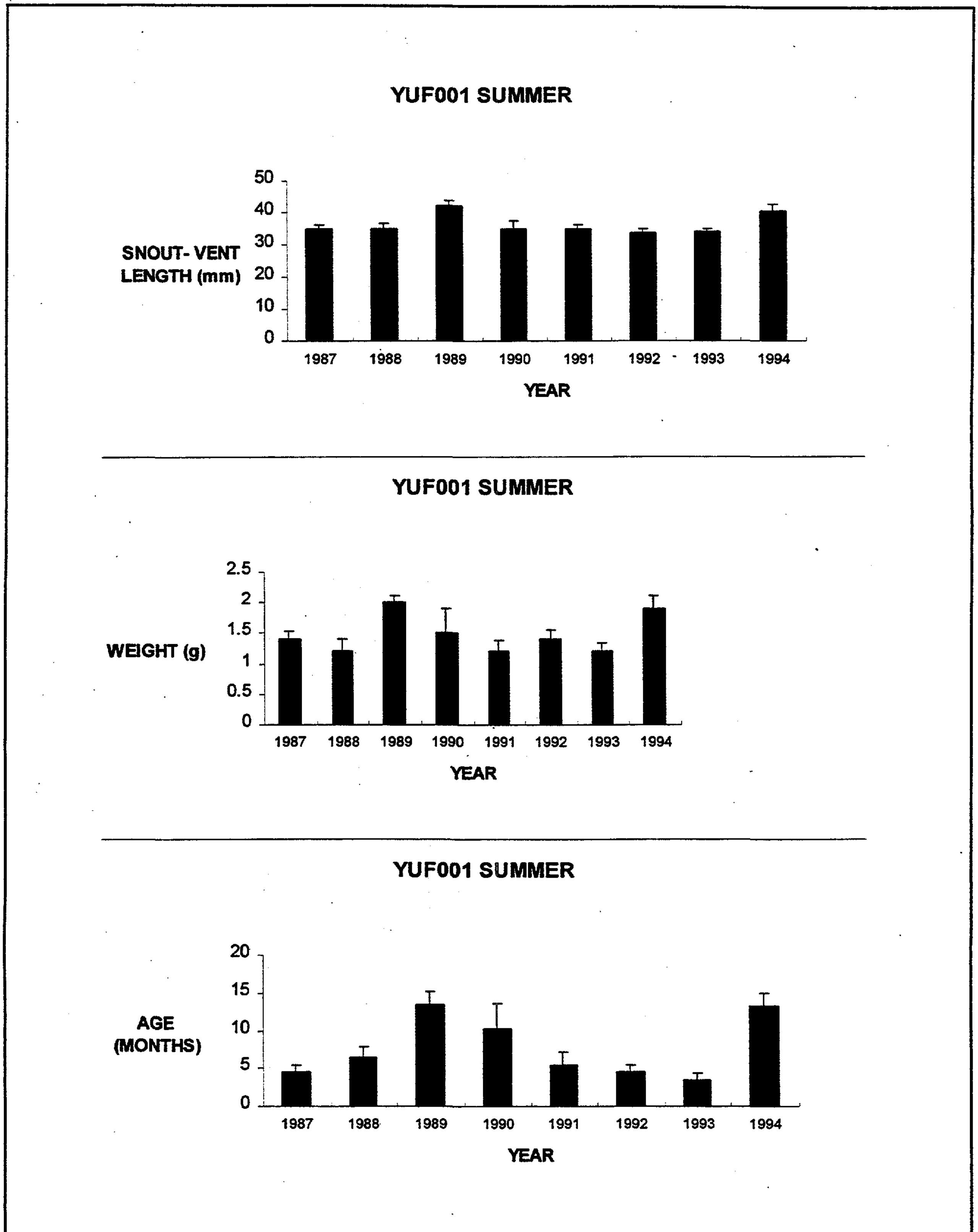

Figure 1-9. Uta SVLs, weights, and ages in summer from 1987 to 1994 at YUF001 on Yucca Flat.

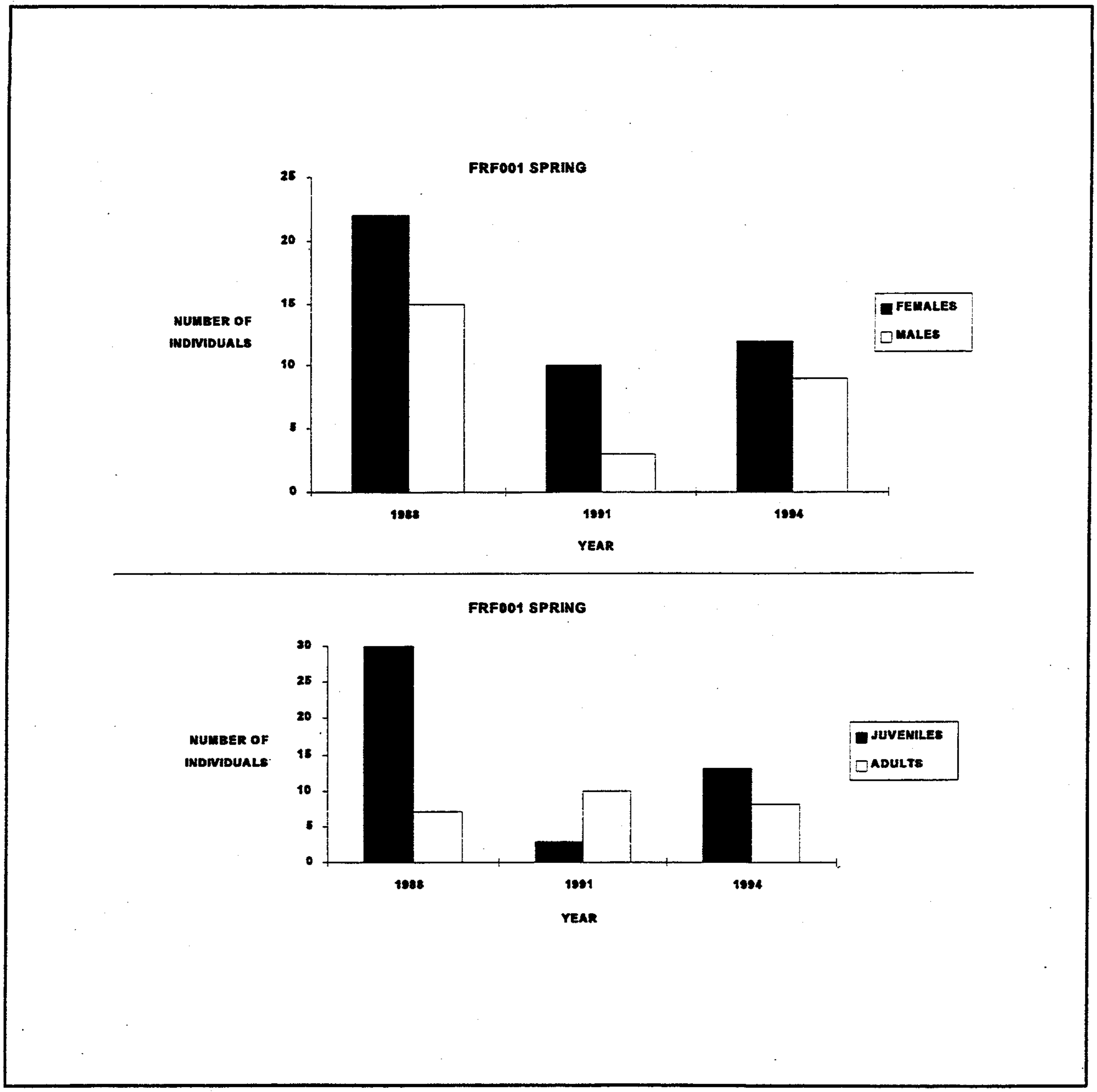

Figure 1-10. Sex ratios and age class composition of the uta population of FRF001 on Frenchman Flat from 1988 to 1994.

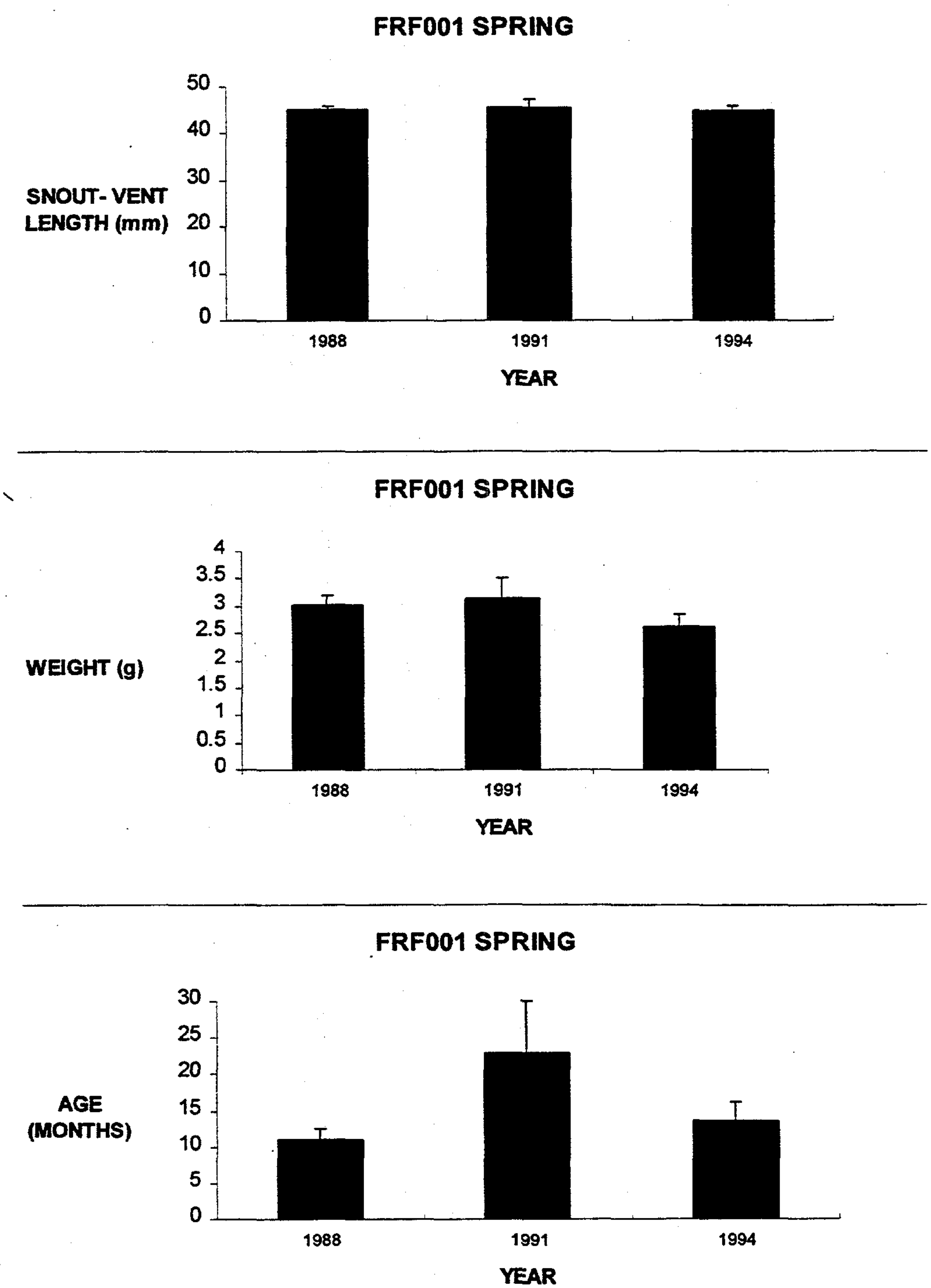

Figure 1-11. Uta SVLs, weights, and ages in spring at FRF001 on Frenchman Flat from 1988 to 1994.

be higher, but were quite variable (24.5 ± 21.5/ha). Pooled data for uta yielded an estimate of 30.1 ± 9.0/ha. Multiyear comparisons of sex ratios revealed a relatively constant pattern across years (X^2 = 0.82, 3 d.f., P = 0.84), with females typically outnumbering males on this plot (Figure 1-12). In contrast, the ratio of adults to hatchlings varied sharply across years (X^2 = 20.97, 3 d.f., P , 0.001, Figure 1-12). Hatchlings greatly outnumbered adults in all years except 1994 (Figure 1-12). Multiyear comparisons of uta SVL (KW = 10.50, 3 d.f., P = 0.015, Figure 1-13), weight (KW = 10.24, 3 d.f., P = 0.017, Figure 1-13), and age (KW = 14.81, 3 d.f., P = 0.002, Figure 1-13) suggested that these parameters differed across years.

Pahute Mesa Study Area (PAM001)

This plot was studied only in the summer. Like the other baseline plots this area is inhabited primarily by uta. Uta and horned lizards were seen, although only uta were abundant enough for a density estimate. Adult uta were relatively common (56.2 ± 31.5/ha) as were hatchlings (48.1 ± 8.2/ha). The pooled estimate for uta of all ages was 97.0 ± 18.8/ha.

Uta summer sex ratio was relatively constant across years (X^2 = 5.62, 6 d.f., P = 0.47, Figure 1-14). In contrast, the fraction of the population represented by hatchlings varied greatly across years (X^2 = 79.35, 6 d.f., P < 0.0001, Figure 1-14). Multiyear comparisons of uta SVL (KW = 76.9, 6 d.f., P < 0.0001, Figure 1-15), weight (KW = 88.3, 6 d.f., P < 0.0001, Figure 1-15), and age (KW = 147.5, 6 d.f., P < 0.0001, Figure 1-15) suggested that these parameters differed across years. There was a decrease in uta densities on this plot across the study period (adult plus hatchling estimates pooled, r = - 0.801, 6 d.f., P = 0.03, Figure 1-16).

DISTURBANCES

Several blast sites were examined in 1994. Examination of blast and control areas reveals strong similarities in species composition; again, plots were dominated by uta. There is some suggestion that uta may be a higher proportion of the lizard community on blast as opposed to control plots.

T1 Blast Site YUF009 and Control Areas YUF010

Sampling took place in the spring and summer. In spring, uta, horned lizards, whiptails, and leopard lizards were seen on the control plot, while only uta were seen on the blast area. In

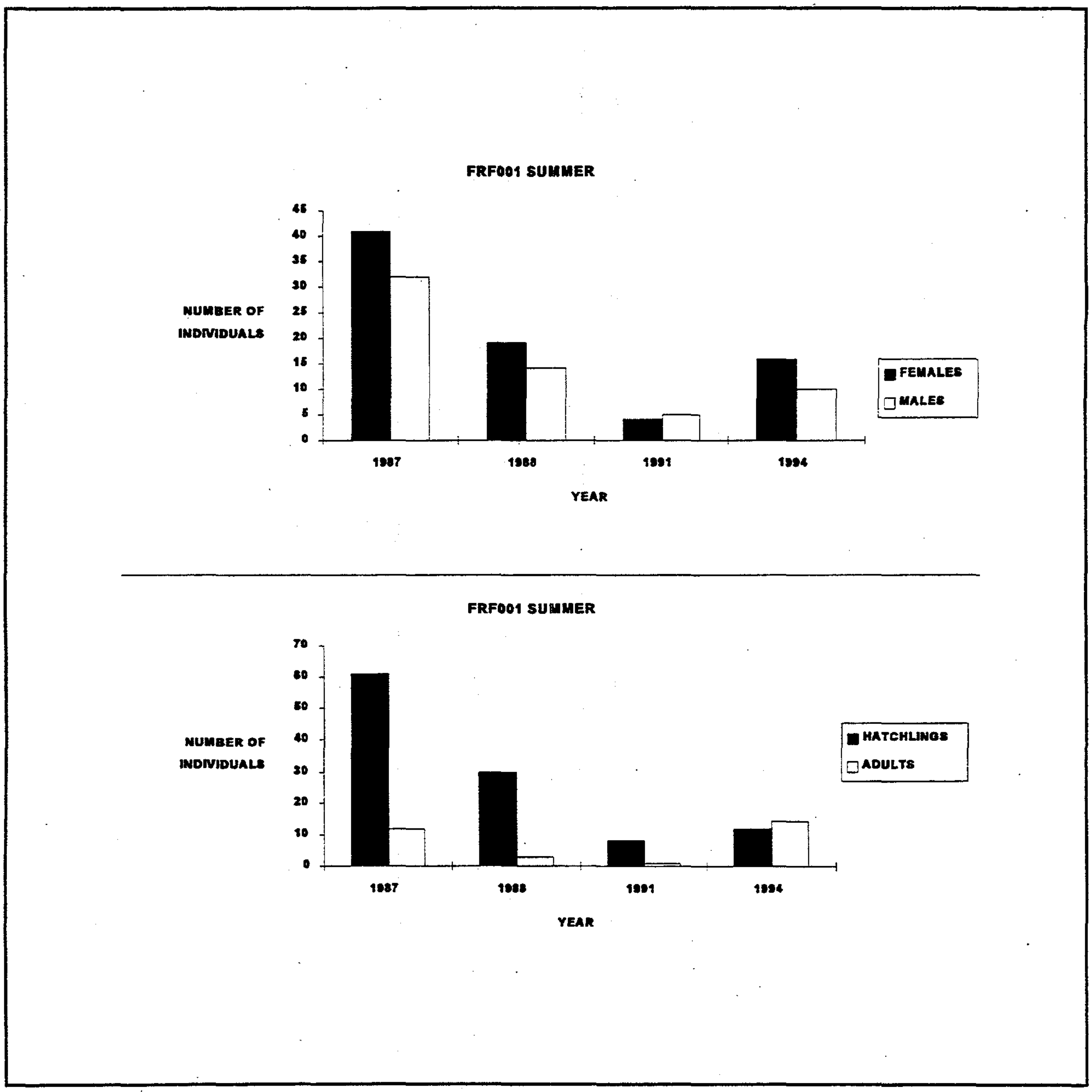

Figure 1-12. Sex ratio and age class composition of the uta population in summer at FRF001 on Frenchman Flat from 1987 to 1994.

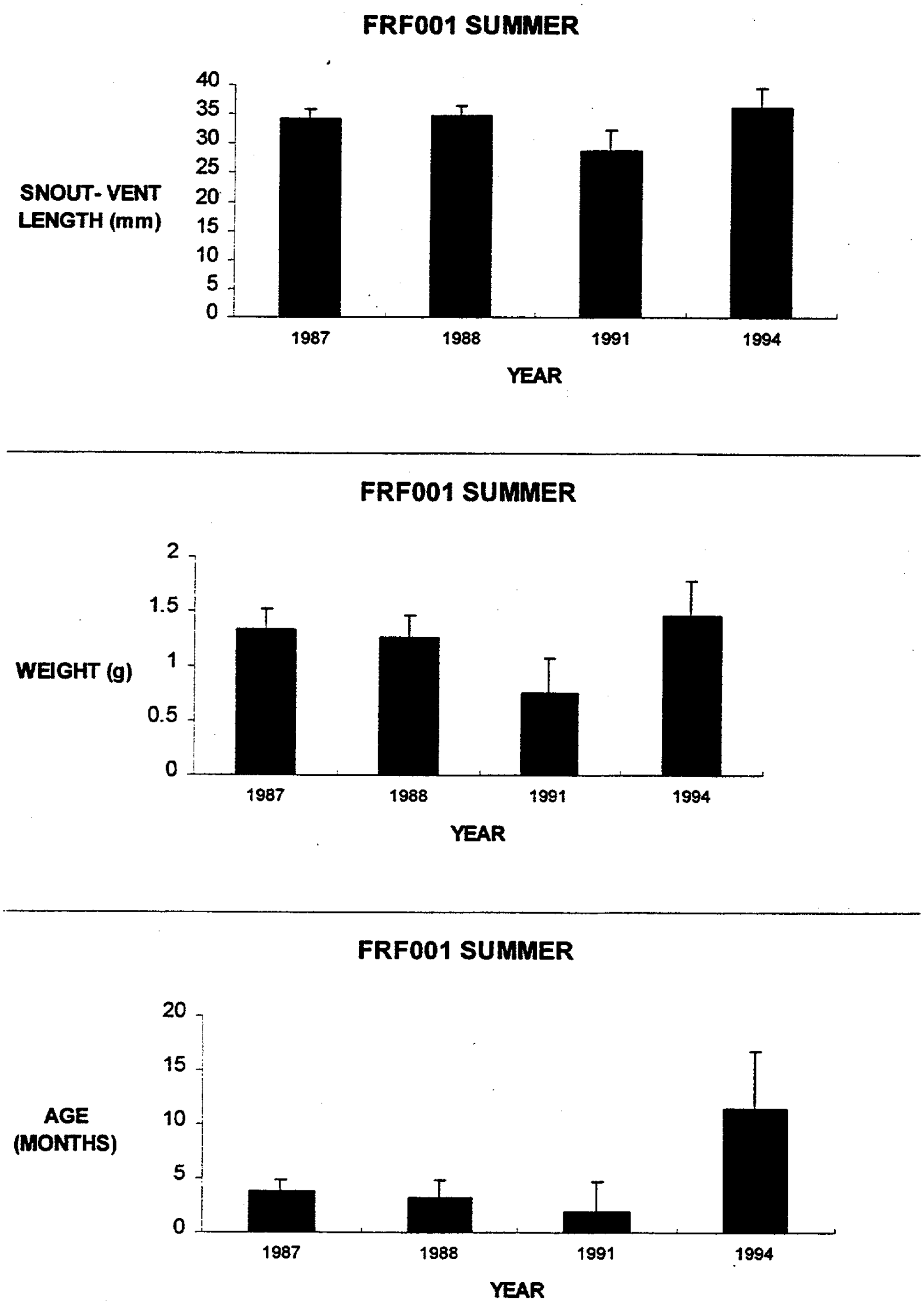

Figure 1-13. Uta SVLs, weights, and ages in summer at FRF001 on Frenchman Flat from 1987 to 1994.

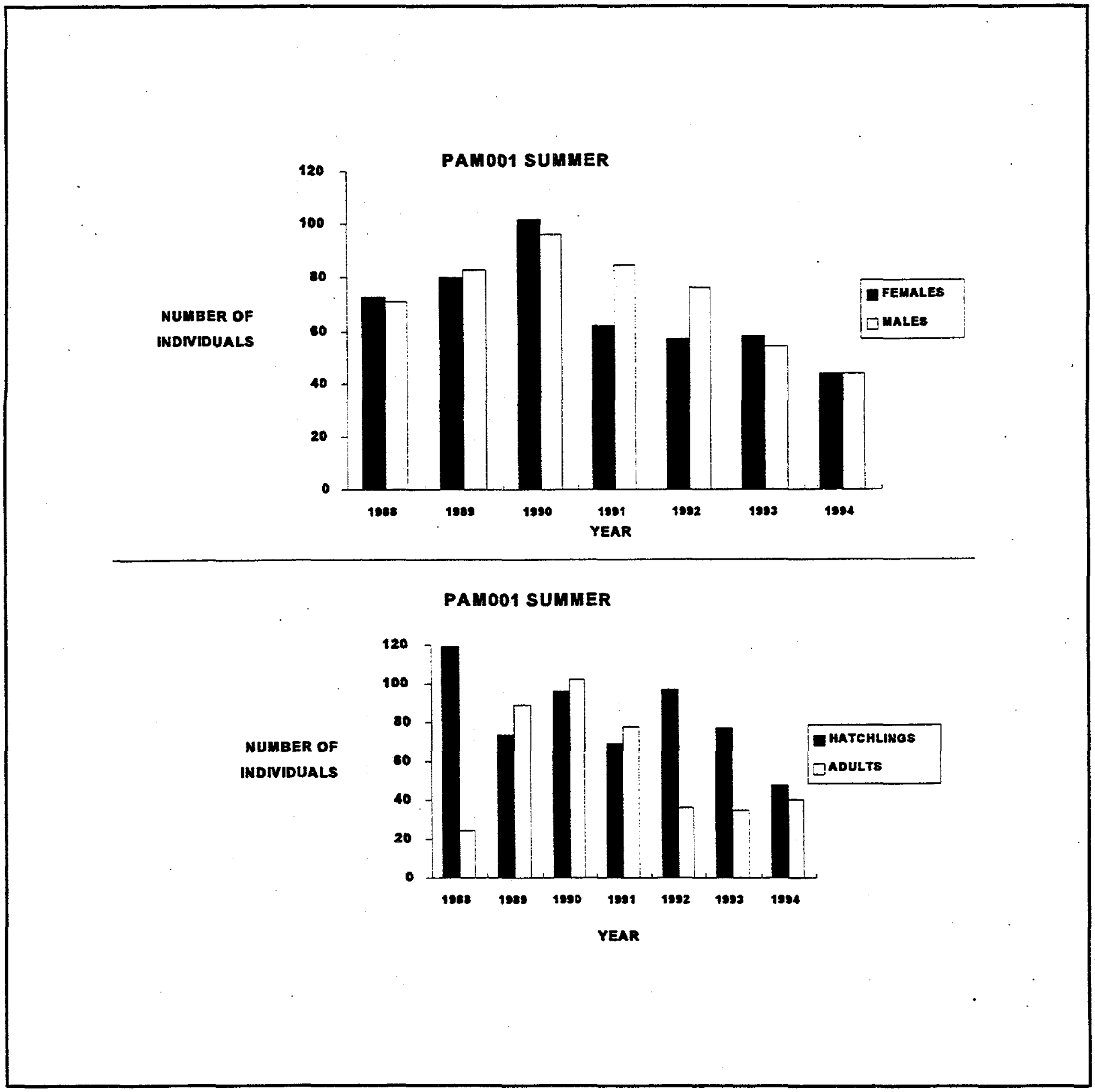

Figure 1-14. Sex ratio and age class composition of the uta population in summer at PAM001 on Pahute Mesa from 1988 to1994.

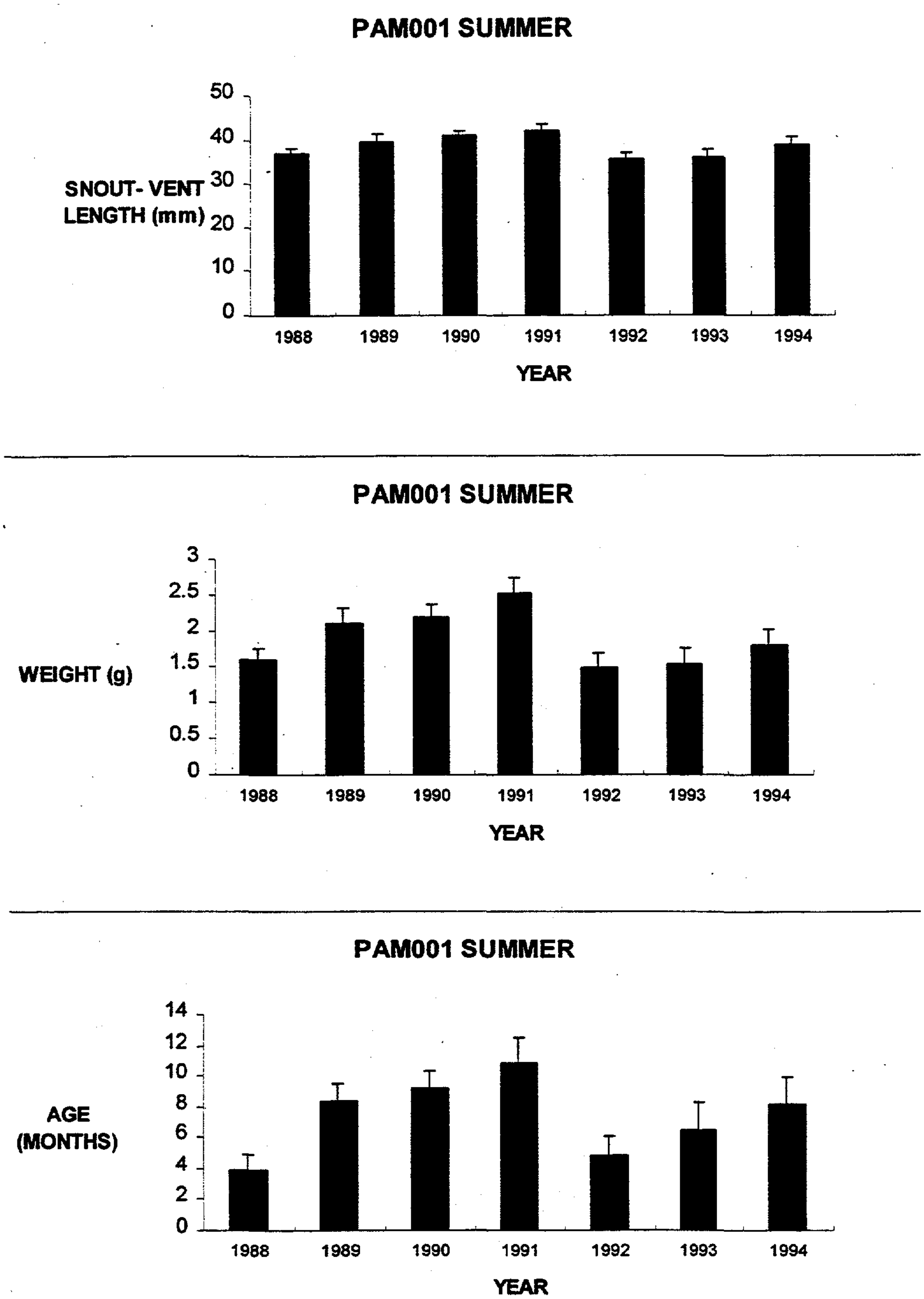

Figure 1-15. Uta SVLs, weights, and ages for a population in summer at PAM001 on Pahute Mesa from 1988 to 1994.

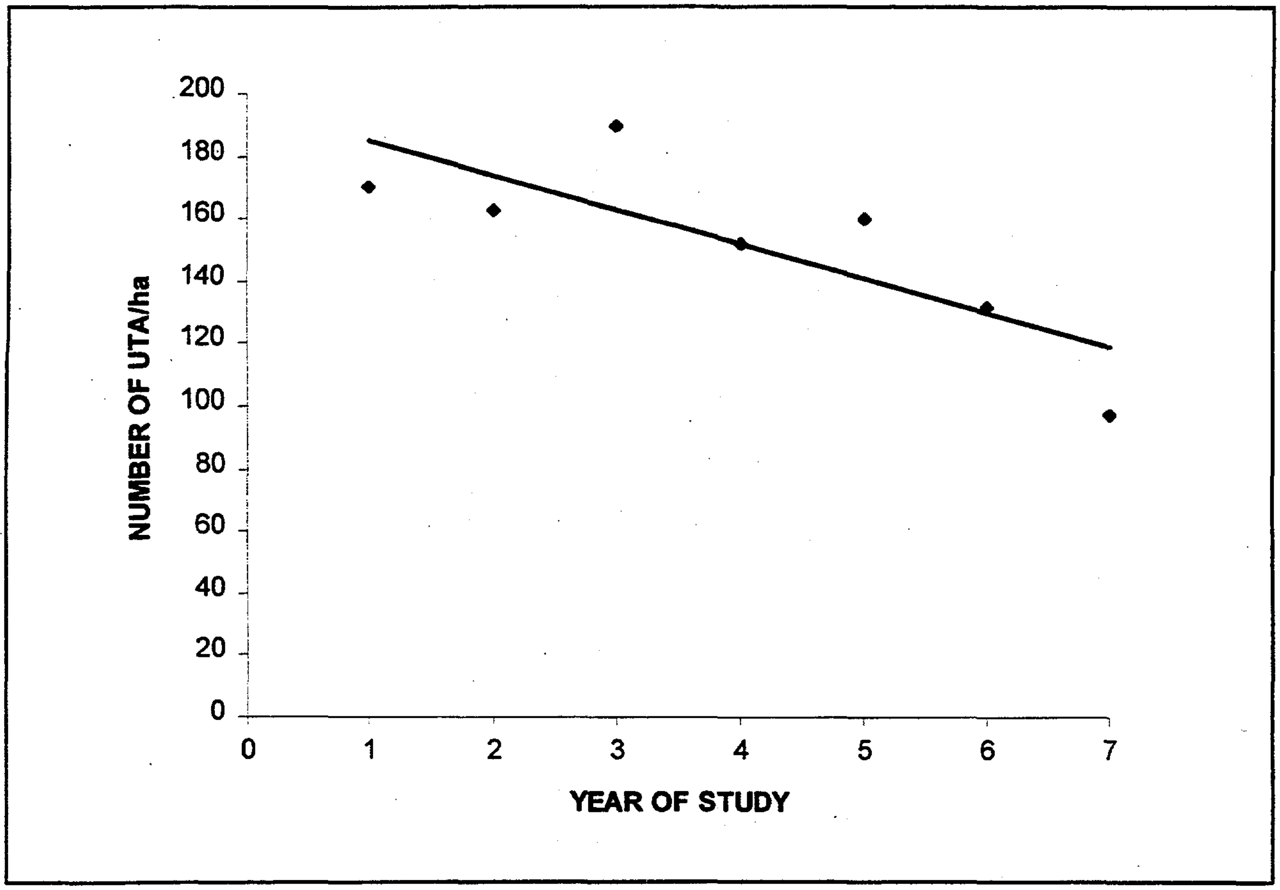

Figure 1-16. Relationship between uta density in summer (adults plus hatchlings pooled) and year of study at PAM001 on Pahute Mesa.

both areas, only uta were abundant enough to allow generation of density estimates. Juvenile uta densities estimated by mark-recapture techniques appeared to be higher on the control area (27.0 ± 10.5/ha) relative to the blast area (14.2 ± 0.0/ha). Comparing the number of juvenile uta actually caught, however, revealed no difference in numbers ($X^2 = 1.32$, 1 d.f., $P = 0.256$). Adult uta on the control area (74.1 ± 13.8/ha) appeared to occur at higher densities relative to the blast area (45.2 ± 8.5/ha). Comparing the number of adult uta caught offers some support for this suggestion ($X^2 = 2.86$, 1 d.f., $P = 0.096$). Pooling uta of all ages results in the suggestion that uta were more common on the control area (103.0 ± 19.3/ha) than on the blast area (59.8 ± 9.0/ha). Comparing the total number of uta caught in these areas suggested a similar pattern ($X^2 = 4.15$, 1 d.f., $P = 0.044$).

Sex ratios did not differ between the blast and control areas ($X^2 = 1.18$, 1 d.f., $P = 0.28$, Figure 1-17). Age class distributions also did not differ between areas ($X^2 = 0.028$, 1 d.f., $P = 0.88$, Figure 1-18).

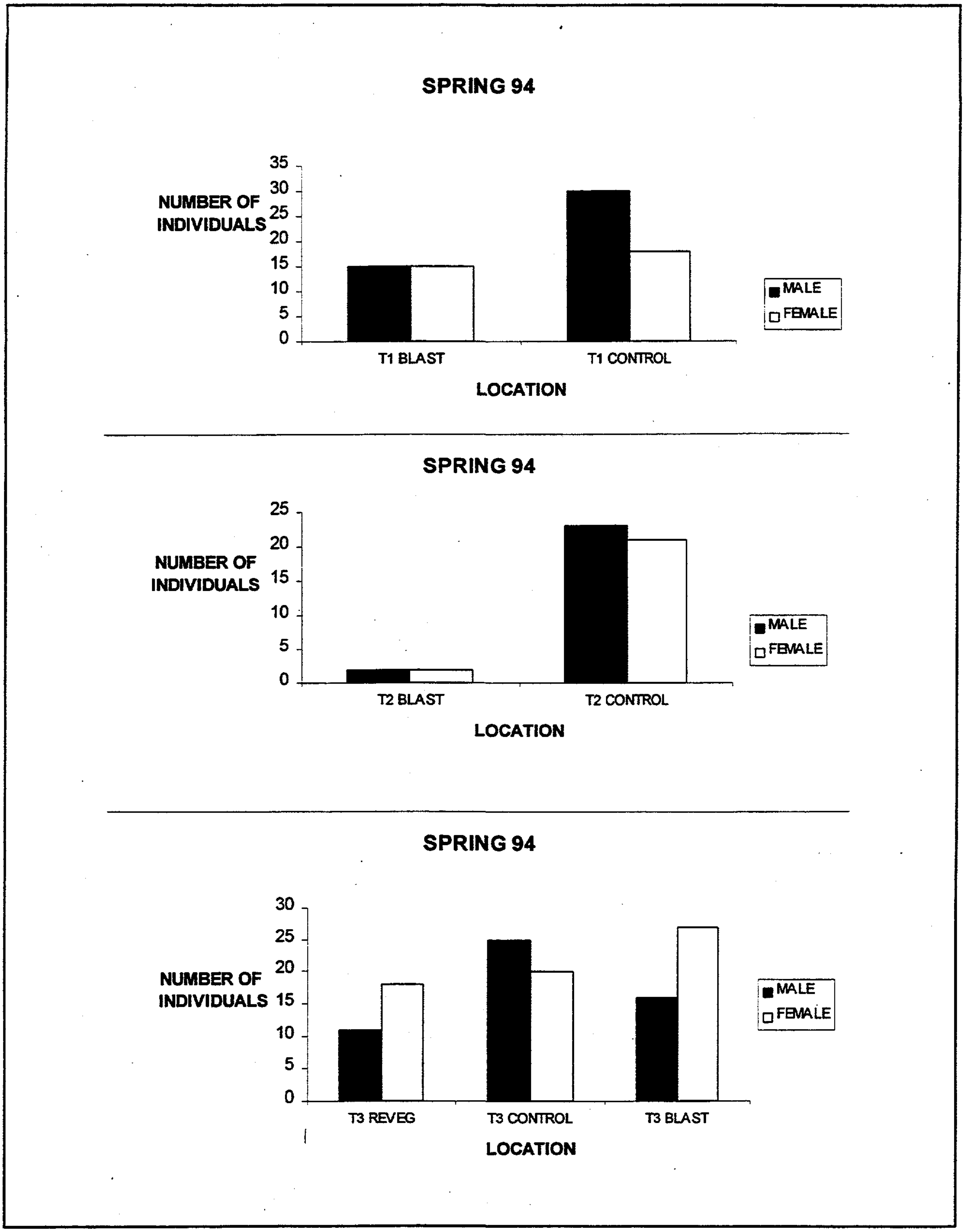

Figure 1-17. Sex ratios of uta populations in spring 1994 on three tower blast sites and their controls.

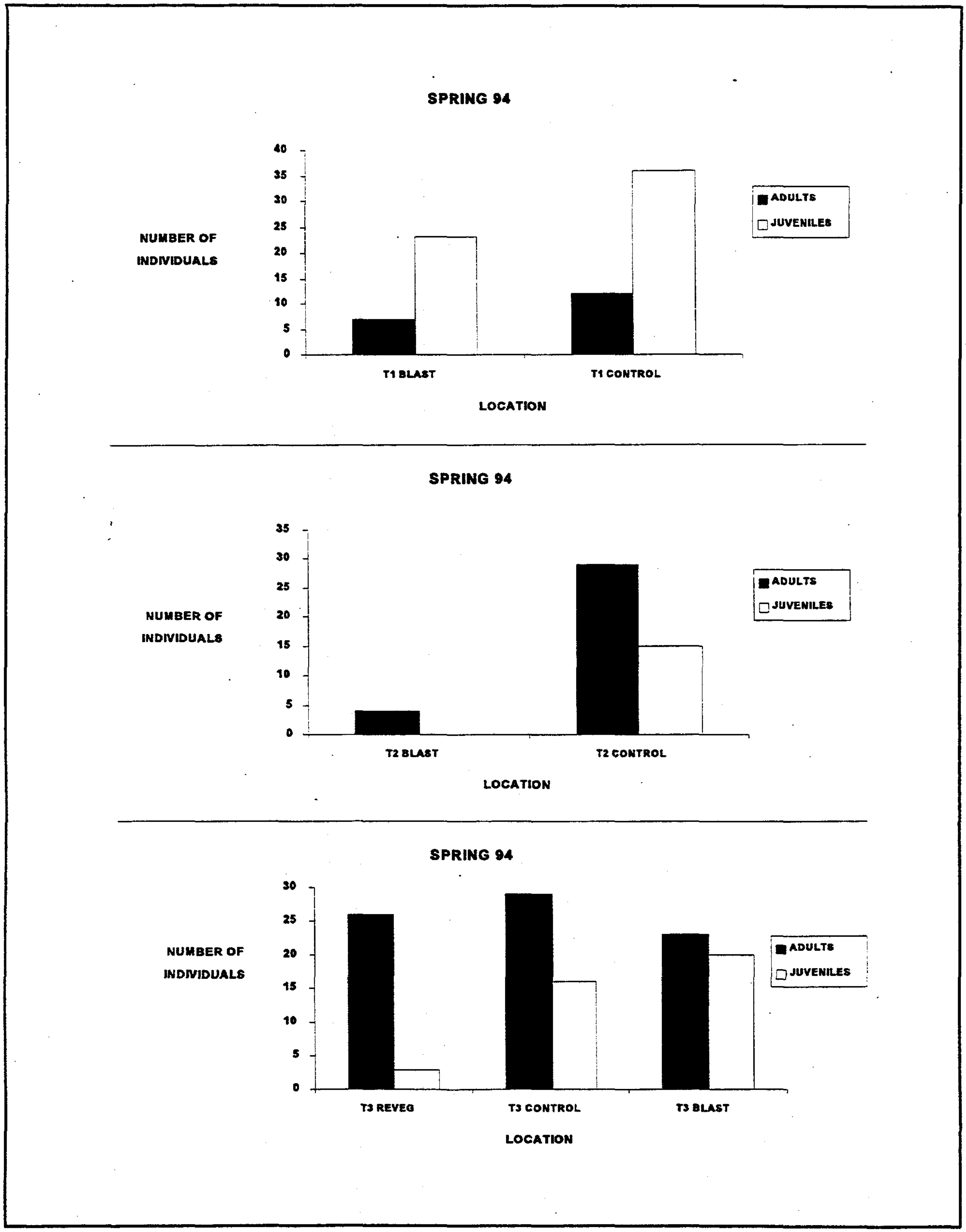

Figure 1-18. Uta age class composition for populations on the tower blast plots and their controls in spring 1994.

Average uta SVL was greater on the blast area relative to the control area (MWU = 1047.5; N = 30, 48; $P = 0.001$; Figure 1-19). In a similar manner, mean weight on the blast area was greater than on the control area (MWU = 1047; N = 30, 48; $P = 0.001$, Figure 1-20). Finally, uta ages did not differ between the two areas (MWU = 813.5; N = 30, 48; $P = 0.254$, Figure 1-21).

In summer, uta, horned lizards, whiptails, zebra-tails, desert spiny lizards, and leopard lizards were seen on the control area, while uta, horned toads, and desert spiny lizards were seen on the blast area. Uta were the most common species on these plots and only they were abundant enough for analysis. There were too few adult utas on either area to generate a density estimate, implying that many adults had died or left these areas since spring. The number of hatchling uta on the control area (50.8 ± 14.6/ha) appeared to be similar to that on the blast area (32.5 ± 8.3/ha). Comparison of the number of hatchlings actually caught yields a similar pattern ($X^2 = 1.6$, 1 d.f., $P = 0.207$). Finally, pooling uta of all age classes appears that densities were similar on the control (64.3 ± 21.9/ha) relative to the blast area (37.1 ± 9.9/ha). Again, comparison of the number of uta caught in these areas revealed a similar pattern ($X^2 = 2.18$, 1 d.f., $P = 0.161$).

Sex ratios did not differ between the control and blast areas ($X^2 = 0.058$, 1 d.f., $P = 0.81$, Figure 1-22). The ratio of hatchlings to adults also did not differ between plots (Fisher Exact Probability test = 0.334, Figure 1-23), with hatchlings being the majority of lizards on both plots (89% on blast areas, 85% on the control area).

Average uta SVL was slightly longer on the blast area relative to the control area (MWU = 348; N = 18, 28; $P = 0.03$, Figure 1-24). Weight exhibited a similar pattern (MWU = 350.0; N = 18, 28; $P = 0.027$, Figure 1-25). Finally, uta on the blast and control areas did not differ in average age (MWU = 309.5; N = 18, 28; $P = 0.127$, Figure 1-26).

T2 Blast Site and Control Areas (YUF014, YUF015)

These plots were sampled in spring and summer. In spring, uta and whiptails were seen on the blast area, while uta and horned lizards were seen on the control plot. Only uta were abundant enough to generate a density estimate. Adult uta density on the control area (57.7 ± 9.8/ha) appeared to be higher than on the blast area (7.1 ± 0.0/ha). Densities of juvenile uta appeared to be higher on the control area (31.2 ± 8.7/ha) than on the blast area (0.0 ± 0.0/ha). Sample sizes on the blast area were too low to allow statistical comparisons

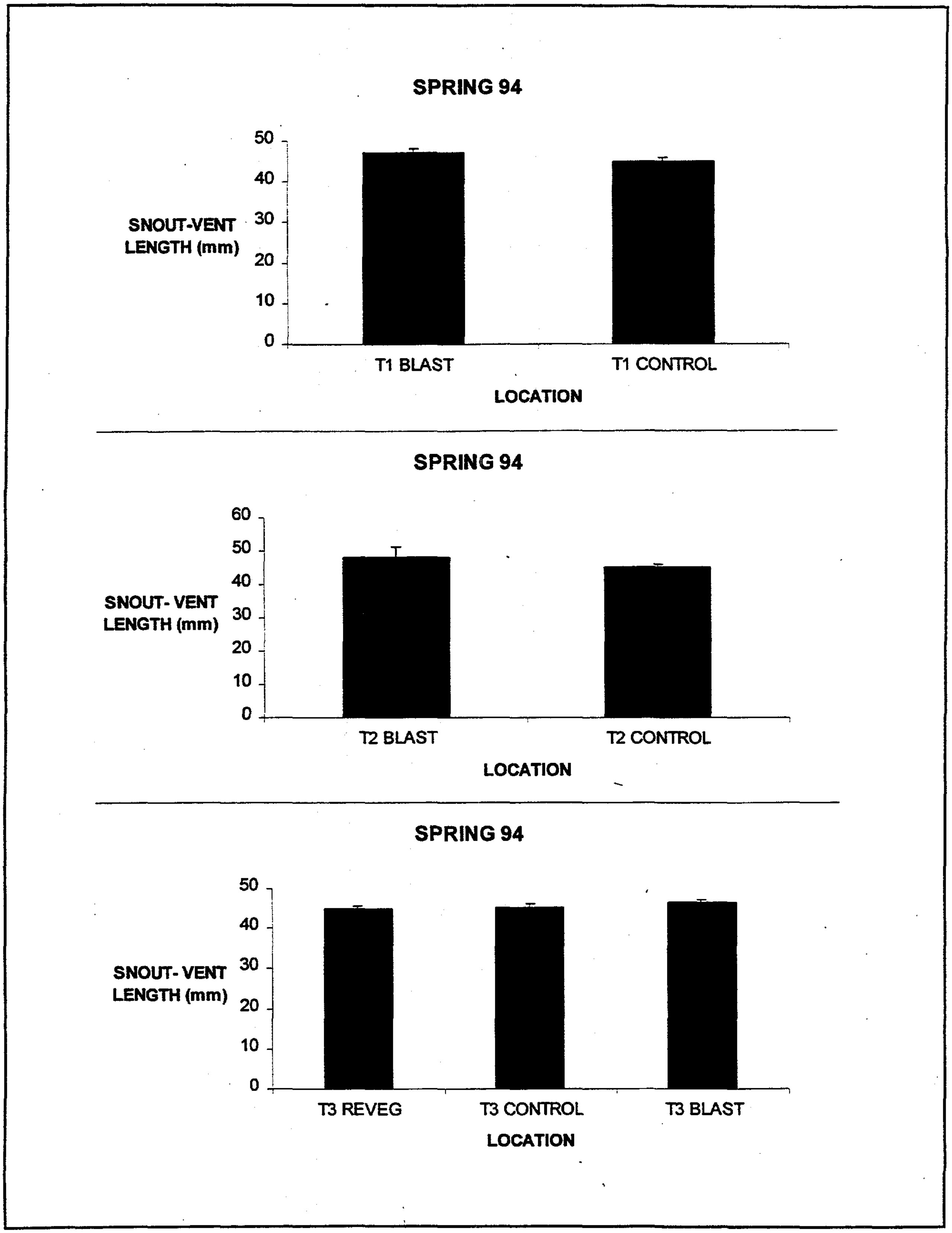

Figure 1-19. Uta SVLs on tower blast plots and their controls in spring 1994.

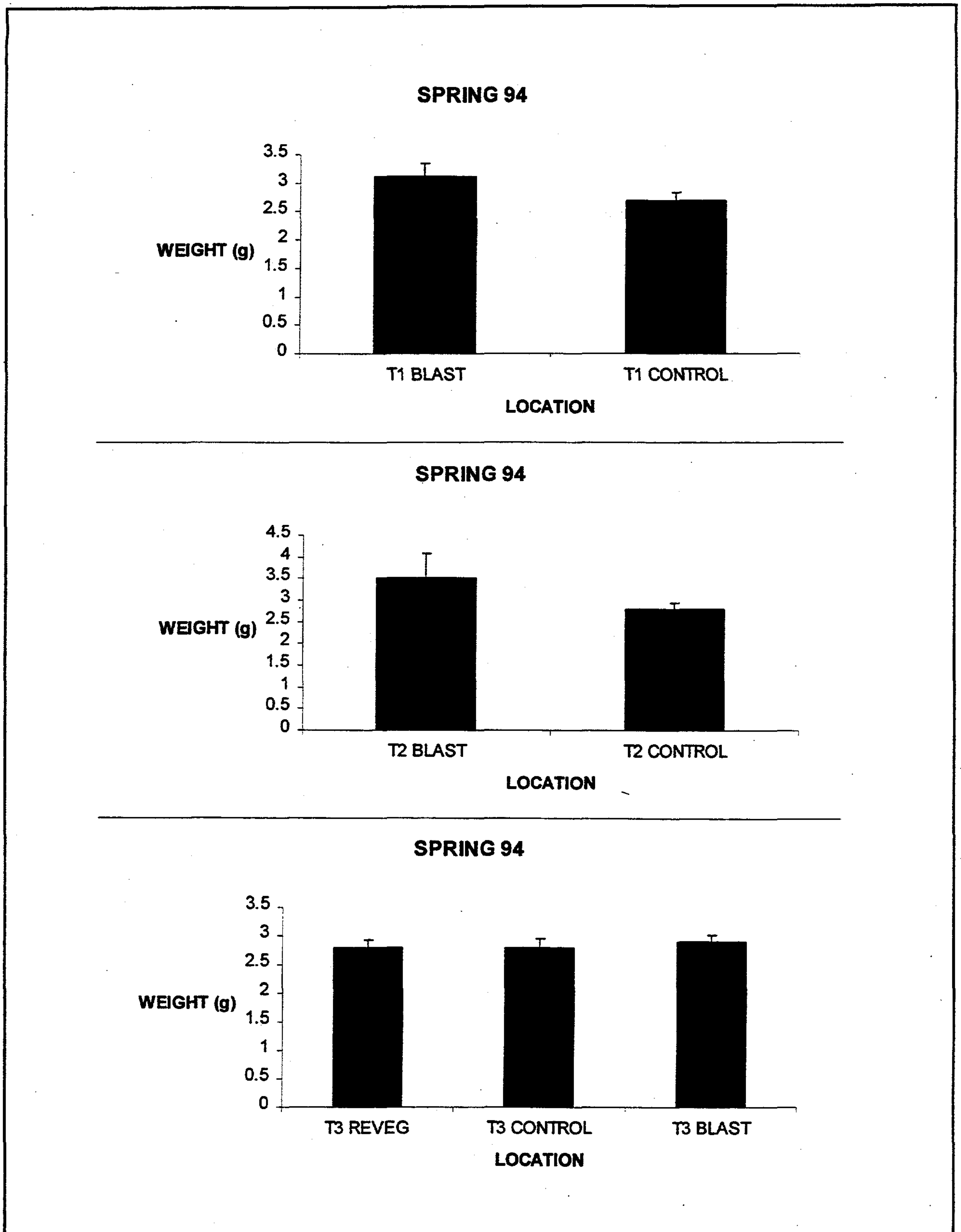

Figure 1-20. Uta weights on tower blast plots and their controls in spring 1994.

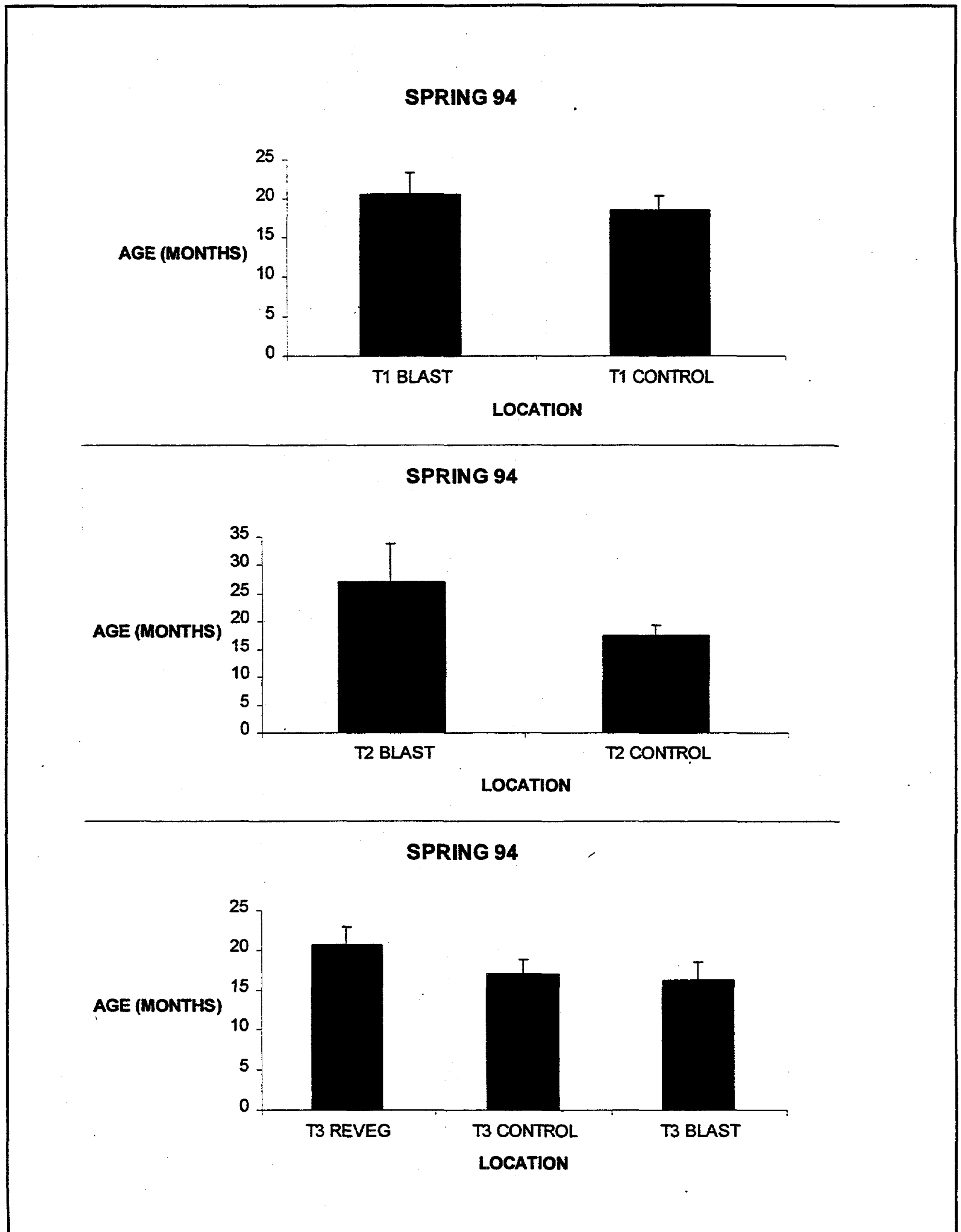

Figure 1-21. Uta age on tower blast plots and their controls in spring 1994.

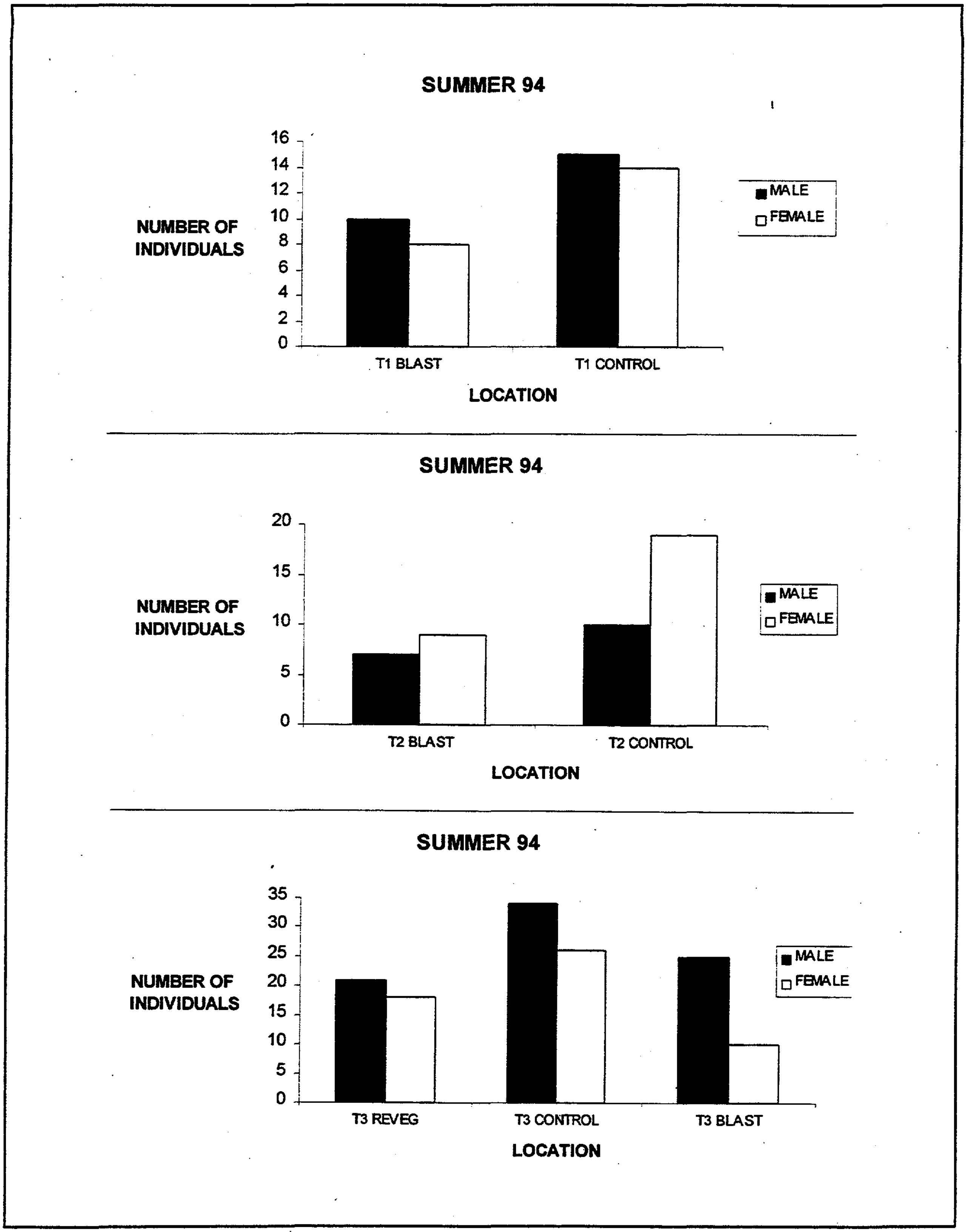

Figure 1-22. Sex ratios of uta populations on three tower blast plots and their controls in summer 1994.

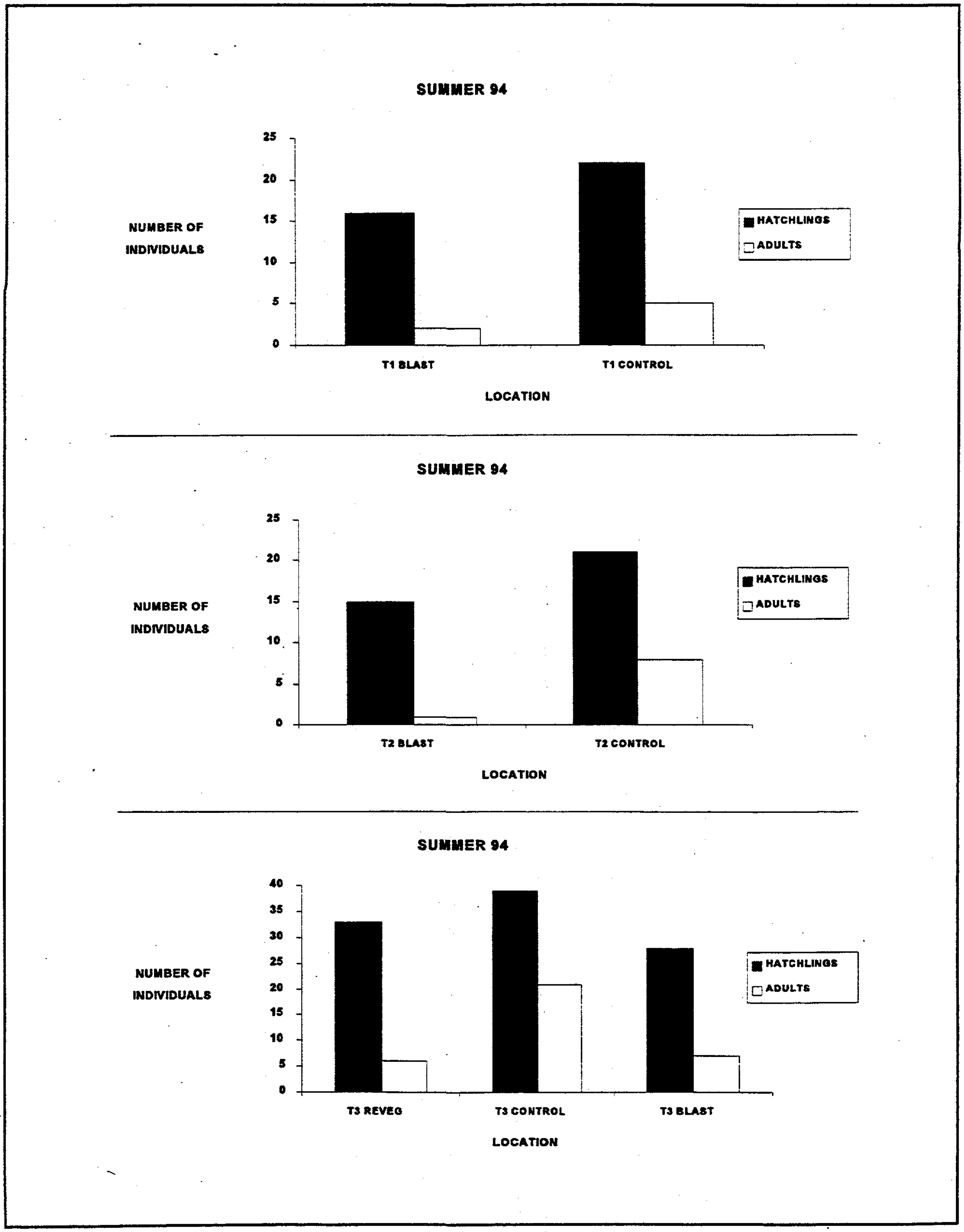

Figure 1-23. Age class composition of uta populations in summer on tower blast plots and their controls in 1994.

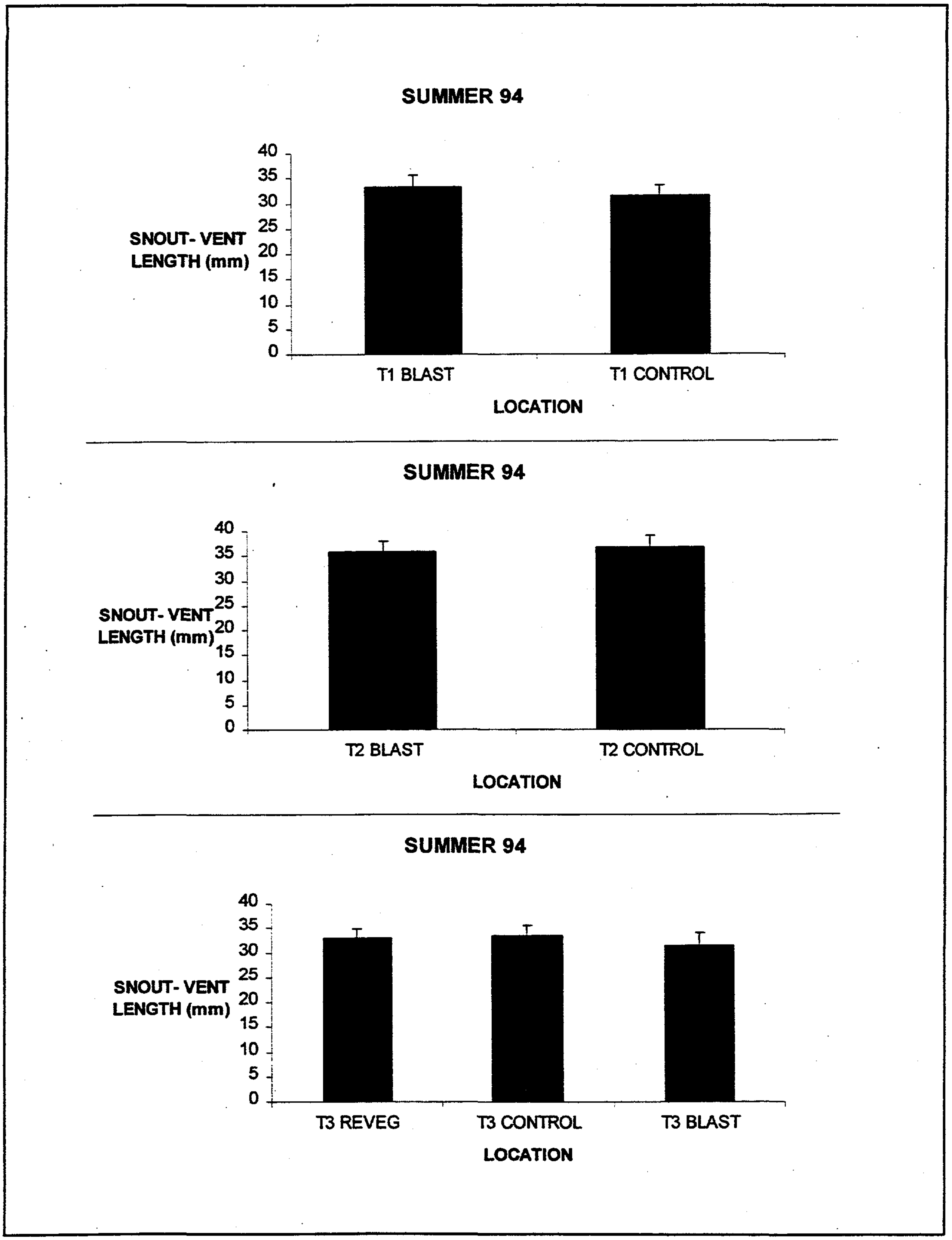

Figure 1-24. Uta SVLs on tower blast plots and their controls in summer 1994.

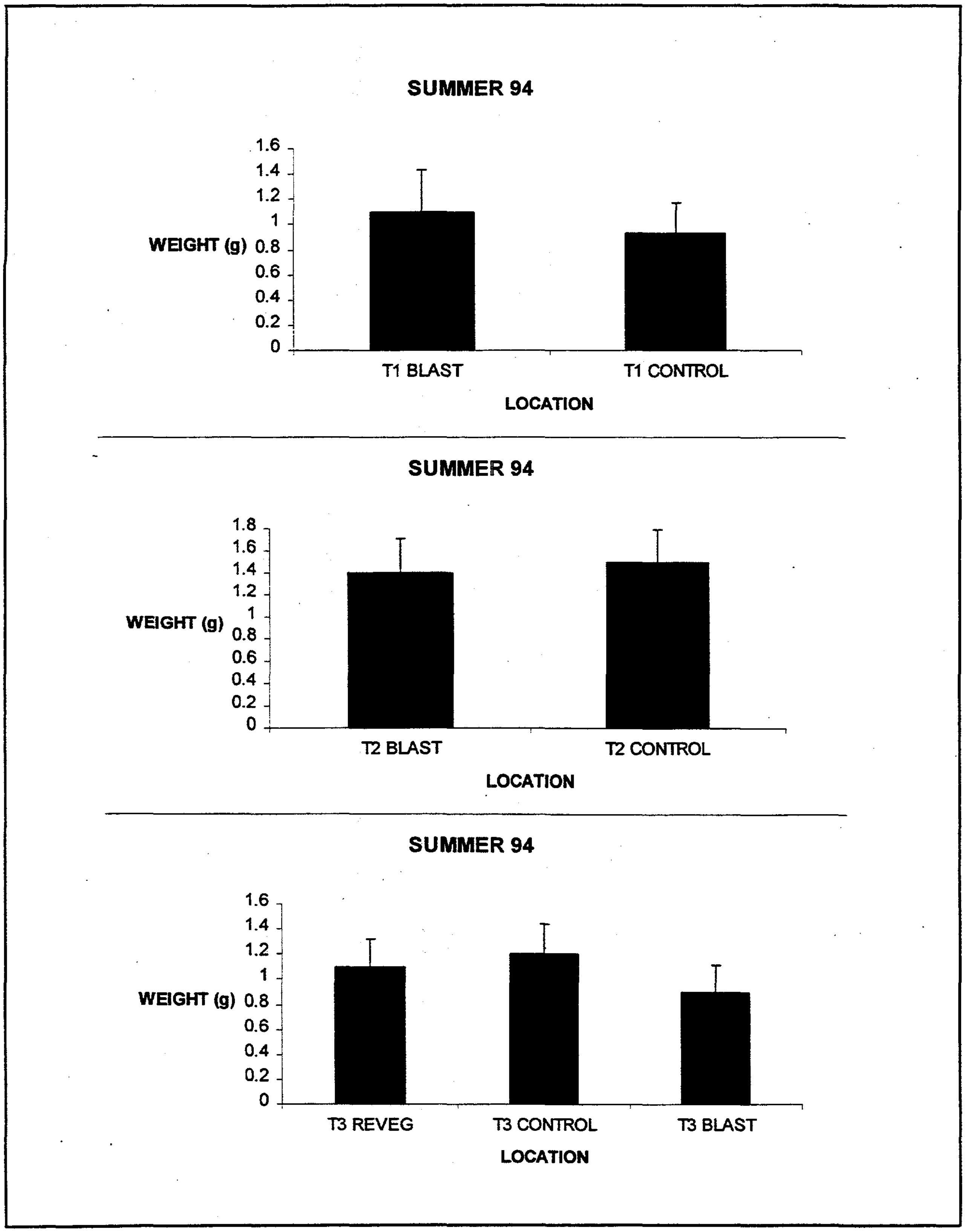

Figure 1-25. Weights of uta from populations from tower blast plots or their controls in summer 1994.

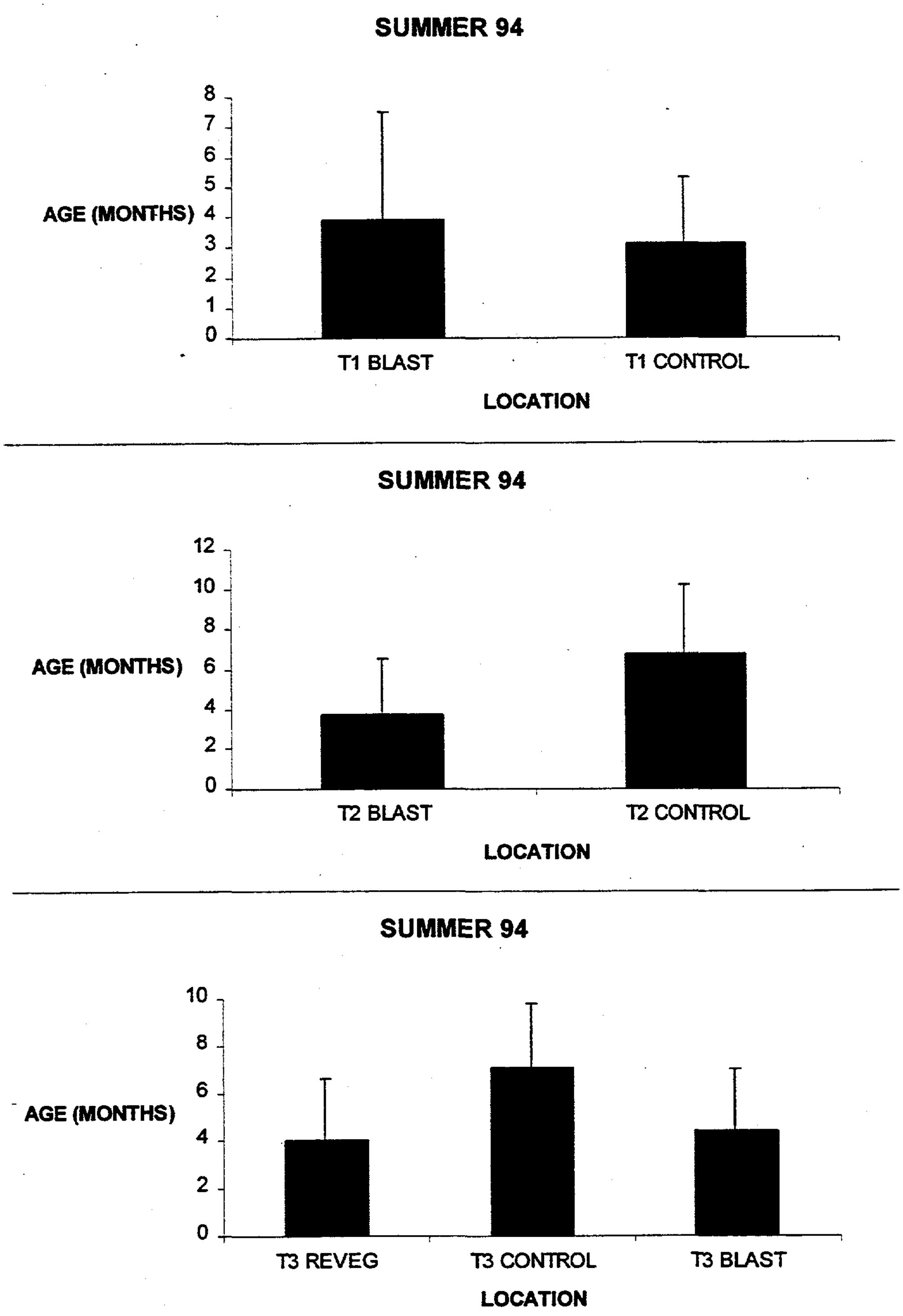

Figure 1-26. Uta ages on tower blast plots and their controls in summer 1994.

of the numbers of juveniles or adults caught across plots. Pooling uta of all age classes, densities appeared to be much higher on the control area (89.4 ± 13.9/ha) relative to the blast area (7.1 ± 0.0/ha).

Sex ratios did not differ between control and blast areas (Fisher Exact Probability Test P = 0.6631, Figure 1-17). The age structure, although biased towards adults on the blast area and juveniles on the control area, cannot be regarded as different (Fisher's Exact Probability P = 0.213, but see results below for age, Figure 1-18).

Both body size estimates (SVL: MWU = 142.5; N = 4, 44; P = 0.040, Figure 1-19, and weight: MWU = 149.5; N = 4, 44; P = 0.022, Figure 1-20) suggested that uta on the blast area were larger than those on the control area. Comparison of ages suggested the blast area was occupied by older uta (MWU = 143.0; N = 4, 44; P = 0.018, Figure 1-21).

By summer, uta and horned lizards were present on the control plot, while uta, horned toads, and whiptails were present on the blast area. Uta was the only species present at high enough densities to merit analysis. Adult uta were not abundant enough to generate a density estimate on the blast plot (only one was seen), whereas the eight adults caught on the control plot did allow an estimate to be calculated (14.2 ± 0.0/ha). Hatchling uta density estimates were somewhat similar on the control plot (40.2 ± 6.4/ha) and the blast plot (29.0 ± 5.4/ha). Comparison of the number of hatchlings caught also reveal a similar pattern (X^2 = 1.0, 1 d.f., P = 0.277). Pooling uta, age classes yield blast area estimates of 30.6 ± 5.0/ha and apparently higher estimates of 55.0 ± 7.3/ha on the control area. Comparisons of the total number of uta caught provides some evidence that there were more uta on the control plot (X^2 = 3.75, 1 d.f., P = 0.054) relative to the blast plot.

Sex ratios did not differ across blast and control areas (X^2 = 0.38, 1 d.f., P = 0.55, Figure 1-22). Age structure was biased towards hatchlings on the blast area relative to the control, although the difference was not large enough for statistical significance (X^2 = 2.93, 1 d.f., P = 0.09, Figure 1-23). Both estimates of uta body size (SVL: MWU = 257.5; N = 16, 29; P = 0.368, Figure 1-24, weight: MWU = 268.5; N = 16, 29; P = 0.752, Figure 1-25) did not differ between control and blast areas. In a similar manner, age distributions did not differ across plots (MWU = 260.5; N = 16, 29; P = 0.491; Figure 1-26).

T3 Blast Site, Control, and Revegetated Areas (YUF013, YUF012, YUF011)

These plots were sampled in both spring and summer. Spring samples revealed uta and leopard lizards were present on the T3 control area; uta on the T3 blast area; and uta, leopard lizards, and horned lizards on the T3 revegetation site. Uta were the only lizards abundant enough for analysis. Densities of uta ≥ 1 year old were similar on the blast area (52.5 ± 12.1/ha), the revegetated area (48.5 ± 7.7/ha), and the control area (59.8 ± 12.0/ha). A chi-square test comparing the number of uta ≥ 1 year old captured in the three areas ($X^2 = 0.39$, 2 d.f., $P > 0.80$) also suggests similar numbers in the three areas. There were too few uta < 1 year old captured on the revegetation plot to make a comparison. Pooling uta of all age classes yields estimates of 56.3 ± 10.4/ha for the revegetated area, 59.8 ± 12.0/ha for the control, and 87.8 ± 11.6/ha for the blast area. Number of uta caught (all ages pooled) did not differ across the three areas ($X^2 = 3.89$, 2 d.f., $P = 0.151$).

Sex ratios did not differ across the three areas (blast area 37.9% male, revegetation area 37.2% male, control area 55.6% male, $X^2 = 3.65$, 2 d.f., $P = 0.17$ Figure 1-17). Age-class comparisons revealed an interesting pattern with uta < 1 year old representing a rare group on the revegetation plot but relatively common on the control and T3 blast areas (Figure 1-18, $X^2 = 10.39$, 2 d.f., $P < 0.01$). Uta ages also differed across areas with the revegetated area containing older individuals relative to the other two areas (KW = 8.816, 2 d.f., $P = 0.012$, Figure 1-21). Age-class composition did not differ between the blast and control areas ($X^2 = 1.09$, 1 d.f., $P = 0.30$, Figure 1-18). Differences in SVL were marginally nonsignificant (KW = 5.824, 2 d.f., $P = 0.054$) with the blast area tending to contain longer uta (Figure 1-19). Body weights did not differ across the three areas (KW = 1.28, 2 d.f., $P = 0.528$, Figure 1-20).

Summer sampling revealed uta, leopard lizards, and whiptails on the control area; uta on the T3 blast area; and uta, horned lizards, and whiptails on the revegetation area. Uta were again the only species abundant enough to merit analysis. Densities of adult utas were variable but appeared to be higher on the control (43.6 ± 20.5/ha) and blast areas (16.9 ± 10.5/ha) relative to the revegetated area (7.1 ± 0.0/ha). A chi-square test comparing number of adults caught in these areas during the summer sample ($X^2 = 12.46$, 2 d.f., $P < 0.01$) also suggests the control area contained more adults relative to the other two areas. Estimates of hatchling uta densities were highly variable (blast area 61.7 ± 20.9/ha, control area 103.8 ± 52.9/ha, revegetated area 59.9 ± 15.8/ha) and are best regarded as similar across areas. Number of hatchling utas that were caught also did not differ between plots (X^2

plots (X^2 = 1.82, 2. d.f., P > 0.30). Pooling both uta estimates (hatchlings plus adults) suggests there may have been more uta present on the control area (146.1 ± 49.1/ha) relative to the blast area (80.9 ± 27.4/ha) or the revegetated area (60.6 ± 14.3/ha). Pooling counts of hatchling and adults caught on plots reveals that uta were about 50 percent more abundant in summer on the control plot (60) relative to either the blast area (35) or the revegetation plot (39, X^2 = 8.07, 2 d.f., P = 0.025).

Sex ratios did not differ between plots (X^2 = 2.78, 2 d.f., P = 0.255, Figure 1-22). Age-class comparisons were again interesting, as by summer hatchlings represented 85 percent of the population in the revegetated areas and 80% on the blast area, but only 65 percent of the population on the control plot. These differences were marginally nonsignificant (X^2 = 5.57, 2 d.f., P = 0.065, Figure 1-23). Age-class composition did not differ between control and blast areas (X^2 = 2.01, 1 d.f., P = 0.265). Uta ages did not differ across the three study areas (KW = 2.62, 2 d.f., P = 0.27, Figure 1-26). These results could reflect differences in adult survival, emigration, or reproductive rate. Uta SVL differed between the three study areas (KW = 7.61, 2 d.f., P = 0.022, Figure 1-24) as did weight (KW = 6.8, 2 d.f., P = 0.033, Figure 1-25).

Rodent Denuded Area and Control (MER002, MER003)

These plots were sampled in both spring and summer. In spring, uta were the only lizards seen on either plot. Adult uta density estimates for the control plot (14.2 ± 0.0) and the rodent denuded plot (12.4 ± 5.0) overlap extensively, suggesting that densities do not differ. A chi-square test comparing the number of adults actually caught suggests a similar conclusion (X^2 = 0.12, 1 d.f., P > 0.90). The number of juvenile uta present on the rodent denuded plot (16.5 ± 2.2/ha) appeared to be similar to that on the control plot (16.0 ± 0.0/ha). Comparisons of the number of juveniles caught on these plots suggests no difference in densities (X^2 = 0.0, 1 d.f., P = 0.99). Pooled density estimates for uta of all age classes appeared similar on the control (30.2 ± 0.0/ha) and rodent denuded plots (28.6 ± 4.9/ha).

The sex ratio did not differ between the control and the rodent denuded plot (X^2 = 0.08, 1 d.f., P > 0.90, Figure 1-27). Age-class distributions did not differ between the control (nine hatched in 1992, eight in 1991) and rodent denuded area (nine in 1992, six in 1991, X^2 = 0.16, 1 d.f., P = 0.71, Figure 1-27). In spring, neither SVL (MWU = 145.5, P = 0.495, N = 15, 17, Figure 1-28), weight (MWU = 142.5, P = 0.571, N = 15, 17, Figure 1-28), nor age (MWU = 118.5, P = 0.693, N = 15, 17, Figure 1-28) differed

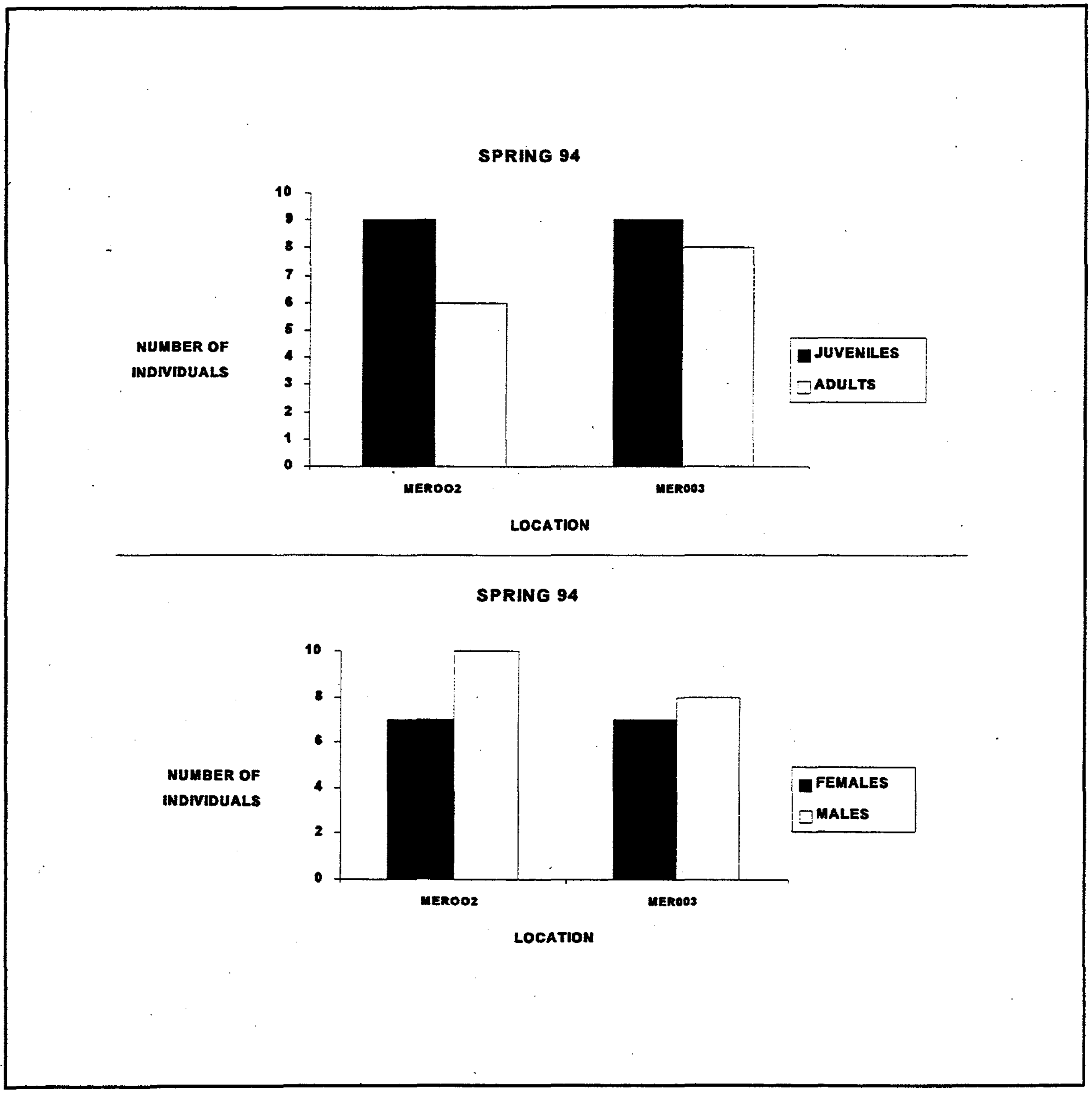

Figure 1-27. Sex ratios and age class composition of uta populations measured on a rodent-denuded plot or its control in 1994.

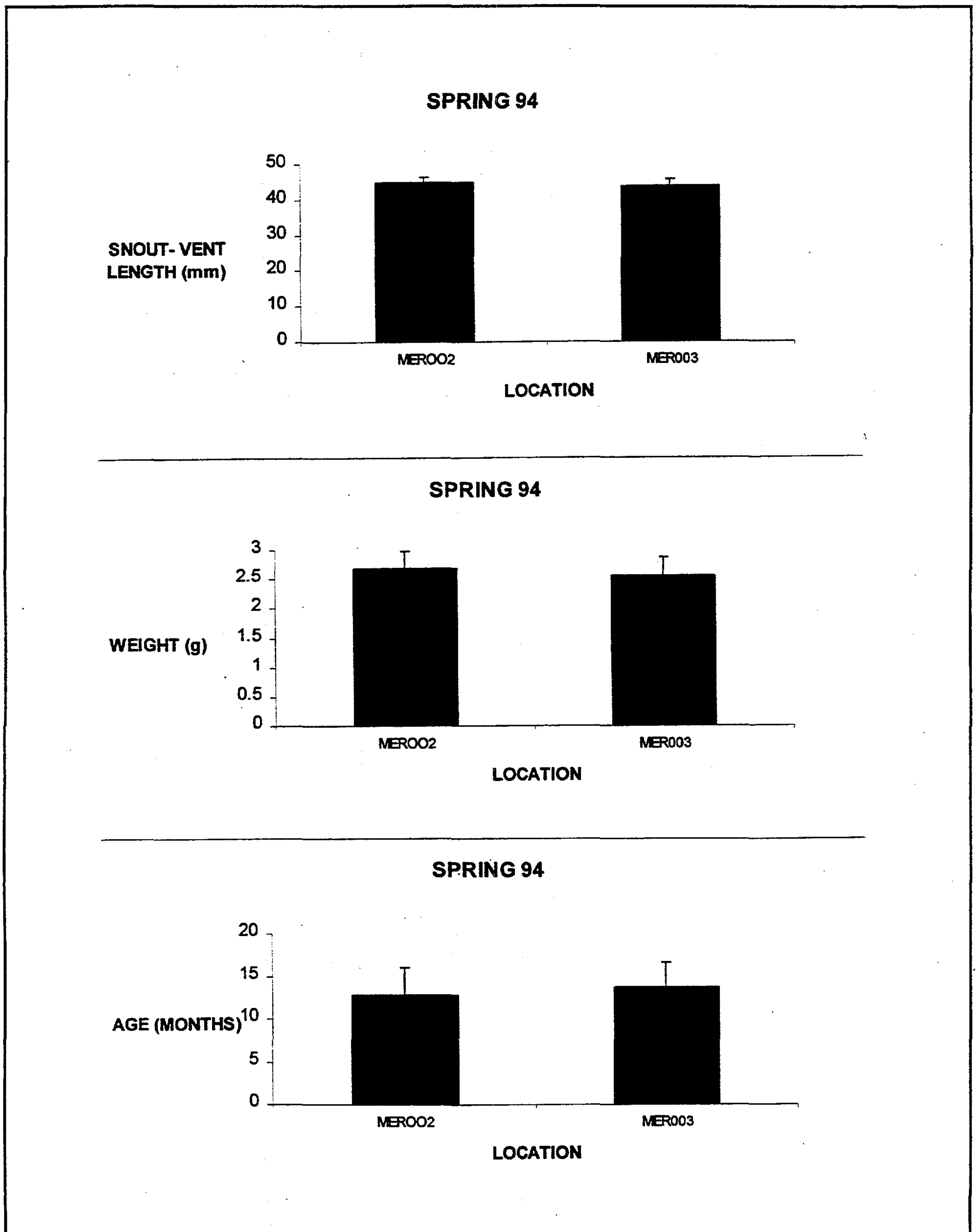

Figure 1-28. SVLs, weights, and ages of uta from a population on a rodent-denuded area and from a population on a nearby control area in 1994.

between the control and rodent denuded plots. Age distributions were such that it appeared all uta had entered these populations in either 1991 or 1992.

In summer, uta, horned lizards, leopard lizards, and whiptails were seen on the rodent denuded plot while only uta and whiptails were seen on the control plot. Uta were the most common lizard, but even they were not abundant enough to make density estimates for either the hatchlings or the adults (rodent denuded plot 5 adult and 11 hatchling uta; control, 8 adults and 1 hatchling uta). Pooling age classes yielded large enough sample sizes to make density estimates. Uta densities on the rodent denuded plot (28.4 $\pm$ 0.0/ha) appear similar to those on the control area (30.2 $\pm$ 30.2/ha), especially given the extreme variation on the control plot. Comparisons of the actual counts of uta captured revealed a similar pattern (X^2 = 1.96, 1 d.f., P = 0.17).

The sex ratio did not differ across plots (X^2 = 0.34, 1 d.f., P = 0.58, Figure 1-29). Age-class distributions differed markedly between areas, with the control area containing mainly adults, while the rodent denuded area contained mainly hatchlings (X^2 = 3.98, 1 d.f., P = 0.047, Figure 1-29). Uta had longer SVLs on the control plot (42.6 $\pm$ 2.6 mm) relative to the rodent denuded plot (29.8 $\pm$ 5.0 mm, MWU = 30.5, 15, 8 d.f., P = 0.018, Figure 1-30). Uta weight showed a similar pattern (control 1.93 $\pm$ 0.47 g, rodent denuded plot 1.02 $\pm$ 0.51 g, MWU = 37, 15, 8 d.f., P = 0.46, Figure 1-30). These differences probably occurred because of the age differences between areas (control 14.7 $\pm$ 5.4 months, rodent denuded area 4.5 $\pm$ 3.8 months, MWU = 27, 15, 8 d.f., P = 0.005, Figure 1-30).

Sedan Crater Study Areas (YUF016, YUF017, YUF018)

In spring, uta, horned lizards and whiptails were seen on the plot 457 m from ground zero; while uta, leopard lizards, horned lizards, and whiptails were seen at 1067 m; and uta and whiptails were seen at 1600 m from ground zero. Uta was the only lizard abundant enough for analysis. In spring, adult density at 457 m from ground zero (44.4 $\pm$ 24.3/ha) appeared to be higher than that 1067 m away (no estimate, only 1 adult caught), and at 1600 m (no estimate, only 4 adults caught). Juveniles were too uncommon at 457 m (none caught) to generate a density estimate; however, estimates at 1067 m (51.6 $\pm$ 36.4/ha) and 1600 m (16.0 $\pm$ 0.0) appeared to be higher. When all uta age classes were pooled, densities at 467 m from ground zero (44.4 $\pm$ 24.3/ha) appeared to be similar to those at 1067 m (57.5 $\pm$ 41.5/ha) and 1600 m (27.1 $\pm$ 9.6/ha). Comparisons of the number of uta caught on these plots (X^2 = 0.18, 2 d.f., P = 0.913) suggests densities were similar across plots.

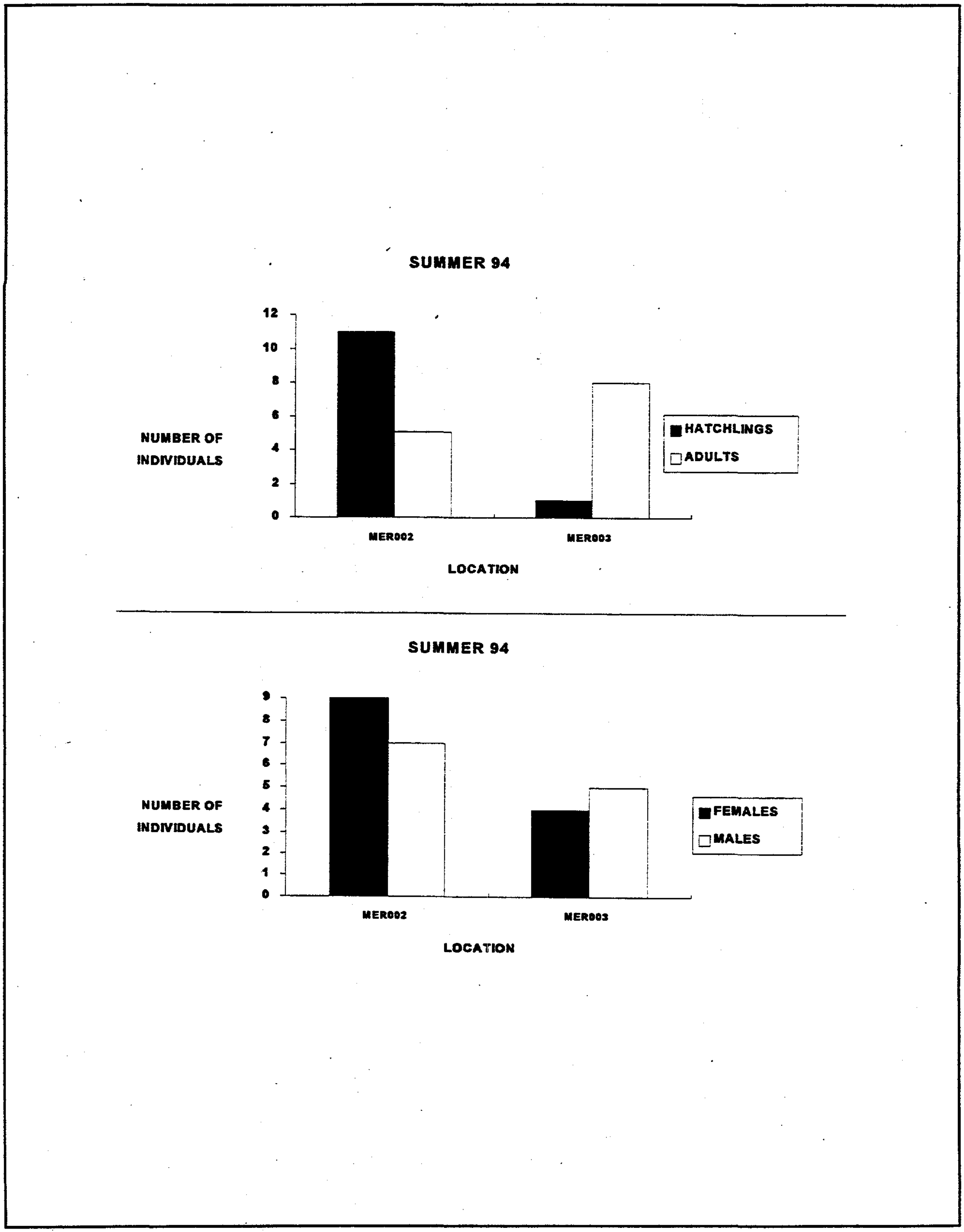

Figure 1-29. Sex ratio and age class composition of a uta population on a rodent-denuded area and on its nearby control in 1994.

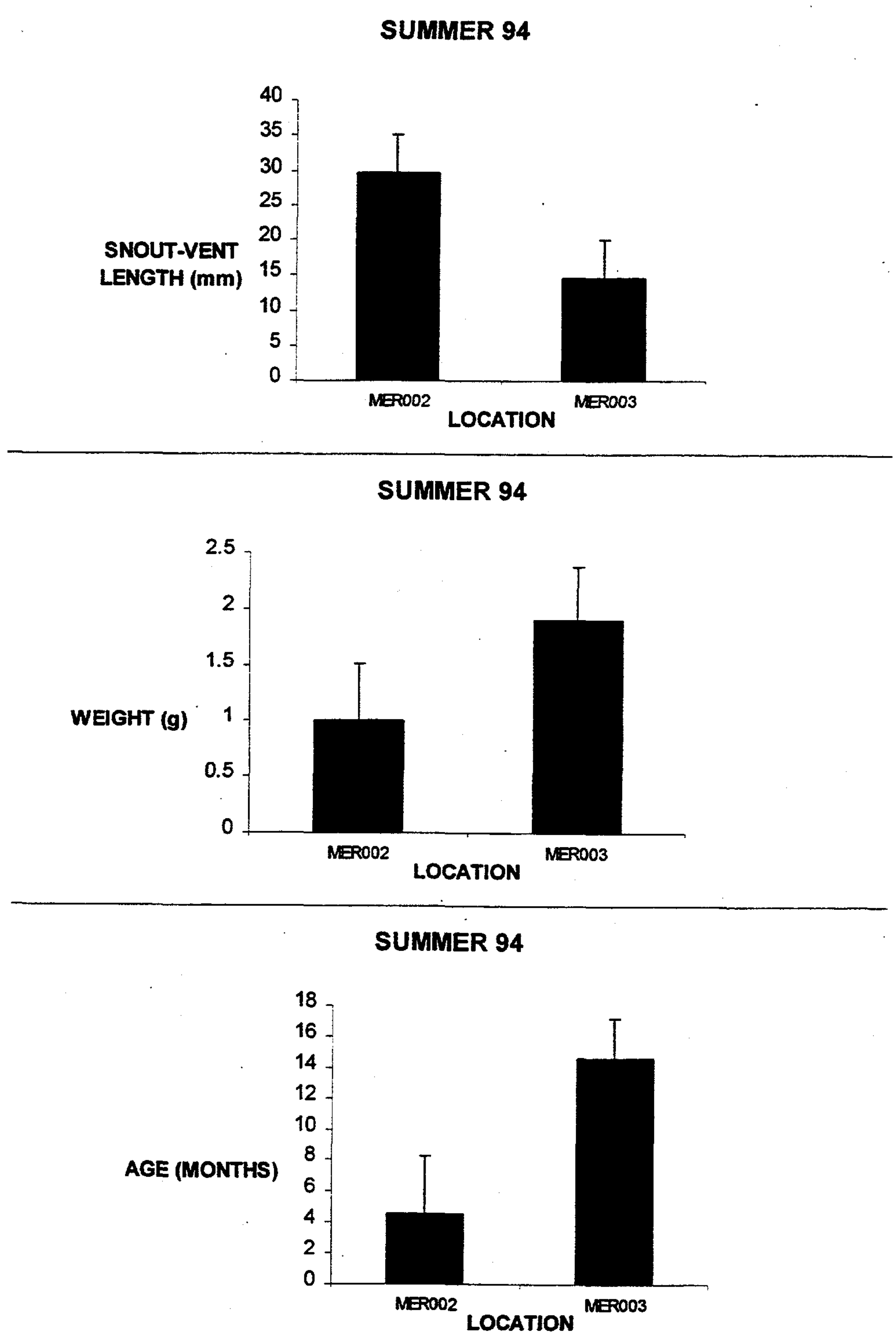

Figure 1-30. SVLs, weights, and ages of uta in summer 1994 from populations on a rodent-denuded plot and its control.

Sex ratios did not differ enough across study plots to be considered different ($X^2 = 3.7$, 2 d.f., $P = 0.13$, Figure 1-31). Age class composition differed markedly across plots ($X^2 = 28.6$, 2 d.f., $P < 0.001$, Figure 1-31). The plot nearest ground zero consisted of all uta > 1 year old, whereas the more distant plots were largely occupied by hatchling uta.

Both estimates of body size (SVL and weight) differed across plots (Figure 1-32). Uta were both longer (KW = 20.12, 2 d.f., $P < 0.001$) and heavier (KW = 23.18, 2 d.f., $P < 0.001$) on the plot 457 m from ground zero relative to the plots at 1067 m or 1600 m. Uta ages also differed across plots (KW = 29.11, 2 d.f., $P < 0.001$, Figure 1-32) with the 457 m plot dominated by older lizards and the 1067 m and 1600 m plots dominated by lizards born the previous year.

By summer, uta, horned lizards, leopard lizards, and whiptails were seen on the plot 457 m from ground zero; while uta, horned lizards, leopard lizards were seen on the plot 1067 m from ground zero; and uta, leopard lizards, and whiptails were seen on the plot 1600 m from ground zero. Only uta were abundant enough for analysis. Adult uta were too rare to generate a density estimate. Hatchling uta density estimates were highly variable (457 m plot 64.7 ± 22.2/ha, 1067 m plot 8.2 ± 6.0/ha, 1600 m 30.2 ± 30.2/ha). Comparison of the number of hatchlings caught across plots suggests that hatchlings were uncommon on the 1067 m and 1600 m plots relative to the 457 m plot ($X^2 = 14.4$, 2 d.f., $P < 0.001$). Pooling uta of all age classes yielded estimates of 57.9 ± 7.2/ha at 457 m from ground zero, 22.7 ± 7.8/ha at 1067 m, and 23.1 ± 10.3/ha at 1600 m. Comparison of the number of uta caught at these distances revealed a similar pattern with more uta seen at 457 m and fewer seen at 1067 m or 1600 m ($X^2 = 13.0$, 2 d.f., $P = 0.0019$).

Sex ratios were similar across plots ($X^2 = 3.9$, 2 d.f., $P = 0.151$, Figure 1-33). Age-class structure was similar across plots. Because of small sample sizes, data were pooled from the two plots most distant from ground zero for this analysis ($X^2 = 1.35$, 1 d.f., $P = 0.25$, Figure 1-33).

Both measures of body size (SVL: KW = 3.98, 2 d.f., $P = 0.136$; weight: KW = 4.67, 2 d.f., $P = 0.097$, Figure 1-34) did not differ across plots. Uta age also did not differ across plots (KW = 5.04, 2 d.f., $P = 0.08$, Figure 1-34).

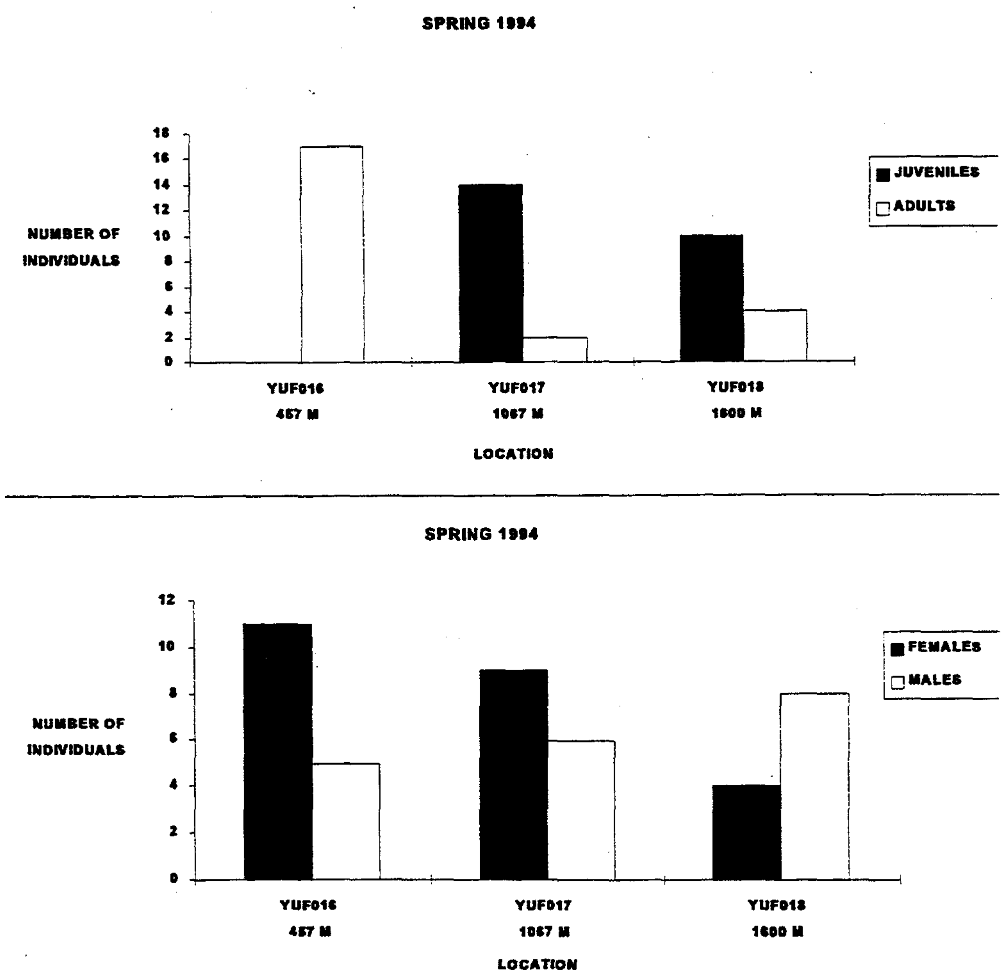

Figure 1-31. Sex ratios and age composition in spring 1994 of uta populations located on three plots at increasing distances from the ground zero of Sedan Crater.

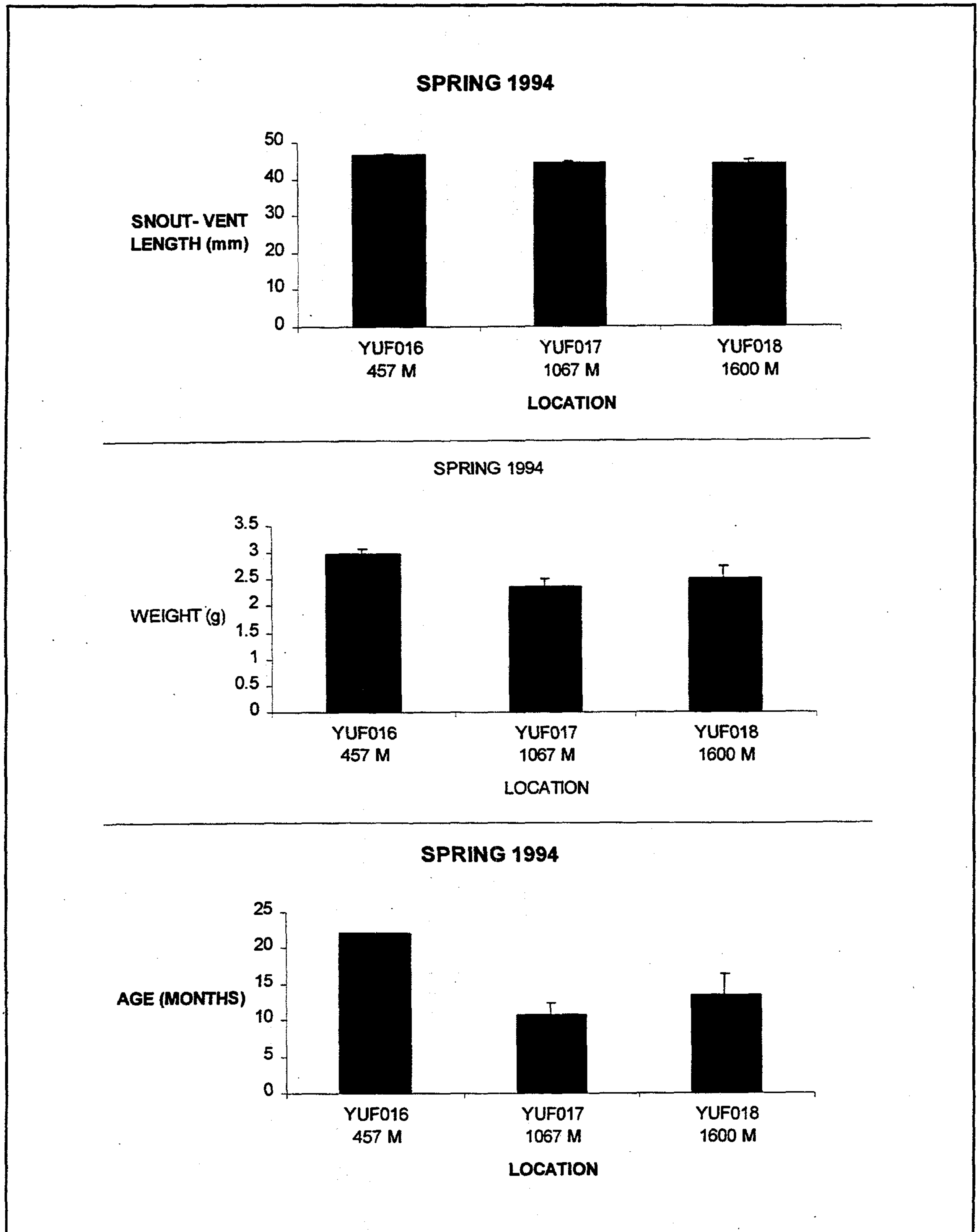

Figure 1-32. SVLs, weights, and ages of uta in spring 1994 from three populations located at increasing distances from ground zero of Sedan Crater.

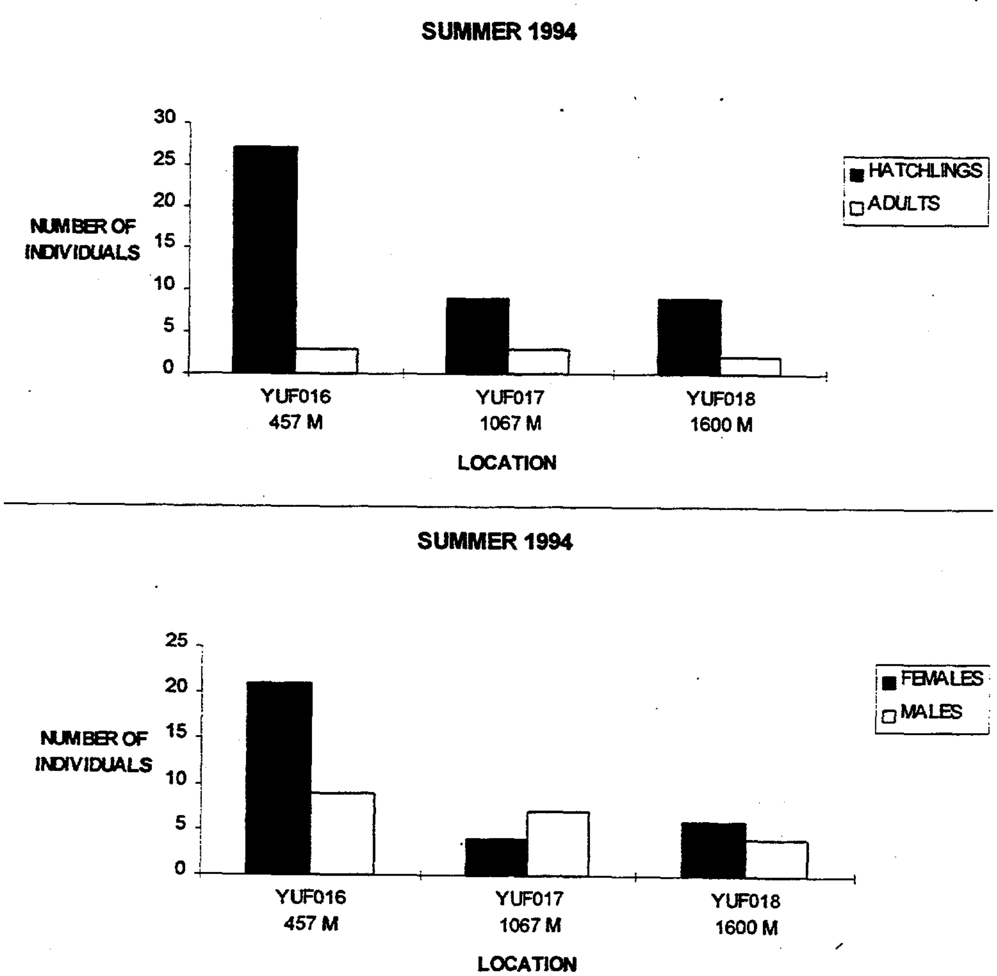

Figure 1-33. Sex ratios and age class composition in summer 1994 of uta populations located at three distances from ground zero of Sedan Crater.

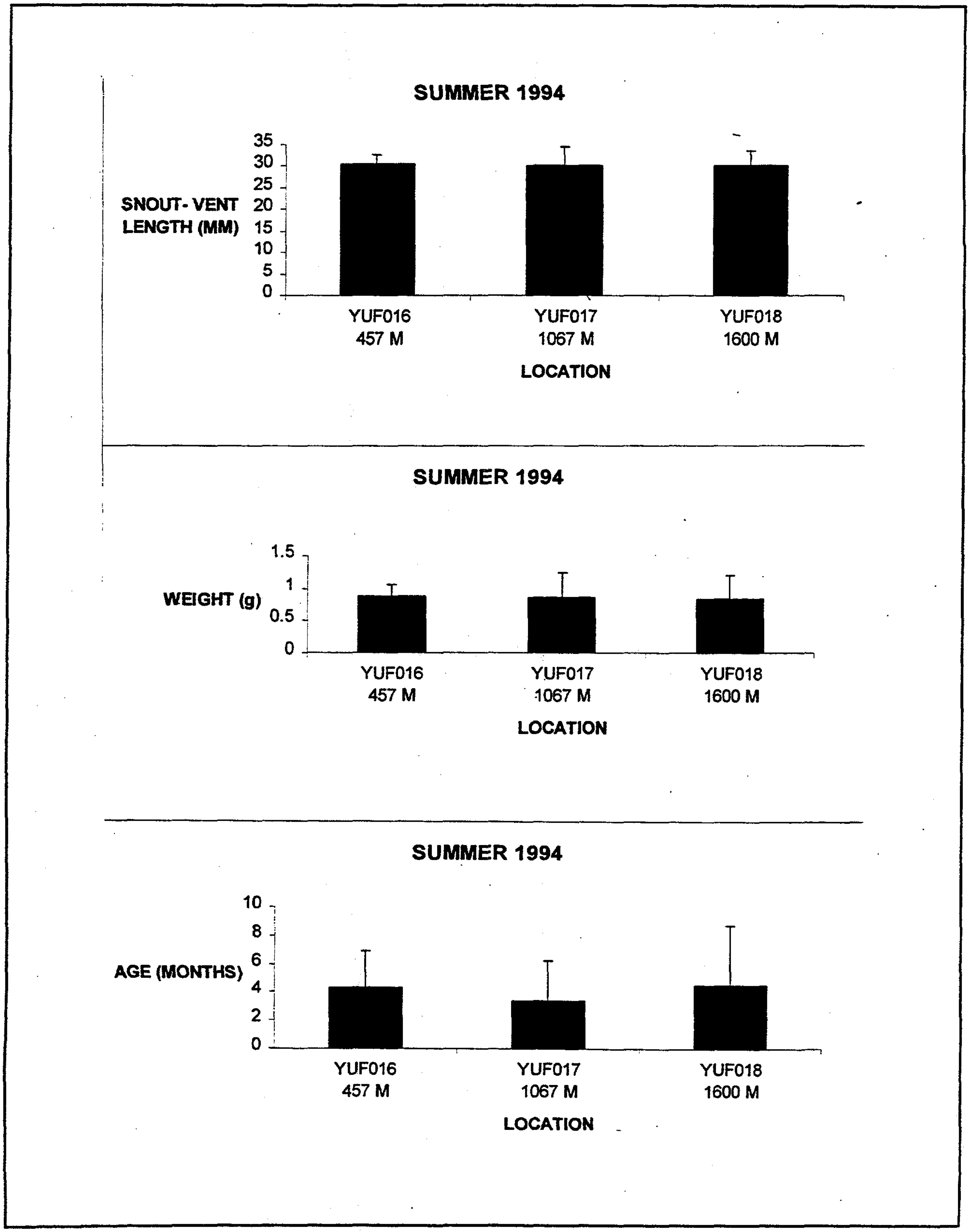

Figure 1-34. SVLs, weights, and ages of uta in 1994 from populations on three study plots located at increasing distances from ground zero at Sedan Crater.

TECHNIQUE EVALUATION

Lizard Preference Tests

Uta, offered a choice between an *Ambrosia* with an adjoining rock and a similar sized *Ambrosia* lacking an adjoining rock, spent significantly more time near the shrub with the rock ($N = 24$, $x = 6$, $P = 0.022$, Figure 1-35). Uta were more likely to be located in a large *Ambrosia* clump relative to a smaller one, although this bias was nonsignificant ($N = 20$, $x = 6$, $P = 0.116$, Figure 1-35). In species choice tests, *Larrea* and *Ambrosia* were selected approximately as often ($N = 20$, $x = 8$, $P = 0.504$) as were *Ambrosia* and *Krameria* ($N = 23$, $x = 8$, $P = 0.21$, Figure 1-36).

Diel Sampling Effects

Number of *Uta* seen did not differ across observers ($F_{2, 67} = 0.184$, $P = 0.833$) but did differ between enclosures ($F_{1, 67} = 6.888$, $P = 0.011$) and time of survey ($F_{1, 67} = 4.087$, $P = 0.047$). Differences between enclosures probably reflects true differences in number of lizards present (enclosure 9 typically contained more lizards than enclosure 10); however, some of the difference may reflect differences in habitat complexity. This latter effect was not incorporated into the design, but could be in future years to estimate effects of habitat differences across the NTS on lizard counts. Time effects were substantial as estimates at the second sampling period were only 63% of those at the first sampling period that occurred on average 1 hour and 9 minutes earlier. Correlations of lizard counts between observers were high (Bruce x Lisa $r = 0.694$, 70 d.f. $P < 0.001$; Bruce x Dan $r = 0.638$, 70 d.f. $P < 0.001$; Dan x Lisa $r = 0.549$, 70 d.f. $P < 0.01$) again implying a high degree of consistency in counts.

Population Fluctuations

Average annual population change as a proportion of total population change over the study period varied tremendously at both Pahute Mesa (mean change 26.4%, range 8.1 to 44.2%) and Yucca Flat (mean 32.6%, range 5.3 to 77.0%), Figure 1-37). Change was inconsistent in direction and varied greatly from year to year (Figure 1-37). Population changes at Pahute Mesa and Yucca Flat were not temporally consistent; that is, decreases at YUF001 were not coincidental with changes on PAM001 (Figure 1-37).

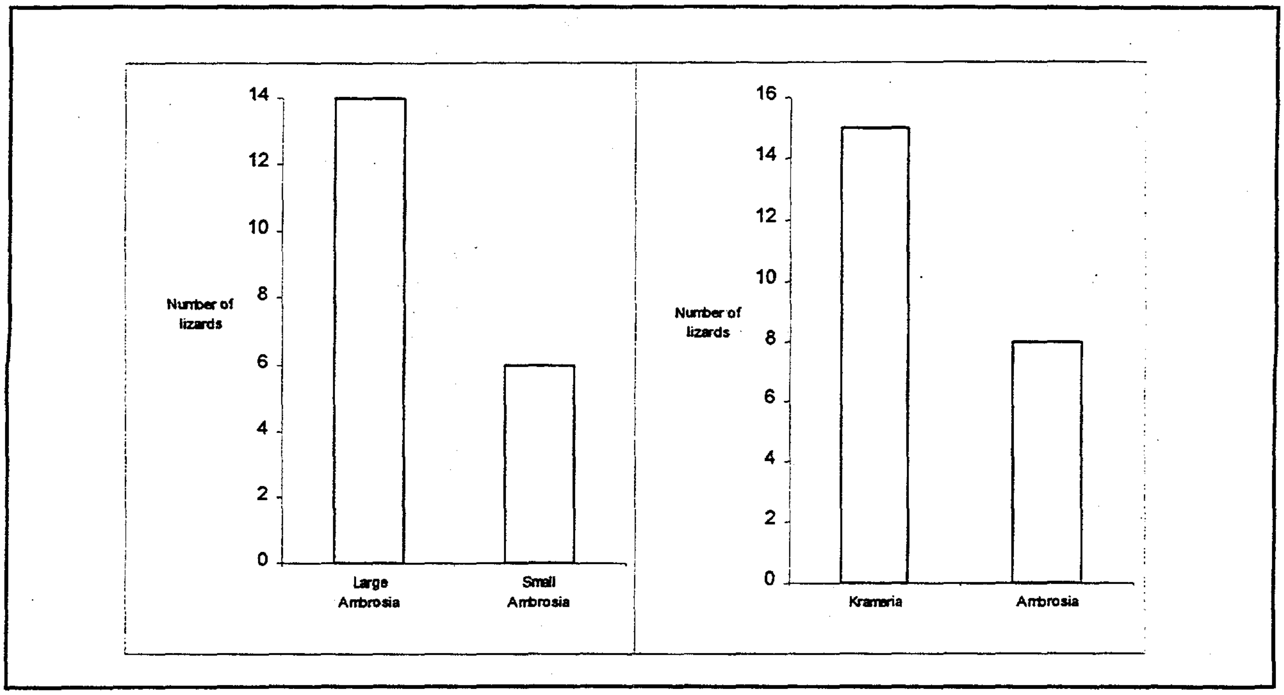

Figure 1-35. Results of two habitat preference tests where individual uta were offered a choice between two habitats.

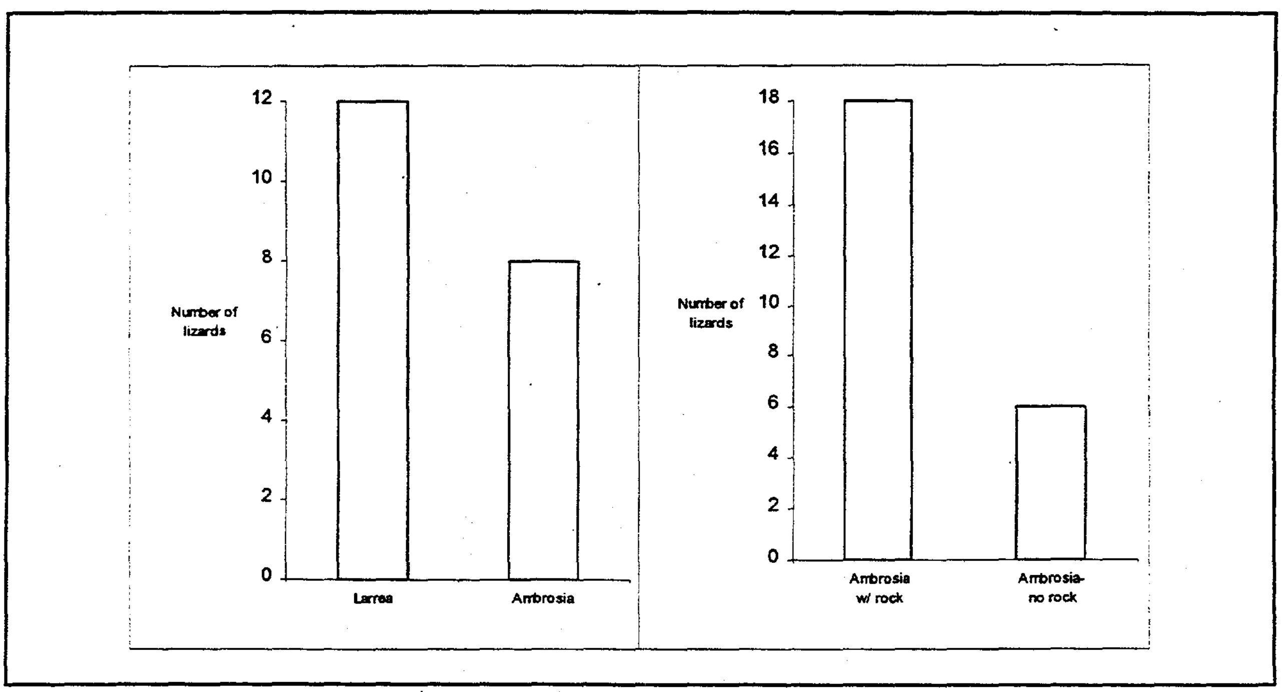

Figure 1-36. Results of two habitat preference tests in which individual uta were offered a choice between two habitats.

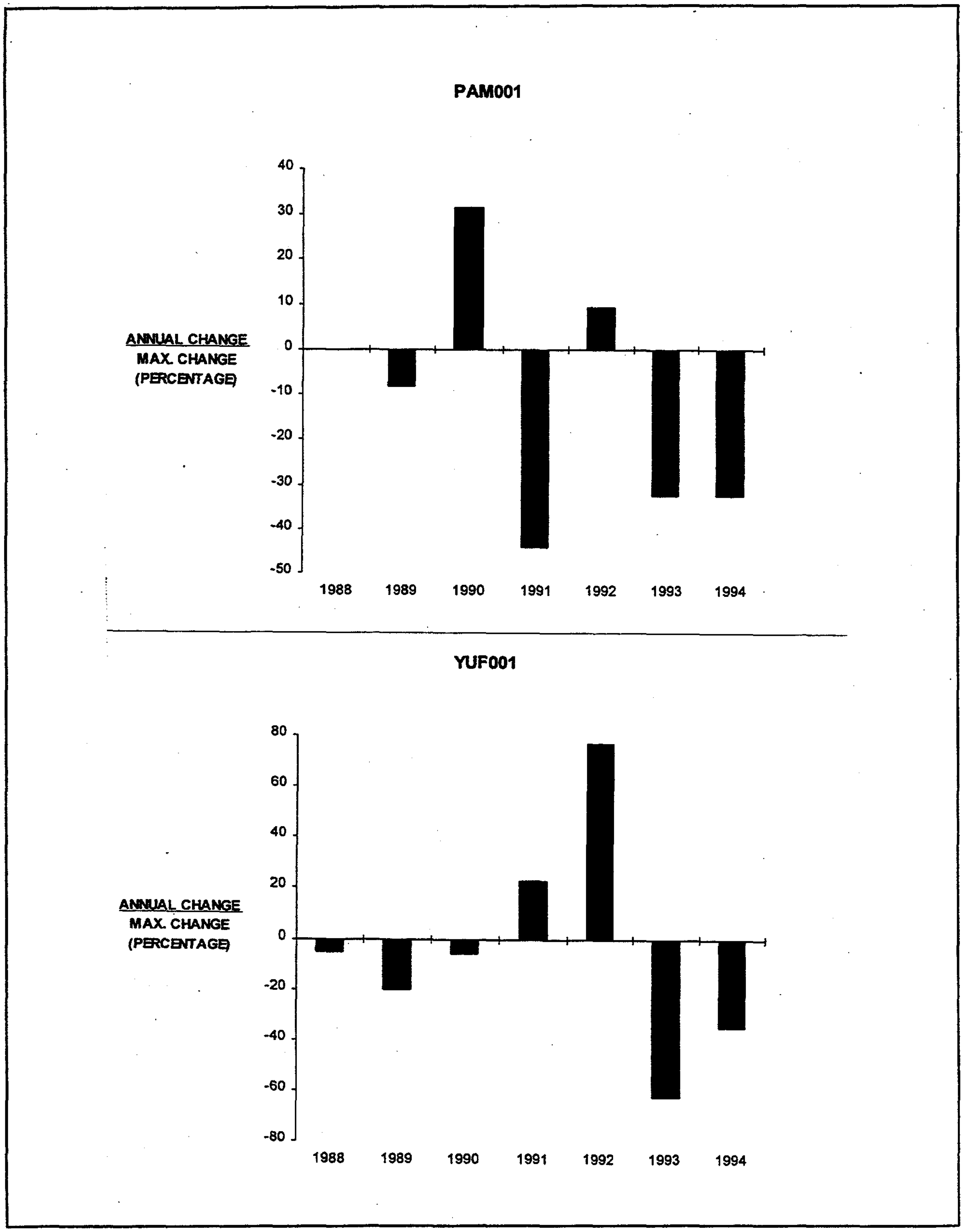

Figure 1-37. Measures of annual change in uta density estimates for uta populations on Yucca Flat and Pahute Mesa.

Spatial Variation in Lizard Traits

In spring, plot FRF001 located near the basin bottom in Frenchman Flat (965 m in elevation) was sampled from 14 to 17 March 1994, while the slightly higher YUF001 plot near the basin bottom in Yucca Flat (at 1237 m) was sampled from 4 to 12 April 1994. In spring, about five times as many uta were caught on the Yucca Flat plot as on the Frenchman Flat plot ($X^2 = 61.4$, 1 d.f., $P < 0.0001$). Density estimates suggest a similar pattern. Sex ratios did not differ between these two areas ($X^2 = 0.108$, 1 d.f., $P = 0.60$) nor did the ratio of juveniles to adults ($X^2 = 0.02$, 1 d.f., $P = 0.90$, Figure 1-38). Uta SVLs (MWU = 1161, 1 d.f., $P = 0.978$, Figure 1-39), weights (MWU = 1064, 1 d.f., $P = 0.527$, Figure 1-39), and ages (MWU = 973.5, 1 d.f., $P = 0.216$, Figure 1-39) were similar on the Frenchman Flat and Yucca Flat sites.

In summer, the Frenchman Flat site was sampled from 18 to 21 July 1994, while the Yucca Flat site was sampled from 1 to 5 August 1994. By summer, numbers shifted and only three times as many uta were caught on YUF001 as FRF001 ($X^2 = 32.2$, 1 d.f., $P < 0.0001$). Density estimates mimicked this pattern. Sex ratios again did not differ between the two areas ($X^2 = 3.65$, 1 d.f., $P = 0.088$). Age-class composition did differ between areas ($X^2 = 5.77$, 1 d.f., $P = 0.017$) with hatchlings under represented relative to adults on Yucca Flat. Uta were shorter (MWU = 782, 1 d.f., $P = 0.02$) and weighed less (MWU = 717.5, 1 d.f., $P = 0.006$) on FRF001 relative to YUF001 in the summer. Uta were slightly, although significantly, younger on FRF001 than on YUF001 (MWU = 813, 1 d.f., $P = 0.08$).

Uta were sampled on the Yucca Flat basin bottom plot (YUF001) from 14 to 22 April 1993, while the foothills plot (YUF003) was sampled from 23 to 29 April 1993. These plots were 2.2 km apart and the foothills plot was approximately 64 m higher in elevation. Fewer uta were captured per unit area on the basin plot (82) relative to the foothills plot (123, $X^2 = 8.2$, 1 d.f., $P = 0.006$). Density estimates (YUF001 85 $\pm$ 11, YUF003 121 $\pm$ 13) suggest a similar conclusion. Sex ratios differed between these areas with the basin bottom plot containing more males and foothills plot more females ($X^2 = 4.61$, 1 d.f., $P = 0.035$). The ratio of juveniles to adults also differed ($X^2 = 18.06$, 1 d.f., $P < 0.001$) with juveniles more common than adults on the basin bottom but less common than adults in the foothills. Uta were longer (MWU = 1677.5, 1 d.f., $P < 0.001$), heavier (MWU = 1331.5, 1 d.f., $P < 0.001$), and older (MWU = 1698, 1 d.f., $P < 0.001$) on the foothills relative to the basin bottom plot.

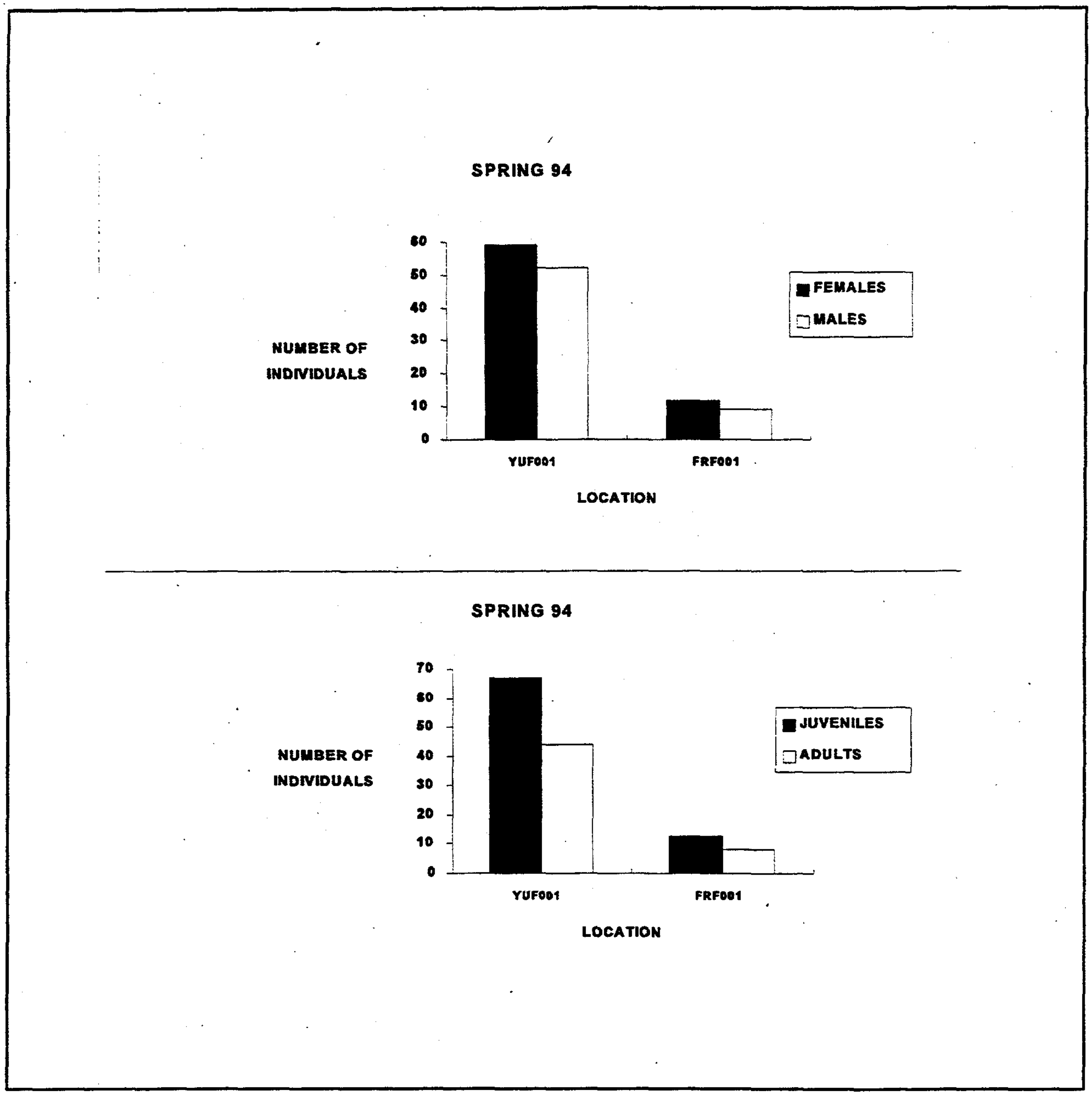

Figure 1-38. Sex ratios and age class composition of uta populations in spring 1994 to YUF001 a basin-bottom plot on Yucca Flat and on FRF001 a basin-bottom plot on Frenchman Flat.

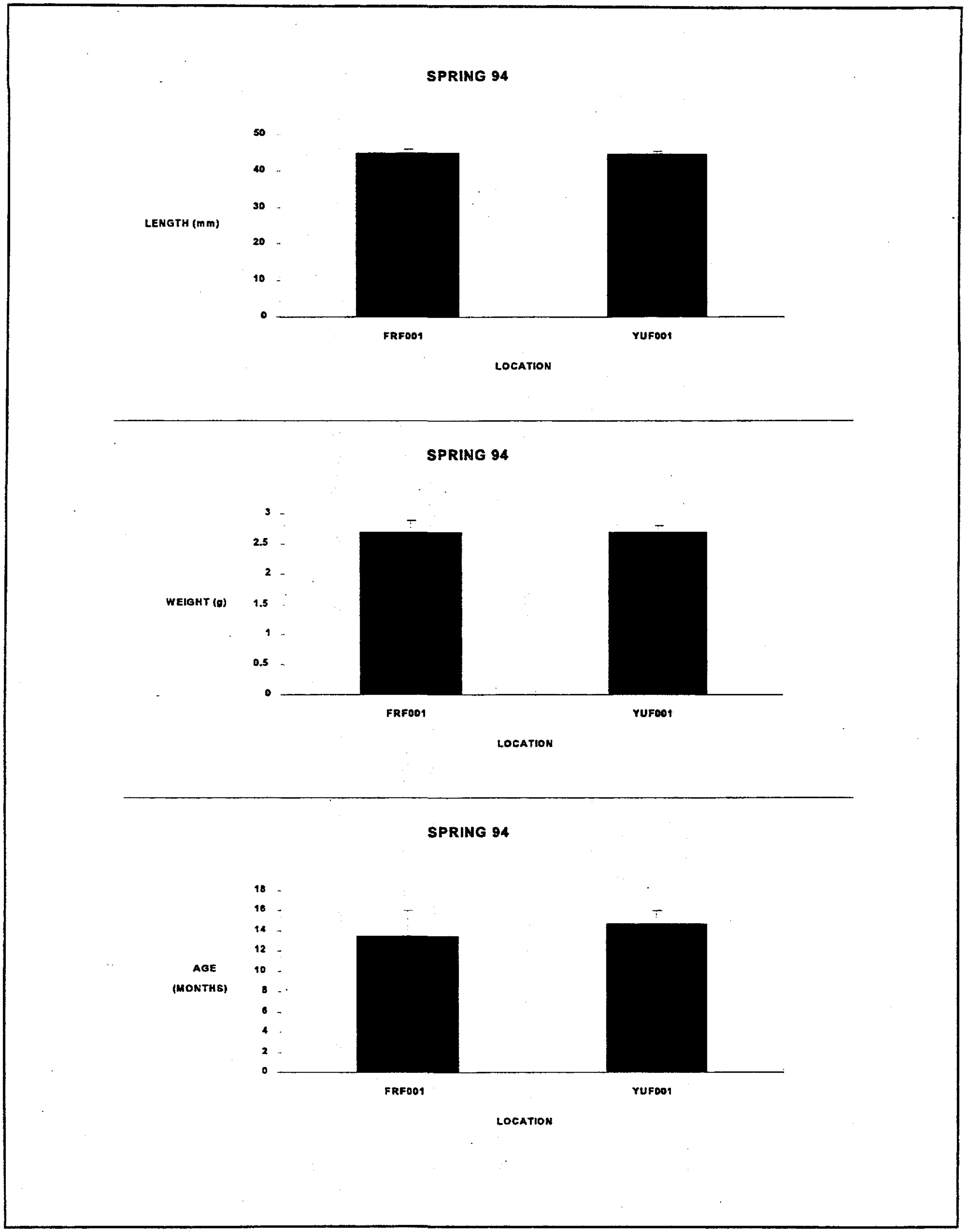

Figure 1-39. SVLs, weights, and ages of uta in 1994 from two populations: FRF001 from the basin bottom on Frenchman Flat and YUF001 from the basin bottom on Yucca Flat.

Uta were sampled on the Yucca Flat basin bottom plot from 16 to 20 August and the foothills plot was sampled from 23 to 26 August 1993. More uta were caught per unit area on the foothills plot (253) relative to the basin bottom plot (156) (X^2 = 23.0, 1 d.f., P < 0.001). An examination of density estimates also appears to support this conclusion. Sex ratios did not differ across plots (X^2 = 0.54, 1 d.f., P = 0.47) nor did the relative proportions of hatchlings and adults (X^2 = 1.20, 1 d.f., P = 0.28). Uta in the foothills and basin bottom had similar SVLs (MWU = 9535.5, 1 d.f., P = 0.152) and ages (MWU = 10029.5, 1 d.f., P = 0.796). Differences in uta weights were close to statistical significance with lizards in the foothills being slightly heavier (MWU = 9266.5, 1 d.f., P = 0.059).

Another basin bottom to foothills comparison was made in 1994. The FRF001 (a 1.1 ha basin bottom plot) plot was sampled from 14 to 17 March 1994, and the FRF013 plots (a series of eight 800-m^2 plots scattered over a 2-km long area in the foothills) were sampled from 21 to 29 March 1994. The plots were approximately 11 km apart with the foothills plot about 185 m higher in elevation. On a per-unit-area basis, the foothills plots (155 uta) contained about seven times as many uta as the basin bottom area (21 uta, X^2 = 102.0, 1 d.f., P < 0.0001). Sex ratios did not differ across plots (X^2 = 0.913, 1 d.f., P = 0.35). The ratio of juveniles to adults also did not differ between the basin bottom and foothills areas (X^2 = 1.73, 1 d.f., P = 0.19). Uta had similar SVLs (MWU = 1047, 1 d.f., P = 0.391) and weights (MWU = 1038.5, 1 d.f., P = 0.626) on the two areas. Uta ages also did not differ from basin bottom to the foothills (MWU = 1048, 1 d.f., P = 0.369).

The basin bottom site was sampled from 18 to 21 July, and the foothills site was sampledfrom 25 to 29 July 1994. In summer, the foothills (100 uta) again appeared to contain many more uta per unit area relative to the basin bottom site (26 uta, X^2 = 43.4, 1 d.f., P < 0.0001). Sex ratios did not differ between plots (X^2 = 0.155, 1 d.f., P = 0.70). The difference between ratios of hatchlings to adults was close to statistically significant (X^2 = 3.38, 1 d.f., P = 0.07) with 46% of utas in the basin-bottom plot being hatchlings but only 26% of utas on the foothills plot being hatchlings. Utas on the foothills plot were both longer (MWU = 460.5, 1 d.f., P = 0.004) and heavier (MWU = 511.0, 1 d.f., P = 0.019) than uta on the basin bottom. There was no difference in age of utas between these areas (MWU = 635.5, 1 d.f., P = 0.363).

TORTOISE STUDIES

In 1994, 19 marked desert tortoises inhabited the Rock Valley plots. Seventeen individuals were recaptured in the spring and/or autumn of 1994. Animals were measured, weighed, and inspected to evaluate their general health status (Table 1-1). Two of five tortoises in Plot A were not captured, two juveniles that were initially marked in 1992. The four adults in Plot B were observed in 1994, one male for the first time since 1992 and all ten tortoises in Plot C were measured. A marginal amount of ephemeral forage was available in the enclosures to feed upon between April and June 1994. Several tortoises were recaptured in the autumn of 1994 and few showed positive growth.

During the past eight years, 82 free-roaming tortoises (located outside of the Rock Valley enclosures) were marked, measured, and released on the NTS by REECo/UCLA/BECAMP personnel. None were recaptured in 1994, most likely because little effort was applied towards this goal. One tortoise marked and released on 5 May 1977 during the International Biological Program was recaptured on 31 May 1994 approximately 75 m from its release location. The animal was an adult in 1977 and grew a small amount (5 mm in carapace length, 6 mm in plastron length) in the past 17 years.

DISCUSSION

BASELINE PLOTS

Transect results from near the Yucca Flat baseline plot (YUF001) suggest that both whiptail abundances and abundances of all lizards present (pooled across species) were lower in 1994 relative to 1993. Uta numbers appeared to stay about the same. Results from plot studies in spring suggest adult uta numbers were up from 1993, and juvenile numbers were about the same. Historically, the number of utas present on this plot has shifted greatly from spring to following spring (Figure 1-3). Sex ratios have remained constant (Figure 1-2), but the relative contribution of juveniles and adults to the population has changed greatly across years (Figure 1-3). Year-to-year shift in springtime SVLs, weights, or ages were pronounced (Figure 1-4) and appear to reflect year-to-year shifts in success at reproduction the prior year.

Table 1-1. Desert tortoise measurements in the Rock Valley enclosures in 1994. I = Immature, NO = Not observed.

	ANIMAL	SEX	DATE	WEIGHT (g)	CARAPACE (mm)	PLASTRON (mm)	GROWTH (mm)
PLOT A	88	I	NO				
	89	I	NO				
	2444	♀	28 April	2500	228	224	
			30 August	1800	230	225	+1
	4111	♂	30 August	2400	255	249	+2[a]
	4415	♂	16 March	4475	281	253	
			29 August	3650	281	252	-1
PLOT B	1112	♂	28 April	4075	287	262	
			29 August	3175	290	260	-2
	1212	♂	14 April	3625	276	261	
			29 August	2950	278	261	0
	4444	♂	29 August	3225	267	254	
	8822	♀	29 August	1600	226	207	-1[a]
PLOT C	1211	♂	28 April	2925	256	245	
			29 August	2525	257	245	0
	1222	♀	28 April	1750	220	214	
			29 August	1375	222	213	-1
	1411	♀	16 March	2400	229	219	
			29 August	1925	230	217	-2
	2111	♂	28 April	2575	242	228	
			29 August	2150	242	229	+1
	4121	I	9 May	1175	177	168	
		(♀)	29 August	925	177	168	0
	4414	♂	16 March	2975	256	235	
			29 August	2425	259	234	-1
	4811	♀	16 March	2275	234	224	
			29 August	1725	234	223	-1
	5111	♀	28 April	2275	232	221	
			29 August	1825	236	222	+1
	6111	♂	16 March	4300	284	282	
			29 August	3000	285	283	+1
	8222	♀	28 April	2450	234	228	
			29 August	1850	234	226	-2

[a]Autumn 1993 plastron length used to determine growth.

Comparison of lizard abundance from summer 1993 to summer 1994 revealed marked reductions (Figure 1-8). Not only was number of adults down, but the number of new young produced was also low relative to historical norms. Both factors suggest that 1994 was a year of low lizard survival. This was a dry year with little new plant biomass produced. As a consequence, invertebrate biomass (a key component of lizard diet) was also likely to be low. Examination of multiyear patterns reveals that some attributes of lizard biology are invariant, while others fluctuate a great deal. The sex ratio (Figure 1-7) remained unchanged over the eight years of this study, hovering around one male per female. On the other hand, estimated densities varied greatly over the study. Circumstantial evidence suggests this variation is related to rainfall, with low densities occurring in drought years. Inspection of Figure 1-6 suggests that hatchling production drops precipitously in drought years. The lack of a correlation between density and year implies no long-term increasing or decreasing trend in uta population size. Inspection of Figure 1-6 suggests that nonhuman effects (most likely rainfall) are leading to the observed density changes.

The Frenchman Flat baseline plot was studied in 1987, 1988, 1991, and 1994. Sex ratios remained constant across years in both spring and summer surveys (Figures 1-10, 1-12). In contrast, the ratio of juveniles to adults in the spring or hatchlings to adults in summer varied greatly across years (Figures 1-10, 1-12). Most of this variation was due to large fluctuations in juvenile (10x) or hatchling (8x) numbers across years. Body weights, SVLs, and ages differed across years (Figures 1-11, 1-13). These shifts appear to reflect the influx of young individuals into the population.

The Pahute Mesa baseline plot was sampled annually in the summer from 1988 through 1994. There was an overall decrease in uta densities over this time span (Figure 1-16). Whether this is related to testing activities is not clear. Nine underground nuclear tests were performed in Area 20 near this plot over this study period. These results suggest that additional work to test for a relationship between nuclear testing and uta population declines is merited in this area.

While the sex ratio stayed constant on the Pahute Mesa baseline plot at about one male per female year after year, the ratio of hatchlings to adults changed markedly across years (Figure 1-14). Body weight, SVLs, and ages also differed from year to year, reflecting shifts in age composition in the population (Figure 1-15).

Several conclusions emerge from eight years of baseline studies. The most important is that most lizard traits vary a great deal from year to year. Baseline plots are presumably far enough removed from testing or other human activities that these do not directly influence lizards. It is possible that long-term cumulative impacts of nonsite-specific effects (e.g., fallout) could influence lizards on these plots. In the absence of direct human impacts, lizard traits varied several hundred percent across years. The variation in traits was not directional, that is, there was no overall upward or downward trend in lizard traits on the Yucca Flat or Frenchman Flat sites. The downward trend in lizard densities on the Pahute Mesa plot is inconsistent with these results. The positive (but nonsignificant) correlation between rainfall patterns and lizard density on the Yucca Flat site suggests that precipitation patterns may explain some of the year-to-year fluctuations in lizard populations (Figure 1-6). Density changes did not vary consistently across baseline plots. This is probably because precipitation effects will differ across plots as a function of evapotranspiration. It would be expected that evapotranspiration would be less at the high elevation sites, so rainfall amounts would be experienced as greater amounts in those areas. The lack of an overall trend to the data suggests that uta populations on most relatively undisturbed baseline areas are neither in a decreasing spiral reacting to cumulative effects of testing nor rebounding from past depressions in population size.

Year-to-year shifts in body size (SVL or weight) and in estimated ages, largely appear to reflect age-class composition shifts due to the influx in some years of large numbers of hatchlings. These shifts in body size have potentially important impacts on both the lizards' prey populations (Polis and Yamashita 1991) and for taxa that prey on lizards. Uta have relatively large clutches and produce several clutches per year (Turner et al. 1970, Turner et al. 1982); thus, the potential for rapid change in population size is great. Baseline studies have established that population sizes can change several hundred percent over a very short time frame and that populations can rebound from near extinction over a time frame of one to three years. These parameters provide a useful context for examining lizard population parameters from disturbed plots.

DISTURBED SITES

Three tower test sites and nearby controls were examined in 1994. These tower tests denuded the local vegetation and released radioactive material into the air at the blast sites. At all three blast sites the perennial vegetation was still largely lacking in 1994, about 40 years after the tests (Hunter 1994 in press). The T2 site appears to have somewhat more perennial vegetation relative to its control in comparison to the other tower sites and their controls. The T3 blast site was unusual in several respects. At this site we examined a revegetated area in addition to the blast site and its control. Also, while largely unvegetated, the T3 site had a large coverage of dead tumbleweeds and in spring a thick mat of germinating annuals associated with these tumbleweed clumps. The revegetated site was sparsely occupied by transplanted *Atriplex canescens*.

Results for T1 and T2 were similar. Uta were the only abundant lizards present and were more abundant on control plots relative to blast plots in the spring. By summer, uta numbers were still lower on the T1 blast site relative to its control (although not low enough for statistical significance), and significantly lower on the T2 blast relative to its control. Both blast sites contained older, larger utas relative to their controls in the spring. By summer, T1 still exhibited this pattern, while ages, weights, and SVLs were indistinguishable on the T2 blast and control plots. Body size differences may reflect the age bias towards older individuals on the blast sites and/or reflect enhanced growth under conditions of low densities found there.

Results for the T3 sites were more complicated. Uta numbers did not differ between blast and control areas in the spring; however, by summer uta densities on the control exceeded those on the blast area. The revegetated area contained about as many uta as the blast plot. Uta were much more common on the T3 blast site relative to the other two blast areas in the summer (Figure 1-22), perhaps because of the large amount of cover offered by tumbleweed clumps. Small mammal numbers were also approximately 25% higher on the blast relative to the revegetation and control plots (Saethre 1995). Small mammal burrows and tumbleweeds both could offer uta refuge from predators. Thus, these factors may in part explain the relatively large numbers of uta on the T3 blast area.

Age-class composition did not differ between the T3 blast and control areas in spring or summer. The revegetated area contained a greater proportion of adults relative to the control or T3 blast areas in the spring. By summer, the control area contained a higher proportion of adults relative to the revegetated or blast areas. The control area contained larger uta in summer, most likely reflecting the bias towards a higher proportion of adults there relative to the T3 blast or revegetated areas.

The pattern across all three blast sites and controls appears to be one of reduced densities on blast areas with low survival of young uta, such that blast areas are occupied each spring by a few old adults. In contrast, control areas have higher densities and are composed of a more balanced mix of young and old uta. The number of uta that persist on a plot from spring to summer (a measure of survival and migration patterns) also appears to be greatly reduced (14.3%) on blast sites relative to the control sites (24.6%). Interestingly, survival during the same general period was 59% on the Yucca Flat baseline plot. The baseline results come from a single plot, so they are somewhat suspect. Nevertheless, if they are representative of nondisturbed areas, these results raise the possibility that the blast control plots may themselves be partially effected by testing activities. These results have important implications for the spatial scale of future studies.

Another 1994 disturbance study contrasted lizard traits between a relatively large area essentially unoccupied by perennial vegetation (potentially denuded by gophers) and a nearby control area, that contains vegetation more typical of this area. The rodent-denuded plot and control area had similar densities in the spring. By summer, densities were still indistinguishable, but major changes had taken place in their populations. Whereas, body size and age characteristics were too variable to be regarded as different, the age-class compositions were different. At this time, the disturbed area was occupied almost exclusively by hatchlings, while the control area was occupied almost exclusively by adults. It is not clear whether this pattern reflects in situ effects, the outcome of migration, or both factors. This dispersion suggests that the perennial-less, rodent denuded area may be a poor area for adult survival. The high relative abundance of hatchlings in this area could either mean that this is a good place for reproduction or that this is a marginal area for uta, and that adults leave and hatchlings wind up there by displacement from the more desirable, nondisturbed areas.

Three plots were arranged at increasing distances from Sedan Crater, a crater resulting from a test designed to breach the surface. In 1994, the close plot was still quite sandy (throwout from the original blast) and largely lacking perennial vegetation (1.4% plant cover), while the two more distal plots had high perennial coverages - 13.8% and 20.3% respectively (Hunter 1995). In spring, the proximal plot consisted of almost all adults, while the more distal plots contained a high proportion of juveniles. The overall densities were similar across plots. By summer, the proximal plot contained two to three times as many uta as the more distal plots. This difference was due to the production of more young on the proximal plot, as all three plots contained about the same number of surviving adults. The spring to summer transfer of juveniles and adults to summer adults (an estimate of uta survival from spring to summer) was also similar across plots (17.6%, 18.8%, and 14.3% near to far from the crater). The spring and summer results are at odds with each other (high numbers of young produced at the proximal plot but low densities the following spring) unless survival from late summer to the following spring is low on this plot, relative to the more distal plots. This area should be given closer scrutiny in the future. In many respects, the Sedan Crater results mirror those observed at the tower blast sites. The disturbed areas appear to be areas where offspring survival is low, and plots are occupied primarily by old adults and continually recolonized by immigration.

TECHNIQUE STUDIES

Several small studies were performed to examine sampling techniques. In one experiment, three investigators sampled a captive uta population twice daily during the middle and towards the end of our usual morning sampling period. Lizard counts dropped to 63% of the initial count by the second sampling period. It is most likely that the result arises from increasing temperatures driving the lizards underground. It is also possible that this result occurs because of researchers hassling the lizards. Due to time and manpower constraints, treatments were not added in which uta were sampled at the second sampling period but not at the first. Thus, some lizards not seen during second samples could have been missed because they were hiding after the investigators' initial search. This experiment should be followed up to tease these two alternatives apart. If the result occurs because of time of day, then time of sampling can have a large effect on number of uta seen and must be carefully factored into the sampling procedures. An additional outcome of this study was that the three investigators (of dissimilar sampling experience) obtained similar counts. This suggests that investigators are largely interchangeable in lizard surveys. Woodward et al. (1994) obtained a similar result for timed survey counts of lizards near the Device Assembly Facility (DAF) in Frenchman Flat.

Uta densities on baseline plots changed very rapidly. The annual average change was 25% of the maximum change (lowest to highest estimated densities) observed over the eight years of study. Year-to-year shifts in density ranged up to 77% of this maximum change. This rapid shift in population size suggests that uta populations have the capacity to rebound from disturbances quite rapidly, on time frames of two to three years. This suggests that observable differences in densities between disturbed areas and controls (as observed at most disturbed sites in 1994) imply that the local environment has itself not recovered from the initial disturbance. As discussed above, for lizards this disturbance appears to be removal of the perennial vegetation. Fluctuations in uta populations were not temporally consistent between Yucca Flat and Pahute Mesa (see 1992 and 1993 in Figure 1-37). These differences between the mesa and the lowland site probably are outcomes of differences in precipitation or evapotranspiration. Nevertheless, they point out the spatial variation in uta traits across the NTS and remind investigators that it is foolish to use just a few sites to monitor DOE's effects on the flora and fauna.

Several data sets were compared in 1994 explicitly to examine spatial variation in uta traits. The original data sets were not collected for this purpose and were sampled sequentially and not simultaneously. This means the samples are temporally confounded (i.e., part of the differences attributable to spatial effects may arise because one plot was sampled before the other). In these comparisons, the samples were collected anywhere from one to three weeks apart. The sampling sequence was set up to sample different plots as close to the same phenological season as possible (i.e., higher elevation plots were sampled later in the spring or summer than low elevation plots). These studies also suggest large spatial variation in lizard traits. Foothills areas contain higher uta densities and there is some evidence that reproduction may be more successful there. The differences are so large relative to the differences in sampling dates that it is unlikely that the temporal factors are causing the majority of the pattern, and it is more likely the result of true spatial differences. The significance of these results is that it appears that lizards in largely undisturbed areas vary greatly from basin to basin or from basin bottom to the foothills. This pattern suggests that studies designed to examine NTS-wide effects need to pay special attention to spatial dispersion of study sites and need to sample widely.

MANAGEMENT IMPLICATIONS OF LIZARD STUDIES AT THE NTS

Lizard studies on the NTS in 1994 and prior years reveal effects of several DOE disturbances on lizards. Above-ground blasts, subsidence craters, fires, road construction and maintenance, and construction around buildings all drastically reduce lizard population sizes (Woodward 1994). The differences in population sizes between these disturbances and nearby control areas are large and continue to persist decades after the original disturbances. Given the rapid shifts in population sizes on largely undisturbed baseline sites, this suggests these effects will persist into the foreseeable future. These studies raise several issues. First, these studies were limited to a small spatial scale, raising the question of whether the results are general and apply NTS-wide. A program with a more dispersed set of sampling sites would answer this question. This sampling approach need not be long term. Second, the results raise the issue of how much of the NTS has been impacted by these various sorts of disturbances. This question could also be answered with a revised sampling approach. The results also raise questions about causality, which have important implications for the cost of mitigation. All disturbances discussed above remove the perennial vegetation. It is possible that removal of the vegetation decreases lizard-carrying capacity (by removing insects, Lightfoot and Whitford 1991) and thus, increasing competitive interactions; or that it removes hiding refuges for lizards and thus, increases predation on them. Both competition and predation are argued to have important influences on population sizes (Woodward and Mitchell

1991) including potentially for lizards on the NTS (Turner et al. 1973). Alternatively, some DOE effects on lizards such as those associated with craters or blast sites may have radiological causes. This is especially likely for lizards because they are relatively sensitive to radiological effects (French et al. 1974, Medica et al. 1973, Turner 1975). Finally, these results raise the issue of what should be done to deal with these impacts on lizards. Is mitigation necessary and, if so, to what degree?

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SMALL MAMMAL POPULATIONS ON THE NEVADA TEST SITE, 1994

by

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ABSTRACT

In 1994, the Basic Environmental Compliance and Monitoring Program (BECAMP) completed its eighth year of monitoring the small mammal population on the NTS. The project was focused on trends in heteromyid rodent populations at two baseline sites and five areas disturbed by past DOE programs. Other locations sampled were an area denuded by gophers, a fenced and previously irradiated area, and a waste storage site that had been cleaned and revegetated. Additional trapping took place to survey hantavirus around townsites and in areas with expected high deer mouse densities.

Kangaroo rats continued to be the most common heteromyid rodent on the NTS. The chisel-toothed kangaroo rat was the most abundant rodent on the Yucca Flat baseline site for the second year in a row. The little pocket mouse persisted at low numbers at most sites in 1994. On the Frenchman Flat baseline site, the number of individuals of this species captured in 1994 was similar to 1988, after nearly disappearing during a drought period.

Total numbers inhabiting nuclear event sites were equal to or lower than those at nearby undisturbed sites, however, species diversity was always lower in the blast areas. Species diversity at the Sedan site also increased as distance from the crater edge increased.

Other mice and rats were present at low numbers on undisturbed sites. For example, deer mouse (*Peromyscus maniculatus*) densities were reduced by two-thirds from 1993, a peak year. Fifteen percent of *Peromyscus maniculatus* tested at two remote locations in the northern third of the NTS were positive for hantavirus antibodies.

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INTRODUCTION

PROJECT OBJECTIVES

The DOE created BECAMP in 1987. Under this program, several DOE contractors and national laboratories were given specific tasks to monitor radiological and biological components of the NTS. REECo was tasked to monitor the flora and fauna of the NTS, excluding endangered, threatened, or candidate species. The objective of REECo/BECAMP was to maintain a record of the distribution and abundance of flora and fauna on the NTS and to assess the impacts of DOE activities. Another facet of the program was to determine changes in distribution and abundance over time. This was accomplished by comparing historic and recent data. This chapter covers the REECo monitoring program developed to assess present small mammal populations and the effect, if any, DOE activities may have on them.

The original intent of the program was to sample "pristine" sites representing the major habitats of the NTS every year and to monitor several disturbed sites on a three-year cycle. Plots were to be sampled once in the spring and once in the summer. The NTS is located on the boundary of the Mojave and Great Basin desert "communities," ranging in elevation from about 935 m at the bottom of a valley to 2290 m on the top of a mesa. Vegetation assemblages of the Mojave and Great Basin deserts occur on the NTS (Allred et al. 1963 Beatley 1974a; O'Farrell and Emery 1976) and segue into unique habitat mosaics of the Transition Desert. Five pristine sites were chosen, two mesa sites and three valley sites. Less common vegetation assemblages were sampled only if they could be related to a disturbance and used as a control.

The original regime of monitoring was abandoned in 1989 in favor of concentrating study on disturbed sites. For this, disturbed sites were grouped according to type of impact (blast effect, crater, fire, drill pad, roadside, etc.), and different groups and associated controls were sampled on a three-year cycle. One baseline site (Yucca Flat, the area with the most disturbance related activity) was chosen to be sampled every year with the remaining four baseline sites sampled every three to four years. Sites were trapped once in the sampling year except under special circumstances.

HISTORICAL STUDIES OF THE AREA

Brigham Young University (BYU) initiated cataloging mammals on the NTS in 1959 (Allred and Beck 1963; Jorgensen and Hayward 1965). Studies were undertaken by the University of California, Los Angeles to determine rodent demographics and effects of chronic radiation (French et al. 1966 and 1967, French et al. 1974, French et al. 1968, Maza et al. 1973). Rodent studies in Rock Valley were part of the International Biological Program (IBP) during the 1970s (Chew 1975, Dingman 1975, Turner 1973 and 1975, Turner and McBrayer 1974), and the Nevada Applied Ecology Group (NAEG) studied rodents at several contaminated sites on the NTS (Moor and Bradley 1974 and 1987; Bradley and Moor 1975, 1976, and 1978; Bradley et al. 1977a, b; Moor et al. 1977; O'Farrell and Sauls 1987).

BECAMP SMALL MAMMAL STUDIES

In general, seed eaters make up half of the rodents inhabiting desert regions (Brown and Harney 1993). The granivory "guild" includes all heteromyids and several murid genera such as *Peromyscus* and *Reithrodontomys*. Combinations in rodent assemblages are nonrandom and vary temporally and spatially according to the abiotic and biotic factors available and how well these factors meet the requirements of the individual species (see Brown and Harney 1993 for a review). Climate and geological factors ultimately determine what species will be present at a site (Feldhammer 1979). Population size is also tempered by competition with coexisting rodents, vegetation availability, predation, parasitism, and disease. The NTS varies considerably in vegetation and elevation and therefore rodent communities. Because of this, BECAMP chose to focus on the most ubiquitous rodents: the heteromyids.

In the summer of 1987, three baseline sites and an area burned by a 1985 lightning fire were studied (Hunter and Medica 1989). In 1988, monitoring continued at the three baseline sites. Two new baseline sites on mesas were added in 1988, along with eight disturbed areas, concentrating on areas impacted by above- and belowground nuclear testing (Saethre and Medica 1992).

In 1989, three crater bottoms, two areas scraped of all vegetation, and an alpha radiation contaminated site were studied. Two additional blast areas, the burned area studied in 1987, and a roadside were trapped in 1990, completing the first three-year cycle of disturbed site monitoring (Saethre 1994a). Monitoring was discontinued at the alpha contamination site and in 1993, a scraped area on Pahute Mesa was trapped for the first time (Saethre 1994c).

During 1993, a type of hantavirus carried by rodents was linked to several deaths in the four corners area of the southwestern United States. The so-called Muerto Canyon virus is present in rodent (mainly *Peromyscus maniculatus*) urine or feces and is passed to humans when aerosolized particles of infected excreta are inhaled. After confirmed cases of the hantavirus infection in humans in southern Nevada, DOE requested that BECAMP workers follow the Centers for Disease Control (CDC) prevention guidelines for handling rodents. In 1994, the rodent trapping program was expanded to include collecting blood samples for hantavirus antibody analysis.

Along with the Yucca Flat and Frenchman Flat baseline sites, 1994 was the year for resampling the four blast areas and 1988 sites. Relative locations are shown in Figure 2-1. Latitude and longitude of all BECAMP sites were determined using a Global Positioning System (GPS) and are found in Saethre (1994c).

SITE DESCRIPTIONS AND MONITORING METHODS

BASELINE SITES

Yucca Flat

This site on the western side of Yucca Flat is at an elevation of 1237 m. It has a large and diverse selection of plant species present, but is dominated by *Lycium andersonii* and *Grayia spinosa* (Beatley 1979). Soil surface is predominantly desert pavement. The valley is a closed basin with a dry lake bed in the southeastern portion.

The plot was a 12 x 12 staked grid (144 stations) with 15 m between stakes (2.72 ha) and two traps per station (288 total). Small mammals were trapped with Sherman live traps (8 x 9 x 30 cm). Traps were baited with rolled oats and birdseed in the early evening (1800+ hours) of 16-18 May 1994. Shades were used when vegetation was inadequate. Traps were checked shortly after sunrise on 17-19 May and closed for the day. On the last day, all bait was removed from the traps and poured into plastic bags to avoid supplementing normal food sources. Earlier trapping took place on 28-30 July 1987, 26-28 April and 11 August 1988, 9-10 and 12 May 1989, 16-18 May 1990, 7-9 May 1991, 13-16 May 1992, 24-25 June 1992, and 18-20 May 1993. The August 1988 and June 1992 data are not reported here.

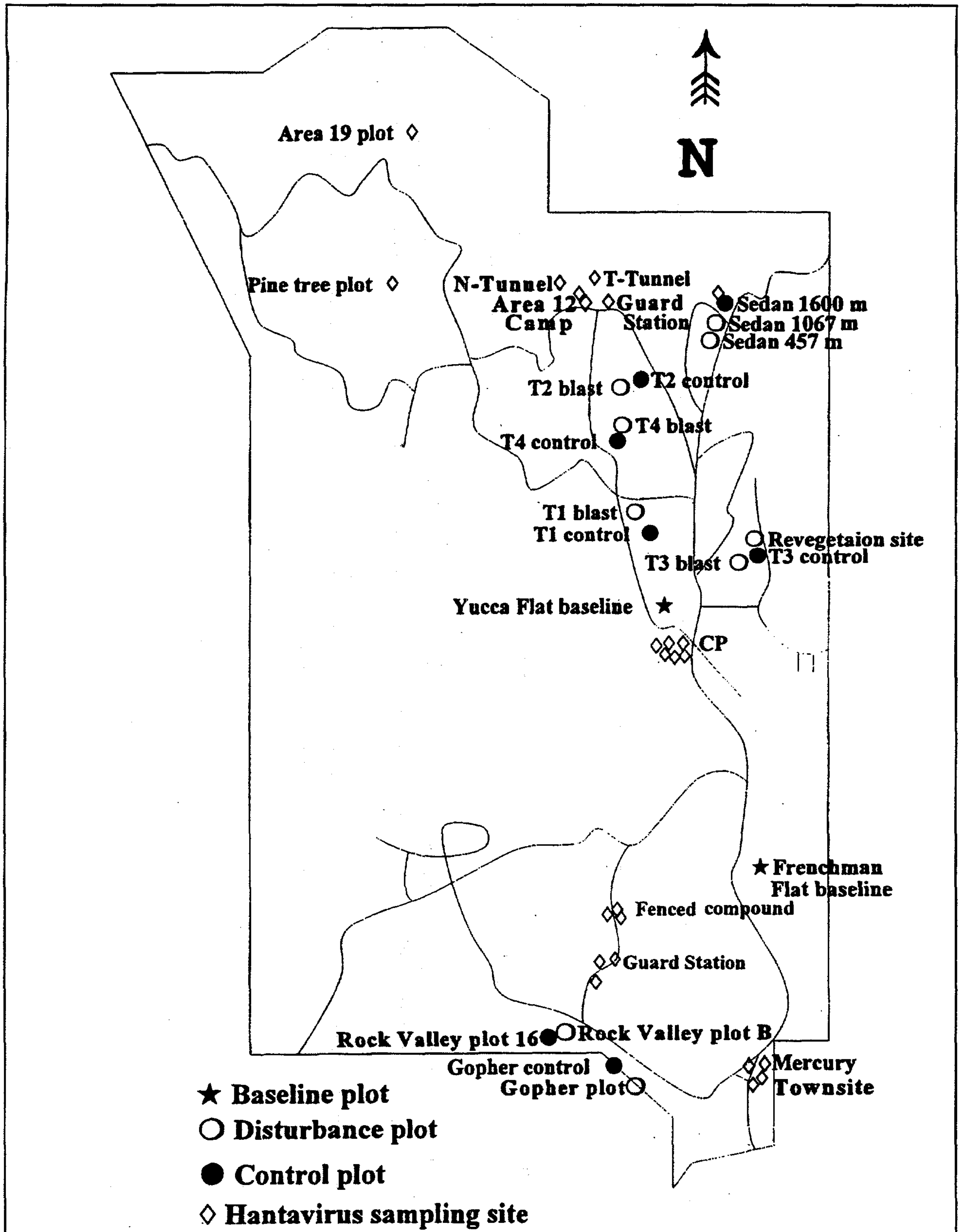

Figure 2-1. Location of small mammal sites studied by BECAMP in 1994.

Each captured animal was marked with a unique ear tag or toe-clip number. Species, new or recapture, animal number, sex, external reproductive condition, grid location, and any remarks were recorded on data sheets. Animals were weighed to the nearest gram and released at the point of capture. Bait was removed from cheek pouches of heteromyids before weighing.

Frenchman Flat

A dry lake bed occupies the eastern portion of Frenchman Flat, a closed basin directly south of Yucca Flat. This area is sandier than Yucca Flat and has more typical Mojave desert vegetation (*Larrea tridentata/Ambrosia dumosa*). The elevation at this plot (located west of the playa) at 965 m is lower and the area receives less annual precipitation than the Yucca Flat site. Plot set up and data collection were the same as the Yucca Flat baseline site. Traps were baited during the late afternoon on 9-11 May 1994 and checked the mornings of 10-12 May. Earlier trapping dates were 7-9 July 1987, 12-14 April and 5 August 1988, 30 April - 2 May and 18-19 June 1991, and 10-12 May 1994. August 1988 and June 1991 data area not included in this report.

DISTURBED SITES

Blast Sites and Control Areas

Four areas used for aboveground testing from 1952 to 1957 (T-sites) and one belowground test detonated in 1962 (Sedan) were studied in 1994. Disturbances from tests included intense ionizing and thermal radiation, fire, and blast damage. Areas near ground zero (GZ) are contaminated and fenced as radiation exclusion (RADEX) areas. Animals were trapped outside these fences.

T1

This area is on the western side of Yucca Flat, 4.7 km north of the Yucca Flat baseline site and 1310 m in elevation. Blast effects from four test series decimated the vegetation in a circular area of approximately 500 ha. In the last 40 years, the area has been invaded by Russian thistle and brome grasses. By 1994, the area had scattered shrubs and bunch grasses.

Historically, T1 was studied by BYU (White and Allred 1961). Two BECAMP plots are located on a BYU trap line at 960 m and 1760 m southeast of GZ (Figure 2-2). The 960 m plot (1317 m elevation) is located outside the RADEX area, but well within the apparent blast area. The 1760 m plot (1320 m elevation) is in an undisturbed mixed shrub area. Bunch grasses were also abundant on the 1760 m plot.

Procedures on disturbed plots were the same as on baseline plots except for plot size. Two plots, a disturbance and a control, were set up at each study site. Each plot at T1 was a smaller, 8 x 8 unit grid (1.10 ha). Sites were smaller than baseline plots so that a disturbed and a control plot could be checked at the same time by one biologist per plot. Traps were checked at T1 and its control on 14, 16-18 May and 9-10 August 1988, 14-16 May 1991, and 24-26 May 1994. August 1988 results are not included here.

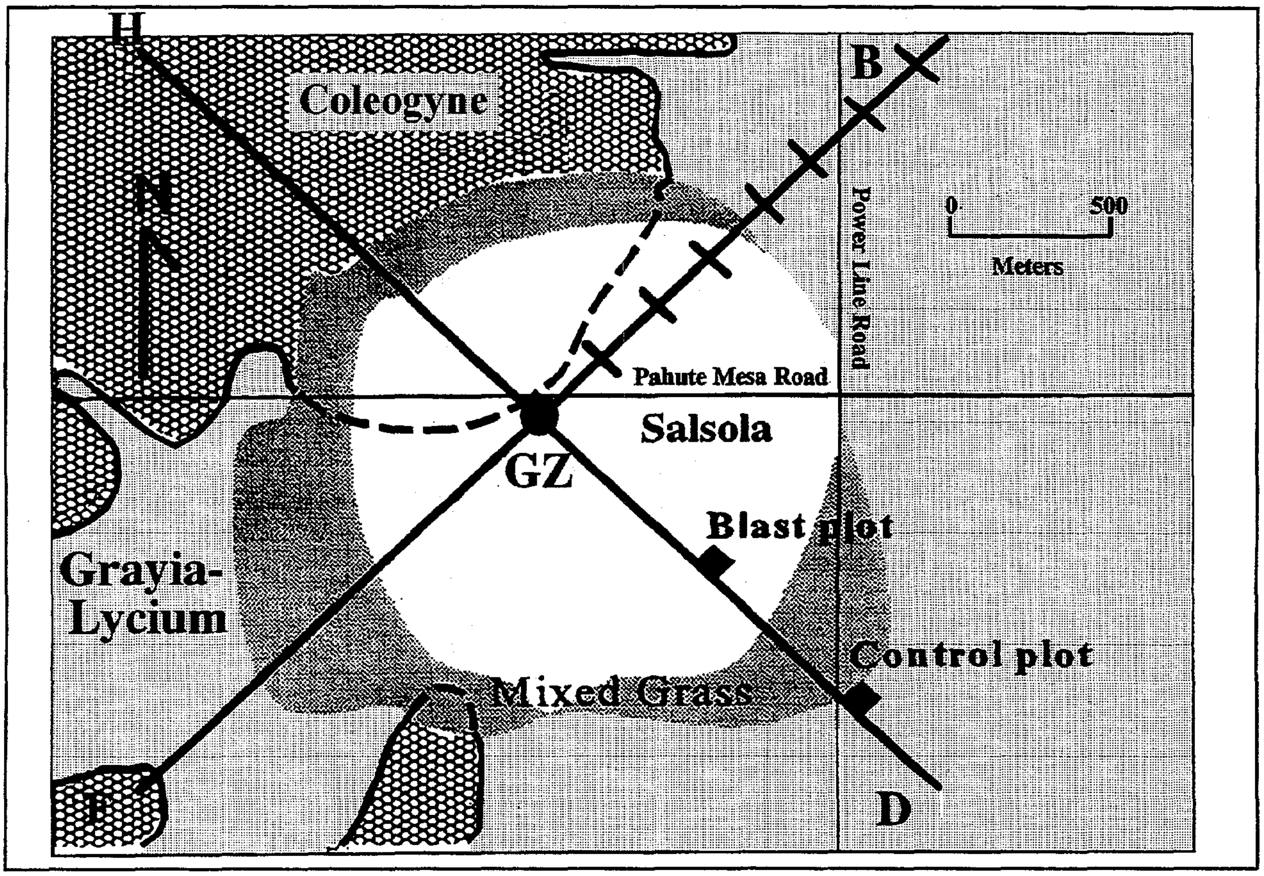

Figure 2-2. Vegetation zones around T1 ground zero, BYU traplines (White and Allred 1961) and location of BECAMP plots (■).

T4

The T4 GZ is 5.5 km north of T1 GZ on the western side of Yucca Flat. This site was the location of a series of tests between 1952 and 1957 (Kordas and Anspaugh 1982). An 8 x 8 unit trapping grid was erected 570 m SW from the RADEX area, but well within the blast area. Another grid was established 1355 m SW of GZ in undisturbed blackbrush habitat. This site was first trapped on 26-28 June 1990. In 1994, the grids were trapped for only two days (28-29 June). The 1990 data were therefore adjusted to reflect only the first two nights of trapping.

T2

The GZ at T2, 5.2 km north of T4 GZ, was the location of four tower tests between 1952 and 1957 (Kordas and Anspaugh 1982). Two additional GZs, one at 1500 m SE and one 1500 m NE, designated T2a and T2b, hosted single tests in 1957 (Figure 2-3). Disruption from the

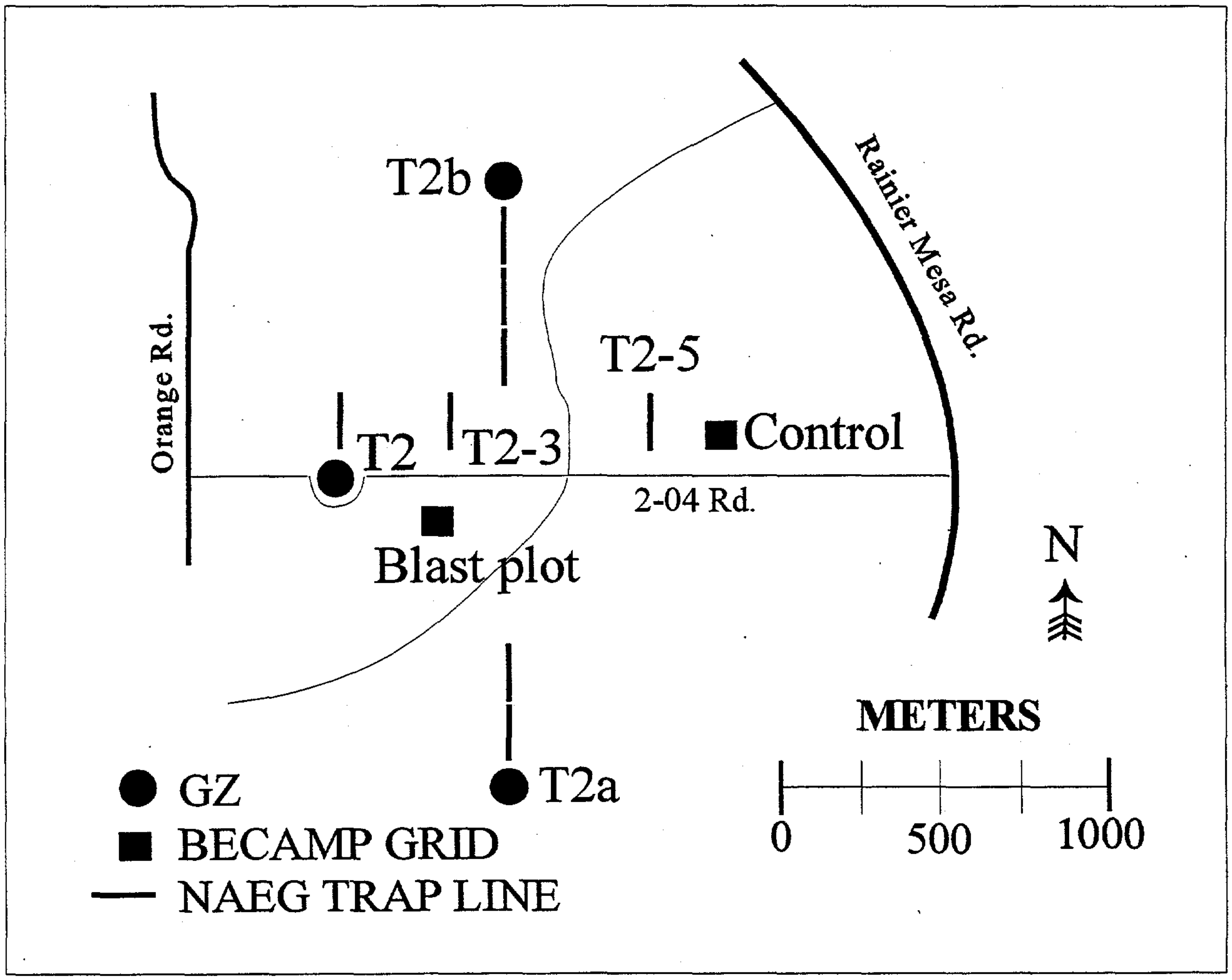

Figure 2-3. Location of BECAMP plots at T2 in relation to ground zeroes and NAEG traplines (O'Farrell and Sauls 1987).

blasts cleared perennial shrubs from the immediate area out to approximately 1300 m. Roads and drag lines also cross from all directions. The blast area has since been invaded by Russian thistle, perennial grasses, and scattered burrobush (Shields et al. 1963, O'Farrell and Sauls 1987, Hunter 1994b). When this site was measured in 1990, most of the vegetation was dead. In 1994, this was not the case.

The T2 was used as part of the NAEG program to assess small mammals inhabiting nuclear event sites (O'Farrell and Sauls 1987). In that study, traplines of 210 m (15 traps at 15 m) were established at 152 and 457 m from each of the three Gzs, as well as 762 m south of T2b and 1524 m east of T2 (a control line). These sites were trapped monthly between July 1982 and May 1993, and results for all months were combined for each trapline. BECAMP set up 8 x 8 grids at 400 m (1371 m elevation) and 1650 m east of T2 (Figure 2- 3) and set traps on 26-28 June 1990 and 28-30 June 1994. Results for NAEG traplines T2-3 and T2-5 are reported for comparison. However, sites are not directly comparable due to study design differences.

T3

This area has no historical data on small mammals. Unlike the other T-sites, T3 is on the eastern side of Yucca Flat, where the soil is sandier and the mix of shrubs is different. Vegetation on the blast area is almost entirely Russian thistle and the soil is compacted except in areas with rodent activity. Elevation at this site is 1236 m. The trap grid in the blast area is located 700m SE of GZ. The control for this site is shared with a nearby revegetation area.

At the T3 blast and control sites, 5 x 15 grids (1.26 ha) were used due to disturbances other than blast effects that were present. Traps were opened on 20, 25-26 May 1988, 21-23 May 1991, and 7-9 June 1994.

Sedan Crater Site

A 104-kiloton thermonuclear cratering test in northeastern Yucca Flat was detonated on 6 July 1962. The blast created a crater 98 m deep and ejected earth out to 762 m. The lip of the crater was as high as 38 m. This area is unique in that biological studies were performed on the immediate, close-in effects of the blast (Jorgensen et al. 1963).

Before the test, BYU set up plots on the NE 57° azimuth (16A line) centered on GZ (Figure 2-4) and trapped small mammals at the following meters from GZ: 305, 610, 915, 1220, 1525, 2134, and 2743. Depth of the overburden along the line was up to 11 m, tapering to less than 1 m at 601 m from GZ and to less than 0.1 m at 762 m. Due to the complete burial by overburden, animals were not trapped post-test closer than 915 m.

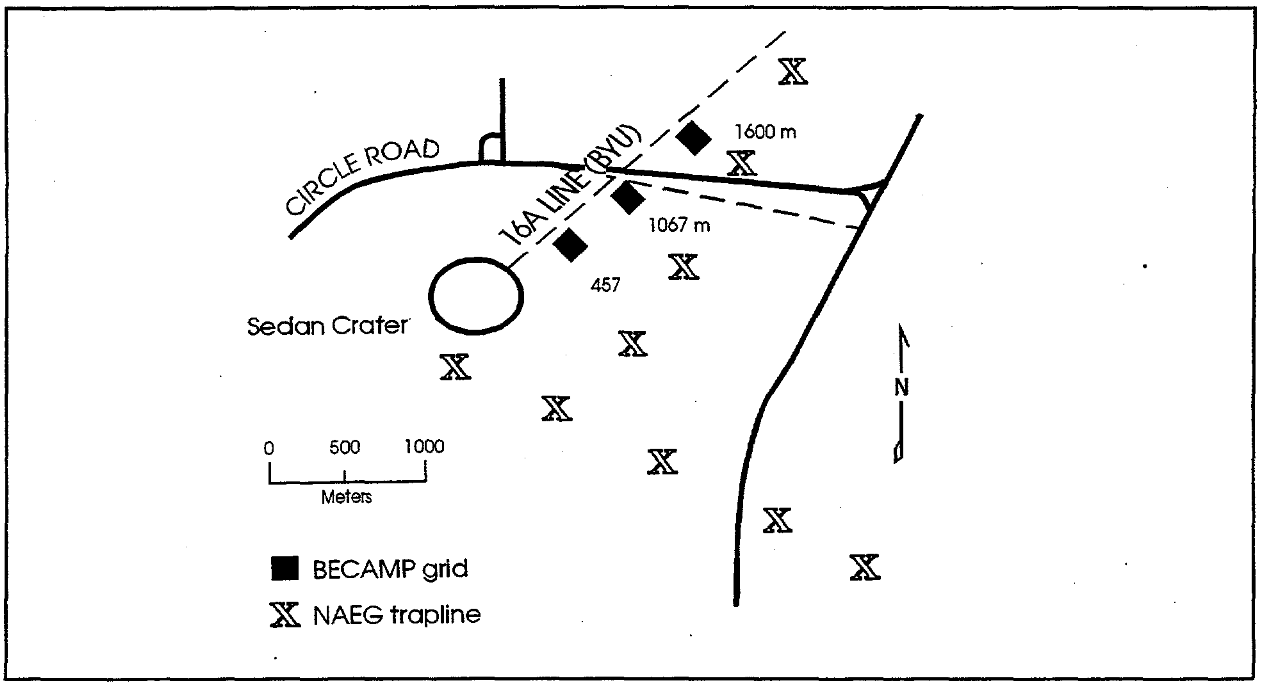

Figure 2-4. Location of BYU, NAEG, and BECAMP trapping sites at Sedan.

Perennial vegetation on the 16A line was destroyed out to 601 m by blast burial and blast effects. This zone is now dominated by bunch grasses. Between 601 and 1524 m, vegetation showed some blast effects, but presently consists of mixed shrubs and bunch grasses. Beyond the blast damage, vegetation is mostly blackbrush, which was not characteristic of close-in vegetation before the 1962 event. A more complete history of this site is found in Hunter (1994b).

In 1982-1983, Sedan was trapped monthly by NAEG. For this study, traplines were located northeast and southeast of GZ (O'Farrell and Sauls 1987). In 1988, BECAMP set up 8 x 8 grids along the 16A line at 457 m, 1067 m, and 1600 m (Figure 2-4). Traps were set 11-13 July 1988, 8-10 July 1991, and 11-13 July 1994.

Rock Valley

This area on the southern boundary of the NTS contains three fenced and one unfenced 9-ha circular plots (A - D) and a 46-ha IBP validation site (Figure 2-5). Several years of small mammal population data have been collected from this relatively undisturbed area of the NTS. Between 1964 and 1981, plot B was continuously exposed to gamma radiation from a cesium-137 source and lizards, plants, and small mammals were assayed to determine the effects of reoccuring low-level radiation (French et al. 1974). Rock Valley was also part of IBP from 1970 through 1976 (Turner 1973 and 1975, Turner and McBrayer 1974). The 12 x 12 mammal grids on two of the historical plots, the southwestern quarters of plots B and D (IBP plot 16) were trapped on 14-16 June 1988, 11-13 June 1991, and 14-16 June 1994.

A National Oceanic and Atmospheric Administration (NOAA) weather station has been operational at Rock Valley since 1963.

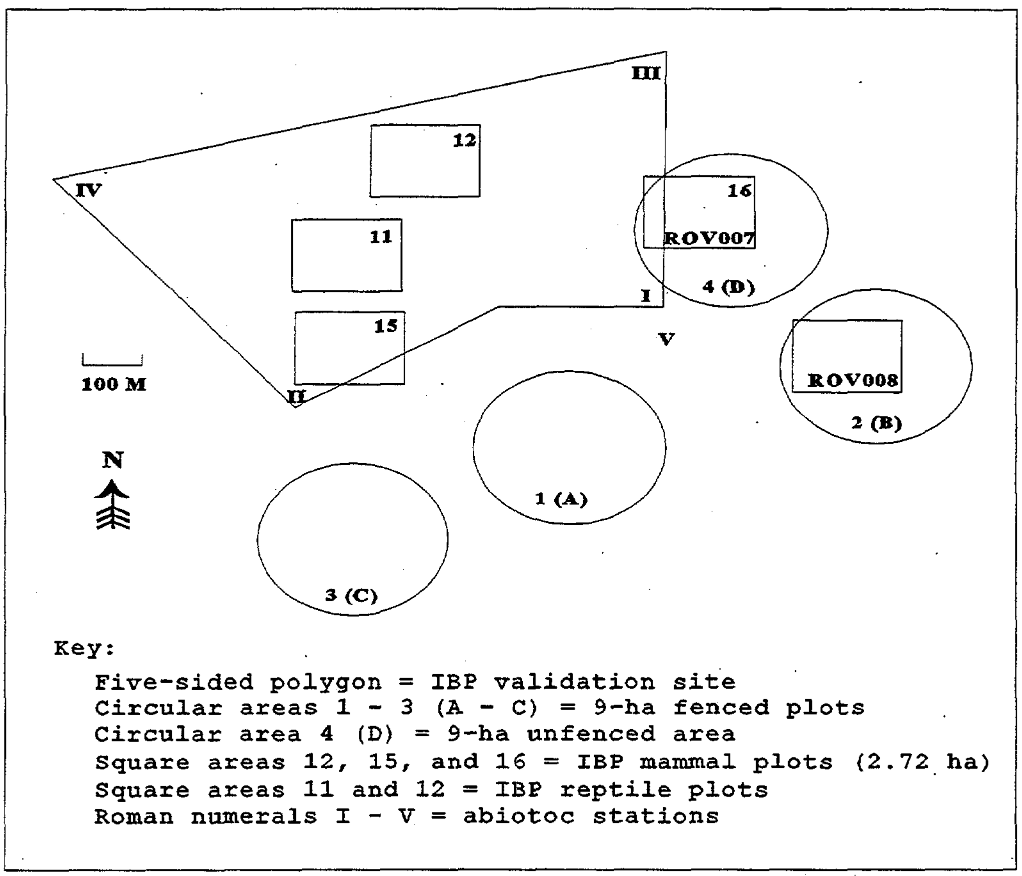

Figure 2-5. Layout of Rock Valley study plots.

Revegetation Site

Beginning in the mid-1950s, debris from aboveground nuclear detonations was consolidated at several waste sites. In 1987, radioactive metal, concrete, and lumber were removed from the 3B waste site, a fenced location in eastern Yucca Flat. Several centimeters of topsoil, and hence all vegetation, were removed. The total disturbed area was approximately 5 ha.

BECAMP established a 14 x 5 trapping grid (1.575 ha) in the cleared area in 1988 to document resident rodents and recolonization of the area. The control plot for T3 is directly south of this site and was used as an undisturbed comparison plot. Mammals were trapped at the same time as at the T3 blast and control areas (20, 25-26 May 1988). In the spring of 1989, the entire fenced area was "ripped" to a depth of about 15 cm to loosen the topsoil. Young perennial shrubs were transplanted on the site (*Atriplex canescens*, *A. polycarpa*, and *Larrea tridentata*). The area is fenced with 2-inch mesh to limit lagomorph grazing. The site was trapped again on 21-23 May 1991 and 7-9 June 1994.

Rodent-Denuded Area

Several large areas on the NTS of up to ~65 ha have been disturbed by rodents (Hunter et al. 1980). These sites contain almost no perennial vegetation and appear to be maintained by gopher activity. A plot on one of the larger sites located on the southern edge of the NTS was trapped on 21-22, 26 July 1988, 23-25 July 1991, and 19-21 July 1994. Escape cover on this site is limited to sparse stands of prince's plume (*Stanleya pinnata*) and several dead shrubs. The soil on the denuded area is finer than the nearby area used as a control. Normal vegetation on the control site is dominated by creosote bush/bursage (*Larrea tridentata/Ambrosia dumosa*). Grid size on both plots was 8 x 8 (1.44 ha).

DISTRIBUTION OF HANTAVIRUS ON THE NTS

As part of a statewide effort, four areas with high human population (Mercury townsite, CP, Area 12, and a fenced compound) and six areas outside of most worker activity were sampled in 1994 for the presence of hantavirus. One area studied in 1993 was sampled for hantavirus in 1994 so that a comparison between years was possible. Sampling did not begin until mid-June and all traps were located outside of buildings.

On most of the selected sites, 50 traps (25 Sherman and 25 mesh) were laid out in 2 lines, alternating trap type. At Mercury, CP, and Area 12, two to four replicates were trapped to sample different habitats. Sites were trapped for at least two nights and a third night was added if most of the rodents on the second morning were new. Two sites on Pahute Mesa (pine tree plot and the Area 19 plot) and the Sedan 1600 meter plot had existing 8 x 8 grids and only Sherman traps were used. Species, sex, reproductive condition, age, weight, and trap type were recorded on data sheets. Blood samples were drawn from all *Peromyscus* and related species (i.e., Muridae family) and representative individuals of other species on the NTS (heteromyids and ground squirrels) via orbital sinus bleed. Animals were marked with a black or red permanent felt pen and released. Blood analyses for Muerto Canyon virus antibodies were conducted at the DNA lab at the University of Nevada Reno Department of Microbiology.

DENSITY ESTIMATION

The population size and a hypothetical standard error of the estimate were calculated for the most common species using a mark and recapture method (Seber 1982:138). Calculations gave an estimate of population in number per plot (N*) plus or minus two standard errors (2 se approximated a 95% confidence interval). Density estimates could not be calculated for species without recaptures.

To estimate number of animals per hectare (N/ha), N* and 2 se were divided by the plot size in hectares. An se of zero resulted when no new animals were captured on the last day, or when all of the previously marked animals were captured on the last day - a common occurrence with the kangaroo rats. An overall "naive density" (number per hectare) was estimated for a site by dividing the number of individuals captured by the grid size.

SPECIES DIVERSITY INDEX

The Shannon formula (Zar 1984) was used as an index of species diversity (H′) at each site. A high value for H′ suggests that several common species are residing at a location and a high diversity exists.

A t-test (Zar 1984) was used to compare species diversity at a disturbed site with its control in the same year or to compare the same site between different years. Any differences between two sites or changes over time in the species diversity may show a loss of diversity (a decrease in H′) or an increase in maturity due to succession (increase in H′) at a site. This was a convenient method of quickly assessing differences in two plots that may have similar species richness, but different amounts of each species captured.

OTHER STATISTICAL ANALYSES

A mean weight and standard error of the mean (se) were calculated for each sex of two age classes (adult and juvenile) of the most common species. Weights for all these animals, even pregnant females, were included. Mean weights were analyzed using two-way analysis of variance (F) for site (or year) and sex (ANOVA, RS/1, BBN Software Products Corp., Cambridge, MA). The weight for an individual was averaged if captured more than once, although weight is known to decrease in subsequent captures (Kaufman and Kaufman 1994). Weights on paired disturbance plots were compared by plot and sex for 1994. When comparing between years, a plot was only compared to itself by year and sex. Newman-Keuls Multiple Range Test (NKMRT) was used for a multiple comparison test when ANOVA showed significant results. Total biomass between paired plots was compared using a t-test on median values. Sex ratios and trap successes were compared by analyzing contingency tables with the chi-square (x^2) statistic. Unless otherwise indicated, degrees of freedom equal one. Degrees of freedom appear as a subscript following the test statistic (e.g., $F_{2,238}$ =2.110). Results were significant when probability (P) was equal to or less than 0.05.

PRECAUTIONS AGAINST HANTAVIRUS

CDC guidelines were followed to reduce the risk for infection (CDC 1993). Protective clothing, eye shield, gloves, and respiratory protection were used by all trapping personnel. Before traps were returned from the field, bait was poured into plastic bags and discarded.

RESULTS

ABBREVIATIONS AND NOTATIONS

To simplify tables, species' names appear in results tables as the abbreviations listed in Table 2-1. Scientific names follow (Wilson and Reeder 1993). Plot names are abbreviated with three letters designating the valley or mesa (e.g., YUF =Yucca Flat) plus a unique three-digit code for that area starting with 001 (YUF001 = Yucca Flat). An asterisk (*) in density tables indicates recapture data was insufficient to calculate a density. Numbers in parentheses are individuals captured. Error bars in weight figures represent two standard errors of the mean. Only rodents were used to calculate overall density, species number,

Table 2-1. Abbreviations used in results tables for scientific names of small mammals.

Abbreviation	Scientific Name	Common Name
RODENTIA		
Geomyidae		
THOBOT	*Thomomys bottae*	Botta's pocket gopher
Sciuridae - Squirrels and chipmunks		
AMMLEU	*Ammospermophilus leucurus*	White-tailed antelope squirrel
SPETER	*Spermophilus tereticaudus*	Round-tailed ground squirrel
TAMDOR	*Tamias [=Eutamias] dorsalis*	Cliff chipmunk
Heteromyidae - rats and mice with cheek pouches		
CHAFOR	*Chaetodipus formosus*	Long-tailed pocket mouse
DIPDES	*Dipodomys deserti*	Desert kangaroo rat
DIPMER	*Dipodomys merriami*	Merriam's kangaroo rat
DIPMIC	*Dipodomys microps*	Chisel-toothed kangaroo rat
DIPORD	*Dipodomys ordii*	Ord's kangaroo rat
PERLON	*Perognathus longimembris*	Little pocket mouse
PERPAR	*Perognathus parvus*	Great Basin pocket mouse
Muridae - mice, rats and voles		
NEOLEP	*Neotoma lepida*	Desert woodrat
ONYTOR	*Onychomys torridus*	Southern grasshopper mouse
PERCRI	*Peromyscus crinitus*	Canyon mouse
PERERE	*Peromyscus eremicus*	Cactus mouse
PERMAN	*Peromyscus maniculatus*	Deer mouse
PERTRU	*Peromyscus truei*	Pinyon mouse
REIMEG	*Reithrodontomys megalotis*	Western harvest mouse
LAGOMORPHA		
Leporidae - rabbits and hares		
LEPCAL	*Lepus californicus*	Black-tailed jack rabbit
SYLAUD	*Sylvilagus audubonii*	Desert cottontail rabbit
SYLNUT	*Sylvilagus nuttallii*	Nuttall's cottontail rabbit
CARNIVORA		
Mustelidae - mustelids		
MUSFRE	*Mustela frenata*	Long-tailed weasel

species diversity, and percent of total captured. Other small mammals captured are reported for completeness. Descriptions of the perennial and ephemeral plant compositions on plots studied in 1994 are discussed in the appropriate vegetation sections of this report and should be referred to for a more detailed account of the flora on these sites.

MAMMALS ON THE NTS

Fifty-seven mammal species occur on or near the NTS, the majority of which are typed of rodents (Jorgensen and Hayward 1965; O'Farrell and Emery 1976; Medica 1990; EG&G/EM 1992 and 1993; Saethre and Medica 1992; Saethre 1994a,b). Of the 23 rodent species, the most ubiquitous are kangaroo rats and pocket mice. These heteromyids are well-adapted to xeric conditions, nocturnal, and largely granivorous (Reichman 1991).

Several other seed-eating rodents share habitat with heteromyids on the NTS, but most persist at low densities. Omnivorous squirrels are, for the most part, diurnal, but are often captured when traps are baited too early in the evening or left open late in the morning. Therefore, relative abundance of these species may not be accurately reflected in this report. The black-tailed jackrabbit and desert cottontail are also found throughout the NTS. These animals are not regularly captured during trapping and their relative abundances are usually assessed by less quantitative means (e.g., roadkill observations and encounters during lizard transects).

Small mammal populations in 1994 were at or above levels observed before the severe drought conditions of 1989-1991, when little or no ephemeral plants germinated and perennial plants were either dormant or dead (Hunter 1994a). Results from sites studied in 1994 are summarized below according to plot type or disturbance.

BASELINE MONITORING SITES

Yucca Flat (YUF001)

YUF001 has been trapped yearly from 1987 through spring 1994. During this time fluctuations in the rodent trap success and density coincided with the local drought beginning in 1989 and ending in 1991 (Figure 2-6). Both the spring density ($F_{1,12} = 5.045$, $P = 0.0443$) and trap success ($F_{1,12} = 6.118$, $P = 0.0293$) showed a significant linear correlation with winter precipitation from the previous year.

Significant decreases in trap success occurred between July 1987 and April 1988 (x^2 = 24.043, P < 0.00001), April 1988 and May 1989 (x^2 = 30.773, P < 0.0001), and May 1989 and May 1990 (x^2 = 9.872, P = 0.00168). A significant increase (x^2 = 22.943, P < 0.0001) was seen from May 1990 to May 1991. Because overall trap success fluctuated with precipitation, the trap successes for individual species did not remain constant (Figure 2-7).

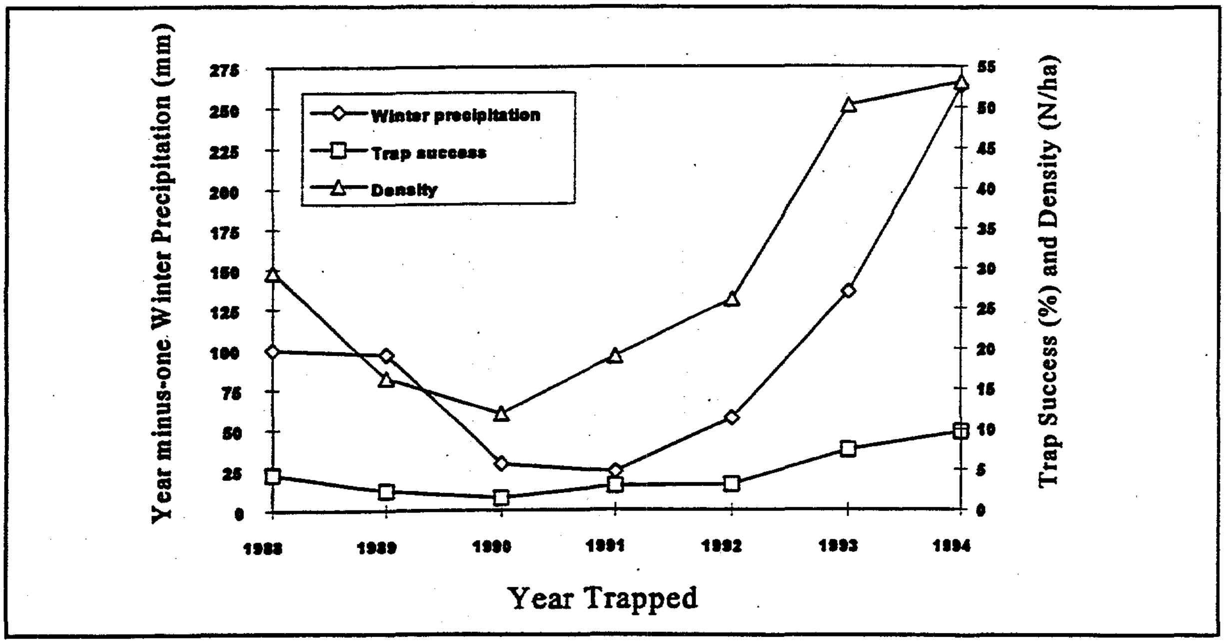

Figure 2-6. Relationship between winter precipitation and trap success and rodent density at the Yucca Flat baseline site.

While overall trap success increased in 1991, 1992, 1993, and 1994, only in 1991 did trap success increase appreciably for *Perognathus longimembris*. In 1992, this species fell into another decline (Figure 2-7, Table 2-2), with only eight individuals captured. Four of those were recaptures from 1988 and 1989. Only two new individuals were captured in 1989 and six in 1990. Nine individuals were captured in 1993 with one a recapture from spring 1988 and two recaptures from summer 1992 (Figure 2-8). Nine were also captured in 1994 with two of those recaptures: one from summer 1992 and one from 1993.

Estimates of spring density for the most common rodents on YUF001 showed a continual reduction until 1991 (Table 2-2). Most noticeable was the 53% decrease in density of *P. longimembris* in 1989, followed by a decrease of 9% in 1990, and a 61% increase in 1991. These results coincided with low rainfall in 1989 and 1990 and higher rainfall in 1988 and 1991.

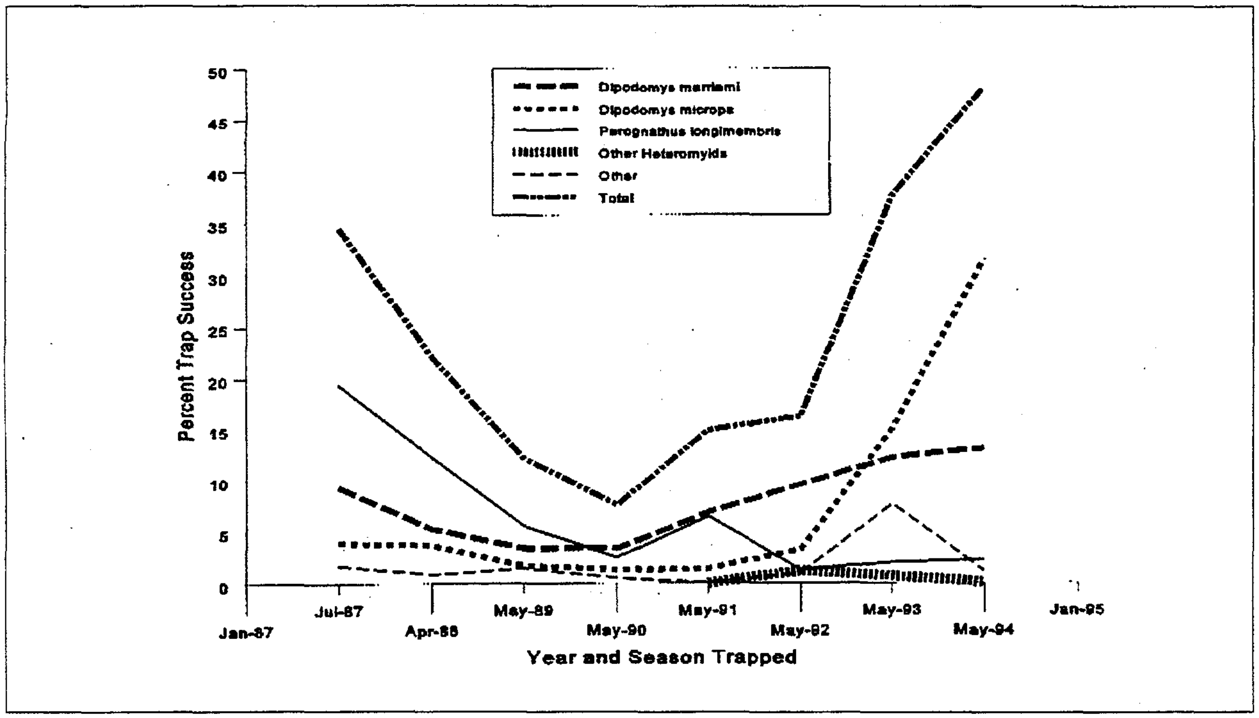

Figure 2-7. Overall trap success by species at the Yucca Flat baseline site, 1987 through 1994. X-axis is not to scale.

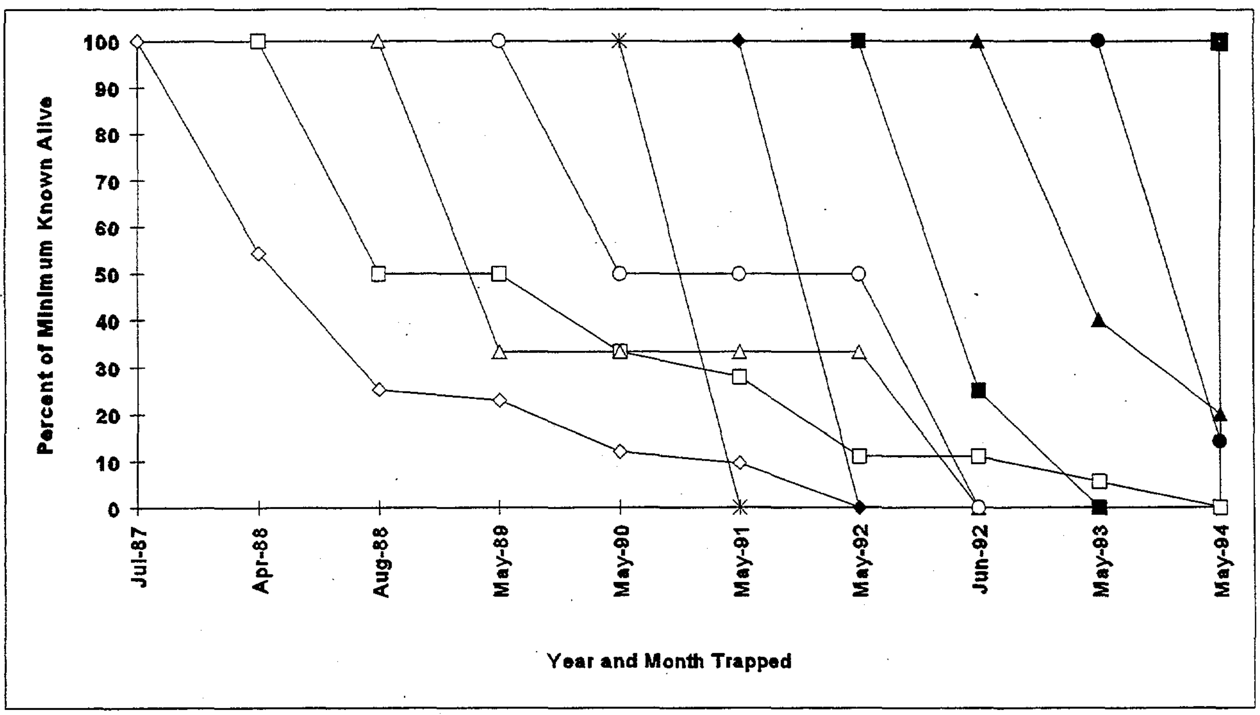

Figure 2-8. Year-to-year survivorship and recruitment of *Perognathus longimembris* as a percent of cohort size at the Yucca Flat baseline site from 1987 through 1994. X-axis is not to scale.

Table 2-2. Estimated density (N*/ha ± 2 se) and species diversity (H′) on the Yucca Flat plot (YUF001) in 1987 through 1994. Numbers in parentheses are individuals. Shaded portion (lagomorphs) was not included in density and species diversity estimates.

	1987	1988	1989	1990	1991	1992	1993	1994
CHAFOR	---	---	---	---	---	2.3±0.5 (7)	* (3)	* (1)
DIPMER	9.8±0.3 (32)	5.2± 0 (17)	3.4±0 (11)	5.0±1.3 (14)	7.4±0 (24)	15.1±1.7 (45)	16.7±1.4 (51)	14.4±0.5 (46)
DIPMIC	5.0±0.7 (16)	5.2±0.8 (16)	2.7±0.7 (8)	2.3±1.0 (6)	1.2±0 (4)	5.4±0.7 (17)	20.9±1.2 (65)	34.8±0.9 (111)
PERLON	27.8±2.4 (83)	19.0±1.8 (57)	9.0±1.6 (26)	8.2±4.7 (16)	13.2+3.5 (33)	3.4±1.9 (8)	3.4±1.4 (9)	2.8±0.2 (9)
PERPAR	---	---	---	---	---	---	* (1)	---
ONYTOR	* (9)	* (2)	* (3)	* (3)	---	5.2±5.9 (7)	3.9±1.4 (11)	* (1)
PERERE	---	---	---	---	---	* (1)	* (2)	---
PERMAN	* (1)	---	* (4)	---	---	---	4.4±0.4 (14)	* (2)
REIMEG	---	---	---	---	(1)	---	2.5±1.5 (6)	* (2)
AMMLEU	* (2)	* (4)	* (1)	---	---	---	* (1)	---
LEPCAL	---	---	---	---	---	---	* (2)	---
SYLAUD	---	* (1)	---	---	---	---	---	* (5)
N/ha N	44.1 (143)	29.6 (96)	16.4 (53)	12.0 (39)	19.1 (62)	26.2 (85)	50.3 (163)	53.1 (172)
SPECIES	6	5	6	4	4	6	10	7
H′	0.5037	0.4898	0.6052	0.5292	0.4110	0.5840	0.6925	0.4140

Although densities of *Dipodomys merriami* and *P. longimembris* increased from 1990 to 1991, the estimated density of *D. microps* continued to decline until 1992. In 1994, the number of *D. microps* captured was the highest ever at this site, surpassing *D. merriami* as the most commonly captured species for the second year in a row. The distribution of the total captured population among species for the eight years (Figure 2-9) changed dramatically in the last three years. While heteromyids made up 78 to 97% of individuals in any year, the composition changed from predominantly *Perognathus longimembris* in 1987 through 1991 to mostly *Dipodomys microps* in 1993 and 1994. In 1992, *D. merriami* was the dominant species.

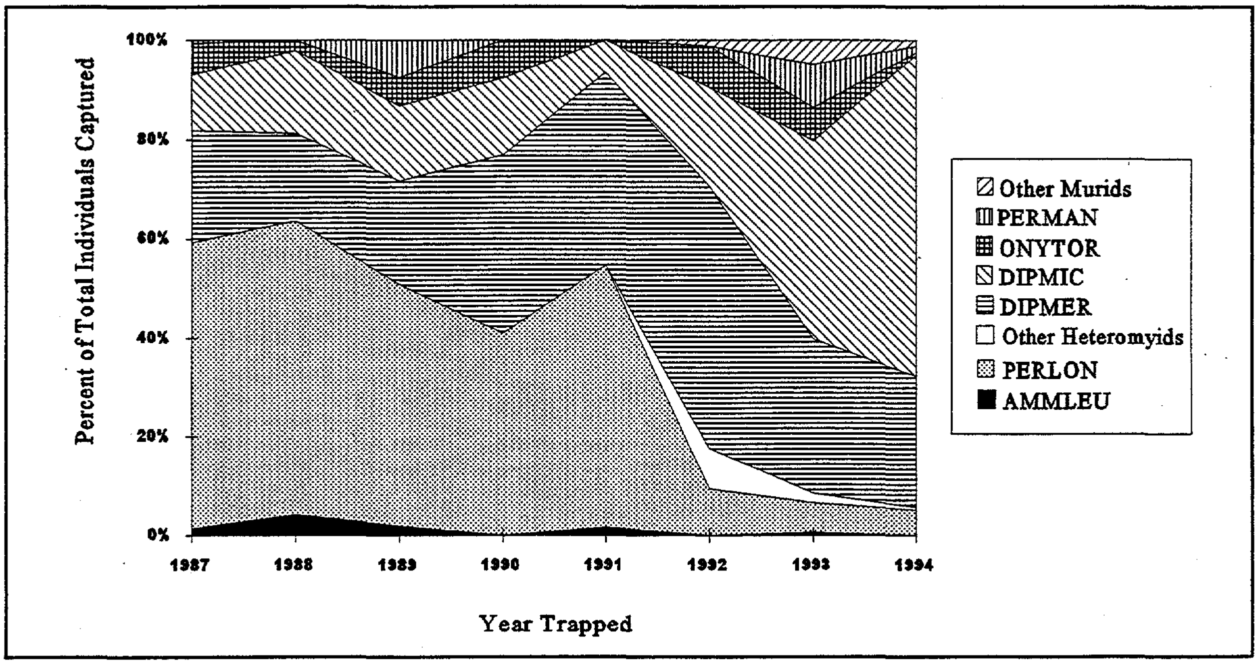

Figure 2-9 - Distribution of individuals captured each year by species at YUF001.

Because of the change in species distribution, species diversity (Table 2-2) decreased significantly in 1991 (t_{78} = 2.327, P = 0.0226). A significant increase in species diversity occurred in 1992 (t_{146} = 3.229, P = 0.00153) and remained high in 1993.

Sex ratios (Table 2-3) for each species captured on YUF001 from 1987 to 1993 did not differ significantly from 1:1 (x^2, P > 0.05) except for the following instances in 1990 four times as many female as male *P. longimembris* were captured (x^2 = 6.25, P = 0.0124) and in 1993 only males of this species were captured (x^2 = 9.00, P = 0.00270). In May 1992, slightly more male *Dipodomys merriami* and significantly more male *Chaetodipus formosus* were captured (x^2 = 3.756, P = 0.0526 and x^2 = 7.00, P = 0.00815). In 1994, significantly more female *D. microps* were captured (x^2 = 5.631, P = 0.0176). Combining all species for each year, only in 1992 were significantly more males than females captured (x^2 = 8.576, P = 0.00341).

Table 2-3. Sex ratio (♂/♀) for small mammals captured on the YUF001 baseline plot from 1987 through 1994.

	1987	1988	1989	1990	1991	1992	1993	1994
CHAFOR	---	---	---	---	---	7/0	1/2	1/0
DIPMER	13/19	11/6	5/6	9/5	12/12	29/16	27/24	22/24
DIPMIC	9/7	9/7	6/2	4/2	2/2	12/5	33/32	43/68
PERLON	44/39	27/30	13/13	3/13	14/19	5/3	9/0	5/4
PERPAR	---	---	---	---	---	---	0/1	---
ONYTOR	2/7	2/0	2/1	2/1	---	2/5	7/4	0/1
PERERE	---	---	---	---	---	1/0	1/1	---
PERMAN	0/1	---	3/1	---	---	---	8/6	1/1
REIMEG	---	---	---	---	---	---	4/2	2/0
AMMLEU	0/2	2/2	0/1	---	1/0	---	[a]	---
TOTAL	68/75	51/45	29/24	18/21	29/33	56/29	90/72	74/98

[a]One animal of undetermined sex not included.

The mean weight of adult male *D. merriami* was significantly greater than that of adult female *D. merriami* in 1988 and 1989 (Saethre and Medica 1992 Saethre 1994a), but not in any other year. Both sexes showed the same pattern of highest mean weight in 1992 and 1993 (Figures 2-10 and 2-11). Overall, spring mean weights of adult *D. merriami* varied significantly by year ($F_{5,135}$ = 7.6, P < 0.0001), but not sex ($F_{1,135}$ = 2.11, P = 0.148). A multiple comparison test (NKMRT) showed adult mean weight in 1993 to be significantly heavier than those of 1988, 1990, and 1991 (Saethre 1994c).

Male *D. microps* were on average heavier than females captured in the same year (Figures 2-12 and 2-13) and were significantly heavier in 1994 ($F_{1,109}$ = 12.31, P = 0.000656). Spring mean weight did not show any trend for either sex over the last seven years.

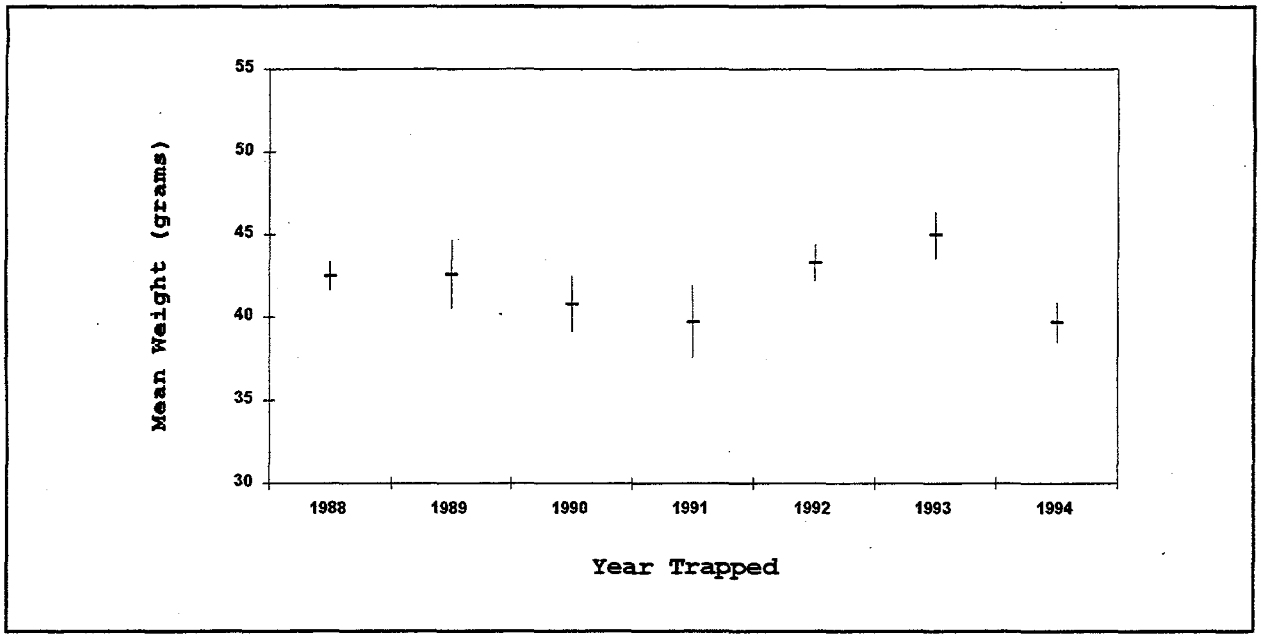

Figure 2-10. Trend in adult male *D. merriami* mean weights at YUF001 from 1988 through 1994.

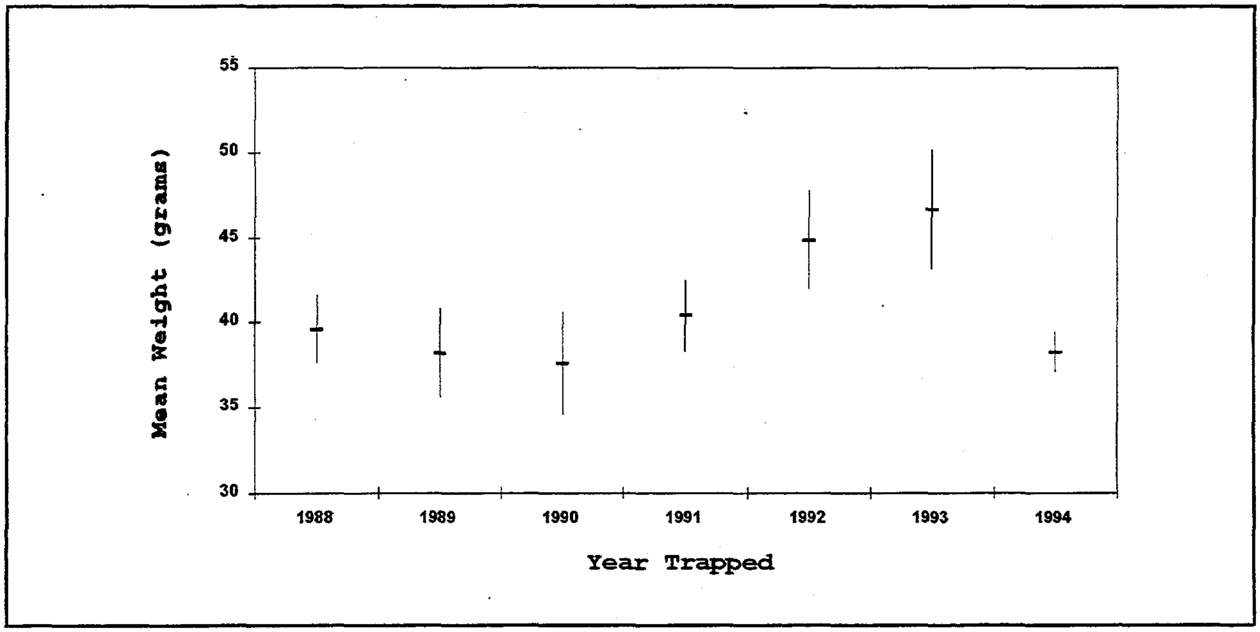

Figure 2-11. Trend in adult female *D. merriami* mean weights at YUF001 from 1988 through 1994.

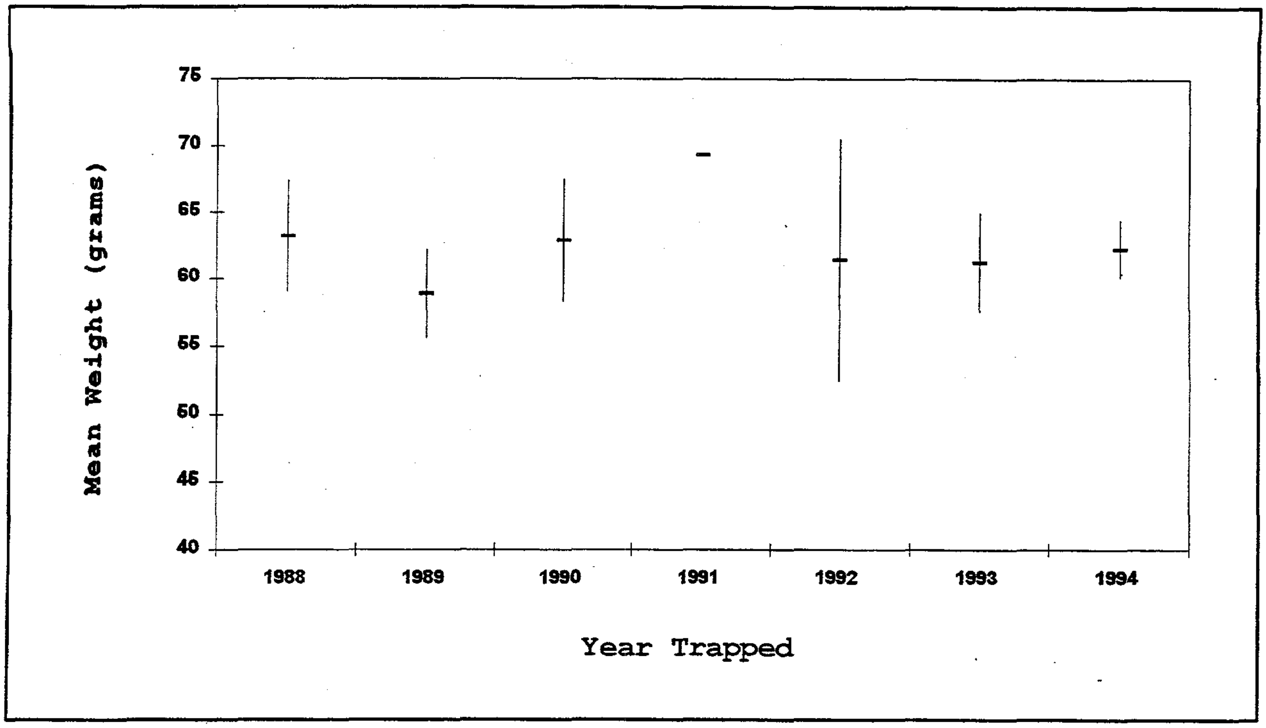

Figure 2-12. Trend in adult male *D. microps* mean weights at YUF001 from 1988 through 1994.

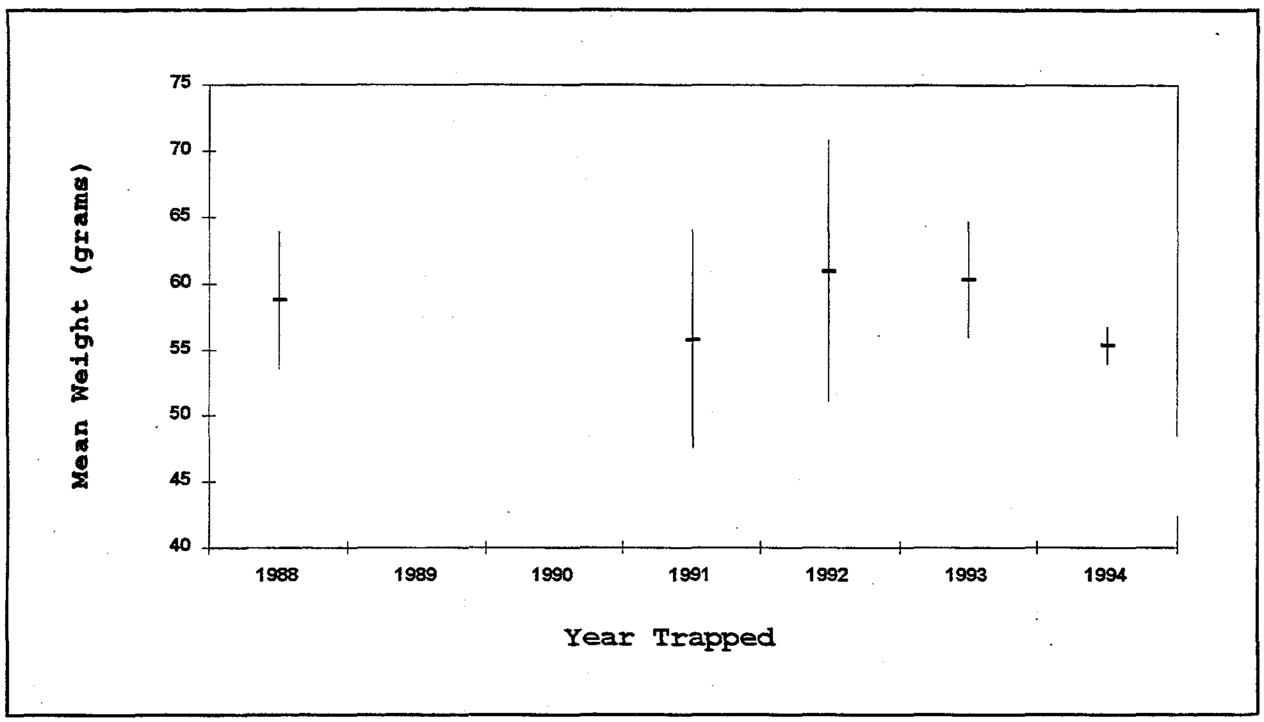

Figure 2-13. Trend in adult female *D. microps* mean weight at YUF001 from 1988 through 1994.

The mean weight of adult male *Perognathus longimembris* (Figures 2-14 and 2-15) did not differ significantly from the mean weight of adult females in 1988, 1989, or 1990 (P > 0.10), but males were significantly heavier in 1991 (Saethre 1994a). In 1992, the three females were heavier than males and all were judged to be pregnant. No females were captured in 1993 for comparison and mean weights in 1994 were nearly identical.

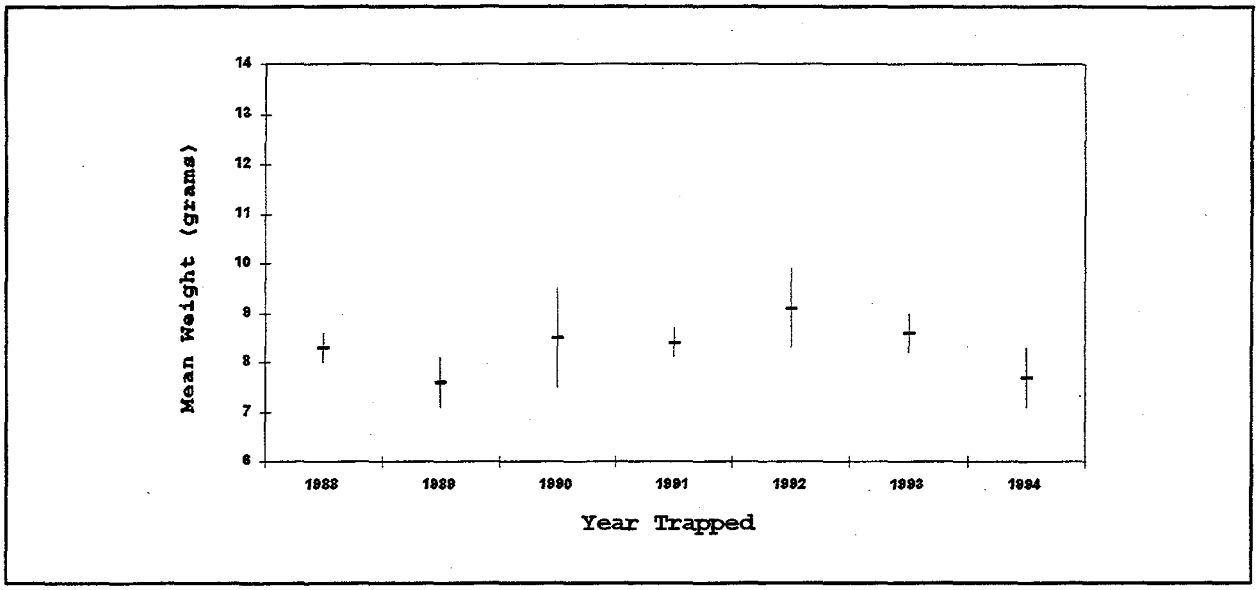

Figure 2-14. Trend in adult male *P. longimembris* mean weight at YUF001 from 1988 through 1994.

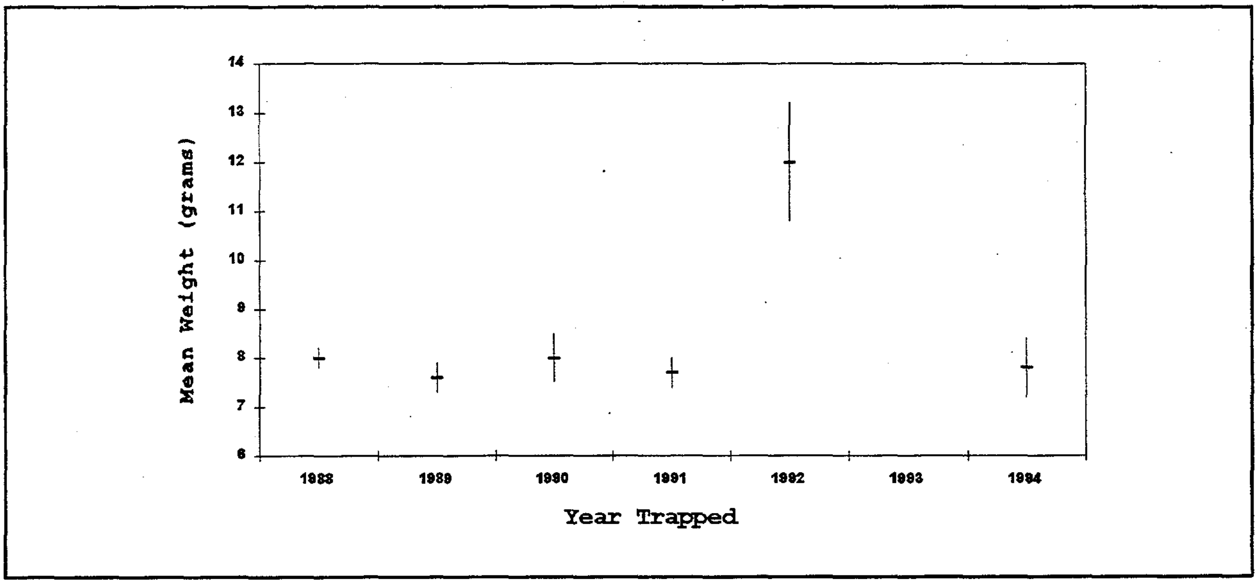

Figure 2-15. Trend in adult female *P. longimembris* mean weight at YUR001 from 1988 through 1994.

Frenchman Flat (FRF001)

Precipatation and annual plant germination and growth were excellent in Frenchman Flat in 1993 (Hunter 1994d) and, çonsequently, in 1994 the number of adult kangaroo rats was the highest ever at this site (Table 2-4). In contrast, 1994 winter precipitation was less than the 26-year average and germination growth of ephemeral plants was less than the previous two years (Hunter 1995) while animal numbers at this site were relatively high. The 1993 winter precipitation and plant values are barometers of 1994 spring animal densities as the adult rodent population in spring is a reflection of the reproduction and survival of animals from the previous summer. Trap success in spring 1994 was 28%, higher than spring 1988 (17%) and 1991 (5%), but similar to summer 1987 (26%). While these values appeared to correspond to the pattern of winter rainfall in Frenchman Flat over the same time frame (Figure 2-16) there was no significant correlation to winter rainfall from the previous year ($r^2 = 0.886$, $N = 4$, $F_{1,2} = 7/341$, $P = 0.114$) .

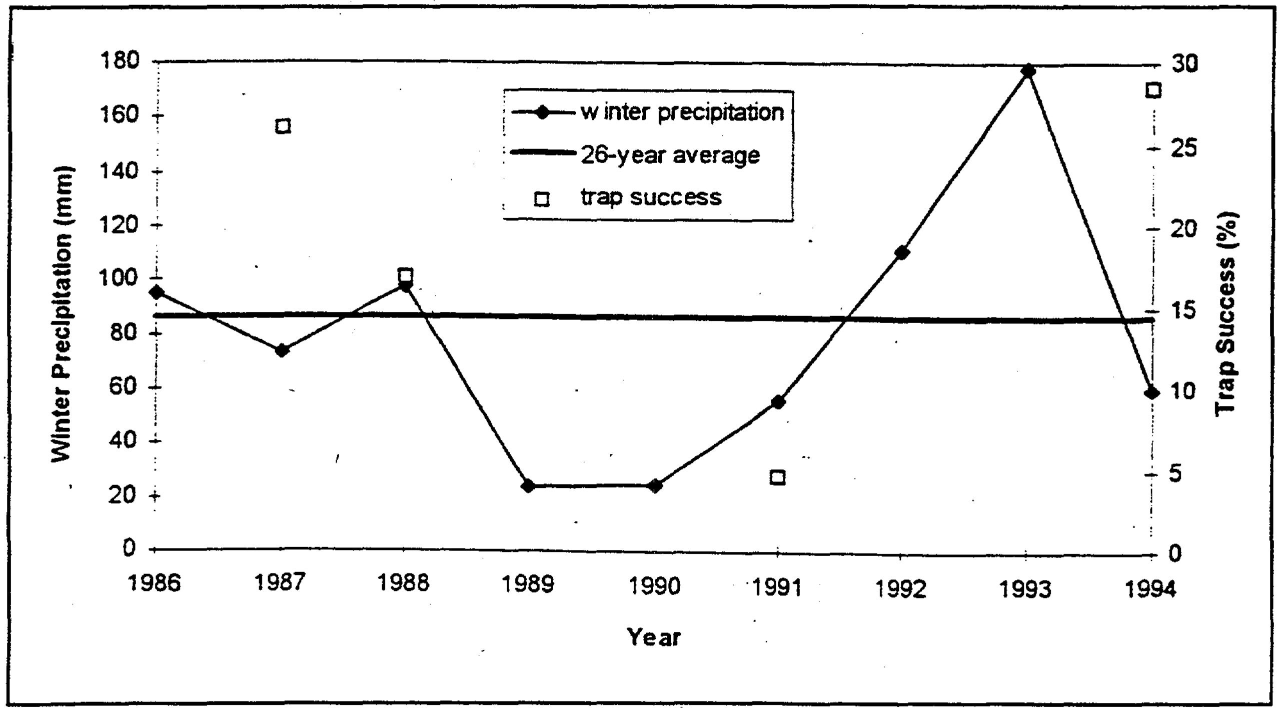

Figure 2-16. Winter precipitation and trap success by year at the Frenchman Flat baseline site.

Table 2-4. Estimated density and species diversity of small mammals captured on the Frenchman Flat baseline site (FRF001).				
	1987 7-9 July	1988 12-14 April	1991 30 April-2 May	1994 10-12 May
CHAFOR	--	--	* (1)	3.2±0.3 (10)
DIPMER	11.4±0.8 (36)	4.9±0 (16)	4.3±0 (14)	16.8±0.5 (54)
PERLON	26.6±2.9 (77)	24.2±4.0 (64)	* (2)	25.6±5.8 (61)
ONYTOR	* (3)	* (1)	---	* (1)
AMMLEU	* (4)	* (1)	---	---
SPETER	* (1)	---	---	---
Totals	37.4 (121)	25.3 (82)	5.3 (17)	38.9 (126)
Species	5	4	3	4
H′	0.3875	0.2204	0.2512	0.4142

The density of *Dipodomys merriami* was more than twice as high in the summer of 1987 than in the spring of 1988. This was due to the large number of juveniles in the 1987 population. There was no appreciable decline in numbers from 1988 to 1991 although the intervening years had lower than average rainfall and negligible amounts of ephemeral vegetation (Hunter 1994a). *Perognathus longimembris* appeared to be more sensitive to the drought conditions as this species experienced a marked decline from 1988 to 1991, returning to 1988 numbers in 1994 (Table 2-4).

Species diversity at the FRF001 plot was higher in 1994 than in any other year and significantly greater than 1988 ($t_{138} = 4.311$, $P < 0.001$). This was likely due to the appearance of *Chaetodipus formosus*.

The percent of total captures shifted significantly between years (Table 2-5), with *P. longimembris* the most common rodent in 1987 and 1988, *D. merriami* the most common in 1991, and these two species co-dominant in 1994. Sex ratios of the most common species did not differ from 1:1 in any year with the exception of *C. formosus*; one male and nine females were captured in 1994 (Table 2-6).

Table 2-5. Distribution of species captured by percent of total on the FRF001 plot in 1987, 1988, 1991, and 1994.

SPECIES	1987	1988	1991	1994
CHAFOR	---	---	5.9	7.9
DIPMER	29.8	14.5	82.3	42.9
PERLON	63.6	78.1	11.8	48.4
ONYTOR	2.5	1.2	---	0.8
AMMLEU	3.3	1.2	---	---
SPETER	0.8	---	---	---
TOTALS	100.0	100.0	100.0	100.0

Table 2-6. Sex ratio (♂/♀) of small mammals captured on the FRF001 plot in 1987, 1988, 1991, and 1994.

SPECIES	1987	1988	1991	1994
CHAFOR	---	---	1/0	1/9
DIPMER	15/21	9/7	6/8	29/25
PERLON	39/38	25/39	1/1	32/29
ONYTOR	2/1	0/1	---	0/1
AMMLEU	2/2	1/0	---	---
SPETER	0/1	---	---	---
TOTALS	58/63	35/47	8/9	62/64

The mean weight of adult *D. merriami* (Figures 2-17 and 2-18) were significantly lower in 1994 than in 1988 and 1991 (females: $F_{2,37} = 5.623$, $P = 0.007$; males: $F_{2,41} = 48.07$, $P < 0.0001$). However, there was no difference between sexes in any year.

The mean adult weights of *P. longimembris* (Figures 2-19 and 2-20) did not differ between years for females ($F_{2,66} = 2.85$, $P = 0.065$). Males, however, weighed significantly less in 1994 ($F_{2,55} = 4.82$, $P = 0.012$). No trend can be described with sampling at three-year intervals.

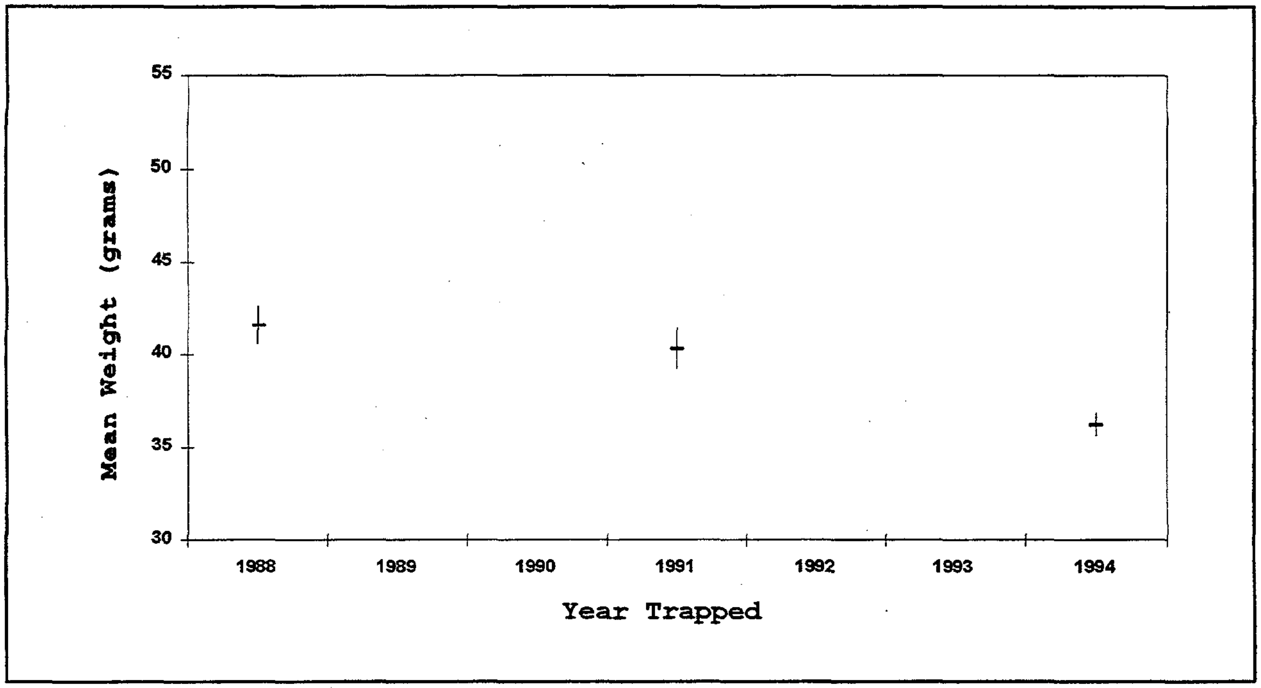

Figure 2-17. Trend in adult male *D. merriami* mean weight at FRF001.

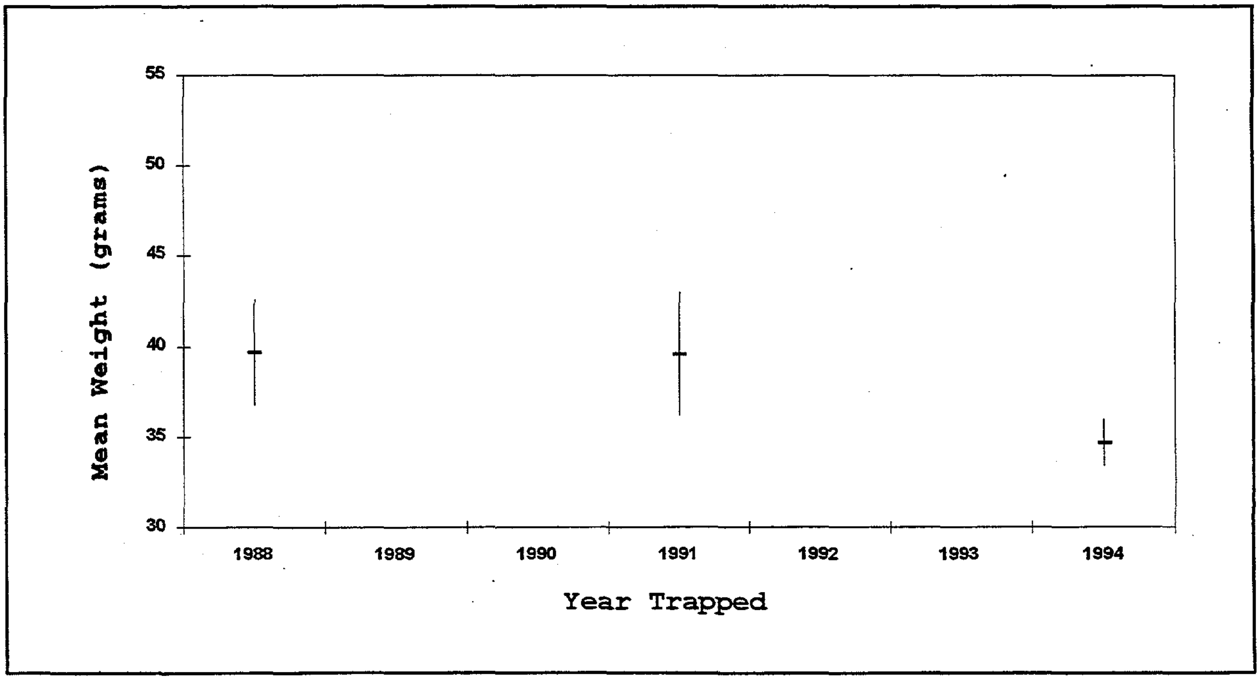

Figure 2-18. Trend in adult female *D. merriami* mean weight at FRF001.

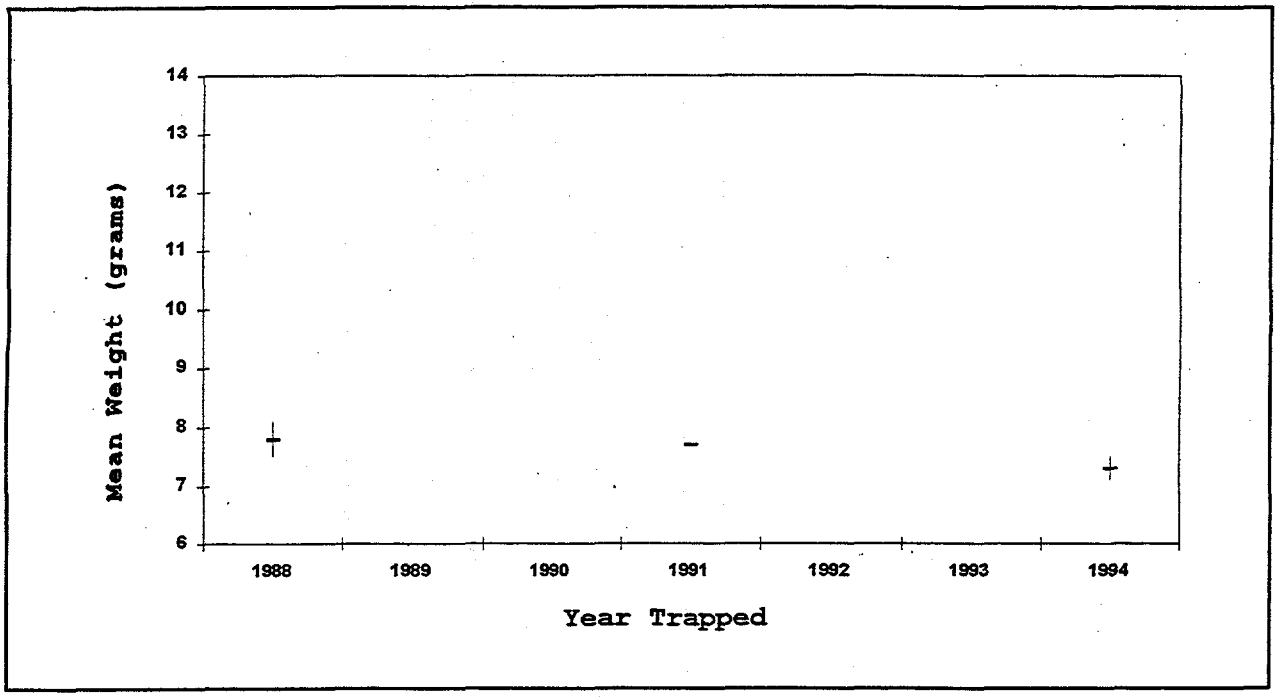

Figure 2-19. Trend in adult male *P. longimembris* mean weight at FRF001.

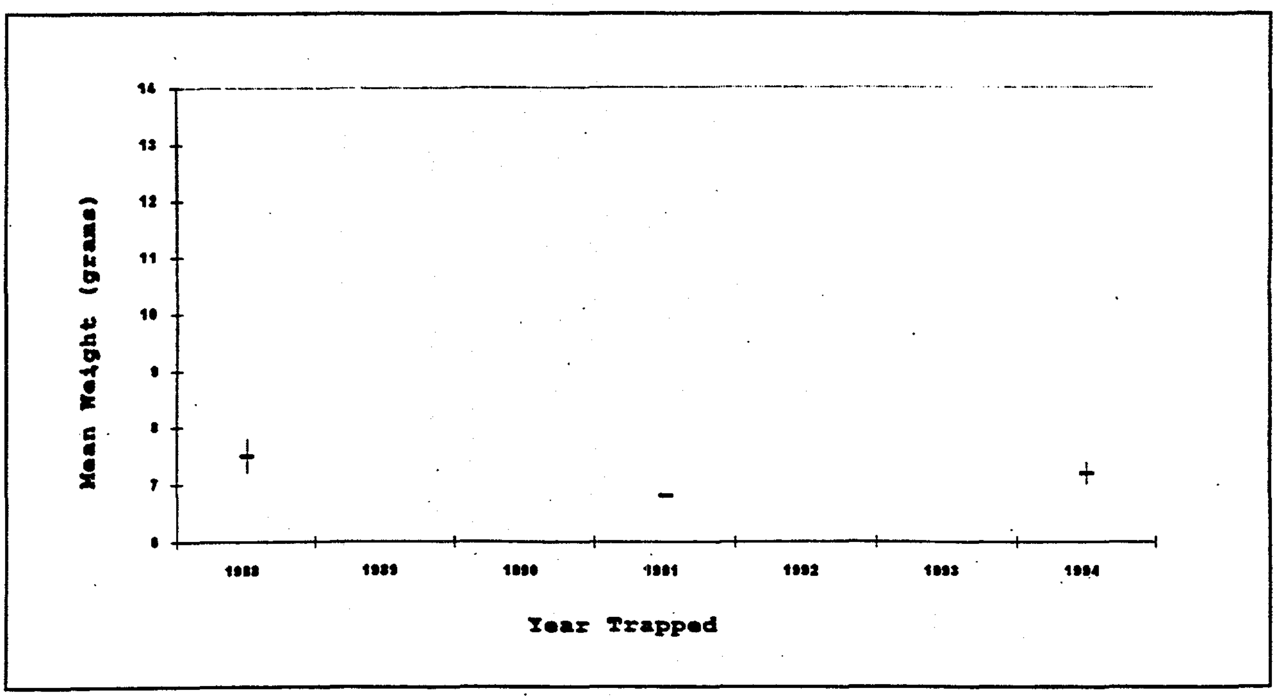

Figure 2-20. Trend inadult female *P. longimembris* mean weight at FRF001.

DISTURBED SITES

Blast Areas

T1 Blast and Control (YUF009 and YUF010)

Trap success was higher on the control than on the blast area in 1988 (26% and 20%), 1991 (12% and 9%), and 1994 (43% and 37%). Estimated densities of *Dipodomys merriami* doubled on both the control and T1 blast site from 1988 to 1994 while that of *D. microps* increased by nearly six times on the control and was captured for the first time on the blast area plot (Table 2-7). *Perognathus longimembris* decreased on the control by nearly a factor of six and all but disappeared on the blast plot. Species diversity was higher on the control in all three years and significantly higher in 1991 ($t_{40} = 2.828$, $P = 0.00729$) and 1994 ($t_{142} = 4.958$, $P < 0.0001$).

Table 2-7. Estimated density and species diversity of small mammals captured on the T1 blast area and control.

	Blast (YUF009)			Control (YUF010)		
	16-18 May 1988	14-16 May 1991	24-26 May 1994	16-18 May 1988	14-16 May 1991	24-26 May 1994
CHAFOR	* (1)	---	---	---	---	---
DIPMER	19.6±2.0 (27)	12.9±2.3 (17)	41.6±3.0 (57)	14.8±4.8 (17)	10.5±0.4 (15)	27.3±0.8 (39)
DIPMIC	---	---	6.9±0 (10)	3.9±1.5 (5)	* (1)	20.7±1.5 (29)
PERLON	5.0±0.6 (7)	* (1)	* (1)	27.3±2.1 (38)	4.5±2.7 (5)	7.6±5.5 (7)
ONYTOR	* (1)	---	---	* (3)	* (1)	* (1)
PERMAN	* (4)	* (1)	---	---	---	---
REIMEG	---	---	---	* (4)	---	* (3)
AMMLEU	---	---	---	* (3)	---	---
THOBOT	* (1)	---	---	---	---	---
N/ha (N)	28.5 (41)	12.5 (18)	47.2 (68)	48.6 (70)	15.3 (22)	54.9 (79)
Species	6	2	3	6	4	5
H′	0.4672	0.0932	0.2136	0.5635	0.3817	0.4823

Dipodomys merriami comprised a majority of the captured population on the blast area in all three years. The most common rodent captured on the control, however, was not consistent between years (Table 2-8). In 1988, *P. longimembris* made up over 50% of the captures and decreased to less than 10% in 1994. Less than 25% of the individuals in 1988 were *D. merriami* and this species was by far the most common in 1991. In 1994, both of the kangaroo rats were abundant.

Table 2-8. Distribution of species by percent of total individuals captured at T1 blast and control areas.

SPECIES	Blast (YUF009)			Control (YUF010)		
	1988	1991	1994	1988	1991	1994
CHAFOR	2.4	---	---	---	---	---
DIPMER	65.9	94.4	83.8	24.3	68.2	49.4
DIPMIC	---	---	14.7	7.1	4.6	36.7
PERLON	17.1	---	1.5	54.3	22.7	8.9
ONYTOR	2.4	---	---	4.3	4.6	1.3
PERMAN	9.8	5.6	---	---	---	---
REIMEG	---	---	---	5.7	---	3.8
AMMLEU	---	---	---	4.3	---	---
THOBOT	2.4	---	---	---	---	---
TOTALS	100.0	100.0	100.0	100.0	100.1	100.1

Sex ratios for each species captured did not significantly favor either sex in any year on these two sites. Mean weight for adult *D. merriami* in 1994 did not differ by site ($F_{1,92} = 0.03$, $P = 0.863$) or sex ($F_{1,92} = 1.43$, $P = 0.235$). The same was true for *D. microps* (site: $F_{1,36} = 1.21$, $P = 0.279$; sex: $F_{1,36} = 0.13$, $P = 0.722$). Total biomass was similar on both sites in 1994 (blast = 2586 g and control = 2948 g) with no significant difference between median values (blast = 40.0 g, control = 39.2 g; $t_{144} = 0.575$, $P = 0.566$).

Table 2-9. Sex ratio (♂/♀) of small mammals on T1 blast and control.						
SPECIES	Blast (YUF009)			Control (YUF010)		
	1988	1991	1994	1988	1991	1994
CHAFOR	1/0	---	---	---	---	---
DIPMER	17/10	8/9	25/32	11/6	10/5	16/23
DIPMIC	----	---	6/4	4/1	1/0	19/10
PERLON	5/2	---	0/1	17/21	3/2	6/1
ONYTOR	0/1	---	---	2/1	0/1	1/0
PERMAN	1/3	0/1	---	---	---	---
REIMEG	---	---	---	2/2	---	0/3
AMMLEU	---	---	---	3/0	---	---
THOBOT	0/1	---	---	---	---	---
TOTALS	24/16	8/10	31/37	39/31	14/8	42/37

T4 Blast and Control (YUF025 and YUF016)

Trap success was slightly higher on the control (10%) than on the blast (7%) in 1990, but relatively the same in 1994 (blast = 44%, control = 45%). Both sites had about the same number of individuals captured in each year, however, the control site had more variety of species captured in both years. Species diversity (Table 2-10) was significantly higher on the control in both years (1990: $t_{17} = 5.842$, $P < 0.0001$; 1994: $t_{149} = 6.289$, $P < 0.0001$). *Dipodomys microps* was captured only on the control in 1990 and on both sites in 1994. *D. microps* and *Perognathus longimembris* increased on the control in 1994.

The distribution of species captured (Table 2-11) was similar between years for each plot except that *D. microps* was captured for the first time on the blast area and comprised 6.5% of the individuals captured. There was also an increase in the percentage of *D. microps* and *P. longimembris* captured on the control.

Table 2-10. Estimated density and species diversity of small mammals captured on the T4 GZ site and control in 1990 and 1994.

SPECIES	Blast (YUF025)		Control (YUF026)	
	1990	1994	1990	1994
CHAFOR	---	---	---	* (1)
DIPMER	7.2±1.1 (10)	57.8±7.2 (72)	7.8±0.7 (11)	36.6±3.6 (49)
DIPMIC	---	3.5±0 (5)	* (1)	11.5±9.2 (9)
PERLON	---	---	* (2)	12.5±0 (18)
ONYTOR	---	---	* (1)	---
AMMLEU	---	---	---	* (1)
N/ha (N)	6.9 (10)	53.5 (77)	10.4 (15)	54.2 (78)
Species	1	2	4	5
H′	0	0.1044	0.3723	0.4305

Table 2-11. Distribution of species captured by percent of total individuals at T4 GZ and control in 1990 and 1994.

SPECIES	Blast (YUF025)		Control (YUF026)	
	1990	1994	1990	1994
CHAFOR	---	---	---	1.3
DIPMER	100.0	93.5	73.3	62.8
DIPMIC	---	6.5	6.7	11.5
PERLON	---	---	13.3	23.1
ONYTOR	---	---	6.7	---
AMMLEU	---	---	---	1.3
TOTAL	100.0	100.0	100.0	100.0

Sex ratios could not be statistically tested in 1990 due to inadequate sample size (Table 2-12). In 1994, males were not significantly more numerous than females on either plot (blast: x^2 = 1.0519, P = 0.305; control: x^2 = 1.2821, P = 0.258).

Table 2-12. Sex ratio (♂/♀) of small mammals on T4 blast and control.				
SPECIES	Blast (YUF025)		Control (YUF026)	
	1990	1994	1990	1994
CHAFOR	---	---	---	1/0
DIPMER	6/4	39/33	6/5	27/22
DIPMIC	---	4/1	0/1	4/5
PERLON	---	---	1/1	11/7
ONYTOR	---	---	0/1	---
AMMLEU	---	---	---	1/0
TOTAL	6/4	43/34	7/8	44/34

The mean weight of adult *D. merriami* at T4 blast varied significantly between years ($F_{1,51}$ = 9.57, P = 0.003) and sex ($F_{1,51}$ = 8.61, P = 0.005). On the control area adult mean weight was also significant for year ($F_{1,23}$ = 6.94, P = 0.015) and sex ($F_{1,23}$ = 5.32, P = 0.030). Total biomass increased on both sites from 1990 (from 396 g to 2790 g on the blast and from 538 g to 2458 g on the control). There was, however, no significant shift in the median values between years at each site (41.0 to 38.0 g on the blast, t_{85} = 1.494, P = 0.727; 39.5 to 37.3 g on the control, t_{92} = 0.259, P = 0.706).

T2 Blast and Control (YUF014 and YUF015)

Trap success was higher on the control in both 1990 (21%) and 1994 (40%) than on the blast area (6% in 1990 and 23% in 1994). Density in 1990 (Table 2-13) was poor at both sites due to severe drought conditions and there was no significant difference in species diversity between blast and control in 1990 (t_{36} = 0.913, P = 0.367). This was not so in 1982-83 nor in 1994 when the control areas had significantly higher diversity than the blast sites (1982-83: t_{120} = 2.463, P = 0.0152; 1994: t_{134} = 5.477, P <0.0001).

Table 2-13. Estimated density and species diversity at T2 blast area, July 1982-May 1983, June 1990, and June 1994.

	Blast (YUF014)			Control (YUF015)		
	T2-3a	YUF014		T2-5a	YUF015	
	457 m E	400 m E		1525 m	1650 m E	
	1982-83[a]	1990	1994	1982-83[a]	1990	1994
CHAFOR	(1)	* (2)	---	(1)	---	---
DIPMER	(40)	7.1±2.1 (9)	38.5±2.0 (59)	(21)	22.5±2.1 (31)	33.3±1.6 (47)
DIPMIC	---	---	---	(6)	---	10.3±1.7 (14)
PERLON	(8)	---	---	(16)	* (1)	10.4±6.2 (10)
NEOLEP	(1)	---	---	---	---	---
ONYTOR	(1)	---	---	(7)	* (1)	---
PERCRI	(1)	---	---	---	* (1)	---
PERERE	(1)	---	---	---	---	---
PERMAN	(32)	---	* (1)	(10)	---	---
AMMLEU	(1)	* (2)	* (5)	(12)	* (2)	7.6±7.6 (6)
N/ha (N)	(83)	9.0 (13)	45.1 (65)	(73)	25.0 (36)	53.5 (77)
Species	9	3	3	7	5	4
H'	0.5246	0.3607	0.1518	0.7597	0.2254	0.4670

[a]Data from O'Farrell and Sauls 1987.

A significant change from 1982-83 was the shift away from *P. maniculatus/D. merriami* co-dominance at T2-3 (Table 2-14). *P. maniculatus* made up a significant portion of the individuals at T2-5 as well. These two sites were dominated by *D. merriami* captures in 1990 and 1994.

Table 2-14. Distribution of species by percent of total individuals captured at T2 blast area

	Blast (YUF014)			Control (YUF015)		
	T2-3a	YUF014		T2-5a	YUF015	
	457 m E	400 m E		1525 m E	1650 m E	
	1982-83[a]	1990	1994	1982-83[a]	1990	1994
CHAFOR	1.2	15.4	---	1.4	---	---
DIPMER	48.2	69.2	90.8	28.8	86.1	61.0
DIPMIC	---	---	---	8.2	---	18.2
PERLON	6.0	---	---	21.9	2.8	13.0
NEOLEP	1.2	---	---	---	---	---
ONYTOR	1.2	---	---	9.6	2.8	---
PERCRI	1.2	---	---	---	2.8	---
PERERE	1.2	---	---	---	---	---
PERMAN	38.6	---	1.5	13.7	---	---
AMMLEU	1.2	15.4	7.7	16.4	5.6	7.8
Totals	100.0	100.0	100.0	100.0	100.1	100.0

[a]Data from O'Farrell and Sauls 1987.

Although nearly twice as many female *D. merriami* were captured on the T2 control area in 1990 (Table 2-15), this was not significant (x^2 = 2.613, P = 0.106).

Table 2-15. Sex ratio (♂/♀) of small mammals at T2 blast area.				
	Blast (YUF014)		Control (YUF015)	
	400 m E		1650 m E	
	1990	1994	1990	1994
CHAFOR	2/0	---	---	---
DIPMER	7/2	30/29	11/20	23/24
DIPMIC	---	---	---	8/6
PERLON	---	---	1/0	5/5
ONYTOR	---	---	1/0	---
PERCRI	---	---	1/0	---
PERMAN	---	0/1	---	---
AMMLEU	1/0[a]	1/3[a]	0/2[a]	1/5
Totals	10/2	31/33	14/22	37/40

[a]One animal of undetermined sex not included.

Total biomass on the control in 1990 (1299 g) was three times as high as the total biomass on the blast area (483 g), but median values (blast = 40.8, control = 35.8) were not statistically different (t_{46} = 0.930, P = 0.357). Total captured biomass was considerably higher on both plots in 1994 (2511 g on blast and 2876 g on control), but median values were not significantly different (blast = 38.3 g, control = 38.8 g; t_{135} = 0.225, P = 0.807).

T3 Blast and Control (YUF013 and YUF014)

Trap success was higher on the control in 1988 (22%) and 1991 (7%) than on the blast area (9% in 1988 and 5% in 1991). However, in 1994, the blast had a higher trap success (43%) than the control (30%). Similar to the other blast sites, the dominant rodent on the T3 blast area for all three years was *Dipodomys merriami* (Table 2-16). This blast area also was the only one of the four sites where the total number of rodents captured on the disturbed area was greater than on the control. This is likely related to the large amount of ephemeral vegetation on the T3 blast area, which was nearly 4 times as great as on the control (Hunter 1995).

Species diversity (Table 2-16) was significantly higher on the control site in all three years (1988: t_{23} = 3.603, P = 0.0233; 1991: t_{12} = 5.620, P = 0.000113; 1994: t_{141} = 3.189, P = 0.00176). This was consistent with results from the other three blast sites.

Table 2-16. Estimated density and species diversity of small mammals at T3.

	Blast (YUF013)			Control (YUF012)		
	1988	1991	1994	1988	1991	1994
DIPME	8.5±1.0	5.7±0	43.2±1.4	10.8±0	4.4±0	27.3±1.5
DIPMIC	---	---	5.3±0.8 (8)	4.1±1.1	* (1)	7.2±0.9
PERLO	* (1)	---	---	12.6±1.7	2.5±0	* (3)
NEOLE	---	---	* (1)	---	---	---
ONYTO	---	---	---	* (1)	---	---
PERMA	---	---	---	* (2)	---	---
AMMLE	* (2)	---	* (2)	10.8±12.1	---	8.8±7.0 (8)
N/ha	10.2 (16)	5.7 (9)	49.5 (78)	33.0 (52)	7.6 (12)	40.6 (64)
Species	3	1	4	6	3	4
H'	0.2614	0	0.2232	0.6217	0.3855	0.4267

The percentage of *D. merriami* on the control increased since 1988, while the percentage of P. longimembris decreased so that these two species were no longer co-dominant at the control plot in 1994 (Table 2-17). *D. microps* increased on the control and, like T1 and T4, was captured for the first time on the blast site.

Table 2-17. Distribution of species by percent of total individuals captured on the T3 blast

	Blast (YUF013)			Control (YUF012)		
	1988	1991	1994	1988	1991	1994
DIPMER	81.3	100.0	85.9	34.6	58.3	65.6
DIPMIC	---	---	10.3	9.6	8.3	17.2
PERLON	6.3	---	---	36.5	33.3	4.7
NEOLEP	---	---	1.3	---	---	---
ONYTOR	---	---	---	1.9	---	---
PERMAN	---	---	---	3.8	---	---
AMMLEU	12.5	---	2.6	13.5	---	12.5
TOTALS	100.1	100.0	100.1	99.9	99.9	100.0

The sex ratio of *D. merriami* (Table 2-18) did not significantly favor females on the blast in 1994 (x^2 = 3.358, P = 0.0669). Total biomass in 1994 was higher on the blast (3140 g) than on the control (2758 g), but median values were not different (t_{138} = 0.874, P = 0.383). In 1988, total biomass was nearly three times higher on the control (1687 g and 639 g) and the median values (blast = 41.0 g, control = 23.0 g) were significantly different (t_{64} = 2.940, P = 0.00456). In 1991, the two sites were similar (385 g on control and 380 g on blast) and medians (blast = 42.3 g, control = 39.3 g) were not significantly different (t_{21} = 0.108, P = 0.915). The total biomass was the highest at both sites in 1994 (blast = 3140 g, control = 2758) and again, medians (blast = 38.0 g, control = 39.0 g) were not significantly different (t_{138}, = 0.874, P = 0.383).

Table 2-18. Sex ratio (♂/♀) of small mammals on T3 blast area and control.						
SPECIES	Blast (YUF013)			Control (YUF012)		
	1988	1991	1994	1988	1991	1994
DIPMER	8/5	7/2	26/41	9/9	4/3	21/21
DIPMIC	---	---	5/3	2/3	1/0	4/7
PERLON	1/0	---	---	8/11	3/1	2/1
NEOLEP	---	---	1/0	---	---	---
ONYTOR	---	---	---	1/0	---	---
PERMAN	---	---	---	0/2	---	---
AMMLEU	2/0	---	0/2	3/4	---	5/2[a]
TOTALS	11/5	7/2	32/46	23/29	8/4	32/31

[a]One animal of undetermined sex not included.

Sedan Crater Site (YUF016, YUF017, and YUF018)

The area closest to GZ on the 16A line was disturbed before the 1962 event, so pre-test vegetation was not uniform along the line. Consequently, rodent assemblages also varied pre-test. *Perognathus longimembris* was the most common species captured before and immediately after the test on all sites (Jorgensen et al. 1963). Pre-test estimated densities for this species ranged from 5.7 animals per hectare at 610 m up to 29.7/ha at 1524 m from GZ. Another pocket mouse, *Perognathus parvus*, comprised a large portion of the pre-test heteromyid community within 1000 m and disappeared from all plots post-test except for the 1524 m site. *Dipodomys microps* was prevalent outside 1500 m, while *D. merriami* was absent pre- and post-test from the two plots farthest from GZ (Jorgensen et al. 1963). BYU reported densities for only these four species.

In 1988, trap success was similar at the three sites (457 m = 19%, 1067 m = 21%, 1600 m = 19%). In 1991, the 1067 m site had a higher trap success (23%) than the 457 m (15%) and 1600 m (13%) sites. The trap success continued to show no coherent pattern in 1994 when the two closest plots (457 m = 47% and 1067 m = 48%) had higher trap successes than the farthest plot (1067 m = 33%).

During the BECAMP censuses, density of *D. merriami* (Table 2-19) was inversely related to distance from GZ except in 1991, when more were captured on the 1067 m plot (YUF017) than the close-in plot (YUF016) and also during 1982-1983, when this species was captured uniformly at traplines greater than 1000 m from GZ and absent at two of the three traplines within 1000 m (O'Farrell and Sauls, 1987).

Numbers of *Perognathus longimembris* were also consistent between lines during 1982-83 trapping. However, in 1988, 1991, and 1994, this species was absent from the plot closest to GZ. During BECAMP trapping, *D. microps* densities increased with distance from GZ and this same general pattern occurred during trapping by NAEG (O'Farrell and Sauls 1987).

Species diversity increased with distance from GZ and appeared to be positively correlated with perennial shrub cover, biomass, and total volume (Figure 2-21). Perennial plant parameters appeared to correspond to increasing distance from GZ. Species diversity was significantly different between distances from GZ in 1982-83 ($F_{1,7}$ = 32.315, $P < 0.0001$) but did not show any pattern with increasing distance from GZ in 1982-83 ($F_{1,7}$ = 0.456, $P = 0.705$). Species diversity is apparently a function of perennial plants, while numbers of animals captured is governed by the available ephemeral vegetation.

The percentage of *Dipodomys merriami* captured on the BECAMP plot closest to GZ (YUF016) did not change appreciably between the three years (Figure 2-22). There was, however, a 22% decrease in the percentage of *D. merriami* captured from 1991 to 1994 on the middle plot (YUF001). The percentages of this species on the undisturbed plot (YUF018) increased by 44% from 1988 to 1991 and then decreased by 41% from 1991 to 1994. The changes on YUF018 reflected a decrease in *Perognathus longimembris* and an increase in *D. microps* at this site.

Table 2-19. Estimated density and species diversity of small mammals on the Sedan plots. Shaded portion is not included in totals.

	YUF016			YUF017			YUF018		
	1988	1991	1994	1988	1991	1994	1988	1991	1994
CHAFOR	* (1)	---	---	---	---	---	---	---	---
DIPMER	23.7±2.6 (32)	17.1±1.3 (24)	52.6±2.9 (73)	20.0±0 (29)	27.7±2.4 (38)	38.7±1.4 (55)	10.8±1.2 (15)	10.4±0 (15)	11.8±0 (17)
DIPMIC	---	* (1)	4.9±0 (7)	---	* (2)	14.0±0.6 (20)	5.8±0.9 (8)	2.8±0 (4)	20.3±0.7 (29)
PERLON	---	---	---	---	* (1)	* (4)	4.3±0.7 (6)	4.5±2.7 (5)	* (2)
NEOLEP	---	---	---	---	---	---	---	* (1)	---
ONYTOR	---	---	---	* (1)	---	---	* (4)	* (1)	---
PERMAN	---	---	---	---	---	---	---	* (1)	* (3)
AMMLEU	* (1)	---	---	* (2)	* (2)	* (1)	4.2±0 (6)	---	* (1)
SYLAUD	---	---	---	* (1)	---	* (1)	* (1)	---	---
N/ha (N)	23.6 (34)	17.4 (25)	55.6 (80)	22.9 (32)	29.9 (43)	55.6 (80)	27.8 (39)	18.8 (27)	36.1 (52)
Species	3	2	2	2	4	4	5	6	5
H′	0.1149	0.0729	0.1289	0.1610	0.2094	0.3512	0.6523	0.5482	0.4591

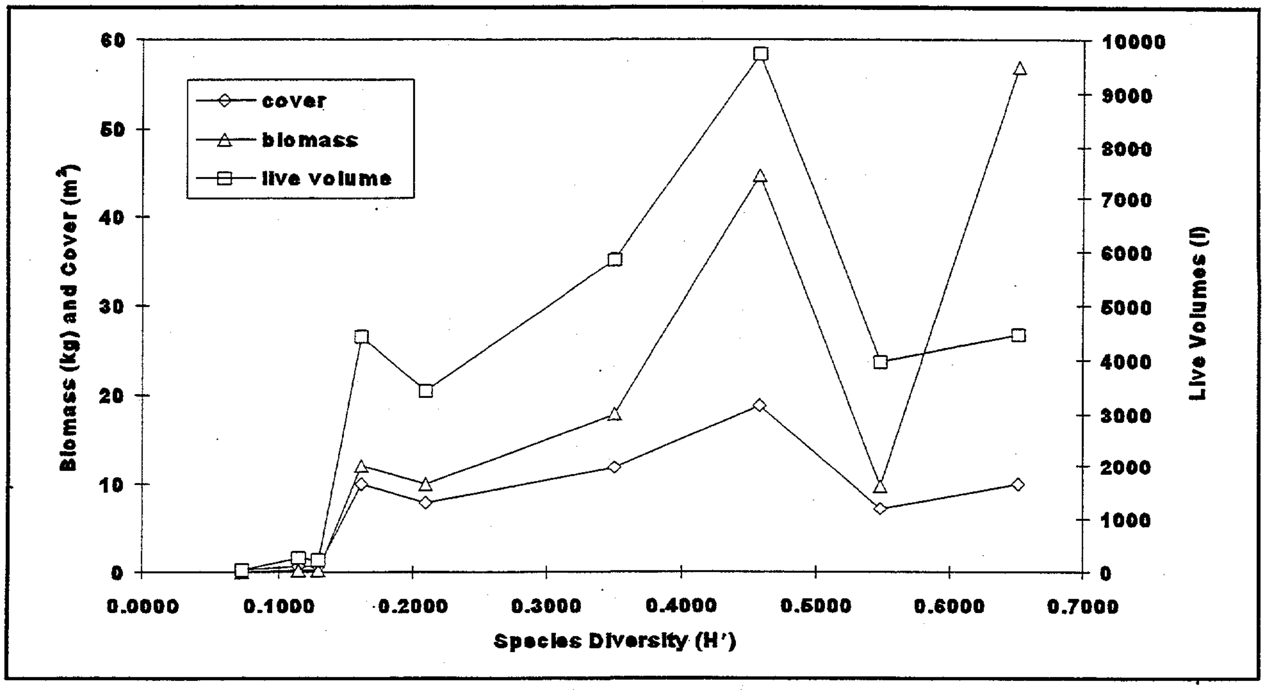

Figure 2-21. Relationship between perennial plant parameters (biomass, cover, and live volume) and small mammal species diversity at the Sedan study area in 1988, 1991, and 1994.

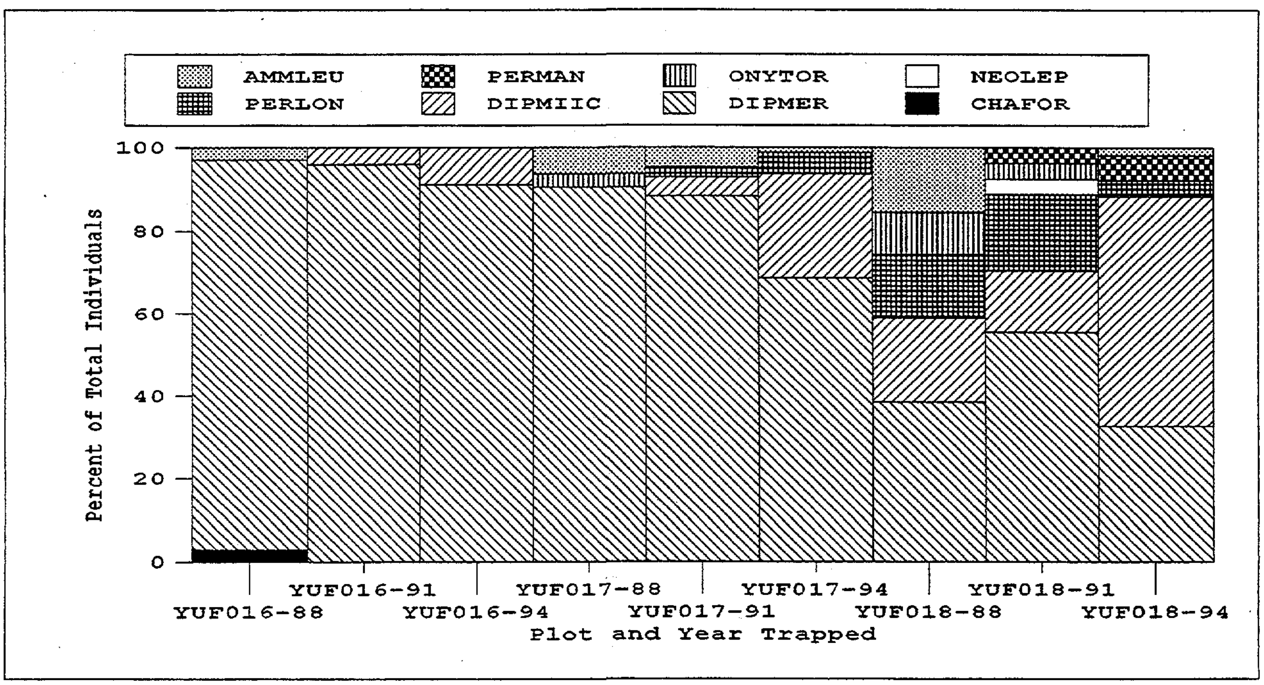

Figure 2-22. Distribution of species captured at Sedan by plot and year.

Several other species including *Peromyscus eremicus*, *P. crinitus*, *P. truei*, *Reithrodontomys megalotis*, and *Perognathus parvus* were captured by NAEG and have not been captured since (O'Farrell and Sauls 1987). A species not captured previously is the desert woodrat, *Neotoma lepida*, which was captured on the undisturbed area plot in 1991. Another change from earlier trapping involved *Peromyscus maniculatus*. This species comprised 24 to 58% of the individuals captured within 1000 m of GZ in 1982-1983. This coincided with the three lines where *Dipodomys merriami* was either absent or numbers were low. Between 1000 m and 2440 m (lines where *D. merriami* numbers were high), *P. maniculatus* accounted for 2.8 to 16.7% of the individuals captured.

The only plot which had a greater number of males captured was the undisturbed site, YUF018 (Table 2-20). Although the sex ratio on YUF018 in 1994 favored males (Table 2-20), this wa not significant ($x^2 = 3.769$, $P = 0.0522$).

Median biomass in 1994 on the control plot (total = 2467 g, median = 51.7) was significantly higher than either of the plots in the zone of disturbance (YUF016 total = 3080 g, median = 38.4 g; YUF017 total = 2467 g, median = 39.6 g) in 1994 ($F_{2,209} = 9.83$, $P < 0.0001$), but not in the other two years. Median biomass on the 457 m plot in 1988 was 39.2 g and in 1991 was 39.0 g, while on the 1067 plot median values were 37.7 g and 37.2 g, respectively. Median biomass on the 1600 m plot was similar (39.3 g in 1988 and 37.3 g in 1991).

Table 2-20. Sex ratio (♂/♀) of small mammals captured on the Sedan plots.

	YUF016			YUF017			YUF018		
	1988	1991	1994	1988	1991	1994	1988	1991	1994
CHAFOR	1/0	---	---	---	---	---	---	---	---
DIPMER	17/15	13/11	39/34	18/11	20/18	26/29	8/7	7/8	11/6
DIPMIC	---	0/1	4/3	---	2/0	8/12	5/3	1/3	18/11
PERLON	---	---	---	---	0/1	1/3	3/3	3/2	1/1
NEOLEP	---	---	---	---	---	---	---	0/1	---
ONYTOR	---	---	---	1/0	---	---	1/3	0/1	---
PERMAN	---	---	---	---	---	---	---	1/0	2/1
AMMLEU	0/1	---	---	0/1[a]	1/1	1/0	4/2	---	1/0
Total	18/16	13/12	43/37	19/12	23/20	36/44	21/18	12/15	33/19

[a]One animal of undetermined sex not included.

Rock Valley Fenced Area and Control (ROV008 and ROV007)

Winter precipitation in Rock Valley preceding the 1972 and 1991 trapping was lower than most other years (Figure 2-23) and coincided with lower numbers of small mammal captures in those two years (Table 2-21). Very few animals were captured at either site in 1991 due to the drought. Total number of animals captured on IBP plot 16 in June 1994 was comparable to April 1973.

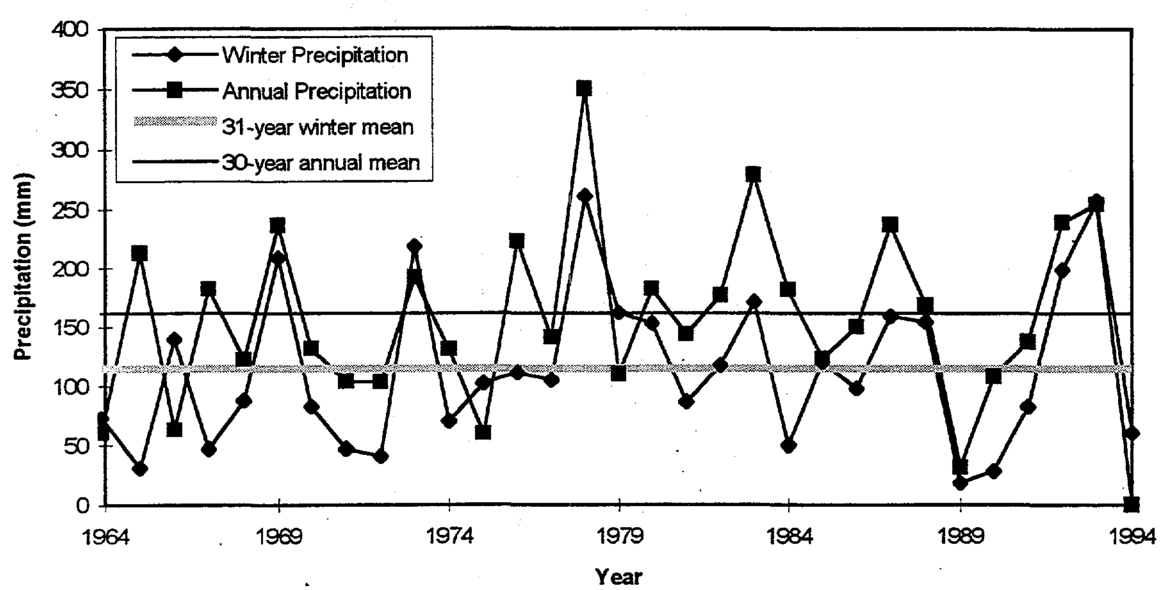

Figure 2-23. Annual (January through December) and winter (September through March) precipitation in Rock Valley, 1964-1994.

In 1972 and 1973, *Perognathus longimembris* was by far the most common rodent at this site. This species, along with *Dipodomys microps*, made up a large proportion of the captured population in 1988. However, in 1994, *Dipodomys merriami* and *D. microps* were most common (Table 2-21). *Chaetodipus formosus* was also common in 1972-73 on IBP plot 16.

In the fenced area, the habitat is too rocky for *P. longimembris*. Instead, kangaroo rats and the long-tailed pocket mouse were most abundant: *D. microps* in 1988, *C. formosus* in 1991, and *D. merriami* in 1994 (Figure 2-24). French et al. 1974 noted that kangaroo rats died out after five years inside of another, nonirradiated fenced area and persisted at very low numbers in a third plot, indicating that the fence rather than the radiation may be the cause of the population decline.

Table 2-21. Estimated density and species diversity of small mammals at the Rock Valley plots. Shaded portion was not included in totals.

	Unfenced Area - IBP Plot 16 (ROV007)						Fenced Area (ROV008)		
	June 1972[a]	April 1973[b]	August 1973[b]	June 1988	June 1991	June 1994	June 1988	June 1991	June 1994
CHAFOR	12.0 (39)	1.5 (5)	25.6 (83)	* (2)	* (2)	8.3±0.6 (6)	2.9±0.4 (9)	1.5±0 (5)	13.0±0.3 (42)
DIPMER	3.7 (12)	---	1.5 (5)	4.4±0.4 (14)	4.6±1.8 (12)	14.9±0.8 (47)	1.9±0 (6)	* (1)	31.8±1.0 (101)
DIPMIC	4.6 (15)	7.4 (24)	5.6 (18)	11.8±0.4 (38)	* (1)	10.5±0.8 (33)	26.4±0.5 (85)	* (1)	16.1±0.7 (51)
PERLON	34.9 (113)	15.1 (49)	50.3 (163)	10.4±0.7 (33)	* (6)	* (3)	---	---	---
ONYTOR	1.5 (5)	1.9 (6)	16.2 (20)	3.1±0 (10)	---	* (1)	1.9±0 (6)	---	* (1)
PERCRI	0.6 (2)	0.3 (1)	0.3 (1)	---	---	---	---	---	---
PERMAN	---	---	---	* (2)	---	---	---	---	---
AMMLEU	0.9 (3)	---	0.9 (3)	* (5)	* (3)	* (1)	* (7)	---	* (3)
THOBOT	---	1.9 (6)	2.5 (8)	---	---	---	---	---	---
MUSFRE	---	---	---	* (1)	---	---	* (1)	---	---
Other[c]	---	---	0.3 (1)	---	---	---	---	---	---
N/ha (N)	58.3 (189)	28.1 (91)	93.2 (302)	32.1 (104)	7.4 (24)	34.3 (111)	34.9 (113)	2.2 (7)	61.1 (198)
SPP	7	6	9	7	5	6	5	3	5
H'	0.5295	0.5439	0.5574	0.6624	0.5757	0.5415	0.3908	0.3458	0.4829

[a]Density calculated from Turner 1973.
[b]Density calculated from Turner and McBrayer 1974.
[c]Neotoma lepida or Spermophilus tereticaudus.

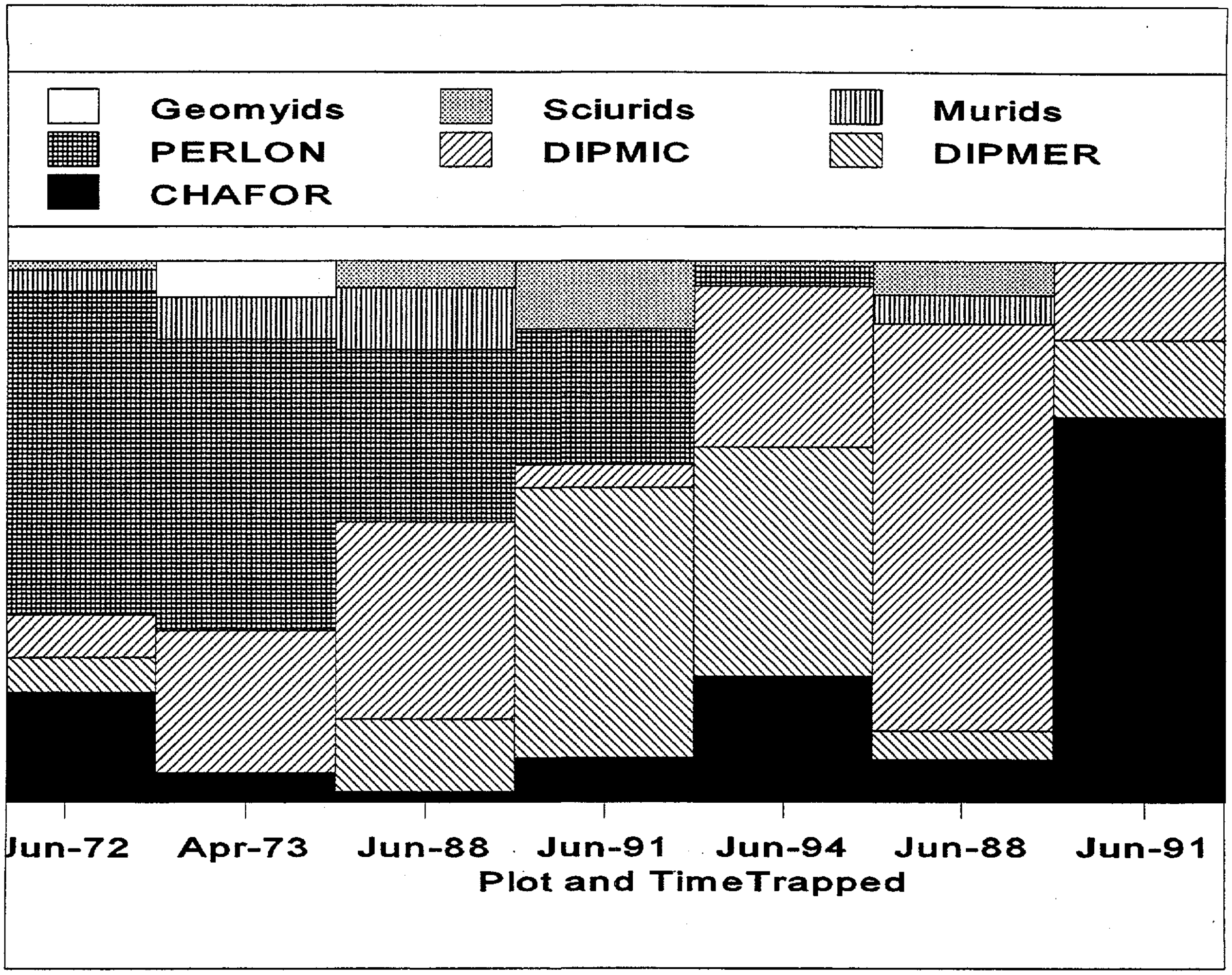

Figure 2-24. Distribution of species captured at the Rock Valley plots. Columns 1-5 are the control (plot 16) and 6-8 are fenced (plot B).

Sex ratios for the most common species did not differ from 1:1 in any year (Table 2-22). Total biomass in 1988 was 1.5 times higher on the fenced plot (5207 g) than on the unfenced area (3368 g) and the median was significantly higher (t_{211} = 3.173, P = 0.001732). The median weight on the unfenced area (36.5 g) was skewed toward the lighter weighing *P. longimembris* which was absent from the fenced area (median of 50.0 g). With the decrease in *D. microps* and *P. longimembris* in 1991, total biomass on both sites was actually higher on the unfenced site (678 g) than on the fenced plot (190 g), but median biomass was similar (unfenced = 22.0 g, fenced = 20.0 g). In 1994, the fenced area had the higher total biomass (7100 g compared to 4260 g) but, again, medians (unfenced = 38.0 g, fenced = 35.0 g) were not significantly different (t_{305} = 1.108, P = 0.269).

Table 2-22. Sex ratio (♂/♀) of small mammals on the Rock Valley plots.						
	Unfenced Area (ROV007)			Fenced Area (ROV008)		
	June 1988	June 1991	June 1994	June 1988	June 1991	June 1994
CHAFOR	0/2	1/1	12/14	4/4[a]	2/3	18/24
DIPMER	9/5	5/7	24/23	3/3	0/1	51/49a
DIPMIC	20/18	1/0	19/14	41/44	1/0	26/25
PERLON	19/14	3/3	1/2	---	---	---
ONYTOR	7/3	---	1/0	4/1[a]	---	0/1
PERMAN	1/1	---	---	---	---	---
AMMLEU	3/2	1/2	1/0	1/5[a]	---	1/2
Total	59/45	11/13	58/53	53/56	3/4	96/101

[a]One animal of undetermined sex not included.

Revegetation Site (YUF011)

The year 1988 was not a remarkable year for rodents on the cleared area. All eleven captures were within 30 m of the north and east edges of the plot. This coincided with the closest areas of remnant vegetation. Trap success on the revegetated area (6%) was nearly a fourth of that on the control (22%) in 1988. Number of rodents inhabiting the revegetated site was the same in 1991, except that rodents were captured near the center of the plot. Trap success was approximately twice as high on the control (7%) as on the revegetated site (3%) in that year. Several burrows indicated that rodents were residing in the revegetation area. The trap success in 1994 was actually higher on the revegetated area (37%) than on the control 30%).

The 1994 rodent community on the revegetated site was similar to the control. The most common species on the control area in 1988, *D. merriami* and *P. longimembris*, were not co-dominant on the cleared area (Table 2-23). Instead, *D. merriami* made up a large percentage of the captured population. *P. longimembris* was nearly absent from the revegetated area in 1994.

Table 2-23. Estimated density and species diversity of rodents on the Area 3 revegetation site.

	Revegetation (YUF011)			Control Area (YUF012)		
	1988	1991	1994	1988	1991	1994
DIPMER	5.2±0.5 (8)	5.1±3.1 (6)	33.8±1.2 (48)	10.8±0 (18)	4.4±0 (7)	27.3±1.5 (42)
DIPMIC	* (1)	---	8.3±0 (12)	4.1±1.1 (5)	* (1)	7.2±0.9 (11)
PERLON	* (2)	3.2±0.9 (4)	* (1)	12.6±1.7 (19)	2.5±0 (4)	* (3)
ONYTOR	---	---	* (1)	* (1)	---	---
PERMAN	---	---	---	* (2)	---	---
AMMLEU	---	---	* (3)	10.8±12.0 (7)	---	8.8±7.0 (8)
N/ha	7.0	6.4	40.6	33.0	7.6	40.6
Species	3	2	4	6	3	4
H'	0.3730	0.2923	0.3205	0.6217	0.3855	0.4267

Species diversity was significantly different between the two sites only in 1988 ($t_{15} = 2.350$, $P = 0.0324$). However, it was higher on the control in all three years (Table 2-24). The percentage of individuals captured was fairly consistent on the revegetated area over the three years for *D. merriami*, however, the 60 to 75% of the captured population made up by this species were similar to that on the control only in 1994.

Sex ratios for both sites did not differ from 1:1 in any year (Table 2-25). Total biomass on the two sites was also similar in 1994 (2613 g on YUF011 and 2758 g on YUF012) after being significantly higher on the control in 1988 ($t_{60} = 3.011$, $P = 0.00381$). Mean weight for adult *D. merriami* by sex were identical on both plots in 1994.

Table 2-24. Distribution of species captured as a percent of total individuals on the 3B revegetation site.

	Revegetation Site (YUF011)			Control (YUF012)		
	1988	1991	1994	1988	1991	1994
DIPMER	72.7	60.0	75.0	34.6	58.3	65.6
DIPMIC	9.1	---	18.8	9.6	8.3	17.2
PERLON	18.2	40.0	---	36.5	33.3	4.7
ONYTOR	---	---	1.6	1.9	---	---
PERMAN	---	---	---	3.8	---	---
AMMLEU	---	---	4.7	13.5	---	12.5
Totals	100.0	100.0	100.1	99.9	99.9	100.0

Table 2-25. Sex ratio (♂/♀) of small mammals on the 3B revegetation site and control.

	Revegetation Site (YUF011)			Control (YUF012)		
	1988	1991	1994	1988	1991	1994
DIPMER	4/4	4/2	27/21	9/9	4/3	21/21
DIPMIC	1/0	---	5/7	2/3	1/0	4/7
PERLON	0/2	1/3	---	8/11	3/1	2/1
ONYTOR	---	---	0/1	1/0	---	---
PERMAN	---	---	---	0/2	---	---
AMMLEU	---	---	2/1	3/4	---	5/2[a]
Totals	5/6	5/5	34/30	23/29	8/4	32/31

[a]One animal of undetermined sex not included.

Rodent-denuded Area (MER002 and MER003)

Although escape cover is limited, animal activity is high on this site. This may be due to the abundance of ephemeral vegetation. In the absence of competition from perennials, the annuals appeared to flourish. Trap success was higher on the control in 1988 (26%) than on the gopher site (11%), but higher on the gopher site in 1991 (36%) than on the control (22%). In 1994, trap success was similar on the two sites (gopher = 45%, control = 44%).

Species diversity (Table 2-26) was significantly higher on the control in all three years (1988: $t_{33} = 2.332$, $P = 0.0259$; 1991: $t_{99} = 6.756$, $P < 0.0001$; 1994: $t_{163} = 3.774$. $P = 0.000225$). However, overall density was higher on the disturbed area in 1991 and the same in 1994. *D. merriami* was the most abundant rodent on the denuded area in all three years (Table 2-26) and during the drought year of 1991, this species was relatively abundant. On the control area, *Chaetodipus formosus* was common in 1988 and 1991. *C. formosus* did not return to predrought density on the control site in 1994. *Perognathus longimembris* density appeared to remain relatively steady on the control in the three years trapped. While there was evidence of gopher activity on the site, no gophers were captured in the Sherman traps used.

Table 2-26. Estimated densities and species diversities of rodents captured on the rodent-denuded area.

	Denuded (MER002)			Control Area (MER003)		
	1988	1991	1994	1988	1991	1994
CHAFOR	---	* (1)	---	18.6±6.8 (20)	10.6±2.1 (14)	3.5±0 (5)
DIPMER	6.9±0 (10)	39.8±1.8 (56)	42.3±1.5 (60)	10.5±0.6 (15)	14.1±2.1 (19)	35.3±2.5 (49)
DIPMIC	4.5±1.2 (6)	* (3)	12.6±2.0 (17)	6.4±0.8 (9)	---	9.2±0.6 (13)
PERLON	---	---	* (2)	8.0±2.7 (10)	5.4±1.6 (7)	7.6±4.2 (8)
ONYTOR	* (2)	---	---	* (3)	* (2)	* (1)
AMMLEU	* (2)	---	* (2)	* (1)	* (1)	5.1±1.0 (7)
N/ha (N)	13.9 (20)	41.7 (60)	56.3 (81)	40.3 (58)	29.9 (43)	57.6 (83)
Species	4	3	4	6	5	6
H'	0.5074	0.1227	0.3182	0.6655	0.5443	0.5164

During the drought, *D. microps* decreased on both plots and *D. merriami* comprised a larger percentage of the captured population (Table 2-27). This continued into the 1994 captured population on both plots. Ground squirrels also were well represented in the captured population on the control.

Table 2-27. Distribution of species captured as a percent of total individuals on the denuded site and control.

	Denuded Site (MER002)			Control (MER003)		
	1988	1991	1994	1988	1991	1994
CHAFOR	---	1.7	---	34.5	32.6	6.0
DIPMER	50.0	93.3	74.1	25.9	44.2	59.0
DIPMIC	30.0	5.00	21.0	15.5	---	15.7
PERLON	---	---	2.5	17.2	16.3	9.6
ONYTOR	10.0	---	---	5.2	4.7	1.2
AMMLEU	10.0	---	2.5	1.7	2.3	8.4
Totals	100.0	100.0	100.1	100.0	100.1	99.9

The sex ratio for *D. merriami* (Table 2-28) significantly favored females on the denuded area in 1994 (x^2 = 4.267, P = 0.0389). There were no differences in the other two years or for any other species, although several more female than male *D. merriami* were captured on the control in 1994.

Total biomass was higher on the control in 1988 (1589 g, 903 g on MER002) and higher on the denuded area in 1991 (1950 g, 1113 g on MER003). Total biomass on the two plots was similar in 1994 (3480 g on MER002 and 3568 g on MER003). The median values were significantly different in 1988 (gopher = 45.7 g, control = 19.7 g; t_{76} = 4.017, P = 0.000137) and 1991 (gopher = 33.8 g, control = 23.5 g; t_{100} = 2.700, P = 0.00800), but not in 1994 (gopher = 40.7 g, control = 40.5 g; t_{160} = 0.104, P = 0.917).

Table 2-28. Sex ratio (♂/♀) of small mammals on the denuded site and control.						
	Denuded Site (MER002)			Control (MER003)		
	1988	1991	1994	1988	1991	1994
CHAFOR	---	0/1	---	10/10	8/6	2/3
DIPMER	5/5	29/27	22/38	8/7	10/9	20/29
DIPMIC	2/4	2/1	7/10	5/41	---	7/6
PERLON	---	---	1/1	5/5	2/5	3/4[a]
ONYTOR	1/1	---	---	2/1	1/1	0/1
AMMLEU	1/1	---	1/1	1/0	0/1	6/1
Totals	9/11	31/29	31/50	31/27	21/22	38/44

[a]One animal of undetermined sex not included.

PREVALENCE OF HANTAVIRUS ON THE NTS

Sites sampled for hantavirus and a summary of the results are shown in Table 2-29. The distribution of species sent for analysis from the area does not reflect the normal fauna of that area since *Peromyscus maniculatus* and related species were selectively sampled. A large number of kangaroo rats were captured at all sites except the Pahute Mesa site and only a few of these had blood samples taken. Not all blood samples sent to Reno were analyzed. *Peromyscus* species had highest priority for analysis since *P. maniculatus* was suspected to be the primary carrier.

Based on trapping results for the last eight years, deer mice are widespread. However, the abundance of *P. maniculatus* corresponds to elevation (Figure 2-25). Highest densities of *P. maniculatus* occur at middle to higher elevations where the dominant vegetation is pinyon pine. The zones of density roughly fall out in the pattern shown in Figure 2-26.

Sample size for this project was low due to the lower density of *Peromyscus* in 1994 after particularly high densities in 1993 (Figure 2-25). An example of this decrease is the Area 19 site, PAM007. This site was first trapped in 1993 as the control for a nearby bladed area. An area off of the plot was trapped later in 1993 and blood samples were drawn for hantavirus analysis.

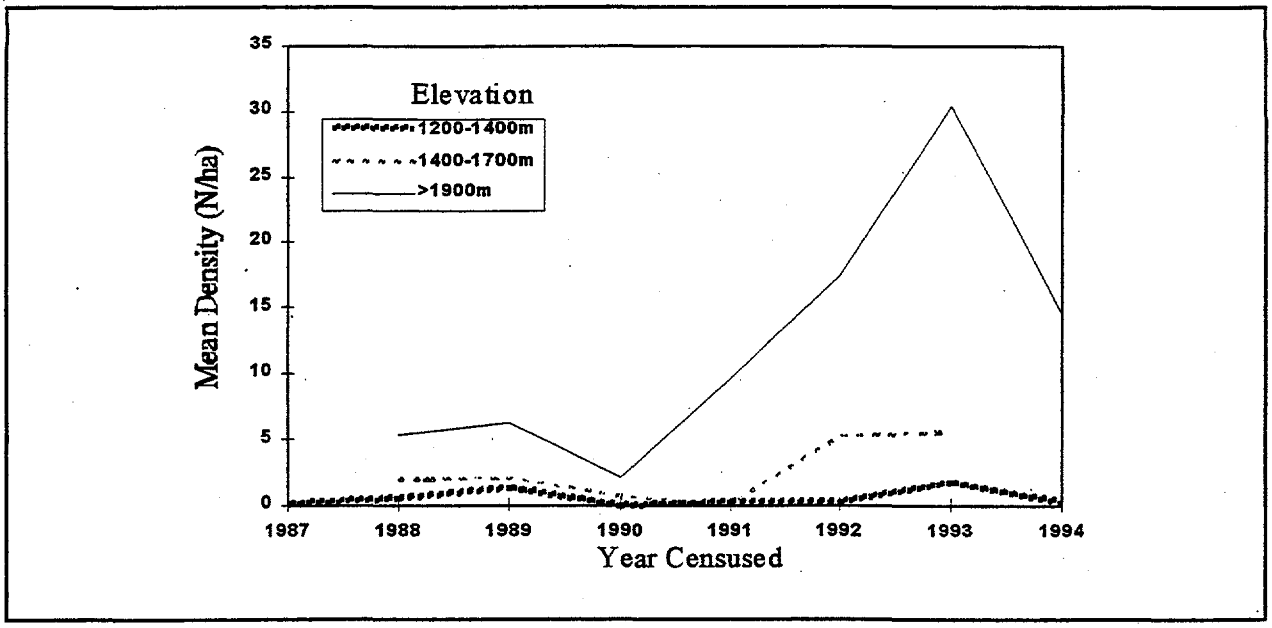

Figure 2-25. Annual trend in deer mouse density on the NTS by elevation.

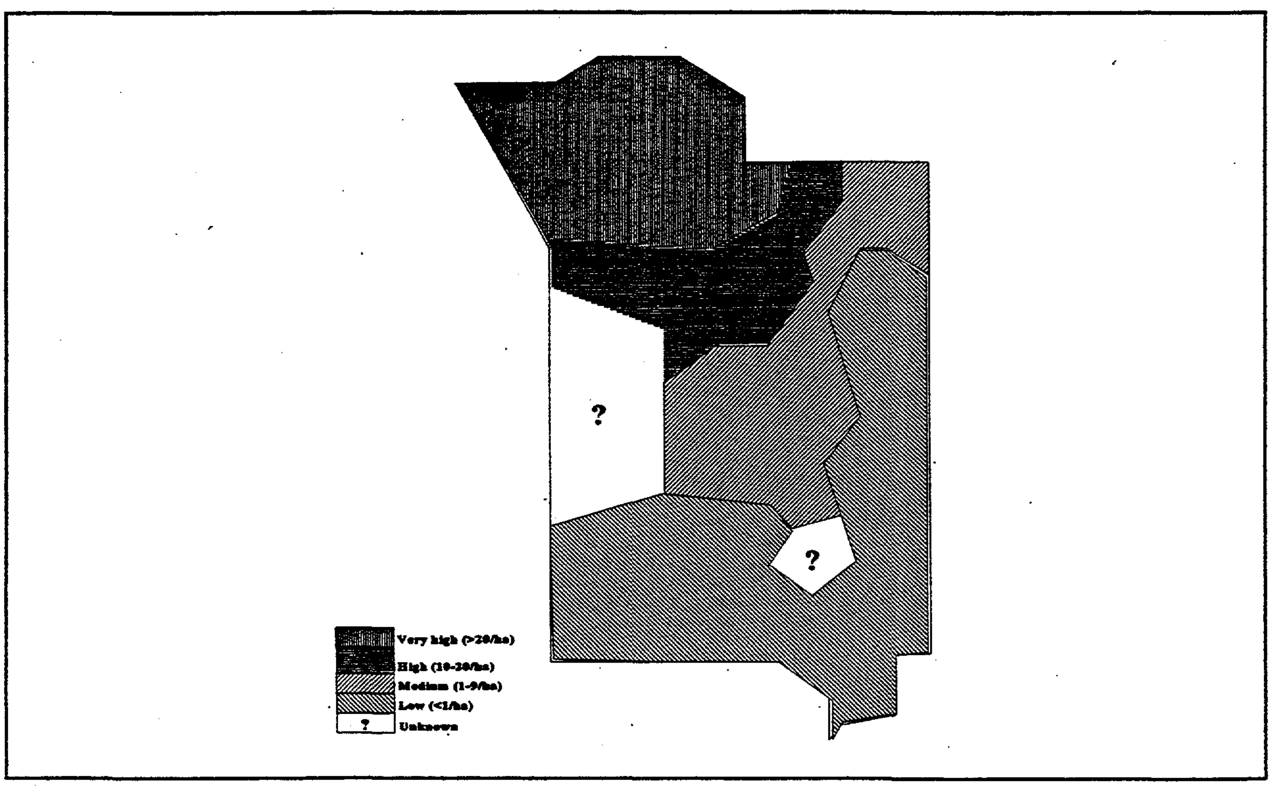

Figure 2-26. Distribution of deer mice abundance on the NTS.

Table 2-29. Summary of hantavirus presence on the NTS in 1994. NR = no results.

AREA	# SITES	# SAMPLES	# SAMPLED BY SPECIES	# POS.
23- Mercury Town	4	6	3 *Neotoma lepida* 3 *Peromyscus eremicus*	*0* *0*
6 - CP	6	14	9 *Neotoma lepida* 3 *Peromyscus eremicus* 2 *Peromyscus maniculatus*	*0* *0* *0*
27 - Fenced Compound	3	7	5 *Neotoma lepida* 2 *Peromyscus maniculatus*	*0* *0*
27 - Guard Stn.	3	3	2 *Perognathus longimembris* 1 *Neotoma lepida*	*NR* *0*
10 - Sedan	1	1	1 *Peromyscus maniculatus*	*1*
12 - Guard Stn.	1	1	1 *Peromyscus maniculatus*	*0*
- T-Tunnel Rd.	1	3	1 *Neotoma lepida* 2 *Peromyscus maniculatus*	*0* *0*
- N-Tunnel Rd.	1	2	1 *Neotoma lepida* 1 *Peromyscus maniculatus*	*0* *0*
- Camp	2	3	2 *Neotoma lepida* 1 *Peromyscus truei*	*0* *0*
17 - Pine tree plot	2	2	1 *Peromyscus maniculatus* 1 *Peromyscus truei*	*0* *0*
19 - Dead Horse Flat	1	21	21 *Peromyscus maniculatus*	*3*
TOTALS 7	25	63	2 *Perognathus longimembris* 22 *Neotoma lepida* 6 *Peromyscus eremicus* 31 *Peromyscus maniculatus* 2 *Peromyscus truei*	*NR* *0* *0* *4* *0*

The density of deer mice at the Area 19 site decreased in 1994 to less than a third of the 1993 density (Table 2-30). In 1993, 18 rodents were captured in this area and had blood samples tested, 17 were *P. maniculatus* and one was *Perognathus parvus*. Four of the 17 were seropositive for hantavirus antibodies (23%) and three of the 21 captured in 1994 were positive (14%). This suggests that the prevalence of hantavirus in deer mice varies spatially and temporally, however, this was not significant ($x^2 = 0.534$, $P = 0.465$). Further investigation over a longer time would help define any real pattern.

Table 2-30. Estimated density (N/ha±2 se), distribution of species captured (%T), and sex ratio (♂/♀) of small mammals captured on the Area 19 Pahute Mesa undisturbed area (PAM007) in 1993 and 1994. Shaded area was not included in totals.

	13-15 July 1993			16-18 August 1994		
	N/ha (N)	%T	♂/♀	N/HA (N)	%T	♂/♀
PERPAR	6.3±0.5 (9)	12.0	4/5	* (1)	4.3	0/1
PERMAN	53.8±10.2 (61)	81.3	31/30	16.2±2.0 (22)	95.6	12/9[a]
TAMDOR	* (5)	6.67	1/4	---	---	---
SYLNUT	* (2)	---	1/1	---	---	---
TOTALS	52.1 (75)	100.0	36/39	16.0 (23)	100.0	13/9
SPECIES	3			2		
H'	0.2619			0.0777		

[a]One animal of undetermined sex not included.

DISCUSSION

The Yucca Flat baseline plot has been useful in providing changes on a yearly basis in species composition, relative densities of the most common species, and sex distributions of populations at a relatively "pristine" site. To date, eight years of small mammal data are available for this site. Trends may be used to interpolate what may have happened at other NTS sites during the years between censuses. Disturbed sites and controls have information on the effects, if any, of the disturbance and recovery over time.

BASELINE SITES

Apparently, most sites have recovered from drought conditions in less than two years, however, results at the Yucca Flat baseline site suggest that *Perognathus longimembris* continues to lag behind pre-drought densities. In recent years, the very small *P. longimembris* has been present at low densities, while *Chaetodipus formosus*, a medium-sized species typical of the intermountain sagebrush and Mojave Desert regions (Schmidley et al. 1993), has increased in virtually all areas of the NTS. One possible explanation for this is the fluidity of the range of *P. longimembris* on the NTS. The boundaries of a species' distribution are dynamic and, as may be the case with *P. longimembris*, often withdraw from the more marginal quality areas of its range (such as the more gravelly soil of western Yucca Flat) where it is unable to compete as effectively.

It is possible that the relatively long life-span of this species (French et al. 1967 and 1974, Zeng and Brown 1987), while contributing to its survival, was undermined by a lack of reproductive output or high dispersal from the Yucca Flat baseline site in 1989 and 1990 and increased competition in 1991 through 1994. During drought years, this species showed a decline on every site censused on the NTS, suggesting that the decline was due to a factor other than dispersal.

Some degree of seasonal and annual periodicity has been demonstrated in heteromyid rodent populations in other deserts (Brown and Harney 1993). Food availability largely determines the magnitude of population fluctuations and plant productivity is determined by the amount and timing of precipitation (Rosenzweig, 1968, Beatley 1974b). Most rodents (particularly heteromyids) are herbivores or granivores and therefore depend on adequate quantities of plant biomass, most importantly from annual plants, for reproduction and growth (Kenagy 1972 and

1973, Van de Graaff and Balda 1973, Reichman and Van de Graaff 1973 and 1975, Kenagy and Bartholomew 1981). This, in turn, places precipitation, particularly that of winter, as the main control of population size (Beatley 1976). The trend on YUF001 clearly indicates a significant, positive correlation with winter rainfall (Figure 2-6).

The trend of *P. longimembris* at the Frenchman Flat baseline plot, a return to pre-drought density, is unlike the continued reduction at the Yucca Flat plot and may be due to lack of competition from other granivorous rodents. One potential replacement species is the larger *Chaetodipus formosus*. This species was first captured at the FRF001 site in 1991 and at a nearby roadside site in 1990 and it was more numerous than *P. longimembris* at the roadside in 1993 (Saethre 1994c). The sandy habitat at the FRF001 site may inhibit a large scale invasion of *C. formosus*.

That *D. microps* did not recover as fast as *D. merriami* may be explained by the lack of facultative reproduction in *D. microps*. Where *D. merriami* and *P. longimembris* are able to gain water and food resources for reproduction from green material of annual plants and may successfully reproduce for most of the active season (Bradley and Mauer 1971, Kenagy 1973), *D. microps* is usually limited to only one reproductive bout per year and only then if there is adequate green perennial vegetation, *Atriplex canescens* in particular (Beatley 1969, Kenagy 1972 and 1973). Sufficient late winter/early spring precipitation in 1991 caused an adequate amount of annual plant germination (Hunter 1994a) and growth of green perennial vegetation (Hunter 1994b) however this site was trapped before the emergence of juveniles and it was not possible to assess success of the 1991 reproductive season of *D. microps*. In 1992 (Hunter 1994c) and 1993 (Hunter 1994e), winter precipitation and perennial plant growth were excellent and *D. microps* numbers returned to pre-drought or better. The large increase in this species from spring of 1993 to spring of 1994 was a result of high reproduction in 1992 and 1993 and overwinter survival to 1994.

Heteromyids fill available niches by exhibiting specific foraging microhabitat preferences and behavior which correlate with overall differences in morphology and size (Reichman and Price 1993). Interspecific competition for resources (primarily seeds) influences the organization of a rodent community, resulting in a regular pattern of body sizes in coexisting rodents (Bowers and Brown 1982, Price and Brown 1983, Brown and Harney 1993). It may be that while numbers of *Perognathus longimembris* were depressed, similar sized mice (*Peromyscus eremicus*, *P. maniculatus*, and *Chaetodipus formosus*) filled the empty niche space and are competing for the same resource patches. The increase in (*Dipodomys microps*) may also have affected competition although forage patterns differ.

DISTURBANCE-RELATED EFFECTS ON RODENT COMMUNITIES

The typical effect of disturbance on rodents appears to be indirect in that rodents disperse from areas that have had a decrease or loss in vegetation. Although rodents spend most of the time in burrows well below the ground, loss of cover will increase not only predation risk but also competition with other individuals for remaining resources.

Dipodomys merriami was the dominant rodent on disturbed areas. Over the last eight years, this species has consistently been the most prevalent rodent on disturbed areas of the NTS. Rodents have not recolonized disturbed areas in the same proportion found in the surrounding native vegetation.

Almost twice as many species were captured on the NAEG plots at T2 and Sedan during the year-long trapping effort. That fewer species were captured by BECAMP is not surprising as only three days of trapping every three years is not conducive to developing a complete faunal picture of an area. The 1982-83 trapping regime also included peanut butter in the bait mix which may be more effective at attracting less granivorous genera such as *Neotoma*, *Onychomys,* and *Peromyscus*,; although on areas where *P. maniculatus* is abundant, BECAMP has had no problem capturing this species without the aid of peanut butter. A more likely explanation is that 1982-83 were back-to-back winters of good precipitation and rodents were at peak diversity and density.

The absence of *P. longimembris* from the revegetated area in 1994 may be due to the nature of the soil surface. After the surface was ripped in 1989, the resulting furrows were still present in 1991. By 1994, these had weathered down to less than 3 cm and the surface was compacted. *P. longimembris* was never abundant on either site and declined considerably in the so-called native vegetation. Therefore, colonization by this species was probably limited.

It would appear that species recolonized the cleared and revegetated area disproportionately to their relative proportions on the control area (Table 2-24). This is not surprising as the vegetation assemblages are different. The control consists of mixed small shrubs, while the revegetated area is almost entirely large saltbushes (*Atriplex canescens*). When *Dipodomys microps* was abundant on control sites, it was also present on disturbed areas, particularly when *A. canescens* was abundant. This indicates that although the disturbed area was poor to marginal habitat, pressure to disperse or some attractive feature (saltbushes) favored using the disturbed areas.

Pooling plots in Yucca Flat (the only area with more than two sites in any year) showed that species diversity was greater on the undisturbed areas compared to the disturbed sites. Comparing the last eight years, 1993 and 1994 had the highest average species diversity, number of species captured, and trap success.

HANTAVIRUS ON THE NTS

It would appear that *Peromyscus* from the southern two-thirds of the NTS have not been exposed to the virus or are not carriers. It is more likely that the virus is present throughout the NTS, but that densities are so low in some areas that occurrence and transmission of the virus between rodents are also low. Until more animals from the lower elevations are tested, any enclosed area (e.g., building, shack, trailer, pit, etc.) that is infested with rodents should be treated as a potential hazard and precautions should be taken when entering these areas.

CONCLUSIONS

RODENTS ON THE NTS

Species diversity continued to be high at undisturbed sites on the NTS. Although several species have not been captured in recent years (see Saethre 1994c, O'Farrell and Emery 1976), the biotic community of the NTS appears to have prospered in spite of severe disturbances related to testing and maintenance activities. Recovery of small mammals from drought conditions appears to be complete except for the little pocket mouse in Yucca Flat. This phenomenon may be a cumulative, long-term effect of testing or only part of a cyclical life history.

Of some concern is the apparent lack of recovery of perennial vegetation and, hence, rodents other than *D. merriami* on the blast areas. It cannot be determined at this time if this is due to residual effects of testing or the vastness of the disturbed area. These sites have had nearly 40 years for germination of shrubs to occur, yet this has only occurred on a small scale. The lack of shrub cover precludes immigration of many rodent species that eschew open areas. Many of the GZs are large and, while depending on seed dispersal from surrounding undisturbed areas via wind and rodents, may not present the most favorable situations for germination events. A large number of granivores inhabiting blast areas may actually deplete the seed bank and reduce germination. The ecotonal edges may in fact represent the only recovery at these sites. The rodent trapping grids are located far from the edges and are therefore not likely to demonstrate rapid recovery.

Rodents have a large impact on the arid ecosystem on the NTS in that they comprise a major portion of the prey base for vertebrate predators. They also loosen soil and disperse seeds and compete with other seed-eating taxa (e.g., ants). Kangaroo rats have been termed a "keystone guild" in that removal of these rodents has resulted in less soil disruption, more litter accumulation, taller perennial and annual grasses, and decreased foraging by granivorous birds. In addition, rodents typical of grasslands have previously colonized in a desert scrub habitat (Brown and Heske 1990, Brown and Harney 1993). That an important component of the desert has fared well on the NTS indicates that the local area is relatively typical in ecological conditions.

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STATUS OF HORSES, DEER, AND BIRDS ON THE NEVADA TEST SITE, 1994

by

Paul Greger

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ACKNOWLEDGEMENTS

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ABSTRACT

Surveys were conducted to assess trends of feral horses, mule deer, and raptors on the NTS. The feral horse population numbered 56 animals in 1994, a 14% decline over the past two years, and appeared to be controlled by mountain lion predation. The mean sighting rate of mule deer was 50% of the 1993 level, suggesting mule deer were less abundant on the NTS. Sighting rates suggest that raptors are more abundant on Yucca Flat than Frenchman Flat. Relative abundance of raptors on Yucca Flat was at least double or greater in spring and summer in 1994 over 1993, while on Frenchman Flat abundance was similar between years. Known locations of ravens nests were visited to record reproductive use. Raptors and ravens appear to be benefitting from the use of man-made structures on the NTS.

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INTRODUCTION

During 1988, studies were begun to assess wildlife use of water sources, horse and deer population trends, and raptor abundance on NTS. The results of these studies are found in Romney and Greger (1992), Greger and Romney (1994 a,b,c,) and Greger (1994).

The NTS horse population was studied to describe horse usage of habitats and assess population trends. An increase in the population could pose adverse impacts to the environment, while a decrease could suggest potential negative impacts on horses.

Horses were examined for tritium to develop some basic information on the radionuclide body burdens of horses. Tritium was initially found in fresh scats from two horses during 1993 (Greger 1994), and because of low sample size, horses were sampled again in 1994. Tritium was sampled because it is highly mobile and widespread on the NTS, and because there are public concerns about the effects of radioactive isotopes on biota. Tritium was sampled because it was less expensive than other analyses and samples could be easily obtained with minimal harassment of horses. However, sampling of radionuclides in horses should not be limited to tritium, but should be expanded to sample other fission byproducts and plutonium. The knowledge of radioactive body burdens of horses may be important because horses could transport radionuclides around the NTS and deposit them via their excreta.

Grass samples were collected from sites throughout the horse range and analyzed for tritium. This was a pilot project to assess general availability of tritium for uptake by horses based on the assumption that grasses are a major component of the horses diet.

Mule deer population trends on the NTS were determined from 1989 through 1993 because DOE activities could potentially impact deer, and there may be public concerns over such impacts.

Raptors were monitored on the NTS from 1989-92 to provide some basic information on relative abundance of common species (Greger and Romney 1994 b,c). In 1993, raptor studies compared use between roads with and without pole-lines along a disturbed habitat corridor (Greger 1994). Road surveys in 1994 compared seasonal relative abundance of raptors between the Frenchman and Yucca Flats.

Raven nesting was studied at active nest sites. Many nests were on man-made structures and were used in successive years. The man-made structure sites were studied to see if ravens might benefit from use of such structures.

During 1993, numerous dead animals including grebes, ducks, hawks, owls, passerine birds, small mammals, and coyotes were found in the plastic lined ponds of the Under Ground Test Area Operable Unit (UGTA). Because the potential for impact to sensitive species of animals and migratory birds exists, visits were made to the ponds at UGTA sites to monitor animal mortality.

Visits to several springs were made to determine the chukar abundance during the summer. This was performed because information was needed to decide if the chukar populations were large enough to withstand the removals requested by the Nevada Department of Wildlife (NDOW).

FERAL HORSE MONITORING

METHODS

Feral Horse Population

A biologist located horse bands monthly from March-November by driving roads along a standardized course and hiking into selected areas on foot in the northern regions of the NTS. To locate the horses, Tippipah Highway, Rainier Mesa Road, and 2-07 Road were driven on Yucca Flat: Pahute Mesa Road, StockadeWash Road, Airport Road, and Buckboard Mesa Road were driven west of the Eleana Range. A horse census was performed by counting individual horses identified from unique color patterns. Additional details of horse monitoring are given in Greger and Romney (1994a).

Tritium Sampling

Fresh fecal samples were collected opportunistically from four horses from northern areas of the NTS to examine the tritium content. The bands of horses were observed until a known individual produced a scat. The sample was immediately collected, taking care not to mix local soil with the sample.

Three grass samples from the Red Rock Valley burn area (Area 17), and one sample from each of seven other representative locations (undisturbed sites) within the horse range, were collected for tritium analysis. One sample was collected near Sedan Crater (disturbed site) because tritium levels were expected to be higher there relative to other regions, and horses were known to graze in this area.

Each grass sample was collected by hand and represents a composite sample from many individual plants (>50) within a radius of 100-200 m. In the field, samples were placed in a clean quart glass Mason jar with a metal lid. They were stored in a freezer in Mercury until transferred to the lab for analysis. Fecal and grass samples were analyzed for tritium by REECo Analytical Services Department (ASD). Water was extracted from the samples, prepared with a scintillation cocktail, and counted with a scintillation counter. Tritium values are expressed as microcuries per millimeter of water.

RESULTS

Feral Horse Population

Feral horses *(Equus caballus)* ranged over an area of about 325 km^2 of transition zone between the Mojave and Great Basin Deserts. Horses occupied habitats between 1300 and 2000 m of elevation and made seasonal movements within this range (see Greger and Romney, 1994a for range map).

Horses were segregated into thirteen bands and a small number of bachelor males. Fifty-six horses were counted during 1994 (Table 3-1). Member changes occurred in seven bands. Six of thirteen bands were stable (i.e., no member changes) in 1994 (Table 3-1). Mean band size ($\pm$ 1 se) excluding foals during 1994, was 3.8 $\pm$ 0.42. Mean harem size, ($\pm$ 1 se) excluding daughters was 2.3 $\pm$ 0.4. The male:female sex ratio was 0.81:1.0. Mean band size, harem size, and sex ratios changed little over the past four years.

The death (disappearance) of the stallion from band A allowed the dispersal of three females. Two of three females were later joined by a different bachelor male forming a new band (V). Female number 9 (originally from band A) joined band I.

Table 3-1. Status of horse bands in fall on the NTS in 1994. N = 56 individuals.

Band	Horse Identification numbers and status
A	disbanded, Stallion number 11 missing and presumed dead
B	Blacks 27, 30, 69, Bay 20: Stable band
C	Grey 46, Bays 1, 7, 21, 22: Stable band
E	Bays 13, 16, 17, 18, Greys 35, 37: Stallion 13 reacquired all females from stallion 44 in band U. Band U was disbanded in spring of 1994.
F	Bays 4, 52, 53, 62, 67: Stable band
G	Bays 50, 31: Member changes, Bay 51 and Grey 55 left band G
H	Bays 2, 51, 58, 60: Member changes (51 new member, 61 left)
I	Bays 15, 9, 24, 38, 47: Member changes (6 missing, 9 new member)
J	Bays 3, 57, Grey 56, Black 61: Member changes (61 new member)
K	Bay 19, Sorrel 40, Blacks 29, 63: Stable band
L	Sorrel 54, Bay 64: Stable band
N	Bays 48, 12: 48 not observed with 12 in the fall, 65 observed replacing stallion 48 at year end.
V	Black 28, Bays 8, 59: New band formed, females from original band A.
W	Bay 43, 55: Stable band
Bachelor males	10, 25, 36, 42, 44, 45, 49, 65

All males in bands are underlined:

Locations of horse bands are shown in Figures 3-1 through 3-33. Bands K, B, and N were observed only east of the Eleana Range (Figure 3-1). Ten bands were observed only on the west side of the Eleanas (Figures 3-1, 3-2). One exception to this pattern was band V (Table 3-1) which crossed the Eleanas from Yucca Flat to Area 19 in summer, and returned to north Yucca Flat in fall (Figure 3-1).

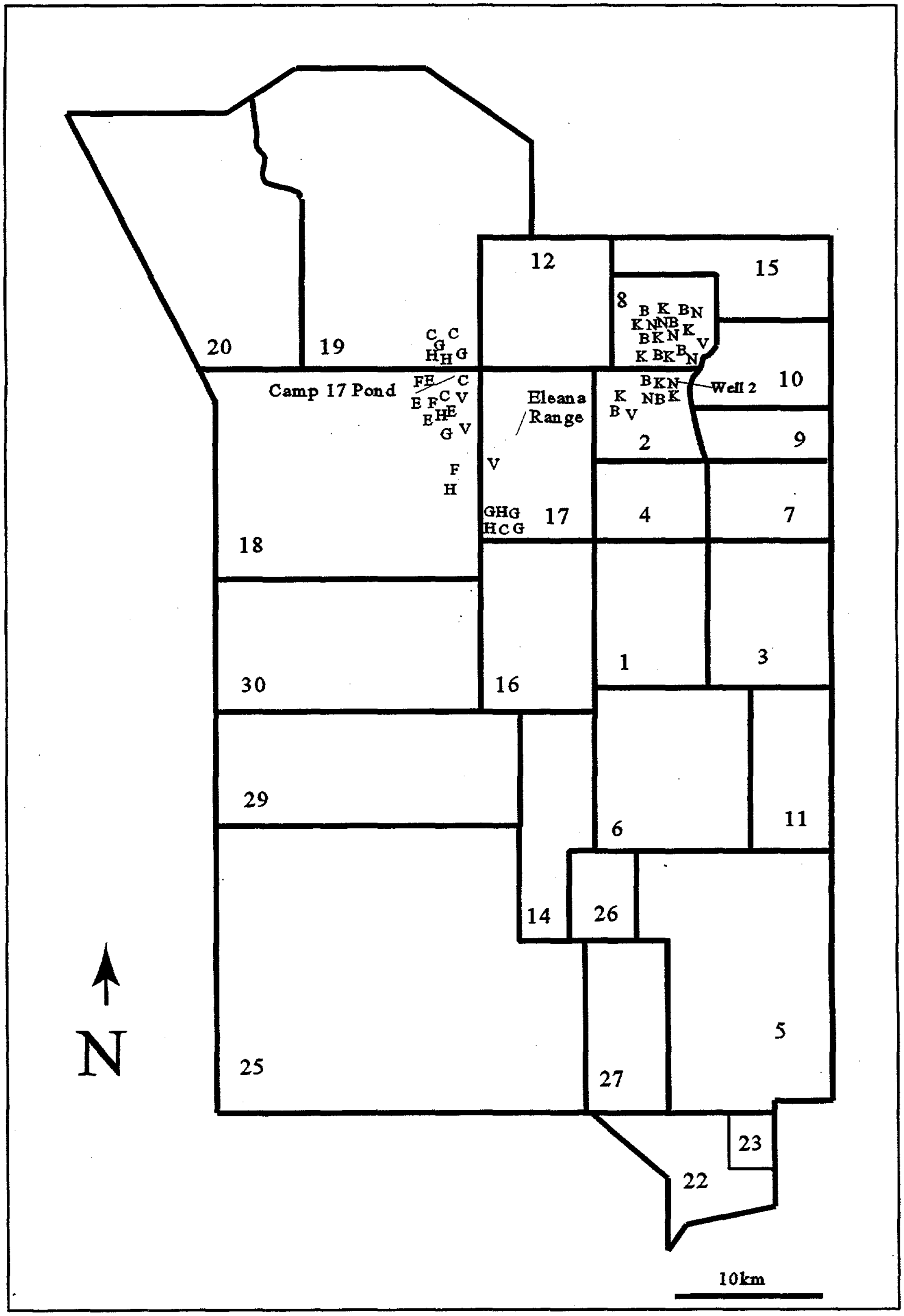

Figure 3-1. Approximate locations of feral horse bands at the NTS during 1994 (N = 55 sightings). Band locations are shown by respective letters.

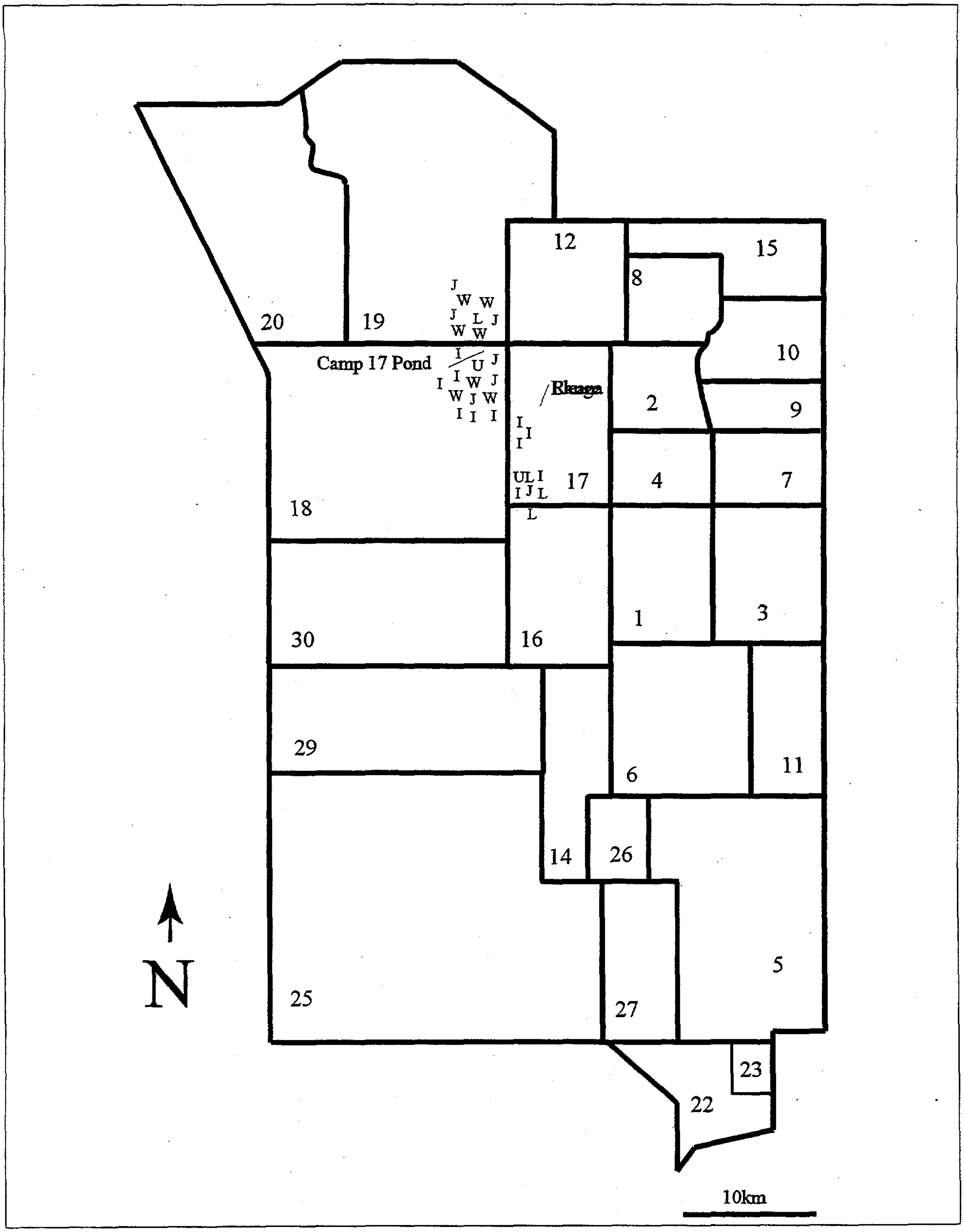

Figure 3-2. Approximate locations of feral horse bands at the NTS during 1994 (N = 31 sightings). Band locations are shown by respective letters.

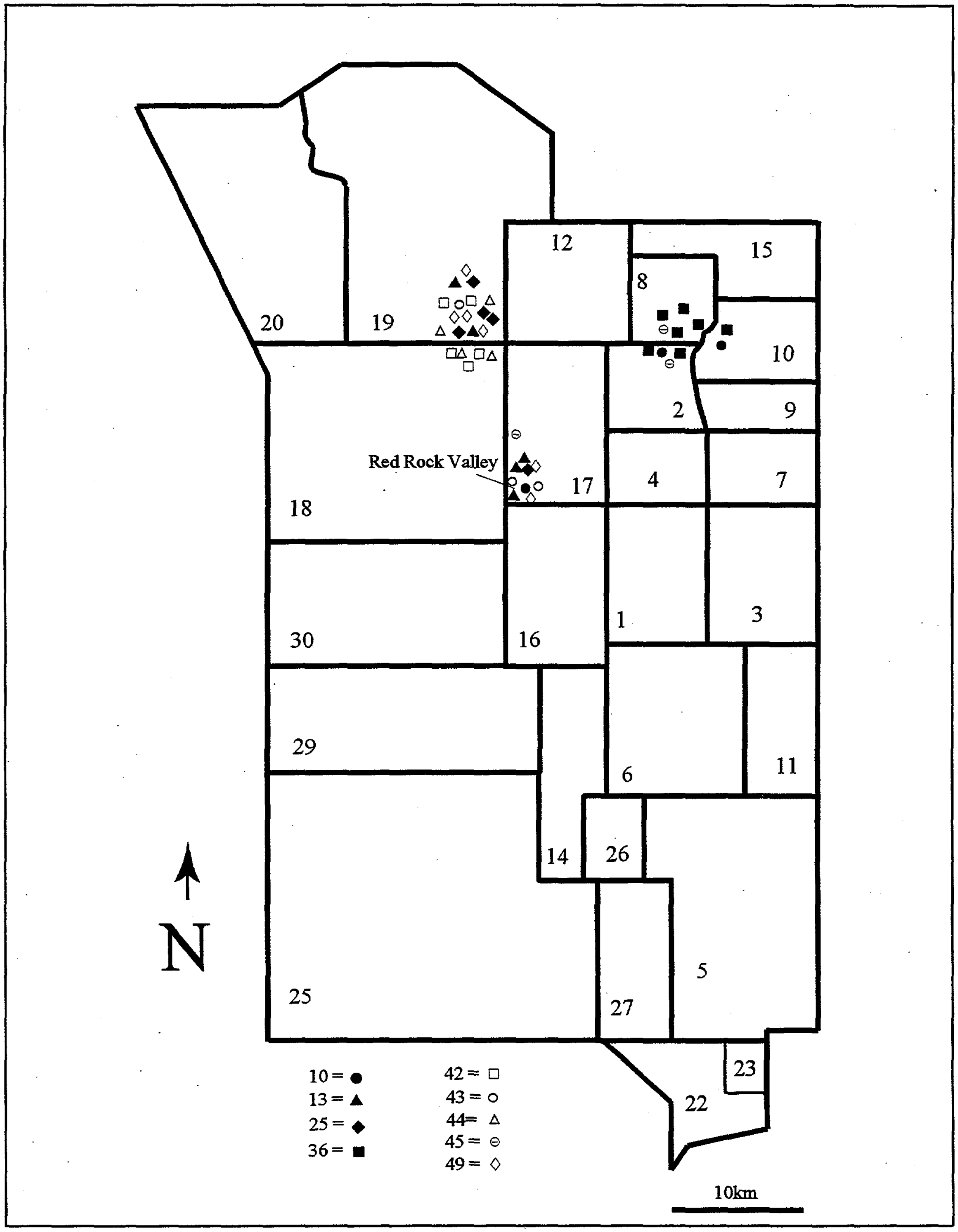

Figure 3-3. Approximate locations of bachelor male horses during 1994 (N = 41 sightings). Horse identification numbers shown above with respective symbols.

Locations of bachelor males are shown in Figure 3-3. Two movement patterns are evident from the location data. First, two bachelor males moved across the Eleanas Range to Yucca Flat. Second, four bachelor males moved back and forth from Red Rock Valley to Area 19 on the west side of the Eleanas Range.

Only three of eleven foals were known to survive through the fall of 1994 (Table 3-2). Four apparently healthy foals disappeared between two and twenty-one days after they were first observed, and four foals were observed only once before they disappeared (Table 3-2).

Table 3-2. Mare reproductive summary and status of foals. N is the number of observations. Final date was the last date a foal was observed within a band. Missing foals are presumed dead.

Mare	Band	Dates of foals		N	Status
		Initial	Final		
31	G	7 April 94	-	1	Missing
51	G	7 April 94	13 April 94	2	Missing
22	C	10 May 94	12 May 94	2	Missing
35	E	23 May 94	-	1	Missing
56	J	13 June 94	-	1	Missing[a]
30	B	6 July 94	------	8	Alive
29	K	6 July 94	------	8	Alive
61	J	25 July 94	15 August 94	3	Missing
59	V	25 July 94	-	1	Missing
12	N	25 July 94	------	4	Alive
24	I	2 August 94	9 August 94	3	Missing

[a] Remains of a foal were located.

On 19 July 1994 remains of one foal were found covered with pinion needles under a pinion tree about one mile east of the Camp 17 pond in Area 18. The remains consisted of the head and three lower leg extremities with canine tooth punctures, several thigh bones, and some additional partially crushed bones. This was the first freshly killed foal located to date on the NTS. The remains were completely scavenged within one month.

Trends in the horse population are shown in Table 3-3. Population size has decreased from a high of 65 individuals in 1992 to a low of 56 in 1994, a 14% decrease over two years.

Table 3-3. Status of feral horses on the NTS 1990-94.

Age class	1990	1991	1992	1993	1994
Adults[1]	59	57	57	57	53
Three year old	0	0	2	2	3
Two year old	0	2	2	4	0
Yearlings	2	2	4	0	0
Foals	9	12	17	11	11
Total surviving[2]	61	61	65	63	56

[1] Adults were visually estimated to be older than three years of age in 1989-90 based on relative body size. [2] Yearlings or older.

Foal survival from 1990-93 was estimated at 22%, 33%, 0%, and 0% respectively based on total number observed (Table 3-3). The mean foal survival rate was 14% over four years of study.

Tritium Sampling

All four horse scat samples contained detectable levels of tritium ($\overline{X} = 5.57 \times 10^{-6} \pm 2.74 \times 10^{-6}$ μCi/ml $\pm$ 2 se, Table 3-4). Tritium was detected in ten of eleven grass samples. Grass samples near Sedan crater showed much higher levels of tritium than other areas (Table 3-5). Tritium levels measured above detection limits are considered to be accurate with a confidence of 95% or greater. Values that fall below detection limits have no reliability as to what the true value may be. The range of activity measured was large, varying from 6.8×10^{-7} to 1.15×10^{-3} μCi\ml (Table 3-5).

Table 3-4. Tritium results (μCi/ml of water) from fecal samples of horses collected from various locations on the NTS during 1994. Detection limits were 9.22 x 10^{-7} μCi/ml for all samples.

Date	Horse #	Band	Location	Concentration μCi/ml
6 July 94	19	K	Yucca Flat Area 8	4.04 x 10^{-6}
10 August 94	29	K	Yucca Flat Area 8	7.30 x 10^{-6}
18 August 94	28	V	Horse Wash Area 17	2.55 x 10^{-6}
23 August 94	18	E	Camp 17 Pond	8.41 x 10^{-6}

Table 3-5. Tritium results (μCi/ml of water) from grass samples collected from various locations on the NTS during 1994. Detection limits were 9.47 x 10^{-7} μCi/ml for all samples.

Date	Area	Location	Concentration μCi/ml
19 July 94	17	Red Rock Valley Burn	1.85 x 10^{-6}
19 July 94	17	Red Rock Valley Burn	1.82 x 10^{-6}
19 July 94	17	Red Rock Valley Burn	1.69 x 10^{-6}
8 August 94	17	Horse Wash, 100 meters from PMR	5.27 x 10^{-6}
8 August 94	18	500 meters east of Camp 17 Pond	6.83 x 10^{-7}
9 August 94	17	Yucca Flat, 1km West of TH 44[a]	3.32 x 10^{-6}
9 August 94	8	Northern Yucca Flat	5.13 x 10^{-6}
15 August 94	12	G Tunnel Rd/Rainier Mesa Road	7.0 x 10^{-6}
16 August 94	17	Stockade Wash Road	4.62 x 10^{-6}
23 August 94	2	Yucca Flat, Orange Road O-50[a]	4.62 x 10^{-6}
13 September 94	10	1100-1200 feet north of ground zero at Sedan Crater	1.15 x 10^{-3}

[a] Radsafe Road location numbers. PMR is Pahute Mesa Road. TH is Tippipah Highway.

DISCUSSION

Horse Population

Horse bands have shown regular usage of specific areas on the NTS each year of study (Greger and Romney 1994a, c; Greger 1994). For example, bands K, B, and N were consistently located on northern Yucca Flat in areas east of the Eleana Range (Figure 3-1). Most other bands on the NTS were observed only on the west side of the Eleanas and in Red Rock Valley (Figures 3-1 - 3-2). Horse distribution appears to be related to water availability. Most bands that occupied northern Yucca Flat in 1994 used Well 2, of Area 2 extensively (Figure 3-1). Similarly most bands west of the Eleanas used Camp 17 Pond heavily during summer months while moving to and from Red Rock Valley burn, an area of heavy grazing in spring and summer (Figures 3-1 - 3-2). Captain Jack Spring was not heavily used by horses in the summer of 1994.

One exception to this pattern was band V, which moved across the Eleanas Range in 1994, indicating that bands are not restricted to particular regions of their total range. Band V was formed by bachelor number 28 who in previous years had been observed to move back and forth across the Eleana Range. The two females (8, 59) in band V were observed west of the Eleana Range with number 28 in 1994, but in four previous years as members of band A, they were never observed to cross the Eleanas. This example illustrates the importance that band structure (i.e., the stallion) has in determining the movements of horses.

The horse population at the NTS has actually declined by 8% over the last four years, largely due to limited recruitment to the population and some additional adult mortality. This contrasts strongly with the increases of 9-30% reported for horse populations in the western U.S. in the last decade (Eberhardt et al. 1982, Berger 1986, Wolfe 1986, Garrott and Taylor 1990, Garrott et al. 1991). Mountain lion predation could explain missing foals at the NTS, although direct evidence to support this theory is limited. In 1994 as in previous years, apparently healthy foals have disappeared over short durations (days to weeks) since they were first observed. During 1994, the remains of one foal was found which appeared to have been eaten by a mountain lion. Although actual cause of death was unknown, the foal's skull and leg bones had large canine punctures and the remains were covered with debris, two characteristics used by Turner et al. (1992) to document mountain lion predation of foals in Nevada. Other potential causes of foal losses not yet investigated include predation by coyotes or bobcats, disease, food limitation, and inbreeding mortality.

Mean foal survival at the NTS was estimated at about 14% over four years and is much lower than other values reported. Typical foal survival reported from horse populations in the west has varied from 67-93% (Berger 1986, Siniff et al. 1986, Wolfe 1986). Mean foal survival averaged 27% over four years in the Montgomery Pass Wild Horse Territory in Nevada where mountain lion predation was controlling the growth rate of the herd (Turner et al. 1992). The numbers of foals recorded at the NTS do not account for foals that were born and died without being observed (e.g., A mare was visually pregnant, but a foal was never observed with her. Greger & Romney 1994c). Therefore, foal survival rates at the NTS are conservative.

Tritium Sampling

Tritium levels measured in horses during 1994 at the NTS were too low to have any harmful effects on horses or their offspring. Tritium activity levels from horse scats were about 10^6 times lower than experimental whole body levels in rats, where some effects on tissues were shown. For example, constant body tritium activity levels of pregnant lab rats held at 1 to 100 μCi/ml (producing doses of 0.3-30 rads/day to the embryo and fetus) showed various effects including micrencephaly, sterility, stunting, litter size reduction, and increased resorption (Cahill and Yuile 1970). At body activities of 1 μCi/ml, the only changes noted were a slight increase in length of offspring and increase in the weights of the liver and heart. Sterility was shown at body tritium levels of 50-100 μCi/ml (Cahill and Yuile, 1970). In addition, Laskey et al. (1973) found effects of body tritium on the F_1 adult rats and F_2 neonates. Continuous exposure at 10 μCi/ml produced a 30% reduction in the testes weight of the F_1 adult, but no impairment on growth or reproductive ability. Further effects on the F_2 neonates were decreased body weight at 1 and 10 μCi/ml, and decreased litter size and resorption at 10 μCi/ml (Laskey et al. 1973).

Eight of nine locations sampled within horse range on the NTS in 1994 showed detectable levels of tritium (Table 3-5). The data suggest that low levels of tritium occur in grasses over widespread areas where the samples were taken. Because horses forage in this region, it is possible they could take up tritium by eating vegetation. Horses may also take up tritium by drinking from contaminated ponds although, at present, only the E Tunnel Pond has free water with elevated tritium. Sampling of vegetation (i.e., shrubs) should be further investigated in northern areas of the NTS to better describe the extent of tritium availability in the region.

Horses commonly dig holes, kick up dust, eat soil, inhale dust, and may breach fences to enter areas that may have contaminated soil on the NTS. There is a potential risk that horses could take up and transport or resuspend radionuclides other than tritium from contaminated areas to other locations. For these reasons, it is recommended to DOE that contaminated areas on the NTS be kept free of horse intrusions.

MULE DEER MONITORING

METHODS

Mule deer *(Odocoileus hemionus)* were counted using spotlights along roads (Figure 3-4) on three nights in October. Surveys began at about 2030 hours and finished at about 2400-0100 hours. Two observers in each of two vehicles scanned opposite sides of the road at all times. Driving speed varied between 6-18 kph depending on road conditions. When deer were sighted, the vehicle was stopped, the area was scanned by both observers, and the number of deer was counted. Deer were not counted if seen while backtracking over the survey route. A relative abundance measure (number of deer/km) was calculated by dividing total deer observed by linear distance searched. The relative abundance of mule deer was plotted across years to determine the trend.

RESULTS

The relative abundance measure of mule deer during 1994 was 0.21 deer/km (2 se = 0.08). This value was about 50% lower in 1994 compared to 1993 (Figure 3-5). Over six years of monitoring, levels of deer abundance changed with lowest levels measured in 1991 and 1994.

DISCUSSION

Trends in relative abundance of mule deer appear consistent with availability of moisture from 1989-94. From 1989 through 1991, relative abundance declined steadily during drought (Figure 3-5). In 1992-93 as the drought eased, numbers of deer increased. Finally, the relative abundance of deer appeared to decline in 1994 (Figure 3-5). This decline could be a result of deer emigration from the area because of water limitation during summer and fall. Closure of several well reservoirs on Pahute Mesa (Figure 3-4), could have limited the availability of water to the population. Giles and Cooper (1985) stated that deer populations on the NTS were tied to water sources.

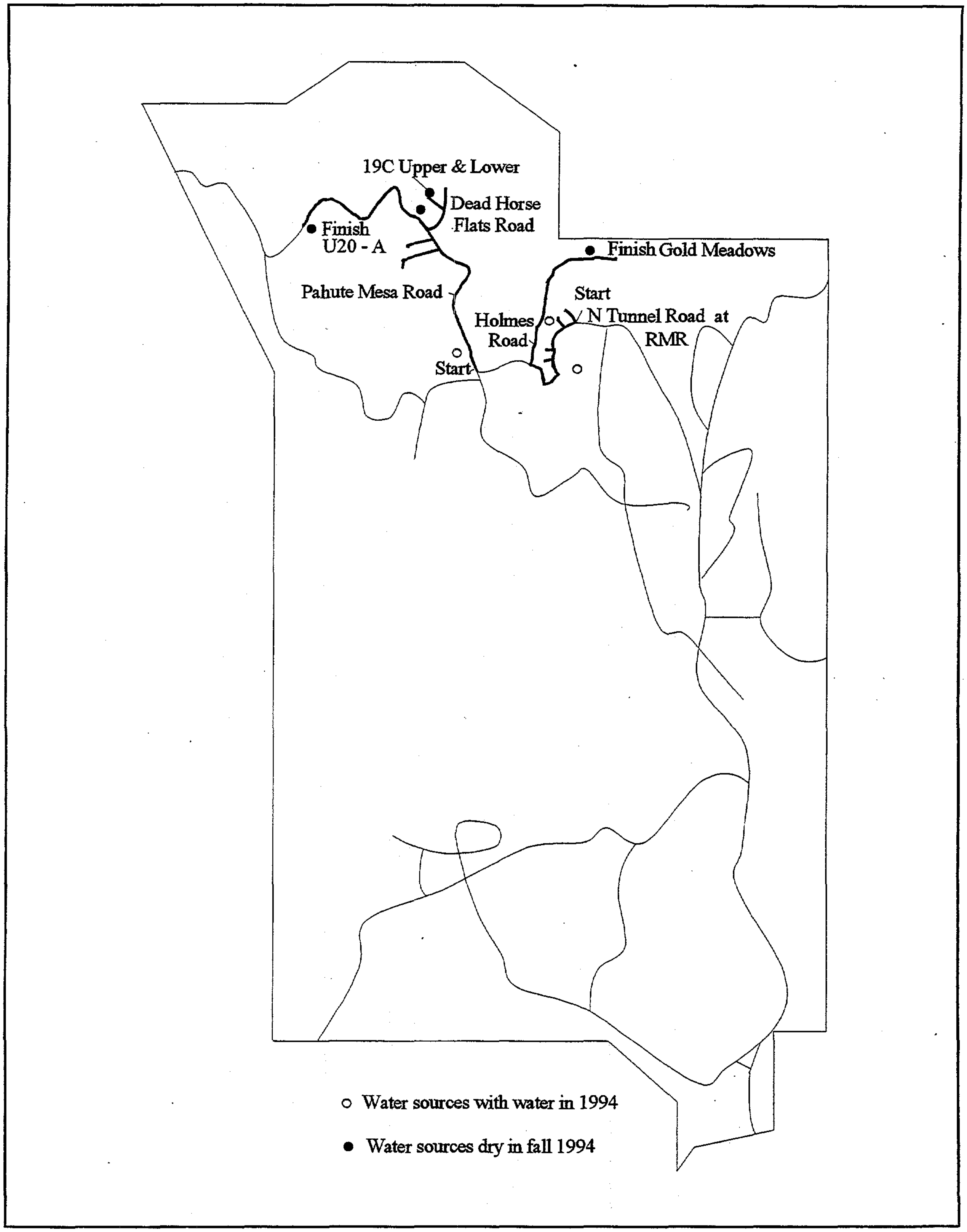

Figure 3-4. Roads (bold) where mule deer surveys were performed. Status of water sources is shown during deer survey period.

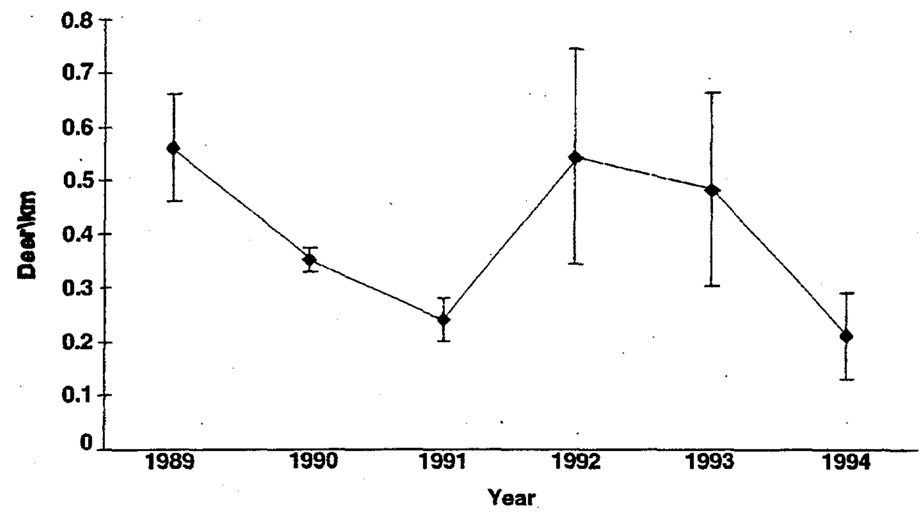

Figure 3-5. Relative abundance measures ($\pm$ 2 se) of mule deer determined from road surveys at the NTS from 1989-1994.

Variation of deer counts within years was quite large, especially during 1992 and 1993. This variation was associated with weather changes on one of three survey nights. Fewer deer were counted on cold windy nights compared to warm calm nights. On cold windy nights, the deer were less visible because they stayed near thick cover as opposed to warm calm nights when deer were observed more in the open. Based on variability of the data, increasing sample frequency to greater than three nights per year should be considered if surveys are to be continued.

RAPTOR MONITORING

METHODS

A biologist performed road surveys to determine the relative abundance of raptor species. Highway segments on Frenchman and Yucca Flats were sampled to determine if raptor abundance differed between regions. Orange Road on Yucca Flat was surveyed to provide information on use of habitats without pole lines. While driving at about 65-70 km/hr, a biologist located hawks on the Mercury Highway and Rainier Mesa road segments, and while driving at about 25-30 km/hr, located them on Orange Road (Figure 3-6). Surveys were

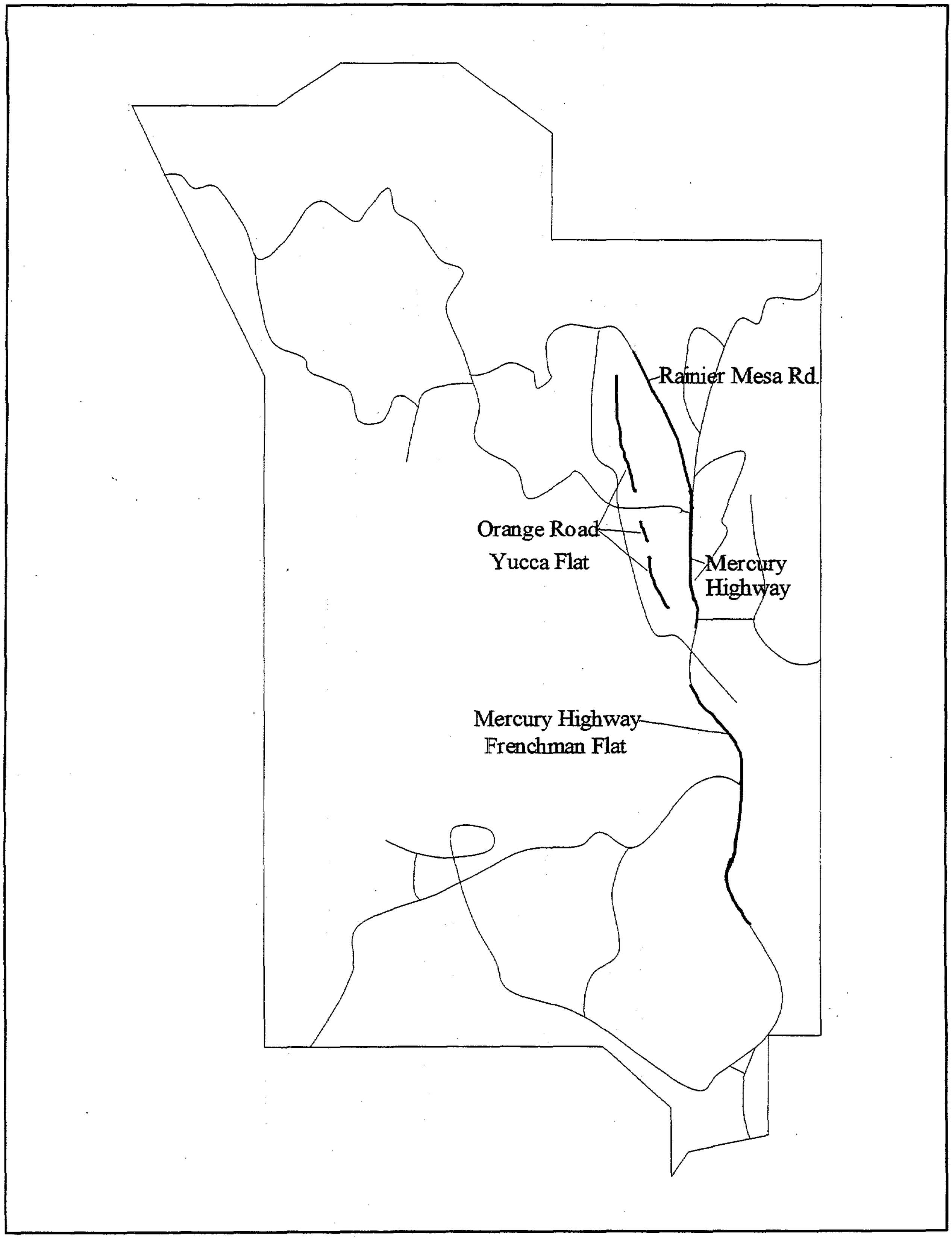

Figure 3-6. Roads on Frenchman and Yucca Flats (bold) where raptors were counted.

conducted between 0900 hrs and 1300 hrs on Frenchman and Yucca Flats during spring (March-June), summer (July-August), and fall (September-November). Because bird activity can be affected by time of day and temperature changes, sampling order for Frenchman and Yucca Flats were alternated throughout the year to compensate for any potential effects. Temperature, wind speed (m/sec), and cloud cover were also recorded for each sighting. Raptor surveys were not performed on windy (>7 m/sec), stormy, or excessively cold days (<5° C). Wind speed was measured with a hand held turbometer. Distances driven were measured by the vehicle's odometer.

Raptors were identified with the use of 7x power binoculars or spotting scope (20x). Time, location, and behavior (flying or perched) were recorded for each sighting. Perched birds were recorded as being in the sun or shade. Counts were expressed per unit distance (number per 100km).

Within seasons, the differences in relative abundance of species were tested between regions with a Wilcoxon paired signed-rank test. Chi square tests were used to determine if raptors chose shade positions on poles more often than expected over positions in direct sunlight during summer. Expected values used to examine frequency of shade use by raptors were based on equal probability (50% chance of using either shade or sunlit areas), even though sunlit areas were much larger than shaded areas on crossbeams. A list of common and scientific names of the birds is shown in Table 3-6.

Table 3-6. A list of common and scientific names of the birds cited in this report.

Common Name	Scientific name
Golden eagle	*Aquila chrysaetos*
Red-tailed hawk	*Buteo jamaicensis*
Northern Harrier	*Circus cyaneus*
Prairie Falcon	*Falco mexicanus*
American Kestrel	*Falco sparverius*
Burrowing Owl	*Speotyto cunicularia*
Chukar	*Alectoris chukar*
Common raven	*Corvus corax*

RESULTS

The most frequently sighted raptors along the standardized route were red-tailed hawks *Buteo jamaicensis*, golden eagles *Aquila chrysaetos*, and American kestrels *Falco sparverius* (Table 3-7). Prairie falcons *Falco mexicanus*, and turkey vultures *Cathartes aura*, were uncommon in 1994 along Mercury highway segments.

Table 3-7. Species composition of raptors (total number sighted) during standard road transects during 1994. Data from all roads included (N = 63 surveys). Percent of the total count in Parentheses.

	Frenchman Flat				Yucca Flat			
Species	Spr	Sum	Fall	Total	Spr	Sum	Fall	Total
Red-tailed hawk	10	7	3	20(74.1)	25	24	15	64(36)
Golden eagle	3	0	2	5(18.5)	10	12	19	41(23)
American kestrel	1	0	1	2(7.4)	13	19	5	37(20.8)
Prairie falcon	0	0	0	0	6	9	4	19(10.7)
Turkey vulture	0	0	0	0	4	2	1	7(3.9)
Northern harrier	0	0	0	0	1	0	3	4(2.2)
Burrowing owl	0	0	0	0	3	1	1	5(2.8)
Unidentified Buteo	0	0	0	0	1	0	0	1(0.6)
Totals	14	7	6	27	63	67	48	178
Number of surveys	8	8	5		8	8	5	

Spring = 17 March - 9 June, Summer = 7 July - 25 August, Fall = 14 September - 1 November. Orange Road data (N = 21 surveys) pooled with Yucca Flat.

Red-tailed hawks, golden eagles and American kestrels were the most commonly observed species along the Orange Road transect (away from pole lines). Northern harriers *Circus cyaneus*, and burrowing owls *Speotyto cunicularia*, were observed along Orange Road, but not along the Mercury Highway on Yucca Flat. On Yucca Flat, burrowing owls have commonly used culverts under roads for breeding sites in previous years and were observed near burrows in soft soil berms along roads in 1994. Relative abundance of raptors was significantly higher on Yucca Flat compared to Frenchman Flat for all seasons (Table 3-8).

Table 3-8. Relative abundance measures for raptors, (number/100 km $\pm$ 2 se), by season and region for roads with pole lines (Mercury Highway and Rainier Mesa Road) driven during 1994. N = number of surveys. Test results show value of T for Wilcoxan matched pairs signed-rank test.

Location	Spring	Summer	Fall
1-Frenchman Flat Mercury Highway	7.6 ± 4.1 N = 8	4.9 ± 4.5 N = 8	6.7 ± 5.5 N = 5
2-Yucca Flat Mercury Highway/RMR	24.9 ± 5.8 N = 8	34.0 ± 4.4 N = 8	31.1 ± 9.5 N = 5
Test Results 1 vs 2	T = 0, $P < 0.01$	T = 0, $P < 0.01$	T = 0, $P < 0.01$

From 179 observations of raptors made along the Mercury Highway on Frenchman and Yucca Flats combined, 93% (167) were perched on poles, 4% (7) were seen on wires, while only 3% (5) were flying when first observed. Turkey vultures and northern harriers did not perch on poles.

Raptors began using shade positions on poles during early June and this use continued through the end of August. Air temperatures on the ground measured during this period varied from a low of 28° C in June to a high of 39° C in late July. Perching raptors used shade on Yucca Flat predominantly during the summer. From June through August, only 13 hawks (all red-tails) were observed on Frenchman Flat. Only two were observed to use shade on poles.

Overall, each raptor species used shade and sunlit positions on poles differently on Yucca Flat during the summer ($\chi2 = 18.0$, 3 d.f., $P < 0.001$). Red-tailed hawks used shade (23 in shade, 8 in sun) on poles on Yucca Flat more often (non-randomly) than would be expected by chance alone ($\chi2 = 7.26$, 1 d.f., $P < 0.001$). However, during the summer on Yucca Flat, prairie falcons (10 in shade, 5 in sun : $\chi2 = 1.66$, 1 d.f., $P > 0.10$) and golden eagles (9 in shade, 4 in sun : $\chi2 = 1.92$, 1 d.f., $P > 0.10$), used poles randomly with respect to shade or direct sunlight. Conversely, American kestrels were perched in direct sunlight with greater frequency that would be expected due to chance (1 in shade, 12 in sun: $\chi2 =$

9.2, 1 d.f., $P < 0.01$). Throughout the year on Frenchman Flat, raptors rarely used shaded positions ($N = 4$) on poles.

DISCUSSION

The sighting rate of raptors (number/100 km) on pole lines on Yucca Flat in 1994 was about four times higher in spring and twice as high in summer compared to 1993 (Greger 1994). This suggests raptors were more abundant in 1994 than 1993. Overall, significantly greater numbers of raptors were seen on Yucca Flat compared to Frenchman Flat, suggesting relative abundance was higher there. On Frenchman Flat, counts of raptors were similar between years.

Red-tail hawks were the most frequently observed raptor perched on poles in 1994. Extensive use of poles suggests raptors may benefit from such use. Potential benefits include increased hunting success and body cooling through shade use. Preston and Beane (1993) reported that red-tailed hawks hunt mostly (60-80%) from an elevated perch. Furthermore, Ballam (1984) reported that red-tailed hawks had significantly higher hunting success from perches than from other forms of hunting such as flapping or soaring. In the Mohave desert, tall powerline towers may provide birds with a wider range of vision, easier takeoff, and greater attack speed when hunting prey on the ground (Knight and Kawashima 1993).

Raptors may benefit from cooling in summer by using shade on poles. Poles on the NTS are much higher (three to four times) than other available natural perches on the flats such as Joshua trees, and cooling may be more effective on higher perches (assuming air temperatures are lower) than lower perches during summer. Ballam (1984) reported that instead of soaring to thermoregulate, red-tails sought shade, became inactive, and began to pant when ambient temperatures reached 27° C. This agrees well with data collected on the NTS, where raptors often used shade on poles when ground temperatures exceeded 26-28° C.

OTHER BIRD MONITORING

METHODS

Known locations of active raven nests from previous years were checked for reproduction during April and May of 1994, and new nests were located and visited. Date, location, type of nest structure, numbers of eggs (when possible), nestlings, and fledglings were recorded for each visit.

Visits to selected springs on the NTS were made to estimate chukar abundance. A visual estimate of total numbers flushed was made upon arrival at each spring. Springs were visited during June and July.

Plastic lined ponds at UGTA sites were searched for dead birds and animals. Date, location, number of dead birds or mammals, and presence or absence of water, were recorded for each visit. Remains were identified when possible.

RESULTS

Ravens

Mean number of raven nestlings (± se) recorded for selected nests (N = 9) was 3.3 ± 0.58 with a range of 2-4 nestlings (Table 3-9). Ravens fledged 1 to 3 birds per nest.

Table 3-9. Common raven (*Corvus corax*) nests monitored for reproduction on NTS.

Final Date	Location	Nestlings	Fledglings
5-9-94	Frenchman Gravel Gertie Site, Area 5	-	0[1]
5-9-94	Huron King Structure, Area 3	3	3
5-10-94	Mid Valley Bunker, Area 16	2	-
5-24-94	Wood house, Area 1	-[2]	-[2]
5-26-94	Railroad Trestle Frenchman lake, Area 5	2	2
5-31-94	Casing Yard Garage, Area 6	3	3
6-2-94	White Elephant Structure, Area 9	-	3
6-2-94	North Frenchman Flat Structure, Area 5	2	0
6-2-94	Champagne Building, Area 3	4	1
6-2-94	Bilby Crater Structure, Area 3	4	3
6-2-94	Joshua tree nest, Area 1	3	3
6-7-94	Shaker Plant Building, Area 4	4	3
6-9-94	Trailer on 2-04 Road, Area 2	-[3]	1

[1] Nest blown off perch during storm . [2] Nestlings reported but number not verified and number fledged unknown. [3] Five eggs observed in nest on 4-20-94, number of nestlings unknown.

Over the past four years ravens used approximately 26 nest sites, 20 (77%) were on man-made structures and only 6 (23%) were on natural sites (Figure 3-7). Numerous nest sites were used in two or more consecutive years (Table 3-10).

Table 3-10. Annual use of selected nesting sites by ravens on the NTS from 1991-1994. X = young fledged; A = nesting attempt, but no young known to fledge.

Location	1991	1992	1993	1994
Gravel Gertie Poles, Area 5	X	X	X	A
Structure North of Waste Mgmt. Area 5		X	X	A
Mid-Valley Bunker, Area 14	X	X	X	X
Fuel Dock Structure, Area 6		X	X	
6-06 Road Joshua tree, Area 6	X	X		
Casing Yard Garage, Area 6	X	X	X	X
Champagne Building, Area 3	X	X		X
Huron King Structure, Area 3		X	A	X
U3CN Crater, Area 3	X	X	A	X
Shaker Plant Building, Area 4		X	X	X
White Elephant Structure, Area 9		X	X	X
Sample Mgmt. Bldg. Area 25		X	X	

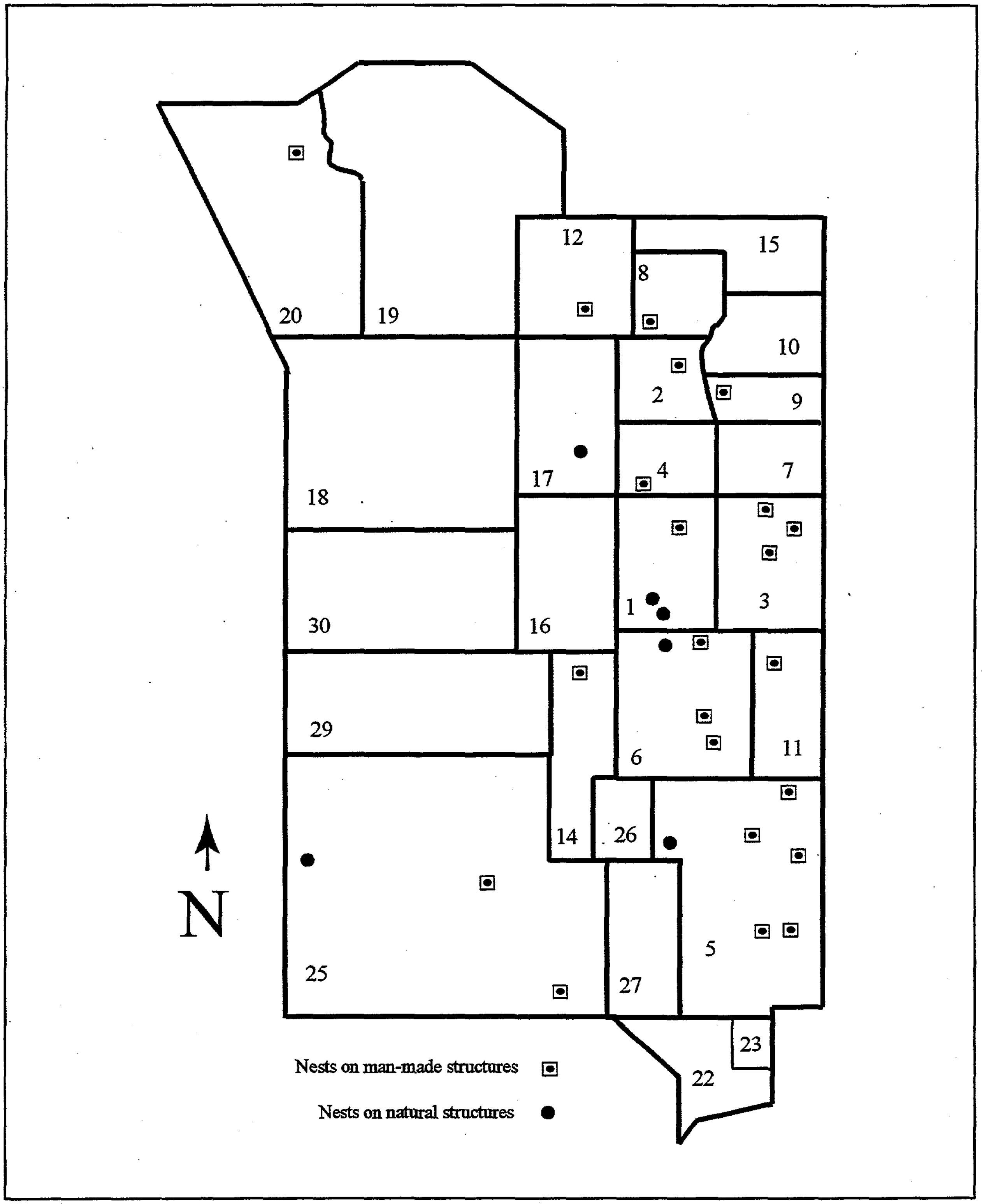

Figure 3-7. Approximate locations of active raven nest sites (N = 26) on the NTS from 1991-1994 .

Chukar Abundance

Results of observations of chukars at selected water sources on the NTS are shown in Table 3-11. Few birds were observed in 1994.

Table 3-11. Numbers of chukar (*Alectoris chukar*) observed at springs at the NTS during 1994. Counts are visual estimates of birds flushed on arrival at the water source. Gold Meadow Sump was dry when visited.

Date	Spring	Number
7 June 94	Tippipah	0
14 June 94	Topopah	30 to 50
6 July 94	Tub	0
11 July 94	Gold Meadow	0
12 July 94	Tippipah	20 to 25

UGTA Ponds

Results of visits to selected ponds to record dead animals and conditions are given in Table 3-12.

Table 3-12. Numbers of dead animals recorded on visits to lined ponds at UGTA Project well sites during 1994.

Date	Well	Number dead	Water present	Comments
16 March	ER 10-J	0	Yes	
16 March	ER 6-1	2	Yes	Unidentified dead birds in pond
16 March	ER 6-2	0	No	
31 March	ER 6-1	5	Yes	Dead ducks in pond
4 April	ER 10-J	0	Yes	
9 May	ER 6-3	3	No	Dead coyotes in pond
9 May	ER 6-2	0	No	

Table 3-12. (continued)

Date	Well	Number dead	Water present	Comments
12 May	ER 12-1	0	No	
12 May	ER 19-1	0	Yes	Both ponds with water
31 May	ER 19-1	0	Yes	
11 July	ER 19-1	0	Yes	Both ponds with water
28 July	ER 10-J	0	No	
11 August	ER 19-1	0	Yes	Water level low
20 September	ER 19-1	0	Yes	Water in one pond
26 October	ER 6-1	0	No	Ponds dry since August
1 November	ER 10-J	0	No	Ponds dry since July

DISCUSSION

Ravens used numerous man-made structures on the NTS for perching and breeding. These included poles, bunkers, old buildings, large containers, storage garages, some of which no longer had any functional purpose. Ravens have fledged young from nests on ten or more man-made structures in consecutive years (Table 3-10) suggesting these structures may have some positive impact for local raven populations. Few nests on natural sites have been located for comparison (Figure 3-7). Ravens may benefit from structures because shade provided may enhance survival of young. Because ravens could impact tortoises, DOE might consider making some of these nest sites inaccessible to ravens. On some sites removing poles, boarding up openings, or closing doors would make them unusable to ravens. Removals of large structures would be much more expensive.

Relatively few dead animals were recorded in UGTA ponds during the year, indicating negligible effects on species populations. The presence of coyote remains in ER 6-3 seemed rather inexplicable. Numerous ponds appeared to be dry by mid-summer 1994, which would greatly reduce impacts to birds during fall migration.

Causes of deaths of aquatic species such as ducks and grebes are unknown. One hypothesis is that detergents used to remove fill during drilling operations may remove protective oils from certain bird species causing hypothermia and inhibiting flying, trapping them within the steep slopes of the pond. Proximate causes of bird deaths should be investigated.

Limited observations at springs suggest that chukar populations levels on the NTS in 1994 were too low to warrant removals by NDOW. Local chukar populations may decline in years following sparse rainfall if food becomes limited or if springs dry up. Habitats around Topopah Spring have supported the largest concentrations of chukar known at the NTS. Hundreds of chukars were observed at Topopah Spring in 1989 during single visits (Greger and Romney 1994a), but very few were observed in 1994.

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STATUS OF EPHEMERAL PLANTS ON THE NEVADA TEST SITE, 1994

by

Richard B. Hunter

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ABSTRACT

Ephemeral plants have been monitored on the NTS in order to determine trends in undisturbed populations and to monitor effects of DOE operations on those populations. In 1994 six undisturbed populations scattered over the NTS were sparse, producing 0 to 1.6 ± 1.5 g/m^2 by May, consistent with low winter rainfall. Regression equations, which crudely predict ephemeral biomass from rainfall data, were derived for Yucca Flat ($r^2 = 0.81$) and Rock Valley ($r^2 = 0.90$) baseline plots.

Effects of DOE operations were examined at five sites of above-ground nuclear explosions, one scraped and leveled drill pad, and a revegetated waste-cleanup site. For comparison, a rodent-denuded area and an area of hand removed shrubs were examined. Wherever shrubs and other perennial plant live volume was reduced, ephemeral population densities were greater than controls, regardless of cause of removal. On disturbed areas, when shrubs had recovered to near-control live-volumes, ephemeral numbers and biomass were not different from undisturbed areas.

Effects of introduced brome-grasses on native populations in the lower altitudes were examined on four plots where the *Bromus* species were partially removed. Only one plot showed significant increases in native species. In Mercury Valley, the small native grass *Vulpia octoflora* was approximately 20 times as dense on the removal plot as on the control. In addition, in Rock Valley, the short-lived herbaceous perennial *Eriogonum inflatum* survived better from previous years on the *Bromus* removal plot. Other species germinated in 1994 in densities too low to test for significant effects.

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INTRODUCTION

Goals of ephemeral sampling in 1994 were:

- Monitor long-term trends in NTS ephemeral populations.
- Determine changes in ephemeral populations related to DOE activities.
- Distinguish between the effects of DOE operations and the effects of competition by exotic species on native NTS ephemeral populations.

The year 1994 was the eighth consecutive year of ephemeral plant monitoring on the NTS under BECAMP, funded by DOE. Monitoring results for 1987 through 1993 were reported by Hunter and Medica (1989) and Hunter (1992, 1994a, b, c). The program examines ephemerals on both baseline and disturbed areas, with most disturbance plots sampled on a three-year cycle.

In 1994, 28 sites were sampled, including all five baseline sites and one historical monitoring plot. DOE disturbances were studied at sites of four atmospheric nuclear tests (T-sites) and one underground cratering test (SEDAN), a scraped and compacted drill pad, and one cleaned and revegetated waste site. Four plots were sampled around the Device Area Facility (DAF), which was being completed in northern Frenchman Flat. Those studies are reported separately (Woodward et al. 1995). Herbicide study plots associated with some of the baseline and disturbance plots were also resampled. Because many plot groups consisted of two or three plots there were only 16 independent locations.

STUDY SITES AND METHODS

Locations of sites sampled for ephemerals in 1994 are shown in Figure 4-1. The site designations, and their disturbance and vegetative characteristics are shown in Table 4-1. Latitudes and longitudes of the plots can be found in Saethre (1994, Appendix D).

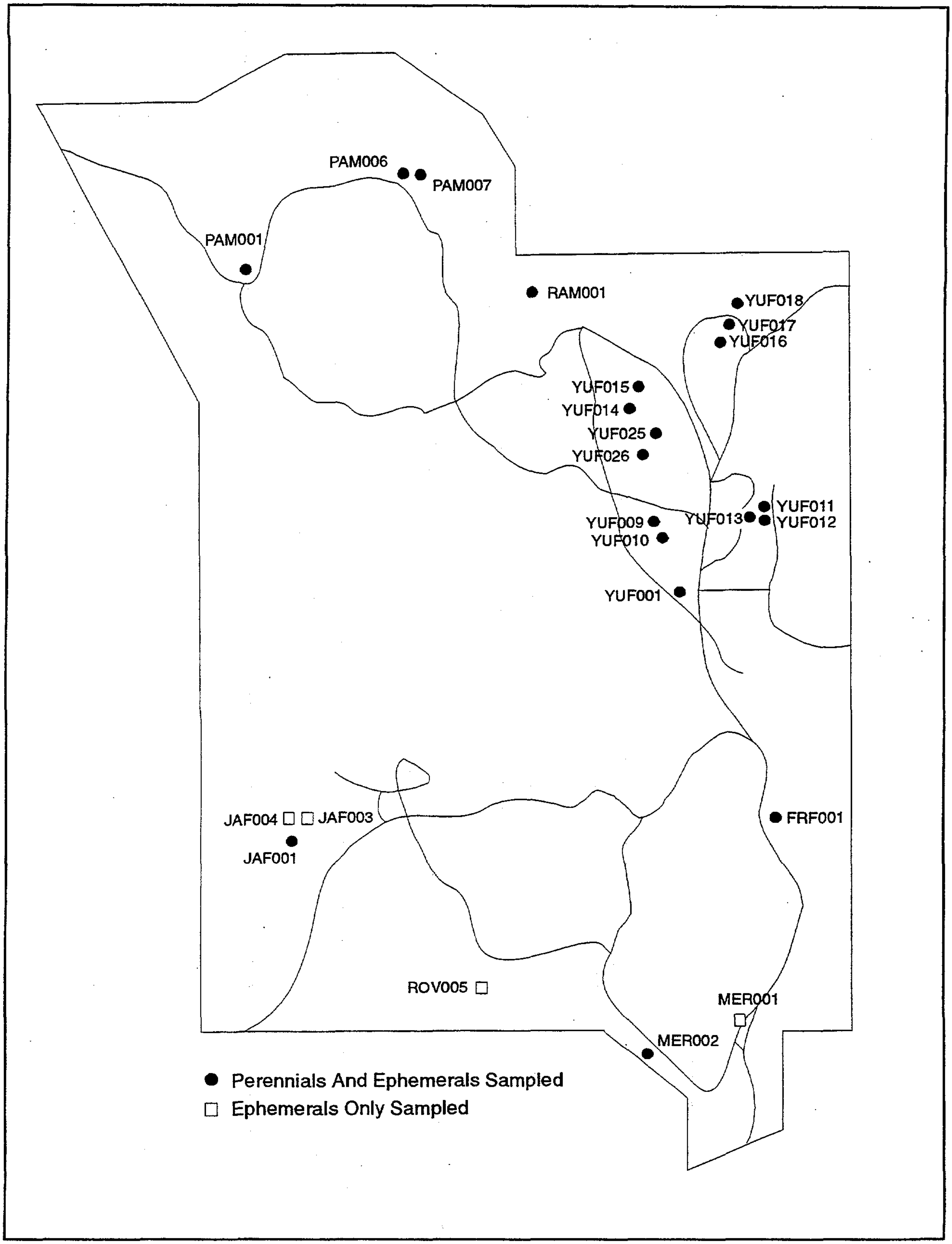

Figure 4-1. Ephemeral plant study sites in 1994.

Table 4-1. NTS plots sampled for ephemerals in 1993.

Site designation	Location	Type - shrub community	Elevation (meters)
JAF001	Jackass Flats	Baseline - *Larrea/Ambrosia*	954
FRF001	Frenchman Flat	Baseline - *Larrea/Ambrosia*	965
ROV005	Rock Valley	Beatley plot 3 - *Larrea/Ambrosia/Grayia/Lycium*	1036
YUF001	Yucca Flat	Baseline - *Grayia/Lycium*	1237
PAM001	Pahute Mesa	Baseline - *Artemisia nova*	1923
RAM001	Rainier Mesa	Baseline - Pinyon Forest	2283
FRF001x	Frenchman Flat	Herbicide - *Larrea/Ambrosia*	965
MER002x	Mercury Valley	Herbicide - Gopher area	1076
ROV005x	Rock Valley	Herbicide - *Larrea/Ambrosia/Grayia/Lycium*	1036
YUF001x	Yucca Flat	Herbicide - *Grayia/Lycium*	1237
DAF	North Frenchman Flat	(Multiple sites) *Larrea/Ambrosia* to *Coleogyne/Yucca*	±1150
MER001	Mercury Valley	Shrub removal plot - *Larrea/Ambrosia*	1161
JAF003	Jackass Flats	Gopher area - *Stanleya*	963
JAF004	Jackass Flats	Gopher control - Beatley 7 - *Larrea/Ambrosia*	963
YUF009	Yucca Flat	T1 blast area	1279
YUF010	Yucca Flat	T1 Control - *Grayia/Lycium*	1267
YUF011	Yucca Flat	3B revegetated site	1242
YUF012	Yucca Flat	Control T3 & 3B - *Tetradymia*	1239
YUF013	Yucca Flat	T3 blast area	1236
YUF014	Yucca Flat	T2 blast area	1371
YUF015	Yucca Flat	T2 control - *Grayia/Lycium*	1338
YUF016	Yucca Flat	Sedan throwout area - grasses	1318
YUF017	Yucca Flat	Sedan blast area - *Hymenoclea*	1327
YUF018	Yucca Flat	Sedan control - *Coleogyne*	1335
YUF025	Yucca Flat	T4 blast area - *Hymenoclea*	1317
YUF026	Yucca Flat	T4 control - *Grayia/Lycium*	1320
PAM006	Pahute Mesa	U19ac drill pad - grasses	2134
PAM007	Pahute Mesa	U19ac control - Pinyon forest	2134

WEATHER AND GERMINATION

Rainfall data were supplied by the National Oceanic and Atmospheric Administration, Weather Service Nuclear Support Office. It routinely monitors rainfall at fifteen sites scattered around the NTS.

Soil moisture was monitored with Colman Fiberglass block electrical resistance probes (Soil Test, Lake Bluff, IL), using techniques reported in Hunter and Greger (1986). Assumptions used to convert readings to soil moisture were significant simplifications and are discussed in Hunter (1994b, c). Searches for newly germinated seedlings were made after measuring electrical resistance of the probes and results were recorded on the same data sheet.

SITE SELECTION

Sites disturbed by DOE activities were all selected between 1987 and 1990. They were placed either in locations of previous plant or animal studies (T1, T2, revegetation site, and Sedan) or in locations selected as representative of the whole disturbed area and far from any edges. Sites for ephemerals were near, but not within the mammal trapping grids. The size limitations for the trapping grids were more stringent than the requirements for ephemerals and took precedence in site selection. Plots on the T-sites were several hundred meters from the nearest undisturbed vegetation, on areas thought not to have been subsequently disturbed. Control plots were 50 to 100 meters from the edge of the disturbance being studied, but were sometimes closer to later disturbances such as dirt roads or buried cables.

The drill pad was approximately 10 ha in size and was adjacent to the frequently graded Dead Horse Flats Road and a power line. The graded area selected was on the north side, outside a fenced potential crater area and approximately centered between the roadside disturbance and the western undisturbed edge, approximately 50 meters away. The control was about 200 m east in undisturbed pinyon-juniper forest.

The 4-ha revegetated site was cleared of radioactive waste in 1988 and revegetated by UCLA in 1989. It was located next to the T3 blast area and shared its control plot.

The $\sim$200-m^2 shrub-removal plot and an adjacent control were set up by UCLA in 1985 in Mercury. Soil moisture probes were installed December 1984 - March 1985 and shrubs were removed in September 1985 with a mattock. New perennials growing on the shrub-removal plot have been removed annually, but annual plants were allowed to grow at will. The only disturbance has been weekly to bi-weekly measurement of soil moisture. Foot traffic has been minimized and was virtually limited to censusing the ephemerals in spring of each year. The control plot, which also had soil moisture probes, is 3-4 m from the shrub removal plot.

One relatively small gopher-denuded area in Jackass Flats was sampled in 1994. It is a bare area roughly 5 ha in size near the dirt road to J12 Well. Its control plot, approximately 100 m W, is Beatley Plot 7.

Herbicide plots were set up in 1989. Four pairs of circular plots, each 100 m^2 and surrounded by metal lawn-edging, were placed in four valleys in 1989. One is near Beatley Plot 3 in Rock Valley, one is on the rodent-denuded area in Mercury Valley, and two are near the baseline plots in Frenchman and Yucca Flats. Densities of *Bromus rubens* and *Bromus tectorum* were too low to warrant control measures until 1992, after which spot-applications of Ornamec®, a grass specific, fluazifop-based, herbicide (Hunter 1994b) were made. Spray was applied only under shrubs or in dense concentrations of *Bromus*, and was intended to reduce densities, but not eliminate the species. In 1994, the Rock Valley and Mercury gopher area plots were sprayed on March 14. *Bromus* was hand harvested from the Frenchman Flat plot at the time of census.

EPHEMERAL CENSUSES

The census technique involved counting and harvesting all plants within twenty 0.025-m^2 quadrats (15.8 cm x 15.8 cm) randomly placed along a 50-m tape. Harvested specimens were dried and weighed to determine mean biomass by species, and the numbers reproductive (with buds, flowers, or fruit) were recorded. Notes of grazing damage, diseases on the plants, and animal disturbances in the quadrats were recorded when present. For each quadrat, estimates were made of percent shade by shrubs, percent rock and litter on the surface, and percent of the quadrat on the soil mounds that build up under shrubs. Nested areas of 100 m^2 and 1000 m^2 surrounding the tape were then searched for the presence of species not encountered in the smaller areas. In 1994, species not found in the quadrats were counted in the 100-m^2 area, or in a portion of that area, to allow a crude density estimation on rarer species. Species thought to be potentially misrepresented by quadrat data were also counted in the 100-m^2 area to provide alternative estimates. Herbs from bulbs and rhizomes were sampled with ephemerals, using the same techniques.

The herbicide plots and shrub removal plots each had 25 instead of 20 quadrats harvested, and the whole plots (100 and ~ 200 m^2 respectively) were searched for rarer species, rather than

100 and 1000 m^2. Rabbit pellets were routinely counted in quadrats at the same time as ephemeral species were harvested. The purpose was primarily to ensure a careful search of the quadrats.

Plant nomenclature followed Kartesz and Kartesz (1980) after identification following Munz (1974) or Welsh et al. (1987) and comparison with herbarium specimens. *Salsola* is all referred to as *S. australis,* following Young (1991).

For species distributions and median densities, paired control/disturbance plots were considered a single site, and the density on controls was used to determine median density. For several species (*Bromus tectorum, Salsola australis, Eriogonum deflexum*), this excluded the densest concentrations, since they occurred in highest densities on disturbances. When both quadrat densities and counts in 100 m^2 were available, quadrat density was used.

In order to correlate seed production in *Bromus* species with biomass measured in quadrats, 19 each of *Bromus rubens* and *Bromus tectorum* were harvested along roads in northern Yucca Flat on May 3, 1994. Plants were selected to represent a range of sizes and were individually bagged and air-dried. Individual florets of both species were counted. Because many of the florets of *Bromus tectorum* appeared to be sterile, individual florets were subsampled and examined with a hand lens to check for viable seed.

Means and standard errors were calculated by the computer spreadsheet RS1 (BBN software). Students' t-tests were done by hand or in Microsoft EXCEL, assuming equal variances. Error estimates in the text are two standard errors of the mean, unless otherwise noted. Standard errors are provided as an indicator of variability, and were determined without checking for normal distributions. Actual plant distributions were quite patchy.

RESULTS AND DISCUSSIONS

WEATHER AND GERMINATION

Winter rainfall fell primarily from December through February and was relatively light on all areas (Table 4-2). Ephemeral germination occurred over several weeks from mid-January to mid-February, and somewhat later at higher elevations. Germination was greater under shrubs than in the open.

Table 4-2. Fall and winter rainfall (mm) on the NTS, September 1993 through April 1994 (NOAA - NTS Nuclear Support Office).							
AREA→	Mercury Valley	Rock Valley	Jackass Flats	Frenchman Flat	Yucca Flat	Pahute Mesa	Rainier Mesa
SEP	0.0	0.2	0.5	0.0	1.0	0.8	6.9
OCT	5.3	7.6	11.2	5.1	9.9	16.3	14.2
NOV	4.3	7.1	8.4	9.1	12.4	10.2	20.8
DEC	12.4	14.2	18.8	11.4	11.9	11.9	22.4
JAN	4.1	8.1	15.2	6.1	9.1	8.1	11.7
FEB	18.3	16.8	16.5	17.8	17.5	10.2	46.7
MAR	6.9	6.1	8.6	10.4	18.0	20.1	29.0
APR	8.1	4.1	12.4	10.9	6.6	20.1	25.1
TOTAL	59.4	64.3	91.7	70.9	86.6	97.5	176.8

Soil moisture levels in Mercury estimated for the top 30 cm reached a maximum of only 5.9 mm in mid-February (Table 4-3), compared to 47.2 mm in late January 1993. Very sparse germination occurred in mid-February.

Table 4-3. Soil water available to plants (mm) in the top 30 cm in Mercury, Nevada.					
DATE	RAINFALL	mm H_2O	DATE	RAINFALL	mm H_2O
7 JUL 93		-0.6	13 JAN 94		4.5
12 AUG		0.0	3 FEB	6.9	5.2
9 SEP		-0.9	15 FEB	6.8	5.9
27 SEP		-0.9	3 MAR	4.7	3.5
7 OCT		1.6	17 MAR	0.2	1.8
14 OCT	5.2	1.6	5 APR	6.6	2.0
20 OCT		1.7	14 APR		1.1
9 NOV		2.5	21 APR		-0.1
16 NOV	3.8	3.8	19 MAY	8.1	1.4
22 NOV	0.7	3.8	26 MAY		-0.2
2 DEC	2.3	4.4	1 JUN	1.3	-0.4
14 DEC		5.7	16 JUN		-0.1
6 JAN 94	9.5	5.2	28 JUN		-1.3

BASELINE PLOTS

Yucca Flat

The Yucca Flat baseline site (YUF001), sampled annually since 1988, is representative of much of the NTS. Winter ephemerals germinated there in February, 1994, and persisted into early May. Mean biomass on April 26 was 1.6 ± 1.5 g/m^2 and mean density was 112 ± 96/m^2, both less than 10% of the previous year's values (Table 4-4). Almost the whole population (95% of number, 99% of biomass) consisted of the introduced weedy grass *Bromus rubens*.

Table 4-4. Species richness (number of species per 1000 m^2), densities (n/m^2 ± 2 se), and total above-ground biomass (g/m^2 ± 2 se) of spring ephemerals on the southwestern Yucca Flat baseline plot sampled in April, 1988-1994.

	1988	1989	1990	1991	1992	1993	1994
SEP-APR rain, mm	120	30	29	57	135	263	87
Species	21	0	0	22	35	32	13
Density, n/m^2	1956±1114	0	0	78±70	172±133	1762±689	112±96
Biomass, g/m^2	21±5	0	0	0.5±0.5	26±26	18±9	1.6±1.5
Shrub live volume m^3/100 m^2	16.7	15.6	11.6	10.9	11.9	19.2	18.3
% *Bromus* (n/m^2)	97	-	-	82	62	50	95
% *Bromus* (g/m^2)	86	-	-	86	61	61	99

Densities were highly correlated with the presence of soil mounds, wind-deposited accumulations of soil and litter that occurred under shrubs ($r^2 = 0.89$, $F_{1,18} = 139$, $p < 0.0001$). Densities were considerably higher in quadrats on mounds (260 ± 202/m^2) than in those without (13 ± 11) ($t_7 = 2.43$, $P = 0.05$). They were less correlated with shade ($r^2 = 0.20$; $F_{1,18} = 5.60$, $P = 0.03$).

Mean weight per plant for *Bromus rubens* was 13 ± 6 mg, and 57% of the population was producing seed. Only three *Bromus* occurred in quadrats without mound soil. Three quadrats with 44 of the 53 *Bromus* (83%) all occurred in quadrats shaded by *Lycium andersonii*.

OTHER BASELINE SITES

On most other baseline sites, ephemeral production was comparable to 1991 values when rainfall amounts were similar (Table 4-5). In Jackass Flats, however, densities were less than $2/m^2$, the threshold for detection with twenty 0.025 m^2 quadrats versus 164 $\pm$ 76 in 1991. Animal foraging might be responsible, as several grazed annuals and numerous small foraging pits were seen. In the 100-m^2 area there were 30 plants, primarily *Vulpia octoflora* (17) and *Bromus rubens* (9). There were also four *Menodora spinescens* and two *Acamptopappus shockleyi* shrub seedlings.

In Frenchman Flat, densities were very low (Table 4-5) and plants were small (12 $\pm$ 5 mg per plant). All annuals seen in the 100-m^2 area were counted. They were dominated by *Bromus rubens* (69 of 113) and *Chaenactis fremontii* (30).

At the Rock Valley plot (Beatley Plot 3) *Bromus rubens* densities were 40 $\pm$ $46/m^2$, which accounted for the total population. Ninety percent of the *Bromus* were in four shaded quadrats, only one of which was on a mound. In the 100- and 1000-m^2 areas, only one other species was seen, *Eriogonum inflatum* (2 in 100 m^2).

On Pahute and Rainier Mesas there were no ephemerals encountered in the quadrats. There were 16 in 100 m^2 on Pahute Mesa and 8 per 100 m^2 on Rainier Mesa, some of which were biennials and short-lived perennials, rather than strict annual plants.

Ephemeral densities from 1991 through 1994 did not closely track total rainfall amounts (Table 4-4, Table 4-6). The correlation coefficient between September-April rainfall and density for Yucca Flat 1988-1993 and the baseline sites 1991-1993 was 0.539, significantly different from a zero slope ($F_{1,13} = 5.32$, $P = 0.038$), but explaining an unsatisfying amount of variation ($r^2 = 0.35$). Biomass was highly variable from point to point, indicated by large error terms on baseline plots in dry years (Table 4-5). Distribution was more uniform, and error terms proportionately smaller, in years and places with high densities, such as 1988 and 1993.

Table 4-5. Sample dates, precipitation totals, densities, and mean biomass for BECAMP baseline sites, 1991-1994.

LOCATION	Jackass Flats	Frenchman Flat	Rock Valley	Pahute Mesa	Rainier Mesa
PLOT DESIGNATION	JAF001	FRF001	ROV005	PAM001	RAM001
ELEVATION m	954	965	1036	1923	2283
SAMPLE DATE - 1991	MAY 7	APR 11	APR 3	-	-
SAMPLE DATE - 1992	APR 8	APR 8	APR 16	May 27	Jun 24
SAMPLE DATE - 1993	APR 28	MAY 3	APR 29	JUN 3	JUL 22
SAMPLE DATE - 1994	APR 18	APR 13	APR 18	JUN 7	JUL 21
RAIN - 1991	98	57	83	-	-
RAIN - 1992	222	112	200	171	355
RAIN - 1993	268	179	259	124	372
RAIN - 1994	92	71	64	98	177
$n/m^2 \pm 2$ se - 1991	164 ± 76	18 ± 21	106 ± 62	-	-
$n/m^2 \pm 2$ se - 1992	164 ± 101	28 ± 14	386 ± 251	154 ± 61	1.5 ± 2.2
$n/m^2 \pm 2$ se - 1993	140 ± 68	898 ± 279	2118 ± 1009	64 ± 51	6 ± 9
$n/m^2 \pm 2$ se - 1994	<2	16 ± 13	40 ± 46	<2	<2
$g/m^2 \pm 2$ se - 1991	10 ± 10	0.1 ± 0.1	0.50 ± 4	-	-
$g/m^2 \pm 2$ se - 1992	7 ± 8	3 ± 4	24 ± 21	2.6 ± 1.4	2.6 ± 1.4
$g/m^2 \pm 2$ se - 1993	4.3 ± 2.2	57 ± 99	72 ± 36	1.2 ± 1.0	0.05 ± 0.07
$g/m^2 \pm 2$ se - 1994	0 ± 0	0.2 ± 0.2	0.2 ± 0.2	0 ± 0	0 ± 0

Discussion - Baseline Sites

In comparison with 1993, ephemeral population densities were reduced more than 90%, and therefore, were insignificant in terms of the population dynamics of the group. Populations on baseline plots were dominated by the few *Bromus rubens* that germinated, and germination was the factor controlling numbers. Rainfall was low and growth slight, so seed production was expected to be small.

With numbers controlled by germination conditions, it would be useful to know seed bank sizes for the different species. Although there is a small amount of information on seed bank sizes and germination requirements from the Death Valley area (Went 1949, Went and Westergaard 1949), no data is available for the NTS. Seed banks of both *Bromus* and the native species should have been largely determined by the productive 1992 and 1993 years (Table 4-5), seed predation by granivores, and time and microhabitat conditions prior to 1994 germination events.

There is enough data from two of the BECAMP study sites to derive simple regression equations to predict biomass of spring ephemerals from rainfall. Annual plants in Rock Valley have been studied since 1963 (data from J. C. Beatley and International Biological Program [IBP] studies published by Turner et al. are summarized in Hunter 1994a). Turner and Randall (1987) published an equation based on six year of IBP data useful for predicting Rock Valley annual plant biomass from September-March rainfall. Their data has been combined with BECAMP data to produce a revised equation, $\log(g/m^2) = 2.642 \times \log(\text{SEP-APR rain} - 25\text{ mm}) - 4.222$ ($r^2 = 0.895$, $p < 0.0001$), similar to Turner and Randall's $\log(g/m^2) = 1.976 \times \log(\text{SEP-MAR rain} - 26.2) - 2.746$.

For the Yucca Flat baseline plot, there are seven years of data, and a similar equation can be calculated, $\log(g/m^2) = 3.964 \times \log(\text{SEP-APR. rain} - 25) - 7.469$ ($r^2 = 0.81$, $P = 0.004$). Predictions of the two new equations versus actual measured values (Table 4-6) show considerable deviation from the measured values, but error terms on ephemeral production are large, associated with very high spatial heterogeneity. Either equation gives a qualitative idea of ephemeral plant production on either site. It is likely that those values lying outside the actual values $\pm$ 2 se are indications of factors affecting ephemeral production other than rainfall. Complicating factors (such as seed reserves, timing of precipitation, nutrient fluctuations, and competition with shrubs) may cause such excursions as the relatively high production in Yucca Flat in 1992 and the low 1993 production. Because they are based solely on rainfall, and the logarithmic relationship allows large errors at high rainfall amounts, these equations are not adequate as models to detect effects of DOE operations on ephemeral populations.

Table 4-6. September-April rainfall (mm) in Yucca Flat and Rock Valley compared to predicted and actual biomass production (g/m^2 dry weight) of winter ephemeral plants. The predictive equations based on YUF001 and ROV005 data are in the text.

YEAR	RAIN	Yucca Flat PREDICTION	Rock Valley PREDICTION	ACTUAL
YUCCA FLAT BASELINE PLOT				
1988	120	2.35	10.1	21±10
1989	30	0	0	0±0
1990	29	0	0	0±0
1991	57	0.03	0.57	0.5±0.5
1992	135	4.2	14.8	26±26
1993	263	89.5	114	18±9
1994	87	0.43	3.3	1.6±1.5
ROCK VALLEY, BEATLEY PLOT 3				
1987	167	11.6	29.2	18±10
1988	28	28.2	52.8	36±16
1989	18	-	-	0±0
1990	32	0	0	0.06±0.06
1991	83	0.3	2.77	0.5±0.4
1992	200	26.4	50.6	24±21
1993	259	83.7	109	72±36
1994	64	0.07	0.96	0.2±0.2

There was some indication that the ephemeral population on the Yucca Flat baseline plot might have been nutrient limited in 1994. The high correlation between numbers and mound soil is reminiscent of the "fertile island" hypotheses suggested by early observers such as Went (1942) and Muller (1953). The presence of the largest concentrations of *Bromus rubens* under *Lycium andersonii* shrubs is also significant. Studies of nitrate concentrations under desert shrubs showed values under *Lycium andersonii* (31 ± 9 and 86 ± 50 μg/g, mean ± 95% confidence limits) were considerably higher than under any other species (10 ± 9 for *Ephedra* *nevadensis* was next highest) or on bare soil (2 ± 1)(Hunter et al. 1982). An association with mound soil was not found on Rock Valley or Frenchman Flat baseline plots.

BLAST AREAS

In 1994, ephemeral plants on the blast areas were generally more abundant and produced greater biomass than did those on control sites nearby. However, on the T4 blast area, where shrub populations had recovered to near-control live volumes, density and biomass were approximately equal on blast and control areas (Table 4-7). Densities and biomass were also higher on several of the blast areas than on the Yucca Flat baseline plot (112 ± 96/m^2, 1.6 ± 1.5 g/m^2; Table 4-4).

Table 4-7. Winter ephemeral densities (n/m^2) and biomass (g/m^2) on Yucca Flat blast areas sampled April 21 - May 9, 1994. **Bolded pairs** are significantly different by t-test at $p \leq 0.05$.

SITE	PERENNIALS % OF CONTROL	n/m^2		g/m^2	
		BLAST	CONTROL	BLAST	CONTROL
T1	0.35	**1064±337**	**392±189**	**44±11**	**7.9±4.9**
T2	6.18	**676±224**	**222±171**	**47±18**	**7.1±4.9**
T3	0.11	**1372±513**	**92±75**	**14.7±4.2**	**3.6±3.5**
T4	90.84	204±120	350±255	16.5±10.3	24.5±13.1
SEDAN 1000'	2.91	**134±50**	**12±10**	**2.0±1.2**	**0.2±0.2**
SEDAN 3000'	72.26	**264±277**	**12±10**	**3.4±2.6**	**0.2±0.2**

There were significant differences between blast and control areas in numbers of species found per 0.025-m^2 quadrat (Table 4-8), which should be attributed to the general increase in density on the blast areas rather than to differences in total species. Total species on each site in the 1000-m^2 area were not significantly different (t_9 = 2.06, P = 0.07) between blast and control areas, although the data suggest numbers of species might be lower on the blast areas (Table 4-8).

Table 4-8. Ephemeral species per 0.025-m^2 quadrat and total species in 1000 m^2 on blast areas and nearby control sites. **Bold** indicates pairs significantly different ($p < 0.001$ in each case) by t-test.

SITE	SPECIES PER QUADRAT		TOTAL SPECIES	
	BLAST	CONTROL	BLAST	CONTROL
T1	2.2±0.5	1.6±0.4	10	24
T3	**2.2±0.5**	**0.9±0.4**	6	10
T4	1.6±0.6	1.4±0.6	19	26
T2	**2.5±0.5**	**1.0±0.3**	12	20
SEDAN 1000'	**1.2±0.3**	**0.3±0.3**	8	14
SEDAN 3000'	**1.4±0.5**	**0.3±0.3**	15	14

A few species were associated with either the blast or control areas. In particular, the density of *Bromus rubens* was often lower on the blast area than the control (T1, T3, T4), though on T2 it was significantly greater on the blast area ($t_{38} = 2.13$, $P = 0.05$). In contrast, *Bromus tectorum* was often denser on the blast areas (T1, T3, T2). *Erodium cicutarium* was denser on T4 blast area than on the control. *Salsola australis* was denser on blast areas than controls (T3, Sedan 1000', Sedan 3000') (see Appendix B for details). Five species were found only on blast areas and 16 only on controls, but densities were too low to test for significant differences (see Appendix A for details).

Discussion - Blast Areas

Ephemerals were sampled on blast areas in 1990, 1991, and 1994, all relatively dry years. Within that limitation, the results appeared the same in all years. There were denser populations of ephemerals on the blast areas than on the controls, and biomass produced was greater on the blast areas. As note by Hunter (1994a), similar results were found on 18 of 22 pairs of sites where shrubs had been removed from one of the pair by blast, fire, scraping, or gophers. Thus ephemerals are limited by shrubs, not by type of disturbance.

Biodiversity, which can be expressed as species richness (numbers of species in a defined area, Tables 4-4, 4-8), is an important property of the ephemeral populations. Greater numbers of species per quadrat on the blast areas appeared to be an effect of increased density of most species rather than increased total species on the blast areas. There were more species per quadrat on the blast areas, but with 1000-m^2 sample areas there were more on the control areas. The reduced environmental heterogeneity present on the blast areas, as a result of shrub removal (and hence shrub cover and mound removal - Appendix B), may reduce the total numbers of species found on the blast areas. Since most ephemeral species are relatively rare and the sampling technique was intended to survey group properties, many species data were insufficient to demonstrate a dependence on shrubs, mounds, or even association with blast or control areas. For example, only the most common species, primarily the introduced grasses and *Salsola australis,* could be shown to be more frequent on either control or blast areas. Investigation of species diversity relationships on the blast areas would take different and more species-specific study techniques.

The process favoring ephemerals on the blast areas is probably reduced use of water by shrubs, and thus greater growth and seed production by ephemerals. Plant competition, however, is a complex phenomenon involving many correlated variables (Harper 1977), and it would be difficult to prove water was the most important variable. No data are available on water use by ephemerals or water availability to ephemerals on the blast areas.

SHRUB-REMOVAL PLOT

Total ephemeral density, total biomass, and numbers of species were consistently greater on the plot with shrubs removed since sampling began (Table 4-9). In 1994, density was significantly greater ($t_{48} = 7.1$, $P < 0.0001$), total biomass was significantly greater ($t_{48} = 1.98$, $P = 0.054$), and species per 0.025 m^2 quadrat was significantly greater (bare $= 1.72 \pm 0.29$ shrub $= 0.08 \pm 0.11$; $t_{48} = 10.4$, $P < 0.0001$). For the fifth consecutive year, when germination occurred, there were more species on the shrub-removal plot than on the control ($P > 0.10$, sign test). *Bromus rubens* remained reduced in density on the bare plot, but two other introduced species, *Erodium cicutarium* and *Schismus arabicus,* made up 89% of numbers and 83% of biomass on the plot. There were more than 30 of a native species, *Eriogonum inflatum,* on the bare plot, but only four were seen on the whole area of the control, suggesting it too was favored by shrub removal ($X^2=19.9$, $p<0.001$).

Discussion - shrub-removal plot

The significance of the shrub-removal plot data lies primarily as a comparison to results on the blast areas. Disturbance on the blast areas was by repeated nuclear weapons explosions, while that on the shrub-removal plot was by hand (mattock and hand-pulling). The similarity of results - increased ephemeral numbers, biomass, and species per quadrat - suggests the effects on the blast areas can be explained solely by the removal of shrubs.

Table 4-9. Ephemeral population characteristics on a plot with shrubs removed in 1985 and its adjacent control in Mercury, 1986-1994. In 1989, there was no germination on either plot. Rainfall is total for SEP-APR, error terms are ± 2 se.

YEAR →	1986	1987	1988	1990	1991	1992	1993	1994
RAINFALL	139	103	157	36	74	156	201	59
SAMPLE DATE	3/28	4/14	4/05	4/04-5	4/04	4/28-29	4/26-7	4/07
SHRUBS REMOVED								
n/m²	1099 ±577	616 ±401	3070 ±1044	8±7	269±151	594±178	5296 ±1439	423±117
g/m²	21±10	36±17	32±11	0.08±0.08	0.54±0.26	27±11	40±8	2.0±0.7
mg/plant (*Bromus*)	25±6	70±31	12±2	4	-	76	37±12	3±1
spp./0.6 m²	12	14	17	3	8	19	22	6
spp./plot	-	-	-	5	22	35	35	10
Bromus, % of n	72	74	62	25	0	0.5	0.7	6
CONTROL								
n/m²	358±191	395±249	581±306	0	22±16	58±24	868±345	5±7
g/m²	2.6±1.5	5±4	10±5	0	0.04±0.02	2.7±1.5	22±13	0.02±0.04
mg/plant (*Bromus*)	13±3	14±2	25±4	-	2.1±0.2	134	27±10	6
spp./0.6 m²	7	6	11	0	3	9	18	2
spp./plot	-	-	-	2	12	32	32	3
Bromus, % of n	47	89	76	-	43	3	8.5	66

Another possible comparison is between blast areas and burned areas. In both cases, large areas of shrubs were removed and annual plants quickly appeared (Shields et al. 1963, Hunter and Medica 1989). Ephemeral populations on blast and control sites in 1994 were significantly different (Table 4-8), but in 1993 burned areas did not differ from controls (Hunter 1994c). Explanations of the disparity might include the more recent disturbance on the burned areas, which were denuded by fire between 1985 and 1988, and the differences in weather between 1993 and 1994. The longer time period without shrubs on the blast areas might have allowed ephemeral populations to differentiate more from controls. Alternatively, the relatively large amount of rainfall received in 1993 may have minimized the differences between bare and shrub-populated sites on the burned areas. However, ephemeral populations on the shrub-removal plot increased the first season after shrub removal and showed significant differences in density and biomass from the control plot in both the wet 1993 and dry 1994 (Table 4-9). Shrub removal plot results, therefore, do not upport either explanation and imply there was some other difference between burned areas and those disturbed by nuclear weapons.

Dominance by *Erodium cicutarium* on the shrub removal plot may be related to the seed burial mechanism for this species. Its seeds tend to bury themselves with winding and unwinding of the coiled style after separation. When germination is poor due to light rains, as in 1994, *Erodium cicutarium* is often one of the few species to germinate. *Erodium cicutarium* was also an early invader on the T2 blast area (Shields et al. 1963) and one area west of the Sedan blast (H. O. Hill, personal communication). It is a European species introduced to Southern California prior to the late 18th century (Frenkel 1970).

RODENT-DENUDED AREA

Ephemerals on the Jackass Flats rodent-denuded area were denser, produced more biomass, and included more species per quadrat than on the control (Table 4-10). Mean plant size was also greater on the denuded area.

Table 4-10. Ephemeral population characteristics on a Jackass Flats rodent-denuded area and its control in 1994. Error terms are 2 se. (**Bold** pairs differ by t-test at $P \leq 0.01$.)

	RODENT-DENUDED	CONTROL
n/m^2	**118 ± 36**	**6.0 ± 6.6**
g/m^2	**8.0 ± 3.9**	**0.11 ± 0.15**
mg/plant	**0.09 ± 0.05**	**0.019± 0.017**
total species	15	7
species/quadrat	**1.2 ± 0.3**	**0.15 ± 0.16**

Species composition differed considerably between the two sites. The majority of the control population was made up of *Bromus* species (67% in quadrats, 85% of those counted in 100 m^2), while the majority of the rodent area population consisted of a below-ground herbaceous perennial, *Tiquilia plicata*. The other two species found in the rodent area quadrats were also short-lived perennials, *Machaeranthera canescens* and *Astragalus lentiginosus* var. *micans/variabilis*. In 100 m^2, there were 22 *Bromus tectorum* and 1 *Bromus rubens,* in proportions significantly different from the control (17 *Bromus tectorum* versus 66 *Bromus rubens;* $\chi^2 = 43.8$, $P < 0.0001$). There were also 111 *Euphorbia albomarginata*, another below-ground herbaceous perennial, and 14 *Anisocoma acaulis* on the gopher plot, but none on the control.

Two of the 20 quadrats fell on old gopher mounds and one other fell on an "animal disturbance." No animal activity was noted at any of the 20 control quadrat locations.

Discussion - Rodent-denuded Area

This plot has only been sampled in relatively dry years (1989 and 1994), hence the results lack generality. Population characteristics were similar to other areas with shrubs removed. Some of the species appeared specifically associated with the particular disturbance, suggesting rhizomatous perennials like *Tiquilia plicata* and *Euphorbia albomarginata* may be particularly well suited to disturbance by gophers and other rodents. Those two rhizomatous perennials were the only "ephemerals" sampled in 1989 below 1300 m (on this same site - Hunter 1994a), when drought prevented germination of seeds. *Tiquilia plicata* shoots increased in density between 1989 and 1994 from 26 $\pm$ 7 to 106 $\pm$ 35 per square meter ($t_{38} = 4.48$, $P = 0.0001$).

Anisocoma acaulis has rarely been seen on BECAMP plots. It was noted in 1993 in Frenchman Flat associated with roadside disturbance (Hunter 1994c), and in 1992 in one of three subsidence craters sampled in Yucca Flat (Hunter 1994b). Soils were sandy in all three areas.

REVEGETATION SITE

Only two species were found in quadrats, *Salsola australis* (172 $\pm$ 90) and *Eriogonum deflexum* (18 $\pm$ 21/m^2). One plant each of two others, *Descurainia sophia* and *Astragalus lentiginosus var. Fremontii,* was found in 1000 m^2. The ephemeral population was approximately equivalent to the control in density (190 $\pm$ 95 versus 92 $\pm$ 75/m^2) and biomass

(3.0 ± 1.8 versus 3.6 ± 3.5 g/m^2). Species composition on the revegetated site was like that on the adjacent T3 blast area, which also consisted primarily of *Salsola australis* seedlings (Appendix B). The low diversity (total of four species) contrasted with 12 species found on the same site in 1991 (Hunter 1994a), 10 on the control, and six on T3.

Discussion - Revegetation Site

Density and biomass of ephemerals on the revegetated site were comparable to values on the adjacent undisturbed control. This suggests the shrub population, whose live volume exceeded that of the control in 1994 (Hunter 1995), was limiting ephemeral growth. Since many more species were seen in 1991, most species presumably did not germinate, suggesting the shrubs transplanted to the site were significantly depleting available soil water five years after planting.

DRILL PAD

Densities on the drill pad were comparable to control values (12 ± 13 versus 12 ± 12/m^2), as was biomass (0.15 ± 0.18 versus 0.40 ± 0.44 g/m^2), mean size per plant (14 ± 12 versus 32 ± 16 mg/plant), and species per quadrat (0.25 ± 0.25 versus 0.20 ± 0.18). Species seen on the drill pad were largely introduced weeds (*Salsola australis, Sisymbrium altissimum, Bromus tectorum,* and *Descurainia sophia*). On the control, the most frequent species was *Phlox stansburyi,* a rhizomatous perennial. Total species were 9 on the drill pad and 14 on the control. The only species common to both sites was *Astragalus lentiginosus var. Fremontii.*

Discussion - Drill Pad

At 2134 m, annual plants and herbaceous perennials make up a small part of the total vegetation (see perennials report). The presence of the weedy introduced species on the drill pad, but not on the control can be attributed to clearing of the normal forest vegetation. Recovery of the perennials appeared to be rapid on this site and the ephemerals declined dramatically. (In 1991, *Salsola australis* at 2562 ± 694/m^2 made up 98% of the population; it was only 6 ± 6/m^2 [50%] in 1994 [Hunter 1994a]).

HERBICIDE PLOTS

Ephemeral densities on the herbicide plots were uniformly low in 1994, consistent with the low rainfall and observations elsewhere. On control plots, *Bromus* densities ranged from 3%

to 26% of 1993 values, while native species ranged from 0.2% to 4% (Table 4-11; Hunter 1994c). *Bromus* was essentially absent both years on the Frenchman Flat sprayed plot and ranged from 10% to 31% of control densities on the other three treated plots. *Bromus* densities were significantly lower than controls on the Rock Valley and Yucca Flat sprayed plots but not on the Frenchman Flat and Mercury Valley plots.

Table 4-11. Ephemeral densities (n/m^2) and biomass produced (g/m^2) on herbicide and control plots in 1994. **Bold** pairs are significantly different by t-test at $P \leq 0.05$.

PLOT	*Bromus*		Natives	
	SPRAYED	CONTROL	SPRAYED	CONTROL
$n/m^2 \pm 2$ se				
Rock Valley	**13 ± 11**	**134 ± 47**	5 ± 5	3 ± 4
Mercury	128 ± 52	414 ± 323	**205 ± 72**	**67 ±22**
Frenchman	3 ± 4	2 ± 3	2 ± 3	2 ± 3
Yucca Flat	**29 ± 32**	**184 ± 138**	13 ± 9	6 ± 6
$g/m^2 \pm 2$ se				
Rock Valley	**0.1 ± 0.1**	**1.0 ± 0.5**	-	0.01 ± 0.01
Mercury	**2.3 ± 1.5**	**8.1 ± 4.9**	4.4 ± 2.2	2.3 ± 1.5
Frenchman	0.04 ± 0.06	0.1 ± 0.2	0.01 ± 0.02	0.01 ± 0.01
Yucca Flat	0.7 ± 0.7	2.9 ± 2.5	0.09 ± 0.07	0.12 ± 0.13

Only on the Mercury gopher area herbicide plot did enough native annuals germinate to suggest an effect of herbicide application. There, the small native grass, *Vulpia octoflora* was found at 110 ± 61/m² on the sprayed plot and only 5 ± 7/m² on the control ($t_{48} = 3.4$, $P = 0.001$). *Bromus rubens* densities were 31% of those on the control and *Bromus* biomass was significantly reduced on the sprayed plot (Table 4-11; $t_{48} = 2.42$, $P = 0.02$). Densities of all native species combined on the Mercury plots were significantly higher than on the controls ($t_{48} = 3.7$, $P = 0.0006$), largely a result of the *Vulpia* germination.

Mean weight per plant may have been lower for *Vulpia octoflora* on the Mercury control plot (2.5 ± 1.0 mg) than on the sprayed plot (5.6 ± 1.1 mg; $t_{19} = 1.94$, $P = 0.07$). Sizes were equal on those two plots for *Bromus rubens* and *Euphorbia albomarginata*, the other two species with densities high enough to test for size differences.

On the sprayed Mercury plot, the percent of *Bromus* plants with buds, flowers, or fruit was reduced (20 ± 16% versus 65 ± 16%; $t_{36} = 3.8$, $P = 0.0005$). *Vulpia octoflora* plants on both plots were all reproductive, suggesting the *Vulpia* is relatively insensitive to fluazifop.

Although native ephemerals were very rare on the Rock Valley herbicide plots, the short-lived perennial *Eriogonum inflatum* differed on the two plots. On the 100-m^2 sprayed plot, 57 live and one dead *Eriogonum inflatum* were counted, while on the control plot there was one live and 20 dead ($\chi^2 = 69$, $P < 0.0001$). Both live and dead plants were at least one year old, most having flowered, but the dead ones were dried out with no green parts.

Discussion - Herbicide Plots

As in previous years, the four pairs of herbicide plots behaved differently. Germination of native species was poor in Rock Valley, Yucca Flat, and Frenchman Flat and, except for the expected reduction in *Bromus* density in Rock Valley and Yucca Flat, little could be determined from sampling. On the Mercury plots, more plants germinated and densities of the various species ranged from 4 to 13% of the previous year's values. Densities have previously been high on this gopher area (Hunter 1992), and the increased germination may reflect a larger seed bank. The surprising 237-fold increase in *Bromus* density there from 1992 to 1993 (Hunter 1994c) suggested better seed burial on this rodent-denuded site might be a factor in maintaining high density populations. A large seed bank and improved mixing of seed with surface soils might explain the single-year effectiveness of the herbicide treatment there, which contrasted with multi-year density reductions on the Rock Valley and Yucca Flat plots (Hunter 1994c, Table 4-11).

There was a difference in *Vulpia octoflora* densities between the two Mercury plots in 1992, the first year these plots were sprayed (55 ± 34 versus 4 ± 6; $t_{40} = 2.95$, $P = 0.005$), but not in 1991 (8 ± 4 versus 2 ± 2, not significant) or 1993 (984 ± 508 versus 356 ± 559; $t_{40} = 1.66$, $P = 0.10$), when it was not sprayed and *Bromus* densities were equal on the two plots (Hunter 1994a, b, c).

In the early- and mid-1970s, *Vulpia octoflora* was the densest species of annual plant on Rock Valley IBP study plots (Turner and McBrayer 1974, Turner 1976). In the late 1980s and early 1990s it has been greatly exceeded in density by *Bromus rubens*. Results on the Mercury

Valley herbicide plot, where *Vulpia* increased on the sprayed plot relative to the control plot, suggest that *Bromus* does significantly compete with *Vulpia*. It may inhibit germination of *Vulpia*, or it may reduce size, and therefore seed production, reducing the size of the *Vulpia* seed bank.

The differences in *Eriogonum inflatum* populations on the Rock Valley herbicide plots suggests that *Bromus* competes with the larger ephemeral species, perhaps by rapidly drying the surface soil in late spring. It raises the question whether it may similarly prevent establishment of shrub and perennial grass seedlings (Hall 1994).

ANCILLARY OBSERVATIONS

Of 89 total species identified from all sampled locations, the most frequently encountered was *Bromus rubens* (Table 4-12), as in 1992 and 1993 (Hunter 1994b, c). (In 1989-91 it was seventh, though its median density was highest [Hunter 1994a].) *Bromus tectorum* was as frequently encountered, though at lower median density. It appeared in 1994 at several lower elevation sites where it was absent in 1988.

Table 4-12. The ten most frequently encountered ephemeral species on the NTS in 1994, with number of sites (of 16) occupied, ranges in elevation (m), and median densities (n/m^2) on the occupied plots.

SPECIES	# of sites	RANGE (m)	median density
*Bromus rubens**	13	954-1371	40
*Bromus tectorum**	13	965-2283	0.09
Astragalus lentiginosus	12	963-2283	0.07
Machaeranthera canescens	10	963-1923	0.87
*Salsola australis**	9	963-2134	2
Eriogonum deflexum	9	965-2134	2
Chaenactis stevioides	9	963-1371	0.36
Mentzelia albicaulis	9	963-2134	0.02
Cryptantha nevadensis	8	965-1371	0.04
Cryptantha circumscissa	8	965-1371	0.03

* Introduced species.

Rabbit pellets have been systematically censused since the second drought year, 1990, as a way of ensuring careful examination of quadrats without apparent plants. The available data for plots sampled in 1994 are included in Table 4-13.

Table 4-13. Rabbit pellet densities (n/m^2) on plots sampled in 1994.

PLOT	1990	1991	1992	1993	1994
FRF001		0.4 ± 0.4	20 ± 26	8 ± 7	10 ± 8
FRF001XC		0.8 ± 0.6	11 ± 8	4 ± 6	5 ± 5
FRF001XS		0.1 ± 0.1	15 ± 11	2 ± 4	2 ± 3
JAF001		0.0 ± 0.1	8 ± 9	0 ± 0	4 ± 6
MER001E	3 ± 2	3 ± 2	58 ± 24	4 ± 6	27 ± 16
MER001W	0.6 ± 0.4	0.4 ± 0.3	18 ± 17	2 ± 4	7 ± 6
MER002XC	6 ± 3	1.0 ± 0.4	64 ± 28	40 ± 56	38 ± 20
MER002XS			232 ± 60	4 ± 8	14 ± 15
PAM001				18 ± 16	0 ± 0
PAM006	0.0 ± 0.0				38 ± 30
PAM007	0.6 ± 0.6				28 ± 40
RAM001	4 ± 2				102 ± 75
ROV005	0.5 ± 0.4	1.5 ± 0.9	48 ± 42	8 ± 12	8 ± 9
ROV005XC		0.4 ± 0.3	22 ± 23	2 ± 4	20 ± 13
ROV005XS		0.2 ± 0.2	16 ± 23	6 ± 7	13 ± 11
YUF001	2.3 ± 0.5	0.6 ± 0.7	18 ± 12	4 ± 6	30 ± 19
YUF001XC		0.2 ± 0.2	2 ± 4	10 ± 11	10 ± 12
YUF001XS		0.3 ± 0.2	13 ± 9	6 ± 7	43 ± 39
YUF009		0.7 ± 0.5			26 ± 14
YUF010		0.3 ± 0.3			4 ± 6
YUF011		0.0 ± 0.0			26 ± 35
YUF012		0.7 ± 0.5			14 ± 13
YUF013		0.9 ± 0.6			8 ± 10
YUF014	0.4 ± 0.3				30 ± 12

Table 4-13. (continued)					
PLOT	1990	1991	1992	1993	1994
YUF015	1.2 ± 0.7				20 ± 16
YUF016		0.6 ± 0.4			8 ± 7
YUF017		0.6 ± 0.3			16 ± 17
YUF018		0.0 ± 0.1			22 ± 25
YUF025	1.2 ± 0.7				16 ± 12
YUF026	2.5 ± 1.3				9 ± 10
mean ± 2 se	2 ± 1	0.7 ± 0.4	39 ± 31	8 ± 5	20 ± 7

Seed production by *Bromus rubens* was estimated by regressing seed numbers on plant weight, resulting in the equation:

$$SEEDS = 533 \times PLANT\ WEIGHT\ (g) + 2.22$$

Adjusted r^2 was 0.989, $F_{1,17} = 1573$, $P < 0.0001$ (Figure 4-2).
Seeds of the sampled *Bromus tectorum* were largely either empty or immature in the samples taken. An estimate of viable seed production was not possible for that species.

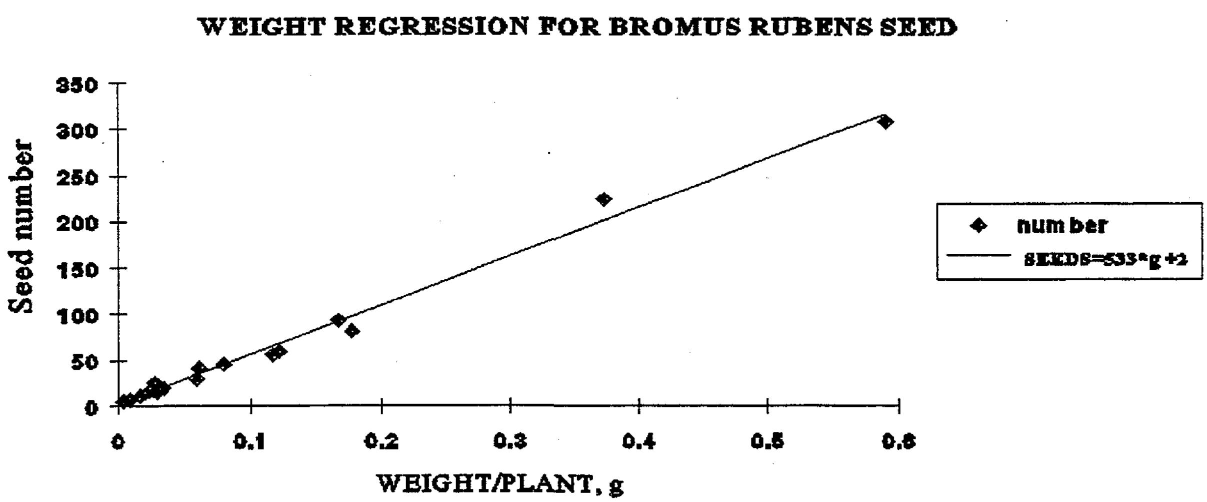

Figure 4-2. Weight Regression for *Bromus Rubens* Seed.

There were 46 instances when density estimates were available from both quadrat data and counts in the 100-m^2 areas. In only three cases was the 100-m^2 estimate larger ($P < 0.01$; sign test). The normal instance was to find 1 plant in the 20 quadrats (2/m^2) but almost always < 100 in the 100-m^2. Means for the two groups were 2.75 $\pm$ 0.56 and 0.51 $\pm$ 0.31/m2 ($t_{90} = 7$, $P < 0.0001$). In only one instance was the 100-m^2 count above the quadrat mean + 2 se.

Discussion - Ancillary Observations

Bromus tectorum became more frequent in 1994. It increased its range and densities during the 1980s on the NTS (Hunter 1991) and was apparently continuing the process.

Median densities of other frequent species were low, consistent with the low rainfall, and their occurrence in Table 4-12 is of little importance. Several species moved onto and off the list from 1993, reflecting likely differences in germination under marginal conditions. *Astragalus lentiginosus* and *Machaeranthera canescens* can survive through a summer and be present a second year in the absence of germinating rainfall. This was seen in 1989 and 1990 when germination at lower elevations was negligible (Hunter 1994a). Their presence on the list may therefore reflect 1993 germination and survival conditions.

Rabbit pellet data indicate some fluctuation in either rabbit densities or grazing pressure on particular sites. The low densities in 1990 and 1991 reflect a noticeable population decline during the drought years of 1989-90, but fluctuations since that time cannot be explained, nor are there data to confirm populations actually changed from 1992-1994. The pellet data on the Yucca Flat baseline plot (YUF001, Table 4-13) are not consistent with observations of rabbits on lizard transects (Saethre 1995, Table 2-28).

Seed production data are expected to be useful in modeling ephemeral populations. Estimates of seed production, seed removal by granivores, germination, and loss of viability with time would allow retrospective estimates of seed bank parameters. There are considerable historical data on a number of these factors which might generate significant insights into NTS ecosystem functioning (O'Farrell and Emery 1976).

Search techniques differ significantly between quadrats and 100 m^2. When harvesting plants from quadrats, a researcher must sit on the ground searching for plants in a small defined area. All plants are eventually harvested from the quadrat and separated by species into data are therefore more accurate. The implication of the comparative sampling data is that only about one in five members of a species is recognized while standing. Since the 1000-m^2 area is given an even more cursory search, there are likely many rarer species present at study sites which are not being recognized with the current techniques.

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EPHEMERAL APPENDIX A

This table includes locations and rough densities of all annual and below-ground perennial species sampled on the NTS in 1994. Entries after each species name are plot names (see Saethre, Status of Mammals on the Nevada Test Site, 1993 for locations, altitudes, and descriptions). Letter code X indicates a Bromus exclusion plot sprayed with a grass-specific herbicide, C stands for control (i.e., untreated), and S for sprayed. A final A indicates it was present in quadrats and information is available in Appendix B on its density, weight per plant and per square meter, and reproductive status. A final B indicates it was seen in the 100-m^2 search area, and a final C indicates it was only seen in the 1000-m^2 area. An asterisk indicates the total area in B was not searched and numbers counted were adjusted to 100-m^2. The number following B is the tally of individual plants counted in the 100-m^2 area. An * indicates greater than the number given.

Amsinckia species MER002XSB9

Amsinckia tessellata MER002XCB3, MER002XSA, YUF009C3, YUF010B20, YUF015A, YUF017C, YUF018C, YUF025B20*, YUF026A

Anisocoma acaulis FRF001C1, JAF003B14

Astragalus calycosus RAM001C

Astragalus lentiginosus fremontii DAF, JAF003A, JAF003B21, MER002XCB3, MER002XSB2, PAM001B3, PAM006B1, PAM007B28, RAM001C, YUF001B13, YUF001XCA, YUF001XCB2, YUF009B10, YUF010B8, YUF011C, YUF012B8, YUF013B, YUF013C2, YUF015B6, YUF016B2, YUF016C9, YUF017B10*, YUF025B2, YUF026B6,

Astragalus purshii PAM001B13

Astragalus tidestromii MER001WB2

Baileya multiradiata MER001WB2

Bromus rubens DAF, FRF001A, FRF001B69, FRF001XCA, FRF001XCB40, FRF001XSB4, JAF001B9, JAF003B1, JAF004A, JAF004B66*, MER001EA, MER001WA, MER002XCA, MER002XSA, ROV005A, ROV005XSA, YUF001A, YUF001XCA, YUF001XSA, YUF009A, YUF010A, YUF011C, YUF012A, YUF013B2, YUF014A, YUF015A, YUF017A, YUF018A, YUF025A, YUF026A

Bromus species DAF, FRF001XSA, FRF001XSB7, JAF003B2, JAF004A, JAF004B23*, MER002XSA, YUF009A, YUF010A, YUF012A, YUF013A, YUF014A, YUF015A, YUF016A, YUF017A, YUF018A

Bromus tectorum FRF001XCB3, FRF001XSB1, JAF003B22, JAF004B17*, MER002XCB9, MER002XSA, PAM001C, PAM006B150*, PAM007B1, RAM001C, ROV005XCB3, YUF001C, YUF009A, YUF010A, YUF010B32*, YUF011C, YUF012B170*, YUF013A, YUF014A, YUF015A, YUF015B250*, YUF016A, YUF017A, YUF018A, YUF018B36, YUF025B3, YUF026B475*

Calycoseris wrightii DAF, MER002XSB1

Camissonia boothii YUF001XCB1

Camissonia brevipes DAF

Camissonia claviformis FRF001XCB1, ROV005XCB2, YUF010B7, YUF012B2

Camissonia kernensis YUF015C, YUF018C, YUF026B10

Camissonia species YUF001XSA

Castilleja martinii PAM007B1

Castilleja species PAM001C

Caulanthus cooperi DAF

Caulanthus lasiophyllus DAF

Centrostegia thurberi (= *Chorizanthe thurberi*) YUF010A, YUF010B62*, YUF026C

Chaenactis carphoclinia DAF

Chaenactis douglasii RAM001B4

Chaenactis fremontii FRF001A, FRF001B30, FRF001XCB10, FRF001XSB12, JAF001C

Chaenactis species JAF001B2, JAF003B1

Chaenactis stevioides DAF, JAF003B2, MER002XCA, MER002XSA, YUF001A, YUF001B, YUF001XSA, YUF010A, YUF010B650*, YUF012A, YUF014A, YUF015B5, YUF017B10, YUF018B3, YUF025B12, YUF026B36*

Chaenactis xantiana JAF004B3

Chenopodium incanum YUF010A, YUF010B, YUF013A

Chenopodium species PAM006C

Chorizanthe brevicornu ROV005XCB

Chorizanthe rigida DAF, ROV005XSB

Chorizanthe watsonii YUF015A

Cleome lutea PAM006C

Crepis occidentalis PAM007C

Cryptantha ambigua RAM001B2

Cryptantha circumscissa DAF, FRF001B2, MER002XSA, YUF001C, YUF009A, YUF009B2, YUF010B4, YUF014A, YUF014B4, YUF015A, YUF015B41*, YUF017B3, YUF018B1, YUF025A, YUF025B26, YUF026B26*

Cryptantha micrantha YUF010B2

Cryptantha nevadensis DAF, FRF001A, FRF001B1, FRF001XCB2, ROV005XCB, YUF001A, YUF001XCA, YUF010A, YUF010B3, YUF012B, YUF015B2, YUF025B1, YUF026D

Cryptantha pterocarya DAF, JAF003B1, ROV005XSB, YUF001XCA, YUF001XSA YUF010B2, YUF014B, YUF015A, YUF015B2, YUF017A, YUF017B31*, YUF018B1, YUF025B1, YUF026B7

Cryptantha species FRF001B2, YUF012A, YUF025A

Cryptantha virginensis DAF, MER001WB39

Cymopteris ripleyi YUF010C20

Delphinium andersonii PAM007C

Descurainia pinnata DAF

Descurainia sophia PAM006B100*, YUF011C, YUF025A, YUF025B21

Dichelostemma pulchellum MER002XCA, MER002XCB2, MER002XSA

Eriastrum eremicum MER002XSB1,YUF015C, YUF026B14

Erigeron pumilus PAM001B9, YUF026C

Eriogonum deflexum DAF, FRF001A, FRF001B1, MER001WA, PAM007B1, YUF001B, YUF001XSB3, YUF009A, YUF011A, YUF012A, YUF013A, YUF016A, YUF017A,YUF017B54*, YUF018B19, YUF025A, YUF026A, YUF026B20

Eriogonum inflatum DAF, MER001WA, MER001WB10+, ROV005B2, ROV005XCB, ROV005XSA, ROV005XSB57, YUF014C

Eriogonum maculatum FRF001B1, FRF001XCA, YUF001C, YUF010C, YUF014C, YUF026B9

Eriogonum nidularium YUF001B, YUF001XSB3, YUF010A, YUF015A, YUF015B9, YUF017B2, YUF018B4,YUF025B5, YUF026A, YUF026B125*, YUF001XCB2

Eriogonum species YUF014C, PAM006A

Eriophyllum pringlei JAF003B1, YUF010B25*, YUF015B9

Erodium cicutarium DAF, MER001EA, MER001WA, MER002XSB4, ROV005XCB, YUF014A, YUF015B, YUF025A, YUF026A

Eschscholtzia glyptosperma DAF, FRF001B1

Euphorbia albomarginata DAF, FRF001C1, JAF003B3, MER002XCA, MER002XSA, YUF001B2, YUF009A, YUF009B2, YUF017B171*, YUF025B14, YUF026B2

Fritillaria atropurpurea PAM007C

Gayophytum ramossisimum PAM007B12

Gilia transmontana DAF

Gilia species DAF, MER002XCA, PAM007B1, YUF016A, YUF017B2, YUF018B1

Glyptopleura marginata FRF001B1

Hymenoxys cooperi PAM007B3
Ipomopsis congesta RAM001B9
Ipomopsis polycladon DAF, YUF026B1
Langloisia schottii JAF003B2, YUF010B, YUF026B2
Lepidium lasiocarpum YUF015C, YUF026B1, YUF001XSA
Linanthus dichotomus MER002XSA
Lupinus brevicaulis PAM007B5
Lygodesmia exigua DAF, JAF004C2, MER002XCB1, YUF001XSA
Machaeranthera canescens DAF, JAF003A, MER002XCA, MER002XSA, MER002XSB116, PAM001B5, YUF001B49, YUF001XCA, YUF001XCB20, YUF001XSB40, YUF009C, YUF010A, YUF010B36*, YUF012B129*, YUF014A, YUF014B140*, YUF015B45*, YUF016B1, YUF016C3, YUF017B31*, YUF018B1, YUF025B2, YUF026C
Malacothrix californica ssp glabrata DAF, FRF001XCB1, YUF001C, YUF001XSA, YUF010B30, YUF018B1, YUF026B8
Mentzelia albicaulis DAF, FRF001B3, FRF001XSA, FRF001XSB5, JAF003B1, PAM006B12, YUF001XSB2, YUF009C8, YUF010B4, YUF012A, YUF012B4, YUF017B4, YUF018B1, YUF025B1, YUF026B2
Monoptilon bellidiforme/bellioides FRF001B1
Oenothera caespitosa YUF016C
Orobanche corymbosa PAM001C
Oxytheca perfoliata YUF010B, YUF018B1, YUF026B9
Pectocarya platycarpa MER001WB
Pectocarya setosa YUF015C, YUF025A, YUF025B6
Pectocarya species ROV005XCA, ROV005XCB
Phacelia fremontii DAF, YUF015B, YUF025B1
Phacelia vallis-mortae PAM007C, YUF001B3, YUF001XCB1, YUF010B
Phlox stansburyi PAM007A
Psathyrotes annua YUF016C3
Rafinesquia neomexicana DAF
Salsola australis DAF, JAF004B2, PAM006A, YUF001XCA, YUF001XSB7, YUF009A, YUF010A, YUF011A, YUF012A, YUF013A, YUF014A, YUF014B13, YUF015A, YUF015B24, YUF016A, YUF017A, YUF018B5, YUF025A, YUF025C1, YUF026B1
Schismus arabicus DAF, JAF001B1, MER001WA
Sisymbrium altissimum DAF, PAM006A, PAM006B258*

Stephanomeria exigua DAF, JAF001C
Stephanomeria parryi YUF015B15, YUF017A, YUF017B24, YUF018B9, YUF026C
Stephanomeria virgata YUF010B
Streptanthus cordatus RAM001B2
Streptanthella longirostris JAF004C1
Tiquilia plicata JAF003A
Viguiera multiflora YUF026B1
Vulpia octoflora FRF001XCB3, JAF001B17, JAF003B5, JAF004A, JAF004B9, MER001WA, MER002XCA, MER002XSA, ROV005XCA, ROV005XCB1
Unknown Crucifer FRF001B1
Unknowns JAF001B, JAF004B3

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EPHEMERAL APPENDIX B

The following tables include summary data for ephemerals harvested from 0.025-m^2 quadrats (usually 20) on the NTS during 1994. Numbers are reported as means for the quadrats ($\bar{X}$), as densities (n/m^2), biomass (g/m^2), and weights per plant (mg). Mean weight per plant and percent of a sample reproductive (having buds, flowers, or fruit) was averaged over the occupied quadrats, while total number per quadrat, total weight per quadrat, and mean weight per plant were averaged over all 20 quadrats. Error limits ($\pm$ 2 se) are presented without checking for normal distribution. Species abbreviations are the first three letters of the genus combined with the first three of the species and can be determined from Appendix A. Results are presented in alphabetical order by plot name, as listed below.

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	DAF10-5	BRORUB	6 ± 8.8	0.065 ± 0.097	11 ± 2	50 ± 100
DATE	5/2/94					
%ROCK	34.9 ± 11.2					
%LITTER	19.1 ± 9.0					
%COVER	23.0 ± 18.5					
%MOUND	17.3 ± 16.2					
PELLETS/M2	36.0 ± 32.3					
TOTAL N/M2	6.0 ± 8.8					
TOTAL G/M2	0.07 ± 0.10					
AVG AVG WT/P	0.01 ± 0.00					
AVG SPP/QUAD	0.1 ± 0.14					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	DAF20-5	BRORUB	46 ± 31.9	1.666 ± 2.049	21 ± 19	40 ± 28
DATE	4/28/94					
%ROCK	66.6 ± 15.2					
%LITTER	18.1 ± 7.7					
%COVER	22.9 ± 15.7					
%MOUND	21.9 ± 16.6					
PELLETS/M2	10.0 ± 7.9					
TOTAL N/M2	46.0 ± 31.9					
TOTAL G/M2	1.7 ± 2.1					
AVG AVG WT/P	0.02 ± 0.02					
AVG SPP/QUAD	0.5 ± 0.3					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	DAF2	BRORUB	2 ± 4.0	0.004 ± 0.007	2 ±	0
DATE	4/20/94	BROSP	2 ± 4.0	0.005 ± 0.010	3 ±	0
%ROCK	100.0 ± 0.0	CHORIG	2 ± 4.0	0.005 ± 0.009	2 ±	0
%LITTER	2.9 ± 2.2	ERIDEF	46 ± 37.3	0.624 ± 0.621	14 ± 8	0 ± 0
%COVER	0.0 ± 0.0	PHAFRE	2 ± 4.0	0.036 ± 0.072	18 ±	100
%MOUND	0.0 ± 0.0	SALAUS	6 ± 12.0	0.034 ± 0.068	6 ±	0
PELLETS/M2	22.0 ± 15.9	SCHARA	2 ± 4.0	0.003 ± 0.006	2 ±	100
TOTAL N/M2	62.0 ± 35.5					
TOTAL G/M2	0.7 ± 0.6					
AVG AVG WT/P	0.01 ± 0.01					
AVG SPP/QUAD	0.7 ± 0.2					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	DAF16-1	ERIDEF	2 ± 4.0	0.020 ± 0.040	10 ±	100
DATE	4/25/94	SCHARA	2 ± 4.0	0.016 ± 0.031	8 ±	100
%ROCK	14.5 ± 4.8					
%LITTER	5.0 ± 2.5					
%COVER	3.7 ± 7.5					
%MOUND	0.0 ± 0.0					
PELLETS/M2	0.0 ± 0.0					
TOTAL N/M2	4.0 ± 5.5					
TOTAL G/M2	0.035 ± 0.049					
AVG AVG WT/P	0.009 ± 0.002					
AVG SPP/QUAD	0.10 ± 0.14					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	FRF001	BRORUB	8 ± 9.4	0.112 ± 0.142	14 ± 8	50 ± 58
DATE	4/13/94	CHAFRE	4 ± 5.5	0.042 ± 0.062	10 ± 8	100 ± 0
%ROCK	14.2 ± 5.2	CRYNEV	2 ± 4.0	0.042 ± 0.083	21 ±	100 ±
%LITTER	13.8 ± 10.0	ERIDEF	2 ± 4.0	0.006 ± 0.012	3 ±	0 ±
%COVER	21.7 ± 17.0					
%MOUND	11.0 ± 13.0					
PELLETS/M2	9.5 ± 7.6					
TOTAL N/M2	16.0 ± 13.5					
TOTAL G/M2	0.20 ± 0.22					
AVG AVG WT/P	0.012 ± 0.005					
AVG SPP/QUAD	0.35 ± 0.26					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	FRF001XC	BRORUB	2 ± 3.2	0.097 ± 0.195	61 ±	100 ±
DATE	4/20/94	ERIMAC	2 ± 3.2	0.006 ± 0.012	4 ±	0 ±
%ROCK	14.2 ± 4.6					
%LITTER	8.4 ± 7.8					
%COVER	12.1 ± 13.3					
%MOUND	15.6 ± 14.6					
PELLETS/M2	4.8 ± 5.3					
TOTAL N/M2	3.2 ± 4.4					
TOTAL G/M2	0.10 ± 0.19					
AVG AVG WT/P	0.032 ± 0.057					
AVG SPP/QUAD	0.080 ± 0.11					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	FRF001XS	BROSP	3 ± 4.4	0.040 ± 0.063	13 ± 13	50 ± 100
DATE	4/20/94	MENALB	2 ± 3.2	0.012 ± 0.024	8 ±	100 ±
%ROCK	12.2 ± 4.1					
%LITTER	17.4 ± 10.7					
%COVER	13.6 ± 11.7					
%MOUND	10.0 ± 8.0					
PELLETS/M2	1.6 ± 3.2					
TOTAL N/M2	4.8 ± 5.3					
TOTAL G/M2	0.05 ± 0.07					
AVG AVG WT/P	0.011 ± 0.008					
AVG SPP/QUAD	0.12 ± 0.13					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	JAF001		0 ± 0			
DATE	4/18/94					
%ROCK	12.7 ± 5.6					
%LITTER	12.6 ± 11.3					
%COVER	12.8 ± 13.5					
%MOUND	9.5 ± 10.5					
PELLETS/M2	4.0 ± 5.5					
TOTAL N/M2	0 ± 0					
TOTAL G/M2						
AVG AVG WT/P						
AVG SPP/QUAD	0 ± 0					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	JAF003	ASTLEN	2 ± 4.0	0.016 ± 0.032	8 ±	0 ±
DATE	4/11/94	MACCAN	10 ± 7.9	2.139 ± 2.551	214 ± 207	0 ± 0
%ROCK	20.0 ± 4.7	TIQPLI	106 ± 35.0	5.887 ± 2.400	54 ± 9	0 ± 0
%LITTER	3.7 ± 1.4					
%COVER	0 ± 0					
%MOUND	8.0 ± 10.6					
PELLETS/M2	16.0 ± 9.0					
TOTAL N/M2	118.0 ± 36.0					
TOTAL G/M2	8.041 ± 3.9					
AVG AVG WT/P	0.086 ± 0.049					
AVG SPP/QUAD	1.2 ± 0.3					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	JAF004	BRORUB	2 ± 4.0	0.003 ± 0.007	2 ±	0 ±
DATE	4/11/94	BROSP	2 ± 4.0	0.054 ± 0.109	27 ±	0 ±
%ROCK	5.4 ± 2.6	VULOCT	2 ± 4.0	0.057 ± 0.113	28 ±	100 ±
%LITTER	6.9 ± 3.2					
%COVER	15.3 ± 12.8					
%MOUND	54.8 ± 19.7					
PELLETS/M2	10.0 ± 11.4					
TOTAL N/M2	6.0 ± 6.6					
TOTAL G/M2	0.11 ± 0.15					
AVG AVG WT/P	0.019 ± 0.017					
AVG SPP/QUAD	0.15 ± 0.16					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	MER001E	BRORUB	3 ± 6.4	0.020 ± 0.039	6 ±	0 ±
DATE	4/7/94	EROCIC	2 ± 3.2	0.004 ± 0.008	2 ±	0 ±
%ROCK	57.4 ± 13.4					
%LITTER	19.9 ± 10.4					
%COVER	37.8 ± 17.4					
%MOUND	24.2 ± 15.1					
PELLETS/M2	27.2 ± 16.5					
TOTAL N/M2	4.8 ± 7.0					
TOTAL G/M2	0.023 ± 0.040					
AVG AVG WT/P	0.004 ± 0.004					
AVG SPP/QUAD	0.080 ± 0.11					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	MER001W	BRORUB	26 ± 29.2	0.064 ± 0.069	3 ± 1	14 ± 29
DATE	4/7/94	ERIDEF	2 ± 3.2	0.008 ± 0.016	5 ±	0 ±
%ROCK	48.4 ± 11.0	ERIINF	2 ± 3.2	0.258 ± 0.516	161 ±	100 ±
%LITTER	17.0 ± 4.8	EROCIC	333 ± 117.3	1.599 ± 0.577	6 ± 1	0 ± 0
%COVER	0.080 ± 0.16	VULOCT	2 ± 3.2	0.003 ± 0.007	2 ±	100 ±
%MOUND	25.4 ± 14.0	SCHARA	43 ± 30.6	0.044 ± 0.033	1 ± 0.2	0 ± 0
PELLETS/M2	6.7 ± 6.2					
TOTAL N/M2	423.3 ± 117.2					
TOTAL G/M2	2.0 ± 0.7					
AVG AVG WT/P	0.008 ± 0.007					
AVG SPP/QUAD	1.7 ± 0.3					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	MER002XC	BRORUB	414 ± 323.3	8.125 ± 4.854	23 ± 16.0	65 ± 16
DATE	4/19/94	CHASTE	3.0 ± 4.4	0.012 ± 0.017	4 ± 2.7	100 ± 0
%ROCK	25.89 ± 7.4	DICPUL	2 ± 3.2	0.022 ± 0.044	14 ±	0 ±
%LITTER	26.7 ± 11.2	EUPALB	48 ± 25.7	2.201 ± 1.520	47 ± 22.0	71 ± 23
%COVER	15.958 ± 10.5	GILSP	2 ± 3.2	0.007 ± 0.015	5 ±	0 ±
%MOUND	0 ± 0	MACCAN	8 ± 8.0	0.037 ± 0.041	5 ± 2.3	0 ± 0
PELLETS/M2	38.3 ± 19.5	MIRPUD	2 ± 3.2	0.342 ± 0.685	214 ±	0 ±
TOTAL N/M2	483.2 ± 322.0	VULOCT	5 ± 7.0	0.013 ± 0.020	2 ± 1.1	100 ± 0
TOTAL G/M2	10.8 ± 5.1					
AVG AVG WT/P	0.03 ± 0.01					
AVG SPP/QUAD	1.8 ± 0.4					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	MER002XS	AMSTES	3 ± 6.4	0.059 ± 0.117	18 ±	0 ±
DATE	4/19/94	BRORUB	27 ± 31.6	0.285 ± 0.336	11 ± 6.460	13 ± 14
%ROCK	18.0 ± 4.2	BROSP	93 ± 49.5	1.716 ± 1.451	16 ± 8.120	21 ± 19
%LITTER	25.2 ± 10.8	BROTEC	8 ± 8.0	0.348 ± 0.536	34 ± 33.632	100 ± 0
%COVER	4.2 ± 3.4	CHASTE	10 ± 11.6	0.074 ± 0.110	6 ± 5.559	22 ± 44
%MOUND	9.2 ± 10.8	CRYCIR	2 ± 3.2	0.005 ± 0.010	3 ±	0 ±
PELLETS/M2	14.5 ± 15.4	DICPUL	8 ± 9.2	0.111 ± 0.143	13 ± 7.213	0 ± 0
TOTAL N/M2	332.8 ± 102.7	EUPALB	67 ± 26.0	3.456 ± 1.983	48 ± 15.887	60 ± 18
TOTAL G/M2	6.7 ± 3.3	LINDIC	2 ± 3.2	0.001 ± 0.003	1 ±	0 ±
AVG AVG WT/P	0.021 ± 0.006	MACCAN	3 ± 4.4	0.004 ± 0.007	2 ±	0 ± 0
AVG SPP/QUAD	2.64 ± 0.58	VULOCT	110 ± 61.2	0.662 ± 0.383	6 ± 1.1	100 ± 0

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	PAM001		0 ± 0			
DATE	6/7/94					
%ROCK	70.0 ± 12.1					
%LITTER	23.3 ± 10.6					
%COVER	30.3 ± 16.1					
%MOUND	18.0 ± 14.0					
PELLETS/M2	0 ± 0					
TOTAL N/M2	0 ± 0					
TOTAL G/M2						
AVG AVG WT/P						
AVG SPP/QUAD	0 ± 0					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	PAM006	ERISP	4 ± 8.0	0.025 ± 0.049	6 ±	0 ±
DATE	6/7/94	SALAUS	6.0 ± 6.6	0.108 ± 0.157	18 ± 20.7	0 ± 0
%ROCK	6.5 ± 2.5	SISALT	2.0 ± 4.0	0.023 ± 0.045	11 ±	0 ±
%LITTER	37.9 ± 15.8					
%COVER	13.3 ± 12.5					
%MOUND	0 ± 0					
PELLETS/M2	38.0 ± 29.9					
TOTAL N/M2	12.0 ± 13.1					
TOTAL G/M2	0.16 ± 0.18					
AVG AVG WT/P	0.014 ± 0.012					
AVG SPP/QUAD	0.25 ± 0.25					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	PAM007	PHLSTA	12 ± 11.8	0.400 ± 0.441	32 ± 16.5	0 ± 0
DATE	6/7/94					
%ROCK	15.2 ± 8.1					
%LITTER	40.6 ± 17.2					
%COVER	35.6 ± 20.0					
%MOUND	21.5 ± 16.6					
PELLETS/M2	28.0 ± 40.3					
TOTAL N/M2	12.0 ± 11.8					
TOTAL G/M2	0.40 ± 0.44					
AVG AVG WT/P	0.032 ± 0.016					
AVG SPP/QUAD	0.20 ± 0.18					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	RAM001		0 ± 0			
DATE	7/21/94					
%ROCK	35.050 ± 19.5					
%LITTER	48.100 ± 19.6					
%COVER	45.7 ± 20.7					
%MOUND	5.3 ± 10.0					
PELLETS/M2	102.0 ± 75.1					
TOTAL N/M2	0 ± 0					
TOTAL G/M2						
AVG AVG WT/P						
AVG SPP/QUAD	0 ± 0					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	ROV005	BRORUB	40 ± 46.4	0.168 ± 0.178	6 ± 3.5	61 ± 41
DATE	4/18/94					
%ROCK	42.4 ± 10.6					
%LITTER	23.5 ± 14.2					
%COVER	22.3 ± 16.1					
%MOUND	20.0 ± 18.4					
PELLETS/M2	8.0 ± 9.4					
TOTAL N/M2	40.0 ± 46.4					
TOTAL G/M2	0.17 ± 0.18					
AVG AVG WT/P	0.006 ± 0.003					
AVG SPP/QUAD	0.25 ± 0.20					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	ROV005XC	BRORUB	134.4 ± 47.1	0.983 ± 0.508	7.426 ± 2.264	49.7 ± 14.5
DATE	4/19/94	PECSP	1.6 ± 3.2	0.003 ± 0.007	2.050 ±	100.000 ±
%ROCK	45.7 ± 9.6	VULOCT	1.6 ± 3.2	0.006 ± 0.012	3.650 ±	100.000 ±
%LITTER	268 ± 12.8					
%COVER	27.7 ± 16.6					
%MOUND	6.7 ± 8.1					
PELLETS/M2	20.0 ± 12.7					
TOTAL N/M2	139.2 ± 47.4					
TOTAL G/M2	1.0 ± 0.51					
AVG AVG WT/P	0.007 ± 0.002					
AVG SPP/QUAD	0.9 ± 0.2					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	ROV005XS	BRORUB	13 ± 11.0	0.073 ± 0.096	5 ± 4.979	40 ± 37
DATE	4/19/94	ERIINF	5 ± 5.3	0.000 ± 0.000	±	0 ± 0
%ROCK	47.8 ± 8.0					
%LITTER	13.5 ± 5.5					
%COVER	10.8 ± 10.4					
%MOUND	5.6 ± 8.5					
PELLETS/M2	12.8 ± 11.0					
TOTAL N/M2	17.6 ± 12.3					
TOTAL G/M2	0.073 ± 0.096					
AVG AVG WT/P	0.003 ± 0.004					
AVG SPP/QUAD	0.32 ± 0.22					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF001	BRORUB	106 ± 94.2	1.538 ± 1.479	13 ± 6.1	57 ± 26
DATE	4/26/94	CHASTE	2 ± 4.0	0.004 ± 0.007	2 ±	0 ±
%ROCK	39.5 ± 144	CRYNEV	4 ± 5.5	0.019 ± 0.026	5 ± 0.9	100 ± 0
%LITTER	38.3 ± 13.9					
%COVER	24.7 ± 13.3					
%MOUND	22.0 ± 16.1					
PELLETS/M2	30.0 ± 19.14					
TOTAL N/M2	112.0 ± 95.6					
TOTAL G/M2	1.6 ± 1.5					
AVG AVG WT/P	0.011 ± 0.005					
AVG SPP/QUAD	0.7 ± 0.3					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF001XC	ASTLEN	2 ± 3.2	0.035 ± 0.070	22 ±	0 ±
DATE	4/26/94	BRORUB	184 ± 138.5	2.939 ± 2.529	17 ± 7.3	62 ± 23
%ROCK	17.7 ± 8.2	CRYNEV	2 ± 3.2	0.007 ± 0.014	5 ±	100 ±
%LITTER	48.2 ± 14.8	CRYREC	2 ± 3.2	0.015 ± 0.030	9 ±	100 ±
%COVER	34.4 ± 15.3	MACCAN	2 ± 3.2	0.059 ± 0.119	37 ±	0 ±
%MOUND	24.4 ± 14.1	SALAUS	2 ± 3.2	0.015 ± 0.030	9 ±	0 ±
PELLETS/M2	10.4 ± 11.5					
TOTAL N/M2	192.0 ± 138.5					
TOTAL G/M2	3.1 ± 2.5					
AVG AVG WT/P	0.017 ± 0.006					
AVG SPP/QUAD	0.80 ± 0.23					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF001XS	BRORUB	29 ± 32.2	0.658 ± 0.733	21 ± 13.3	60 ± 35
DATE	4/26/94	CAMSP	2 ± 3.2	0.003 ± 0.007	2 ±	100 ±
%ROCK	24.4 ± 8.8	CHASTE	3 ± 6.4	0.007 ± 0.015	2 ±	0 ±
%LITTER	29.6 ± 11.8	CRYREC	3 ± 4.4	0.027 ± 0.038	8 ± 0.3	100 ± 0
%COVER	26.8 ± 15.2	LEPLAS	2 ± 3.2	0.022 ± 0.044	14 ±	100 ±
%MOUND	22.4 ± 15.9	LYGEXI	2 ± 3.2	0.007 ± 0.015	5 ±	100 ±
PELLETS/M2	43.2 ± 38.9	MALGLA	2 ± 3.2	0.022 ± 0.044	14 ±	100 ±
TOTAL N/M2	41.6 ± 33.8					
TOTAL G/M2	0.75 ± 0.76					
AVG AVG WT/P	0.015 ± 0.008					
AVG SPP/QUAD	0.60 ± 0.35					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF009	BRORUB	10 ± 7.9	0.419 ± 0.371	42 ± 17.8	100 ± 0
DATE	5/3/94	BROSP	102 ± 103.4	1.140 ± 1.593	9 ± 3.5	17 ± 28
%ROCK	6.1 ± 1.5	BROTEC	926 ± 315.9	42.353 ± 11.034	58 ± 16.0	99 ± 2
%LITTER	40.0 ± 9.6	CRYCIR	2 ± 4.0	0.002 ± 0.004	1 ±	100 ±
%COVER	0 ± 0	ERIDEF	6 ± 6.6	0.053 ± 0.076	9 ± 9.8	0 ± 0
%MOUND	0.10 ± 0.20	EUPALB	2 ± 4.0	0.146 ± 0.293	73 ±	0 ±
PELLETS/M2	26.0 ± 14.5	SALAUS	16 ± 10.7	0.144 ± 0.109	9 ± 4.6	0 ± 0
TOTAL N/M2	1064.0 ± 336.8					
TOTAL G/M2	44.3 ± 11.2					
AVG AVG WT/P	0.036 ± 0.010					
AVG SPP/QUAD	2.2 0.53					
AVG SPP/QUAD	1.6 ± 0.42					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF010	BRORUB	276 ± 158.4	5.602 ± 3.550	24 ± 10.5	99 ± 2
DATE	5/3/94	BROSP	64 ± 50.7	1.171 ± 1.231	14 ± 7.5	31 ± 30
%ROCK	10.9 ± 5.3	BROTEC	12 ± 20.2	0.900 ± 1.498	77 ± 5.9	100 ± 0
%LITTER	50 ± 14.4	CHASTE	2 ± 4	0.038 ± 0.075	19 ±	100 ±
%COVER	42.3 ± 19.6	CHEINC	2 ± 4	0.026 ± 0.051	13 ±	100 ±
%MOUND	36 ± 19.9	CENTHU	2 ± 4	0.010 ± 0.021	5 ±	100 ±
PELLETS/M2	4 ± 5.5	CRYNEV	2 ± 4	0.013 ± 0.026	7 ±	100 ±
TOTAL N/M2	392 ± 189.0	ERINID	8 ± 9.4	0.027 ± 0.036	4 ± 4.4	67 ± 67
TOTAL G/M2	7.9 ± 4.9	MACCAN	2 ± 4	0.005 ± 0.009	2 ±	0 ±
AVG AVG WT/P	0.020 ± 0.008	SALAUS	22 ± 40.0	0.083 ± 0.150	4 ± 0.1	0 ± 0
AVG SPP/QUAD	1.6 ± 0.4					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF011	ERIDEF	18 ± 21.3	0.053 ± 0.071	2 ± 2.0	0 ± 0
DATE	4/27/94	SALAUS	172 ± 89.6	2.929 ± 1.808	16 ± 39	0 ± 0
%ROCK	17.7 ± 6.0					
%LITTER	30.1 ± 11.9					
%COVER	0 ± 0					
%MOUND	0 ± 0					
PELLETS/M2	26.0 ± 35.9					
TOTAL N/M2	190.0 ± 94.6					
TOTAL G/M2	3.0 ± 1.8					
AVG AVG WT/P	0.013 ± 0.004					
AVG SPP/QUAD	1.1 ± 0.3					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF012	BRORUB	60 ± 62.1	2.366 ± 2.397	70 ± 71.8	76 ± 22
DATE	4/21/94	BROSP	4 ± 8.0	0.015 ± 0.031	4 ±	0 ±
%ROCK	20.3 ± 5.9	CHASTE	6. ± 6.6	0.027 ± 0.034	5 ± 3.2	100 ±0
%LITTER	19.6 ± 11.7	CRYSP	2 ± 4.0	0.340 ± 0.680	170 ±	0 ±
%COVER	12.5 ± 12.2	ERIDEF	6 ± 6.6	0.021 ± 0.024	3 ± 1.4	0 ± 0
%MOUND	9.1 ± 10.2	MENALB	4 ± 8.0	0.240 ± 0.480	60 ±	100 ±
PELLETS/M2	14.0 ± 13.3	SALAUS	10 ± 12.8	0.636 ± 1.206	39 ± 61.9	0 ± 0
TOTAL N/M2	92.0 ± 75.5					
TOTAL G/M2	3.7 ± 3.5					
AVG AVG WT/P	0.04 ± 0.03					
AVG SPP/QUAD	0.9 ± 0.4					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF013	BROSP	114 ± 75.5	1.151 ± 0.629	12 ± 4.5	0 ± 0
DATE	4/27/94	BROTEC	54 ± 34.5	2.297 ± 1.783	42 ± 13.3	100 ± 0
%ROCK	22.7 ± 8.5	CHEINC	4 ± 5.5	0.013 ± 0.019	3 ± 1.6	0 ± 0
%LITTER	30.0 ± 13.9	ERIDEF	2 ± 4.0	0.017 ± 0.034	8 ±	0 ±
%COVER	0 ± 0	SALAUS	1198 ± 507.9	11.176 ± 4.003	12 ± 2.7	5 ± 11
%MOUND	6.6 ± 10.7					
PELLETS/M2	8.4 ± 9.8					
TOTAL N/M2	1372.0 ± 513.1					
TOTAL G/M2	14.7 ± 4.2					
AVG AVG WT/P	0.018 ± 0.005					
AVG SPP/QUAD	2.3 ± 0.5					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF014	BRORUB	450 ± 168.1	29.265 ± 11.787	86 ± 36.7	98 ± 2
DATE	5/5/94	BROSP	6 ± 8.8	0.039 ± 0.068	5 ± 6.3	0 ± 0
%ROCK	29.6 ± 10.9	BROTEC	44 ± 28.4	6.959 ± 4.716	256 ± 189.9	100 ± 0
%LITTER	42.7 ± 14.9	CHASTE	2 ± 4	0.024 ± 0.049	12 ±	100 ±
%COVER	9.2 ± 10.1	CRYCIR	2 ± 4	0.014 ± 0.028	7 ±	100 ±
%MOUND	19 ± 15.8	EROCIC	166 ± 96.5	10.291 ± 8.426	61 ± 45.6	69 ± 18
PELLETS/M2	30 ± 12.8	MACCAN	2 ± 4	0.916 ± 1.832	458 ±	0 ±
TOTAL N/M2	676 ± 223.9	SALAUS	4 ± 5.5	0.032 ± 0.048	8 ± 7.2	0 ± 0
TOTAL G/M2	47.5 ± 17.8					
AVG AVG WT/P	0.11 ± 0.05					
AVG SPP/QUAD	2 .5 ± 0.5					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF015	AMSTES	10 ± 11.4	2.020 ± 2.71963	212 ± 160.7	83 ± 33
DATE	5/5/94	BRORUB	194 ± 171.3	4.939 ± 4.622	27 ± 22.4	84 ± 15
%ROCK	31.2 ± 12.8	BROSP	2 ± 4	0.031 ± 0.063	15 ±	0 ±
%LITTER	40.7 ± 15.9	BROTEC	2 ± 4	0.012 ± 0.024	6 ±	100 ±
%COVER	22 ± 15.0	CHOWAT	4 ± 8	0.023 ± 0.047	6 ±	100 ±
%MOUND	23 ± 17.2	CRYCIR	4 ± 5.5	0.025 ± 0.039	6 ± 6.1	50 ± 100
PELLETS/M2	20 ± 15.9	CRYPTE	2 ± 4	0.051 ± 0.103	26 ±	100 ±
TOTAL N/M2	222 ± 170.8	ERINID	2 ± 4	0.009 ± 0.019	5 ±	100 ±
TOTAL G/M2	7.1 ± 4.9	SALAUS	2 ± 4	0.036 ± 0.072	18 ±	0 ±
AVG AVG WT/P	0.05 ± 0.04					
AVG SPP/QUAD	0.95 ± 0.34					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro ± 2 se
PLOT	YUF016	BROSP	2 ± 4.0	0.014 ± 0.027	7 ±	0 ±
DATE	5/3/94	BROTEC	26 ± 28.0	0.446 ± 0.446	22 ± 21.7	88 ± 15
%ROCK	7.2 ± 2.9	ERIDEF	2 ± 4.0	0.010 ± 0.021	5 ±	0 ±
%LITTER	15.3 ± 8.4	GILSP	2 ± 4.0	0.009 ± 0.018	4 ±	0 ±
%COVER	3.5 ± 5.1	SALAUS	102 ± 36.0	1.530 ± 1.082	14 ± 7.1	0 ± 0
%MOUND	0 ± 0					
PELLETS/M2	8.0 ± 7.3					
TOTAL N/M2	134.0 ± 49.7					
TOTAL G/M2	2.0 ± 1.2					
AVG AVG WT/P	0.015 ± 0.007					
AVG SPP/QUAD	1.25 ± 0.32					

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro	±2 se
PLOT	YUF017	BRORUB	10 ± 14.1	0.284 ± 0.391	30 ± 14.3	100	± 0
DATE	5/4/94	BROSP	48 ± 91.9	0.228 ± 0.316	27 ± 49.0	0	± 0
%ROCK	6.1 ± 3.4	BROTEC	182 ± 192.9	2.686 ± 2.279	30 ± 14.8	96	± 8
%LITTER	27.9 ± 14.0	CRYPTE	2 ± 4	0.003 ± 0.006	1 ±	100	±
%COVER	1.3 ± 2.0	ERIDEF	6 ± 8.8	0.048 ± 0.070	10 ± 11.9	0	± 0
%MOUND	7.7 ± 10.20	SALAUS	14 ± 10.5	0.149 ± 0.127	11 ± 6.7	0	± 0
PELLETS/M2	16 ± 16.8	STEPAR	2 ± 4	0.038 ± 0.076	19 ±	0	±
TOTAL N/M2	264 ± 276.6						
TOTAL G/M2	3.4 ± 2.6						
AVG AVG WT/P	0.023 ± 0.0085						
AVG SPP/QUAD	1.3 ± 0.5						

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro	±2 se
PLOT	YUF018	BRORUB	4 ± 5.5	0.085 ± 0.122	21 ± 11.1	100	± 0
DATE	5/4/94	BROSP	6 ± 6.6	0.043 ± 0.052	7 ± 4.6	33	± 67
%ROCK	17.0 ± 9.4	BROTEC	2 ± 4	0.049 ± 0.099	25 ±	100	±
%LITTER	26.7 ± 9.8						
%COVER	33.3 ± 18.0						
%MOUND	41.0 ± 21.5						
PELLETS/M2	22.0 ± 24.9						
TOTAL N/M2	12.0 ± 10.2						
TOTAL G/M2	0.18 ± 0.21						
AVG AVG WT/P	0.015 ± 0.008						
AVG SPP/QUAD	0.30 ± 0.25						

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro	±2 se
PLOT	YUF025	BRORUB	36 ± 24.6	2.578 ± 1.659	86 ± 30.9	100	± 0
DATE	5/9/94	CRYCIR	2 ± 4.0	0.017 ± 0.035	9 ±	100	±
%ROCK	33.0 ± 8.5	CRYSPA	2 ± 4.0	0.017 ± 0.034	9 ±	100	±
%LITTER	23.9 ± 10.0	DESSOP	2 ± 4.0	0.044 ± 0.088	22 ±	100	±
%COVER	4.5 ± 4.696	ERIDEF	36 ± 28.4	1.050 ± 1.010	26 ± 17.271	29	± 32
%MOUND	0 ± 0	EROCIC	122 ± 92.8	12.733 ± 9.190	178 ± 107.7	88	± 13
PELLETS/M2	16.0 ± 12.2	PECSET	2 ± 4.0	0.095 ± 0.190	48 ±	100	±
TOTAL N/M2	204.0 ± 119.9	SALAUS	2 ± 4.0	0.005 ± 0.009	2 ±	0	±
TOTAL G/M2	16.5 ± 10.3						
AVG AVG WT/P	0.09 ± 0.04						
AVG SPP/QUAD	1.6 ± 0.6						

	X ± 2 se	Species	n/m2 ± 2 se	g/m2 ± 2 se	wt/plant ± 2 se	%Repro	±2 se
PLOT	YUF026	AMSTES	28 ± 16.5	5.532 ± 3.673	235 ± 121.8	89	± 22
DATE	5/9/94	BRORUB	286 ± 241.4	17.476 ± 11.771	77 ± 31.6	94	± 7
%ROCK	25.2 ± 9.8	ERIDEF	2 ± 4.0	0.002 ± 0.003	1 ±	0	±
%LITTER	27.6 ± 10.7	ERINID	2 ± 4.0	0.039 ± 0.078	20 ±	100	±
%COVER	12.4 ± 12.6	EROCIC	32 ± 55.8	1.408 ± 2.065	77 ± 47.2	93	± 14
%MOUND	16.3 ± 14.6						
PELLETS/M2	8.9 ± 10.3						
TOTAL N/M2	350.0 ± 255.2						
TOTAL G/M2	24.5 ± 13.1						
AVG AVG WT/P	0.12 ± 0.05						
AVG SPP/QUAD	1.4 ± 0.6						

STATUS OF PERENNIAL PLANTS ON THE NEVADA TEST SITE, 1994

by

Richard B. Hunter

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ACKNOWLEDGMENTS

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ABSTRACT

This is a progress report of studies monitoring the effects of DOE activities and natural forces on flora and fauna of the NTS in both time and spatial distribution. In 1994, perennial plant populations were monitored on five sites of above-ground nuclear weapons tests, one scraped and leveled drill pad," a revegetated plot, and one rodent-denuded site. In addition, general trends in perennial populations were monitored at baseline sites in each of the NTS' three major valleys and two mesas. The primary technique was censusing of perennials on permanent 100-m^2 belt transects established between 1976 and 1990. Those data were supplemented by censusing individually marked plants of certain low-density species on several baseline sites. Disturbed sites were recensused after a 3-4 year hiatus, while baseline sites were sampled annually for the third or fourth year.

Germination and establishment of perennial grasses and/or the shrub *Chrysothamnus nauseosus* was evident 1000 feet north of Sedan Crater and the T2 blast area in northern Yucca Flat, and on U19ac drill pad on Pahute Mesa. Growth of previously established populations of the shrub *Hymenoclea salsola* and the subshrub *Sphaeralcea ambigua* increased live perennial volume to near control values on the T4 blast area and within 3000 feet from Sedan Crater. Small perennial populations on two blast areas, T1 and T3, in central Yucca Flat, declined in total live volume between 1991 and 1994, despite favorable growing conditions in 1992 and 1993.

Growth of transplanted *Atriplex canescens* on the revegetated area increased total live volume above the adjacent control area. Perennial live volume on the rodent-denuded area remained at <10% of the control, as it has been since 1988. Live volume on baseline plots generally declined slightly from 1993, as expected from low rainfall in 1994.

A separate study was performed to determine the generality of species composition differences associated with a roadside in Frenchman Flat. Species composition was assessed along 50-m lines adjacent to paved roads and in nearby undisturbed vegetation at 95 random points. Similarity of species composition between the two areas was less than expected from removal of species along the roadside, indicating some species are significantly associated with the new roadside habitat, others with the controls.

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INTRODUCTION

Perennial plants on the NTS have been studied since the end of above-ground nuclear weapons testing in the late 1950s (e.g., Shields and Rickard 1961, Beatley 1979). Since 1987, the DOE has monitored the status of the vegetation and animals on the NTS through BECAMP. Its goals were to determine trends in the populations and spatial distributions of plants and animals, and to determine effects of DOE operations on those populations. Natural trends in time have been studied by annually collecting baseline data from minimally disturbed plots set up on the major valleys and mesas of the NTS. Effects of disturbance have been monitored by censusing representative disturbed and adjacent control sites at three-year intervals. Since 1992, each year has been devoted primarily to sampling one particular disturbance type in order to provide replicate study sites for particular disturbances within the same year, minimizing the confounding of time and disturbance effects. The primary disturbance type studied in 1994 was large areas denuded by 1950s above-ground nuclear weapons tests on Yucca Flat. Minor disturbances studied included a scraped and leveled drill pad on Pahute Mesa, a revegetated area in Yucca Flat where surface radioactive contamination was removed in 1987, and a rodent-denuded area in Mercury Valley. Such areas were selected early in the BECAMP program after an investigation of areal extent of various disturbances indicated shrub removal by various agents was likely the primary human cause of changes in NTS plant and animal populations (Hunter and Medica 1992). BECAMP efforts also included investigating one area with radioactive contamination (GMX - Hunter 1994a), subsidence craters (Hunter 1994a, b), and effects of introduced annual weeds (Hunter 1991 and 1994a, b). Studies of perennial plants, ephemeral plants, small mammals, and lizards have been coordinated to provide data from the same spots during the same year.

Work begun in 1993 to characterize the effects of roads on NTS vegetation was supplemented in 1994 with an investigation of perennial plant species composition along most NTS paved roads. The purpose was to confirm the generality of the 1993 finding (Hunter 1994c) that species along the roadside differed from those found in undisturbed areas nearby.

Although many publications on various aspects of NTS vegetation have been produced in the decades of testing, the only study of perennial plants comparable to the BECAMP monitoring effort was work of J. C. Beatley (1979), who reported the status of perennial plants for 1963 and 1975 on a set of 63 plots scattered over the NTS. She found small increases over that period in cover, mean height, and number of plants per site, measured by line intercept transects. Other studies at particular sites, largely by E. M. Romney and A. Wallace

(Wallace et al. 1972, Romney et al. 1973), are available to indicate vegetation conditions in the late 1960s and early 1970s. Those were often done with techniques comparable to BECAMP studies. Results of 1987 through 1993 monitoring of perennial vegetation under BECAMP are in Hunter and Medica (1989) and Hunter (1992, 1994a, b, c).

STUDY SITES

Locations studied in 1994 varied in altitude from 947 m (3100 feet) to 2283 m (7490 feet) and from the edge of Frenchman play to near the peak of Rainier Mesa. Vegetative communities ranged from saltbush scrub near the play edge, through the Mojave, Transition, and Great Basin desert communities to the pinyon forest (Figure 5-1, Table 5-1).

Table 5-1. Sites of perennial plant measurements in 1994. Locations of transects are recorded under the listed label in Appendix A of Saethre 1994b.

DISTURBANCE	LABEL	ELEVATION	DOMINANT	LAST
None	FF67	947	*Atriplex canescens*	1993
None	FF66	948	*Atriplex confertifolia*	1993
None	FF81	951	*Atriplex canescens*	1993
None	FF84	957	*Larrea tridentata*	1993
Baseline	JAF001	954	*Larrea tridentata*	1993
Baseline	FRF001	965	*Larrea tridentata*	1993
Rodents	MER002	1076	*Stanleya pinnata*	1991
Rodent Control	MER003	1103	*Larrea tridentata*	1991
Baseline	YUF001	1237	*Ephedra nevadensis*	1993
T3 Blast	YUF013	1236	*Oryzopsis hymenoides*	1991
T3 Control	YUF012	1239	*Atriplex canescens*	1991
Revegetated	YUF011	1242	*Atriplex canescens*	1991
T1 Control	YUF010	1267	*Ephedra nevadensis*	1991
T1 Blast	YUF009	1279	*Stipa speciosa*	1991

Table 5-1. (continued)

DISTURBANCE	LABEL	ELEVATION	DOMINANT	LAST
T1 Transition	YUF029	1305	*Atriplex canescens*	1991
T4 Blast	YUF025	1317	*Hymenoclea salsola*	1990
T4 Control	YUF026	1320	*Ephedra nevadensis*	1990
Sedan 1000'	YUF016	1318	*Oryzopsis hymenoides*	1991
Sedan 3000'	YUF017	1327	*Hymenoclea salsola*	1991
Sedan 5000'	YUF018	1335	*Coleogyne ramosissima*	1991
T2 Control	YUF015	1338	*Atriplex canescens*	1990
T2 Blast	YUF014	1371	*Chrysothamnus nauseosus*	1990
Marked Pines	PAM008	1920	*Pinus monophylla*	1993
Baseline	PAM001	1923	*Artemisia nova*	1993
Drill Pad Control,	PAM007	2134	*Pinus monophylla*	1991
Drill Pad U19ac	PAM006	2134	*Oryzopsis hymenoides*	1991
Baseline, Marked	RAM001	2283	*Pinus monophylla*	1993

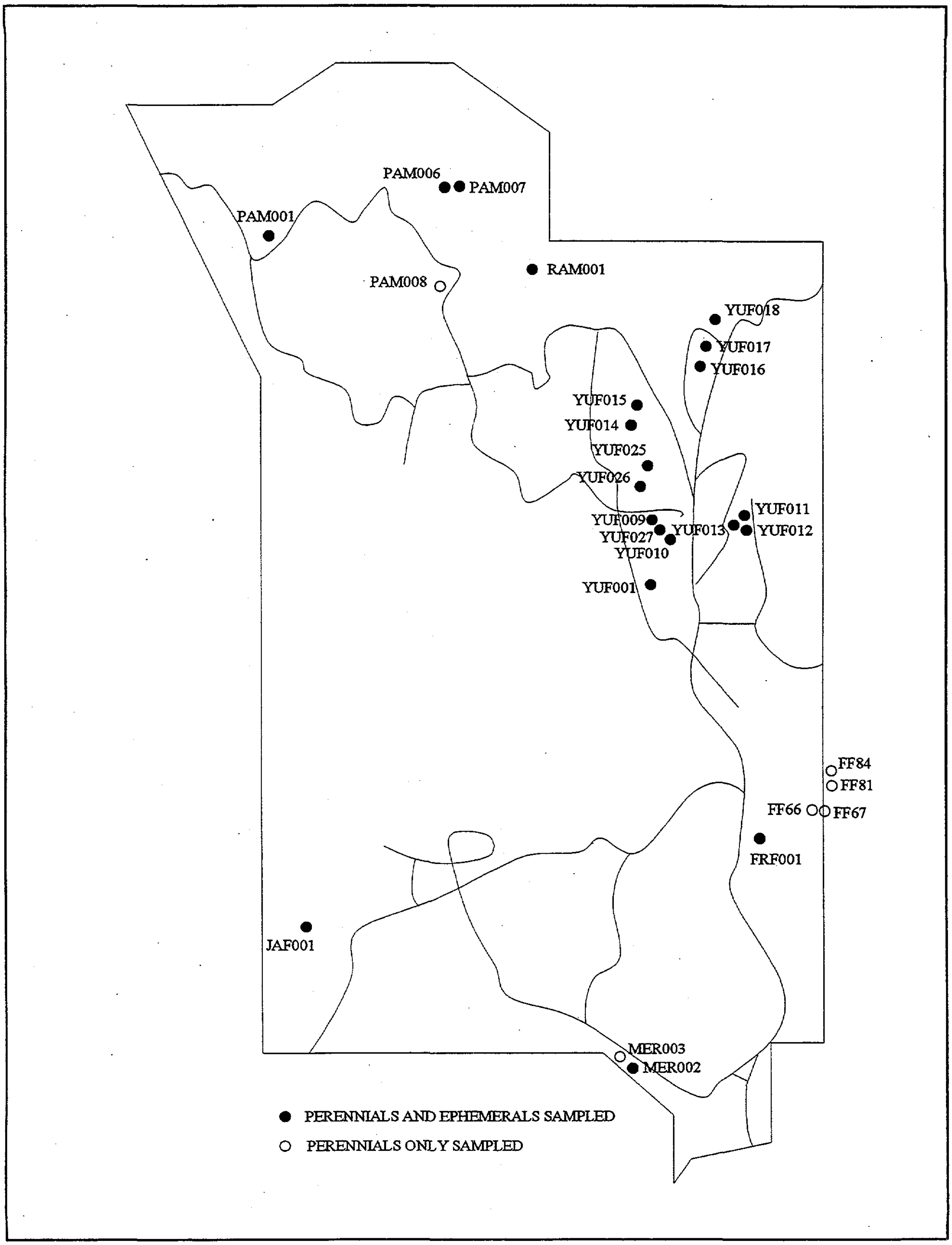

Figure 5-1. Perennial plant study sites in 1994.

RAINFALL

Calendar year rainfall in 1994 was low, comparable to rainfall during the drought years of 1989 and 1990 (Table 5-2). It ranged from 117 mm in Jackass Flats to ≥195 mm on Rainier Mesa (2283 m). Only in December and on Rainier Mesa in February and March did rainfall total 25 mm (one inch) or more in any month at any of the listed sites. Only in February and again in December did it exceed 12 mm at most locations. The consistently low rainfall continued a pattern begun in July 1993, following an unusually wet winter of 1992-93. Total rainfall for the year prior to shrub measurements (July 1993 through June 1994) ranged from 74 to 107 mm at all but the Rainier Mesa station, which totaled 204 mm. Rainfall was thus low, and similar to that of several recent years during which shrub populations were severely reduced in live volume and numbers.

Table 5-2. Precipitation (mm) for the last twelve years on various NTS landforms as reported by the National Oceanic and Atmospheric Administration, Weather Service Nuclear Support Office (NOAA/WSNSO). > indicates some data are missing.

YEAR	JACKASS FLATS	FRENCHMAN FLAT	YUCCA FLAT	PAHUTE MESA	RAINIER MESA
1983	303	222	350	>350	682
1984	258	225	276	197	>348
1985	83	83	106	88	>205
1986	171	152	154	>160	302
1987	>209	163	194	>272	389
1988	132	111	114	>164	263
1989	104	29	63	83	140
1990	108	80	54	169	188
1991	137	79	105	198	359
1992	254	141	220	206	419
1993	266	167	245	147	362
1994	117	108	127	123	195

Soil moisture was monitored with fiberglass resistance sensors (Colman and Hendrix 1949) on three baseline sites which all showed similar water availability patterns. Continuing the pattern of late 1993 (Hunter 1994c), they began the year with small amounts in the surface layers from light winter rains and a residue of moisture below 1-m depth left from the wet spring of 1993. This deep moisture was largely below the root zones; i.e., deeper than 80 to 125 cm. Shallow moisture was depleted by the end of May at each site and deeper water was absent by July (Table 5-3). The deep water may move up and down in the soil with daily and seasonal temperature fluctuations, moving by evaporation-condensation from warmer to cooler depths (Stark and Love 1969). Measured soil temperatures at 150-cm depth ranged from 9.5 to 24°C in Yucca Flat, 11.9 to 25.6°C in Jackass Flats, and 10.2 to 27.9°C in Frenchman Flat. There was essentially no water available for shrub growth after May 31, although a slight, continuous flux of water from deep soils through dormant shrubs is not precluded by these data. The whole NTS is underlain by groundwater at depths of several hundred meters (Black et al. 1994), and the surface is therefore presumed to be the driest point except following rain.

Table 5-3. Depths of wet soil (resistance <900,000 Ohms) at three baseline sites during 1994. There were no sensors below 150 cm. (Two numbers in a cell show a region of wet soil, while the intervening soils between minimum and maximum depths were dry. A single number represents a single sensor wet," while shallower and deeper sensors were dry.)

Frenchman Flat			Jackass Flats			Yucca Flat		
Date	min	max	Date	min	max	Date	min	max
JAN 5	5-15	100	JAN 5	5-50	125-150	JAN 5	5-30	100-150
FEB 3	5-30	100-125	JAN 20	10-50	150	FEB 3	5-15	75-150
MAR 2	5-30	100	FEB 15	5-50	100-150	MAR 2	5-30	100-150
MAR 17	10-30	100	MAR 3	5	150	MAR 17	5-50	100-150
APR 13	5-50	100	MAR 17	10	150	APR 7	5-50	100-150
MAY 31	1	1	APR 6	10	150	APR 26	10-30	100-150
JUN 15	>150	>150	MAY 17	15	50	MAY 31	5-5	100-150
JUN 27	>150	>150	JUN 15	>150	>150	JUN 15	100	150
JUL 7	>150	>150	JUN 27	>150	>150	JUN 27	150	150
JUL 21	5	5	JUL 7	>150	>150	JUL 7	>150	>150
AUG 4	>150	>150	JUL 21	>150	>150	JUL 21	>150	>150

Table 5-3. (continued)								
Frenchman Flat			Jackass Flats			Yucca Flat		
Date	min	max	Date	min	max	Date	min	max
AUG 22	>150	>150	AUG 4	>150	>150	AUG 4	>150	>150
SEP 13	>150	>150	AUG 22	>150	>150	AUG 22	>150	>150
OCT 12	>150	>150	SEP 13	>150	>150	SEP 13	>150	>150
NOV 23	1	5	OCT 12	>150	>150	OCT 12	>150	>150
DEC 15	>150	>150	NOV 29	>150	>150	NOV 23	1-15	150
						DEC 15	1-30	125-150

BLAST AREAS

INTRODUCTION

Blast areas are large areas in Yucca Flat cleared by nuclear weapons tested above ground during the 1950s. Some discrete blast areas are circular with a radius on the order of one mile (1.6 km). Those created by several bombs with different epicenters (as for those dropped from airplanes) are often large elongated or irregular disturbed areas. The blast areas are concentrated in the northern half of Yucca Flat and several are partially disturbed by placement of equipment yards and camps, roads, drill pads, and subsidence craters associated with below-ground weapons tests. BECAMP studies are confined to areas of original blast effects, without the confounding effects of subsequent activities.

Five blast areas were studied in 1994, designated T1, T2, T3, T4, and Sedan (T-sites were exploded on towers, generally several tests at a common center). All had been censused earlier, with information presented by Hunter (1994a). Sedan was a below-ground test purposely designed to create a crater, exploded in July 1962, five years after the final NTS atmospheric tests. Time since the final blast damage was 37 years for the T-sites and 32 years for Sedan.

METHODS

Basic study techniques were those used in previous years. Measurements were recorded of heights, widths, and phenology of all plants on 100 m^2 belt transects permanently marked on the various sites. There is a detailed description by Hunter and Medica (1989), and slight modifications are reported by Hunter (1992, 1994a, b, c). Monitoring techniques in 1994 were again slightly modified from previous years, primarily to improve accuracy of recognition of individual plants. On transects measured in 1994, a wire was added between the two transect end stakes (25 or 50 m apart), which was used as a centerline. The wires were left as part of the transect, so subsequent measurements of position would be more accurate.

Analytical procedures and software were significantly upgraded, reducing chances for error and improving efficiency. Results tables in Appendix C were modified to include data on average growth, and to report two standard errors rather than one. Previous years' data in Appendix A were reanalyzed with the 1994 protocol.

Shrub communities on the NTS adjust to variations in rainfall by growth and shrinkage of existing plants (Hunter 1994c), rather than death and germination of new individuals. Growth/shrinkage (growth) was estimated from measured sizes as $k = [\ln(V2/V1)]/\Delta t$ where V2 was the 1994 volume (height x ½ width 1 x ½ width 2 x π) and V1 was the volume at the previous census (Erickson 1976). Δt was the elapsed time in years. Mean growth $(\overline{k}) \pm 2$ se are presented in Appendix C as an indication of mean and variation about the mean. However, numbers of matched plants of a given species were often small and distribution of growth about the mean could not be easily determined. Therefore, the sign test (Ostle 1963) was used to determine whether mean growth/shrinkage of a particular shrub population was significantly different from zero. On some occasions, when large numbers of values were available, $\overline{k}$ was compared between sites with a t-test, assuming homogeneous variances.

Biomass calculations were based on regressions between volume and dry weight for different species according to data collected in the early 1970s by E. M. Romney (Hunter and Medica 1989). In 1994, biomass of a number of species lacking regression lines was estimated using the regression for *Oryzopsis hymenoides* (1.1 kg/m^3) for all bunchgrasses, *Ambrosia dumosa* (2.5 kg/m^3) for shrubs and trees, and *Sphaeralcea ambigua* (0.43 kg/m^3) for herbs. These were thought to give more accurate estimates of total biomass than ignoring the contributions of species without regression lines.

Numbers, volumes, and decay rates (k) of dead plants are indicators of vegetation conditions in the recent past. They can be used, in theory, to indicate recent deleterious or positive changes in an ecosystem. Data on dead plants were taken at the times of censusing live plants and are included in Appendix A as a source of information which could help, in the future, to interpret data from short-term studies.

Grazing damage to perennials was recorded as a subjective percent of canopy volume removed. Summaries of 1994 grazing data are presented in the text as indications of the presence and habits of herbivores on particular areas. Whether a plant flowered or fruited in the year of a census was also recorded. Those qualitative data are sometimes presented as indicators of differences in growing conditions among different areas. Species names in the text follow Kartesz and Kartesz (1980).

RESULTS

T1

Since 1988, the total live volume of perennial plants on a 200-m^2 transect declined from 955 to 69 liters. The largest drop occurred with death of the single large *Hymenoclea salsola* killed by animals between 1988 and 1991 (Hunter 1994a), but bunchgrasses were also reduced in volume over that period (Table 5-4). In 1994, one additional species, *Viguiera multiflora,* was found on the transect, an herbaceo us species which has been increasing as a roadside weed in Yucca Flat. Total volume of dead plants declined from 1991 to 1994, primarily due to decay of grasses killed in the drought of 1989-90. In spite of unusually wet winters in 1992 and 1993, mean growth rates of the two bunchgrass species on T1 were negative, though neither was significantly different from 0 (sign test). Total cover, a frequently used measure of plant status, declined from 1.14% in 1988, to 0.20% in 1991, and further to 0.17% in 1994. Thus, over the period of monitoring on this blast area, there was no evidence of significant recovery of the vegetation. There was some germination of the grass *Oryzopsis hymenoides* and the herb *Viguiera multiflora* between 1991 and 1994, but overall results from 1988 to 1994 suggested continuing decline rather than recovery.

Table 5-4. Plant live volumes on transects on and adjacent to T1 blast area in central Yucca Flat. The area was cleared of vegetation by several tower-mounted nuclear weapons tests in 1957. Results are live volumes of plant canopy measured on 100 and 200 m^2 transects.

LOCATION	TOTAL LIVE VOLUME (m^2)		
	1988	1991	1994
T1 Blast Area			
shrubs	2.72	0	0
grasses	2.05	0.76	0.34
herbs	0	0	0
T1 Control			
shrubs	113.12	30.88	98.17
grasses	5.36	0.92	0.22
herbs	0	0	0
T1 Transition Zone			
shrubs	-	3.38	7.26
grasses	-	0	0.03
herbs	-	7.11	5.10

The control transect for T1 lies to the east of the blast area, in a shrub assemblage dominated in 1994 by *Ephedra nevadensis* and *Atriplex canescens*. The shrub population most closely fits what Beatley (1976) called a *Grayia-Lycium* assemblage. Both *Grayia* and *Lycium* were present all years, but together made up no more than 15% of canopy volume in any year. Some changes in dominance occurred between 1988 and 1994, as *Atriplex canescens* increased dramatically in 1991-1994, and *Chrysothamnus viscidiflorus* declined significantly along with the grasses. On the control transect live cover went from 25% in 1988, to 7% in 1991, then 18% in 1994. All species had positive average growth from 1991 to 1994, and all those with more than 6 individuals measured at both censuses had more exhibiting positive than negative growth (sign test, $p < 0.05$). Growth measurements on one species, *Oryzopsis hymenoides,* were available from both the control (two plants both grew, $\overline{k} \pm 2$ se $= 0.22 \pm 0.07$) and the blast area (eight grew, eight shrank, $\overline{k} = -0.05 \pm 0.39$). The majority of *Oryzopsis* plants on both sites were new, having germinated since 1991. On the control, none of 29 *Oryzopsis hymenoides* fruited, compared to 13 of 58 on the blast area.

Vegetation on a "transition zone" on the eastern edge of the T1 blast area was first censused in 1991. This area was marked on a BYU map as a mixed grass zone (Tanner and Jorgensen 1963) and in 1991 consisted primarily of recently dead *Atriplex canescens* shrubs. The surviving *Atriplex canescens* included 14 with growth measured, of which three shrank and eleven grew ($\overline{k} = 0.75 \pm 0.38$). Two of the three that shrank were the largest survivors, 98 and 125 liters in 1991. The doubling of total live volume of *Atriplex canescens* on this transect was the result of growth by many small plants generally less than 1 liter in volume in 1991. The small number of unmatched plants and their sizes (1 to 91) suggest there was no new *Atriplex canescens* germination between 1991 and 1994 at this location, although the species did germinate in many places in Yucca Flat in 1992 (Hunter 1994b).

The plant species on the transition transect contributing the most live volume in 1991 and second-most in 1994 was *Mirabilis pudica*, an herbaceous perennial which dies to ground level each year and persists as rhizomes underground. It is often a minor component of undisturbed desert, but did well in 1991 on several disturbed areas (Hunter 1994a). In 1994, 11 of the 27 plants were grazed with 1% to 40% of the canopy volumes removed. One of two *Sitanion jubatum* was grazed (1%), but all other species were not.

T3

T3 blast area is on the east side of Yucca Flat, where original vegetation was described in 1957 by Shields and Rickard as dominated by *Tetradymia canescens* (actually probably *Tetradymia glabrata*). Since 1988, the total live volume of perennial plants declined from 452 to 4 liters (Table 5-5). Live plants included 46 *Oryzopsis hymenoides*, 1 *Mirabilis pudica*, and 2 *Hilaria jamesii* (new in 1994). Only 2 plants alive in 1991 were still alive in 1994, one *Oryzopsis hymenoides* and the *Mirabilis pudica*. The other *Oryzopsis hymenoides* germinated in the intervening years, probably both in 1992 and 1993, when numbers increased on other plots (Hunter 1994b, c). The *Hilaria jamesii* were not noticed in 1991, but this rhizomatous grass could have been dead above ground that year and would have been easily missed. Their small size and the proximity of the two shoots (they were a few centimeters apart) could also be a result of germination and survival of a single seed in the intervening years.

Table 5-5. Plant live volumes on transects on and adjacent to T3 blast area in central Yucca Flat. The blast area was denuded by several tower-mounted nuclear weapons tests in 1957 and the revegetation area was a waste dump cleaned up and plowed in 1989, then planted with small shrub transplants by UCLA. Results are total live volumes of plant canopy measured on 100 and 200 m^2 transects.				
LOCATION	TOTAL LIVE VOLUME (liters/m^2)			
	1986	1988	1991	1994
T3 Blast Area				
shrubs	-	0	0	0
grasses	-	4.42	0.01	0.04
herbs	-	0.10	0.08	0
T3 Control				
shrubs	116.06	148.78	24.26	37.24
grasses	1.59	0.62	0.01	0.05
	1986	1988	1991	1994
herbs	0.89	0.90	1.32	0.57
Revegetation Area				
shrubs	-	0	5.31	45.07
grasses	-	0	0	0
herbs	-	-	0	0

The control for T3 lies just to the east of the blast area. The transect was first measured in 1986 by UCLA as a control for a revegetation program associated with consolidation of mounds of radioactive waste near the edge of the T3 blast area. The waste site was plowed, fenced, and planted with a sparse population of desert shrubs (primarily *Atriplex canescens*) by UCLA in 1989. Perennial vegetation on these two sites are included in Table 5-5.

Perennial vegetation on the control site changed markedly during the monitoring period. Before 1989, the dominant species was *Tetradymia glabrata*, consistent with the report of Shields and Rickard 1957. By 1991 almost all the *Tetradymia glabrata* were dead, and in 1994 *Ephedra nevadensis*, *Atriplex canescens*, and *Ceratoides lanata* made up 82% of live shrub volume. Grasses nearly all died on the control by 1991 and recovered partially in numbers, but not volume, by 1994. Several other less common shrub species changed significantly in the proportions of total live volume on this transect (Appendix A).

In 1991, following severe drought kill in 1989 and 1990, the herbaceous perennial *Mirabilis pudica* did well, but its volume declined again coincidently with partial recovery of shrubs by 1994. If this rhizomatous species is tabulated by combining individual shoots into separate "patches," then the control transect data suggest six of eight original individuals survived from 1986 through 1994, indicating good drought survival potential in this species.

Mirabilis pudica shoots on the blast area of T3 declined from 8 to 1 between 1991 and 1994, and on the control from 12 to 8. In 1991, 5 of 8 on the blast area were grazed (maximum 20% of canopy volume), while only 1 of 12 was grazed on the control. The proportion showing grazing was significantly higher on the blast area by Fisher's Exact Test ($p \leq 0.025$, Siegel 1956). In 1994, two of eight Mirabilis pudica on the control were grazed; the one on the blast area was not.

Total live shrub volume on the revegetated area surpassed that of the much more densely populated control by 1994. The six surviving *Atriplex canescens* had more live volume than the 130 live perennials on the control (Table 5-5). Total cover on the revegetated area, however, was less than on the control (5.7% versus 8.2%), as many of the control species were shorter than the transplanted *Atriplex canescens*. Total live cover on the blast area was an insignificant 0.02%.

Species on the control transect which grew significantly (sign test; $p \leq 0.01$ in each case) between 1991 and 1994 were *Acamptopappus shockleyi, Atriplex canescens, Ceratoides lanata,* and *Polygala subspinosa.* There were not enough plants on the blast and revegetated areas to test significance of growth measurements. Species which flowered or fruited on the control in 1994 were *Atriplex canescens* (62%), *Menodora spinescens* (60%), *Ceratoides lanata* (50%), *Acamptopappus shockleyi* (10%), and *Oryzopsis hymenoides* (4%). On the blast area no plants flowered or fruited, but four of the six *Atriplex canescens* on the revegetated area did.

T4

The T4 blast area is north of the T1 site on the west side of Yucca Flat. As on other T sites the final tests were done in 1957, after tests in 1955 and earlier (Shields and Rickard 1957). The surface soil is rocky. Shields and Rickard measured vegetation to the north and east of T4 and reported dominance by *Grayia spinosa* and *Lycium andersonii* in both places, with significant populations of *Ceratoides lanata,* the grasses *Stipa speciosa* and *Oryzopsis* *hymenoides,* and a lesser presence of several other shrub species. No other data on the T4 area of Yucca Flat were reported before the BECAMP studies of 1990 (Hunter 1994a).

Vegetation on T4 increased considerably between 1990 and 1994. In 1990, the 100-m^2 transect contained 36 *Hymenoclea salsola* shrubs, 87 *Stipa speciosa* bunchgrasses, 246 seedling *Sphaeralcea ambigua*, an herbaceous shrub, and ten *Erioneuron pulchellum*, a small perennial "fluffgrass." Most of the *Hymenoclea salsola, Stipa speciosa*, and about half the *Sphaeralcea ambigua* survived. All *Erioneuron pulchellum* died. The *Stipa speciosa* did not grow significantly, but the *Hymenoclea salsola* did ($p \leq 0.01$) and the six matched *Sphaeralcea ambigua* did ($p \leq 0.05$). Total live volume increased from 12.19 to 42.65/m^2. Growth on the blast area, combined with a decrease in live volume on the control, resulted in perennial live volume approaching that of the control in 1994 (42.65 versus 46.94 l/m^2; Table 5-6).

Table 5-6. Plant live volumes on transects on and adjacent to T4 blast area in western Yucca Flat. The blast area was denuded by several tower-mounted nuclear weapons tests through 1957. Results are total live volumes of plant canopy measured on 100-m^2 transects.

LOCATION	TOTAL LIVE VOLUMES, liters/m^2	
	1990	1994
T4 Blast Area		
shrubs	11.47	31.16
grasses	0.55	0.59
herbs	0.17	10.90
T4 Control		
shrubs	63.86	46.27
grasses	0.03	0.02
herbs	0.04	0.66

The decline of control live volume was partially due to the 1989-90 drought, as plants continued to shrink through 1992 (Hunter 1994b). As on the T1 and T4 controls, in 1994 *Ephedra nevadensis* was the dominant shrub in terms of volume. *Grayia spinosa* and *Lycium andersonii* live volumes both decreased by half and their numbers declined slightly (Appendix A). *Ephedra nevadensis* became dominant by default as it, too, declined slightly in total volume and numbers, though nine of ten matched plants grew (significant at $p \leq 0.05$).

Hymenoclea salsola, however, increased from 0.53 to 4.46 /m^2. It grew on both the blast area and control transects.

Herbaceous perennials on the control plot did well, as *Mirabilis pudica, Viguiera multiflora, Dyssodia cooperi,* and *Astragalus lentiginosus* var. *fremontii* were present in 1994, but not 1990. Grasses increased in number as six seedling *Oryzopsis hymenoides* were present in 1994, but their total live volume was insignificant.

On T4 blast area, 36 of 117 *Sphaeralcea ambigua* were grazed. Other species were not grazed. On the control the one *Sphaeralcea ambigua* was grazed, as was one of six *Oryzopsis hymenoides*. No plant flowered or fruited on the control, but on the blast area three of 32 *Hymenoclea salsola* and 31 *Sphaeralcea ambigua* flowered and/or fruited.

T2

In 1990 all plants on the T2 blast area transect were dead, consisting almost totally of 1,264 small dead grasses. They were largely only counted both years, rather than measured, and the 1990 cover and volume data are therefore underestimated. In 1994, a major change was apparent, as numerous small shrubs were present. Thirty-four *Chrysothamnus nauseosus* and one *Hymenoclea salsola* were found, in addition to 150 *Erioneuron pulchellum.* Total live volume was 3.52 /m^2, 6% of control live volume, and cover was 2%. Mean *Chrysothamnus nauseosus* volume was 9.1 $\pm$ 6.7 liters. Mean size was too large to have germinated and grown in 1994, and the most likely germination time was early 1993.

Dead grasses on T2 decreased in number from 1264 to 808, and dead shrubs decreased from seven to two. It is likely the dead shrubs were killed by the T2 blasts the last ones were in 1957 and final traces were just disappearing between 1990 and 1994.

Table 5-7. Plant live volumes on transects on and adjacent to T2 blast area in northwestern Yucca Flat. The blast area was denuded by several tower-mounted nuclear weapons tests through 1957. Results are total live volumes of plant canopy measured on 100-m^2 transects.

LOCATION	TOTAL LIVE VOLUMES, liters/m^2	
	1990	1994
T2 Blast Area		
shrubs	0	3.45
grasses	0	0.07
herbs	0	0
T2 Control		
shrubs	39.63	56.80
grasses	0.02	0.08
herbs	0	0.10

On the control transect overall volume increased 44% in four years (to 56.99 l/m^2, Table 5-7). Growth occurred in several long-lived species, including *Grayia spinosa* (+710%), *Hymenoclea salsola* (+223%), *Ceratoides lanata* (+126%), and *Lycium andersonii* (+59%). *Atriplex canescens*, however, declined from 22 to 15 /m^2 (-32%), as a single, large, old plant went from 1733 to 182 liters. Four other matched *Atriplex canescens* on the transect grew larger between the two censuses.

On T2 control eight of 26 *Oryzopsis hymenoides* were grazed a maximum of 30%. On the blast area one of the *Chrysothamnus nauseosus* was grazed 50%. No other species showed evidence of grazing on those transects.

Only one *Erioneuron pulchellum* on the blast area fruited. On the control, 10 of 22 *Ceratoides lanata*, four of nine *Atriplex canescens*, one of two *Sphaeralcea ambigua*, and seven of 26 *Oryzopsis hymenoides* fruited in 1994. Only one of the eight grazed *Oryzopsis hymenoides* was recorded as fruiting; others may have budded or flowered but the flower stalks would or could have been grazed off.

Sedan

Three transects were sampled near the Sedan cratering test at 1000, 3000, and 5000 feet (305, 915, 1524 m) from ground zero. Plots are near locations of early studies by UCLA on their "Line 16A" leading northwest of the crater. Data at these locations are available for 1962-4 (Martin 1963), 1975, 1976, 1983-4 (Hunter et al. 1987), 1988 (Hunter 1992), 1991 (Hunter 1994a), and 1994 (Table 5-8). The 1988-94 data were collected under BECAMP and are summarized in this section.

Table 5-8. Plant live volumes on 100 m^2 transects at 1000, 3000, and 5000 feet from Sedan crater center. The 1000-foot line was on throw-out deposits, the 3000-foot line was cleared of vegetation but lacked deposits, and vegetation at 5000 feet was intact after the blast.

LOCATION	TOTAL LIVE VOLUMES, liters/m^2		
	1988	1991	1994
1000 feet			
shrubs	0	0	0
grasses	2.86	0.45	2.36
herbs	0	0	0
3000 feet			
shrubs	39.81	32.49	56.85
grasses	4.51	1.57	1.79
herbs	0.03	0	0.04
5000 feet			
shrubs	123.30	81.67	81.19
grasses	1.52	0	0.02
herbs	0	0	0

The transect at 1000 feet (305 m) is near the outer base of the throw-out mound deposited at the lip of the crater. Throw-out deposits are sandy and several meters deep. Original vegetation and soils were buried by the throw-out deposits. In 1994 perennial vegetation consisted solely of three bunchgrass species: *Oryzopsis hymenoides*, *Stipa speciosa*, and *Sitanion jubatum*. The dominant grass was *Oryzopsis hymenoides*, which increased significantly in number (from 80 in 1988 and 81 in 1991 to 372 in 1994) over the six years studied. Total live volume, however, declined over that period (Table 5-8). Most of the *Oryzopsis hymenoides* present in 1994 were small, probably having germinated in 1992 and 1993 (Hunter 1994b, c), but nearly all present in 1991 survived and 93% increased in size.

At 3000 feet (915 m), *Hymenoclea salsola* dominated perennial live volume in 1994 (52.65 of 58.68 l/m^2). Those plants germinated primarily between 1983 and 1988, when numbers increased from 3 to 57 (Hunter et al. 1987, Appendix A). *Hymenoclea salsola* volume decreased 19% between 1988 and 1991, but nearly doubled (+93%) between 1991 and 1994. Numbers decreased somewhat between 1988 and 1991, although dead shrubs did not increase correspondingly.

There were three *Lycium andersonii* at this location from 1983 to the present (one was present in 1976). Those three plants gradually decreased 33% in live volume over six years (Appendix A).

At 5000 feet, *Coleogyne ramosissima* was dominant from before the Sedan test. Between 1988 and 1994, it varied from 73% to 80% of total live volume, but declined from 94.81 to 70.86 $/m^2$ (-25%). During that period, *Hymenoclea salsola* increased from 2.78 to 7.48 $/m^2$ (+169%), while *Lycium andersonii* decreased from 18.91 to 7.76 (-59%). Grasses were nearly absent in 1994, having all but disappeared during the 1989-90 drought and recovering only slightly afterwards. Poor germination and growth of *Oryzopsis hymenoides* in the control vegetation contrasted markedly with its success at 1000 feet. The logical explanation was that shrubs depleted soil water fast enough to prevent *Oryzopsis hymenoides* germination and growth.

Growth rates of established *Oryzopsis hymenoides* differed at 1000 and 3000 feet ($t_{67} = 6.05$, $p < 0.0001$). The mean growth constant at 1000 feet was 0.74 ± 0.10 ($\overline{k} \pm 2$ se; size increased 110% per year) from 1991 to 1994, versus $+0.11 \pm 0.18$ (+12% per year) at 3000 feet. Two *Oryzopsis hymenoides* at 5000 feet were not the same plants in 1994 as in 1991 and, hence, no growth calculation was possible.

Growth rates of the shrub *Hymenoclea salsola* differed between 3000 feet and 5000 fee ($t_{51} = 4.9$, $p < 0.0001$); at 3000 feet $\overline{k} \pm 2$ se $= +0.27 \pm 0.06$ (+30% per year), and at 5000 feet $\overline{k} = +0.69 \pm 0.16$ (+100% per year). In this case the shrub grew less where total live volume was lower.

Loss of nine *Hymenoclea salsola* at 3000 feet between 1988 and 1991 could not be explained. Many occurred in groups and locations were not exact enough in 1988 to tell which ones were missing in 1991. Possible mechanisms of loss included overgrowth and hiding by a dominant member of a group and differential tape placement (thus excluding borderline plants) as well as loss to gophers, rabbit grazing, or death and subsequent decay. These missing plants were not evident in the "dead shrub" category.

Fruiting among the several species differed among locations. At 3000 feet 79% of the *Hymenoclea salsola* fruited in 1994 while, at 5000 feet, only 12% did ($p = 0.0006$, Fisher exact probability test, Siegel 1956). At 3000 feet 27 of 49 *Oryzopsis hymenoides* fruited, compared to 102 of 372 at 1000 feet. A higher percentage fruited at 3000 feet ($\chi^2 = 21.3$, $p < 0.0001$).

There were no grazed plants at 5000 feet but one of 47 *Hymenoclea salsola* at 3000 feet was grazed (20%) and the only *Sphaeralcea ambigua* was grazed (60%). At 1000 feet only *Oryzopsis hymenoides* (35 of 372) was grazed. The mean amount grazed of those 35 plants was 25 ± 9%, median 15%. No *Oryzopsis hymenoides* was grazed at 3000 feet.

DISCUSSION

Several of the blast areas are conspicuously bare more than 30 years since the events. Having data from a number of other disturbances allows a comparison with recovery rates on those sites. Using the associated control live volume as an indicator of approximate live perennial volume when recovered, approximate recovery rates were calculated for various disturbances (Table 5-16).

Table 5-16. Estimates of recovery rates of perennial vegetation on various NTS disturbances. Live volume totals are from Hunter (1994a, b, c) and this report.

Disturbance	YEAR		Recovery time, yr	Live volume, /m²	Percent of control	Recovery rate %/yr
	disturbed	measured				
Burns						
Red Rock Valley	1988	1992	4	10.77	5.3	1.3
Mid Valley	1986	1993	7	61.73	27.4	3.9
Yucca Flat	1985	1993	8	23.45	21.3	2.7

Table 5-16. (continued)						
Disturbance	YEAR		Recovery time, yr	Live volume, /m^2	Percent of control	Recovery rate %/yr
	disturbed	measured				
Mid Valley	1959	1989	30	192.94	74.0	2.5
Scraped Areas						
Mid Valley	1984?	1992	8	0.34	0.1	0
Pahute Mesa	1979	1994	15	5.81	2.2	0.1
Yucca Flat	1986	1994	8	45.07[a]	119.0	14.9[a]
Roadsides						
Frenchman Flat	continuous	1993	33	93.56	86.2	0.8[b]
Frenchman Flat	1968?	1993	25?	45.35	41.3	1.7
Gopher Area						
Mercury Valley	continuous	1994	-	28.08	7.2	-
Blast Areas						
T1	1957	1994	37	0.34	0.3	0
T3	1957	1994	37	0.04	0.1	0
Blast Areas						
T4	1957	1994	37	42.65	90.8	2.5
T2	1957	1994	37	3.52	6.2	0.2
Sedan 1000'	1962	1994	32	2.36	2.9	0.1
Sedan 3000'	1962	1994	32	58.68	72.3	2.3

[a] This site was revegetated by UCLA in 1989.
[b] Based on assumed 40% removal, with recovery occurring adjacent to scraped area.

Recovery in this sense is aimed at a simple replacement of live perennial plant biomass, which does not imply a restoration of community structure and interactions. Nevertheless, it does indicate there were two disturbance types which have been slow to recover. Several of the blast areas exhibited essentially no recovery after 37 years and some of the drill pads/scraped areas appeared slow to recover in the first 8-15 years. There is considerable circumstantial evidence available to discuss reasons for the slow recovery but the numerous possible hypotheses should be mentioned first (Table 5-17).

Table 5-17. Hypotheses for slow recovery of perennial vegetation on blast areas and scraped sites.	
Factor	Suggested causes of failure to establish perennials
Soil Conditions	Compaction prevents root growth.
	Smooth surface prevents seed lodging and burial.
	Absence of appropriate microorganisms prevents growth.
	Absence of essential nutrients prevents growth.
	Toxic salts or other chemicals prevent growth.
Seed Dispersal	Low seed production outside of disturbed areas limits dispersal onto the sites.
	High wind speed near surface prevents lodging of seeds.
	Absence of caching rodents prevents dispersal onto the sites.
	Size of disturbance may be greater than seed dispersal mechanisms.
Seed Germination	Radiation may kill deposited seeds.
	Surface may dry too rapidly (= absence of shrub shading).
	Weather conditions have been unfavorable since the disturbance.
Seedling Establishment	Predation by rabbits/birds/rodents on germinated seedlings (= absence of nurse plants).
	Competition by annual plants dries soil, killing shrub seedlings.
	Ionizing radiation kills seedlings.
Long-term Survival	Drought limits lifespan to short periods.
	Grazing intensity is greater than growth potential.
	Perennial life spans are naturally shorter than re-establishment frequency.

The observed growth of annual plants since 1958 on the blast areas (Shields & Rickard 1961, Figure 5-2) indicate that seeds do become buried, germinate, establish, and reproduce. Annual plant seeds may lie on or near the surface for several years before germinating. For example, the number of annuals germinating in 1991, following two years of drought, was similar on T1 blast area and its control (Hunter 1994d). The growth of these plants eliminates

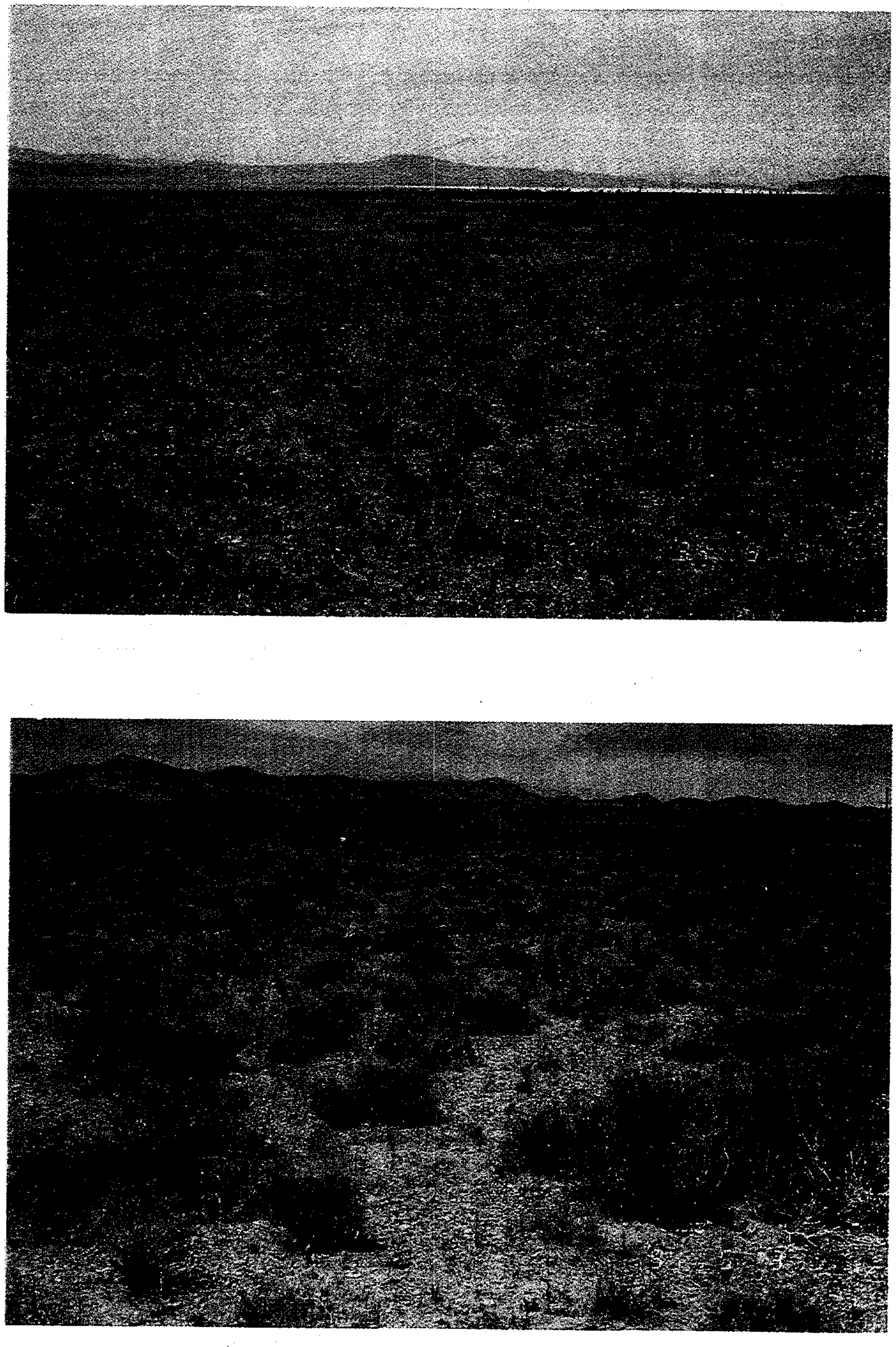

Figure 5-2. Winter annuals plants (largely *Bromus species)* on T1 blast area (top) and the undisturbed control plot on May 3, 1994.

the hypotheses relating to growing conditions such as nutrient limitations, germination conditions, toxicities and radiation damage. (Wallace et al. 1972 report various shrub seeds germinate normally with up to 20,000 to 60,000 R of gamma exposure. Radiation levels on the central blast areas are on the order of 2 R per year [McArthur and Kordas 1987]).

Relatively long-term survival of plants on the blast areas has been occasionally noted. Some perennial grasses which germinated on T1 in 1971, 1978, and 1983 persisted for at least two years after each germination event (E. M. Romney, personal observations reported in Hunter 1992). In addition, shrubs were transplanted onto a location on T1 blast area by A. Wallace and E. M. Romney in December 1971. Twenty of 39 fenced and 39 of 131 unfenced transplants survived until censused in 1976 (Wallace et al. 1980). (Fenced survival was better than unfenced, Chi-square test, $p = 0.03$, d.f. = 1.) Again, those observations eliminate many of the hypotheses relating to physical or chemical growth limitations (radiation, drought, toxic substances, nutrient limitations).

Hypotheses remaining after these observations relate not to absolute survival but to survival of plants only in low densities or for short periods. Low densities might be caused by low densities of germination and establishment success, related to seed dispersal and lodging on the site or low densities of safe-sites where seedlings can establish. The latter seems unlikely because annual plants occur in high densities in near-uniform stands (Figure 5-2). Short life spans could be caused by seasonal drought and soil and air conditions affecting water availability, and also grazing and damage by burrowing animals.

Widespread germination events have rarely been reported on the NTS. Ackerman (1979) reported on a total of 201 seedings of 11 species found in 76 m^2 of annual plant quadrats censused from 1971-1975. Some species germinated with summer and some with winter/spring rains. Only one survived to spring of 1977. Romney noted germination of grass seedlings on T1 blast area in 1971, 1978, and 1983 (Hunter 1992). There was dense germination of *Ambrosia dumosa* in Jackass Flats after heavy rains in July 1983 (Hunter 1989). Germination of *Hymenoclea salsola* at Sedan must have occurred between censuses in May 1983 and 1988, indicated by large increases in numbers at 3000 feet (Hunter 1994a). Those too may have germinated after the July 1983 rains. Small *Hymenoclea salsola* were evident in 1987 and 1988 on many sites in Yucca Flat and Frenchman Flat, with mean sizes ranging from 1 to 87 liters (Hunter 1992). They were present in 1988 on the western portion of T1 blast area at sites previously studied by E. M. Romney (Hunter 1992). By 1994, on the six sites where comparative data were available, numbers uniformly declined

By 1994, on the six sites where comparative data were available, numbers uniformly declined and mean size increased only slightly. Only at 3000 feet from Sedan did mean size exceed 100 liters. (The largest plant on that site was 910 liters, indicating potential size of the species). Since the BECAMP work began in 1987, significant perennial germination occurred only in 1992 and that was largely restricted to *Oryzopsis hymenoides* and *Atriplex canescens* on disturbed areas and to *Artemisia* species on Pahute Mesa, under the parent plants (Hunter 1994b, c). The *Chrysothamnus nauseosus* seen on T2 and U19ac in 1994 could have germinated in either 1992 or 1993, but those sites were not censused then. Finally, germination of *Sphaeralcea ambigua* on T4 blast area and Mid Valley burned area can be presumed in spring of 1990, based on their numbers and small sizes when censused that year. From these observations we conclude that germination is normally restricted to single species, that germination combined with establishment is frequently restricted to disturbed areas, and that it rarely occurs over wide areas. Germination of grasses and herbs (*Sphaeralcea ambigua*) seem more frequent than germination of woody shrubs.

The exact timing of shrub and perennial grass germination has never been observed on the NTS and its occurrence is inferred from plants surviving to the infrequent censuses. Scattered germination of single individuals is sometimes seen; for example, several *Acamptopappus shockleyi* and *Grayia spinosa* seedlings were seen in 1994 during ephemeral plant studies near the Device Assembly Facility (DAF) in Frenchman Flat (Hunter unpublished observations).

Seed dispersal onto the blast areas has never been studied. The *Chrysothamnus* which germinated on T2, and the *Hymenoclea salsola* which established at Sedan in the mid-1980s both have wind dispersed seed (*Chrysothamnus nauseosus* has a parachute-like pappus, *Hymenoclea salsola* has a light seed with large wing-like bracts). *Atriplex canescens* (four-wing saltbush) has wings and established a few plants on throwout mounds around Sedan crater on scattered sites before 1975 (Hunter unpublished observations). These observations suggest that dispersal of at least those species has not been a significant problem.

During the 1994 ephemeral plant censuses notes were taken of perennial seedlings observed while searching 1000-m^2 areas for the rarer ephemeral species. One *Chrysothamnus nauseosus* seedling was noted at Sedan 1000', *Chrysothamnus nauseosus* and *Stephanomeria pauciflora* seedlings (not counted) were noted on the T2 blast area, and seven *Atriplex canescens* were seen on the T3 blast area. Only the *Chrysothamnus nauseosus* on T2 was later evident in the 100-m^2 perennial transects.

The hypothesis that seed burial problems limit revegetation is not consistent with presence of near-normal numbers of small mammals (Saethre 1995). These rodents make numerous small mounds associated with burrows and also make small pits and mounds on the surface during foraging activities. They bury (cache) seed at shallow depths that later germinate in small scattered clusters. Small mammal densities on the blast areas were a significant fraction of control densities (range 31 to 159%, mean $\pm$ 2 se = 91.5 $\pm$ 19.4%, n = 16). This implies both that there is significant surface disturbance, and that there are sufficient seeds (including those of annuals) to support normal granivore populations.

Several remaining hypotheses may all be operative. First, weather conditions suitable for germination of most species may not have occurred since the 1950s. Germination of *Hymenoclea salsola*, bunchgrasses, *Sphaeralcea ambigua*, and *Chrysothamnus nauseosus* leaves many of the dominant species (*Larrea tridentata, Lycium andersonii, Grayia spinosa, Coleogyne ramosissima, Yucca brevifolia*) without documented germination except as isolated individuals. Restoration of natural communities may have been limited because conditions favorable for germination may never have occurred since the last tests.

Second, the absence of shading by shrubs and the reduced wind speed near the ground associated with an intact shrub population may allow the soil surface to dry especially rapidly on the large open areas associated with the blast areas. Percent cover and average plant heights were clearly lower on the blast areas (Appendix C, Figure 5-2). Surface drying could have occurred more rapidly, though it was never measured. Of course, germination of perennials was largely absent from the control areas as well, but rapid drying of those soils could be blamed on water use by established shrubs.

Third, interactions with animals may be especially significant on the large open blast sites. As noted before, small rodent granivores are nearly as abundant on the blast areas as on the controls. Rabbit fecal pellets are approximately as abundant on the blast areas (8 $\pm$ 10 to 30 $\pm$ 12 per square meter) as on the controls (4 $\pm$ 6 to 22 $\pm$ 25) (Hunter ephemerals report). However, though equally abundant, these herbivores have a smaller perennial live volume to forage on and one which is more herbaceous, consisting largely of bunchgrasses, herbs, and young shrubs (Tables 5-4 through 5-8). In addition, there is evidence that shrubs on disturbed areas grow faster (Hunter 1994c for roadsides and burns, Hunter 1989 for Ambrosia, Hunter 1987), have better access to water (Romney et al. 1981, Hunter 1987), and have a higher water content (Hunter, 1987, Steinberger and Whitford 1983). Thus, herbivores may prefer vegetation on the blast areas.

Gophers and ground squirrels are also present on the blast areas and can kill shrubs. Ground squirrels tend to eat bark and buds. They may girdle stems, but won't usually kill a shrub. Gophers eat roots, which quickly kills the shoot. In addition, some rodents, presumably of several species, prefer to burrow under shrubs. On areas of sparse shrubs, most may have burrows baring the upper roots (Figure 5-3). It is not known whether such burrowing affects plant survival or growth, though Yeaton (1978) cited similar burrows as probably shortening the life of cacti (*Opuntia leptocaulis*) growing alone in Big Bend, Texas.

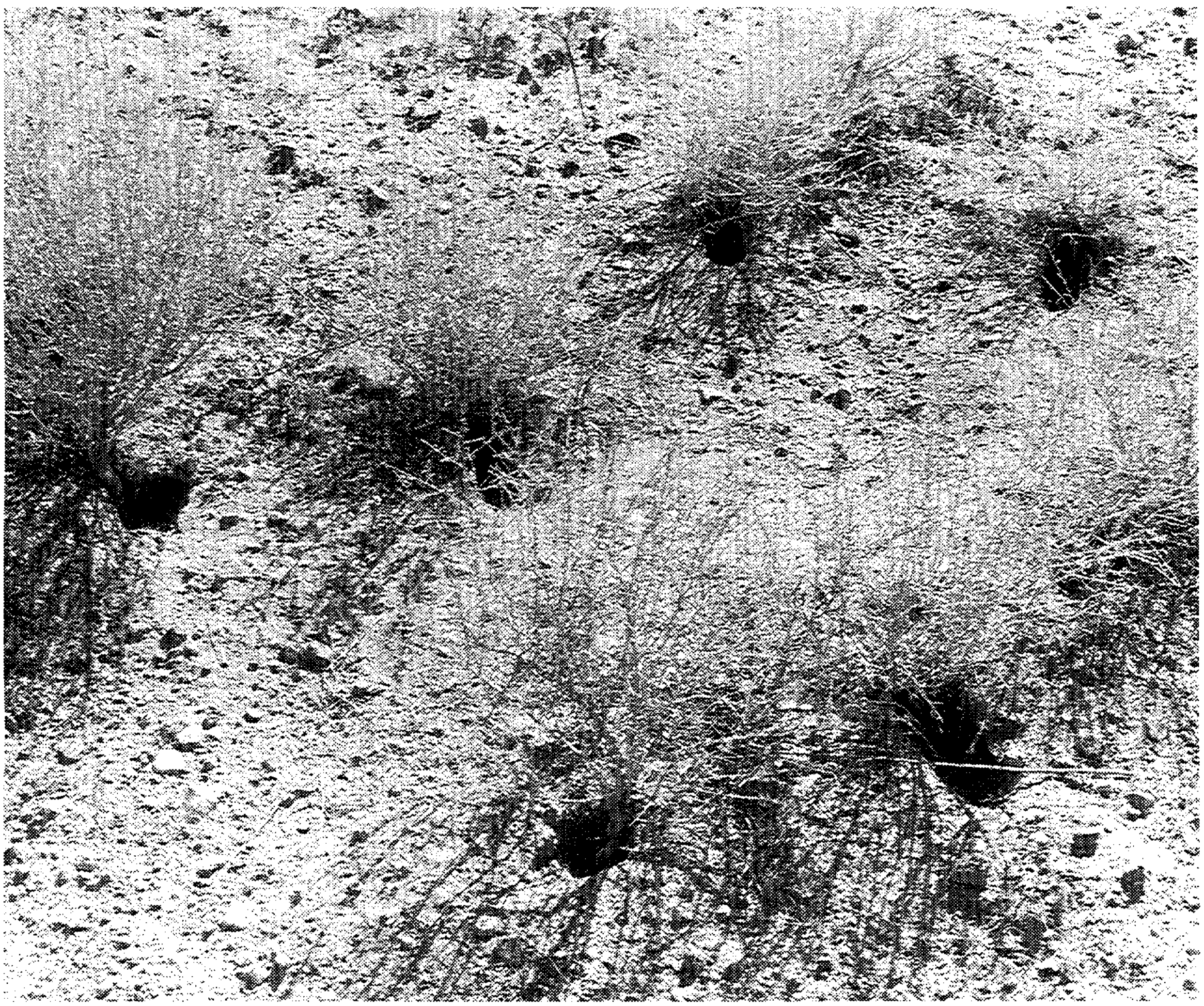

Figure 5-3. Animal holes at the base of each small *Atriplex polycarpa* shrub inhabiting a recovering disturbed area near Daggett, California in 1979. The holes ended at the root in each case.

That introduced annuals might deplete soil water enough to prevent germination or establishment of shrubs has not been addressed on the NTS. However, Melgoza et al. (1990) found *Bromus tectorum* populations reduced water availability to a perennial grass (*Stipa comata*) and a shrub (*Chrysothamnus viscidiflorus*) in northern Nevada and Hall (1994) found reduced survival of *Purshia tridentata* shrub seedlings in the presence of *Bromus tectorum* and other annuals in Utah. Holmgren (1956) similarly found *Bromus tectorum* reduced or eliminated *Purshia* establishment in Idaho.

Finally, for some hypotheses, there is essentially no evidence. There is no information on bird foraging on the blast areas, though it seems possible they might eat the cotyledons from germinated seedlings. Ant and bird foraging for seeds on the blast areas is also undocumented.

With limited data, the most plausible explanation for slow recovery of vegetation on these blast areas is an unbalanced ecosystem in which herbivores and granivores prevent establishment and growth of the shrub guild. This in turn favors the herbivores, as the reduced competition for water leaves remaining plants with higher water contents during seasonal drought. Thus, biological factors rather than physical ones are the most likely cause of slow recovery on the blast areas.

RODENT-DENUDED AREA

INTRODUCTION

In the Mojave Desert sections of the NTS, there are a number of large patches devoid of common shrubs apparently associated with heavy activity of rodents, including gophers, and rabbits (Hunter 1980). One of these areas in west Mercury Valley was monitored in 1988, 1991, and 1994. The areas are often inhabited by a suffrutescent shrub, *Stanleya pinnata*, which is apparently resistant to grazing (Hunter 1987).

METHODS

Methods of study were the same on the gopher area as on the blast areas.

RESULTS

Total live volumes of perennial plants on the rodent area were only 9% of those on its control (Table 5-9). The only species in common on the two areas were *Sphaeralcea ambigua*, an herbaceous shrub, and *Oryzopsis hymenoides*, both of which are common throughout the NTS. Neither *Sphaeralcea ambigua* nor *Oryzopsis hymenoides* contributed even 10% of total live volume at any time on either site.

Table 5-9. Perennial plant live volumes (liters/m^2) on transects on a rodent-denuded area in west Mercury Valley and a nearby control. Measured in July 1988, June 1991, and June 1994.

LOCATION	TOTAL LIVE VOLUMES, /m^2		
	1988	1991	1994
Rodent Area			
shrubs	28.92	10.15	27.94
grasses	0	0	0.01
herbs	0.07	6.00	0.13
Control			
shrubs	261.84	279.53	327.16
shrubs (non-*Larrea)*	83.20	38.21	60.78
grasses	0.02	0.06	0.01
herbs	0.26	0.50	0

On the rodent area, the dominant species was *Stanleya pinnata* (Prince's plume). Fourteen of nineteen present in 1988 died before the 1991 census, when the majority were seedlings. From 1991 to 1994, 11 of 18 survived; five probably germinated and established during that period. There was thus a fairly high turnover rate in this species not reflected in the totals (Appendix A).

At the 1991 census, *Mirabilis pudica* was subdominant, contributing 20% of total live volume on the rodent area (it was absent on the control). *Merabilis pudica* did well on other sites in 1991 (e.g., T3 blast area, see above) and subsequently declined dramatically. On the rodent area, grazing intensity on *Mirabilis pudica* varied considerably among years (G test, $P < 0.0001$; Zar 1974), with five of five grazed 50% to 99% in 1988, of 49 grazed in 1991, and 9 of 32 grazed 5% to 80% in 1994.

Another herbaceous perennial present on the rodent area was *Dichelostemma pulchellum*, a small wild onion sampled in the spring with ephemerals (Hunter, ephemerals report).

The control transect was dominated by *Larrea tridentata* (creosotebush), a large, extremely drought-hardy shrub dominant throughout North American deserts. *Larrea tridentata* contributed 62%, 82%, and 81% of total live biomass in 1988, 1991, and 1994 respectively. The large size and clonal nature of *Larrea tridentata* makes measurement of its positions, sizes, and numbers difficult however and part of its variation in volume is therefore due to changing judgements on those factors among years. The volume of non-*Larrea tridentata* shrubs is, therefore, included in Table 5-9. Their volume decreased by more than 50% between 1988 and 1991, and regrowth in the subsequent three years only partially made up for the loss. Surviving non-*Larrea tridentata* shrubs grew but their numbers were significantly reduced by drought in 1989-91 and made essentially no recovery (i.e., there was no germination). Herbaceous plants and grasses made up an insignificant proportion (0.2% maximum) of perennial live volume on the control.

The proportion of plants grazed was greater on the rodent area in both 1988 (21% versus 4%, $\chi^2 = 15.8$, $p < 0.0001$) and 1994 (21% versus 2%, $\chi^2 = 15.3$, $p < 0.0001$). In 1991 there was no grazing recorded on either plot. On the rodent plot, *Stanleya pinnata* was never grazed, but *Mirabilis pudica, Sphaeralcea ambigua, Astragalus lentiginosus* and *Oryzopsis hymenoides* were. On the control plot *Sphaeralcea ambigua* was grazed, 1 of 13 *Lycium andersonii*, and 1 (which died) of 119 *Acamptopappus shockleyi*. In 1994, the two *Ceratoides lanata* (winterfat) were both grazed (20 and 40%), but no other plant was.

In 1988, 53% of plants on the rodent plot and 41% of those on the control fruited ($\chi^2 = 1.7$, $p = 0.19$). In 1991, the proportions were 15% and 28% ($\chi^2 = 3.27$, $p = 0.07$), and in 1994, 7.5% and 32% ($\chi^2 = 15.2$, $p < 0.0001$). Reproduction was thus better on the control in 1994.

Mean growth rates on the rodent area from 1991 through 1994 were negative ($\overline{k} = -0.44 \pm 0.35$), whereas on the control they were positive ($\overline{k} = +0.19 \pm 0.10$). The difference was significant

(t_{42} = 3.51, p = 0.001), but recall that the species composition was very different on the two transects and that the control was dominated by woody shrubs while the rodent area was inhabited primarily by herbaceous perennials.

DISCUSSION

There are a number of similar areas present on the NTS in the Mojave Desert vegetation associations. Although these rodent-denuded areas are common on the NTS, they are not obvious elsewhere in the Mojave Desert. They range in size from small clearings with some surviving shrubs (Figure 5-4) to large ones such as the 62 ha area observed by Hunter et al. (1980). Their total area on the NTS has been estimated as 1000 ha (Hunter and Medica 1992). Although the several censuses of this area in Mercury Valley do show some of the dynamics in vegetative parameters, they do little to clarify the causes for initiation, growth, and persistence of such denuded areas.

The postulated mechanisms suggested by Hunter et al. (1980) (high herbivory levels by gophers and rabbits) are still undocumented, although a higher-than-normal density of rabbit pellets was found on MER002 in 1992 (Hunter 1994e, Table 5-14). In 1991 it had the highest rodent density of any site trapped (Saethre 1994a), but trapping with seed for bait only accounts for granivores and no gophers were caught or documented on the site or its control. High densities of annual plants, mentioned by both Hunter et al. (1980) and Saethre (1994), were measured in 1988, 1991 and 1994, but high ephemeral densities are found wherever shrubs have been removed (Hunter 1994a, Hunter 1995).

In a review of impacts of gophers on North American vegetation, Mielke (1977) speculated that disturbance (i.e., removal of existing vegetation) can favor gopher invasion by improving growth of forbs (non-grasslike herbaceous plants), their favored foods. He cited both a logged area in Oregon and grazed or mowed prairie areas. Although the rodent-denuded areas on the NTS have not been associated with any particular disturbance, it is possible that general levels of disturbance along roads and for weapons testing activities might have led to their formation by similarly favoring gopher populations.

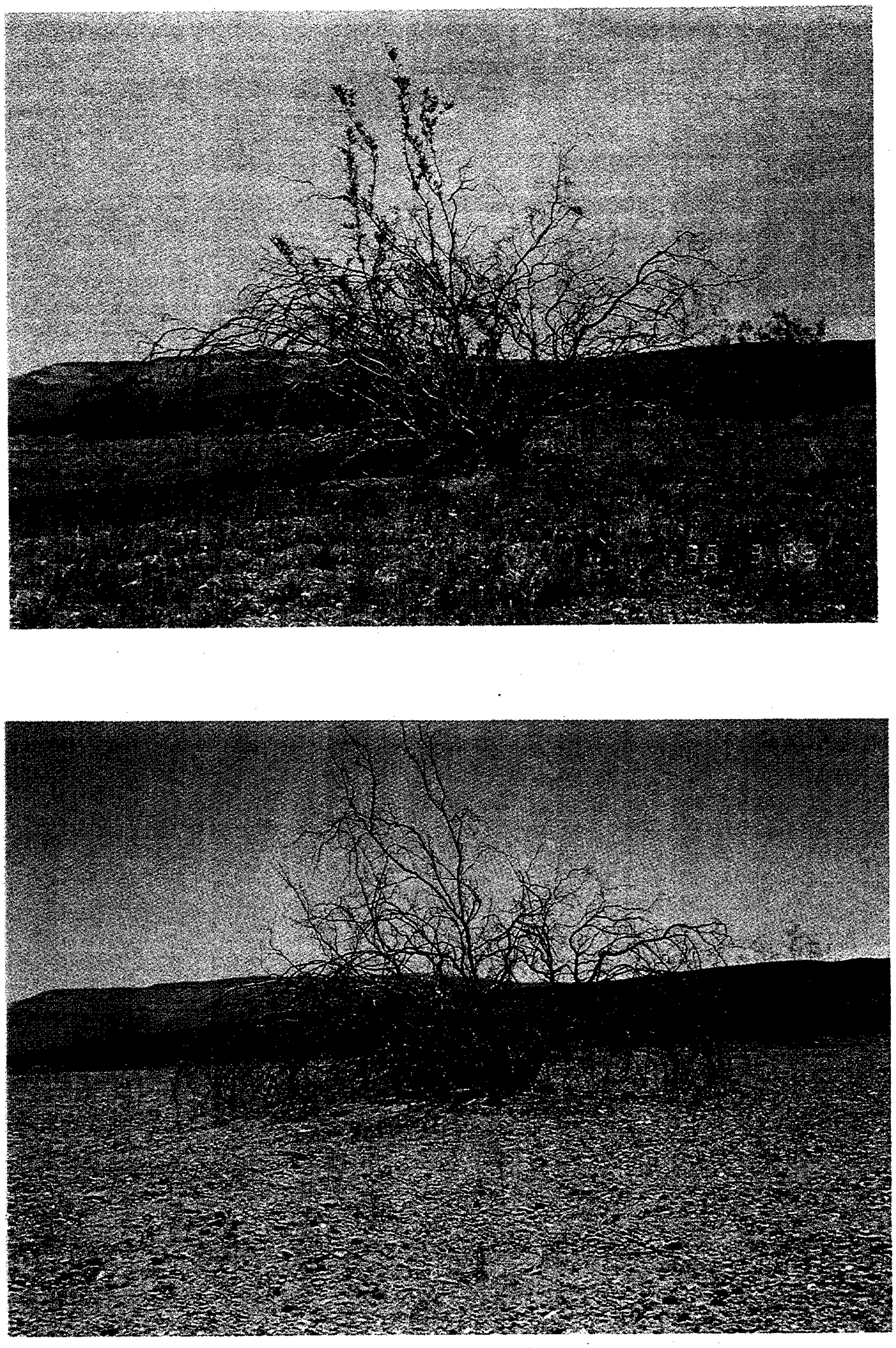

Figure 5-4. A remnant *Larrea tridentata* on a small rodent area (~1 ha) in Jackass Flats. In 1988, (top photo) several branches were alive; in 1990, (bottom) it was dead.

DRILL PADS

INTRODUCTION

Drill pads are areas of several acres cleared of vegetation; leveled; compacted; and, in parts, graveled. They often include a containment pond for drilling mud or water. They are constructed in association with drilling activities for underground nuclear weapons tests and are the site of drilling and staging activities for some months. If a subsidence crater does not form after an underground test, the drill pad itself is the major surface disturbance associated with the test. In 1994, one drill pad on Pahute Mesa (U19ac) was studied.

METHODS

Methods are the same as those used on the blast areas, involving measurement of all perennial vegetation on a 100-m^2 permanently-marked belt transect. Because of the large number of new seedlings, grasses were censused only every tenth meter, primarily being counted in one- or two-square meter areas, with only a median-sized plant being measured. For this reason, plant locations were not exact and growth of individuals present both years was not available. The same was true of the numerous *Arenaria congesta* on the control plot, also measured every tenth meter.

RESULTS

There were at least four species of grass on the drill pad - *Oryzopsis hymenoides, Poa fendleriana, Sitanion jubatum,* and *Stipa comata.* Most (~80%) were small seedlings whose species could not be determined. Most grass volume was contributed by the older individuals of *Oryzopsis hymenoides* and *Stipa comata.* Those older plants had died back significantly since 1991 and total live volume therefore declined on the transect.

On the drill pad grasses dominated, but four new *Chrysothamnus nauseosus* seedlings were present (Table 5-10). There were also a number of gopher mounds, deer pellet clusters, and rabbit pellets ($38 \pm 30/m^2$) in the area, and those shrub seedlings could be easily killed by grazing. Total live volume on the drill pad was only 2% of that on the control transect.

Table 5-10. Perennial plant numbers per 100 m² and live volumes (/m²) on transects on a Pahute Mesa drill pad (U19ac) and a nearby control.				
LOCATION	TOTAL LIVE NUMBERS		TOTAL LIVE VOLUMES	
	1991	1994	1991	1994
Drill Pad				
shrubs	0	4	0	0.06
grasses	281	1910	13.70	5.75
herbs	0	0	0	0
Control				
shrubs	60	63	49.02	43.49
grasses	133	104	1.20	1.00
herbs	305	124	0.06	0.05
woody mats	2771	2037	4.52	12.65
trees	13	18	174.84	207.03

Control vegetation bore little resemblance to that on the drill pad. It was dominated in volume by juniper and pinyon trees (*Juniperus osteosperma* and *Pinus monophylla*). The most numerous species was *Arenaria congesta*, a small, mat-forming, woody perennial. Grasses made up only a small proportion of the population. Increase in total live volume was primarily due to growth of the larger trees. Two new seedling *Juniperus osteosperma* and three new *Pinus monophylla* were present, which reduced mean tree sizes, but did not affect total cover and volumes (Appendix A-1). All five junipers and seven of eight pines present at both censuses grew larger.

Mean tree heights were less than one meter, reflecting the generally young age of the population. The presence of several seedlings suggests the postulated single recent germination event, based on the normal distribution of tree heights (Hunter 1994a), may be an oversimplification.

DISCUSSION

Processes leading to recovery of the vegetative community appeared to be proceeding relatively rapidly on this drill pad. Even though total live volumes were still much reduced, the germination of large numbers of grass seedlings and scattered new shrub seedlings suggest there will be a relatively rapid growth of plants in the next few years. The presence of gopher mounds and deer droppings indicated herbivore presence on the site. Saethre (1994b) found approximately equal numbers but a greater diversity of granivorous rodents on the drill pad than on the control, indicating odent recovery on the site was rapid. A decline in numbers of annual plants since 1991 (Hunter 1994a), when there were numerous *Salsola australis* seedlings, may be an indication of recovery of perennial plant water use on the disturbed site. At this altitude, annual plants are a minor part of the normal ecosystem (Hunter 1994e) and 1994 population parameters were similar on the drill pad and its control.

BASELINE SITES

INTRODUCTION

Baseline sites are plots picked to represent natural areas unaffected by DOE activities, as much as possible. Five such plots were selected in the first two years of the BECAMP program, one for each major valley or Mesa on the NTS: Frenchman Flat, Jackass Flats, Yucca Flat, Pahute Mesa, and Rainier Mesa.

A sixth baseline area was located in Frenchman Flat, northeast of the Liquefied Gaseous Fuels Spill Test Facility. First monitored in 1981, four transects in differing vegetative communities provide long-term study data. In this report only the 1993-1994 results will be discussed. Earlier data are in Hunter et al. (1991) and Hunter (1994a,b,c). The four transects suffered a near-total die-off of shrubs during drought in 1989 and 1990. Because those plots were not affected by early, large spills of hydrogen fluoride gas (Hunter et al. 1991) and are distant from expected effects of more recent spills, they represent undisturbed vegetation in otherwise unstudied habitats near the NTS' playas and are considered baseline plots.

Certain species too rare to fall in significant numbers in the transects have been studied by marking individual specimens and following their fates, measuring size, health, and reproductive parameters annually. These plants were either on baseline plots or areas unaffected by obvious DOE activities.

METHODS

Methods of baseline plot studies are identical to those used on the blast areas. Transect sizes on Pahute and Rainier Mesas were reduced to 50 m^2 each, as the dense populations made sampling 100 m^2 prohibitive.

To study individual plants, each was marked with an aluminum stake or a brass tag on areas gridded for mammal trapping. Mammal grid locations were used to find approximate locations and the tags were used to identify the particular plant. Species studied in 1994 were Joshua trees (*Yucca brevifolia*) and cacti on the Yucca Flat baseline plot, and pine trees (*Pinus monophylla*) on three other plots. Pine trees were marked specifically to follow the fate of those infested by pinyon needle scale in Big Burn Valley, and controls were on the U19ac drill pad control on Pahute Mesa and the Rainier Mesa baseline plot.

RESULTS

Yucca Flat

The baseline site in southwestern Yucca Flat has been censused each year since 1987 and results were fully summarized by Hunter (1994c). Only 1993 and 1994 results are reported here.

Consistent with the reduced rainfall in 1994, total live volumes declined from 19,173 to 18,262 liters. Over all live plants the growth constant ($\overline{k}$) was negative ($\overline{k} = -0.23 \pm 0.18$, 72 grew, 96 shrank, $p < 0.10$, sign test), indicating the average live plant shrank 20% between the two years. Total numbers declined from 245 to 195 plants, primarily due to death (above ground) of herbaceous species, especially *Sphaeralcea ambigua*, *Mirabilis pudica*, and *Oryzopsis hymenoides* (Appendix C). Of these, it is likely most *Sphaeralcea ambigua* and *Oryzopsis hymenoides* died as those that disappeared were mostly young, small seedlings. The *Mirabilis pudica* were large in 1993 and were present when censused in late July 1994, but were dead above ground. *Mirabilis pudica* normally dies to ground level each year and it is expected they survived below ground. Changes in other species followed a similar pattern; young small herbaceous plants died. Small changes in woody species numbers were better explained by errors in measurement, as some thought to be dead grew or others considered outside the transect one year were inside the next, a function of tape placement. One new *Ephedra nevadensis* appeared. Its size indicated it was not a seedling, but a sprout from a rhizome below ground. It was approximately 58 cm from another large *Ephedra nevadensis*. Several *Grayia spinosa* were found deep inside clumps and it is possible they grew from below ground in 1993, but were not noticed that year. A number of *Artemisia spinescens* called seedlings in 1993 were missing in 1994. There were no plants considered seedlings in 1994.

A similar pattern of high, drought-induced, juvenile mortality in 2-4 year-old seedlings was described for the Fornada Experimental Range in New Mexico by Wright (1972).

Of 31 *Atriplex canescens,* 8 grew and 23 shrank ($p < 0.05$, sign test). This species is dioecious (has separate male and female plants) and females produce fruit at the ends of new branches. After fruiting those branch-tips die back, leaving a spiny dead twig at the outside of the canopy. Among the female plants 14 of 16 shrank ($p < 0.01$, sign test) and $\overline{k}$ was -0.62 ± 0.30, while seven of ten male plants shrank ($p > 0.25$, sign test), their $\overline{k}$ being -0.14 ± 0.30. Females shrank significantly more ($t_{23} = 2.23$, $p = 0.036$). Thus, the shrinkage in that species cannot be attributed solely to weather, and should be considered a normal concomitant of heavy seed production in 1993. The sex ratio of 16 females to 10 males is consistent with reported values elsewhere (MacArthur and Freeman 1982, Freeman and MacArthur 1984).

Total live volume regressed on four-year running-mean rainfall introduced in Hunter (1994c) was 18,032 liters, within 2% of measured live volume of 18,262 liters. Thus, shrub volume was in approximate equilibrium with rainfall and could be predicted from weather data. An updated equation, including 1994 data, was:

Total live volume = 5879 +0.0668 x 3-yr running-mean rainfall (liters/100 m^2) [$r^2 = 0.90$].

If the species on this transect are divided by functional groups instead of species (Hay 1994) then the transect is seen to be dominated by drought-hardy, long-lived, woody shrubs which maintained their volume between 1993 and 1994 (Table 5-11). The groups which shrank significantly were the above- and below-ground herbs and the invading shrubs (*Atriplex canescens*). Succulents include cacti and *Yucca brevifolia* (Joshua tree). They are present in the area, but not on this transect, and were censused as individuals on the 2.56 ha mammal plot.

Table 5-11. Live volumes (/m²) on the Yucca Flat baseline plot (YUF001) by functional groups of perennial plants.		
Functional Group	Volume 1993	Volume 1994
Long-lived, drought-hardy shrubs	120.80	125.98
Short-lived, invading shrubs	65.25	53.19
Interspace shrubs	3.14	3.43
Above-ground herbs and bunchgrasses	0.73	0.02
Below-ground perennial herbs	1.82	0.00
Succulents	0.00	0.00
TOTALS	191.74	182.62

Other baseline plots

Censuses have been performed annually on four other baseline plots. Between the 1993 and 1994 censuses, only small changes were apparent in these populations (Table 5-12), primarily death of seedling perennials which germinated in 1992 and 1993.

On the Jackass Flats plot number changes were minimal. Total live volume decreased 21% as most plants shrank (143 out of 204 measured both years - $p < 0.01$, sign test). Species which shrank significantly (i.e., had numbers sufficient to test significance) were *Acamptopappus shockleyi* and *Ambrosia dumosa* ($p < 0.01$). All seven *Larrea tridentata* shrank ($0.05 < p < 0.10$). No live plants were grazed and fruiting varied from 3% in *Ambrosia dumosa* to 57% in *Larrea tridentata.*

On the Frenchman Flat baseline plot numbers declined from 78 to 68, primarily due to loss of seedling *Oryzopsis hymenoides* (Indian Rice Grass). It should be noted that those seedlings can spend a significant proportion of the year dead above ground; are subject to grazing by rabbits; and, when small, are difficult to see (for seedlings a single small dead leaf might be present, for example). Total live volume decreased only 2%, from 139.49 to 136.27 /m². Of 60 plants measured both times 43 shrank ($p < 0.01$), including all 15 Ambrosia dumosa ($p < 0.01$). Only three plants were grazed, two *Ceratoides lanata* (winterfat - 1% & 2%) and one female *Ephedra nevadensis* (Mormon tea - 10%). Fruiting ranged from 0% (of four) in *Acamptopappus shockleyi* to 100% (six of six) in *Larrea tridentata.*

On Pahute Mesa numbers declined from 488 to 419, almost totally due to loss of 70 seedling *Artemisia nova*. In this case death of the seedlings was responsible, as they do not survive below ground and resprout, nor should they have been more difficult to see in 1994 than 1993. One new *Ephedra nevadensis* plant was found and, as in Yucca Flat, was due to a new shoot appearing from below-ground rhizomes about 50 cm from the nearest neighboring sprout. (The rhizomatous habit of this species at higher altitude was noted in Hunter 1994a.) No grazing damage was noted on any plant. Total live volume decreased from 142 to 123 /m^2 (-13%; Table 5-12). This plot is strongly dominated by *Artemisia nova*, which was primarily responsible for the volume decrease (91% was due to loss in that species). Censusing was done in July 1994, prior to flowering of *Artemisia nova*. If done later the extra growth involved in flower and fruit production might have negated the volume loss. In 1993 censusing began August 30, when 56% had buds, flowers, or fruit. In 1994 only 33% had buds, and none were flowering or fruiting when censused. Among other species, only 8 of 77 *Sitanion jubatum* and 3 of 13 *Oryzopsis hymenoides* fruited.

Table 5-12. Density (n/m^2), cover (%), total above-ground live volume (/m^2), $\overline{k} \pm 2$ se, and ratios of dead to live plants on four baseline plots. (The 6.20 n/m^2 for Rainier Mesa 1993 is a correction of erroneous 1993 data.)

	Jackass Flats		Frenchman Flat		Pahute Mesa		Rainier Mesa	
	JUL 93	MAY 94	JUN 93	MAY 94	AUG 93	JUL 94	AUG 93	JUL 94
n/m^2	2.22	2.23	0.83	0.68	9.76	8.38	6.20	6.18
cover	39	34	14	13	43	40	68	70
volume	229	180	139	136	142	123	651	745
$\overline{k} \pm 2$ se	0.01 ±0.11	-0.16 ±0.11	0.46 ±0.29	-0.12 ±0.21	-0.14 ±0.11	-0.06 ±0.09	-0.02 ±0.23	0.17 ±0.19
dead/live	0.58	0.56	1.46	1.51	0.14	0.15	0.07	0.08

On Rainier Mesa, change in total live volume was due totally to growth of four young (1.0- to 2.9-m tall) *Pinus monophylla* and inclusion of one borderline *Juniperus osteosperma* (2.3-m tall) left out of the 1993 census. As on the control plot for drill pad U19ac, trees grew while other species maintained their previous sizes (Table 13). Only three herbs were grazed, each 10%. Fifteen of ninteen species had some reproductive individuals, the average percent reproductive being 30 ± 15 ($\overline{x} \pm 2$ se).

Table 5-13. Distribution of numbers in 50 m^2 and live volumes ($/m^2$) among functional groups of plant species on Rainier Mesa.				
	NUMBERS		VOLUMES	
	1993	1994	1993	1994
trees	20	24	306	405
shrubs	71	64	337	331
grasses	71	86	0.64	0.68
herbs	124	110	3.72	3.74
woody mats	23	22	3.92	5.02
cacti	1	1	0.26	0.12

Gas Spill Transects

Total live volumes on the four gas spill transects were generally low, although the only transect with *Larrea tridentata* (FF84) fared considerably better than the others (Table 5-14).

Table 5-14. Summary parameters (n/100 m^2; $/m^2$) of vegetation on four transects downwind of the Liquefied Gaseous Fuels Spill Test Facility on Frenchman Playa.						
TRANSECT	NUMBER		LIVE VOLUME		DEAD VOLUME	
	1993	1994	1993	1994	1993	1994
FF66	48	31	1.68	0.14	113.05	108.14
FF67	316	269	6.92	3.81	40.39	33.15
FF81	450	421	2.60	1.36	54.47	45.07
FF84	111	98	62.56	60.68	11.69	8.53

Transect FF66 was in a near-monoculture of *Atriplex confertifolia* (shadscale) near the edge of the playa. By 1992, all but one small *Atriplex confertifolia* died (7.5 liters). By 1994 a few small sprouts of *Kochia americana* and five new *Atriplex confertifolia* seedlings which germinated in 1992 were the only residents. Mean volume for the six *Atriplex confertifolia* was 1.5 $\pm$ 3.0 liters and for 25 *Kochia americana* was 0.24 $\pm$ 0.23 liters. Total live volume reached an all-time low of 14 liters, down from 12,121.93 $/m^2$ in 1988 (-99.9%, see dead volume in Table 5-14). Thus, the vegetation at this location essentially ceased to function between 1989 and 1994, even though germination occurred and 1993 was one of the wettest years of record. Given that both species are salt-tolerant, it may be that in the absence of plant transpiration salt moved to the surface and was preventing re-establishment.

Transect FF67, also near the edge of the playa, historically consisted of a mixed *Atriplex confertifolia* (76%), and *Atriplex canescens* (23%) community with a few scattered herbaceous plants (*Sphaeralcea ambigua* and *Stanleya pinnata*). In 1994, one surviving *Atriplex canescens* made up 110 of the 114 liters of *Atriplex canescens* volume. There were 12 small *Atriplex canescens* seedlings. Only three seedlings grew larger from 1993 to 1994, all between 25.7 and 27.0 meters along the transect, suggesting they were in a patch of favorable soil. *Atriplex confertifolia* seedlings outnumbered (247 to 12) those of *Atriplex canescens* in 1994. None of the 37 *Atriplex confertifolia* which grew between 1993 and 1994 occurred between 15.0 and 25.0 or 36.9 and 45.0 meters, again suggesting there were patchy favorable soil conditions.

Grazing was minor on FF66 and FF67. Two *Kochia americana* were grazed about 25% each, and three of nine *Stanleya pinnata* on FF67 were grazed 10%, 80%, and 90%. The heavy grazing on *Stanleya pinnata* was unusual. No plants fruited on either transect in 1994.

Transect FF81 is approximately 1.8 km from the edge of the playa. It has been dominated by *Atriplex canescens* but contained a few other species, especially herbs and bunchgrasses, both before and after the drought. Maximum live volume was 58.45 /m^2 in 1986. In 1991 no live plants were present above ground, though eight of nine *Mirabilis pudica* apparently survived below ground. Total live volume recovered from 0 to 2.60 /m^2 between 1991 and 1993, then declined to 1.36 /m^2 in 1994. Species which can survive below ground (*Oryzopsis hymenoides* and *Mirabilis pudica)* did well, making up 352 of 421 plants in 1994, but shrubs made up 128 of the 136 liters of above-ground live volume.

Of 57 young *Atriplex canescens* on the transect, 23 grew and 24 shrank ($\overline{k} = 0.07 \pm 0.66$). Only one *Sphaeralcea ambigua* was grazed, and 50 of 339 *Oryzopsis hymenoides* fruited (15%).

The final LGF transect monitored (FF84) is about 2.2 km from the playa edge in sandy soil. It is dominated by *Larrea tridentata*, but has included several *Atriplex canescens* and occasional individuals of several other species. Maximum live volume was 128.03 /m^2 in 1986, of which *Larrea tridentata* contributed 122.95. In 1993 and 1994, *Larrea tridentata* live volume totaled 58.27 and 57.10 /m^2 respectively, slightly less than half the maximum. In

1991 *Larrea tridentata* was the only surviving species, but in 1992 many *Oryzopsis hymenoides* and *Atriplex canescens* germinated. By 1994, surviving seedlings of those species contributed 6 and 352 liters respectively. Eighteen of 62 *Oryzopsis hymenoides* fruited, as did four of five *Larrea tridentata* and three of 57 *Atriplex canescens* had buds or flowers (flowers without fruit indicate male plants). Mean volume of the *Atriplex canescens* seedlings was 11 $\pm$ 7 liters, compared to only 2 $\pm$ 1 liters on FF81, 400 m down slope. Growth of those seedlings occurred largely in 1993 ($\bar{k} = 3.06 \pm 0.43$; a 21X increase in mean size), while mean size shrank from 1993 to 1994 ($\bar{k} = -0.14 \pm 0.32$; a 13% decrease).

Marked Individuals

Cacti on the Yucca Flat baseline plot were of two or three species (one tentatively called *Opuntia ramosissima* was ambiguous). Between 1993 and 1994, none of 12 *Opuntia echinocarpa* died. Mean growth was slightly negative ($\bar{k} = -0.19 \pm 0.12$; 9+/2-, $p = 0.1$) over the year. Of 13 live *Opuntia basilaris* (beavertail cactus) first marked in 1992 there were 6 surviving. Two died between 1993 and 1994. Of the six surviving plants two grew and four shrank (not significant, $\bar{k} = -0.38 \pm 1.16$). Three severely damaged cacti had young pads growing from the center of clusters of dead ones, suggesting the cause of damage was more likely physical conditions than disease. Because winters have been mild, and the plants died in an unusually wet year, excess water seems a more plausible cause than frost, though we cannot suggest a physiological mechanism.

There were 33 *Yucca brevifolia* censused on Yucca Flat in 1993. Of those, eight were killed by rabbits before the census in October 1994. The remaining 25 included 2 adults, which in 1994 did not flower or fruit, and 23 small plants, the tallest 57 cm high. Two new ones were found, and one considered dead in 1993 resprouted from the center of the grazed-off stump. Mean heights of the plants measured both years declined from 34.6 to 34.2 cm as most plants shrank one or two centimeters. The continuing reduction of this cohort of young Joshua trees is due to rabbits, which graze them to stubs at or below ground level (see Figure 12 in Hunter 1994a). The loss rate in 1993-4 was greater than in 1992-3 ($\chi^2 = 4.62$, $p < 0.05$), consistent with greater rabbit use in drier years. Since marking first began in 1989, 89 plants have been found on this 2.5 ha plot, of which 25 survived in October 1994. Germination must have occurred years before 1989, as no very small plants were ever seen. Growth of plants in this cohort occurred only in 1992.

Three populations of pine trees were monitored in 1993 and 1994. Fifty random trees on each plot were marked in 1991, with growth and mortality followed since. The plot in Big Burn Valley was infested with pinyon needle scale (*Matsucoccus acalyptus* - Figure 2 in Hunter, 1994b) in 1991 and 1992, but these insects were absent in 1993 and 1994. When censused in August 1994, 38 of the 50 trees survived, one dying since 1993. One more appeared to be dying in 1994, with dead needles and apical meristem, but those symptoms were different from those due to *Matsucoccus acalyptus*, which defoliates the branches. On the other two plots all fifty trees survived, including small seedlings. Mean changes in height on the three plots were significantly different for the 1993-4 period (ANOVA, $F_{2,134} = 14.2$ $p << 0.0001$) at $+7.8 \pm 1.9$ (cm $\pm$ 2 se) (Pahute Mesa), $+2.9 \pm 1.9$ (Rainier Mesa), and -0.7 ± 1.9 (Big Burn Valley).

DISCUSSION

Results of studies of marked individuals in 1994 basically confirmed processes revealed in the first few years of following the population. Surprises found include the remarkable extent of rabbit grazing on young Joshua trees in dry years, the finding of a young population of pine trees on Pahute Mesa, and the unexpected death of many of the beavertail cactus on the Yucca Flat plot. The very slow growth of junipers on the Pahute Mesa baseline plot (Hunter 1994c) was also unexpected. Although recovery processes appear to be slow, the *Matsucoccus acalyptus* infestation no longer appeared to be causing significant mortality. The knowledge gained with minimal effort by these studies helps explain the relative scarcity of many of these species on the areas studied, and allows useful inferences to be made regarding management of rare species on NTS lands.

ROADSIDE DIVERSITY STUDY

INTRODUCTION

In 1993 it was found that species growing along one roadside in Frenchman Flat were different from those growing on a control area (Hunter 1994c). Differences in species composition make comparison of two habitats difficult except in gross parameters such as total live volume, mean height, ratio of live to dead, etc. In 1994 a study was made of vegetation growing along nearly all NTS paved roads to determine if such species composition changes were a widespread phenomenon.

METHODS

In order to measure species presence at a particular point, a 50-m line was walked at three locations: the "scraped" area adjacent to the pavement, the berm of soil raised by scraping, and undisturbed desert usually 50 m from the berm. Because there were frequently other disturbances next to the roadway, such as buried cables, dirt roads, and drainage channels, it was often necessary to go farther than 50 m to find undisturbed vegetation. A species and its position along the line were recorded. The widths of each such line varied--on the roadside being limited by the scraped area, on the berm by the scraped edge on one side and by an estimation of where the roadside influence ceased on the other, and in the undisturbed area largely by the distance a plant was visible. The minimum search path of 50 meters was chosen to approximate the area needed to reach a rough plateau in the species-area curve (Figure 5-5), but new species seen past the end of the 50 meters were occasionally included and the total length searched was recorded. Locations searched were marked and latitude, longitude, and altitude were determined with a GPS unit.

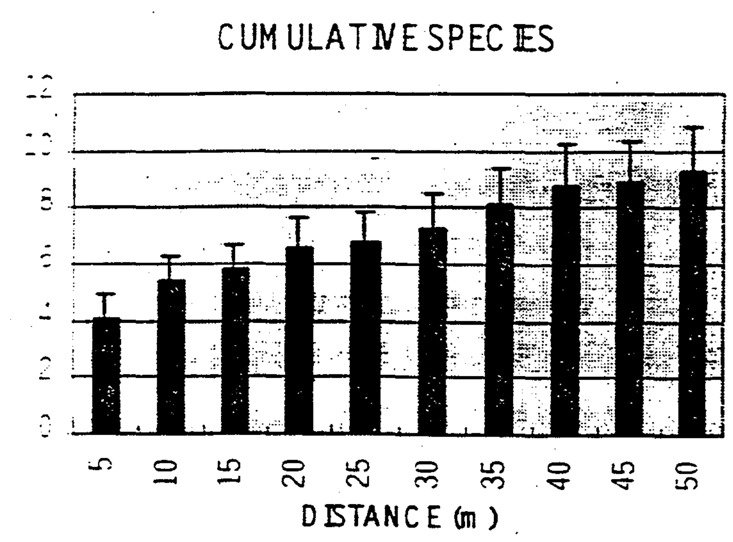

Figure 5-5. Cumulative species encountered in control vegetation on 10 of 95 roadside study sites.

A total of 95 points along NTS paved roads were studied. Within the first mile of each road a random point was selected; thereafter locations were one, then two, then three miles apart, with that pattern repeated until the end of the road was reached. Thus, on a particular road the minimum distance between sample locations was one mile and the maximum three miles. Short roads were sampled more frequently (twice in the first two miles) than long ones (three times in six miles) in an attempt to be sure all roads were sampled. Time constraints prevented sampling on paved roads on Rainier Mesa, which would have added two or three more sites in different habitats.

To compare scraped, berm, and control species compositions, a Sorenson index was calculated for each pair (scraped vs. control, scraped vs. berm, etc.). The Sorenson index is the ratio of species common to two locations to the mean number of species on each. An index of zero indicates there were no species in common, while a ratio of one indicates species compositions were identical on two sites.

RESULTS

Mean number of species on control sites was 9.5 ± 0.9, on the berms was 7.2 ± 0.8, and on scraped areas 4.6 ± 0.7 (mean ± 2 se). The means differ significantly by analysis of variance ($F_{2,282} = 39$, $p \ll 0.0001$). If differences in species composition were caused solely by removal of species on the scraped areas, one would expect a mean Sorenson index (C_s)of 0.48 (4.6/9.5) between scraped and control sites. What was found were a mean C_s of 0.25 ± 0.04 between scraped and control, 0.40 ± 0.05 between scraped and berm, and 0.55 ± 0.05 between berm and control ($F_{2,278} = 45$, p 0.0001). Thus, scraped areas were less similar than would occur simply by removal of species and berms were more similar.

Control sites more than a mile apart were more similar ($C_s = 0.43 \pm 0.04$) than control and scraped sites ($C_s = 0.25 \pm 0.04$) located just 50 m apart ($t_{187} = 6.0$, $p \ll 0.0001$). The same relationship was apparent between scraped sites i.e., they were more similar to scraped sites a mile or more distant ($C_s = 0.42 \pm 0.04$) (Figure 5-7) than to the control site 50 m away ($C_s = 0.33 \pm 0.04$)($t_{135} = 2.97$, $p = 0.004$), after excluding the zero values associated with recently scraped roadsides.

Some species were clearly more frequent on, or restricted to, the scraped area or berm of the roadside (Table 5-15). Similarly, many were restricted to control areas or the control and berm.

Table 5-15. Species significantly associated (χ^2, $p < 0.05$) with roadside scraped, berm, and/or control areas, and presumed factors limiting them from one or the other habitat type. A total of 118 species were encountered.

SPECIES	SITES OCCUPIED (of 95)			EXCLUDING FACTOR
	SCRAPED	BERM	CONTROL	
Acamptopappus shockleyi	7	12	23	scraping, germination
Ambrosia dumosa	11	23	30	scraping
Aristida glauca	11	5	1	short growing season, drought
Artemisia spinescens	0	4	14	scraping
Atriplex canescens	15	41	32	scraping, drought
Atriplex confertifolia	3	13	22	scraping, soil chemistry
Ceratoides lanata	0	19	37	scraping, germination
Chrysothamnus nauseosus	24	22	8	drought
Coleogyne ramosissima	5	12	20	scraping
Ephedra nevadensis	10	39	55	scraping
Eriogonum inflatum	3	3	15	scraping?
Erioneuron pulchellum	10	3	13	shading?
Euphorbia albomarginata	30	9	4	drought?
Grayia spinosa	0	10	41	scraping, germination
Hilaria jamesii	0	2	13	scraping, germination
Krameria parvifolia	0	5	15	scraping, germination
Larrea tridentata	6	26	31	scraping, germination
Lycium andersonii	5	37	54	germination
Machaeranthera	19	15	5	short growing season, drought
Menodora spinescens	3	5	15	scraping, germination
Mirabilis pudica	5	14	18	grazing?
Opuntia echinocarpa	0	4	15	scraping
Sitanion jubatum	3	9	20	?
Stephanomeria pauciflora	29	17	4	short growing season, drought
Tetradymia axillaris	0	6	14	scraping, germination
Tetradymia glabrata	2	7	14	scraping, germination
Yucca brevifolia	0	5	21	scraping, grazing

Based on observations of their habits, a presumption may be made as to the factor(s) excluding particular species from one or more of these environments (Table 5-15). Long-lived shrubs, which take several years to grow to reproductive age, are presumed to be eliminated by scraping. Those which are rarely seen as new seedlings are perhaps absent from the roadside because germination requirements have not been met since the last scraping. Species which seem to require nurse plants to avoid grazing mortality may be absent from the scraped areas because of the low density of the long-lived shrubs. Plants more common on the scraped areas are presumed to be excluded from mature communities by competition for water (i.e., drought).

Differences in density were compared using the distances of first encounter along sample lines among the three habitat types (scraped, berm, control). KW tests performed on those species with more than ten occurrences in each habitat type indicated significant density differences only for *Hymenoclea salsola* (KW $T = 57$, $p \ll 0.0001$) and *Sphaeralcea ambigua* ($T = 62$, $p \ll 0.0001$). Other species tested (*Psorothamnus fremontii, Chrysothamnus viscidiflorus, Atriplex canescens, Ambrosia dumosa,* and *Oryzopsis hymenoides)* did not differ in density at $p = 0.05$, although *Atriplex canescens* ($T = 5.11$, $p = 0.08$) was close and may deserve further study. It occurred at somewhat reduced densities on the scraped areas, suggesting density as well as frequency were reduced by scraping. *Hymenoclea salsola* and *Sphaeralcea ambigua*, both widespread species, did not differ in presence/absence, but did differ in density among the habitat types. Many species which differed in presence/absence (Table 5-15) did not meet the criterion of >10 presences in each habitat type, but the crude density measure did not warrant analyzing small samples for differences.

ROADSIDE DISCUSSION

The purpose of looking at the roadside species composition was to help evaluate results of sampling in 1993 on the 5-05 roadside in 1993. At that site comparisons between vegetative communities at roadside and control locations were confounded by the differences in species composition at the two locations. For example, most of the growth on the roadside was by *Hymenoclea salsola,* which was absent from the control (Hunter 1994c). The survey in 1994 confirmed that differences in species composition between roadside and control were the norm throughout the NTS. Not only are control/roadside comparisons confused, but the finding that scraped area C_s were less than could be explained by removals imply habitat differences along roadsides are significant enough to foster invasion of new species.

Habitat conditions along the edges of paved roads are visibly different from those in undisturbed vegetation. Vollmer (personal communication) found an increased length of growing season in roadside shrubs which he related to extended water availability. Other workers have investigated these visible differences in deserts. Johnson et al. (1975) found 3- to 7-fold increased biomass in the visibly denser vegetation lining a Mojave desert road site, and Lightfoot and Whitford (1991) showed increased water and nitrogen concentrations in roadside plants. The extra water is postulated to be due both to runoff from the road surface and to reduced evaporation from the paved area (Lightfoot and Whitford 1991). On the NTS reduced overall vegetation suggests part of the better growth in the vegetated band next to the road could also be due to reduced competition for water Figure 5-6 (Hunter 1994c).

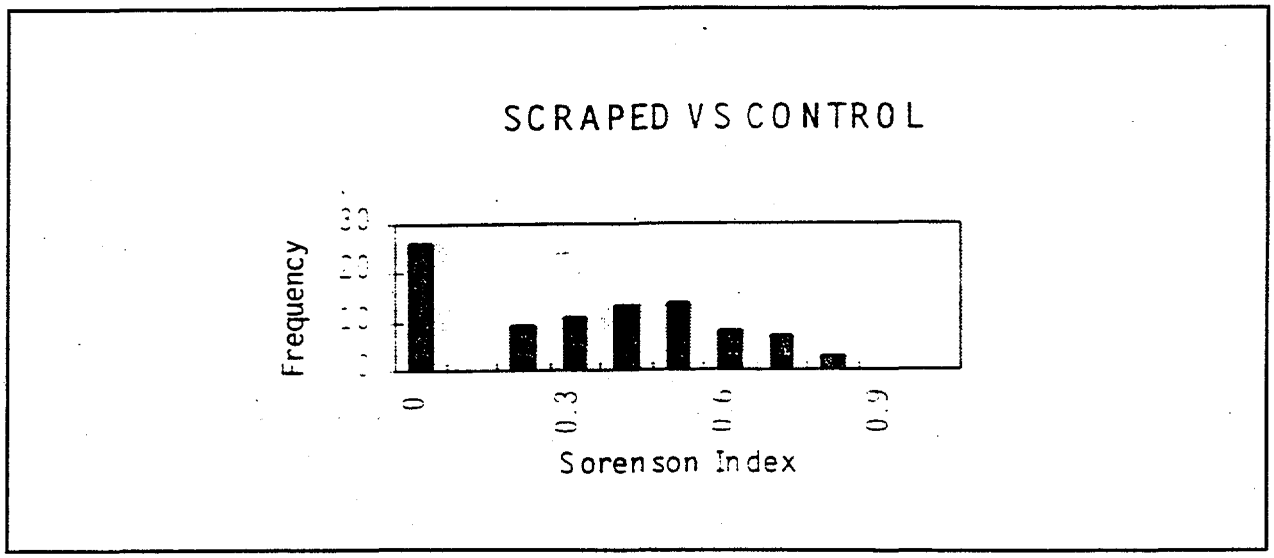

Figure 5-6. Frequency distribution of relative species compositions (Sorenson indices) between scraped roadsides and controls 50 m distant.

Scraping is another factor clearly affecting roadside species composition. Plant survival next to the pavement is difficult due to physical disruption by being run over and scraped off, hence species that can resprout from below-ground like *Stephanomeria pauciflora* and *Euphorbia albomarginata* are favored (Table 5-15). A little farther from the edge, most plants would only be scraped off every few years, which favors those which can establish, grow quickly in compacted soil, and reproduce quickly. Outside the scraped area those which can send roots into the cleared area will be especially favored, but the extra water and loose berm soil near the edge of the scraped area will also permit survival of many species, including those which would normally be crowded out by the more drought-hardy dominant perennials (Figure 5-8).

A number of rare species may be favored by roadside conditions. For example, *Brickellia watsonii*, which grows in crevices on cliff-faces, was found on one abandoned road study site (Orange Road) growing in cracks in the pavement. The scattered presence of *Argemone corymbosa* on NTS roadsides suggests it is favored by conditions there (Hunter 1994f). Similarly, *Baileya multiradiata* in previous years has been strongly evident, blooming along roadsides in certain years and areas. *Viguiera multiflora* was seen in patches along roadsides but was not encountered in any of the random points sampled. Several plants of an unknown *Asclepias* species were seen on Orange Blossom Road near the entrance to Plutonium Valley, and the few known NTS specimens of *Solanum eleagnifolium* and *Sphaeralcea angustifolia* (Hunter 1994e) were also missed by the sparse sampling pattern.

The extended plant growing season and water contents can support a longer reproductive season in roadside animals (Saethre 1994b). The increased water content may also make those plants especially subject to grazing pressures. More abundant insects on the healthier plants can favor feeding by insectivores like lizards, which themselves may be more susceptible to predation due to the lack of shrub cover on the scraped areas (Lightfoot and Whitford 1991, Woodward 1994).

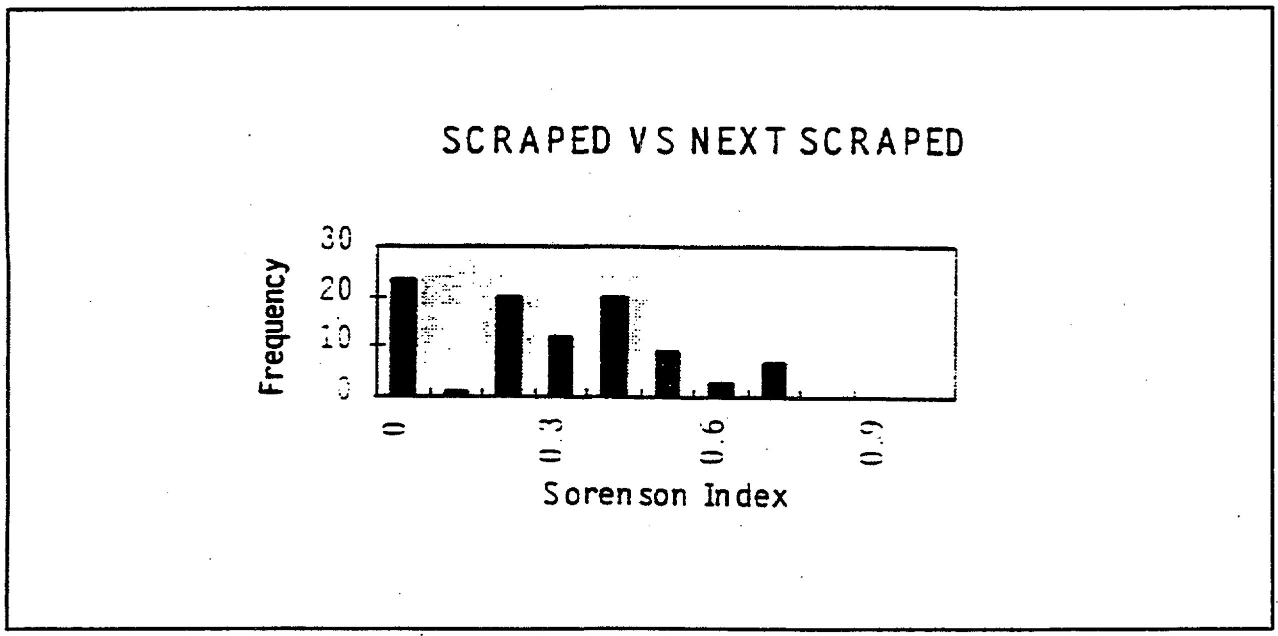

Figure 5-7. Frequency distribution of relative species compositions (Sorenson indices) between scraped areas 1 to three miles apart.

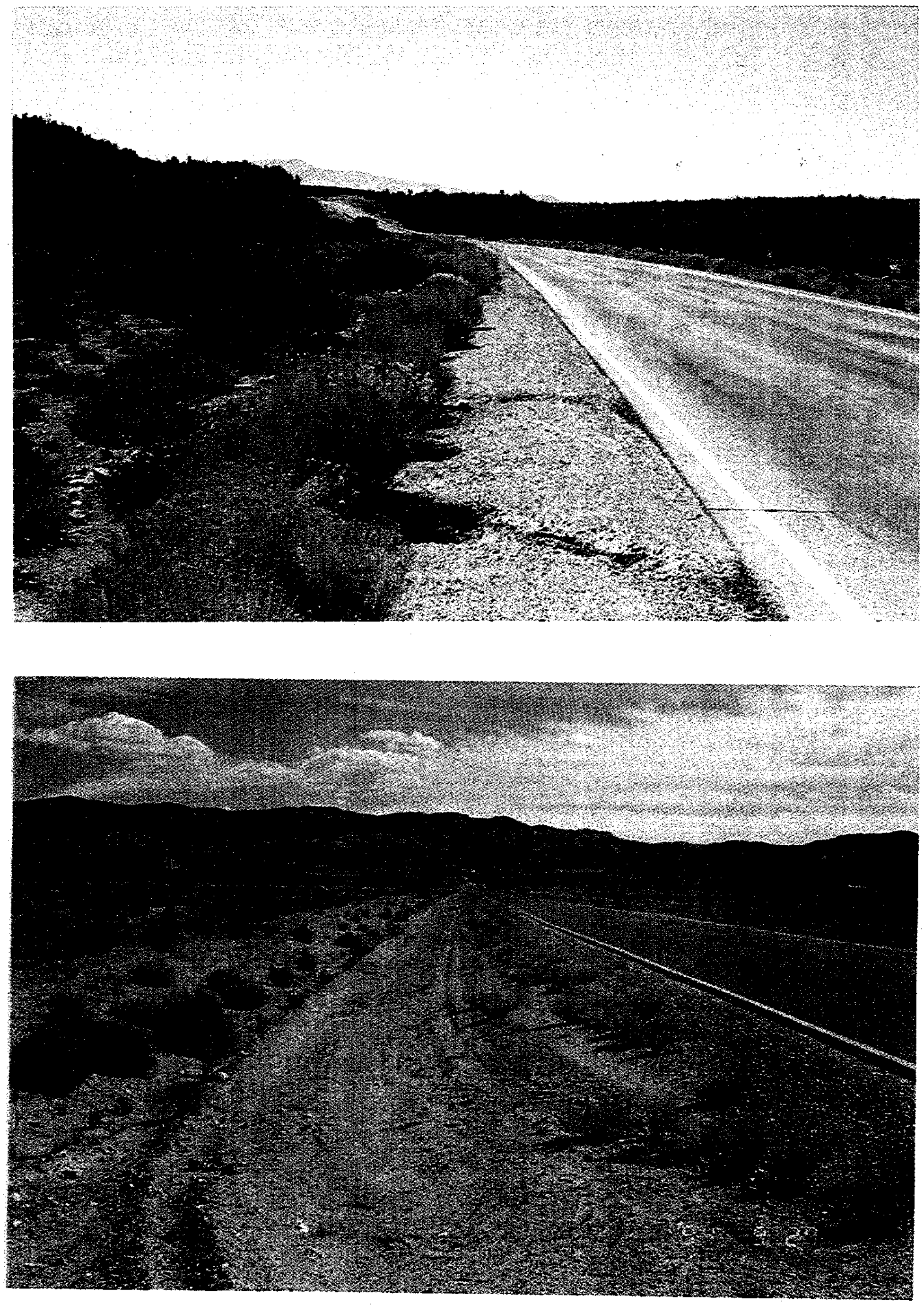

Figure 5-8 - Roadsides showing use of microhabitats by particular species. Top photo shows *Chrysothamnus nauseosus* growing in a trough along Pahute Mesa Road. Bottom shows *Ambrosia acanthicarpa* on recently scraped edge, and *Gutierrezia microcephala* growing on the berm of Mercury Highway in Frenchman Flat. Undisturbed vegetation is pinyon forest (top), *Atriplex-Lycium* (bottom).

A summary of effects of roads on the NTS ecosystems might include the following broad generalizations:

- reduces total area of undisturbed desert by the area of the road and accompanying effects. (Roadside effects on species composition may extend considerable distances [Hunter 1994f; Saethre 1994a; Woodward et al. 1995]).

- acts as a pathway and available habitat for invasion of new species into the previously undisturbed desert (Tyser & Worley 1992, Wilson et al. 1992).

- acts as a mesic refugium during seasonal or climatic drought for insects (Lightfoot and Whitford 1991), lizards (Woodward 1994), small mammals (Saethre 1994a), and plants (Hunter 1994a,b,c).

- concentrates live plant volume in a band next to the scraped area (Hunter 1994c), thereby locally increasing cover, insect abundance, etc.

Secondary results might be to decrease local diversity near the road (e.g., Woodward 1994; our decrease from 9.5 to 4.6 species) but also may increase total diversity (species richness) of the whole area through which the road passes, as Holzapfel et al. (1992) found in Israel. Johnson et al. (1975) found diversity increased next to the road, but they sampled only in the band of obviously increased vegetation. In addition, competitive interactions among species favored or disfavored by the presence of the road may be modified. Because of the complexity of species' interactions those secondary effects are almost impossible to predict.

Although roads are clearly human artifacts and changes associated with them are thus unnatural," whether those changes are bad or good is a matter of judgement. If one looks at ecosystem functioning, in terms of primary productivity, herbivory, predation, and decomposition processes, it may be possible to make a judgement on the overall ecosystem value of a road built through a desert. One might ask, Does a road decrease overall efficiency of water use by the desert ecosystem?" "Does it decrease primary production, or diversity, or ecosystem stability?" "Will it lead to a 'crash' in productivity due to distorted species compositions?

In this sense the road has little effect on primary productivity as indicated by no significant effect found on total live perennial plant volume between the road and control plots (Hunter 1994a, c). Local diversity of plants and rodents may be decreased in the vicinity of the road (Saethre 1994a, 1995), but overall diversity may be enhanced because of increased habitat diversity (Table 5-15). Introduction or increased spread of damaging new species along roads is certainly plausible, as is increased dispersal of damaging native ones (e.g., disease organisms like hantaviruses, predators like *Callisaurus draconides*, or plant parasites like *Cuscuta nevadensis*). However, large fluctuations within functional groups (guilds) of the ecosystem appear to be a natural occurrence tied to weather patterns favoring particular organisms (Saethre 1994b discusses this in connection with roadside mammal fluctuations).

For example, the 'natural' desert in the vicinity of the BECAMP roadside study plots in Frenchman Flat is strongly dominated by *Larrea tridentata.* In 1990 it made up 38,125 of 44,568 liters (85%) of total live volume on the control transects (400 m^2), but only 69% (23,628 of 34,481) on the roadside (Hunter 1994c). Five percent of the roadside community consisted of *Hymenoclea salsola,* which was absent (dead from drought) on the control transects. Yet the growth of plants was greater on the roadside from 1990 to 1993 due to the better growth of *Hymenoclea salsola* (Hunter 1994c), a species better adapted to rapid opportunistic growth during the cool wet springs of 1992 and 1993. Similarly, rodents inhabiting the roadside during the 1989-90 drought had improved reproduction over control rodents (Saethre 1994a,b,c). One could argue that "ecosystem functioning" was improved during that time by the increased habitat diversity created by road construction and use in the previous 30+ years.

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PERENNIAL APPENDIX C

The following tables summarize the perennial plant population parameters on belt transects censused on the Nevada Test Site in 1994 and previous years. Transects were normally 50 m long by 2 m wide (100 m^2), but on Pahute and Rainier Mesas they were 25 by 2 m (50 m^2), and on T1 blast area and T3 control 100 by 2 m (200 m^2). Tables are in alphabetical order by site name. Units of n are counts in the whole transect, mean heights and widths (MHT, MW1, MW2) are in cm, mean cover (MCOV) is in square decimeters (0.01 m^2), total cover (TCOV) is in square meters, mean and total volumes (MVOL, TVOL) are in liters ($m^3 \times 10^{-3}$), mean biomass (MBIO) is in grams, and total biomass (TBIO) in kilograms. The mean growth constant (MGRO; $\overline{k}$ = [1n Vol at time 2/Vol at time 1][/(elapsed time in years]) is unitless. Values are not adjusted for transect size, so for the transects greater or less than 100 m^2 plant cover does not equal percent cover. Error terms are 2 standard errors (2SH, 2SW1, 2SW2, 2SVOL etc.) without checking for normal distributions. Locations of the plots are in the text map (Figure 1) and exact locations are given in Appendix A of the 1993 small mammal report (Saethre 1994b).

Perennial plant species names, authorities, and abbreviations used in Appendix C tables.

SPECIES AND AUTHORITY	ABBREVIATION
Acamptopappus shockleyi Gray	ACASHO
Ambrosia dumosa (Gray) Payne	AMBDUM
Arenaria congesta Nutt. ex Torr. & Gray	ARECON
Artemisia nova A. Nels.	ARTNOV
Artemisia spinescens D.C. Eat.	ARTSPI
Artemisia tridentata Nutt.	ARTTRI
Astragalus calycosus Torr. ex S. Wats.	ASTCAL
Astragalus lentiginosus Doug. ex Hook var. *fremontii* (Gray) S. Wats.	ASTLEN
Astragalus lentiginosus Doug. ex Hook var. *micans* Barneby	ASTMIC
Astragalus (undentified to species)	AST
Astragalus purshii Doug. ex Hook.	ASTPUR
Atriplex canescens (Pursh) Nutt.	ATRCAN
Atriplex confertifolia (Torr. & Frem.) S. Watts	ATRCON
Cactus (unidentified to species)	CACTUS
Ceratoides (Tourn.) *lanata* (Pursh.) J. T. Howell	KRALAN
Chaenactis douglasii (Hook.) Hook. & Arn.	CHADOU
Chrysothamnus nauseosus (Pallas) Britt.	CHRNAU
Chrysothamnus parryi (Gray) Petrak	CHRPAR
Chrysothamnus viscidiflorus (Hook.) Nutt.	CHRVIS
Chrysothamnus viscidiflorus ssp. puberulus (D. C. Eat.) Hall & Clements	CHRVI p
Coleogyne ramosissima Torr.	COLRAM
Cryptantha flavoculata (A. Nels.) Payson	CRYFLA
Delphinium parishii Gray	DELPAR
Dyssodia cooperi Gray	DYSCOO
Ephedra nevadensis S. Wats.	EPHNEV
Ericameria cooperi (= *Haplopappus cooperi*) (Gray) Hall	ERICOO
Eriogonum caespitosum Nutt.	ERICAE
Eriogonum microthecum Nutt.	ERIMIC
Eriogonum ovalifolium Nutt.	ERIOVA
Eriogonum umbellatum Torr.	ERIUMB
Erioneuron pulchellum (H.B.K.) Tateoka	ERIPUL
Generic bunchgrass	GENGRS
Grayia spinosa (Hook.) Moq.	GRASPI
Hilaria jamesii (Torr.) Benth.	HILJAM

SPECIES AND AUTHORITY	ABBREVIATION
Hymenoclea salsola Torr. & Gray ex Gray	HYMSAL
Hymenoxys cooperi (Gray) Cockerell	HYMCOO
Juniperus osteosperma (Torr.) Little	JUNOST
Kochia americana Benth.	KOCAME
Krameria parvifolia Benth.	KRAPAR
Larrea tridentata (Sesse & Moc. ex DC.) Coville	LARTRI
Leptodactylon pungens (Torr.) Nutt. ex Rydb.	LEPPUN
Linanthus nuttallii (Gray) Greene ex Milliken	LINNUT
Lycium andersonii Gray	LYCAND
Menodora spinescens Gray	MENSPI
Mirabilis pudica Barneby	MIRPUD
Opuntia basilaris Engelm. & Bigelow	OPUBAS
Opuntia echinocarpa Engelm. & Bigelow	OPUECH
Opuntia erinacea var. ursina (A. Weber) Parish	OPUERI
Opuntia ramosissima Engelm.	OPURAM
Oryzopsis hymenoides (Roemer & Schultes) Ricker	ORYHYM
Penstemon species (not identified)	PENsp
Phlox stansburyi (Torr.) Heller	PHLSTA
Pinus monophylla Torr. & Frem.	PINMON
Poa fendleriana (Steud.) Vasey	POAFEN
Poa secunda Presl.	POASEC
Polygala subspinosa S. Wats.	POLSUB
Psorothamnus fremontii (Torr. ex Gray) Barneby	PSOFRE
Psorothamnus polydenius (Torr. ex S. Wats.) Rydb.	PSOPOL
Purshia tridentata (Pursh.) DC.	PURTRI
Quercus gambelii Nutt.	QUEGAM
Sitanion jubatum J.G. Sm.	SITJUB
Sphaeralcea ambigua Gray	SPHAMB
Stanleya pinnata (Pursh) Britt.	STAPIN
Stephanomeria pauciflora (Torr.) Nutt.	STEPAU
Stipa comata Trin. & Rupr.	STICOM
Stipa pinetorum M. E. Jones	STIPIN
Stipa speciosa Trin. & Rupr.	STISPE
Streptanthus cordatus Nutt. ex Torr. & Gray	STRCOR
Tetradymia axillaris A. Nels.	TETAXI
Tetradymia glabrata Torr. & Gray	TETGLA
Tiquilia plicata (Torr.) A. Richards	TIQPLI
Viguiera multiflora (Nutt.) Blake	VIGMUL

Frenchman Flat Baseline Plot FRF001 censused 6/2/93 and 5/31/94, 965 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
93	ACASHO	4	18	10	22	12	17	13	3.9	3.6	0.16	9	9	36	28	28	0.11	0.85	0.75
94	ACASHO	4	17	9	23	13	17	12	4.0	3.8	0.16	9	9	35	27	28	0.11	0.06	0.29
93	AMBDUM	16	32	7	38	11	30	11	12.1	8.0	1.94	54	47	861	135	117	2.15	0.59	0.50
94	AMBDUM	17	25	6	34	9	30	10	10.4	6.4	1.77	39	33	659	97	83	1.65	-0.38	0.12
93	EPHNEV	1	58		53		36		15.0		0.15	87		87	122		0.12	0.24	
94	EPHNEV	1	49		41		39		12.6		0.13	62		62	86		0.09	-0.35	
93	GRASPI	3	68	2	67	5	53	10	28.3	7.4	0.85	191	48	573	439	110	1.32	0.37	0.85
94	GRASPI	3	66	2	61	9	55	16	26.4	9.5	0.79	173	56	520	398	130	1.20	-0.11	0.54
93	HYMSAL	2	40	10	40	8	27	13	8.5	5.7	0.17	33	14	65	105	46	0.21	0.98	1.62
94	HYMSAL	2	40	14	42	6	32	5	10.4	3.1	0.21	41	2	81	130	7	0.26	0.25	0.50
93	KRALAN	9	42	8	31	6	24	7	6.3	2.3	0.57	29	12	258	92	38	0.83	0.11	0.37
94	KRALAN	9	38	7	26	6	22	5	4.8	1.8	0.44	20	8	178	63	27	0.57	-0.36	0.39
93	LARTRI	6	97	34	146	70	117	42	160.8	130.5	9.65	1983	2142	11898	2578	2785	15.47	-0.30	0.75
94	LARTRI	6	97	39	136	56	116	54	153.3	134.0	9.20	1983	2317	11897	2578	3012	15.47	-0.13	0.13
93	LYCAND	3	43	16	42	18	30	10	10.4	6.7	0.31	49	40	148	109	87	0.33	-0.22	0.71
94	LYCAND	3	40	12	44	28	34	17	13.5	14.1	0.41	59	65	176	129	142	0.39	0.07	0.49
93	MIRPUD	0																	
94	MIRPUD	1	5		4		2		0.1		0.00	0		0	0		0.00		
93	ORYHYM	33	12	3	1	0	1	0	0.0	0.0	0.00	0	0	0	0	0	0.00	0.60	0.69
94	ORYHYM	21	12	2	2	1	1	0	0.0	0.0	0.01	0	0	1	0	0	0.00	0.17	0.73
93	PSOFRE	1	33		41		20		6.4		0.06	21		21	53		0.05	4.32	
94	PSOFRE	1	28		42		20		6.6		0.07	18		18	46		0.05	-0.14	
93	totals	78									13.86			13949			20.59		
94	totals	68									13.17			13627			19.77		
93	DEDGRS	8	5	3	9	4	7	3	0.6	0.4	0.05	1	1	4	0	0	0.00	0.31	0.51
94	DEDGRS	6	6	3	11	2	9	3	0.8	0.5	0.05	1	1	3	0	0	0.00	-0.07	0.41
93	DEDSHB	106	20	3	26	4	17	3	6.5	2.1	6.91	27	13	2851	52	26	5.51	-0.41	0.29
94	DEDSHB	97	19	3	26	5	19	4	6.9	2.4	6.73	28	16	2700	54	33	5.22	-0.15	0.16
93	totals	114									6.96			2856			5.52		
94	totals	103									6.78			2704			5.22		

Jackass Flats baseline plot, JAFOO1, censused 7/26/93 and 5/25/94, 954 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
93	ACASHO	92	28	2	35	3	27	3	8.92	1.49	8.20	27	5	2499	84	17	7.75	0.15	0.18
94	ACASHO	90	25	1	34	3	26	3	8.1	1.4	7.28	22	4	1953	67	13	6.05	-0.31	0.11
93	AMBDUM	68	27	2	45	4	38	6	15.6	4.4	10.63	51	22	3474	128	56	8.68	-0.28	0.15
94	AMBDUM	67	25	2	42	4	36	4	13.7	2.7	9.20	40	12	2705	101	29	6.76	-0.27	0.18
93	KRALAN	5	39	11	36	6	26	6	7.7	2.6	0.39	27	6	137	88	19	0.44	-0.22	0.24
94	KRALAN	6	34	14	24	11	18	8	4.3	2.7	0.26	16	9	97	52	30	0.31	-0.53	0.72
93	LARTRI	7	91	20	166	61	129	52	203.0	132.8	14.21	2158	1581	15108	2806	2055	19.64	0.21	0.16
94	LARTRI	7	86	19	155	55	113	39	161.7	97.5	11.32	1664	1209	11648	2163	1572	15.14	-0.25	0.18
93	MENSPI	20	24	3	62	14	48	12	29.6	12.4	5.91	86	41	1714	711	343	14.23	0.46	0.15
94	MENSPI	20	21	3	60	15	51	14	31.4	15.4	6.29	83	49	1658	688	406	13.76	-0.20	0.14
93	ORYHYM	30	13	4	2	0	1	0	0.0	0.0	0.01	0	0	1	0	0	0.00	-0.19	0.98
94	ORYHYM	33	19	3	2	1	2	1	0.0	0.0	0.01	0	0	4	0	0	0.00	1.27	0.76
93	totals	222									39.34			22933			50.74		
94	totals	223									34.36			18065			42.03		
93	DEDGRS	47	11	2	12	2	9	2	1.3	0.6	0.59	2	1	79	1	1	0.06	0.83	0.36
94	DEDGRS	43	9	2	9	2	7	1	0.7	0.4	0.31	1	0	33	1	0	0.02	-1.07	0.44
93	DEDSHB	82	17	2	29	3	22	3	6.2	1.1	5.09	13	4	1102	23	6	1.84	0.08	0.13
94	DEDSHB	81	16	2	28	3	22	3	5.8	1.1	4.72	12	3	999	23	7	1.86	-0.24	0.18
93	totals	129									5.68			1181			1.91		
94	totals	124									5.04			1032			1.89		

Pahute Mesa baseline plot PAM001 censused 8/30/93 and 7/18/94, 1923 m. This plot is only 50 m^2. Note small ratio of dead to live shrubs.

YEAR SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
93 ARTNOV	338	23	2	34	3	25	2	9.2	1.3	20.3	30.8	5.6	6783	77	14	16.96	-0.03	0.08
94 ARTNOV	268	22	2	35	3	26	2	9.2	1.2	19.1	28.3	5.2	5886	71	13	14.72	-0.11	0.07
93 ASTPUR	4	5	1	4	2	3	2	0.1	0.1	0.0	0.1	0.1	0	0	0	0.00	2.33	0.38
94 ASTPUR	2	3	1	2	0	1	0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.00	-1.36	
93 CHRVIS	2	32	27	30	31	28	34	8.6	14.7	0.2	36.9	69.4	74	0	0	0.00	-0.15	1.37
94 CHRVIS	2	25	12	29	24	25	21	6.6	9.4	0.1	19.2	31.4	38	0	0	0.00	-0.13	1.37
93 EPHNEV	33	26	3	17	3	14	4	2.2	0.9	0.7	6.9	3.4	229	10	5	0.32	0.59	0.35
94 EPHNEV	34	25	3	16	3	11	2	1.7	0.6	0.6	5.2	2.2	176	7	3	0.25	-0.24	0.25
93 ERICAE	1	2		9		9		0.6		0.0	0.1		0	0		0.00	0.11	
94 ERICAE	2	2	0	5	8	4	6	0.3	0.5	0.0	0.1	0.1	0	0	0	0.00	-0.28	
93 GENGRS	13	9	3	2	2	1	1	0.0	0.1	0.0	0.1	0.1	1	0	0	0.00	0.14	1.64
94 GENGRS	16	8	2	2	1	1	0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.00	0.16	0.50
93 KRALAN	1	18		23		16		2.9		0.0	5.2		5	17		0.02		
94 KRALAN	1	29		15		10		1.2		0.0	3.4		3	11		0.01	-0.48	
93 ORYHYM	13	18	2	7	2	5	2	0.3	0.2	0.0	0.6	0.4	8	1	0	0.01	-0.08	0.34
94 ORYHYM	13	18	2	7	3	5	2	0.4	0.3	0.0	0.7	0.5	10	1	1	0.01	-0.12	0.46
93 SITJUB	79	11	2	5	1	4	0	0.2	0.0	0.2	0.2	0.1	16	0	0	0.02	-0.83	0.30
94 SITJUB	77	11	1	5	1	4	0	0.2	0.0	0.1	0.2	0.1	17	0	0	0.02	0.22	0.36
93 STICOM	2	20	5	5	0	5	0	0.2	0.0	0.0	0.4	0.1	1	0	0	0.00	0.00	
94 STICOM	2	18	5	4	1	4	1	0.1	0.0	0.0	0.2	0.0	0	0	0	0.00	-0.96	0.03
93 STISPE	2	17	17	3	1	3	1	0.1	0.0	0.0	0.1	0.0	0	0	0	0.00	-0.85	
94 STISPE	2	14	12	4	1	3	1	0.1	0.0	0.0	0.1	0.2	0	0	0	0.00	0.27	1.45
93 totals	488									21.5			7118			17.32		
94 totals	419									20.0			6131			15.00		
93 DEDGRS	44	12	2	5	1	4	1	0.2	0.1	0.1	0.2	0.1	9	0	0	0.01	0.09	0.26
94 DEDGRS	41	11	3	5	1	3	1	0.2	0.1	0.1	0.2	0.1	7	0	0	0.01	-0.48	0.19
93 DEDSHB	26	16	3	25	8	16	5	4.9	3.4	1.3	8.3	4.9	215	13	8	0.34	-0.14	0.24
94 DEDSHB	22	14	4	24	10	15	6	4.9	3.9	1.1	7.6	5.2	168	12	9	0.27	-0.60	0.69
93 totals	70									1.4			224			0.35		
94 totals	63									1.1			175			0.28		

Rainier Mesa baseline plot, RAM001 censused 8/5/93 and 7/14/94, 2283 m. This plot is only 50 m^2.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
94	ARECON	2	2	0	5	1	5	1	0.2	0.1	0.0	0.0	0.0	0	0	0	0.00		
93	ARTTRI	50	25	5	41	8	30	6	13.5	4.4	6.8	55.9	27.5	2797	101	50	5.03	0.19	0.33
94	ARTTRI	42	26	5	41	8	31	6	13.9	5.2	5.8	57.1	31.0	2398	103	56	4.32	-0.07	0.16
93	CHADOU	1	3		3		3		0.1		0.0	0.0		0	0		0.00		
94	CHADOU	1	2		4		4		0.1		0.0	0.0		0	0		0.00		
93	CHRPAR	9	31	7	36	14	21	8	7.5	4.5	0.7	26.4	19.1	237	66	48	0.59	-0.30	0.28
94	CHRPAR	9	33	11	38	14	24	8	8.8	5.1	0.8	37.6	26.4	338	94	66	0.85	0.23	0.19
93	CRYFLA	12	5	2	10	3	6	2	0.6	0.3	0.1	0.4	0.2	5	0	0	0.00	0.58	0.60
94	CRYFLA	12	8	2	11	3	8	2	0.8	0.4	0.1	0.7	0.5	6	0	0	0.00	-0.01	0.53
93	ERICAE	5	5	2	11	5	7	4	0.8	0.9	0.0	0.5	0.8	3	0	0	0.00	-0.17	0.18
94	ERIMIC	5	5	1	10	5	8	5	0.8	0.9	0.0	0.5	0.5	2	0	0	0.00	0.07	0.09
93	ERIUMB	8	14	6	12	5	7	2	0.8	0.5	0.1	1.1	0.7	9	0	0	0.00	0.54	0.56
94	ERIUMB	8	15	5	14	5	9	3	1.2	0.8	0.1	2.1	1.5	17	0	0	0.00	0.43	0.32
93	GENGRS	12	12	4	3	2	2	1	0.1	0.1	0.0	0.1	0.1	1	0	0	0.00	-0.73	0.51
94	GENGRS	33	15	2	4	2	2	1	0.1	0.1	0.1	0.2	0.1	8	0	0	0.01	-0.65	0.54
94	JUNOST	1	230		96		96		72.4		0.7	1664.8		1665	0		0.00		
93	LEPPUN	10	17	11	18	12	11	9	3.3	5.2	0.3	18.4	34.5	184	0	0	0.00	0.21	0.29
94	LEPPUN	9	19	16	16	13	14	11	3.9	6.1	0.4	25.8	47.9	232	0	0	0.00	0.32	0.28
93	LINNUT	92	8	2	9	3	7	2	1.3	0.6	0.9	2.5	1.4	178	0	0	0.00	0.74	0.51
94	LINNUT	77	10	2	11	3	9	2	1.4	0.6	0.9	2.8	1.5	178	0	0	0.00	1.04	0.57
93	OPUERI	1	17		33		29		7.5		0.1	12.8		13	0		0.00	0.72	
94	OPUERI	1	18		28		16		3.5		0.0	6.3		6	0		0.00	-0.75	
93	ORYHYM	1	5		1		1		0.0		0.0	0.0		0	0		0.00	-2.60	
93	PENsp	5	11	6	10	2	7	2	0.5	0.3	0.0	0.6	0.5	3	0	0	0.00	1.37	0.06
94	PENsp	5	6	2	10	5	7	3	0.6	0.4	0.0	0.4	0.3	2	0	0	0.00	-1.29	0.40
93	PINMON	15	49	42	47	39	39	34	51.1	54.1	7.7	1013.0	1359.2	15195	2533	3398	37.99	0.57	0.22
94	PINMON	17	46	39	44	38	37	33	52.5	54.9	8.9	1088.9	1430.2	18512	2722	3576	46.28	-0.04	0.32
93	POASEC	33	14	3	6	2	5	2	0.4	0.3	0.1	0.7	0.8	24	1	1	0.03	-0.34	0.42
94	POASEC	25	14	3	4	2	3	1	0.2	0.1	0.1	0.2	0.2	10	0	0	0.01	-0.03	0.47
93	PURTRI	12	66	21	131	43	102	39	139.7	72.2	16.8	1152.0	646.5	13824	2880	1616	34.56	0.16	0.21
94	PURTRI	13	63	19	129	42	95	33	128.4	62.2	16.7	1061.0	591.8	13793	2652	1479	34.48	0.23	0.18
93	QUEGAM	5	32	8	31	10	19	11	5.2	4.3	0.3	17.6	14.7	88	44	37	0.22	0.17	0.09
94	QUEGAM	6	26	10	22	14	15	9	3.8	3.8	0.2	13.1	15.0	79	0	0	0.00	-0.05	0.14

93 SITJUB	8	19	6	4	2	3	1	0.1	0.1	0.0	0.2	0.1	2	0	0	0.00	-1.51	0.72
94 SITJUB	6	16	6	5	2	3	1	0.1	0.1	0.0	0.2	0.2	1	0	0	0.00	-0.43	0.21
94 STIPIN	22	15	3	7	2	4	2	0.3	0.2	0.1	0.4	0.3	15	0	0	0.00	0.01	0.28
93 STISPE	17	11	5	8	3	6	2	0.5	0.3	0.1	0.4	0.3	5	0	0	0.01	-1.52	0.48
93 STRCOR	14	3	1	3	1	3	1	0.1	0.0	0.0	0.0	0.0	0	0	0	0.00	-1.29	0.56
94 STRCOR	15	5	4	3	1	3	1	0.1	0.0	0.0	0.0	0.0	1	0	0	0.00	-0.84	0.69
93 totals	310									33.9			32569			78.43		
94 totals	309									34.9			37262			85.95		
93 DEDGRS	17	5	2	7	1	5	1	0.3	0.1	0.1	0.1	0.1	3	0	0	0.00	-0.53	0.27
94 DEDGRS	20	7	4	5	2	4	1	0.2	0.1	0.0	0.1	0.1	2	0	0	0.00	-0.79	0.47
93 DEDHRB	1	3		13		9		0.9		0.0	0.3		0	0		0.00	-1.92	
94 DEDHRB	2	3	1	5	3	3	1	0.1	0.1	0.0	0.0	0.0	0	0	0	0.00		
93 DEDSHB	4	19	16	58	39	32	18	18.6	15.9	0.7	45.9	48.3	184	65	66	0.26	-0.13	0.44
94 DEDSHB	3	16	20	25	40	21	33	9.3	18.3	0.3	33.1	66.1	99	40	79	0.12	-2.16	0.83
93 totals	22									0.8			187			0.26		
94 totals	25									0.3			101			0.12		

Yucca Flat baseline plot YUF001v2, censused 7/29/93 and 7/29/94, 1237 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
93	ACASHO	10	25	7	32	10	28	11	8.7	6.0	0.87	30	31	304	94	95	0.94	0.72	0.07
94	ACASHO	10	24	8	32	12	26	11	8.5	6.6	0.85	32	38	322	100	117	1.00	-0.18	0.05
93	ARTSPI	16	8	2	7	3	5	2	0.5	0.4	0.08	1	1	10	3	2	0.04	0.21	0.03
94	ARTSPI	9	11	2	12	6	9	7	1.5	1.8	0.13	2	3	21	10	14	0.09	-0.19	0.28
93	ATRCAN	34	52	6	61	10	50	8	29.1	8.1	9.88	183	64	6232	477	166	16.20	0.60	0.10
94	ATRCAN	32	50	7	56	10	44	9	24.3	8.2	7.79	154	62	4930	401	161	12.82	-0.40	0.09
93	EPHNEV	18	42	11	78	25	58	17	49.0	25.7	8.83	306	192	5513	429	268	7.72	0.59	0.06
94	EPHNEV	19	41	10	72	24	57	19	47.4	25.7	9.01	295	191	5602	413	268	7.84	-0.03	0.04
93	ERIPUL	3	1	0	2	0	2	0	0.0	0.0	0.00	0	0	0	0	0	0.00	-0.41	0.00
94	ERIPUL	1	5		2		2		0.0		0.00	0		0	0		0.00		
93	GRASPI	38	50	5	49	7	39	6	17.3	4.1	6.57	96	27	3648	221	62	8.39	0.15	0.14
94	GRASPI	44	51	3	49	6	39	5	17.2	4.0	7.57	94	25	4156	217	58	9.56	0.24	0.18
93	HYMSAL	4	41	8	51	16	40	19	17.4	10.6	0.70	73	49	293	234	156	0.94	0.97	0.26
94	HYMSAL	5	40	9	52	7	45	15	19.1	7.2	0.95	78	39	389	249	125	1.24	0.18	0.04
93	KRALAN	35	39	5	33	4	25	3	7.2	1.6	2.52	32	9	1116	102	28	3.57	0.68	0.17
94	KRALAN	34	35	4	28	4	20	3	5.0	1.3	1.71	20	5	677	64	17	2.17	-0.33	0.21
93	LYCAND	19	41	6	52	12	38	9	18.9	7.3	3.60	88	38	1672	194	84	3.68	0.59	0.07
94	LYCAND	21	42	6	50	13	38	10	19.3	8.0	4.06	97	42	2031	213	92	4.47	0.10	0.16
93	MENSPI	1	10		19		17		2.5		0.03	3		3	21		0.02		
94	MENSPI	1	9		19		17		2.5		0.03	2		2	19		0.02	-0.11	
93	MIRPUD	11	21	5	32	9	21	6	6.3	2.7	0.70	17	9	182	7	4	0.08	0.68	0.14
93	ORYHYM	8	10	4	4	3	3	3	0.2	0.3	0.02	0	1	3	0	1	0.00	0.14	0.35
94	ORYHYM	3	10	13	6	4	5	3	0.3	0.3	0.01	0	1	1	1	1	0.00	-1.47	0.11
93	SITJUB	4	18	3	3	2	3	2	0.1	0.1	0.00	0	0	1	0	0	0.00	1.61	0.22
93	SPHAMB	41	11	3	7	3	4	2	0.5	0.5	0.22	2	2	65	1	1	0.03	0.96	0.18
94	SPHAMB	12	3	1	3	1	2	1	0.1	0.0	0.01	0	0	0	0	0	0.00	-2.10	0.36
93	STISPE	2	22	23	9	8	8	5	0.6	0.8	0.01	2	3	4	2	3	0.00	2.08	0.05
94	STISPE	3	18	4	6	3	4	1	0.2	0.1	0.01	0	0	1	0	0	0.00	-1.03	0.15
93	TETAXI	1	72		55		41		17.7		0.18	128		128	344		0.34		
94	TETAXI	1	57		57		51		22.8		0.23	130		130	351		0.35	0.02	
93	totals	245									34.20			19173			41.96		
94	totals	195									32.35			18262			39.55		
93	DEDGRS	18	11	4	10	3	9	3	1.0	0.6	0.18	2	2	32	1	1	0.02	0.15	0.19

94 DEDGRS	22	13	4	6	2	5	1	0.3	0.1	0.07	1	0	12	0	0	0.01	-0.74	0.11
94 DEDHRB	8	22	5	31	5	24	3	5.9	1.6	0.47	14	7	112	4	2	0.03		
93 DEDSHB	190	20	2	26	2	20	2	5.5	1.1	10.45	16	5	2951	26	8	4.93	-0.39	0.16
94 DEDSHB	171	18	1	25	2	19	2	5.0	0.9	8.54	11	3	1951	19	5	3.33	-0.20	0.15
93 totals	208									10.63			2983			4.96		
94 totals	201									9.08			2074			3.37		

Drill Pad U19ac on Pahute Mesa, censused 7/23/91 and 7/19/94, 2134 m. No matching was possible, and grasses were sampled on only 10 m^2 in 1994, then adjusted to 100 m^2.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO
94	CHRNAU	4	8	6	13	10	7	8	1	2	0	1.5	2.9	6	4	7	0.02
91	GENGRS	115	18	2	3	1	2	1	0	0	0	0.4	0.7	38	0	1	0.04
94	GENGRS	1550	10	1	1	0	1	0	0	0	0	0.0	0.0	19	0	0	0.02
91	ORYHYM	44	46	4	21	3	16	3	3	1	1	17.7	5.0	780	20	6	0.86
94	ORYHYM	60	35	15	10	6	8	4	1	1	1	4.2	5.3	251	5	6	0.28
91	SITJUB	1	40		10		7		1		0	2.2		2	2		0.00
94	SITJUB	10	7		1		1		0		0	0.0		0	0		0.00
91	STICOM	121	58	6	9	1	6	1	1	0	1	5.5	1.6	549	0	0	0.00
94	STICOM	290	24	3	7	1	6	1	0	0	1	1.0	0.5	304	0	0	0.00
91	totals	281									2			1370			0.90
94	totals	1914									2			581			0.31

Drill Pad U19ac control PAM007 censused 7/23/91 and 7/19/94, 2134 m. Only partially censused for *Arenaria congesta, Eriogonum caespitosum*, and *Phlox stansburyi*, their values adjusted to 100 m^2.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
91	ARECON	2380	7	1	7	1	4	1	0.3	0.1	4.0	0	0	360	0	0	0.00		
94	ARECON	1840	8	1	8	2	6	1	0.6	0.3	10.7	1	0	1210	0	0	0.00	-0.28	0.24
91	ARTTRI	41	40	4	62	10	43	7	26.0	7.2	10.7	118	37	4822	212	66	8.68		
94	ARTTRI	39	35	4	64	10	44	8	26.9	7.1	10.5	109	33	4260	197	60	7.67	-0.02	0.06
94	ASTCAL	1	4		2		1		0.0		0.0	0		0	0		0.00		
94	ASTsp	1	3		3		2		0.0		0.0	0		0	0		0.00		
91	CACTUS	1	13		32		19		4.8		0.0	6		6	0		0.00		
94	CACTUS	1	18		22		14		2.4		0.0	4		4	0		0.00	-0.12	
91	CHRVIS	19	14	2	20	5	14	3	2.6	1.2	0.5	4	2	80	10	6	0.20		
94	CHRVIS	24	12	2	20	5	13	3	2.5	1.0	0.6	4	2	89	9	5	0.22	0.12	0.07
91	CRYFLA	7	4	1	4	1	4	1	0.1	0.1	0.0	0	0	0	0	0	0.00		
94	CRYFLA	6	5	1	7	1	6	2	0.3	0.1	0.0	0	0	1	0	0	0.00	0.33	0.14
91	DELPAR	10	4	1	3	1	2	1	0.1	0.1	0.0	0	0	0	0	0	0.00		
91	ERICAE	390	5	1	7	2	5	2	0.4	0.2	1.5	0	0	92	0	0	0.04		
94	ERICAE	196	4	1	8	2	6	1	0.5	0.2	1.0	0	0	55	0	0	0.02	-0.10	0.21
91	ERIOVA	1	2		4		2		0.1		0.0	0		0	0		0.00		
94	ERIOVA	1	7		7		5		0.3		0.0	0		0	0		0.00	0.91	
91	GENGRS	77	12	1	5	1	4	1	0.3	0.1	0.2	0	0	24	0	0	0.03		
94	GENGRS	50	12	1	4	1	3	1	0.1	0.1	0.1	0	0	10	0	0	0.01	-0.21	0.16
94	HYMCOO	4	2	1	2	1	2	1	0.0	0.0	0.0	0	0	0	0	0	0.00		
91	JUNOST	5	89	30	92	21	80	18	60.3	26.2	3.0	595	365	2974	1487	914	7.43		
94	JUNOST	7	72	42	70	36	66	34	49.7	31.8	3.5	530	393	3710	1325	982	9.28	0.11	0.02
91	ORYHYM	2	12	3	18	9	19	7	2.7	2.3	0.1	3	3	6	4	4	0.01		
94	ORYHYM	1	10		8		8		0.5		0.0	1		1	1		0.00	-0.76	
91	PENsp	44	4	2	6	1	4	1	0.3	0.2	0.1	0	1	15	0	0	0.00		
94	PENsp	58	6	1	7	1	5	1	0.3	0.1	0.2	0	0	11	0	0	0.00	0.10	0.20
91	PHLSTA	238	7	1	4	1	3	0	0.1	0.0	0.3	0	0	21	0	0	0.01		
94	PHLSTA	54	6	1	4	1	3	0	0.1	0.0	0.1	0	0	6	0	0	0.00	-0.01	0.17
91	PINMON	8	109	54	101	49	95	49	108.6	71.9	8.7	1814	1439	14510	4534	3598	36.28		
94	PINMON	11	84	50	78	47	75	47	89.1	68.9	9.8	1545	1358	16993	3862	3395	42.48	0.10	0.04
91	POAFEN	11	27	19	14	4	6	4	0.7	0.7	0.1	3	3	59	3	3	0.06		

94 POAFEN	13	18	10	10	9	7	7	0.9	1.2	0.3	2	3	76	3	4	0.08	-0.27	0.20
91 SITJUB	37	16	2	7	2	5	1	0.4	0.3	0.1	1	1	28	1	1	0.03		
94 SITJUB	34	13	1	5	1	4	1	0.2	0.1	0.1	0	0	10	0	0	0.01	-0.22	0.15
91 STISPE	6	14	5	6	3	5	2	0.3	0.4	0.0	1	1	3	1	1	0.00		
94 STISPE	6	10	3	6	6	4	3	0.4	0.6	0.0	0	1	3	1	1	0.00	-0.38	0.12
91 UNKNWN	3	5	2	4	2	2	1	0.1	0.1	0.0	0	0	0	0	0	0.00		
91 totals	3280									29.3			23001			52.77		
94 totals	2347									36.8			26440			59.78		
91 DEDGRS	14	5	1	6	1	6	1	0.3	0.1	0.0	0	0	2	0	0	0.00		
94 DEDGRS	6	6	2	8	2	6	2	0.4	0.2	0.0	0	0	2	0	0	0.00	0.00	0.00
91 DEDHRB	6	5	2	9	7	7	7	0.8	1.2	0.0	1	1	3	0	0	0.00		
94 DEDHRB	6	4	2	6	4	4	4	0.4	0.5	0.0	0	0	2	0	0	0.00	-0.13	
91 DEDSHB	18	15	6	41	17	28	10	14.3	10.2	2.6	25	20	455	35	25	0.62		
94 DEDSHB	11	20	10	52	27	33	17	22.0	20.4	2.4	57	53	628	71	64	0.78	-0.15	0.06
91 DEDTRE	1	69		38		37		11.0		0.1	76		76	127		0.13		
94 DEDTRE	1	46		38		37		11.0		0.1	51		51	85		0.08	-0.14	
91 totals	39									2.8			536			0.75		
94 totals	24									2.6			682			0.86		

Gas spill transect FF66, near the edge of Frenchman playa, censused May or June, 1986-1994, ~940 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
86	ATRCON	64	38	3	62	8	54	9	34.2	9.2	21.91	165	54	10567	776	255	49.66		
87	ATRCON	70	41	3	59	8	52	7	30.9	7.9	21.64	159	49	11122	747	230	52.27	0.03	0.10
88	ATRCON	85	41	3	56	7	50	6	28.2	6.4	23.94	143	40	12131	671	187	57.01	-0.03	0.08
89	ATRCON	71	38	3	49	6	41	6	20.2	5.1	14.34	99	32	7028	465	148	33.03	-0.26	0.28
90	ATRCON	7	27	9	33	14	24	11	7.9	5.8	0.55	26	20	179	120	96	0.84	-1.67	0.32
91	ATRCON	3	27	12	31	17	17	9	4.7	4.6	0.14	15	20	46	72	95	0.22	0.66	0.73
92	ATRCON	53	3	2	3	2	2	1	0.3	0.3	0.13	1	1	38	3	5	0.18	-0.08	0.44
93	ATRCON	19	8	5	5	5	3	3	0.4	0.5	0.05	1	2	12	5	8	0.06	-0.19	
94	ATRCON	6	12	10	7	8	4	5	0.5	0.9	0.03	2	3	8	7	14	0.04	-0.49	0.12
86	KOCAME	53	12	2	10	2	8	1	0.8	0.3	0.41	1	1	75	4	2	0.23		
87	KOCAME	75	11	1	8	1	6	1	0.5	0.2	0.39	1	0	57	2	1	0.18	-0.14	0.27
88	KOCAME	52	12	2	8	1	8	1	0.7	0.2	0.36	1	1	62	4	2	0.19		
89	KOCAME	40	5	2	4	1	3	1	0.1	0.1	0.05	0	0	6	0	1	0.02	-4.64	1.04
90	KOCAME	2	6	9	5	7	4	5	0.2	0.4	0.00	0	0	0	1	1	0.00	0.79	0.56
91	KOCAME	23	7	2	3	1	3	1	0.1	0.1	0.03	0	0	4	1	1	0.01	0.03	4.56
92	KOCAME	32	16	3	10	2	8	2	0.8	0.3	0.26	2	1	57	5	3	0.18	3.78	0.41
93	KOCAME	29	22	3	17	3	12	3	2.0	0.9	0.58	5	3	155	17	9	0.48	1.39	0.26
94	KOCAME	25	5	2	5	1	4	1	0.2	0.1	0.05	0	0	6	1	1	0.02	-4.75	0.36
86	totals	117									22.33			10642			49.90		
87	totals	145									22.03			11179			52.45		
88	totals	137									24.30			12193			57.21		
89	totals	111									14.39			7034			33.05		
90	totals	9									0.55			180			0.84		
91	totals	26									0.17			51			0.23		
92	totals	85									0.39			95			0.35		
93	totals	48									0.63			168			0.54		
94	totals	31									0.08			14			0.05		
88	DEDSHB	9	36	6	55	15	47	14	23.3	11.1	2.10	96	58	864	301	183	2.71		
89	DEDSHB	41	24	5	37	11	31	9	15.9	8.1	6.51	71	48	2917	223	150	9.13	0.28	0.21
90	DEDSHB	133	30	3	46	6	39	6	22.0	5.0	29.32	103	28	13653	321	87	42.72	0.08	0.23

91 DEDSHB	125	32	3	49	6	41	6	23.7	5.3	29.62	112	30	13950	347	93	43.42	-0.30	1.24
92 DEDSHB	116	31	3	49	6	41	5	22.3	4.9	25.86	100	28	11566	166	46	19.27	-0.29	0.24
93 DEDSHB	113	32	3	49	6	39	5	21.7	5.1	24.56	100	30	11305	197	61	22.30	-0.21	0.12
94 DEDSHB	102	32	3	52	6	42	6	24.1	5.4	24.53	106	29	10814	210	59	21.38	-0.17	0.19

Gas spill transect FF67 near Frenchman Playa, censused May-June, 1986-1994, ~940 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
86	ATRCAN	18	35	5	45	9	41	9	16.9	6.2	3.04	69	33	1243	180	85	3.23		
87	ATRCAN	19	41	6	48	10	38	9	17.3	7.1	3.29	87	48	1644	225	124	4.28	0.19	0.19
88	ATRCAN	22	35	6	38	8	32	8	12.2	4.8	2.68	55	25	1207	143	64	3.14	-0.25	0.17
89	ATRCAN	16	30	6	33	7	30	8	9.1	3.6	1.46	33	16	535	87	41	1.39	-1.49	0.66
90	ATRCAN	6	36	17	35	16	24	12	8.6	5.4	0.52	41	33	246	107	86	0.64	-1.80	0.85
91	ATRCAN	1	49		41		36		11.6		0.12	57		57	148		0.15	-0.62	
92	ATRCAN	31	5	5	3	4	3	3	0.5	1.0	0.10	3	5	46	7	13	0.12	-0.23	
93	ATRCAN	19	12	6	11	6	7	5	1.7	2.6	0.32	8	16	160	22	42	0.42	2.07	0.21
94	ATRCAN	13	10	8	10	7	8	7	1.9	3.0	0.24	9	17	114	23	44	0.30	-1.12	0.32
86	ATRCON	31	37	3	59	7	52	6	25.8	4.8	8.00	100	22	3109	471	102	14.61		
87	ATRCON	39	40	2	57	6	46	6	23.0	4.9	8.96	100	26	3917	472	121	18.41	0.30	0.20
88	ATRCON	45	38	3	53	6	43	6	20.5	4.8	9.22	88	25	3964	414	117	18.63	0.03	0.11
89	ATRCON	32	33	3	45	8	38	7	16.9	5.7	5.42	65	25	2067	304	116	9.71	-0.80	0.46
90	ATRCON	9	35	8	40	14	33	11	12.4	8.2	1.12	54	44	483	252	208	2.27	-0.83	0.37
91	ATRCON	0									0.00			0			0.00		
92	ATRCON	684	2	0	2	0	2	0	0.0	0.0	0.12	0	0	3	0	0	0.02		
93	ATRCON	284	12	1	11	1	9	1	1.0	0.1	2.90	2	0	426	7	1	2.00	4.65	0.04
94	ATRCON	247	11	1	10	1	8	1	0.8	0.1	1.95	1	0	258	5	1	1.21	-0.69	0.17
86	SPHAMB	3	18	3	15	6	15	6	1.9	1.4	0.06	3	3	10	2	1	0.00		
87	SPHAMB	3	10	7	6	6	3	3	0.2	0.3	0.01	0	0	1	0	0	0.00	-1.79	
88	SPHAMB	1	5		5		5		0.2		0.00	0		0	0		0.00		
93	SPHAMB	1	3		2		2		0.0		0.00	0		0	0		0.00		
86	STAPIN	1	20		12		14		1.3		0.01	3		3	0		0.00		
87	STAPIN	5	21	2	11	6	8	4	0.9	0.7	0.05	2	1	10	0	0	0.00	0.11	
88	STAPIN	4	18	11	13	8	7	5	0.9	1.1	0.03	2	4	10	0	0	0.00	1.09	0.16
92	STAPIN	6	6	2	4	1	4	1	0.1	0.1	0.01	0	0	1	0	0	0.00		
93	STAPIN	12	36	14	15	5	13	5	2.0	1.0	0.22	10	6	106	0	0	0.00	4.43	0.25
94	STAPIN	9	13	6	9	4	7	3	0.6	0.4	0.05	1	1	9	0	0	0.00	-2.99	0.38
87	UNKNWN	1	13		8		7		0.4		0.00	1		1	0		0.00		
86	Totals	53									11.11			4366			17.85		
87	Totals	67									12.30			5572			22.68		
88	Totals	72									11.93			5181			21.77		
89	Totals	48									6.88			2602			11.11		

90 Totals	15									1.63			729			2.91		
91 Totals	1									0.12			57			0.15		
92 Totals	721									0.23			50			0.13		
93 Totals	316									3.44			692			2.42		
94 Totals	269									2.25			381			1.51		
88 DEDHRB	2	20	12	36	43	19	17	6.6	11.0	0.13	16	30	33	0	0	0.00		
89 DEDHRB	6	20	9	19	16	13	11	3.6	5.1	0.22	10	13	58	0	0	0.00	0.59	0.23
90 DEDHRB	4	25	6	26	19	18	8	4.5	4.9	0.18	12	14	48	0	0	0.00	0.09	0.11
91 DEDHRB	4	28	7	24	14	16	8	3.5	3.2	0.14	11	11	43	0	0	0.00	-0.12	0.05
93 DEDHRB	1	7		4		2		0.1		0.00	0		0	0		0.00		
94 DEDHRB	1	1		1		1		0.0		0.00	0		0	0		0.00		
88 DEDSHB	6	23	4	31	8	24	4	6.0	2.3	0.36	15	7	89	35	15	0.21		
89 DEDSHB	31	33	5	43	7	34	6	13.8	4.3	4.27	56	22	1741	157	68	4.88	0.47	0.17
90 DEDSHB	60	33	3	48	5	39	5	17.7	3.7	10.60	71	19	4265	193	55	11.60	0.00	0.15
91 DEDSHB	74	32	2	47	5	38	4	16.9	3.4	12.48	65	16	4804	176	47	13.01	-0.21	0.12
92 DEDSHB	77	30	2	44	5	34	4	14.6	3.0	11.27	53	13	4083	145	38	11.15	-0.22	0.13
93 DEDSHB	83	28	3	38	5	30	4	12.5	3.1	10.34	49	15	4039	135	44	11.19	-0.42	0.13
94 DEDSHB	83	24	3	36	5	27	4	11.3	2.9	9.40	40	12	3315	109	35	9.03	-0.26	0.10
88 Totals	8									0.49			122			0.21		
89 Totals	37									4.49			1800			4.88		
90 Totals	64									10.78			4313			11.60		
91 Totals	78									12.62			4847			13.01		
92 Totals	77									11.27			4083			11.15		
93 Totals	84									10.34			4039			11.19		
94 Totals	84									9.40			3315			9.03		

Gas spill transect FF81 censused May-June, 1986 - 1994, ~945 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
86	ATRCAN	37	37	6	56	11	49	10	29.1	9.4	10.76	150	59	5538	389	153	14.40		
88	ATRCAN	38	35	4	51	9	43	7	21.2	6.4	8.06	95	35	3599	246	90	9.36	-0.03	0.26
89	ATRCAN	35	37	5	47	10	44	9	21.3	7.4	7.46	104	45	3650	271	116	9.49	-0.60	0.29
90	ATRCAN	4	34	17	42	43	37	46	23.5	42.1	0.94	131	247	524	341	643	1.36	-1.47	0.73
91	ATRCAN	0																	
92	ATRCAN	148	5	0	3	0	2	0	0.1	0.0	0.09	0	0	5	0	0	0.01		
93	ATRCAN	82	16	2	9	1	6	1	0.7	0.2	0.54	1	1	119	4	2	0.31	3.10	0.42
94	ATRCAN	57	16	2	10	2	7	1	0.8	0.2	0.43	2	1	99	4	2	0.26	-0.07	0.66
92	ATRCON	1	1		1		1		0.0		0.00	0		0	0		0.00		
86	KRALAN	5	37	15	25	10	23	7	5.1	3.7	0.25	24	28	120	77	90	0.38		
88	KRALAN	5	29	12	22	12	17	10	3.7	3.9	0.19	15	20	75	48	64	0.24	-0.40	0.30
89	KRALAN	3	26	8	21	13	17	7	3.2	3.2	0.10	10	12	29	31	37	0.09	0.31	0.22
86	MIRPUD	13	13	3	25	6	20	5	4.4	1.6	0.57	7	3	88	3	1	0.04		
88	MIRPUD	4	21	5	32	11	27	7	7.0	3.5	0.28	16	11	63	7	5	0.03	0.52	0.14
92	MIRPUD	3	17	5	20	6	15	3	2.3	0.8	0.07	4	3	12	2	1	0.01		
93	MIRPUD	11	22	4	25	7	17	5	4.0	2.1	0.44	11	6	118	5	3	0.05	1.14	0.31
94	MIRPUD	13	7	2	8	3	5	2	0.4	0.3	0.05	0	0	5	0	0	0.00	-3.68	1.49
86	ORYHYM	24	24	2	7	2	7	2	0.5	0.2	0.11	1	1	29	1	1	0.03		
88	ORYHYM	12	1	0	7	3	5	2	0.4	0.3	0.05	0	0	0	0	0	0.00	-1.00	0.19
89	ORYHYM	8	21	4	17	4	18	6	2.7	1.4	0.21	6	3	45	6	3	0.05	7.02	0.22
92	ORYHYM	294	13	0	1	0	1	0	0.0	0.0	0.03	0	0	4	0	0	0.00		
93	ORYHYM	349	15	1	3	0	2	0	0.0	0.0	0.14	0	0	21	0	0	0.02	1.54	0.17
94	ORYHYM	339	15	0	2	0	2	0	0.1	0.0	0.18	0	0	30	0	0	0.03	1.71	0.09
86	SPHAMB	38	16	2	11	1	10	1	0.9	0.3	0.35	2	1	71	1	0	0.03		
92	SPHAMB	5	2	0	3	1	2	1	0.1	0.1	0.00	0	0	0	0	0	0.00		
93	SPHAMB	8	6	2	5	2	4	2	0.2	0.2	0.02	0	0	1	0	0	0.00	1.81	0.24
94	SPHAMB	12	5	1	6	2	5	1	0.3	0.1	0.03	0	0	2	0	0	0.00	0.53	0.73
86	totals	117									12.06			5845			14.88		
88	totals	59									8.57			3736			9.62		
89	totals	46									7.77			3725			9.63		
90	totals	4									0.94			524			1.36		
91	totals	0																	
92	totals	451									0.19			21			0.02		

93	totals	450									1.14			260			0.38		
94	totals	421									0.70			136			0.29		
88	DEDGRS	6	1	0	9	5	6	3	0.5	0.5	0.03	0	0	0	0	0	0.00		
89	DEDGRS	5	8	4	15	7	11	5	1.5	0.9	0.07	1	1	6	1	1	0.00		
90	DEDGRS	20	9	2	8	2	6	1	0.4	0.1	0.08	0	0	8	0	0	0.01	-0.63	0.33
91	DEDGRS	23	7	2	9	2	8	2	0.6	0.3	0.15	1	0	12	0	0	0.01	-0.01	0.20
92	DEDGRS	28	4	1	9	2	7	1	0.5	0.2	0.14	0	0	6	0	0	0.01		
93	DEDGRS	19	4	1	9	2	7	2	0.6	0.2	0.12	0	0	5	0	0	0.00	-0.04	0.24
94	DEDGRS	15	3	1	9	2	6	1	0.5	0.2	0.07	0	0	2	0	0	0.00	-0.67	0.36
88	DEDHRB	10	23	5	28	7	21	6	4.9	1.7	0.49	12	5	121	3	1	0.03		
89	DEDHRB	18	23	3	21	4	22	4	4.1	1.3	0.74	10	4	185	3	1	0.05	-0.06	0.19
90	DEDHRB	17	19	3	26	6	18	5	4.5	1.6	0.76	10	4	167	3	1	0.05	-0.29	0.27
91	DEDHRB	15	20	3	25	6	19	4	4.2	1.6	0.63	10	4	145	3	1	0.04	-0.24	0.23
94	DEDHRB	1	19		14		15		1.6		0.02	3		3	1		0.00		
88	DEDSHB	4	36	12	59	38	58	42	36.0	36.2	1.44	154	170	614	256	283	1.02		
89	DEDSHB	12	23	9	47	16	39	15	19.0	11.9	2.28	63	53	754	109	92	1.31	-1.72	0.68
90	DEDSHB	45	33	5	57	9	47	9	28.0	9.1	12.60	128	51	5764	224	88	10.07	0.07	0.10
91	DEDSHB	53	32	4	55	9	48	8	27.9	8.2	14.77	120	42	6381	210	72	11.12	-0.02	0.08
92	DEDSHB	67	26	4	43	8	37	7	19.2	6.3	12.50	80	32	5217	201	80	13.04		
93	DEDSHB	51	31	5	49	9	42	9	23.3	8.5	11.87	107	46	5442	185	80	9.43	-0.10	0.13
94	DEDSHB	50	29	4	46	9	39	8	21.4	7.5	10.71	90	36	4502	156	63	7.79	-0.36	0.51
88	totals	20									1.96			736			1.06		
89	totals	35									3.10			945			1.37		
90	totals	82									13.43			5938			10.12		
91	totals	91									15.54			6538			11.17		
92	totals	95									12.64			5223			13.05		
93	totals	70									11.99			5447			9.44		
94	totals	66									10.80			4507			7.79		

Gas spill transect FF84 NE of Frenchman Playa, censused May-June 1986, 89-94, ~945 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
86	ATRCAN	4	40	7	56	21	57	19	27.4	16.2	1.10	109	76	438	284	198	1.14		
89	ATRCAN	3	38	8	47	21	44	14	17.3	11.2	0.52	69	50	206	178	129	0.53	-0.17	0.10
90	ATRCAN	1	38		51		48		19.2		0.19	73		73	190		0.19	-0.30	
92	ATRCAN	50	8	1	5	1	4	1	0.2	0.1	0.10	0	0	10	1	0	0.03		
93	ATRCAN	37	20	3	21	5	17	4	4.0	1.7	1.47	12	6	426	30	16	1.11	3.06	0.43
94	ATRCAN	31	19	4	22	5	18	4	4.3	1.8	1.33	11	7	352	30	17	0.92	-0.14	0.32
86	HYMSAL	1	25		33		24		6.2		0.06	16		16	50		0.05		
90	HYMSAL	1	9		17		14		1.9		0.02	2		2	5		0.01		
86	LARTRI	6	110	26	156	41	120	43	163.3	100.4	9.80	2049	1639	12295	2664	2131	15.98		
89	LARTRI	5	109	25	156	56	141	53	194.9	117.6	9.74	2363	1609	11813	3071	2091	15.36	-0.09	0.11
90	LARTRI	5	107	28	155	47	138	52	185.9	109.2	9.29	2242	1555	11210	2915	2021	14.57	-0.03	0.11
91	LARTRI	5	96	35	147	59	114	56	156.7	115.1	7.83	1820	1535	9100	2366	1996	11.83	-0.53	0.60
92	LARTRI	5	87	41	117	53	96	37	101.8	59.7	5.09	1104	781	5519	1435	1016	7.17	-0.72	0.20
93	LARTRI	5	90	29	134	49	94	33	110.9	60.9	5.55	1165	757	5827	1515	984	7.57	0.40	0.18
94	LARTRI	5	91	37	125	47	96	40	106.1	59.5	5.31	1142	775	5710	1484	1007	7.42	-0.14	0.07
86	ORYHYM	4	19	11	5	7	5	7	0.4	0.9	0.02	2	3	6	2	3	0.01		
92	ORYHYM	78	17	0	1	0	1	0	0.0	0.0	0.01	0	0	1	0	0	0.00		
93	ORYHYM	69	12	1	2	1	2	0	0.0	0.0	0.03	0	0	4	0	0	0.00	0.57	0.19
94	ORYHYM	62	15	1	3	0	2	0	0.1	0.0	0.04	0	0	6	0	0	0.01	1.15	0.31
86	PSOPOL	1	31		45		39		13.8		0.14	43		43	107		0.11		
89	PSOPOL	1	24		34		50		13.4		0.13	32		32	80		0.08	-0.09	
90	PSOPOL	1	24		40		32		10.1		0.10	24		24	60		0.06	-0.30	
86	SPHAMB	4	12	4	14	5	9	3	1.1	0.7	0.04	2	1	6	1	1	0.00		
86	TIQPLI	1	1		1		1		0.0		0.00	0		0	0		0.00		
86	totals	21									11.15			12803			17.29		
89	totals	9									10.39			12051			15.97		
90	totals	8									9.60			11309			14.83		
91	totals	5									7.83			9100			11.83		
92	totals	133									5.20			5530			7.20		
93	totals	111									7.04			6256			8.69		
94	totals	98									6.67			6068			8.35		

89 DEDGRS	4	15	3	6	10	7	10	0.9	1.8	0.04	1	3	5	1	2	0.00		
90 DEDGRS	1	13		17		20		2.7		0.03	3		3	3		0.00	-0.40	
91 DEDGRS	1	13		32		23		5.8		0.06	8		8	6		0.01	0.80	
92 DEDGRS	1	10		24		13		2.5		0.02	2		2	2		0.00	-1.10	
93 DEDGRS	1	5		14		11		1.2		0.01	1		1	0		0.00	-1.24	
94 DEDGRS	1	5		10		8		0.6		0.01	0		0	0		0.00	-0.76	
89 DEDHRB	2	16	29	10	17	5	8	0.6	1.3	0.01	2	4	4	1	1	0.00		
89 DEDSHB	3	48	8	73	20	77	17	45.8	22.3	1.37	212	70	636	285	81	0.85		
90 DEDSHB	5	48	10	80	19	72	19	47.9	22.4	2.39	230	126	1152	348	216	1.74	0.23	0.42
91 DEDSHB	8	40	10	68	20	54	17	32.3	16.4	2.59	147	89	1177	228	145	1.82	-0.26	0.31
92 DEDSHB	8	37	10	57	16	55	19	28.3	14.2	2.26	117	61	932	179	93	1.43	-0.29	0.08
93 DEDSHB	8	41	13	61	19	54	19	30.2	15.2	2.42	146	92	1169	251	159	2.00	0.03	0.10
94 DEDSHB	10	32	11	46	20	37	17	18.7	10.9	1.87	85	59	853	146	101	1.46	-0.32	0.08
89 totals	9									1.42			645			0.86		
90 totals	6									2.42			1156			1.74		
91 totals	9									2.65			1185			1.83		
92 totals	9									2.29			935			1.43		
93 totals	9									2.43			1169			2.01		
94 totals	11									1.88			853			1.46		

Mercury Valley gopher area MER002 censused 7/28/88, 6/24/91, and 6/08/94. Dead herbs were dead *Stanleya pinnata* in 1988, but were called unknown dead shrubs in 1991 and 1994, 1076 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
88	ASTLEN	10	7	2	7	2	7	2	0.5	0.3	0.05	0.4	0.4	4	0	0	0.00		
94	ASTLEN	1	17		18		12		1.7		0.02	2.9		3	0		0.00		
88	MIRPUD	6	5	3	7	4	5	3	0.3	0.4	0.02	0.3	0.5	2	0	0	0.00		
91	MIRPUD	49	13	3	14	4	12	3	2.6	2.3	1.28	11.8	19.7	578	5	8	0.25	1.52	0.35
94	MIRPUD	32	6	1	6	2	4	1	0.3	0.2	0.10	0.3	0.2	9	0	0	0.00	-0.94	0.19
91	ORYHYM	1	29		2		2		0.0		0.00	0.1		0	0		0.00		
94	ORYHYM	1	26		6		5		0.2		0.00	0.6		1	1		0.00	0.64	
88	SITJUB	2	19	2	4	1	4	1	0.1	0.1	0.00	0.2	0.1	0	0	0	0.00		
88	SPHAMB	1	16		5		10		0.4		0.00	0.6		1	0		0.00		
91	SPHAMB	3	17	18	17	21	11	11	2.3	3.9	0.07	7.4	13.9	22	3	6	0.01		
94	SPHAMB	2	9	5	7	1	6	2	0.3	0.1	0.01	0.3	0.3	1	0	0	0.00	-0.98	0.30
88	STAPIN	19	70	11	42	12	40	11	17.2	8.1	3.27	152.2	84.5	2892	0	0	0.00		
91	STAPIN	18	23	14	17	12	17	12	7.0	8.0	1.25	56.4	74.9	1015	0	0	0.00	0.05	0.01
94	STAPIN	16	42	15	45	21	39	17	23.7	21.3	3.79	174.6	189.3	2794	0	0	0.00	0.75	0.25
88	totals	38									3.34			2899			0.00		
91	totals	71									2.60			1615			0.26		
94	totals	52									3.91			2806			0.00		
88	DEDHRB	31	52	7	63	13	53	10	33.2	10.3	10.30	211.0	84.9	6541	0	0	0.00		
91	DEDHRB	6	16	11	13	11	13	8	2.2	3.4	0.13	8.0	15.0	48	0	0	0.00	-0.14	
94	DEDHRB	1	39		38		24		7.2		0.07	27.9		28	0		0.00	-0.16	
88	DEDSHB	14	15	6	39	10	31	8	10.6	4.5	1.49	14.5	8.2	203	24	14	0.34		
91	DEDSHB	58	41	6	43	8	38	7	18.1	6.1	10.50	115.6	51.1	6704	193	85		-0.21	0.08
94	DEDSHB	47	41	6	48	8	37	7	18.1	5.7	8.50	105.0	43.4	4933	175	72	8.22	-0.14	0.06
88	totals	45									11.78			6744			0.34		
91	totals	64									10.64			6753					
94	totals	48									8.57			4961			8.22		

Mercury Valley gopher area control MER003 censused 7/29/88, 6/19/91, and 6/9/94, 1103 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
88	ACASHO	118	25	2	32	3	29	3	8.9	1.7	10.5	28	8	3284	86	24	10.18		
91	ACASHO	37	21	2	23	4	19	3	3.8	1.1	1.4	9	4	349	29	12	1.08	-0.52	0.12
94	ACASHO	39	27	3	23	4	20	3	9.0	2.4	3.5	28	9	1099	87	29	3.41	0.42	0.03
88	AMBDUM	9	20	9	22	13	18	11	5.2	5.7	0.5	19	24	170	47	59	0.43		
91	AMBDUM	7	31	20	24	11	23	10	5.6	5.2	0.4	15	17	107	38	41	0.27	0.29	0.24
94	AMBDUM	8	26	6	24	16	24	13	12.0	9.4	1.0	39	40	315	99	99	0.79	0.32	0.04
88	EPHNEV	4	56	17	67	36	73	35	45.6	34.4	1.8	287	233	1150	402	326	1.61		
91	EPHNEV	7	43	18	50	40	46	27	27.4	25.7	1.9	177	177	1236	247	247	1.73	0.08	0.04
94	EPHNEV	12	41	13	50	40	46	27	16.8	17.0	1.8	117	131	1292	164	184	1.81	-0.24	0.11
88	GRASPI	24	44	7	45	10	39	11	18.1	9.3	4.3	104	70	2500	240	162	5.75		
91	GRASPI	13	41	6	41	11	35	7	13.0	5.0	1.7	61	30	799	141	68	1.84	0.03	0.09
94	GRASPI	12	59	8	45	10	38	7	28.7	13.5	3.4	195	119	2335	448	274	5.37	0.25	0.05
88	HYMSAL	8	27	5	19	7	18	5	3.0	1.7	0.2	9	6	73	29	20	0.23		
91	HYMSAL	6	26	4	20	3	23	3	3.7	1.0	0.2	10	4	60	32	12	0.19	0.15	0.10
94	HYMSAL	4	32	5	21	4	23	5	5.7	4.3	0.2	19	15	75	60	47	0.24	0.16	0.03
88	KRALAN	2	22	22	18	30	16	25	3.7	7.2	0.1	12	24	24	38	76	0.08		
91	KRALAN	2	34	24	28	25	24	31	6.6	11.3	0.1	29	54	58	93	174	0.19	0.72	0.20
94	KRALAN	2	19	20					1.0	1.7	0.0	3	5	6	9	17	0.02		
88	LARTRI	3	151	28	201	56	223	25	355.8	128.2	10.7	5388	2413	16163	7004	3136	21.01		
91	LARTRI	5	121	50	190	80	172	87	310.0	261.9	15.5	4826	4913	24132	6274	6387	31.37	0.06	0.03
94	LARTRI	4	142	46	216	78	195	97	406.3	336.0	16.3	6660	6333	26638	8657	8234	34.63	0.02	0.01
88	LYCAND	13	48	5	71	14	69	16	43.5	19.9	5.7	217	113	2820	477	248	6.20		
91	LYCAND	11	43	10	50	17	44	15	21.4	10.4	2.4	110	58	1212	242	127	2.67	-0.27	0.16
94	LYCAND	11	38	8	57	17	49	15	20.2	11.1	2.2	87	48	956	191	106	2.10	-0.31	0.10
88	OPUBAS	1	11		5		5		0.2		0.0	0		0	0		0.00		
88	ORYHYM	1	30		10		10		0.8		0.0	2		2	3		0.00		
91	ORYHYM	1	35		12		18		1.7		0.0	6		6	7		0.01	0.32	
94	ORYHYM	1	22		12		18		0.2		0.0	1		1	1		0.00	-0.82	
88	SPHAMB	9	19	7	13	6	10	3	1.1	0.6	0.1	3	2	26	1	1	0.01		
91	SPHAMB	4	25	17	21	11	19	14	3.8	3.7	0.2	13	14	50	5	6	0.02	0.67	0.22
94	SPHAMB	2	7	1	5		4		0.2	0.2	0.0	0	0	0	0	0	0.00	0.47	

88	totals	192									33.9			26212			45.51		
91	totals	93									23.8			28009			39.36		
94	totals	95									28.5			32717			48.37		
94	DEDHRB	2	40	2	24	1	17	5	9.4	9.6	0.2	37	37	74	11	10	0.02		
88	DEDSHB	66	18	3	39	6	37	6	15.7	5.3	10.3	46	21	3033	78	34	5.15		
91	DEDSHB	174	22	2	42	4	37	3	15.4	2.9	26.8	48	13	8383	80	22	13.97	0.01	0.03
94	DEDSHB	162	20	2	44	4	40	4	13.3	2.7	21.5	39	12	6293	64	20	10.38	-0.22	0.06
88	totals	66									10.3			3033			5.15		
91	totals	174									26.8			8383			13.97		
94	totals	164									21.7			6368			10.40		

Revegetation Site 3B YUF011 next to T3 blast area, censused 6/17/91 and 6/14/94, 1242 m. (Control is also T3 control, page 326.)

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
91	ATRCAN	7	34	14	44	17	44	18	18.4	10.1	1.29	76	50	531	197	130	1.38		
94	ATRCAN	6	79	12	117	26	100	21	94.9	36.7	5.69	751	311	4507	1953	807	11.72	0.78	0.22
91	ASTLEN	1	4		5		4		0.2		0.00	0		0	0		0.00		
91	totals	8									1.29			531			1.38		
94	totals	6									5.69			4507			11.72		

Sedan Crater 1000 feet from ground zero YUF016 censused 7/6/88,7/15/91 and 7/7/94, 1318 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
91	GENGRS	8	13	2	1	1	1	0	0.0	0.0	0.0	0	0	0	0	0	0.00	-0.48	
94	GENGRS	1	11		1		2		0.0		0.0	0		0	0		0.00	0.15	
88	ORYHYM	80	21	3	6	2	5	2	0.7	0.6	0.6	3	3	256	4	3	0.28		
91	ORYHYM	81	20	1	4	1	3	0	0.1	0.0	0.1	0	0	28	0	0	0.03	0.50	0.07
94	ORYHYM	372	18	2	5	1	4	1	0.3	0.1	0.6	1	0	192	1	0	0.21	0.74	0.06
94	SITJUB	3	15	1	3	3	2	2	0.1	0.1	0.0	0	0	0	0	0	0.00	0.67	
88	STISPE	27	17	4	6	1	6	2	0.4	0.2	0.1	1	1	30	1	1	0.03		
91	STISPE	7	21	4	11	5	9	5	1.0	0.7	0.1	2	2	17	3	2	0.02	0.42	0.08
94	STISPE	10	20	7	11	6	10	6	1.5	1.3	0.1	4	4	44	5	5	0.05	0.29	0.01
88	UNKNWN	1	3		7		10		0.5		0.0	0		0	0		0.00		
88	live	108									0.7			286			0.31		
91	live	96									0.2			45			0.05		
94	live	386									0.7			236			0.26		
88	DEDGRS	11	33	7	38	10	34	7	11.3	5.0	1.2	43	24	469	31	17	0.34		
91	DEDGRS	25	15	3	20	5	16	4	3.2	1.4	0.8	7	4	171	5	3	0.13		
94	DEDGRS	19	10	2	20	6	18	5	3.7	1.6	0.7	4	2	83	3	2	0.06	-0.25	0.03
88	dead	11									1.2			469			0.34		
91	dead	25									0.8			171			0.13		
94	dead	19									0.7			83			0.06		

Sedan Crater 3000 feet from ground zero YUF017 censused 7/6/88, 7/15/91 and 7/7/94, 1327 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
88	HYMSAL	57	28	3	33	7	30	7	12.9	6.7	7.4	59	39	3355	188	125	10.74		
91	HYMSAL	48	30	3	36	7	34	6	13.4	6.0	6.4	57	34	2724	182	109	8.72	0.02	0.08
94	HYMSAL	47	38	4	49	8	43	7	22.0	8.1	10.4	112	55	5265	358	175	16.85	0.27	0.05
88	LYCAND	3	52	5	69	7	73	4	39.9	4.4	1.2	209	44	626	459	96	1.38		
91	LYCAND	3	53	4	68	14	62	11	33.4	13.0	1.0	175	62	525	385	136	1.15	-0.07	0.01
94	LYCAND	3	48	4	64	6	58	7	28.9	2.8	0.9	140	25	420	308	54	0.92	-0.07	0.03
88	ORYHYM	101	29	2	12	1	12	1	1.4	0.3	1.4	4	1	438	5	1	0.48		
91	ORYHYM	58	23	2	10	2	8	2	0.9	0.4	0.5	3	1	146	3	1	0.16	-0.32	0.10
94	ORYHYM	49	22	2	12	2	10	2	1.2	0.3	0.6	3	1	153	3	1	0.17	0.11	0.13
88	SPHAMB	2	31	5	8	1	9	3	0.5	0.2	0.0	2	1	3	1	0	0.00		
94	SPHAMB	1	16		19		18		2.7		0.0	4		4	2		0.00		
88	STISPE	6	27	7	9	2	9	3	0.7	0.3	0.0	2	1	13	2	2	0.01		
91	STISPE	7	21	6	9	4	8	3	0.7	0.4	0.0	2	1	11	2	1	0.01	-0.02	0.02
94	STISPE	8	22	5	14	3	11	3	1.4	0.6	0.1	3	2	26	4	3	0.03	0.27	0.09
88	live	169									10.0			4436			12.61		
91	live	116									8.0			3406			10.04		
94	live	108									11.9			5868			17.97		
88	DEDGRS	71	12	2	8	1	8	1	0.7	0.2	0.5	1	0	72	1	0	0.05		
91	DEDGRS	103	10	1	14	2	11	1	1.6	0.3	1.6	2	1	211	1	0	0.15	-0.25	0.06
94	DEDGRS	83	7	1	13	1	11	1	1.3	0.2	1.1	1	0	91	1	0	0.07	-0.21	0.09
88	DEDSHB	2	17	22	67	67	65	74	43.7	72.9	0.9	114	220	229	191	367	0.38		
91	DEDSHB	2	17	23	59	78	45	50	28.5	50.7	0.6	76	149	152	112	219	0.22	-0.23	0.03
94	DEDSHB	4	18	12	51	32	38	23	19.7	23.7	0.8	52	76	209	83	110	0.33	0.00	0.04
88	dead	73									1.3			301			0.43		
91	dead	105									2.2			363			0.38		
94	dead	87									1.9			301			0.40		

Sedan Crater 5000 feet N of ground zero YUF018 censused 7/8/88, 7/15/91, and 7/6/94, 1335 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
88	COLRAM	64	48	3	55	7	52	6	26.2	5.4	16.8	148	38	9481	770	199	49.30		
91	COLRAM	75	42	3	49	6	37	5	17.5	3.8	13.1	87	23	6554	454	118	34.08	-0.17	0.05
94	COLRAM	81	42	3	48	6	36	4	17.1	3.5	14.0	87	22	7086	451	112	36.85	0.02	0.04
88	GENGRS	4	34	7	5	1	5	1	0.2	0.1	0.0	1	0	3	1	0	0.00		
88	HYMSAL	11	34	12	35	19	36	16	15.7	12.8	1.7	87	81	955	278	260	3.06		
91	HYMSAL	8	29	11	34	15	25	11	8.7	5.2	0.7	33	22	267	107	71	0.85	-0.42	0.06
94	HYMSAL	8	49	14	67	19	61	26	38.1	24.7	3.0	234	188	1870	748	601	5.98	0.69	0.05
88	LYCAND	6	55	7	83	9	86	22	55.8	16.2	3.3	315	118	1891	693	260	4.16		
91	LYCAND	7	46	11	68	26	56	21	36.2	19.1	2.5	192	116	1346	423	254	2.96	-0.12	0.04
94	LYCAND	6	38	11	67	26	49	25	31.4	22.4	1.9	129	111	776	285	244	1.71	-0.32	0.10
88	ORYHYM	22	31	5	14	4	13	4	2.0	1.1	0.4	7	5	149	7	6	0.16		
91	ORYHYM	2	7	10	1	0	1	0	0.0	0.0	0.0	0	0	0	0	0	0.00	-2.00	0.16
94	ORYHYM	2	18	1	2	0	2	1	0.0	0.0	0.0	0	0	0	0	0	0.00		
94	SITJUB	1	22		6		6		0.3		0.0	1		1	1		0.00		
88	STISPE	1	28		3		3		0.1		0.0	0		0	0		0.00		
91	STISPE	1	11		2		1		0.0		0.0	0		0	0		0.00	-0.81	
94	STISPE	1	34		8		4		0.3		0.0	1		1	1		0.00	1.31	
88	live	108									22.3			12479			56.68		
91	live	93									16.3			8167			37.90		
94	live	99									18.9			9733			44.54		
88	DEDGRS	15	11	3	13	4	13	3	1.6	0.8	0.2	2	1	31	2	1	0.02		
91	DEDGRS	81	15	2	11	1	9	1	1.0	0.3	0.8	2	1	125	1	0	0.09	-0.07	0.04
94	DEDGRS	67	11	5	9	1	7	1	0.6	0.2	0.5	1	0	53	0	0	0.04	-0.38	0.09
88	DEDSHB	4	16	9	36	15	36	15	10.8	7.1	0.4	15	10	62	26	16	0.10		
91	DEDSHB	14	15	4	23	10	17	9	5.1	3.9	0.7	11	9	159	19	16	0.26	0.06	
94	DEDSHB	15	16	7	25	10	18	8	5.5	3.5	0.9	14	12	259	27	19	0.47	-0.49	0.15
88	dead	19									0.7			93			0.13		
91	dead	95									1.5			284			0.36		
94	dead	82									1.4			312			0.51		

T1 blast area YUF009 censused 8/12/88, 6/24/91, and 6/29/94, 1279 m. This transect is 2 by 100 m (200 m^2).

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
88	CHRVIS	1	62		112		100		88.0		1	545		545	0		0.00		
91	GENGRS	1	7		6		5		0.2		0	0		0	0		0.00		
88	ORYHYM	68	23	2	13	2	13	1	1.6	0.3	1	5	1	316	5	1	0.35		
91	ORYHYM	41	29	3	9	2	6	2	0.6	0.3	0	2	2	101	3	2	0.11	0.00	0.19
94	ORYHYM	59	17	2	7	2	4	1	0.3	0.2	0	1	1	44	1	1	0.05	-0.05	0.23
88	STISPE	14	25	6	14	5	13	5	2.0	1.0	0	7	4	94	7	4	0.10		
91	STISPE	11	34	6	13	5	9	4	1.2	0.9	0	5	4	52	5	4	0.06	0.10	0.14
94	STISPE	10	19	3	14	5	9	3	1.2	0.9	0	3	2	25	3	2	0.03	-0.22	0.12
94	VIGMUL	2	6	3	6	1	4	0	0.2	0.0	0	0	0	0	0	0	0.00		
88	totals	83									2			955			0.45		
91	totals	53									0			153			0.17		
94	totals	71									0			69			0.08		
88	DEDGRS	5	17	6	16	7	18	9	2.7	2.0	0	5	5	26	4	3	0.02		
91	DEDGRS	32	22	3	21	3	16	2	3.0	0.7	1	8	2	248	6	2	0.18		
94	DEDGRS	46	11	1	12	2	11	2	1.2	0.3	1	2	0	72	1	0	0.05	-0.52	0.09
88	DEDSHB	8	8	4	10	4	10	4	0.9	0.4	0	1	0	6	1	1	0.01		
91	DEDSHB	6	5	2	14	4	10	4	1.2	0.5	0	0	0	3	1	0	0.00		
94	DEDSHB	4	5	2	12	4	8	5	0.8	0.6	0	0	0	2	1	1	0.00	-0.04	0.03
88	totals	13									0			32			0.03		
91	totals	38									1			251			0.19		
94	totals	50									1			74			0.06		

T1 blast area control YUF010 censused 8/9/88, 6/25/91, and 6/29/94, 1267 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
88	ATRCAN	68	31	3	21	3	17	2	4	1	2	15	6	973	38	16	2.53		
91	ATRCAN	21	27	5	21	7	16	4	3	2	1	13	10	276	34	26	0.72	-0.14	0.23
94	ATRCAN	29	46	7	47	10	39	8	19	6	5	111	43	3212	288	112	8.35	0.75	0.11
88	CHRVIS	58	32	3	39	6	34	5	14	4	8	58	28	3377	146	71	8.44		
91	CHRVIS	27	18	2	19	4	13	3	2	1	1	5	3	133	12	6	0.33	-0.99	0.18
94	CHRVIS	27	35	3	43	6	34	6	13	4	4	49	15	1335	124	38	9.34	0.61	0.04
88	EPHNEV	18	43	10	57	24	54	22	42	25	7	260	185	4685	364	259	6.56		
91	EPHNEV	15	39	8	57	26	37	19	29	26	4	164	167	2460	230	234	3.44	-0.15	0.13
94	EPHNEV	14	44	11	62	26	50	24	39	31	5	269	269	3760	376	377	5.26	0.15	0.08
91	GENGRS	1	7		1		1		0		0	0		0	0		0.00		
94	GENGRS	1	26		5		5		0		0	1		1	1		0.00		
88	GRASPI	17	44	6	41	14	35	13	16	9	3	88	57	1496	202	132	3.44		
91	GRASPI	3	33	24	30	39	17	21	7	13	0	39	74	116	89	169	0.27	-0.76	0.51
94	GRASPI	3	54	14	58	21	46	10	22	12	1	124	97	373	286	224	0.86	0.52	0.06
88	HILJAM	67	16	3	4	1	4	2	0	0	0	0	0	21	0	0	0.01		
91	HILJAM	87	16	2	3	0	3	0	0	0	0	0	0	7	0	0	0.01		
94	HILJAM	160	14	2	2	1	2	0	0	0	0	0	0	7	0	0	0.00		
94	HYMSAL	2	22	12	18	26	13	18	3	5	0	8	15	15	24	47	0.05		
88	KRALAN	20	31	6	26	7	22	6	6	3	1	24	16	484	77	51	1.55		
91	KRALAN	11	25	6	19	5	15	5	3	1	0	9	6	96	28	18	0.31	-0.50	0.26
94	KRALAN	13	44	8	37	8	30	8	10	4	1	51	25	663	163	79	2.12	0.45	0.04
88	LYCAND	5	32	6	52	34	32	25	20	19	1	59	61	297	131	134	0.65		
91	LYCAND	4	33	5	42	23	34	29	15	20	1	54	79	217	119	174	0.48	0.20	0.01
94	LYCAND	6	36	10	61	22	34	16	19	13	1	76	66	459	168	145	1.01	0.18	0.05
88	ORYHYM	21	23	4	11	2	10	2	1	0	0	3	1	54	3	1	0.06		
91	ORYHYM	3	27	23	7	3	7	2	0	0	0	1	1	4	1	1	0.00	-0.47	0.08
94	ORYHYM	29	19	3	3	1	3	1	0	0	0	0	0	11	0	0	0.01	0.22	0.01
88	SITJUB	165	24	1	6	1	6	1	0	0	1	1	0	180	1	0	0.20		
91	SITJUB	0																	
94	SITJUB	6	21	4	2	1	1	0	0	0	0	0	0	0	0	0	0.00		
94	SPHAMB	1	7		7		7		0		0	0		0	0		0.00		
88	STISPE	69	27	2	10	3	9	2	1	1	1	5	3	281	5	3	0.31		

91 STISPE	15	19	5	14	8	12	5	2	3	0	5	6	81	6	6	0.09	0.15	
94 STISPE	12	15	5	5	2	4	2	0	0	0	0	0	4	0	0	0		
91 TETAXI	1	38		9		9		1		0	2		2	7		0.01		
88 totals	508									25			11847			23.75		
91 totals	188									7			3392			5.65		
94 totals	303									18			9840			21.01		
88 DEDGRS	21	19	3	10	3	9	2	1	0	0	2	1	39	1	1	0.03		
91 DEDGRS	197	13	1	7	1	6	1	1	0	1	1	0	195	1	0	0.21		
94 DEDGRS	94	9	1	9	1	7	1	1	0	1	1	1	96	1	0	0.07	-0.21	0.09
88 DEDSHB	37	33	7	44	9	46	10	22	8	8	103	46	3822	172	77	6.36		
91 DEDSHB	131	30	2	37	5	30	4	13	3	17	59	21	7786	149	53	19.46		
94 DEDSHB	98	26	3	40	5	32	5	14	4	13	54	20	5245	85	33	8.36	-0.12	0.08
88 totals	58									8			3861			6.38		
91 totals	328									18			7981			19.68		
94 totals	196									15			5738			9.04		

T1 transition zone YUF029 censused 7/1/91 and 7/5/94, 1305 m.

YEAR SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
91 ATRCAN	19	20	6	22	10	16	7	4.7	3.7	1	18	17	337	46	44	0.87		
94 ATRCAN	18	36	5	34	8	29	7	9.4	3.9	2	40	19	723	104	49	1.88	0.75	0.38
91 LYCAND	1	14		7		12		0.7		0	1		1	2		0.00		
94 LYCAND	1	21		14		9		1.0		0	2		2	5		0.00	0.27	
91 MIRPUD	20	17	3	49	17	31	13	18.7	13.4	4	36	27	711	15	11	0.31		
94 MIRPUD	27	16	3	30	12	19	8	8.6	6.5	2	20	19	510	9	8	0.22	-0.34	0.42
91 ORYHYM	1	16		7		1		0.1		0	0		0	0		0.00		
94 ORYHYM	33	19	2	2	0	2	0	0.0	0.0	0	0	0	3	0	0	0.00		
94 SITJUB	2	20	22	3	2	2	0	0.0	0.0	0	0	0	0	0	0	0.00		
94 VIGMUL	2	10	10	3	4	3	3	0.1	0.1	0	0	0	0	0	0	0.00		
91 totals	41									5			1049			1.18		
94 totals	83									4			1239			2.11		
91 DEDGRS	200	11	1	10	1	8	1	1.0	0.2	2	1	0	274	1	0	0.20		
94 DEDGRS	144	8	1	12	1	9	1	1.2	0.4	2	2	1	228	1	1	0.17	-0.24	0.06
94 DEDHRB	2	26	4	43	9	33	23	11.3	10.0	0	28	21	57	8	6	0.02	0.91	
91 DEDSHB	107	30	3	40	6	32	6	16.1	5.1	17	65	22	6916	110	38	11.78		
94 DEDSHB	84	28	3	46	7	36	6	19.3	6.0	16	64	20	5369	109	35	9.16	-0.15	0.09
91 totals	307									19			7190			11.98		
94 totals	230									18			5653			9.34		

T2 blast area YUF014 censused 7/31/90 and 7/13/94, 1371 m. Grasses were largely only counted (not measured or location recorded) in 1990 and only 12 of 100 m^2 were measured for grasses in 1994. Totals were adjusted to 100 m^2. The *Chrysothamnus nauseosus* germinated since 1990, probably 1992 or 1993.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
94	CHRNAU	34	14	4	20	5	15	4	3.4	1.6	1	9.1	6.7	308	23	17	0.77		
94	ERIPUL	150	3	0	5	1	4	1	0.2	0.1	0	0.0	0.0	7	0	0	0.00		
94	HYMSAL	1	33		43		33		11.1		0	36.8		37	118		0.12		
90	totals	0									0			0			0		
94	totals	185									2			352			0.89		
90	DEDGRS	1264	3	1	5	4	6	1	0.2	0.2	3	0.0	0.0	3	0	0	0.00		
94	DEDGRS	808	3	0	9	1	7	1	0.6	0.1	5	0.2	0.1	160	0	0	0.01		
90	DEDSHB	7	3	1	6	3	5	1	0.2	0.2	0	0.1	0.1	1	0	0	0.00		
94	DEDSHB	2	3	2	7	6	3	0	0.2	0.1	0	0.0	0.0	0	0	0	0.00	0.25	
90	totals	1271									3			1			0.00		
94	totals	810									5			160			0.01		

T2 control YUF015 censused 8/01/90 and 7/11/94, 1338 m. Several dormant *Lycium andersonii, Grayia spinosa, and Hymenoclea salsola*, were not measured in 1990 (couldn't determine live size), and are not included in either TVOL or TBIO for that year, or MGRO for 1994.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
90	ATRCAN	9	49	13	54	35	42	29	33.1	46.4	3.0	245	375	2202	636	975	5.73		
94	ATRCAN	9	55	10	66	23	43	16	26.9	15.1	2.4	167	98	1500	433	256	3.90	0.31	0.34
94	CHRVIS	1	40		49		46		17.7		0.2	71		71	177		0.18	1.10	
90	EPHNEV	1	54		126		79		78.2		0.8	422		422	591		0.59		
94	EPHNEV	2	49	28	102	69	73	31	62.0	64.0	1.2	349	487	697	488	682	0.98	0.09	
90	ERICOO	2	34		48		25		9.4		0.1	32		32	0		0.00		
94	ERIPUL	3	3	2	7	5	6	3	0.4	0.4	0.0	0	0	0	0	0	0.00		
90	GRASPI	7	37	9	28	12	24	12	6.1	5.0	0.2	22	15	89	51	35	0.20		
94	GRASPI	5	43	5	60	36	50	30	31.8	39.4	1.6	144	183	721	332	421	1.66	0.29	0.14
94	HILJAM	38	11	4	2	1	2	1	0.0	0.0	0.0	0	0	1	0	0	0.00		
90	HYMSAL	26	19	4	18	6	14	6	3.5	2.8	0.9	13	14	338	42	44	1.08		
94	HYMSAL	21	30	4	43	8	36	7	14.1	5.5	3.0	52	28	1093	167	90	3.50	0.71	0.27
90	KRALAN	22	31	4	23	4	18	4	3.6	1.4	0.8	12	5	260	40	17	0.83		
94	KRALAN	16	33	4	41	6	30	5	10.2	3.0	1.6	37	13	587	117	41	1.88	0.33	0.16
90	LYCAND	11	39	14	59	39	53	41	33.2	35.3	1.3	155	167	620	341	368	1.36		
94	LYCAND	9	41	7	55	18	43	17	23.0	14.4	2.1	110	83	986	241	184	2.17	0.07	0.26
94	ORYHYM	26	22	5	3	1	2	1	0.1	0.1	0.0	0	0	6	0	0	0.01		
94	SPHAMB	2	21	16	19	9	13	9	2.0	2.2	0.0	5	8	10	2	3	0.00		
90	STISPE	1	22		7		7		0.4		0.0	1		1	1		0.00		
94	STISPE	1	17		7		6		0.3		0.0	1		1	1		0.00		
94	UNKNWN	1	37		30		29		6.8		0.1	25		25	0		0.00		
90	totals	79									7.1			3965			9.80		
94	totals	134									12.3			5699			14.27		
90	DEDGRS	171	14	1	5	1	4	0	0.2	0.0	0.3	0	0	60	0	0	0.04		
94	DEDGRS	79	8	1	9	1	7	1	0.6	0.1	0.5	1	0	42	0	0	0.03	-0.11	0.14
90	DEDSHB	84	23	4	33	6	26	5	11.8	4.2	9.9	53	23	4446	72	37	6.09		
94	DEDSHB	62	28	4	41	6	34	6	14.5	4.1	9.0	59	23	3662	86	37	5.36	-0.07	0.29
90	totals	255									10.3			4505			6.13		
94	totals	141									9.5			3704			5.39		

T3 blast area YUF013 censused 6/8/88, 6/17/91, and 6/14/94, 1236 m.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGRO	2SGRO
94	HILJAM	2	13	6	1	0	1	0	0.0	0.0	0.00	0.0	0.0	0	0	0	0.00		
88	MIRPUD	3	18	3	15	12	14	7	2.0	2.3	0.06	3.3	3.6	10	1	2	0.00		
91	MIRPUD	8	15	6	10	2	8	2	0.6	0.3	0.05	1.0	0.8	8	0	0	0.00	-1.09	0.37
94	MIRPUD	1	7		12		4		0.4		0.00	0.3		0	0		0.00	-0.12	
88	ORYHYM	151	18	1	11	1	10	1	1.2	0.3	1.84	2.9	1.2	442	3	1	0.49		
91	ORYHYM	2	13	14	3	0	10	13	0.2	0.3	0.00	0.4	0.7	1	0	1	0.00	0.13	1.09
94	ORYHYM	46	17	3	2	0	2	0	0.0	0.0	0.02	0.1	0.1	4	0	0	0.00	0.96	
88	totals	154									1.90			452			0.49		
91	totals	10									0.05			9			0.00		
94	totals	49									0.02			4			0.00		
88	DEDGRS	13	7	3	14	5	13	5	2.0	1.3	0.26	2.1	2.1	27	2	2	0.02		
91	DEDGRS	163	9	1	11	1	10	1	1.1	0.2	1.74	1.2	0.4	202	1	0	0.15	-0.28	0.17
94	DEDGRS	133	3	1	11	1	10	1	1.1	0.3	1.52	0.7	0.3	87	0	0	0.06	-0.47	0.07
94	DEDHRB	1	31		100		79		62.0		0.62	192.3		192	55		0.06		
88	DEDSHB	1	5		9		7		0.5		0.00	0.2		0	0		0.00		
91	DEDSHB	4	7	7	12	7	10	6	1.1	1.0	0.04	1.2	1.6	5	2	3	0.01		
88	totals	14									0.26			27			0.02		
91	totals	167									1.78			207			0.16		
94	totals	134									2.14			280			0.12		

T3 control YUF012, also control for revegetation site 3B, censused 5/14/86, 8/5/88, 7/3/91, and 6/16/94, 1239 m. Dead plants were not measured in 1986. *Stipa speciosa* were called *Oryzopsis hymenoides* in 1988. Growth of DEDHRBs is due to growth and death of the aerial parts of the rhizomatous *Mirabilis pudica*.

YEAR	SPECIES	n	MHT	2SH	MW1	2SW1	MW2	2SW2	MCOV	2SCOV	TCOV	MVOL	2SVOL	TVOL	MBIO	2SBIO	TBIO	MGR	2SGR
86	ACASHO	109	18	2	21	3	16	2	3.8	0.9	4.14	10	3	1075	31	8	3.33		
88	ACASHO	73	20	2	25	3	24	3	6.2	1.4	4.55	16	4	1162	49	14	3.60	0.33	0.11
91	ACASHO	24	14	3	12	3	8	3	1.1	0.7	0.26	2	2	49	6	5	0.15	-0.98	0.35
94	ACASHO	21	22	3	29	5	22	4	5.7	2.0	1.19	15	8	310	46	24	0.96	0.83	0.23
86	ATRCAN	68	39	4	38	6	29	6	13.0	4.1	8.84	73	29	4994	191	76	12.98		
88	ATRCAN	65	35	3	33	6	29	5	11.1	3.9	7.23	50	18	3257	130	48	8.47	-0.11	0.13
91	ATRCAN	16	32	5	28	8	18	6	5.2	2.6	0.83	20	11	326	53	30	0.85	-0.30	0.35
94	ATRCAN	17	48	6	54	11	43	8	20.8	7.0	3.53	107	38	1827	279	100	4.75	0.82	0.33
86	ATRCON	1	28		42		36		11.9		0.12	33		33	156		0.16		
86	CHRVIS	20	34	6	51	14	42	12	22.5	10.3	4.49	96	51	1911	239	127	4.78		
88	CHRVIS	19	38	8	48	13	44	13	21.9	10.5	4.15	102	54	1932	254	135	4.83	0.11	0.12
94	CHRVIS	2	23	3	21	16	11	7	2.0	2.5	0.04	5	6	9	11	15	0.02		
86	EPHNEV	6	61	24	104	47	83	36	83.1	44.4	4.99	620	357	3721	868	499	5.21		
88	EPHNEV	10	51	17	56	28	63	33	38.9	29.4	3.89	277	232	2772	388	325	3.88	0.05	0.04
91	EPHNEV	6	60	16	111	33	84	32	82.3	43.6	4.94	566	350	3396	792	490	4.75	-0.05	0.11
94	EPHNEV	6	63	22	106	34	78	30	74.1	38.0	4.45	543	289	3260	761	404	4.56	-0.13	0.32
86	GRASPI	2	43	16	19	26	10	12	2.1	3.8	0.04	11	20	21	24	46	0.05		
86	HYMSAL	3	14	7	13	5	9	1	0.8	0.2	0.03	1	1	4	4	2	0.01		
88	HYMSAL	2	18	16	15	10	14	10	1.8	2.3	0.04	4	7	8	14	23	0.03	0.74	
86	KRALAN	95	31	3	27	3	20	3	5.7	1.3	5.38	23	7	2144	72	21	6.86		
88	KRALAN	71	29	3	28	3	24	3	6.4	1.3	4.55	23	7	1607	72	21	5.14	0.03	0.08
91	KRALAN	48	23	3	17	3	12	3	2.4	1.0	1.16	7	4	358	24	12	1.15	-0.60	0.22
94	KRALAN	48	33	3	26	4	21	4	5.5	1.7	2.64	22	8	1041	69	26	3.33	0.49	0.31
86	LYCAND	3	47	14	41	14	40	18	13.7	10.8	0.41	60	36	181	133	80	0.40		
88	LYCAND	3	49	23	44	18	47	20	17.6	14.2	0.53	77	40	230	169	88	0.51	0.12	0.05
91	LYCAND	4	49	16	51	30	34	17	15.1	11.9	0.60	69	49	275	151	108	0.61	-0.27	0.18
94	LYCAND	4	37	18	49	30	36	24	17.6	16.7	0.70	66	72	266	146	158	0.58	-0.17	0.25
86	MENSPI	16	16	6	41	17	35	16	19.0	11.7	3.05	53	36	855	444	300	7.10		
88	MENSPI	14	15	5	47	21	43	19	25.8	15.9	3.62	62	41	863	512	339	7.17	0.20	0.15
91	MENSPI	13	15	4	39	18	32	16	16.0	10.9	2.09	34	24	444	283	202	3.68	-0.36	0.16
94	MENSPI	10	18	5	47	14	37	14	16.2	9.6	1.62	39	33	391	324	274	3.24	0.29	0.29

86 MIRPUD	17	8	3	9	5	6	3	0.8	0.6	0.14	1	1	18	0	0	0.01		
88 MIRPUD	9	13	4	9	4	10	5	1.0	0.8	0.09	2	2	15	1	1	0.01	-0.12	1.41
91 MIRPUD	12	20	13	21	10	12	6	3.2	3.1	0.39	17	28	205	7	12	0.09	0.29	0.68
94 MIRPUD	8	6	3	7	5	5	4	0.3	0.3	0.02	0	0	2	0	0	0.00	-1.33	0.91
86 ORYHYM	135	31	2	7	1	5	1	0.5	0.1	0.64	2	1	257	2	1	0.28		
88 ORYHYM	98	19	2	7	1	6	1	0.5	0.1	0.48	1	0	115	1	0	0.13		
91 ORYHYM	1	24		21		6		1.0		0.01	2		2	3		0.00	0.32	
94 ORYHYM	97	19	1	2	0	2	0	0.1	0.0	0.05	0	0	10	0	0	0.01	0.01	
86 POLSUB	51	7	1	21	4	15	3	3.6	1.4	1.86	3	1	156	8	3	0.39		
88 POLSUB	32	9	2	14	5	11	4	2.3	2.0	0.75	5	6	149	12	15	0.37		
91 POLSUB	43	5	1	12	4	8	3	1.6	1.7	0.55	2	3	57	4	7	0.14	-0.51	0.24
94 POLSUB	45	6	1	20	5	14	3	3.2	2.0	1.31	3	3	114	7	8	0.28	0.49	0.31
86 SITJUB	161	32	1	3	1	2	0	0.1	0.1	0.19	0	0	61	0	0	0.07		
88 SITJUB	39	19	2	3	1	3	1	0.1	0.1	0.05	0	0	9	0	0	0.01		
86 SPHAMB	4	15	7	9	4	7	3	0.6	0.4	0.02	1	1	4	0	0	0.00		
88 SPHAMB	4	18	9	15	10	14	3	1.9	1.6	0.07	4	5	17	2	2	0.01	0.13	0.25
91 STEPAU	1	13		19		10		1.5		0.01	2		2	5		0.00		
91 STISPE	1	31		1		1		0.0		0.00	0		0	0		0.00	-0.06	
86 TETGLA	29	55	6	85	12	64	10	48.7	10.1	14.12	299	69	8684	809	188	23.45		
88 TETGLA	24	58	4	87	9	86	9	62.0	10.0	14.87	372	72	8925	1004	195	24.10	0.05	0.05
91 TETGLA	1	33		15		14		1.6		0.02	5		5	15		0.01	-0.03	
94 TETGLA	2	47	20	66	57	52	45	31.5	46.2	0.63	171	280	343	462	757	0.92		
86 UNKNWN	1	12		5		4		0.2		0.00	0		0	0		0.00		
86 totals	721									48.46			24120			65.08		
88 totals	463									44.86			21061			58.24		
91 totals	170									10.85			5121			(11.44)		
94 totals	260									16.19			7571			18.67		
88 DEDGRS	10	12	4	6	2	6	2	0.3	0.2	0.03	1	1	6	0	0	0.00		
91 DEDGRS	142	12	1	8	1	5	1	0.5	0.2	0.77	1	0	121	1	0	0.09	-0.22	0.27
94 DEDGRS	97	7	1	10	1	7	1	0.7	0.2	0.70	1	0	65	0	0	0.05	-0.13	0.13
91 DEDHRB	1	13		10		8		0.6		0.01	1		1	0		0.00		
94 DEDHRB	6	35	7	43	27	36	9	14.1	11.5	0.85	55	49	330	16	14	0.09	0.89	0.27
88 DEDSHB	24	21	5	34	8	34	8	11.7	4.2	2.80	33	15	780	51	25	1.22		
91 DEDSHB	247	28	2	39	4	32	3	15.8	3.0	38.91	75	18	18621	125	33	30.95	-0.03	0.10
94 DEDSHB	186	24	2	41	4	33	4	15.8	3.2	29.28	60	16	11041	105	28	19.49	-0.20	0.07

88	totals	34	2.84	786	1.23
91	totals	390	39.68	18743	31.04
94	totals	289	30.83	11436	19.63