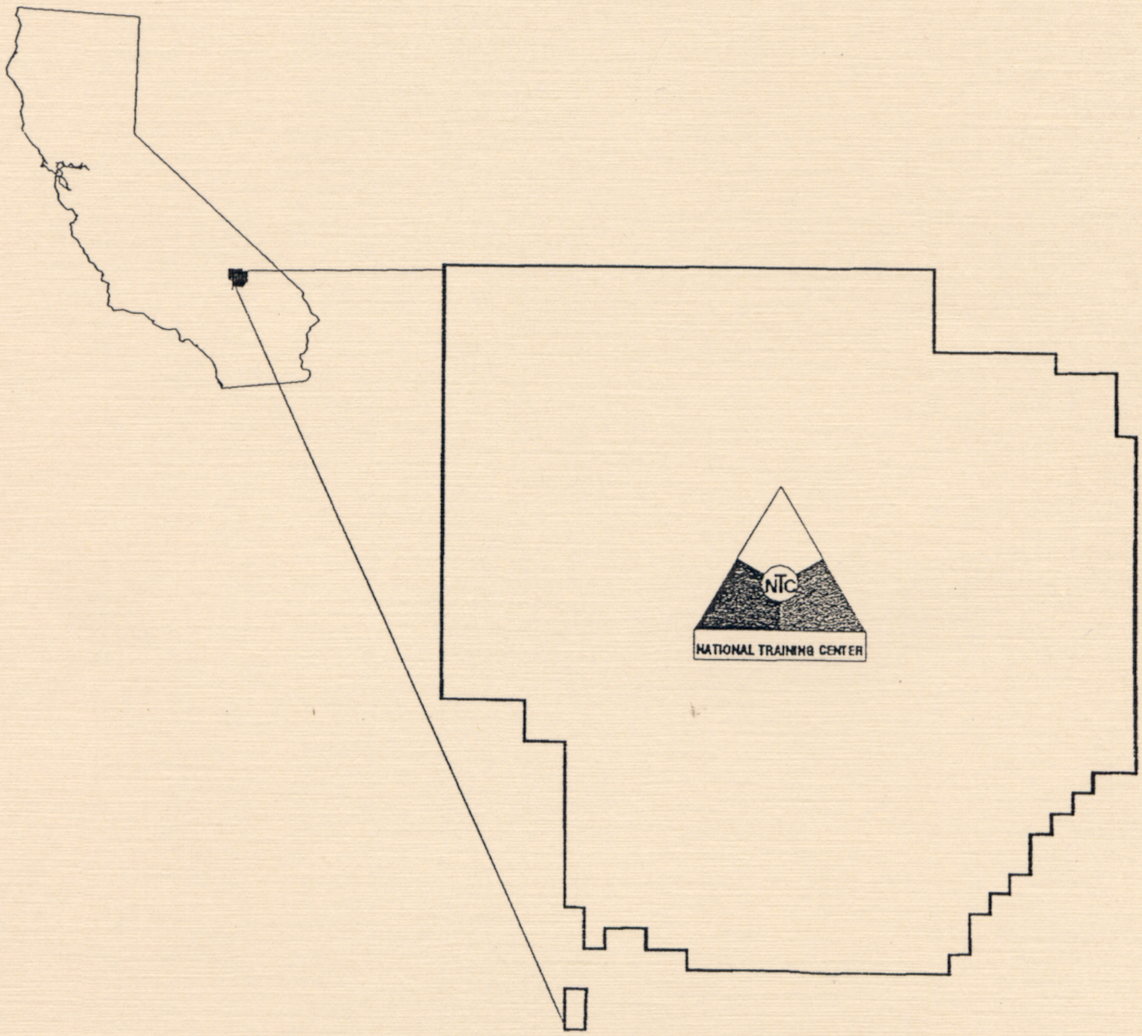
HERPETOLOGICAL SURVEYS AND PHYSIOLOGICAL STUDIES

National Training Center, Fort Irwin, California

October, 1995



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FINAL REPORT
HERPETOLOGICAL SURVEYS AND PHYSIOLOGICAL STUDIES ON THE WESTERN PORTION OF FORT IRWIN NTC

Prepared under contract with

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1. INTRODUCTION

In 1993, the U. S. Army initiated a study to establish baseline herpetological data for Fort Irwin (Morafka, 1994; Nagy and Brown, 1994). Prior to this, the herpetological resources of the National Training Center (NTC) were relatively unstudied. A general knowledge of the reptile and amphibian species present on the base existed, determined by incidental sightings and the Army's Land Condition Trend Analysis project (LCTA), but no specific data existed. As a result, two groups of researchers were contracted to study the herpetofauna of the entire base. One team from the University of California, Los Angeles (UCLA) concentrated their efforts in the western portion of the base, while a second team from California State University, Dominguez Hills (CSUDH), led by Dr. David J. Morafka, surveyed the southern and eastern portions of the base.

For both groups, the two major objectives of the initial (1993) study were 1) to examine the presence and relative frequencies of the reptile and amphibian species on the base, and 2) to establish the baseline data and protocol needed for future monitoring and comparative studies such that the impact of military training exercises could be assessed. In order to enable the assessment of the effects of military exercises on the herpetofauna of Fort Irwin, we first needed to establish baseline data (control data) from undisturbed areas. We selected study sites which were representative of the variety of habitats found across the base, and subsequently sampled the herpetofauna of these sites. If a predictive relationship between species assemblages and habitat/substrate types can be established for undisturbed areas, it may then be possible to extrapolate to the entire base to predict the overall herpetofauna. In addition, if we know the past habitat/substrate conditions of an area, we can also predict the historic reptile and amphibian assemblages prior to disturbance by military activities. We can then compare the historic assemblage to the present herpetofauna in order to assess the impact of military training exercises.

A unique objective of the 1993 UCLA study was to initiate a physiological study of a diurnal lizard species. Using the doubly labeled water method (Nagy, 1983), the energetics and water relations of the desert horned lizard (*Phrynosoma platyrhinos*) were studied. Such a study offers a deeper examination of the actual health of reptile populations than is gained from simple numerical counts. For example, in a single year the number of lizards in two areas may be identical, thus indicating similar conditions. Yet, a physiological analysis of the populations may reveal that one population is in extreme negative energy or water balance. This difference may be caused by some kind of external stress and could result in an increase in age-specific mortality. Sole reliance on numerical estimates of population size could take many years to indicate that one population is less "healthy" than another and may be declining, while a physiological analysis is a much quicker indicator of such phenomenon. Knowing these measurements for lizards in undisturbed areas, it will be possible to compare them to lizards in disturbed areas in the future to assess any effects on the health of the lizards that may be due to military training exercises.

The desert horned lizard was chosen as a representative of the local herpetofauna because it is fairly ubiquitous in occurrence and intermediate in ecological requirements. While other reptile species often constitute a larger percentage of biomass, such as the side-blotched lizard (*Uta stansburiana*), many of these species are considered "weed" species. These species often prosper in disturbed areas which could bias an assessment of the effects of disturbance on the herpetofauna as a whole.

The two primary objectives of the present study (1994) were 1) to continue the monitoring of the undisturbed study sites established in 1993 in order to strengthen the baseline data set, and 2) to continue the physiological study initiated in 1993 of the desert horned lizard (*Phrynosoma platyrhinos*). The design of the 1994 project followed the protocol established in 1993, and incorporated the findings and recommendations of that study. A combination of visual transect surveys of diurnal reptile species, pit-fall, and road patrolling studies were used in both years to assess the presence of various herpetological species. The study sites established in 1993 were used again in the 1994 study, and the same horned lizard population was also studied. In both years, the UCLA team was responsible for surveying the western portion of Fort Irwin, and consequently our efforts were concentrated in areas which were determined to be representative of western habitats.

The results of the 1994 study are presented here. Included in this report is a statistical analysis of the 1994 findings, as well as a comparison with the 1993 data. The results of diversity studies and physiological findings are discussed, and future recommendations made.

2. METHODS

2.1 STUDY SITES

Transect Sites

Of the six sites sampled in the 1994 visual transect surveys, five of these were established in the 1993 study (Nagy and Brown, 1994). These sites were originally selected according to the following criteria:

i) representative of the various habitat/substrate combinations typical of the western portion of the base;

ii) maximize the number of habitat types represented;

iii) complementary with the sites chosen by Dr. Morafka in the southern and eastern portions of the base so that we could combine our results for statistical analysis;

iv) good accessibility to maximize surveying efficiency; and

v) proximity to the Army's Land Condition Trend Analysis study sites to allow for comparison of results.

In 1993, ten study sites were established, each of which was surveyed four times. A major finding of 1993 was that four samplings at each site often did not yield enough data to allow for statistical comparisons. One recommendation from the 1993 study was to continue to monitor the established survey sites while increasing the survey intensity, so in 1994 we doubled the number of times each transect was sampled. To replicate the total survey time expended in 1993, the number of transects surveyed in 1994 were halved. As a result, we chose to use five of the ten established sites located on the Goldstone portion of the base and surveyed them eight times each. The CSUDH team similarly decreased the number of their study sites while doubling the survey intensity. We selected the five sites that most represented the habitats of western Fort Irwin. In addition to the five sites at Goldstone, we also included one site located in the Granite Mountains which added another habitat type to our survey.

Each transect was a 1000 m long line placed in homogenous habitat. Ten-foot-tall PVC poles, flagged and supported by steel reinforcing bars, were placed at each end and at the apex of each transect for use as visual guides. Wooden stakes, with painted numbers, were placed every 100 m. Bright flagging was attached to all stakes and to bushes every 50 m. The shape of the transect (e.g. straight line, circle, U-shaped) depended on the study site characteristics. Site descriptions, locations (GPS and UTM coordinates), and elevations are given below (see also Figure 1); the site names were chosen previously and have been retained for consistency:

a. **H1T1** - 35°23′ 19" N, 116° 54′ 19" W, Northing 3915944, Easting 508599, Altitude 929 m. On the northern side of Goldstone Dry Lake, this site is characterized by a saltbush (*Atriplex sp.*) plant community on a typical flat, playa alluvial substrate.

b. **H1T3** - 35° 19′ 59" N, 116° 54′ 14" W, Northing 3909799, Easting 508747, Altitude 929 m. Located 0.16 km from the end of Goddard Road, this site has a saltbush (*Atriplex sp.*) plant community growing on a granitic alluvial substrate.

c. **H1T5** - 35° 20' 00" N, 116° 53' 13" W, Northing 3909822, Easting 510271, Altitude 929 m. Located just north of the Mojave Dish station, creosote bush (*Larrea tridentata*) and joshua trees (*Yucca brevifolia*) dominate the vegetation and the substrate consists of granitic and volcanic alluvium.

d. **H2T2** - 35° 18' 32" N, 116° 49' 19" W, Northing 3907118, Easting 516198, Altitude 1016 m. This site is just west of Goldstone Rd. approximately 2.5 km northwest from the Goldstone gate. The dominant vegetation is a typical creosote bush (*Larrea tridentata*) plant community with a granitic alluvium substrate.

e. **H2T4** - 35° 18' 16" N, 116° 49' 07" W, Northing 3907725, Easting 516492, Altitude 1029 m. Located adjacent to Goldstone Rd. and site H2T2, this site is a large volcanic rock outcrop, with a decomposed volcanic alluvium. The vegetation is sparse save a few creosote bushes and annual grasses.

f. **GRANITES** - 35° 31'42" N, 116° 51'30" W, Northing 3930200, Easting 512250, Altitude 1170 m. This site was placed at the foot of a large granitic boulder outcrop in the Granite Mountains, located in the northwestern area of Fort Irwin. Creosote bush comprised a majority of the vegetation, but there were also many blackbush plants (*Coleogyne ramosissima*), which do not occur on the other sites, and joshua trees. The substrate consists of a granitic alluvium. Due to its distant location, this site was surveyed only four times.

Pit-fall Trap Sites

One pair of pit-fall trap lines was established adjacent to each of three transects (H1T3, H1T5, H2T4). Each trap line consisted of an aluminum flashing drift fence 17 m long and 20 cm high. It was sunk 2.5 cm into the ground, and held vertically between pairs of wooden stakes set every 0.3 m. At each end of the drift fence and one on either side, about 5 m from the end, aluminum canisters (15 x 30 cm) were buried flush with the soil surface. A total of 25 canisters were installed, usually four per drift fence. At each site, the two drift fences were placed perpendicular to each other such that they would intercept animals traveling in all compass headings and would direct them into the traps. Shade covers, needed for humane trap operation during the day, were constructed by hinging one side of two masonite squares (30 x 30 cm) together, and placing them in tepee fashion over each canister. The placement of these covers did not appear to impair the success of the traps, and may have actually attracted animals seeking shade. The covers were removed at night, and lids were used to seal the cans when the traps were not being used. When operational, the traps were checked in the early morning and afternoon, and additionally at noon on hot days. Each animal caught was identified, recorded, photographedif appropriate, and released.

Physiology Study Site

The study site for the 1993 physiological investigation was 0.8 km of an old tank trail (approximately 39°20'20" N, 116°53'15" W; Northing 3910600, Easting 509700; Altitude 929 m) . This road runs adjacent to the southwestern side of Goldstone Lake and intersects Goddard Road, 3.7 km from the Goldstone Road turnoff (see Figure 2). When we first attempted to locate horned lizards for the 1994 study, we found very few individuals located on the old tank trail. It appeared that the population had shifted to the east by about 0.5 km. In order to obtain enough lizards for the DLW study, we added two new dirt roads. One road (Goldmine Rd.) runs from the Mojave Dish station and cuts across to Goddard Rd.; it is 1.0 km in length. The second road (Dish Rd.) is a continuation of the tank trail on the southern side of Goddard Rd. and intersects Goldmine Rd. at a 90 degree angle; this road is approximately 0.6 km long (Figure 2). Lizards were located by car and by foot along these roads and for 50 m on either side of each road.

2.2 DATES OF STUDY

This project began in April of 1994. Nine days throughout April, May, and June were required for the visual surveys of the six transect lines (see Table 1 for dates). The pit-fall traps were run for a total of five days during the study period. The nocturnal road patrols were done intermittently throughout April, May, June, and July of 1994. The physiological data were collected during May, June, and July.

2.3 METHODOLOGY

Transects

The visual transect surveys consisted of three or more people walking along the 1000 m transect line and reporting every reptile seen. While the recorder walked along the line, the other spotters walked on either side approximately 10 m from the recorder to ensure that all reptiles were seen. Sightings were called out and recorded; the team stopped the search while recording data so that the visual search conducted by the recorder was not impaired. The surveys were conducted during maximal diurnal reptile activity times in the early to midday hours (0700 H to 1500 H. Pacific Standard Time corrected for daylight savings). Because reptile activity even varies within the peak hours of 0700 H to 1500 H, both the direction the transect was walked (forward or reverse) and the time it was surveyed (e.g. early morning vs. late morning) were equalized (Table 1). To standardize methods, the same individual (T.K. Brown) acted as recorder for all surveys. For each survey, we recorded the date, initial and final time, initial and final soil and air temperature, weather patterns, observers, the number of animals sighted per 100 m, over the 1000 m transect, and the age group of the animals (juvenile vs. adult) where possible (Figure 3). Our survey methods were standardized with those of Dr. Morafka.

Physiology

The desert horned lizard (*Phrynosoma platyrhinos*) was selected in 1993 for the physiological study. Many features of these lizards make them an ideal species for such a study, including the ease of capture and recapture, and their occurrence throughout much of the base. Desert horned lizards are also a good "representative" or indicator species for the local herpetofauna, because they are neither overly sensitive nor immune to habitat disturbances. Their use will aid future comparisons between disturbed and undisturbed areas.

We used the doubly labeled water method (Lifson and McClintock, 1966) to measure various physiological parameters, including rates of CO_2 production and water flux. Doubly labeled water (DLW) contains enriched levels of isotopes of hydrogen (H^*) and oxygen (O^*). In an animal whose body water is enriched with an oxygen isotope, the O^* concentration declines exponentially through time, but the slope for the O^* washout as a function of time is steeper than the slope for H^* washout. While both O^* and H^* are lost in the form of water, O^* is also lost as CO_2. By comparing the difference in the concentrations of the two isotopes from the initial and final blood samples of a labeled animal, the amount of CO_2

produced can be determined. This allows for the calculation of field metabolic rates. Rates of water influx and efflux can also be determined from the isotope data, and can be used to estimate food intake. This information can be used to estimate the energy requirements for both individuals as well as an entire population.

After being caught by hand, each lizard was processed as follows. It was weighed (± 0.1 g), snout-vent length measured (± 1.0 mm), painted with highly visible colors of a water-soluble acrylic paint, uniquely toe-clipped for future identification, and its sex was determined and recorded. Individuals were injected intraperitoneally with approximately 60 microliters of doubly labeled water ($H^2H^{18}O$). The lizard was then held captive for approximately one hour while the isotopes equilibrated throughout the body water of the individuals, then an initial blood sample (0.1 ml) was taken from the post-orbital eye sinus. Blood samples were flame-sealed in heparinized glass hematocrit tubes, placed on ice, and returned to UCLA. The lizards were immediately released where captured and a flag was set to mark the capture site. Any subsequent sightings of the lizard were marked with flagging in order to determine their general movements and home ranges. Approximately fourteen days later the lizards were recaptured, weighed, and a second blood sample was taken. Blood samples were also taken from two un-injected lizards to serve as background samples for determining the natural abundance of the isotopes. Because the background levels of natural isotope occurrence are both low as compared to injection levels, and do not vary significantly between individuals of the same population, a large background sample size is not necessary.

In the laboratory, pure water was vacuum distilled from the blood, and the isotopes were analyzed by mass spectrometry (deuterium) and proton-activation analysis (oxygen-18). Water influx and CO_2 production rates were calculated using the equations for linearly changing body water volumes (Nagy, 1980; Nagy and Costa, 1980). Metabolic rate, determined by CO_2 production, was expressed as metabolic energy expenditure using the factors 25.7 kJ l^{-1} CO_2^{-1} for an insectivorous lizard (Nagy, 1983). Total body water was calculated as the O^{18} dilution space (Nagy, 1980).

2.4 STATISTICAL ANALYSIS

Descriptive statistics, linear regression, and analysis of variance (ANOVA) were used to analyze the 1994 visual transect survey results as well as compare them with the 1993 findings. F-tests were used to determine significance, and the significance level was accepted as = 0.05. Because there were twice as many replicate samples of each transect in 1994, it was sometimes necessary to randomly draw four of the eight 1994 surveys to obtain data for comparison to the 1993 results. Each 1000 m transect was also broken down into its ten 100 m increments for some of the analyses. Paired t-tests, Mann-Whitney Rank sum tests, and Wilcoxon signed rank tests were used to analyze the 1994 physiological results, and to compare these with the 1993 results.

3. RESULTS

3.1 1994 TRANSECT SURVEYS

Each of the five Goldstone transects was surveyed eight times, and the Granite Mts. transect was surveyed four times, which together required a total of 102 person-hours. The survey time for each transect varied slightly, depending upon the terrain. On average, the volcanic rock transect (H2T4) required 62 minutes to survey, while the other four Goldstone transects each required approximately 32 minutes. The four surveys of the Granite Mts. study site were completed in one day; each pass averaged 50 minutes. While starting soil temperatures had no significant effect on the subsequent total number of individuals seen, the starting time did ($r=-.32$, $n=40$, $P<.05$). There was a general decrease in the number of individuals seen as the day progressed (Figure 4). Another interesting finding was that the wind also affected the number of reptiles seen. Wind was r-oughly categorized as no breeze (NB, 0 knots), slight breeze (SB, 0-10 knots), full breeze (FB, 10-20 knots), and very breezy (VB, +20 knots). There was a significant difference in the number of individuals seen depending on wind speed ($F_{3,395}=40.6$, $P < .0002$), with the most reptiles seen on NB days and the least on VB days.

Over 600 individual reptiles, representing fifteen species, were recorded during the visual transect surveys (Table 3). Diurnal lizards represented 97 percent of all reptiles seen (Table 3). A two-factor ANOVA comparing site with number of species revealed a highly significant difference between sites ($F_{4,395}=14.3$, $P<.0002$). Additionally, the types of diurnal lizard species found on each transect were also significantly different ($F_{9,3555}=106.1$, $P<.0002$). The total number of individuals seen on each transect was also highly significantly different ($F_{4,395}=15.3$, $P<.0002$). A summary of the characteristics of each transect is listed below:

a. **H1T1** - The *Atriplex* playa transect supported five reptiles species, and 92 animals were seen (Figure 5; Table 3). This site ranked lowest in species diversity, and medium in total count. The side-blotched lizard (50 animals) and the western whiptail (33 animals) accounted for 91 percent of the lizards seen. No snakes were seen, yet other evidence such as snake skin sheds and road patrols suggest their presence.

b. **H1T3** - The *Atriplex* alkali transect also supported five species, and 99 lizards were recorded (Figure 5; Table 3). Like H1T1, this site was lowest in species diversity and medium in total count. While the side-blotched lizard (35 animals) and the western whiptail (50 animals) together comprised the majority of lizards seen (86%) as at H1T1, there was a reversal in the relative proportions of those two species.

c. **H1T5** - The creosote/joshua tree transect supported the greatest number of reptiles seen (177) and was the second highest in species diversity with eight species recorded (Figure 6; Table 3). This was one of two sites where the threatened desert tortoise, (*Gopherus agassizii*) was found.

d. **H2T2** - The creosote granitic alluvium site was lowest in total count (35 reptiles) and second lowest in species diversity (Figure 6; Table 3). Of the six species seen, the western whiptail represented nearly 75 percent of all the reptiles seen. The one chuckwalla that was sighted was seen adjacent to a nearby granitic outcrop and is most likely not a typical creosote habitat resident. A desert tortoise was also seen once on this transect.

e. **H2T4** - The volcanic rock outcrop was by far the most diverse in terms of species (11 reptiles) and second highest in total count (146 [Figure 7; Table 3]). Five of the species seen on this site were not seen on any other transect during our surveys. This included four snake species and the collared lizard (*Crotaphytus insularis*), a close cousin of the leopard lizard (*Gambelia wislizenii*). This site, along with the creosote joshua tree site (H1T5), represented over 52 percent of all animals recorded during the surveys.

f. **Granites** - On this site we saw 61 reptiles representing seven species. This was the only site where we saw the desert night lizard (*Xantusia vigilis*). This site also supported many chuckwallas and desert spiny lizards (Figure 7; Table 3).

The side-blotched lizard (*Uta stansburiana*) was by far the most common lizard, occurring on all transects, and representing almost half of all individuals seen (Figure 8). The western whiptail (*Cnemidophorus tigris*) was the second most common lizard (32% of all lizards seen) and was also found on all transects (Figure 8). While the side-blotched lizards represented almost 50 percent of all animals seen on four transects, the western whiptail comprised the majority of individuals on both H1T3 and H2T2 (Figures 5 & 6). These two species combined represented over 80 percent of all lizards seen. The third most common lizard was the chuckwalla (*Sauromalus obesus*), which is somewhat surprising given that they are rock specialists; they accounted for 6 percent of all diurnal lizards seen (Figure 8). The two rarest lizards were the leopard lizard (*Gambelia wislizenii*) and the desert night lizard (-*Xantusia vigilis*). The latter species was seen four times on the blackbush transect in the Granite mountains, as compared to once in 1993. The remaining four species (desert horned lizard, zebra-tailed lizard, collared lizard, and desert spiny lizard) were all intermediate in occurrence (Table 3, Figures 5, 6, 7, and 8).

3.2 ANNUAL VARIATION IN TRANSECT SURVEYS

There were many significant differences found between the 1993 and 1994 visual transect survey data for the five Goldstone study sites. A two-factor ANOVA comparing the effects of site and year on total count found a highly significant difference between the two years ($F_{4,1}$ = 9.05, P=.0028). Accounting for the number of survey days, the total number of reptiles seen on each site decreased, on average, 35 percent from 1993 to 1994 (range 15-51%; Figure 9). Yet, while both the total and average (per day) number of reptiles seen in 1994 decreased, the total number of species found per site either remained the same or nearly doubled (Figure 10).

The largest decrease in the number of individuals seen of a given species was shown by the western whiptail. The total count of these lizards decreased by over 40 percent in 1994 for all transects combined (not accounting for the greater surveying effort in that year; Figure 11), and the per person/day total decreased over 70 percent on some transects (Figure 13, 14, & 16). Another interesting difference between the two years was in the relative proportion of juveniles vs. adults. In 1993, juvenile whiptails represented only 15 percent of all whiptails seen, yet in 1994 the proportion of juvenile whiptails jumped to 40 percent; this difference was significant ($F_{1,390}$ = 12.7, P=0.004, ANOVA). The surveys were conducted in roughly the same season, so no differences in the proportion of juveniles were expected. In general, the corrected total count of all species also declined except for the chuckwallas (Figure 16 & 17), leopard lizards (Figure 15), and the side-blotched lizard which increased almost 20 percent on the playa transect (Figure 13). The majority of the increases seen in transect species diversity was due to the sighting of snakes on the volcanic rock outcrop. Between the two years, the relative proportions of the number of individuals of each species generally remained similar for most species; the whiptails and zebra-tails showed a large decrease, while the proportion of side-blotched lizards increased (Figure 12).

3.3 PIT-FALL TRAPS

The pit-fall traps were operated for five complete days (3000 trap hours). Nine animals were trapped (Table 4) and three reptile species were recorded. Two of these were lizard species (*U. stansburiana* and *C. tigris*), and the other a snake, the western shovel-nosed snake (*C. occipitalis*). We also found one mammal (*Perognathus sp.*), one scorpion, and one solpugid (Table 4).

3.4 ROAD PATROLS

Many nights were spent patrolling roads, as it was usually dark by the time transect and pit-fall trap work was completed. Patrols usually lasted about one hour and were conducted along Goldstone and Goddard Rd. Twelve reptiles were sighted during the patrols (Table 5). While most of the animals were snakes, we also discovered a western-banded gecko on July 7, 1994. This was the only species recorded in 1994 that was not detected in 1993.

3.5 PHYSIOLOGY STUDY

Fifty-three horned lizards were captured and processed during the physiology study (5/31/94 to 7/16/94). The sex ratio was almost 3:1 in favor of males. Average body mass was 17.1 g (range 6.5 -24.2 g) and average snout-vent length was 76.5 mm (range 52-90 mm [Table 6]). Twenty-two lizards were injected with doubly labeled water. Twelve were recaptured, on average, 14 days later (range 7-18 d) and provided a second blood sample. The average body mass change per day was 15 percent (range -.51% to 1.85%), but these changes were not significant. The 1994 average body mass was significantly lower than the 22.4 g in the 1993 study group (P=0.0003, Mann-Whitney Rank Sum). Additionally, two horned lizards provided background samples to determine the natural levels of the hydrogen and oxygen isotopes.

Although there were significant differences in the average body mass and percent body mass change between 1993 and 1994, these factors did not have a significant affect on field metabolism within each year. Therefore, we were able to compare the field metabolic rates between the two years. During the summer 1994 study period, the average field metabolic rate in liters of CO_2 / kg*day was 4.1 $\pm$ 1.6 SD (Table 6). This FMR was significantly lower than the average FMR in 1993 (5.9 l CO_2 / kg*day, P=0.008, Mann-Whitney Rank Sum). The average amount of water influx (0.36 ml/d $\pm$ 0.15 SD) was not significantly different from the average water efflux (0.34 ml/day $\pm$ 0.11 SD) in 1994 (P=0.41, n=12, paired t-test). Both the average water influx and efflux in 1993 were significantly higher than in 1994 (water in, P=0.003; water out, P=0.001; Mann-Whitney Rank Sum [Table 6]). In addition, water influx (0.57 ml/d) was significantly higher than water efflux (0.52 ml/d) in 1993.

4. DISCUSSION

4.1 GENERAL METHODOLOGY AND ANNUAL VARIATION

We recorded 631 reptiles representing twenty species during the 1994 field season, and a total of 102 person-hours were spent visually surveying the six transects. It was apparent to us in the field that there was a decrease in both species richness and individual density in 1994 from 1993. The statistical analysis confirmed many of our general observations in the field.

Because reptiles are ectothermic (requiring external sources of heat), their activity patterns are often closely linked with the daily and seasonal solar and thermal schedules. In this study, we were attempting to document the presence and relative occurrence of all reptiles present in the different habitats in Goldstone. To this end, we selected survey times that corresponded to the predicted times of maximal reptile activity, namely the early to late morning hours. While this time frame incorporated the maximal activity patterns, there was a significant decrease seen in the total count towards the late morning hours (Figure 4). This relationship suggests that the visual surveys should only be conducted between 0700 and 1000 H to maximize results (which would allow us to only survey 2-3 transects/day). We were aware of this phenomenon while conducting the surveys, yet there are two main reasons why we continued to survey five transects a day.

First, while the early morning hours are the peak time of reptile activity, not all species are equally active at this time. For instance, many of the lizards are rather thermophilic (heat-loving), and only emerge later in the day when soil temperatures are higher. Likewise, other reptiles are only active early in the day. If we had constrained our surveys to the early hours we would have be introducing sampling bias into our data. Instead, we sampled over a longer time period, and the order of the surveys was randomized, such that each transect was sampled at different times during the day. Second, if we had reduced the number of surveys we conducted each day, a greater number of days would have been necessary to complete the study. The resulting longer study period could also possibly introduce sampling bias due to the seasonal differences present in reptile activity patterns. Starting soil and air temperatures did not have a detectable affect on total count, but these factors are closely linked with the time of day and can also affect reptile activity.

Another interesting phenomenon we noticed while surveying was that total count substantially decreased on windy days. This observation was later statistically confirmed, with the most reptiles being recorded on the least windy days. There is a variety of reasons why wind may cause a decrease in activity. Water conservation is a vital issue facing any desert animal, and wind will increase the evaporative water loss of an animal via convection. Reptiles have rather impermeable skins, but their eyes, which are exposed, may be losing water. Wind may also reduce the activity of the insect prey of many animals, thereby decreasing the foraging efficiency of the lizards and encouraging inactivity. It may also be more difficult to detect predators on windy days when the bushes and soil are blowing around. Finally, it may be more difficult for a person to see reptiles on windy days and so some of the apparent decrease may be sample bias. Unfortunately wind is not extremely predictable, and due to the geography of the Mojave desert, wind is a fairly common occurrence (Bradshaw, 1986).

While it is not really possible to schedule surveys around wind speed, a large sample size will reduce the effects of this factor, which was one of the reasons we decided to double the number of surveys on each transect from 1993 to 1994.

Both the overall total number of animals seen and the number of species recorded in 1994 were about 80 percent of those values from 1993. The statistical analysis demonstrated significant differences between the total annual count and the total number of individuals seen per species between the two years on a given transect. The primary question which arises is what was the cause of such a huge difference?

Desert ecosystems are often characterized by low and more importantly, unpredictable rainfall (Bradshaw, 1986; Louw and Seely, 1982). Both the total amount of rainfall and the time frame over which it is received can have a significant impact on the primary productivity in a given year. For example, two years may each receive 200 mm of precipitation, yet if all of the rain falls on two days in one year, but over two months in another, the primary productivity may be drastically different. Between May 1992 and April 1993, 27.3 cm (10.7 inches) of rain fell on Goldstone; only 5.5 cm (2.15 inches) of rain fell on Goldstone between May 1993 to April 1994 (NOAA, 1992; 1993; 1994). This five-fold difference in precipitation was the most likely cause of the significant decrease in biomass seen in 1994. While 1992 and 1993 were relatively "wet" years, the annual precipitation the desert area has received since 1984 has been substantially less than the average rainfall amount over the past sixty years (NOAA, 1994). Reptile populations may have been experiencing stress for several years as a result of the prolonged deficit in annual precipitation. The sudden drop in rainfall in 1994 may have greatly exacerbated this stress resulting in either large die-offs of individuals, or many individuals may have remained relatively inactive. Another interesting result of the 1994 study was that the decrease in total count was not equal over all species. Some species may be more susceptible to changes in annual rainfall than others. This differential mortality was seen to some degree in the western whiptail. While the adult population significantly decreased from 1993 to 1994, the number of juveniles greatly increased. The increase in juveniles in 1994 may have been due to a successful reproductive season in 1993.

Due to the substantial differences between the two years on a given site, it was not truly valid to combine the 1994 data with the data from Dr. Morafka's study for the purpose of constructing predictive habitat/herpetofauna relationships. Similar decreases were observed in his data for 1994. Rather, these differences illustrate the need for continued monitoring of the control plots, even during experimental studies, to account for annual variation. Once a larger baseline data set is established (larger sample size, smaller variance), it will be feasible to combine data for similar habitats.

4.2 BIODIVERSITY AT FORT IRWIN

Based upon range maps constructed for each reptile species (Stebbins, 1985), and as with the results of 1993, most of the expected species were recorded in 1994. The only threatened species found was the desert tortoise (*Gopherus agassizii*). No amphibians were detected in 1994 on Goldstone or the rest of the base (David Morafka, personal communication). We still suspect that the red-spotted toad (*Bufo punctatus*) may be present on the base and will continue to search for it in the various springs that are present on the base. In addition to the red-spotted toad, there are still three reptile species which we believe may be present in the western portion of Fort Irwin. The long-tailed brush lizard (*Urosaurus graciousus*) was located both years in the southern portion of the base. Fort Irwin encompasses the western edge of the known species distribution for this lizard (Stebbins, 1985). A few brush lizards were sighted just southeast of the Goldstone area, indicating that they may be present in our study area. They can be difficult to sight in the field given their behavior and cryptic body coloration. Additionally, two small snake species may occur in the western portion of the base. Both the western blind snake (*Leptotyphlops humilis*) and the common ground snake (*Sonora semiannulata*) are suspected to live on Goldstone, but they have not been detected via the various survey techniques employed so far.

Of the five species found only in the 1993 study and not in 1994, four were snake species (lyre snake, common kingsnake, spotted leaf-nose snake, and the rosy boa). It is unlikely that these species disappeared in 1994. Rather, because of the harsher conditions of that season, their activities may have been greatly curtailed, thus reducing the chance of us locating them during the survey. The only lizard species located in 1993 and not 1994 was the desert iguana (*Dipsosaurus dorsalis*). These lizards are very thermophilic, emerging only when temperatures generally exceed 40° C, and are thus rarely sighted. The 1993 sighting of this species was adjacent to the road and not even on an established study site. On the other hand, we recorded the desert banded gecko (*Coleonyx vareigatus*) in 1994. This species was suspected to occur in Goldstone, yet was not found in 1993. The single individual recorded was found during a nocturnal road patrol adjacent to a creosote-granitic alluvium habitat. Because these lizards are nocturnal, they are difficult to locate and probably will require extended efforts to detect more of them in the future. In 1994, we also successfully recorded the desert night lizard (*Xantusia vigilis*). This lizard is also a very elusive species and difficult to locate, given that it has a very specialized habitat (usually found only in joshua tree debris). In 1993, a single night lizard was seen once on the creosote/joshua tree transect (H1T5). In 1994, while no night lizards were seen on H1T5, we repeatedly saw night lizards on the blackbush transect, most likely due to the higher density of Joshua trees on that transect.

The volcanic rock transect (H2T4) supported the greatest number of species as well as the second highest reptile density. These results agree with the 1993 results for the same transect (Nagy and Brown, 1994). Joshua tree areas (H1T5) also supported a very high species density/diversity as well as many of the more rare species such as the desert night lizard. The blackbush habitat in the Granite Mts. was very diverse in terms of reptile species. Conversely, the *Atriplex* and creosote transects were the most species-poor sites. The most likely cause of the different species assemblages seen between sites may be due to micro-habitat diversity. The volcanic outcrop, joshua tree transect, and the Granite Mountains transect all have a greater spatial heterogeneity than the other sites. This difference is due to rocky outcrops or boulders and a more variable plant assemblage. This heterogeneity can provide not only a greater array of micro-habitats for protection and shade, but also may provide a wider array of food types. In addition, the soils in these areas are finer and softer than those found at the creosote and *Atriplex* sites and are easier to dig and burrow into. Both the spacial and soil differences help support a more diverse assemblage of reptiles, as was seen in our surveys.

4.3 PHYSIOLOGY

It appears that the summer of 1993 was a more benevolent season for horned lizards than the summer of 1994. Although no significant difference between initial and final body mass was detected, over half of the animals lost weight during the two-week study period in 1994 (Table 6). In addition, half of the animals were in negative water balance (i.e. expended more water than they acquired). These findings are quite contrasting to the results of the 1993 physiology study of the same population. In 1993, the horned lizards grew significantly; all were in significant positive water balance; and field metabolic rates were substantially greater (Nagy and Brown, 1994). While there was at least one reproductive bout (and most likely two) in 1993, no gravid females were found in 1994.

We were able to use the water influx rates to estimate the feeding rates of desert horned lizards. Assuming an average ant weight of 8 mg, and a 65 percent average water content (Whitford and Bryant, 1979), the water intake rates indicate that the horned lizards were eating approximately 72 ants/day in 1994. This value is substantially lower than what we calculated from the 1993 data, which indicated that about 115 ants/day were being consumed that year.

The 1994 results indicate that the horned lizards at the Goldstone population were experiencing physiological stress. Growth, energy intake and expenditure, water flux, and reproduction were all significantly lower than in 1993. These results are consistent with the overall findings of the transect surveys which revealed significant decreases in reptile numbers. The large difference in water intake and balance between the two years is yet another indication that the five-fold decrease in precipitation in 1994 (and perhaps therefore primary productivity and insect abundance) is most likely responsible for the drastic differences seen.

5. RECOMMENDATIONS

The results of the 1994 study, coupled with the comparison to the 1993 study, have produced many recommendations for management strategies and future avenues of research:

1) **We recommend the continued study of the established visual transect sites on Goldstone.** The major finding of this report is that a large difference in both species diversity and total biomass can and does occur even between two years. Before it is possible to extrapolate to other areas of the base, and to begin to assess the effects of military training exercises on the local herpetofauna, more baseline data is needed. With each additional year of replicate data, our understanding of the relationship between habitat, precipitation, and the herpetofauna will increase substantially. If precipitation has as great an effect on biomass as is indicated by the first two years of research at Goldstone, then further studies will be able to more closely delineate this relationship. Understanding this association will be crucial to any attempt at measuring the impact of training maneuvers in different areas and different years.

2) **We recommend continuance of the physiological study of the desert horned lizard.** As discussed previously, field physiological studies are able to more closely investigate the causal mechanisms underlying apparent changes in population structure. A large change in the number of reptiles was seen from 1993 to 1994. This difference was also mirrored by the physiological study of the desert horned lizard. Furthermore, the horned lizards were apparently experiencing water stress. It is quite probable that other reptile species were likewise under water or energy stress in 1994. This may have been the cause of the decrease in the number seen: they were either less active (estivating) or the populations may have lost many individuals. We recommend that the Goldstone population continue to be monitored as a baseline and control data base for future comparisons with impacted areas. Future studies should place more emphasis on obtaining physiological data from juveniles. There was evidence this year that annual variation may effect differential mortality among age classes; it is important to know how a species responds to annual variation in resource abundance (water, food etc.) in order to predict population demographics.

3) **We recommend that a similar study of the presence and relative abundance of Arthropods be initiated.** A multitude of time and money has been expended by the U.S. Army and various researchers to study reptiles, mammals, birds, and plants on replicate study sites across the base. Yet the group of organisms that potentially represents the greatest biomass and a very important ecosystem link has apparently not received similar attention. Many of the local mammal and birds species, as well as most of the reptiles at Fort Irwin, rely on insects . We have demonstrated that precipitation can have a large affect on annual variation in reptile numbers. Yet, without more information about their prey, it is hard to determine if rainfall differences are acting directly on biomass (as a water source) or indirectly, by altering primary productivity (insect's food

source), or both. Doubly labeled water studies can attempt to distinguish these effects, but it is extremely helpful to have data about insect abundance.

4) **We recommend that the Goldstone area remain off-limits.** As we recommended last year, Goldstone should remain off-limits to training exercises because it is such a pristine area. One of the long term goals of the U.S. Army is to determine the effects of their exercises on the biological resources of Fort Irwin. In order to assess such effects, it is critical to have undisturbed control sites for comparison; Goldstone represents such an area. While most of the land was presumably protected while under lease to JPL/NASA, between 1993 and 1994 some of the land, including one of our study sites, was returned to Army jurisdiction and has been subject to heavy traffic. The access to this new land includes the only site where we found the rosy boa (*Lichanura trivirgata*) in 1993. Goldstone is a very species-rich and habitat-diverse area and should be protected.

5) **We recommend that rocky outcrop areas and joshua tree habitats receive special management attention.** These areas supported the most diverse and dense reptile assemblages. As we recommended in 1993, such habitats deserve special attention due to their unique biodiversity. These types of habitats are relatively rare on the base and may require unique management strategies. While both the creosote/granitic alluvium areas and the *Atriplex* alluvium areas supported the lowest species diversity and densities, it is these types of habitats which comprise the majority of the base. Because these habitats are generally flat and vehicle accessible, they are thus the habitats most often used for training activities. The most widespread management strategies of these areas may be necessary in order to preserve the local herpetofauna.

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APPENDICES

APPENDIX A

TABLE 1 - TABLE 6

Table 1. Dates and Daily Order of Visual Transect Surveys

Daily sequence	4/30/94	5/1/94	5/28/94	5/29/94	6/4/94	6/5/94	6/6/94	6/17/94	6/18/94
1	H2T4	H1T1(R)	H2T2	H1T3(R)	H1T3	H1T1(R)	GRAN	H2T4	H1T5(R)
2	H2T2	H1T3(R)	H2T4	H1T5(R)	H1T5	H2T4(R)	GRAN(R)	H2T2	H1T3(R)
3	H1T5	H1T5(R)	H1T1	H1T1(R)	H2T2	H2T2(R)	GRAN	H1T1	H1T1(R)
4	H1T3	H2T2(R)	H1T5	H2T4(R)	H2T4	H1T5(R)	GRAN(R)	H1T3	H2T2(R)
5	H1T1	H2T4(R)	H1T3	H2T2(R)	H1T1	H1T3(R)	-	H1T5	H2T4(R)

Note: An "R" indicates the transect was walked in a reverse fashion.

Table 2. List of Species Seen in Goldstone/Fort Irwin

LIZARDS	
Cnemidophorus tigris	Western Whiptail
Uta stansburiana	Side-Blotched Lizard
Callisaurus draconoides	Zebra-Tailed Lizard
Sceloporus magister	Desert Spiny Lizard
Gambelia wislizenii	Long-Nosed Leopard Lizard
Phrynosoma platyrhinos	Desert Horned Lizard
Crotaphytus insularis	Desert Collared Lizard
Sauromalus obesus	Chuckwalla
Xantusia vigilis	Desert Night Lizard
Dipsosaurus dorsalis*	Desert Iguana
Coleonyx variqatus+	Western Banded Gecko
SNAKES	
Pituophis melanoleucus	Gopher Snake
Arizona elegans	Glossy Snake
Masticophis flagellum	Coachwhip
Trimorphodon biscutatus*	Lyre Snake
Salvadora hexalepis	Western Patch-Nosed Snake
Rhinocheilus lecontei	Long-Nosed Snake
Lampropeltis getulus*	Common Kingsnake
Phyllorhynchus decurtatus*	Spotted Leaf-Nosed Snake
Chionactis occipitalis	Western Shovel-Nosed Snake
Crotalus cerastes	Sidewinder
Crotalus scutulatus	Mojave Rattlesnake
Crotalus mitchelii	Speckled Rattlesnake
Lichanura trivirgata*	Rosy Boa
TORTOISES	
Gopherus agassizii	Desert Tortoise

*Species seen in 1993 and not in 1994 +Species seen in 1994 and not in 1993

Table 3. Summary of Visual Transect Surveys for Diurnal Reptiles

TRANSECT	H1T1 - Atriplex playa			H1T3 - Atriplex alkalai			H1T6 - Creos./Jdah.			H2T2 - Creo./Gran.			H2T4 - Volcanic Rck.			GRAN-Blackbush			SUM (N)	Fraction of SUM
SPECIES	SUM (N)	MEAN/ DAY	MAX/ DAY	SUM (N)	MEAN/ DAY	MAX/ DAY	SUM (N)	MEAN/ DAY	MAX/ DAY	SUM (N)	MEAN/ DAY	MAX/ DAY	SUM (N)	MEAN/ DAY	MAX/ DAY	SUM (N)	MEAN/ DAY	MAX/ DAY	ALL	ALL
C. draconoides	4	0.5	2	6	0.8	3	6	0.8	2	1	0.1	1	2	0.3	1	0			19	3.1
C. tigris	33	4.1	8	50	6.3	21	45	5.6	22	26	3.3	12	32	4.0	14	2	0.3	2	188	30.8
C. insularis													10	1.3	4	1	0.1	1	11	1.8
G. wislizenii	2	0.3	1	3	0.4	2	2	0.3	2										7	1.1
P. platyrhinos	3	0.4	1	5	0.6	3	3	0.4	2				1	0.1	1				12	2.0
S. obesus										1	0.1	1	21	2.6	6	15	1.9	5	37	6.1
S. magister							11	1.4	4				3	0.4	2	10	1.3	3	24	3.9
U. stansburiana	50	6.3	18	35	4.4	12	104	13.0	20	5	0.6	2	73	9.1	15	28	3.5	10	295	48.4
X. vigilis																4	0.5	2	4	0.7
G. agassizii							4	0.5	1	1	0.1	1							5	0.8
C. cerastes							2	0.3	1	1	0.1	1							3	0.5
P. melanoleucus													1	0.1	1				1	0.2
M. flagellum													1	0.1	1				1	0.2
S. hexalepis													1	0.1	1				1	0.2
C. mitchelii													1	0.1	1	1	0.1	1	2	0.3
TOTAL (N)	92	11.5	30	99	12.4	41	177	22.1	54	35	4.4	18	146	18.3	47	61	7.6	24	610	
TOTAL(SPP)	5			5			8			6			11			7			15	

Note: Shown for each transect site is the total number of individuals for each species seen, and the mean and maximum number of individuals of that species seen per day. Also given are the total number of species seen per transect, as well as individual totals for each species and the relative percentages.

Table 4. Results of Pit-fall Trapping

PITFALL TRAP RESULTS

	Species	Individuals Seen
Reptiles:	Cnemidophorus tigris	1
	Uta stansburiana	4
	Chionactis occipitalis	1
Mammals:	Perognathus spp.	1
Insects:	Order Scorpionida	1
	Order Solpugida	1
	TOTAL	9

Table 5. Species List of Reptiles Seen During Road Patrols

ROAD PATROL/ INCIDENTAL SIGHTINGS SUMMARY

Species:	Individuals Seen:
Pituophis melanoleucus	2
Arizona elegans	3
Rhinocheilus leconti	1
Chionactis occipitalis	1
Crotalus cerastes	2
Crotalus scutulatus	2
Coleonyx variegatus	1
TOTAL	12

Table 6. Physiological Study Results from 1993 and 1994 for *Phrynosoma platyrhinos*

VARIABLE	1993	1994
SAMPLE SIZE (n)	8	12
MEAN BODY MASS (g)	22.4 (2.4)	17.1 (2.7)
AVERAGE SVL (mm)	80.7 (4.6)	76.8 (4.3)
BM CHANGE (%/day)	0.3 (0.27)	0.15 (0.64)
WATER INFLUX (ml/day)	0.57 (0.09)	0.36 (0.15)
WATER EFFLUX (ml/day)	0.52 (0.08)	0.34 (0.11)
FIELD METABOLIC RATE		
LITERS CO2/DAY	0.13 (0.02)	0.07 (0.02)
LITERS CO2/KG DAY	5.86 (0.7)	4.08 (1.57)
MILLILITERS CO2/G HR	0.24 (0.03)	0.17 (0.06)

Note: * Standard deviation in parenthesis

APPENDIX B

FIGURE 1 - FIGURE 17

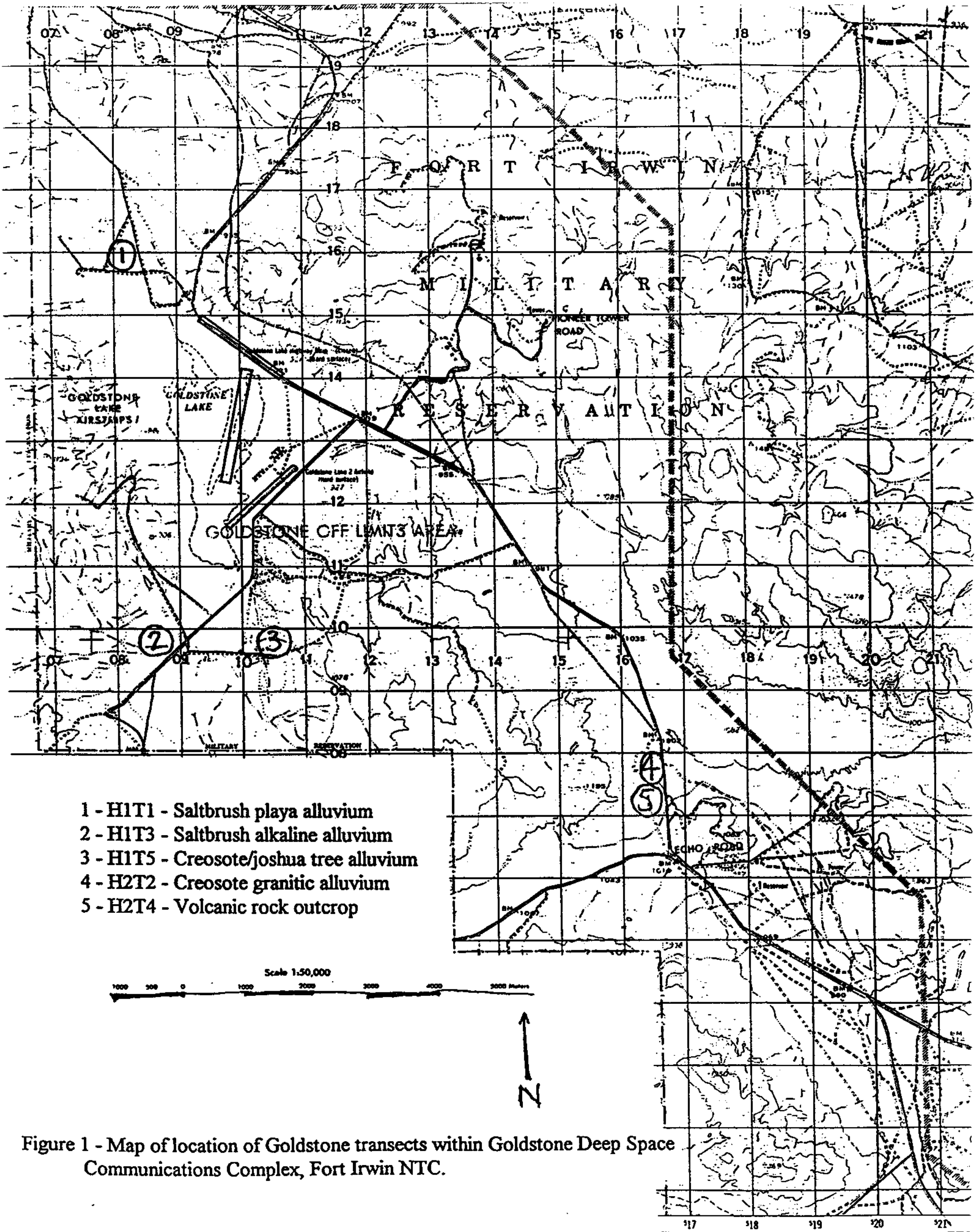


Figure 1 - Map of location of Goldstone transects within Goldstone Deep Space Communications Complex, Fort Irwin NTC.

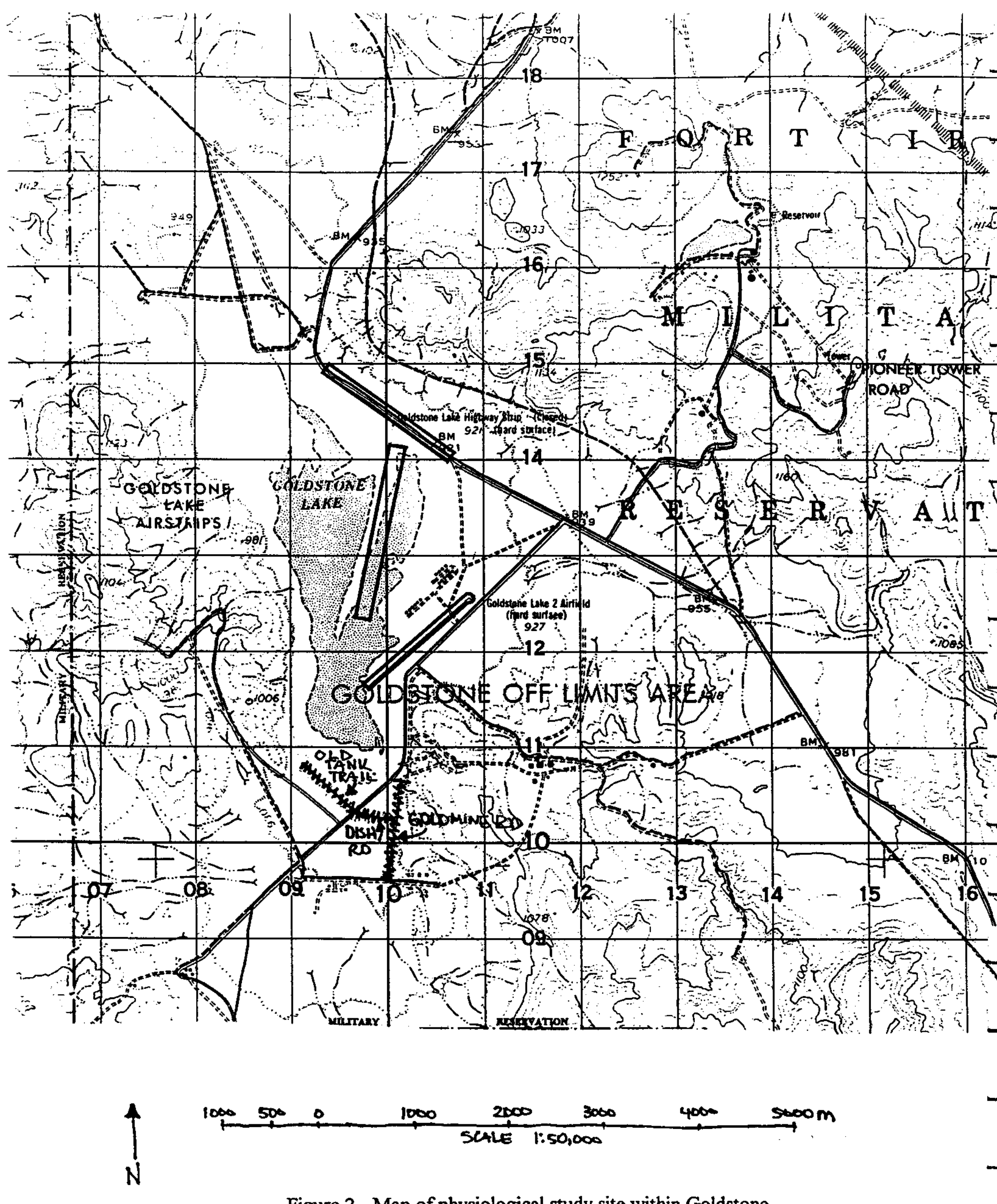


Figure 2 - Map of physiological study site within Goldstone.

FORT IRWIN REPTILE SURVEY

HUB NAME: DATE: PST TIMES: Start - End -

SITE TYPE (VEG. & SUBS): Atriplex playa alluvium

WEATHER:

TEMPERATURE: Start Air - End Air -

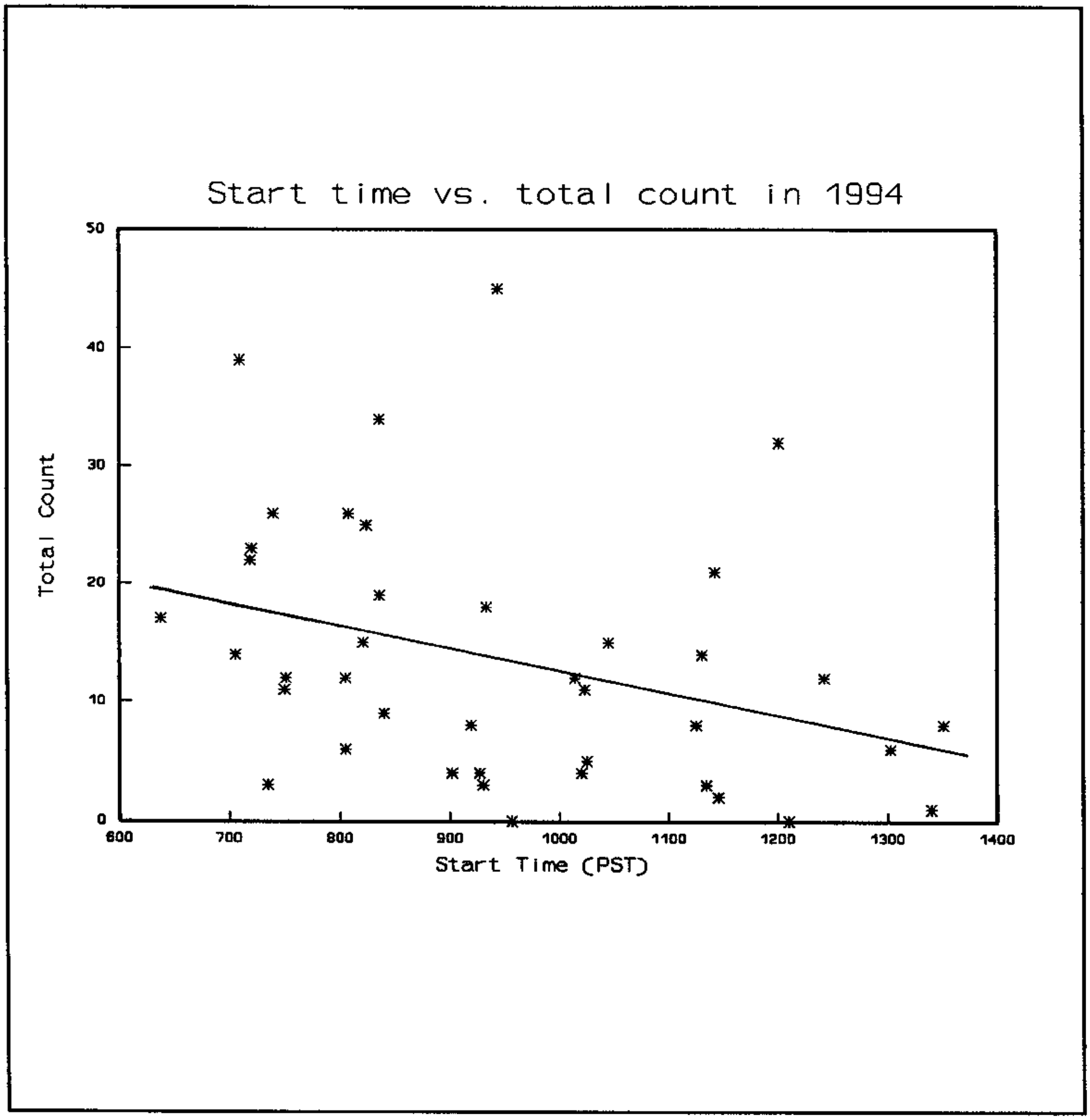
Start Soil - End Soil

OBSERVERS:

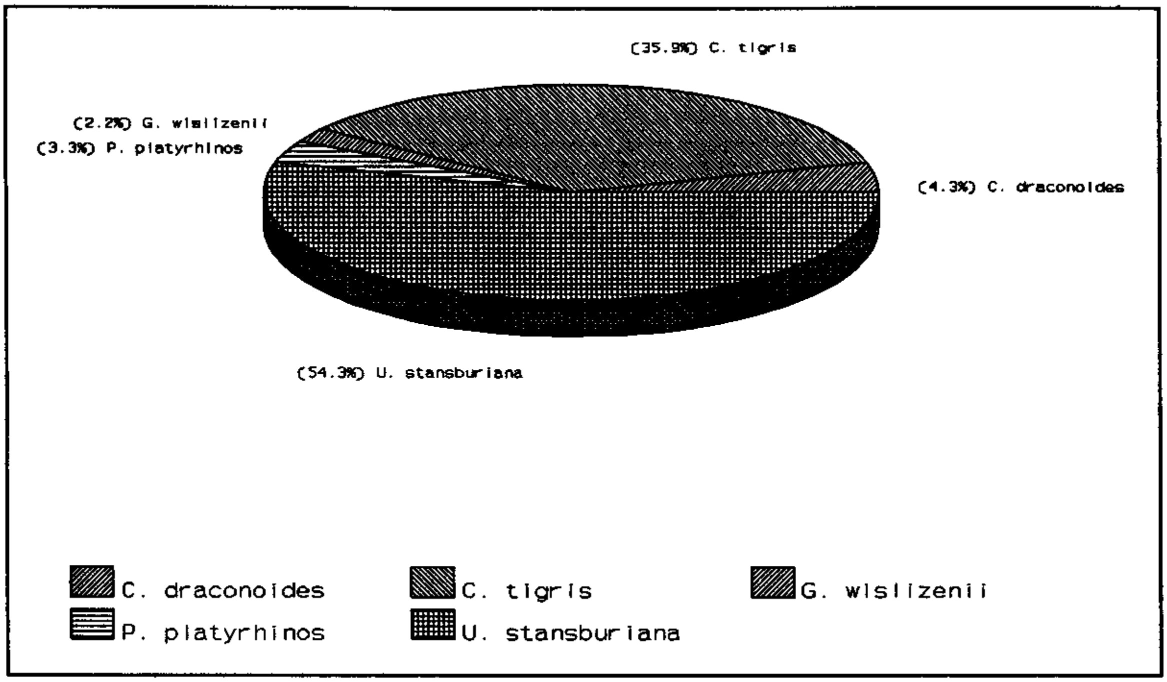
INTERVAL	CALL J	CALL A	CNEM J	CNEM A	GAMB J	GAMB A	DIPS J	DIPS A	PHRY J	PHRY A	SAUR J	SAUR A	SCEL J	SCEL A	UTA J	UTA A	OTHER	
0 to 100m																		
100 to 200m																		
200 to 300m																		
300 to 400m																		
400 to 500m																		
500 to 600m																		
600 to 700m																		
700 to 800m																		
800 to 900m																		
900 to 1000m																		
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3. Sample survey sheet from visual transect surveys.

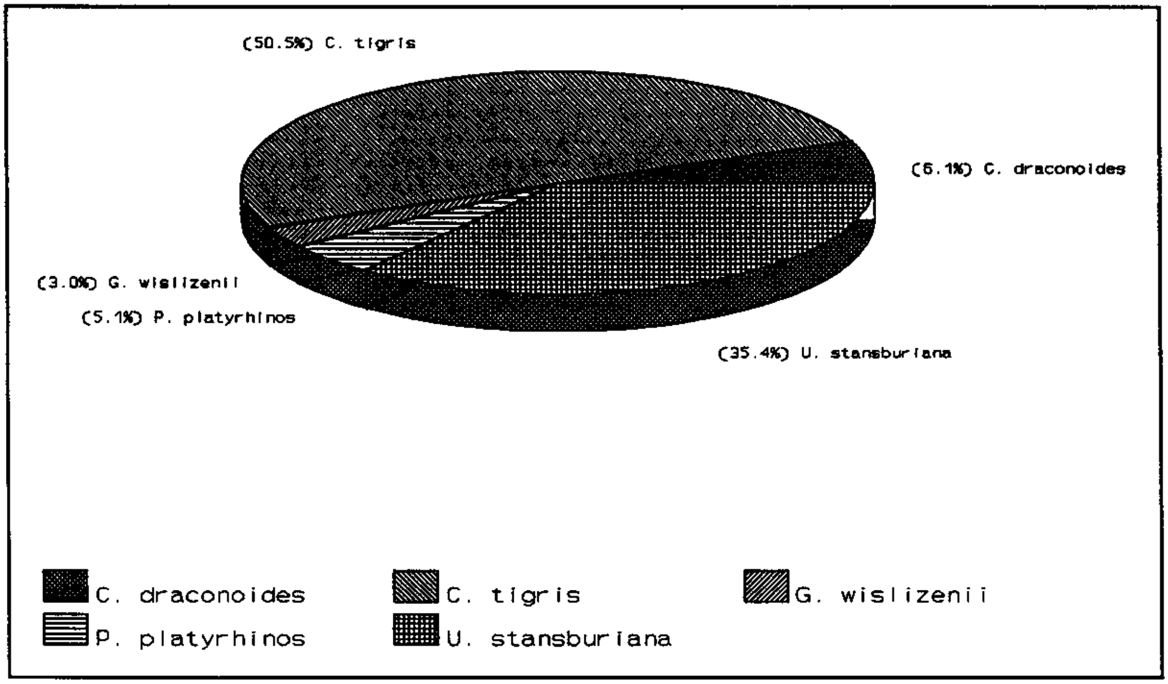
Figure 4. Plot of Starting Time vs. Total Number of Reptiles Seen That Day



Note: r = -0.32, n = 40, $P < 0.05$

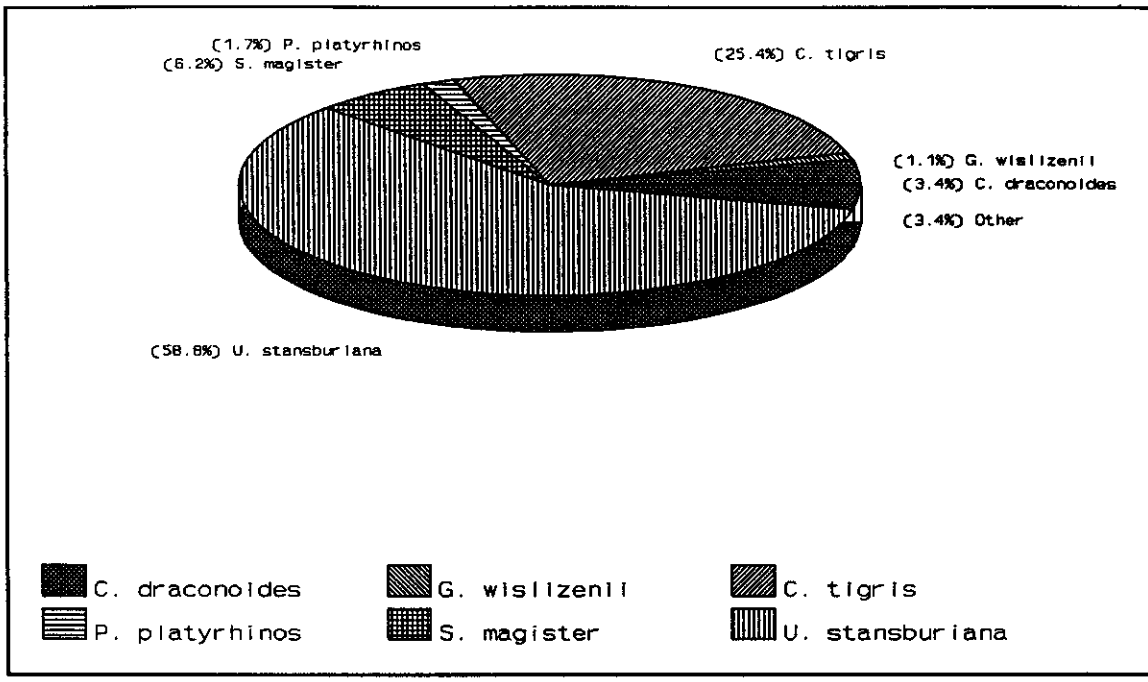


Atriplex Playa Alluvium Results (H1T1)

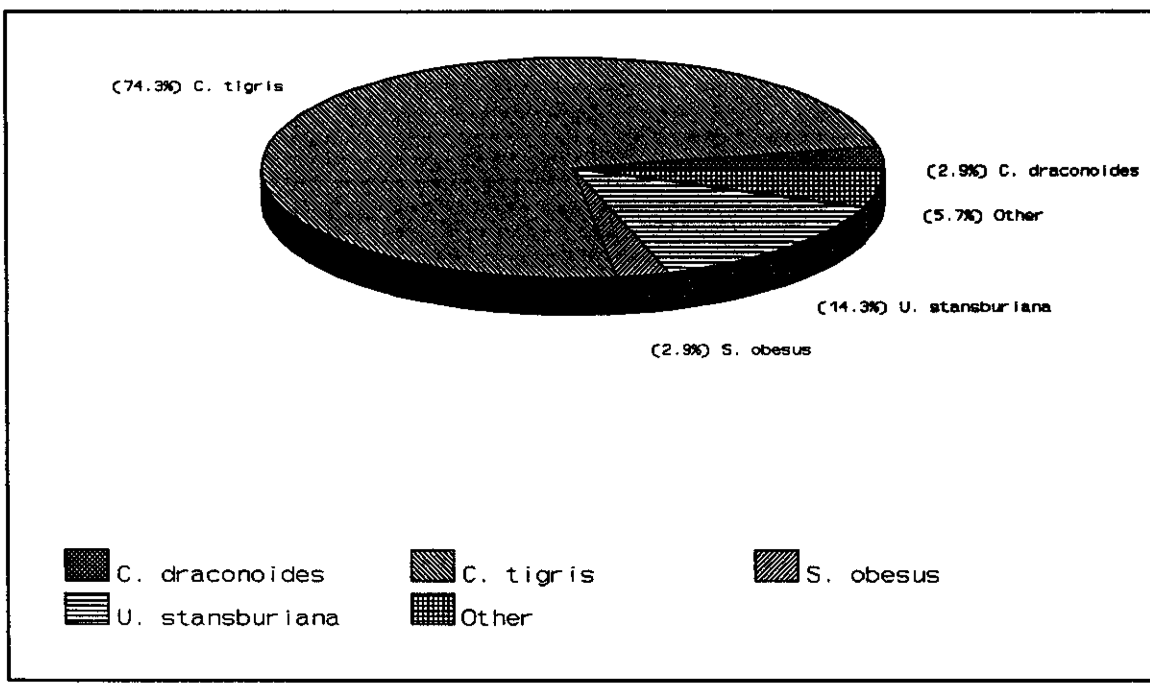


Atriplex Alkaline Alluvium Results (H1T3)

Figure 5. Visual Transect Survey Results in 1994 for H1T1 and H1T3



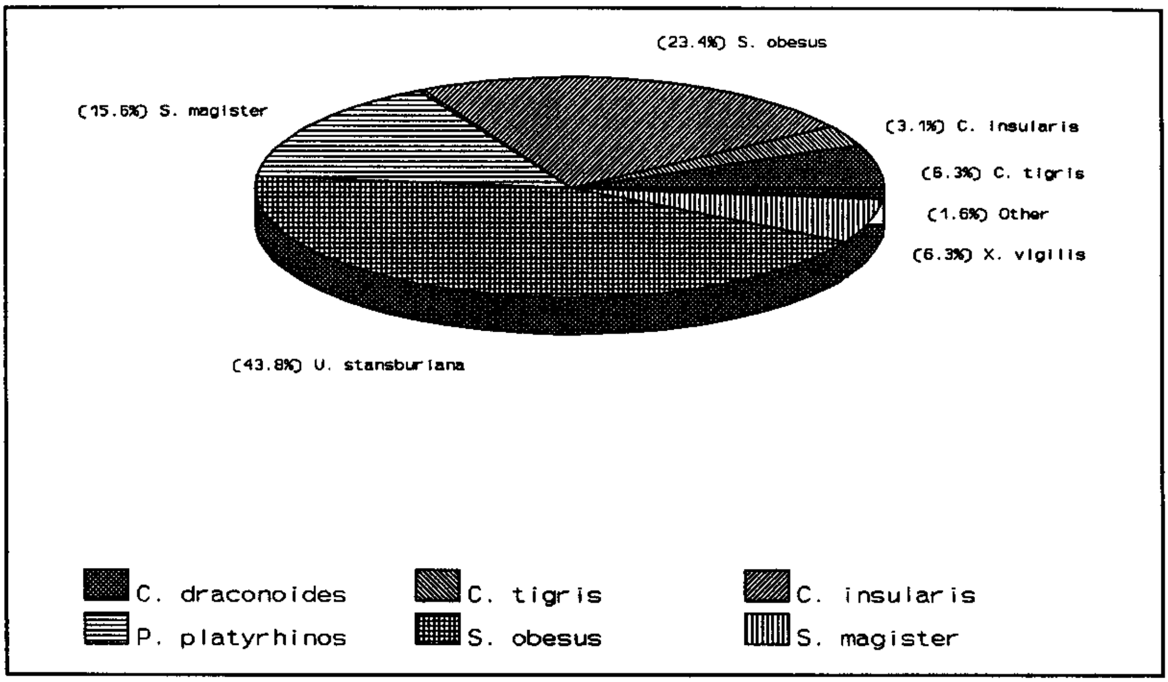
Creosote/Joshua Results (H1T5)



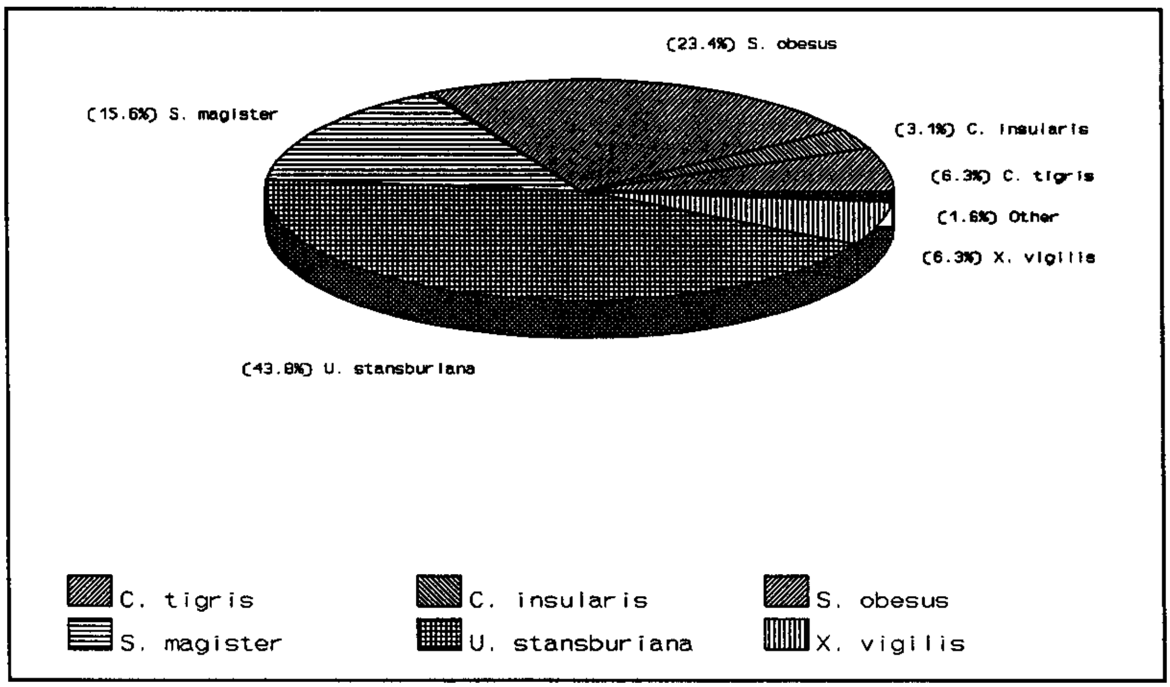
Creosote Granitic Alluvium Results (H2T2)

Note: Other refers to *Gopherus agassizii, Crotalus cerates.*

Figure 6. Visual Transect Survey Results in 1994 for H1T5 and H2T2



Volcanic Rock Outcrop Results (H2T4)



Creosote/Blackbush Results (Granites)

Note: Other refers to *Pituophis melanoleucus, Masticophis flagellum, Salvadora hexalepis, Crotalus mitchelii*

Figure 7. Visual Transect Survey Results in 1994 for H2T4 and Granites

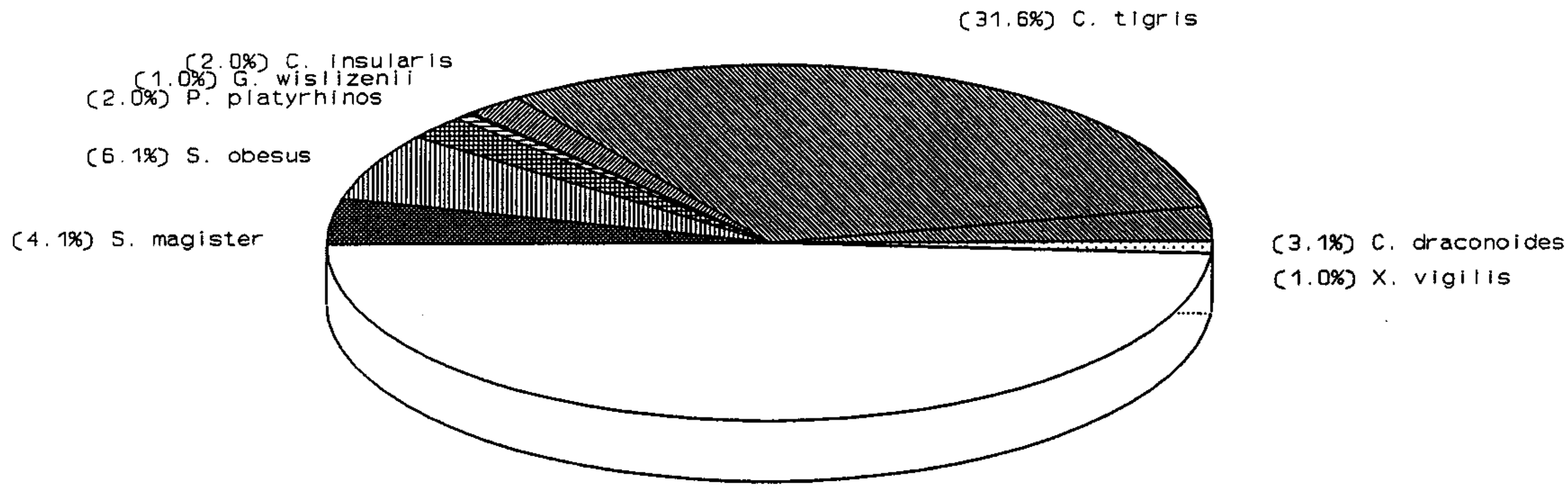


Figure 8. Relative proportions of all diurnal lizards recorded on all transects during visual transect surveys.

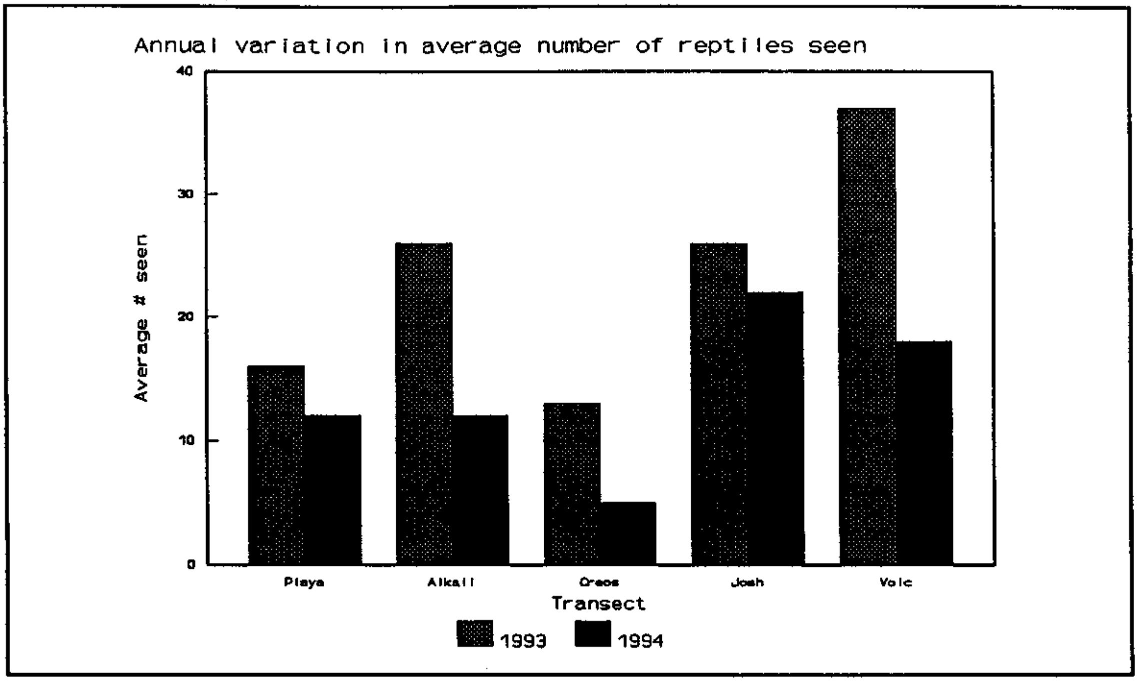


Figure 9 - Annual variation in the average number of reptiles seen per day on each transect in 1993 and 1994.

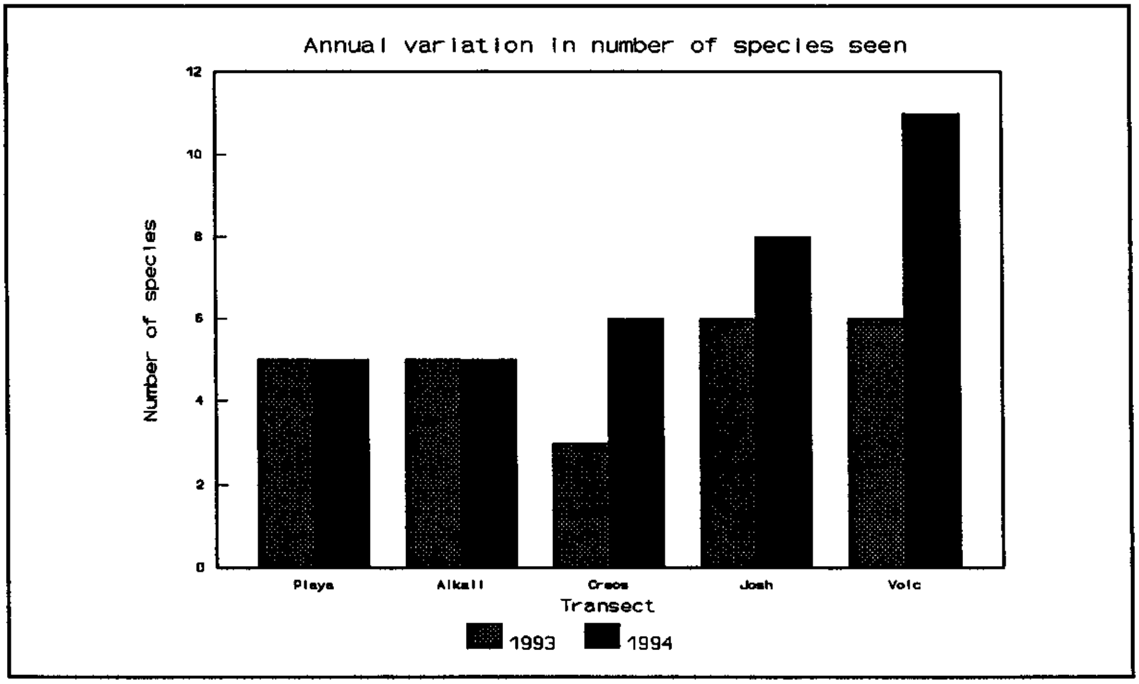


Figure 10 - Annual variation in the total number of species recorded on each transect in 1993 and 1994.

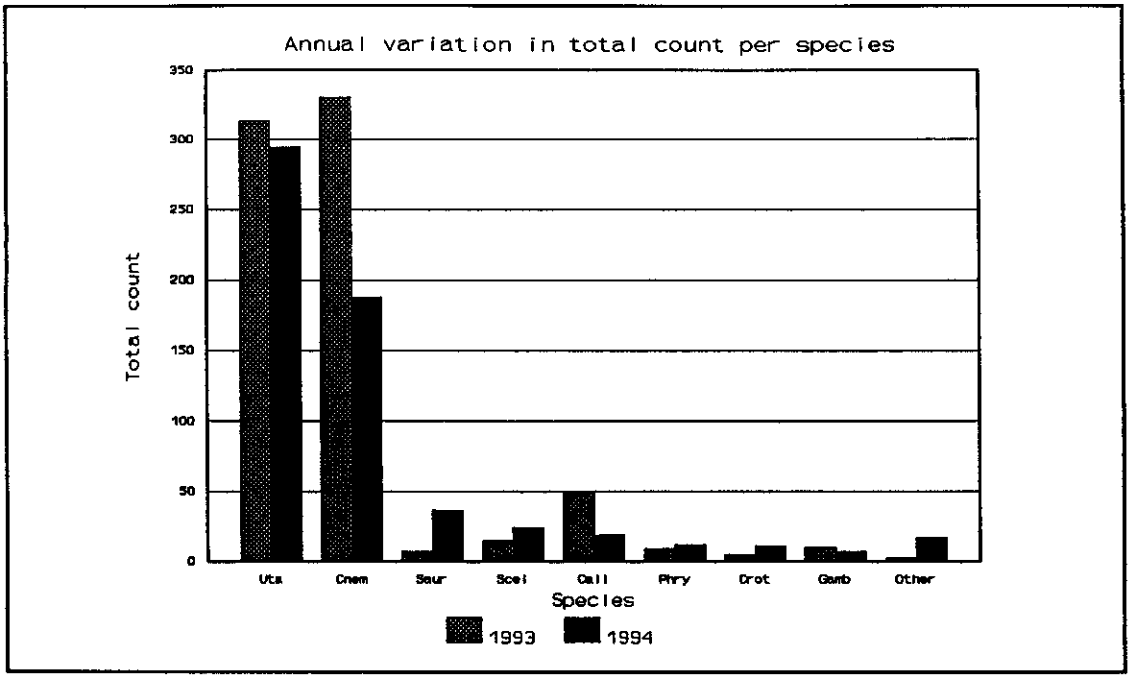


Figure 11 - Annual variation in the total number of animals seen per species for all transects combined

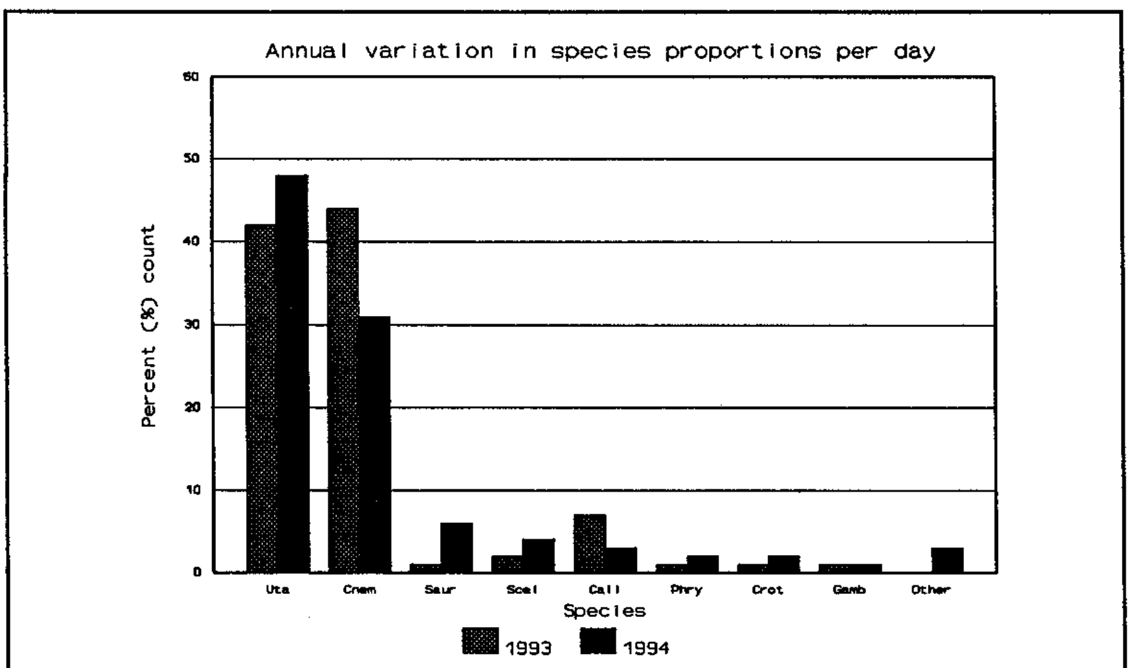


Figure 12 - Annual variation in the average relative proportions of species seen per day for all transects combined.

***Note:** Other refers to *Gopherus agassizii, Crotalus cerastes, Xantusia vigilis, Salvadora hexalepis, Pituophis melanoleucus, Crotalus mitchelli, Masticophis flagellum.*

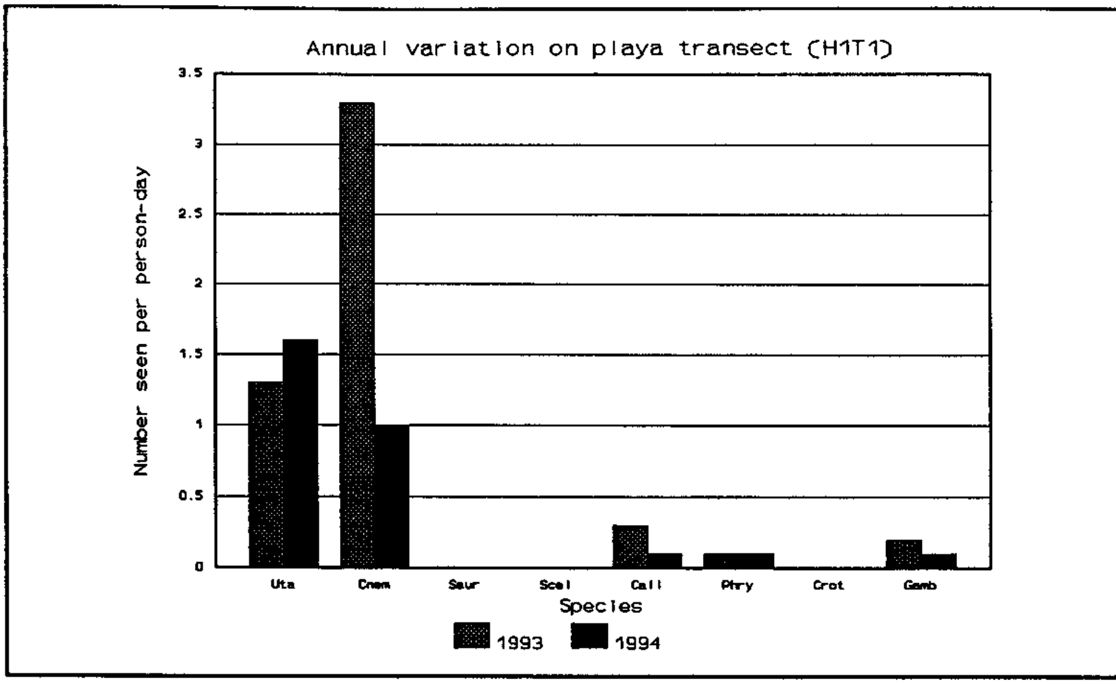


Figure 13 - Annual variation in the number of animals seen of each species per person-day on the Atriplex playa transect (H1T1).

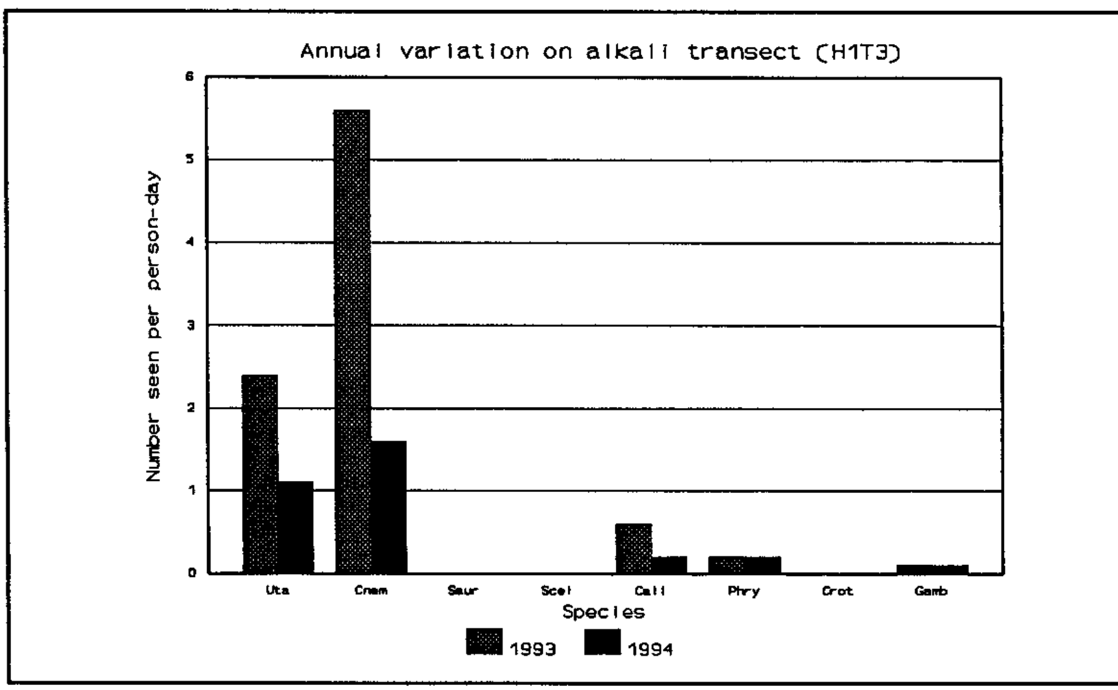


Figure 14 - Annual variation in the number of animals seen of each species per person-day on the Atriplex alkali transect (H1T3).

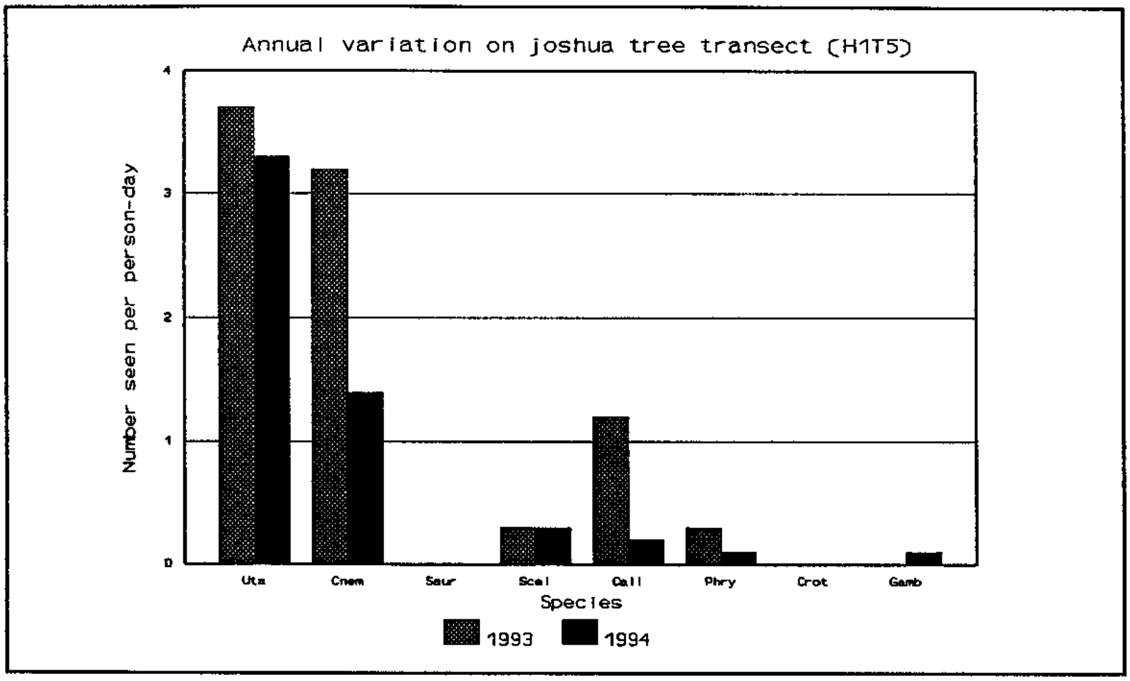


Figure 15 - Annual variation in the number of animals seen of each species per person-day on the joshua tree transect (H1T5).

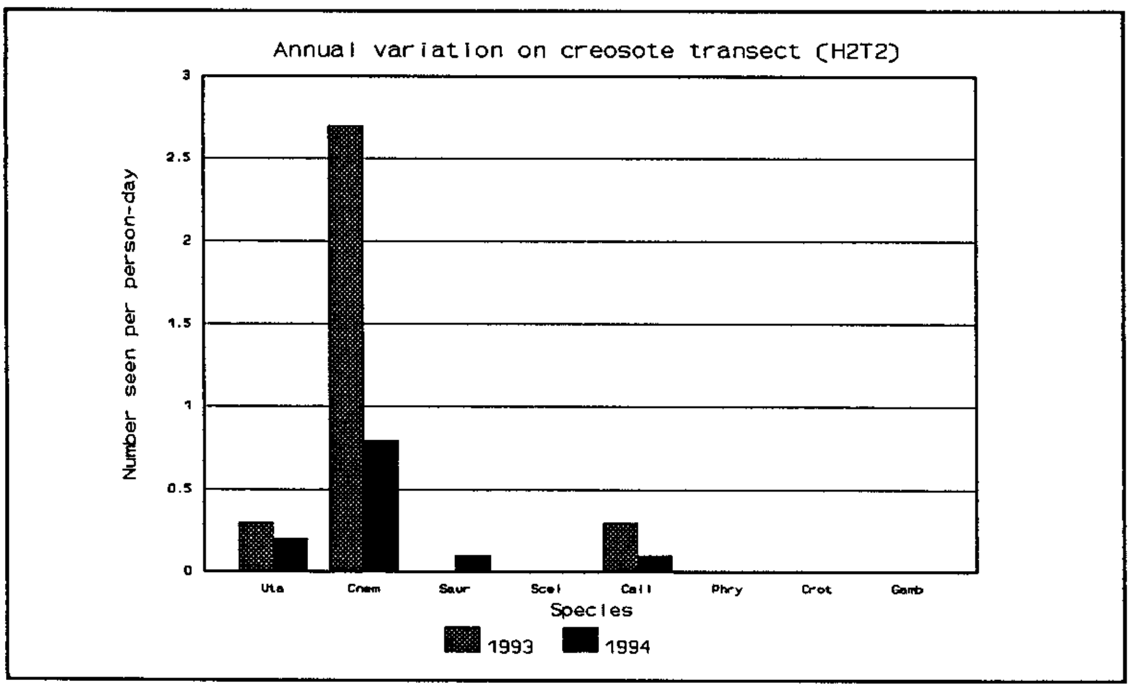


Figure 16 - Annual variation in the number of animals seen of each species per person-day on the creosote transect (H2T2).

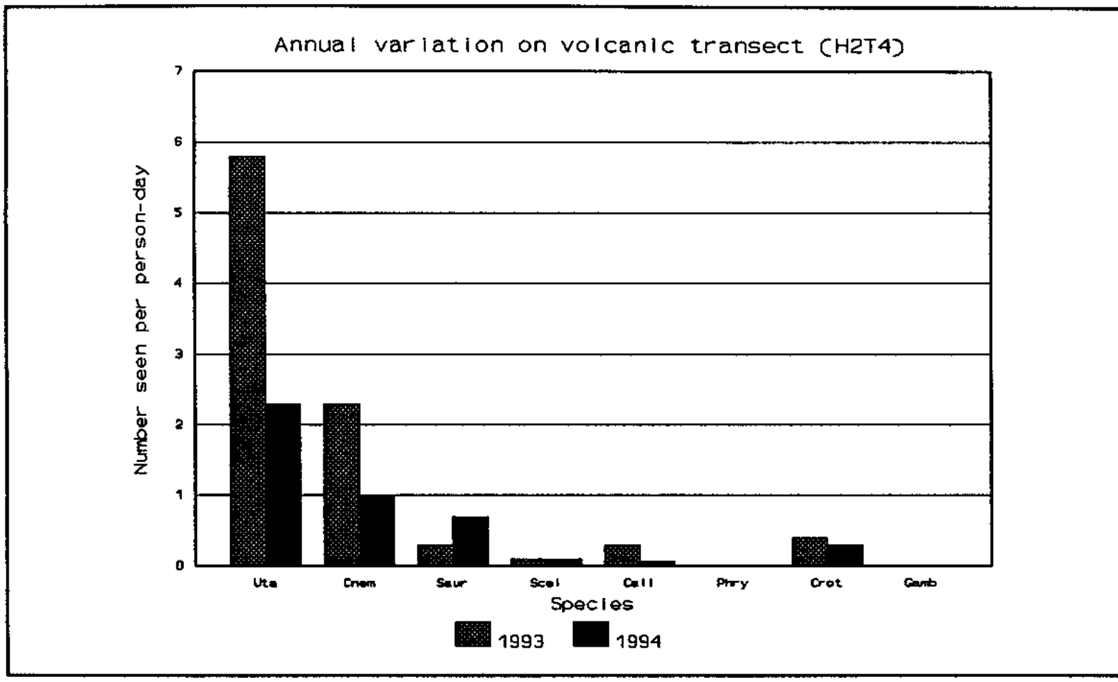


Figure 17 - Annual variation in the number of animals seen of each species per person-day on the volcanic rock transect (H2T4).