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LIZARD SAMPLING TECHNIQUES

by

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TABLE OF CONTENTS

FOREWORD

One of the continuing concerns of the U. S. Atomic Energy Commission are the effects of long exposure to relatively low levels of ionizing radiation. This problem is most interesting when effects are considered in terms of natural populations of plants and animals. An experiment designed to examine this question has been in progress in Rock Valley, at the Nevada Test Site, since 1964. The study has involved populations of mammals, lizards, and some plants.

When we consider the possible response of a natural population of animals to radiation, we must consider not only acute lethality (with rapid extinction) but also sublethal effects operating on natural rates of natality and mortality. A decline in the birth rate of a population may be just as fatal, in a long-term sense, as the immediate death of all individuals. Assessing changes in the demographic performaces of animal populations requires close attention to the size and composition of the populations as they change through time. It is possible to estimate population size indirectly, but we concluded that absolute counts (insofar as possible) would be superior to estimates based on partial samples. Hence, the techniques described hereinafter represent attempts to enumerate all of the individuals present in certain well-defined areas.

One of the most important processes examined in the Rock Valley lizard study is reproduction. Age at maturity, clutch size and frequency, and changes in age-specific fertility, are features of the reproductive process which have been given intensive scrutiny. To some degree reproduction can be inferred from changes in population size and age structure, but the details of year-to-year differences in the fecundity of a species like Uta (which lays several clutches of eggs each season) can only be fully understood if the reproductive process is examined in more detail. One section of the following report is devoted to methods of estimating the individual components of total egg production by various species of lizards.

Observations of continued change in the size and composition of natural populations of animals suggest hypotheses regarding causation. It is extremely difficult to test such hypotheses by continued long-term observation, because of the interaction of a number of uncontrolled variables. Rather it seems best to devise experiments in which environmental variables of likely importance are manipulated in a controlled manner. Another section of this report deals with such attempts.

The procedures to be described have evolved over a period of about 8 years, and they may continue to change to some degree. A number of people have played important roles in the development of our program. I wish to acknowledge particularly the advice of Dr. Donald W. Tinkle of the University of Michigan. The success of the field program is due to Philip A. Medica, Gerard A. Hoddenbach, and Joseph R. Lannom, Jr., whose patience and conscientious devotion to often burdensome tasks has been remarkable. I also wish to express gratitude to the summer employees who have assisted us so effectively through the years: Carl Henderson, Danny Hensley, Greg King, Steve Ruth, Don Smith, Tim Stroud, and Claude Whitmyer.

Finally, it is a pleasure to acknowledge the support of the Environmental Sciences Branch and the Civil Effects Test Organization of the

Division of Biology and Medicine of the U. S. Atomic Energy Commission, whose continued interest in the Rock Valley program has made this work possible.

Frederick B. Turner
Los Angeles, April 1971

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INTRODUCTION

The main study area, consisting of four circular 20-ac (8 ha) areas, is 12 miles west of Mercury, Nye County, Nevada, at 3400 ft above sea level (Fig. 1). Three of these plots are fenced; Fig. 2a is an aerial view of one such area. One of the fenced areas is subjected to continuing gamma irradiation from a centrally located source of ^{137}Cs.

The radiation source is normally at the top of a 50-ft tower (Fig. 2b), but when work is to be done in the irradiated area the source can be lowered into a heavily shielded container at the base of the tower. At the time of installation (January 1964) the source was 33,000 Ci, but since then its strength has decayed to about 28,000 Ci. A specially designed lead shield reduces the intensity of radiation near the tower and produces a radiation field ranging from about 11 R/day near the base of the tower to about 2.5 R/day at the fence. About 14.4 ac (70%) of the enclosure are exposed to 3 to 6 R/day. Only 0.5 ac (2.5%) are exposed to more than 8 R/day. Tissue doses (rads) to animals are appreciably less than the free-air exposures discussed above, principally because of the shielding afforded by burrows and irregularities of terrain. Annual doses to pocket mice (*Perognathus formosus*) have been estimated at 350 rads (French *et al.* 1966); annual doses to *Uta stansburiana* at around twice that (Turner and Lannom 1968). Doses to leopard lizards are on the order of 450 rads/year, while annual doses to whiptail lizards are about half that (Turner and Lannom 1968, Turner *et al.* in press). In all cases most of the radiation is received during the spring and summer, and winter doses are low. A detailed description of the design and installation of the radiation source is given by French (1964).

The three fenced areas are enclosed by a 4 ft fence made of 3 X 3 mesh hardware cloth which has approximately ¼ inch openings. The fence is buried 12 in deep and has a galvanized metal flange on the top to prevent animals from escaping.

Each of the four 20-ac areas contains a rectilinear 15 m grid system (Fig. 3). About 400 can traps are located in each area. These cans have a diameter of 5.3 in, are 11.3 in deep, and are buried flush with the ground (Fig. 4). A galvanized metal insert fits inside the can and can be easily lifted out for inspection. A masonite cover (12 X 12 in) on one-inch legs is placed over each trap. When not in use a #10 can lid seals the trap and a rock secures the lid.

Within each of the four 20-ac areas in a 3.56-ac subplot (Fig. 3) which is used for making counts of Uta. These areas lie within one quadrant, with the innermost corners at the centers of each of the large plots.

An 8 X 30 ft air-conditioned office trailer is located in Rock Valley, and is used for processing lizards and recording data. We also have office and laboratory space, and storage facilities, in the Civil Effects Test Organization (CETO) Laboratory at Mercury.

The Rock Valley plots contain typical assemblages of flatland Mojave Desert reptiles: Uta stansburiana, Cnemidophorus tigris, Phrynosoma platyrhinos, Crotaphytus wislizenii, Coleonyx variegatus, Chionactis occipitalis, Masticophis flagellum, Rhinocheilus lecontei, Crotalus cerastes and Gopherus agassizi. Less common, and in some cases not

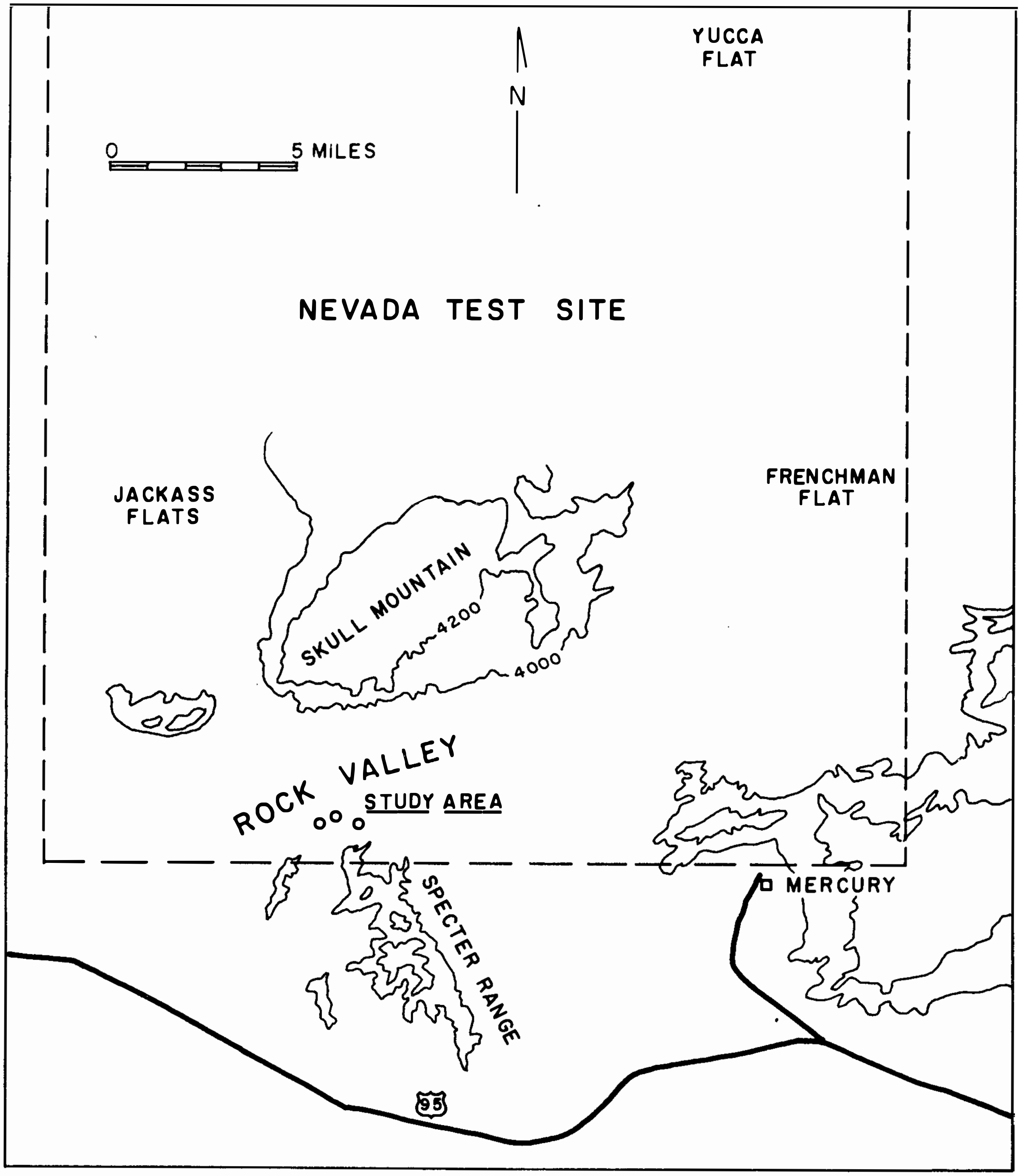

Figure 1. Location of the Rock Valley study area 12 miles west of Mercury, Nye County, Nevada.

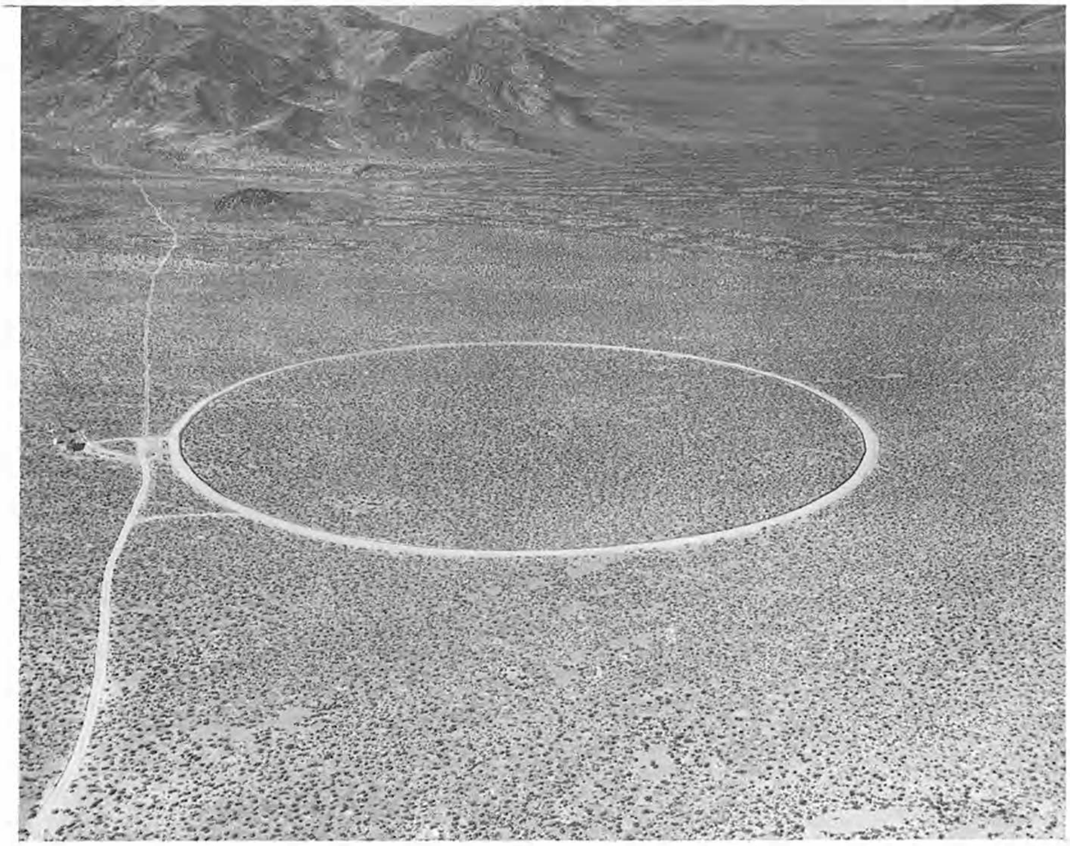

Figure 2a. Aerial view of a fenced control area in Rock Valley. When this picture was taken the other areas had not yet been established.

Figure 2b. Radiation source atop a 50 ft tower. The source is shielded to create a relatively uniform radiation field.

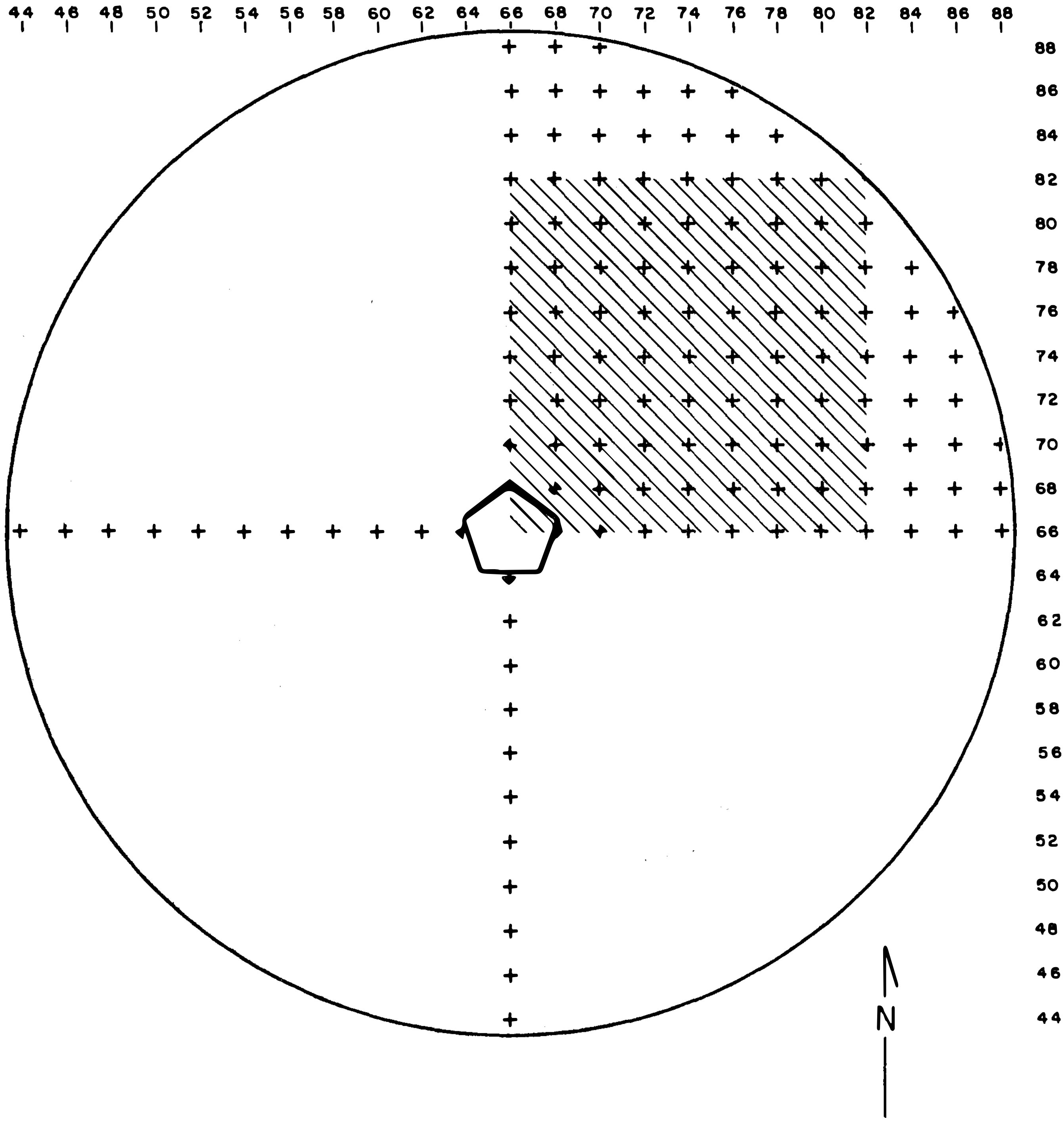

Figure 3. Coordinate system used in the 20-ac plots. The shaded area is a 3.56-ac subplot.

Figure 4. Can trap, trap insert, lid and cover. To the right is a sample stake.

represented in all of the plots, are: Sceloporus magister, Sauromalus obesus, Callisaurus draconoides, Salvadora hexalepis, Pituophis catenifer, Lampropeltis getulus, Sonora semiannulata, and Crotalus mitchelli. In our work we have concentrated on Uta, Cnemidophorus, and Crotaphytus.

ESTIMATING DENSITY

Estimating the spring densities of adult Uta: We work with Uta in a manner similar to that described by Tinkle (1967:10). From two to four people walk back and forth systematically within the 3.56-ac plots described previously. When a lizard is observed, a numbered marker is dropped at the location. Then the lizard is noosed (over 95% of adult Uta are noosed). After capture, Uta are placed in numbered plastic vials. The location, vial number, and marker number are recorded on a 3 X 5 index card so that the lizard can be later returned to the spot where it was captured. Then the lizard in the vial is placed upside down in a sack containing 20 such vials. Empty vials are placed with the lid up. Sampling continues until the entire plot has been searched.

Lizards are taken to the trailer for processing. All Uta are weighed to the nearest .01 g on a "Dial-a-Gram" balance, measured to the nearest mm, palped, toe-clipped if not already marked, and painted. Details regarding procedures are given in Appendixes A-F. After all of the lizards have been processed they are released at points of capture and the numbered markers retrieved.

Uta are collected only within the 3.56-ac subplots described earlier, and not over the entire extent of the 20-ac areas. Each 3.56-ac area is sampled for one week during each of the months of March and April. Our experience has been that all of the resident *Uta* can be enumerated during this time, and the spring density (as of March 1) is taken as the total roster of all different individuals registered. We believe that *Uta* densities can also be effectively estimated indirectly by capture-recapture analysis, assuming that a chain of four or five consecutive samples are utilized (see Turner *et al.* 1970:516, Turner and Medica 1970).

As would be expected, the percentage of the total population enumerated over a period of time increases rapidly at first, but declines as more individuals are registered. With stable weather conditions and uniform sampling effort, the percentage of the *Uta* population marked (P) can be approximated by a function of the following form:

$$P = 1 - e^{-\beta t}$$

with t the number of samples and β an exponent depending on number of workers involved and local environment. When four people were working four study plots in Rock Valley in 1970, β was estimated as about 0.65 (Table I).

Table I. Relationship between sampling effort and proportion of *Uta* population enumerated. Based on data acquired in 1970.

Number of sampling efforts	Actual percent of population registered	Predicted registration (with $\beta = 0.65$)
-	0.0	0.0
1	49.6	47.8
2	76.5	72.7
3	84.5	85.8
4	92.6	92.6
5	95.4	96.1
6	96.9	99.8

The sex and age (in months) of all *Uta* captured are recorded. The maximal life span of Uta in Rock Valley is about 58 months. However, on the basis of size alone, only two age classes can be distinguished in the spring: the young of the preceding summer (up to 9 months of age) and older individuals (20 + months). Animals registered in the spring of 1964 were assigned to these age categories. In 1965, as a result of previous marking, three age categories were recognizable, and in 1966 a few animals known to be 44 months old were registered. No individual has been known to live longer than 58 months. Because of the continued sampling and marking of *Uta* in Rock Valley, the age composition of the populations has been known since 1966 (e.g., see Turner *et al.* 1969a).

Registration of juvenile Uta: During the months of July and August all can traps are opened within the 3.56-ac subplots worked for *Uta*.

Can traps account for 52% to 76% of the hatchlings marked; the remainder are captured for the first time by noosing (Table II).

Table II. Numbers (and percents) of Uta hatchlings trapped and noosed in Rock Valley.

Year	Number trapped	Number noosed	Totals
1967	183 (51.7)	171 (48.3)	354
1968	266 (59.4)	182 (40.6)	448
1969	306 (76.1)	96 (23.9)	402
1970	170 (70.2)	72 (29.8)	242

Each week the hatchlings captured are painted with a different color tail dot. Only hatchlings which are unpainted are noosed. If a painted hatchling is seen the location is recorded. The goal is to enumerate as many hatchlings as possible so that survivorship can be determined the following spring. Survivorship has been estimated simply as the fraction of the total number of juveniles marked in July and August recovered during the ensuing spring. For example, in 1966-7 juvenile survival was estimated as 0.24; in 1967-8 as 0.192 (Turner et al. 1970: 508).

Estimating spring density of Cnemidophorus tigris: Between 1964 and 1966 this species was captured and marked in all four of the 20-ac areas, but since 1966 work has been restricted to the fenced enclosures. Most of the work with this species takes place during May and June of each season, but records are accumulated throughout the summer as opportunities arise. Our work with whiptails has included from as few as two to as many as four people, and procedures have varied somewhat according to staffing. In general, collection of Cnemidophorus has been distributed over the entire 20-ac of each fenced area, and the effort is guided by use of the grid lines. With two people the east-west lines are walked with 15 m between the workers. With three of four people the interval between walkers is 7.5 m.

If a plot is sampled on Monday beginning at the southern end, it is sampled the next day starting at the northern end. In subsequent discussion we use the term "pass" to refer to an assessment (whether by 2, 3 or 4 individuals) of the entire 20-ac, walking east and west along parallel lines. An entire pass requires at least two hours, and may take longer with less than four people or if a large number of whiptails are encountered. When a whiptail is seen all people converge on it and the lizard is noosed. When 4 people worked the plots in 1970 368 whiptails were captured; we estimated that 5% or less were missed when first observed.

Procedures of processing animals are similar to those used with Uta, except that larger plastic vials are used to hold the animals in the field. The paint patterns used for whiptails are different from those used for Uta. Cnemidophorus are painted with rings at the base of the tail instead of dorsal body patterns. The rings are painted on the dorsal and lateral sides of the tail and are visible from the side. Rings are painted in sets of three colors. The most proximal ring indicates sex: males are either white or blue, females are either pink or yellow. Using the above four colors, plus green, there are 25 possible pairs of three colors, totaling 100 possible patterns. Green is used as the proximal color when all of the 100 other patterns have been used and can denote either sex. The more distal rings may be any combination of colors which will distinguish lizards from one another. Lizards painted in this manner are generally recognizable for 3-4 weeks.

Spring densities have, in our view, been most successfully estimated by capture-recapture analysis (Turner et al. 1969b). Our approach, with symbols as used by Bailey (1952), was as follows. Those animals registered in a given year (except the young-of-the-year marked in August and September) were considered the marked cohort (a). All individuals registered in the ensuing year (except for one-year olds and young-of-the-year) constituted the second sample (n), and recaptures (r) were simply those animals originally registered the previous year. Each pair of consecutive years was analyzed separately, and the capture-recapture history of each individual was assessed independently of events in any but the two years in question. This procedure may seem cumbersome, but it is more reliable than capture analyses based on short-term samples. The period of above-ground activity of adult Cnemidophorus in Rock Valley is compressed into a period of about four months (late April to early August). Not all animals are active throughout this period. Females become active later in the season than males. There is a dilution effect as the season advances, and not all of the population is active at any one time (see Tanner and Jorgensen 1963).

We have also attempted to estimate spring density by direct enumeration. In establishing a roster of all animals alive in a given season we consider records from all subsequent seasons. Such minimum registries have always been less than the corresponding capture-recapture estimates. In the three fenced areas the minimum registries averaged about 90% of the capture-recapture estimates (Turner et al. 1969b). We believe that our method of direct enumeration is reasonable when 1) the area is fenced, and 2) the registry for a given year is predicated on data available from that year as well as several subsequent years. In the absence of these conditions, capture-recapture analyses of the sort described above would be more reliable.

In our opinion, simple counts of Cnemidophorus are extremely unreliable measures of density. In fact, because of day-to-day variations in success, such counts are probably not safe estimators of relative abundance. However, in an effort to place this technique on a somewhat sounder footing, we have analyzed the relationship between numbers of whiptails observed and known densities--using data acquired in Rock Valley between 1967 and 1970 (Table III).

The results depend, of course, on the number of people involved and the spacing between individuals as they walk through an area. The data in Table III were based on the numbers of painted Cnemidophorus known to be at large in an area at the time a pass was made. Success was taken simply as the number of painted whiptails seen divided by the number at risk. The number of whiptails seen more than once in a pass averaged 8.5% in 1970, 3.6% in 1969, 3.9% in 1968, and 8.4% in 1967. Several conclusions are suggested by Table III. First, even with four people (walking at an interval of 7.5 m) the average expectancy is to observe only about 0.3 of the Cnemidophorus population. Second, there

Table III. Mean proportions of known marked (painted) *Cnemidophorus tigris* enumerated during four years.

Year	Number of observers	Number of passes analyzed	Mean proportion of marked population observed	Range	Standard deviation	Standard error of mean
1967	3	13	0.273	0.087-0.500	0.133	0.037
1968	2	28	0.235	0.016-0.485	0.113	0.021
1969	2	25	0.231	0.049-0.492	0.105	0.021
1970	4	19	0.312	0.057-0.542	0.114	0.026

may be 5- to 10-fold differences in success at different times, even though the observers are following essentially the same procedures. Whether this is due to oversights or to the inactivity of an appreciable portion of the population on a given day is not clear, though the large variation in "success" argues for the latter (i.e., we do not believe that the efficiency of the observers varies over such a large range). Third, because of time variations in success, it is difficult to argue for statistically significant differences in the results obtained with two and four people. However, intuition suggests that success should increase with the number of observers, and the means do behave in this manner.

Counts of Cnemidophorus along line transects as used by Degenhardt (1966) and Pianka (1970) are, as recognized by these authors, inadequate measures of true density. If these counts are used as indexes of relative abundance, they are probably subject to the same degree of variation indicated in Table III. In our area, if an adequate number of counts (say, 10) were made by four people, and the mean number of lizards observed per count multiplied by 3.3, the resulting figure would be a reasonable approximation of actual density. The multiplier might be expected to differ for other areas, and would very likely vary according to the number of observers and their experience.

Estimating spring density of Crotaphytus wislizenii: Minimal spring densities of leopard lizards have been determined by direct enumeration, in a manner similar to that employed with whiptails (Turner et al. 1969b). We used all of the information available to develop a roster of animals known to be alive in a given year. An animal registered in 1964 and 1966 was known to be alive in 1965. Also, an animal first registered at the age of 20 months was known to have been an unregistered yearling the previous year. Collections of leopard lizards are made at all times of the spring and summer as opportunities arise. Paint patterns used are similar to those used with Uta. Other procedures are like those employed with whiptail lizards.

Recording field data: Appropriate records based on lizards captured and observed in Rock Valley are entered on a basic form (Appendix G). These data are transcribed to IBM cards and ultimately to magnetic tapes which are kept in Los Angeles. Representative print-outs are given in Appendix H.

ASSESSING REPRODUCTION

Reproduction by Uta (clutch frequency): The assessment of clutch frequency in Uta is a time-consuming task, requiring examination of a marked array of reproductive females existing under otherwise normal conditions. This work is conducted in a 3.56-ac area (Plot 5) about 1 mi northeast of the 20-ac areas in Rock Valley. This plot includes a grid similar to that in the 20-ac areas, but the stakes are 7.5 m apart instead of 15 m. All stakes are made of $\frac{1}{4}$ in lath cut 2 ft long and 1-3/4 in wide. Stakes are painted with yellow enamel and numbered with black enamel. The numbers are applied by using a plastic squeeze bottle filled with black paint.

The Uta population of this plot is enumerated in February, and from March until the end of the reproductive season all the female Uta (or as many as possible) are collected every week. The following data are recorded: snout-vent length, weight, location, and palping information.

Each week a different colored tail dot is painted on the lizard. This tail dot is painted at the base of the tail between the thighs (Tinkle 1967:12). Data are recorded on the same data sheet used in Rock Valley.

After the reproductive plot has been worked about three or four weeks, the home range of each resident female Uta is fairly well defined. In order to collect all females each week, it is convenient to use a map (Fig. 5). The map illustrates all captures and observations for the past month. We are thus able to go directly to areas known to be inhabited by female Uta. After a lizard is captured, it is circled on the map and is normally not sought again until the following week. However, if a female is carrying eggs and if she is seen and appears to have deposited her clutch, she is collected again and palped and weighed.

Palping female Uta is done by gently holding the lizard in one hand and letting it pass between the thumb and first two fingers so that it deflates. Eggs are flaccid and sometimes difficult to detect when only a few are present. Yolked follicles are hard when palped and can be rolled between the fingers like BBs. With a little experience the number and size of yolked follicles can be well estimated (Table IV).

Representative sampling data (for 1970) are illustrated in Appendix J. In this manner we can establish the schedule of egg production for a group of females of known age for a given season. Our procedures also give information on differences between individuals and age-groups. For example, the egg-laying regime of yearling females (8-10 months) has often differed from that of older females. Quite commonly the smallest yearlings will not produce a clutch corresponding to the first clutch of older females. The use of such data in attempting to understand annual

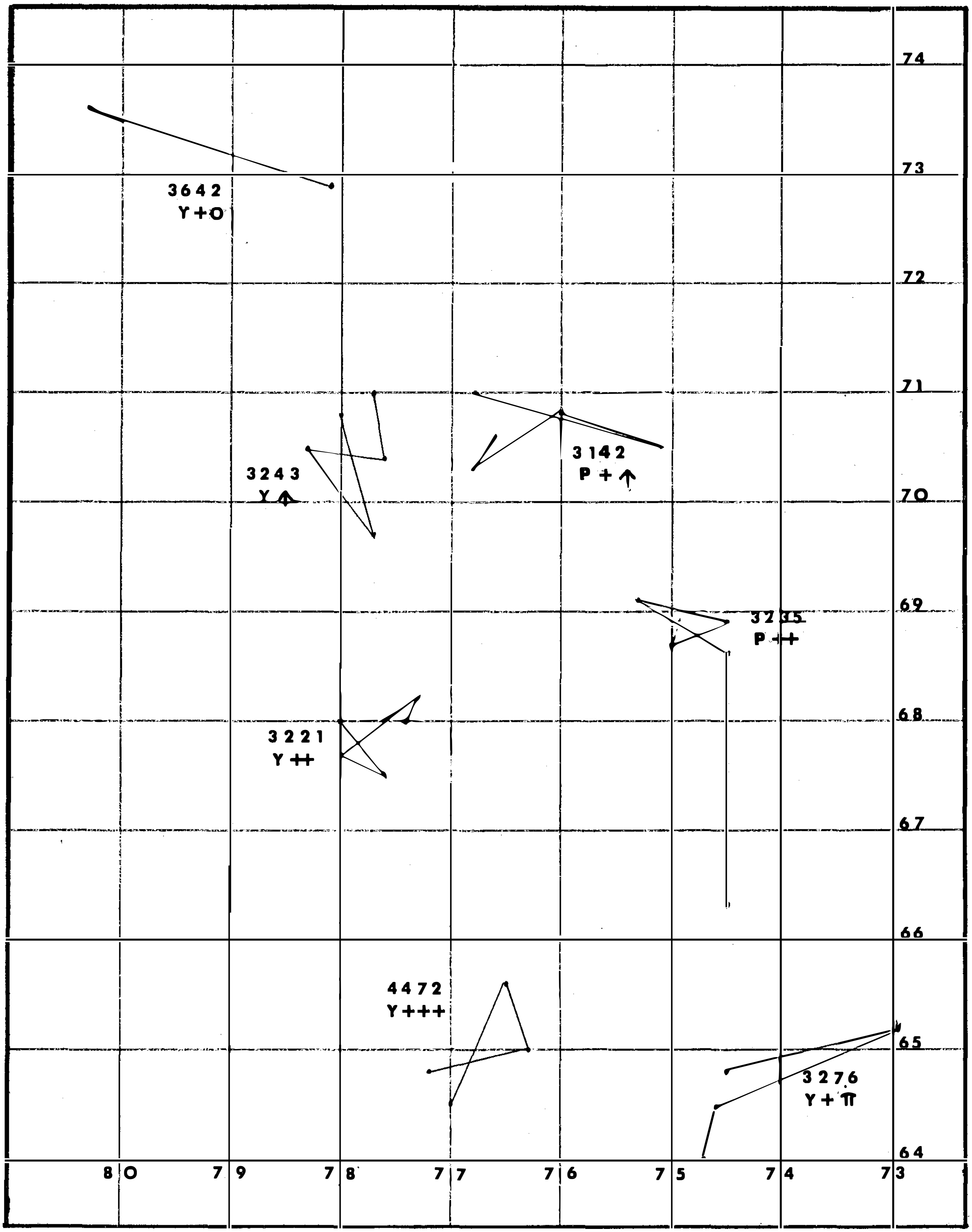

Figure 5. Uta home range map used to locate lizards which are captured weekly in the reproductive plot.

Table IV. Comparison of estimates of reproductive state of female Uta based on palping, and actual counts of eggs and follicles (f) following autopsy.

Locality and date	Palping estimates	Actual condition
Rock Valley,	eggs	eggs
April 1, 1970	5 f (4 mm)	3 f (5 mm) and 2 f (6 mm)
	4 f (4-5 mm)	4 f (6 mm)
	4 f (4-5 mm)	4 f (6 mm)
	? f (4 mm)	3 f (5 mm)
	? f (2-3 mm)	3 f (4 mm)
	? f (2 mm)	f (2 mm)
	small f	f (1 mm)
	small f	f (2 mm)
	small f	f (1 mm)
Mercury Valley,	4 f (3-4 mm)	4 f (5 mm)
April 2, 1970	5 f (5-6 mm)	5 f (6-7 mm)
	eggs	eggs
	5 f (5 mm)	5 f (7 mm)
	4 f (3-4 mm)	5 f (5 mm)
	4 f (6 mm)	4 f (8 mm)
	5 f (4 mm)	4 f (5 mm) and 1 atretic f (3 mm)
	5 f (4-5 mm)	4 f (6 mm)
	3 f (5 mm)	4 f (7 mm)
	? f (2-3 mm)	4 f (5 mm)
	? f (2-3 mm)	3 f (2 mm)

changes in size and composition of Uta populations is illustrated by Turner et al. (1970).

Clutch size: Reproduction by Uta in southern Nevada may begin as early as mid-January in some years. At this time yolk is deposited in the follicles and they begin to enlarge. Animals are collected for autopsy every two weeks in January and February, weekly between March and August, and again every two weeks in September and October. Data based on these females are recorded on a special form (Appendix K), and ultimately transcribed to IBM cards. The primary use of these data has been to estimate clutch size at different times of the season (e.g., see Hoddenbach and Turner 1968).

Reproductive samples of Cnemidophorus and Crotaphytus: Females of these species have been collected in far fewer numbers, and variations in clutch size and frequency are much less well understood in these forms. Sampling of female whiptails is timed according to palping data acquired in the fenced plots (i.e., when follicles or eggs are detected). Female Crotaphytus are collected as the opportunity arises during the breeding season. Data are recorded on the same form used for Uta (Appendix K). As in other studies, we have found distinct size-related differences in clutch size. These are, in part, related to age differences. We have also found surprising differences in reproductivity from one year to the next. Both species may lay more than one clutch during favorable years. In particularly unfavorable years (e.g., 1964, 1970) Crotaphytus may not reproduce at all. Further discussion of these points are given in Turner et al. (1969b and 1969c).

The experimental one-acre plots: Five 1-ac plots (45 X 90 m) separated by galvanized metal sheeting have been constructed about 1 mi west of Mercury. The fences are made of 16/1000 sheet metal 14 in high, and buried 2-4 in beneath the soil surface. The metal is held in place by pencil rod steel posts (1/4 in X 20 in) about 3 ft apart bent to grip the sheet metal. The 50 ft rolls of sheet metal are joined together with five screws. These fences are simple to construct and relatively inexpensive, the sheet metal costs approximately $8.50 for a 50 ft roll and the steel rods $0.40 each (Fig. 6).

These small plots were designed for experiments with Uta, particularly in an attempt to understand the factors influencing clutch size and frequency. Counts of animals within these plots, and assessments of the reproductive states of females are carried out in the same manner described previously. A source of water is nearby, and it is possible to artificially irrigate (by sprinklers) certain of the plots.

ACKNOWLEDGMENTS

We thank Dr. Frederick B. Turner for critically reviewing this manuscript, and Mrs. Yvonne North for typing and preparation of the multilith masters.

Figure 6. Sheet metal fence and supporting stakes encircling one-acre experimental plots.

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Appendix A

Nooses

Lizard nooses are made of black-braided surgical silk thread obtained from Ethicon Inc. (Somerville, New Jersey). The thread can be obtained in various sizes.

Thread size	Lizard species
1	*Crotaphytus*
00	*Uta* (adults) and *Cnemidophorus*
5-0	*Uta* (hatchlings)

The noose should not be any larger than twice the size of the lizard's head. No extra thread should be left to dangle at the end of the pole because this makes it difficult to control the noose. The slip-proof knot used to make the noose is a bowline. A properly fashioned noose of the above material will last several weeks.

Appendix B

Poles

The pole is made from a single unit fiberglass fishing pole with all the eyelets and handle removed. A wire extension is placed on the tip of the pole with a loop on the end. The noose is then attached to the tip with a square knot. The length of the lizard pole that we use depends upon the species it is used for.

Pole length (Including wire tip)	Species
35 in	*Uta* (hatchlings)
40 in	*Uta* (adults) and *Cnemidophorus*
48 in	*Crotaphytus*

Appendix C

Plastic Vials and Cloth Sacks

For *Uta*, we use clear plastic vials (26 X 105 mm) and metal screw top lids with a 1/8 in hole in the center. These vials are available from Lermer Plastics (502 South Avenue, Garwood, New Jersey). *Cnemidophorus* are placed in larger vials made by cutting the bottom out of one vial and gluing it to the top of another using Herbarium cement. When the glue is dry a band of plastic electrical tape is wrapped around the union to reinforce it. A piece of masking tape is placed near the top of the vial bearing a number written with an indelible ink magic marker. The same number is also placed on the bottom of the vial. Cloth sacks for vials are made of coarse muslin. The sack is 12 X 8 in with two 12-in tie straps about 1½ in from the top. This sack holds approximately 20 of the larger plastic vials or 40 of the smaller ones. Small cloth sacks (6 X 9 in) with draw strings are used to hold lizards. These are clipped together with an IDL binder clip No. 100 and ten sacks can be carried in the hip pocket. These sacks are numbered consecutively and are used for larger lizards such as *Crotaphytus* and *Phrynosoma*.

Appendix D

Paint

Testor's model paint is used to paint lizards. The colors used are as follows: #8 blue, #1114 yellow, #1124 green, #5 pink, and #1145 white. The green works best if lightened with white. The paint is placed in nail polish bottles which have had the brushes cut so that they are short ($\frac{1}{4}$ in) and about one-fifth as thick.

Appendix E

Paint Patterns

Uta paint pattern sheet with explanation of symbols:

N = Neck band

NM = Neck midbody (transverse band)

S = Stripe (longitudinal)

All other patterns are painted as they appear on the form. The N or neck band is used in conjunction with many of the other patterns which are self-explanatory. All the animals painted green on this sample sheet are females. Representative records are shown on the next page.

PloT 5 — Uta — Year 1970

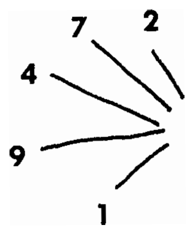
	♂♂ Blue	♂♂ White	♀♀ Pink	♀♀ Yellow	♂ or ♀ Green	
N	3213	3254	3166	3212	3281	
NM		3167	3114	3119	3333	
NS	3225	3255	3256	3215	3129	
N+	3228	3181	3127	3216	3122	
NO	3227	1197	3257	3237	3282	
N●	3226	2142	3238		3283	
N∧	3168	3258	3115	3219	3286	
N‡	3223	3132	3134	3221		
N÷	3251	3259	3164	3224		
Nπ	3222	3111	3187	3239		
M		3263	3114			
S	3229	3261	3262	3231		
+	3153	3126	3264	3234	3232	
++	3172	3191		2124	2149♀	
+++	3151		3265	4472		
O	3152	3269	3266	3236	3284	
OO	3268	3271	3267	3159	3135	
+O	3146	3177		3642	3586	
+∧	3154	3273	3142	3244		
●	3232	3274	3171	3241	3289	
●●	2317	3275	3182		3287	
+●	3233	3277	4176	2417	3291	
∧●	3512	3247	3121	3248	3295	
O●	2141	4182	3214	3135		
∧	3129	3218	3193	3243		
∧∧	9497	3288	3195	3911		
‡	3245	3292	3235	3249		
●/●	3246	3293	3139	3252		
π	3513	3294	3272	3118		
+π			3279	3276		
O∧	3155	3184	3278	3253		

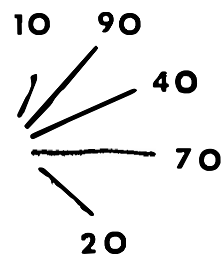
Appendix F

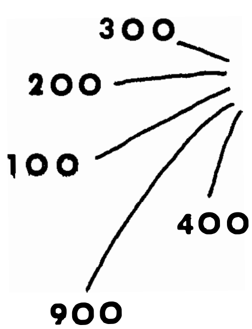
Marking Lizards

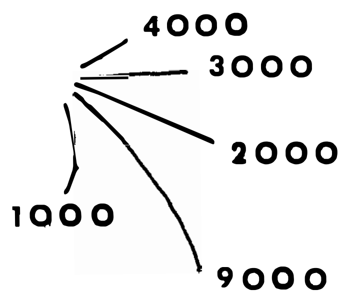
Our system of marking lizards involves cutting at least one toe from each foot. This insures that no lizard which has lost a digit (or digits) accidentally will be mistaken for a marked individual. It also permits the direct identification of each individual because the pattern of digit removal defines the individual's number. The system does not prevent the confusion of the one marked individual with another because of the loss of digits in addition to those removed when an animal was marked. When a natural amputation has occurred prior to marking, it is incorporated in the new mark. The long toe on each hind foot has been given the number 900 or 9000. We have avoided clipping these toes. As can be seen, the number of each lizard is a four-digit number (without zeros). In the case of *Uta* after five years, we may repeat a mark (although this number is converted to a new 5-digit number for recording purposes). For example, if the number 1111 is repeated, it is recorded as 11111 the second time. A simplification of the above system would be to number all feet, clockwise, 1, 9, 4, 7, 2; 10, 90, 40, 70, 20; etc.

LEFT FRONT **RIGHT FRONT**









Appendix G

Basic Data Form

All data are recorded on this form and then transcribed to IBM cards. The data on the form represents captures on May 1, 1970, from the fenced control Plot 1. Each line gives information pertaining to an individual lizard. Columns 73-76 are the paint patterns used on the lizards.

ROCK VALLEY LIZARD PROGRAM

PLOT: 1 DATE: May 21, 1970 NUMBER, COLUMN 22 ________ DAY: 2882

1	3-8	10	18–19	21	23–26	28	30–32	34–36	38–40	42–45	47	51	53	55	57–59	61–63	65	66	68	70–71	73	74	75	76	77	78	79	80
		X	1	1	4156	1	78 1	84 8	049	03 09					143					9	P	W	B					
		X	1	1	4157	1	71 1	52 3	054	03 52					144					9	P	W	W					
		X	1	2	4158	1	65 2	77 8	061	05 01					175					10	W	P	W					
		X	1	2	4159	1	64 7	83 8	052	03 32					141					9	W	P	Y					
		X	1	1	4161	1	56 6	71 3	059	04 91					066	070				10	P	W	G					
		A	1	2	2499	1	76 8	55 0	086	15 59					237				11	22	W	W	G					
		A	1	2	2444	1	73 9	78 5	081	14 23					222				10	21	W	Y	W					
		A	1	2	2485	1	72 0	71 0	082	13 02					244				9	21	W	W	B					
			1	2	2435	2	82 3	72 1											0	21	W	Y	B					
			3	2	3217	2	74 9	76 3											0	10	B		N					
			3	1	3271	2	66 8	58 8											0	10	P		+					
			3	2	3274	2	45 4	57 2											0	10	B		S					
			3	1	3249	2	72 4	78 3											0	10	P		N	M				
		A	4	2	2411	1	49 0	52 0	083	27 19									11	33	W		P	I				
		A	4	2	3141	1	49 3	67 7	082	25 34									11	21	W		D	V				
		X	4	1	3297	1	58 1	69 8	060	10 16										9	P		T					
		X	4	2	3294	1	69 8	46 1	068	12 60										10	W		R	R				
			4	2	3129	2	73 8	80 0											0	21	W		T					
			4	2	3277	2	48 0	72 3											0	9	B		+					
			4	1	3112	2	61 7	85 7											0	22	P		O					

18–19 SPECIES

1. Cnemidophorus
2. Uta
3. Crotaphytus
4. Phrynosoma
5. Coleonyx
6. Callisaurus
7. Chionactis
8. Gopherus
9. Sceloporus
10. Rhinocheilus
11. Masticophis
12. Salvadora
13. Crotalus
14. Sonora

51 DEAD

1. Cause Unknown
2. IN can, Unknown
3. Killed by Lizard
4. Killed by Snake
5. Accident
6. Killed by Lizard in Can
7. Killed by Insect in Can
8. Killed by Drowning in Can
9. Killed by Mouse in Can

53 LEGS MISSING

1. Right Leg, Front
2. Left Leg, Front
3. Right Leg, Rear
4. Left Leg, Rear

1 Plot
3–8 Month, day, year
10 First Capture (X–Lifetime) (A–Season)
21 Sex (0–Unknown) (1–Female) (2–Male)
23–26 Animal Number
28 Capture Method (0–Trap) (1–Hand) (2–Obs.) (3–Obs. in Trap)
30–32) 34–36) Location in Grid Coordinates
38–40 Length (mm.)
42–45 Weight (gr.)
47 Dosimeter (1–Implanted) (2–Removed) (3–Replaced)
55 Repro. Condt. (X–Eggs) (A–Yolk folli.)
57–59 Base of Broken Tail
61–63 Tail Regeneration
65 Notes
66 Notes
68 Months Since Last Capture
70–71 Months of Age
78 Number of Follicles
80 Size Follicles (mm.)

49

Appendix H

IBM Print-Out

Representative print-outs of sampling data from Rock Valley. The first half of the sheet repeats the data in Appendix G. These print-outs are revised monthly to enable us to keep close track of the new animals captured for the year. In Plot 5 and the one-ac plots the print-outs are updated weekly.

	DATE			SP.	SX.	NO.		LOCATION		SV.	WT.	TAIL			AGE	PAINT
1	052170	X	2882	1	1	4156	1	781	848	049	0309	143			09	PWB
1	052170	X	2882	1	1	4157	1	711	523	054	0352	144			09	PWW
1	052170	X	2882	1	2	4158	1	652	778	061	0501	175			10	WPW
1	052170	X	2882	1	2	4159	1	647	838	052	0332	141			09	WPY
1	052170	X	2882	1	1	4161	1	566	713	059	0491	066	070		10	PWG
1	052170	A	2882	1	2	2499	1	768	550	086	1559	237		11	22	WWG
1	052170	A	2882	1	2	2444	1	739	785	081	1423	222		10	21	WYW
1	052170	A	2882	1	2	2485	1	720	710	082	1302	244		9	21	WWB
1	052170		2882	1	2	2435	2	823	721					0	21	WYB
1	052170		2882	3	2	3217	2	749	763					0	10	B N
1	052170		2882	3	1	3271	2	668	588					0	10	P +
1	052170		2882	3	2	3274	2	454	572					0	10	B S
1	052170		2882	3	1	3249	2	724	783					0	10	P NM
1	052170	A	2882	4	2	2411	1	490	520	083	2719			11	33	W PI
1	052170	A	2882	4	2	3141	1	493	677	082	2534			11	21	W DV
1	052170	X	2882	4	1	3297	1	581	698	060	1016				09	P T
1	052170	X	2882	4	2	3294	1	698	461	068	1260				10	W RR
1	052170		2882	4	2	3129	2	738	800					0	21	W T
1	052170		2882	4	2	3277	2	480	723					0	09	B +
1	052170		2882	4	1	3112	2	617	857					0	22	P O
1	040170	X	2832	2		113224	1	708	684	039	0203	066			09	P NM
1	040170	X	2832	2		213225	1	700	701	044	0267	077			09	W +
1	040170	X	2832	2		213226	1	799	724	043	0275	058	003		09	W ++
1	040170	X	2832	2		113227	1	722	719	041	0217	039	003		09	P N+
1	040170	X	2832	2		213228	1	820	724	047	0334	088			10	W +++
1	040170	X	2832	2		113229	1	669	725	043	0256	074			09	P NO
1	040170	X	2832	2		213231	1	679	671	043	0278	079			09	W O
1	040170	X	2832	2		112496	1	695	686	047	0337	075			21	P ND
1	040170	A	2832	2		113121	1	739	741	045	0313	076		8	10	P NS
1	040170	A	2832	2		213148	1	819	792	045	0322	047	029	8	09	W S
1	040170	A	2832	2		113189	1	758	664	044	0321	074		8	09	P N
1	040170		2832	2		112311	2	694	764					1	21	Y ND
1	040170		2832	2		113127	2	733	801					1	09	Y NRR
1	040170		2832	2		213129	2	720	735					1	09	W NDV
1	040170		2832	2		113136	2	746	717					1	10	Y NO
1	040170		2832	2		213139	2	718	824					1	10	W NM
1	040170		2832	2		113162	2	787	726					1	09	Y NS
1	040170		2832	2		113162	2	787	722					0	09	Y NS
1	040170		2832	2		113198	2	723	835					1	09	Y NT
1	040170		2832	2		213215	2	796	735					1	09	W N+
1	040170		2832	2		213219	2	771	764					1	08	W NRR

Appendix J

Uta Clutch Frequency Data Sheet

Reproductive data sheet from Plot 5 for 1970, used to keep records of weekly *Uta* captures. The insert portion explains the meaning of each figure in the box. Some other notations are: "small" for small yolked follicles with no number given, "N" meaning that no yolked follicles were palped, "■" meaning that egg deposition has taken place since the last capture. On the left side of the page is the lizard's identifying number and paint pattern.

PLOT 5 1970

REPRODUCTIVE DATA

	Aug. Sept. 1969	8-14 Feb.	15-21 Feb.	22-28 Feb.	1-7 Mar.	8-14 Mar.	15-21 Mar.	22-28 Mar.	29 Mar. 4 Apr.	5-11 Apr.	12-18 Apr.	19-25 Apr.	26 Apr. 2 May	3-9 May	10-16 May	17-23 May	24-30 May	31 May 6 June	7-13 June	14-20 June	21-27 June	28 June 4 July	5-11 July	12-18 July	19-25 July
Adult ♀♀																									
2124 Y++		3.44 2.22 N	—	—	—	12.46 2.82 Small	16.46 3.00 Small	26.47 2.80 5(5m)	31.47 3.17 (4-5m)	9.47 3.21 Eggs	14.47 3.34 Eggs	20.47 3.54 Eggs	29.46 2.55 N	5.46 2.93 4(3m)	11.48 3.14 4(4m)	18.47 3.51 Eggs									
2149 G++								23.45 3.02 4(5m)	—	7.45 2.24 N	15.44 2.41 4(3m)	20.45 2.53 4(3-4m)	30.44 2.75 Eggs	5.45 2.81 Eggs	11.45 2.16 N	19.45 2.59 3(4m)	25.45 2.85 Eggs	2.44 2.06 N	8.44 2.33 N	15.46 2.58 Eggs?	22.44 2.57 Eggs	30.44 1.81 N	7.44 2.03 N	13.45 2.10 N	
2417 Y+●		3.43 2.43 N	—	—	—	12.44 3.18 4(4m)	20.46 3.33 4(5m)	23.46 2.94 4(4m)																	
3911 YNN		3.45 2.50 N	—	—	6.46 3.21 (2-3m)																				
4472 Y+++		3.43 2.66 N	—	—	—	—	16.46 3.33 (2-3m)	—	—	8.45 3.93 Eggs	14.44 2.73 N	20.45 3.11 Small	30.44 3.39 Small	4.45 3.20 4(5-6m)											
3114 PNM					6.40 1.96 N	11.40 2.02 N	18.40 2.08 N	23.42 2.01 Small	31.42 2.16 Small	6.41 2.26 4(3-4m)	15.41 2.29 4(5m)	20.42 2.36 3(4m)	29.43 2.35 Eggs	4.42 2.31 Eggs											
3115 PNN						12.42 2.24 N	16.42 2.25 Small	—	31.42 2.32 3(3m)	8.44 2.65 3(4m)	14.44 2.68 Eggs	20.45 2.86 Eggs	29.43 2.05 N	4.44 2.32 (2-3m)	11.44 2.55 3(4.5m)	18.44 2.67 Eggs	25.44 1.90 N	1.44 2.38 3(4-5m)	8.44 2.62 Eggs	16.45 1.83 N	23.43 1.83 N	29.44 1.72 N	6.44 1.76 N	13.44 2.03 N	
3118 Yπ		3.40 2.04 N	—	—	—	13.43 2.55 (2-3m)	16.44 2.66 4(3m)																		
3121 PN●							16.41 2.19 Small	—	—	6.43 2.77 4(5m)	14.44 2.94 Eggs	20.43 3.27 Eggs	30.43 3.10 Eggs	4.42 2.21 N	11.43 2.60 Small	18.43 2.88 3(3m)	25.44 2.84 Eggs								
3135 Goo		3.40 2.01 N	—	—	6.43 2.43 Small?	—	18.43 2.73 Small?	26.44 3.13 Eggs?	31.48 3.12 Eggs	6.45 3.14 Eggs	14.45 2.65 (2-3m)	20.45 2.77 4(4m)	29.43 2.85 3(6m)	4.45 2.99 Eggs	11.44 2.10 N	18.45 2.36 2(2-3m)	25.46 2.76 3(4-5m)	2.44 2.25 Small??	8.44 2.51 N	16.45 2.54 N	24.44 2.21 N				
3142 P+N		3.39 1.93 N	—	—	—	13.38 1.72 N	17.38 1.78 Small?	—	1.42 2.22 (3-4m)	6.42 2.53 4(4m)	15.42 2.62 4(6m)	22.43 2.65 Eggs	29.42 2.72 Eggs	4.43 2.16 N	11.44 2.44 3(3-4m)	18.43 2.75 Eggs	26.43 1.89 N	1.44 2.22 Small?	8.43 2.60 3(5m)	16.43 2.61 Eggs	—	29.43 1.91 N	7.42 1.92 N	13.43 2.21 N	
3164 PN+						12.44 2.69 Small??	16.45 3.03 4(2-3m)	—	2.45 3.31 Eggs	7.45 3.36 5(6m)	14.45 3.28 Eggs	20.45 3.40 Eggs	30.44 2.46 N	—	11.45 3.00 3(4m)	18.45 3.25 Eggs	25.45 2.37 N	1.45 2.87 3(3-4m)	8.45 3.14 Eggs	15.45 2.13 N					
3166 PNS					6.39 1.95 N	—	19.41 1.83 N	—	1.43 1.97 Small	—	—	20.44 2.53 Eggs	29.43 2.56 Eggs	6.42 2.09 N											
3193 PN							16.42 2.24 Small	—	—	6.44 2.86 5(4-5m)	17.44 3.03 Eggs	20.44 3.11 Eggs	30.43 2.42 N	6.44 2.73 3(2-3m)	12.44 2.92 3(5m)	18.44 3.08 Eggs	25.44 1.85 N	2.44 2.20 N							
3214 Po●		3.36 1.41 N	—	—	—	—	16.40 2.19 Small	—	1.42 2.47 5(4m)	6.41 2.48 3(6m)	15.42 2.59 Eggs	20.41 2.66 Eggs	29.41 2.08 N	7.42 2.20 3(5m)	12.43 2.23 2(3-4m)	18.43 2.38 3(4-5m)	26.42 3.08 Eggs								
3215 YNS		3.36 1.41 N	—	—	—	—	—	—	1.42 2.53 4(5m)	8.43 2.57 Eggs	15.42 2.54 Eggs	22.41 1.99 N	29.42 2.06 N	—	11.44 2.42 3(5-6m)	20.43 2.57 Eggs	25.43 1.74 N								
3216 YN+		3.38 1.41 N	—	—	6.40 1.98 Small??	—	16.42 2.21 Small??	23.43 1.94 Small	2.44 2.02 (2-3m)	6.43 2.69 3(7m)	14.43 2.36 3(5-6m)	20.44 2.41 Eggs	29.44 2.61 Eggs	4.43 1.94 N	12.44 2.25 Small	20.44 2.48 2(4m)	26.44 2.54 Eggs	2.44 1.85 N	9.44 2.00 N	16.44 2.06 N	25.43 2.00 N	29.44 1.82 N			
3221 YRR		3.36 1.51 N	—	—	6.39 2.00 N	—	16.39 1.85 N	—	1.41 2.21 Small	6.41 2.32 Small	14.43 2.73 4(4m)	20.43 2.82 4(5-6m)	29.43 2.87 Eggs	4.43 2.81 Eggs											
3224 Y÷		3.38 1.74 N	—	—	—	11.41 2.06 N	16.42 2.23 Small	—	1.42 2.30 (2-3m)	7.44 2.60 4(5-6m)	14.44 2.76 Eggs	20.43 2.82 Eggs	29.43 2.09 N	5.43 2.80 3(3m)	13.43 2.60 3(5-6m)	18.43 2.57 Eggs									
3235 PRR									1.39 1.64 N	6.40 1.91 Small	14.42 2.10 Small	20.42 2.15 4(3m)	29.41 2.20 3(4m)	4.42 2.26 3(4-5m)	11.43 2.47 Eggs	19.42 1.91 N	25.43 2.21 3(5m)	1.42 2.45 Eggs	8.42 1.79 N	15.42 1.86 N	22.42 1.94 N	—	6.43 1.96 N	13.42 2.30 N	
3238 YM		3.34 1.29 N	—	—	—	11.36 1.61 N	16.38 1.67 N	—	31.38 1.84 N	6.39 1.93 N	14.40 2.21 3(3-4m)	22.40 2.35 3(6m)	30.39 2.31 Eggs	—	15.46 1.94 N										
3241 Y●		3.29 0.71 N	—	—	—	11.31 0.94 N	—	—	1.34 1.13 N	6.34 1.24 N	14.36 1.40 N	20.37 1.50 N	29.36 1.49 N	4.37 1.69 N	11.39 1.93 Small?	18.39 2.12 2(3m)	25.40 2.15 Eggs	1.39 1.67 N	9.39 1.88 N	15.39 1.74 N	22.39 1.73 N	29.40 1.70 N	7.39 1.68 N	13.39 1.79 N	
3243 YN		3.31 0.84 N	—	—	—	—	17.35 1.32 N	—	1.37 1.65 Small?	9.39 1.86 N	15.40 1.93 N	22.41 2.09 N	—	7.41 2.37 Eggs	—	18.41 1.70 N	25.42 2.04 (2-3m)	1.41 2.32 Eggs							
3256 PNS						11.37 1.65 N	20.38 1.83 N	26.39 1.91 N	31.40 2.00 N	7.42 2.21 N	14.42 2.48 3(5-6m)	20.43 2.55 4(5m)	29.42 2.49 Eggs	4.43 2.65 Eggs	11.43 2.10 N	18.43 2.42 (2-3m)	25.44 2.51 3(5m)	2.43 1.75 N	8.41 2.00 N	15.43 2.11 N	23.43 1.90 N	1.42 1.85 N	6.42 1.81 N	13.43 2.03 N	
3278 PoN							20.32 0.98 N	—	—	6.34 1.27 N	15.36 1.42 N	22.38 1.85 N	30.39 1.81 N	4.40 1.90 Small??	11.41 2.17 3(2-3m)	18.40 2.24 Eggs	25.41 2.26 Eggs	2.41 1.71 N	8.39 1.90 N	—	22.41 1.86 N	29.40 1.73 N	6.40 1.81 N	13.40 1.93 N	
3642 Y+o		3.32 1.02 N	—	—	—	11.35 1.46 N	17.36 1.54 N	—	—	—	14.43 2.27 (2-3m)	20.44 2.65 (3m)	—	4.44 2.73 Eggs	11.44 2.90 Eggs	22.44 2.55 2(4-5m)	25.44 2.58 2(5m)	4.43 2.10 N	8.42 2.44 N	16.44 2.62 3(5-6m)	22.44 2.74 Eggs	29.44 1.78 N	7.43 1.94 N	13.43 2.36 N	

19 • 45 ---- DAY 19 MAY
---- S–V LENGTH
2.59 ---- WT. GRAMS
3(4m) ---- 3(4mm YOLK FOLLICLES)

Appendix K

Reproductive Analysis

Autopsy data are recorded on the reproductive analysis form. The same form is used for all species. Sample data on the sheet are for *Uta* collected on April 22, 1970 in Rock Valley.

REPRODUCTIVE ANALYSIS

SPECIES (1)	AREA (3)	YEAR (5-6)	MONTH (7-8)	DAY (9-10)
2	1	70	04	22

COLLECTOR: Lannom, Ruth & Smith

PAGE: 1

MAN HOURS: 1130 - 1215

ANIMAL NUMBER (12-13)	S-V LENGTH (15-17)	TAIL WHOLE (19-27)	TAIL BASE	TAIL REGENERATION	ANIMAL WEIGHT IN GRAMS (00.000) (29-33)	REPRO. CONDITION (35)	NO. LEFT YOLK. FOLL. NO. RIGHT (37-38)	SIZE LEFT YOLK. FOLL. SIZE RIGHT (40-43)	NO. LEFT OVID. EGGS NO. RIGHT (45-46)	SIZE OF OVID. EGGS (48-51)	NO. LEFT COR. LUT. NO. RIGHT (53-54)	SIZE OF COR. LUT. (56-57)	INTRATERINE MIGRATION (59)	WEIGHT OF OVARIES IN GRAMS (0.000) (61-64)	WEIGHT OF EGGS IN GRAMS (0.000) (66-69)	WEIGHT OF FAT BODIES IN GRAMS (.000) (71-73)	STOMACH WEIGHT IN GRAMS (.000) (75-77)	NOTES (79-80)
1	47		48	16	3 024	2	2 1	05 05						091		015		
2	44		10	02	2 547	2	2 1	07 07						452		000		
3	45		30	29	3 111	2			2 2	10 10				019	771	000		
4	43	70			2 557	2	1 2	06 06						450		000		
5	46		17	24	2 914	2	1 2	05 05						124		014		
6	49		24	01	3 418	2	1 3	06 06						426		000		
7	47		59	10	3 075	2	2 1	06 06						192		011		
8	44		25	28	2 756	2	1 2	07 07						438		000		
9	44	74			2 761	2			1 2	12 12	2 1	03	1	015	545	000		
10	43		48	15	2 417	2	2 1	07 07						373		000		
11	44		37	15	2 529	2	1 2	04 04						060		007		
12	43	69			2 353	2	1 2	05 05						234		000		
13	45	73			2 314	2	1 2	02 02			2 1	01		015		000		
14	40		27	31	1 870	1								008		009		

1 Species
- 1 Cnemidophorus
- 2 Uta
- 3 Crotaphytus
- 4 Phrynosoma

3 Area
- 1 Rock Valley
- 2 Mercury Valley

35 Reproductive Condition
- 1 Pre-reproductive
- 2 Reproductive
- 3 Not reproductive
- 4 Post-reproductive

59 Intrauterine Migration
- 1 Left to right, 1 egg
- 2 Right to left, 1 egg
- 3 Left to right, 2 eggs
- 4 Right to left, 2 eggs
- 5 More than 2 eggs

79-80 Notes
- 01 Add 1.0 to 75-77