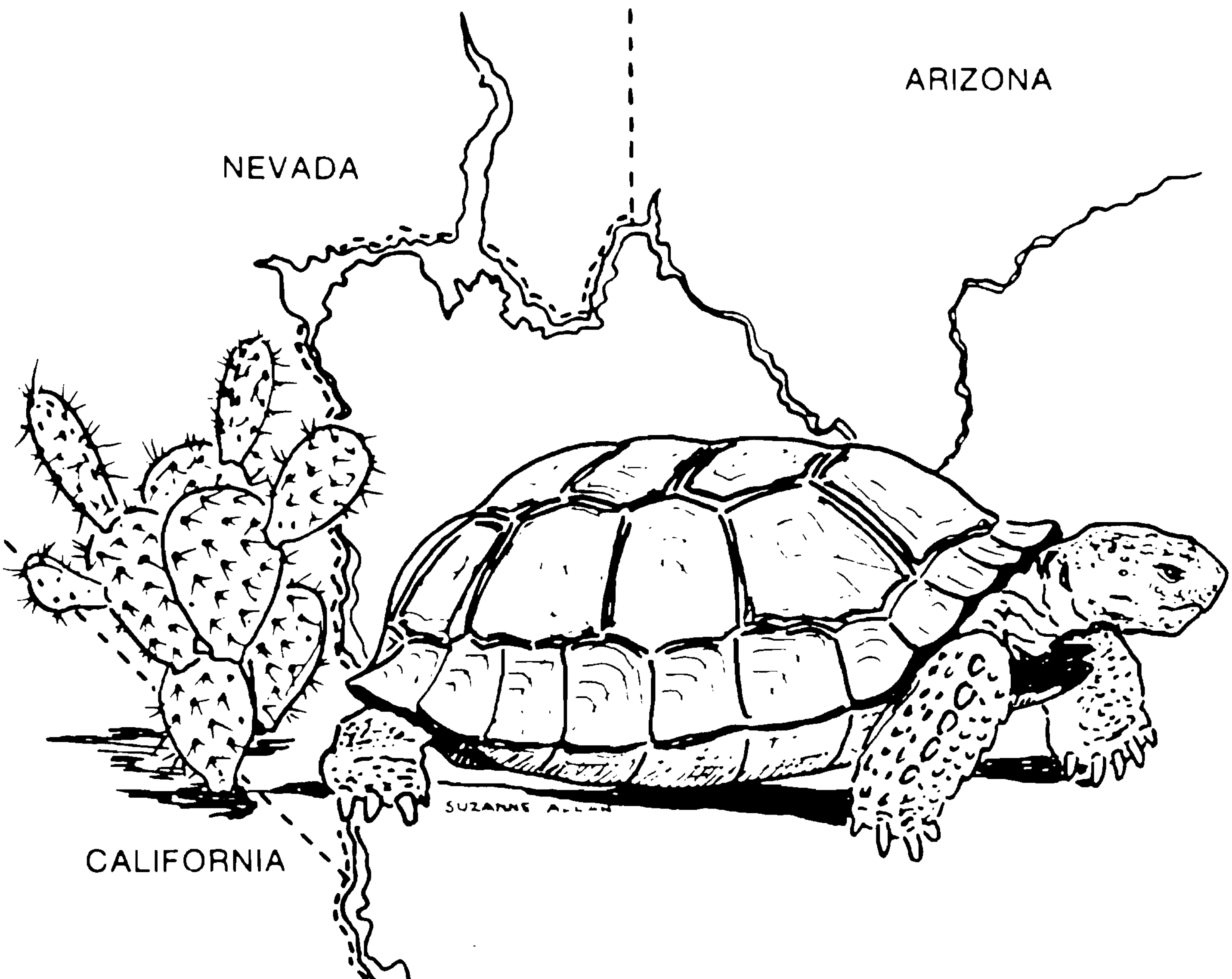
THE DESERT TORTOISE COUNCIL



PROCEEDINGS OF 1992 SYMPOSIUM

DESERT TORTOISE COUNCIL

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A compilation of reports and papers presented at the 17th annual symposium

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These proceedings record the papers presented at the annual symposium of the Desert Tortoise Council. The Council, however, does not necessarily endorse the conclusions reached in the papers, nor can it attest to the validity or accuracy of the data.

DESERT TORTOISE COUNCIL

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(Program abstracts included for papers published elsewhere or manuscripts not submitted by Proceedings deadline. Ed.)

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Annual Awards

Special Achievement Award
California Energy Commission

The California Energy Commission was presented with the "Desert Tortoise Council Special Achievement Award" at the 17th Annual Desert Tortoise Council Symposium. The award was given in recognition of its consistent efforts to protect desert tortoises while carrying out its regulatory and planning responsibilities over the years. The award plaque and a copy of the presentation was presented to all five commissioners at their March 18 business meeting in Sacramento. The California Energy Commission is responsible for long range energy planning, power plant siting, statewide energy conservation, and energy technology development. From the beginning of the Commission's involvement in the California desert area, the desert tortoise has been a focus of its thoughtful and comprehensive examination and treatment through the development of mitigation for power plant related impacts on this animal and its habitat. The Commission has sustained extensive efforts to assist in protecting the desert tortoise by providing considerable multi-year research funding and personnel to examine effectiveness of various mitigation measures.

In carrying out the mandate of its enabling legislation that specifies the consideration of environmental protection, the California Energy Commission has done an exemplary and praiseworthy job.

Desert Tortoise Council Award
Richard Spotts

Richard Spotts, California Representative of Defenders of Wildlife, won the 1992 Desert Tortoise Council Award at the 17th Annual Desert Tortoise Council Symposium. Mr. Spotts' efforts on behalf of alerting conservation publics to funding needs for desert tortoise habitat acquisition, Federal and State listing issues, and his energetic ability to mobilize conservationists to speak out on important issues concerning the desert tortoise and its ecosystem, and other wildlife have been outstanding. The Council congratulates Mr. Spotts for a continuing job well done!

Ultrastructural Changes Due to Upper Respiratory Tract Disease in the Desert Tortoise *Gopherus agassizii*

H.P. Adams, M.E. Cunningham and J.L. La Pointe

An electron microscope study was undertaken to evaluate the changes in the nasal epithelium of the desert tortoise *Gopherus agassizii* with upper respiratory tract disease (URTD). Six clinically healthy tortoises and six ill tortoises were sacrificed in the summer of 1991. The tissue was fixed and processed employing standard methods for electron microscopy. The epithelium of the desert tortoise was found to be composed of a heterogeneous population of cell types associated with specializations in different regions of the nasal cavity. Upon examination all ill and the majority of the clinical healthy animals showed varying degrees of pathological changes in all regions of the nasal epithelium. Widening of the intercellular spaces due to fluid accumulation and invasion of inflammatory cells was moderate to extreme especially in the basal half of the epithelium. In some areas total loss of the normal architecture occurred with degenerating epithelial cells forming 2-3 horizontal layers on the surface. The inflammatory exudate consisted of numerous heterophils, macrophages, and plasma cells. Heterophils were often observed migrating towards the surface where mycoplasma were seen attached to the luminal surface. The mycoplasma tended to be restricted to specific areas of the nasal cavity and always attached to the luminal surface of the epithelial cells. Evidence for direct cytopathic effect by these organisms was inconclusive. No viruses were observed in the nasal epithelium. The damage to nasal epithelium appeared to be primarily due to the inflammatory response of the host.

Mycoplasmal Respiratory Disease: Overview, Similarities, and Potential Lessons for Upper Respiratory Tract Disease in the Desert Tortoise

Mary B. Brown, Elliott R. Jacobson, Isabella M. Fuerst and Paul A. Klein

An overview of respiratory mycoplasmosis in other animal species will be presented with an emphasis on the similarities between these diseases and the upper respiratory tract disease (URTD) in the desert tortoise. What are mycoplasmas, and why do we suspect that they may be involved in URTD? Mycoplasmas are a type of bacteria which lack a cell wall. The absence of a cell wall limits the types of antibiotics which can be used to treat infections. Although penicillin is not effective, other antibiotics such as tetracycline and quinolones may be effective. Our first suggestion that mycoplasmas might be involved in the etiology of URTD came from electron micrographs of the respiratory tract of ill tortoises. Classical mycoplasma-like organisms were found attached to the respiratory surface, often between the cilia. The mycoplasmas looked very much likeorganisms which cause respiratory disease in humans and chickens. After this observation we began to attempt to isolate the mycoplasmas. In conjunction with a detailed pathology study, we have isolated mycoplasmas from 5 of 9 (56%) ill tortoises and 4 of 12 (30%) apparently healthy tortoises, some of which had microscopic lesions. The most common sites of isolation were the choana and nasal passages, but mycoplasmas have been isolated from the trachea, lung, and ovary as well. The ovarian isolation is particularly troublesome since it could reflect a potential for ovarian transmission to offspring. Egg transmission does occur in respiratory mycoplasmosis in poultry. Serological evidence (presented in another abstract) suggests that ill tortoises are more likely to have antibody to the mycoplasma species isolated than are healthy tortoises. Mycoplasmas cause respiratory disease in a number of animals including man, rodents, pigs, and poultry. Although the species of mycoplasma which causes disease is different for each host, there are many common characteristics of the disease and URTD in the tortoise shares many of the characteristics. Many apparently normal animals may carry the mycoplasmas without obvious ill effects. Disease caused by mycoplasmas is often clinically silent, slowly progressing, and chronic. The severity of the disease is exacerbated by environmental factors and stress, and other microbial agents may act synergistically to create even more severe disease. URTD in the tortoise presents a very similar profile, with seemingly healthy animals which break with the disease after the stress of relocation or crowding. The types of lesions seen in other mycoplasmal respiratory infections also share many common characteristics with URTD in the tortoise. In the rat, *Mycoplasma pulmonis* causes focal loss of ciliary action, followed by extensive loss of epithelial cell layers with eventual complete destruction of the respiratory epithelium. This is also seen in URTD. Most respiratory mycoplasmal infections are characterized by an increase in inflammatory cells, especially neutrophils. In the tortoise, foci of inflammatory cells are seen. In electron micrographs, mycoplasmas frequently can be seen attached to the respiratory epithelium just above these areas of inflammation. Because of the similarities between URTD in the tortoise and respiratory mycoplasmosis in other species, it seems logical that we may be able to apply some of the lessons learned in control of these other diseases to URTD. The most extensively studied diseases are those of poultry and rodents. To date, vaccines are not very effective in prevention of infection or disease. The primary (and most successful) method of control has been to determine the presence of antibody to the infectious agent. Any animal with antibody is considered a potential carrier. Selected breeding colonies or flocks have been established which maintain disease-free populations. With the extensive relocation of the desert tortoise, the establishment of seronegative, isolated breeding colonies would seem a logical and essential feature of disease management. Because clinical signs alone cannot distinguish animals which are at risk to break with disease, serological screening to assess the antibody status of an animal is critical to the success of relocation projects and other biological studies.

Seasonal Variations in the Histology of the Lymphoid Structures of Desert Tortoises (*Gopherus agassizii*) with Upper Respiratory Tract Disease

Bobby R. Collins, Elliot R. Jacobson, Isabella M. Fuerst, Mary B. Brown and Paul A. Klein

The ability to mount an effective immune response against potential pathogens requires the presence of a disseminated, functional lymphoid system. Seasonal variation in the cellular density and cytoarchitecture of the central and peripheral lymphoid organs is a common feature of the reptile immune system. Tissue sections from all major organs from both healthy and sick tortoises were examined in the spring and summer of 1991. Histologic evaluation of the tissues resulted in the following observations:

(1) The central organs of the tortoise lymphoid system consist of a spleen and thymus.

(2) The peripheral organs of the tortoise lymphoid system consist of bone marrow, peripheral blood, and lymphoid aggregates in the slivary glands, glottis, trachea, lung, esophagus, small intestine, colon, cloaca, urinary bladder, thyroid gland, testes and chin gland.

(3) Within the season of year, the density of lymphoid cells is greater in the healthy tortoises.

(4) Comparison of the spring and summer animals indicated that summer animals had a greater density of lymphoid cells.

The above results suggest that sick tortoises may be less well prepared to meet the variety of immunological challenges that confront the animal in their native habitat. The determination as to whether or not the decreased lymphoid density is the result of infectious agents, or results in increased susceptibility to infectious agents, must await further analysis.

Health Studies of Sonoran Desert Tortoises

Vanessa M. Dickinson and Carlos Reggiardo

Abstract. Hematological, bacteriological, and parasitic characteristics were sampled for two groups of free-ranging desert tortoises (*Gopherus agassizii*) in the Sonoran desert; one group from Little Shipp Wash, Yavapai County, Arizona, and the other from the Harcuvar Mountains, La Paz County, Arizona.

Free-ranging tortoises were sampled for health characteristics in two collection periods in 1990 and three periods in 1991. Tortoises were captured and fitted with radio transmitters in 1990 with additional captures in 1991. Captured tortoises were weighed, measured, and anesthetized for tissue collection using 15 mg ketamine hydrochloride/kg body weight. Collections included blood samples, nasal flushes, cloacal and throat swabs, and fecal samples.

Analyses of blood characteristics for 1990 showed significant differences between sites for packed cell volume (PCV) in September, and sodium and PCV in November ($P < 0.05$). Analyses of blood characteristic for 1991 showed significant differences between sites for triglycerides, calcium, phosphorus, and vitamin A in May; total protein, cholesterol, and lymphocytes in July; and blood urea nitrogen, creatinine, albumin, vitamins A and E, and osmolality in September ($P < 0.05$). Sixty-seven percent of the blood characteristics differed between months within the two sites for 1991 ($P < 0.05$). Blood characteristics were identical between months in 1990 and between years ($P > 0.05$).

Bacterial swabs were taken from 30 animals in 1990, and 49 animals in 1991. Eighteen species of bacteria were isolated from cloacal and throat swabs, and nasal flushes from the two sites. Potential pathogens were *Pasteurella testudinis* (n = 36), *Shigella*-like bacteria (n = 6), *Salmonella* sp. (n = 1), and *Campylobacter* (n = 1). Fecal analysis indicated that 98% of the tortoises sampled had oxyurid (pinworm) ova (n = 31).

INTRODUCTION

Concern for recent population declines in the desert tortoise (*Gopherus agassizii*) led to the emergency listing of the Mojave (Mohave) desert tortoise on August 4, 1989 as an endangered species (USFWS 1989). The Mojave population, located north and west of the Colorado River, was proposed under regular listing procedures on October 13, 1989, and listed as threatened on April 2, 1990 (USFWS 1990). The Sonoran population includes tortoises south and east of the Colorado River. Both populations are listed as a single entry as a candidate for State endangered or threatened status (AGFD 1988).

An understanding of the health of free-ranging desert tortoises is important when assessing and managing declining populations (Berry 1984). However, relatively little is known about desert tortoise physiology. Desert tortoises tolerate large temporary imbalances in their water, salt, and energy budgets (Dantzler and Schmidt-Nielsen 1966; Minnich 1977; Minnich 1982; Nagy and Medica 1986). Blood chemistry and hematological values are available only from wild and captive Mojave desert tortoises (Minnich1977; Rosskopf 1982; Nagy and Medica 1986; Dickinson and Wegge 1991). Bacteriological cultures from tortoises are limited to a few wild and captive studies (Fowler 1977; Snipes and Biberstein, 1982; Jackson and Needham 1983; Jarchow and May 1989; Knowles 1989; Jacobson and Gaskin 1990; Dickinson and Wegge 1991).

Primary objectives of this ongoing five-year study are to: (1) establish baseline data on hematological and disease factors in populations of desert tortoises, (2) compare selected hematological and disease factors between two different populations of desert tortoises, and (3) compare blood and disease parameters across seasons and years within sites.

METHODS

Weather and climate

Climate data are based on permanent weather stations in Hillside, Arizona and Aguila, Arizona (NOAA 1990-1991). We used data on average monthly maximum and minimum ambient temperature and average monthly precipitation.

General procedures

Two desert tortoise populations were studied in the Sonoran desert. Sonoran populations included the Little Shipp Wash site, Yavapai County, Arizona, and the Harcuvar Mountain site, La Paz County, Arizona (Woodman and Shields 1988; Shields et al. 1991).

Two trips (September, November) were made to each Sonoran desert study site in 1990 to affix radio telemetry units, and collect samples. Three trips (May, July, September) were made to each site in 1991 to collect samples and affix additional radio telemetry units. Populations were compared by examination of blood and tissues taken from adult (> 208 mm median carapace length [MCL]) tortoises encountered at each site. All tortoises were weighed, measured, marked if necessary, and bled. Swabs for bacteriological culture were taken and a fecal sample was obtained if possible.

Each tortoise was outfitted with a radio transmitter for easy relocation and tissue sampling in successive seasons and years. Telonics Model 125 transmitters were affixed with 5-minute gel epoxy to the anterior marginal scutes of adult tortoises. A sample size of 15 radio-tagged tortoises was attempted at each site.

Tortoises were anesthetized using ketamine hydrochloride (15 mg/kg body weight) injected posterior to the left forelimb using a 25-gauge x 5/8" needle, 20 minutes prior to the collection of blood and bacterial swabs.

After tissue samples were taken, tortoises were rehydrated at the axillary notch with 2% body weight of equal parts Normosol (Abbott Laboratories, Chicago, Illinois) and 2.5% dextrose and 0.45% sodium chloride to replace any fluids lost during handling, and to help flush the anesthetic through the kidneys. Tortoises were released during cool times of the day at the site of capture 10-12 hours after injection of the anesthetic.

All tortoises were handled with surgical gloves and maintained in clean individual cardboard boxes to minimize the probability of disease transfer between animals. Between sites, collection equipment was disinfected and all personnel changed clothing, including shoes.

Sample collection and analysis

Blood samples (6 ml) were drawn by jugular venipuncture using 22-gauge x 3/4" needles. Packed cell volume (PCV) was determined as the mean of two capillary tube values. An aliquot (0.6 ml) of whole blood was placed in a lithium heparin-coated microtainer for hemoglobin determination. The remaining whole blood was put into a lithium heparin vacutainer and mixed for approximately 5 minutes. Plasma was collected by centrifuging for 5 minutes. Plasma (usually > 2.5 ml) was placed in cryogenic vials (Whatman Lab Sales, Hillsboro, Oregon) and immediately frozen in liquid nitrogen. Samples were mailed on dry ice to Animal Diagnostic Laboratory, Inc., Tucson, for blood chemistry analyses. Plasma was analyzed for 16 blood characteristics: blood urea nitrogen (BUN), creatinine, total protein, albumin, cholesterol, triglyceride, serum glutamic-oxaloacetic transaminase (SGOT), calcium, phosphorus, sodium, and potassium, vitamin A, vitamin E, copper, zinc, and selenium. Blood was not analyzed for SGOT and zinc in 1991. Creatinine and phosphorus were included in the analyses in 1991. In addition, hemoglobin was determined for samples in 1990 and 1991 and osmolality was only determined for samples in 1991. In 1991, an aliquot of plasma (0.5 ml) was frozen and sent to Valentine Lance, San Diego Zoo, California, for steroid determinations. Blood smears were air dried and sent to APL Veterinary Laboratories, Las Vegas, Nevada, for differential white blood cell counts. One cloacal swab and one throat swab were taken from each tortoise and stored with Culturettes (Becton Dickinson, Cockeysville, Maryland) in 1990 for evidence of *Salmonella* sp. and *Pasteurella* sp. In 1991, one cloacal swab and occasional throat swabs were taken from each tortoise and stored with Transtube (Medical Wire and Equipment Co., Dover, New Jersey). Samples were placed on ice and sent to the Animal Diagnostic Lab, Inc., Tucson, Arizona, for routine cultures. In both years, the nasal fossae of each tortoise was aspirated with 0.9% sodium chloride. One ml of saline from each nasal fossa was placed in a test tube containing tryptic soy broth. Samples were placed in cryogenic vials and immediately frozen in liquid nitrogen. Samples were sent to the University of Arizona Veterinary Diagnostic Laboratory, Tucson, Arizona, for culture, *Mycoplasma* sp. cultures, and *Chlamydia* sp. isolation attempts.

Unpaired blood chemistry data were compared using the Mann-Whitney test; the Wilcoxon signed-rank test was used for paired data. Significance was judged at $P < 0.05$. Statistical tests performed for this study assume independence of blood variables. Alternative procedures accounting for possible correlation among these variables may be informative and will be attempted for the final report.

RESULTS

In 1990, 11 tortoises were sampled at Little Shipp and 19 at Harcuvars. In 1991, 22 tortoises were sampled at Little Shipp, and 27 at Harcuvars. Seven radio-tagged tortoises were found dead in 1991. Six of the seven mortalities occurred in the Harcuvar Mountains. Five of the six were only sampled once (November 1990), while the sixth was never sampled. Only one mortality was recorded at Little Shipp Wash. The carcass showed signs of coyote (*Canis latrans*) or mountain lion (*Felis concolor*) predation.

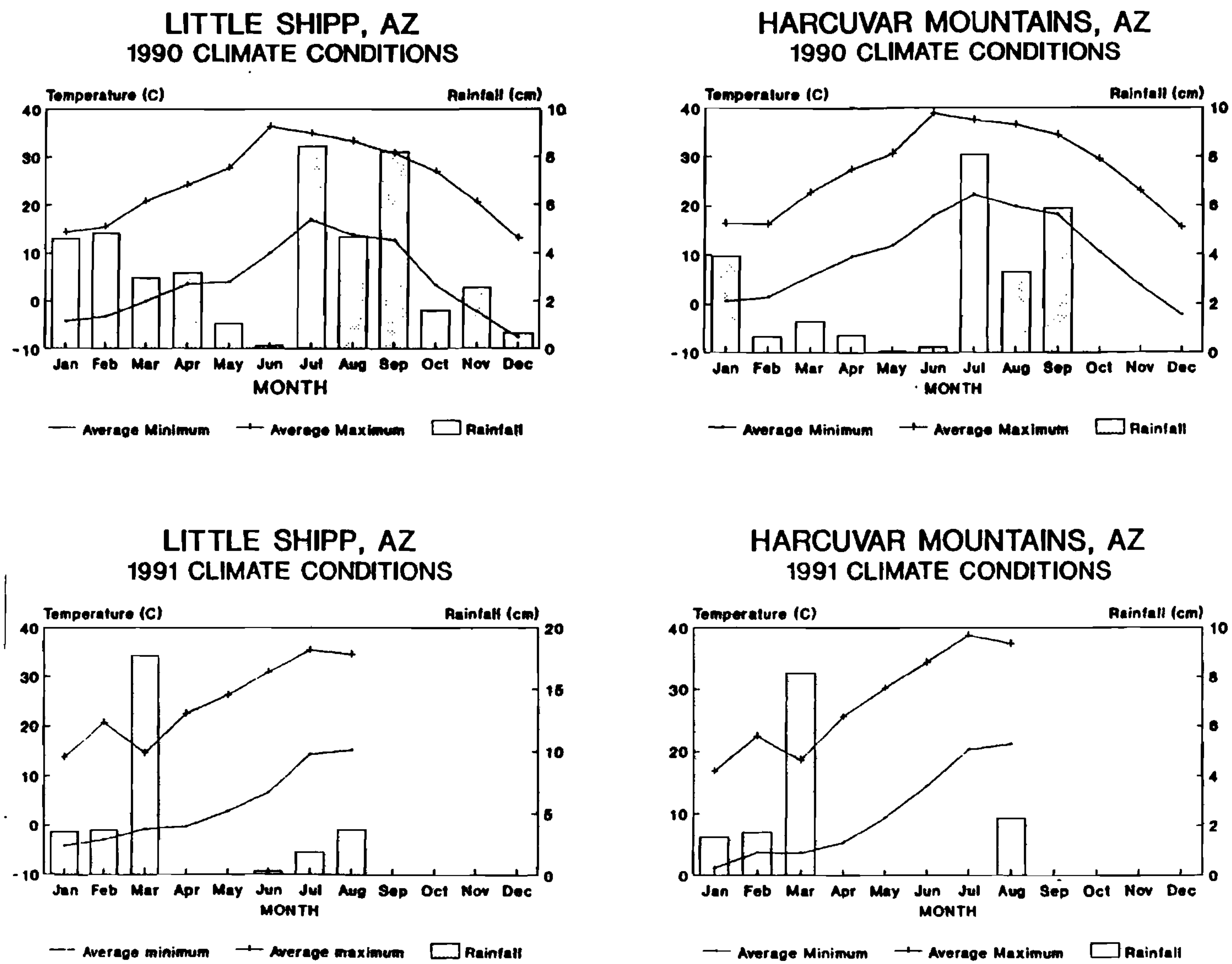

Figure 1. Climate conditions at Little Shipp Wash and Harcuvar Mountain study sites, Arizona, 1990-1991.

Weather and climate

Figure 1 summarizes precipitation and temperature data for both sites in 1990 and 1991. Total summer precipitation (April through August) for Little Shipp in 1990 was 17.32 cm as compared to 5.69 cm in 1991. Total summer precipitation for Harcuvar Mountains in 1990 was 12.41 cm as compared to 2.31 cm in 1991. In addition to less precipitation in 1991 as compared to 1990, temperatures were higher and remained at higher levels during spring and summer. Average spring precipitation (January through March) in 1991 (Little Shipp 24.87 cm; Harcuvars 11.45 cm) probably encouraged spring annual germination and winter annual growth. High temperatures and below average rainfall in 1991 lead to early curing of spring and summer annuals in the Harcuvar Mountains.

Blood chemistry and hematology

Blood chemistry profiles and hematological characteristics are summarized for Little Shipp for 1990 (Table 1) and 1991 (Tables 3 and 5), and for the Harcuvars for 1990 (Table 2) and 1991 (Tables 4 and 6). The analysis of tortoise steroid levels was not available for this report (Lance in prep.). Within given months and years, some differences were discernible between populations. Analyses of blood characteristics for 1990 showed significant differences between sites in PCV ($P < 0.03$) in September, and PCV ($P < 0.002$) and sodium ($P < 0.04$) in November. Analyses of blood characteristic for 1991 showed significant differences between sites for triglyceride ($P < 0.04$), calcium ($P < 0.03$), phosphorus ($P < 0.01$), and vitamin A ($P < 0.003$) in May; total protein ($P < 0.04$), cholesterol ($P < 0.04$), and lymphocytes ($P < 0.04$) in July; and BUN ($P < 0.05$), creatinine ($P < 0.02$), albumin ($P < 0.004$), vitamin A ($P < 0.0009$), vitamin E ($P < 0.02$), and osmolality ($P < 0.0005$) in September. Between month comparisons for Little Shipp showed significant differences for BUN, creatinine, total protein, cholesterol, sodium, potassium, phosphorus, vitamin A, copper, osmolality, hemoglobin, PCV, lymphocytes, and basophils ($P < 0.05$). Between month comparisons for the Harcuvar tortoises showed significant differences for creatinine, total protein, albumin, sodium, potassium, phosphorus, vitamins A and E, osmolality, hemoglobin, heterophils, and lymphocytes ($P < 0.05$). Blood characteristics were identical between months in 1990. Between year comparisons for Little Shipp and Harcuvar sites showed no significant differences in blood characteristics ($P > 0.05$).

Bacteriology

At least 18 species of bacteria were isolated from 79 tortoises; 30 animals in 1990 and 49 in 1991 (Tables 9-10). The heaviest growth of bacteria occurred in fall 1990 and 1991. Spring 1991 had the least number of bacteria present.

The only consistently isolated potential pathogen was *Pasteurella testudinis*, repeatedly recovered from nasal flushes and throat swabs ($n = 36$). There was also one isolation of *Salmonella* sp., one isolation of *Campylobacter* sp., and six isolations of a *Shigella*-like organism of unknown pathogenic significance.

Inoculation of embryonated chicken embryos with the nasal flushes resulted in the isolation of four *Chlamydia*-like agents. *Chlamydia* elementary body-like structures were observed in yolk smears of dead chicken embryos but they could not be sequentially transferred. Their identity and significance is not known. No *Mycoplasma* sp. were isolated from throat swabs and nasal aspirate in 1990 and 1991 ($n = 79$).

Table 1. Desert tortoise blood chemistry profiles and hematology from Little Shipp Wash, Arizona, 1990. NA = not available.

	SEPTEMBER 27 $\bar{x} \pm$ SD (n)	NOVEMBER 7 $\bar{x} \pm$ SD (n)
BUN[1] mg/dl	0 (4)	6.4 ± 12.2 (7)
TP[2] g/dl	3.8 ± 0.4 (4)	4.0 ± 0.7 (7)
ALB[3] g/dl	2.1 ± 0.2 (4)	1.9 ± 0.2 (7)
SGOT[4] IU/l	64.5 ± 19.9 (4)	39.1 ± 12.5 (7)
CHOL[5] mg/dl	149.8 ± 86.1 (4)	127.3 ± 61.5 (7)
TRI[6] mg/dl	272.9 ± 264.1 (4)	254.3 ± 239.1 (7)
Ca[7] mg/dl	12.2 ± 2.2 (4)	10.5 ± 3.5 (7)
Na[8] mEq/l	119.0 ± 6.9 (4)	123.2 ± 2.4 (6)
K[9] mEq/l	NA	4.0 ± 0.4 (6)
VIT A[10] µg/ml	0.6 ± 0.2 (4)	NA
VIT E[11] µg/ml	4.5 ± 3.7 (4)	NA
Cu[12] ppm	0.6 ± 0.1 (4)	NA
Zn[13] ppm	3.7 ± 0.8 (4)	NA
Se[14] ppm	0.03 ± 0.007 (4)	NA
PCV[15] %	26.2 ± 1.9 (4)	23.7 ± 2.4 (7)

[1] Blood urea nitrogen
[2] Total protein
[3] Albumin
[4] Serum glutamic-oxaloacetic transaminase
[5] Cholesterol
[6] Triglyceride
[7] Calcium
[8] Sodium
[9] Potassium
[10] Vitamin A
[11] Vitamin E
[12] Copper
[13] Zinc
[14] Selenium
[15] Packed cell volume

Table 2. Desert tortoise blood chemistry profiles and hematology from Harcuvar Mountains, Arizona, 1990. NA = not available.

	SEPTEMBER 25 $\bar{x} \pm$ SD (n)	NOVEMBER 9 $\bar{x} \pm$ SD (n)
BUN[1] mg/dl	NA	4.8 ± 2.8 (13)
TP[2] g/dl	3.7 ± 0.4 (5)	4.1 ± 1.4 (13)
ALB[3] g/dl	2.0 ± 0.1 (5)	2.2 ± 1.1 (13)
SGOT[4] IU/l	50.0 ± 22.9 (5)	42.8 ± 17.6 (13)
CHOL[5] mg/dl	109.8 ± 75.0 (5)	94.8 ± 73.5 (13)
TRI[6] mg/dl	37.8 ± 15.0 (5)	102.6 ± 234.0 (13)
Ca[7] mg/dl	11.7 ± 0.6 (5)	11.4 ± 2.4 (13)
Na[8] mEq/l	126.0 ± 6.5 (5)	125.6 ± 3.2 (12)
K[9] mEq/l	NA	3.7 ± 0.4 (12)
VIT A[10] μg/ml	0.5 ± 0.07 (5)	NA
VIT E[11] μg/ml	2.8 ± 1.3 (5)	NA
Cu[12] ppm	0.5 ± 0.1 (5)	NA
Zn[13] ppm	3.0 ± 0.4 (5)	NA
Se[14] ppm	0.05 ± 0.01 (4)	NA
PCV[15] %	30.4 ± 2.4 (5)	28.2 ± 2.4 (13)
Hb[16] %	NA	11.7 ± 11.1 (13)

[1] Blood urea nitrogen
[2] Total protein
[3] Albumin
[4] Serum glutamic-oxaloacetic transaminase
[5] Cholesterol
[6] Triglyceride
[7] Calcium
[8] Sodium
[9] Potassium
[10] Vitamin A
[11] Vitamin E
[12] Copper
[13] Zinc
[14] Selenium
[15] Packed cell volume
[16] Hemoglobin

Table 3. Desert tortoise blood chemistry profiles and osmolality from Little Shipp Wash, Arizona, 1991.

	APRIL 30 $\bar{x} \pm$ SD (n)	JULY 2 $\bar{x} \pm$ SD (n)	SEPTEMBER 24 $\bar{x} \pm$ SD (n)
BUN[1] mg/dl	1.4 ± 2.9[b] (7)	4.7 ± 4.6 [b] (6)	0.3 ± 0.5 (7)
CREA[2] mg/dl	0.2 ± 0.9[b,d] (7)	0.4 ± 0.1[b] (6)	0.1 ± 0.1[d] (7)
TP[3] g/dl	3.4 ± 0.3[b] (7)	4.1 ± 0.4[b] (6)	3.5 ± 0.3 (7)
ALB[4] g/dl	1.9 ± 0.1[b] (7)	2.2 ± 0.3[b] (6)	1.9 ± 0.3 (7)
CHOL[5] mg/dl	92.4 ± 26.8[b] (7)	143.8 ± 47.1[b] (6)	118.6 ± 71.3 (7)
TRI[6] mg/dl	192.4 ± 193.7 (7)	19.7 ± 12.3 (6)	204.0 ± 251.9 (7)
Na[7] mg/dl	122.2 ± 3.5[a] (7)	146.2 ± 8.1[a] (6)	132.4 ± 4.7[a] (7)
K[8] mEq/l	4.0 ± 0.7[b] (7)	4.8 ± 0.6[b,c] (6)	3.9 ± 0.6[c] (7)
Ca[9] mg/dl	12.3 ± 1.7 (7)	12.2 ± 2.9 (6)	10.7 ± 2.1 (7)
P[10] mEq/l	2.3 ± 0.9[b] (7)	4.8 ± 4.3[b] (6)	3.4 ± 2.1 (7)
VIT A[11] μg/ml	0.8 ± 0.2[b,d] (7)	0.5 ± 0.1[b] (6)	0.4 ± 0.08[d] (7)
VIT E[12] μg/ml	4.4 ± 3.4 (7)	2.5 ± 1.2 (6)	4.1 ± 4.2 (7)
Cu[13] ppm	0.6 ± 0.1 (2)	0.8 ± 0.1[c] (6)	0.6 ± 0.1[c] (7)
Se[14] ppm	0.05 ± 0.01 (2)	0.03 ± 0.002 (3)	0.04 ± 0.01 (7)
OSMOL[15] mOs/kg	255.1 ± 10.8[d] (7)	269.3 ± 24.6[c] (6)	243.0 ± 7.7[c,d] (7)

[1] Blood urea nitrogen
[2] Creatinine
[3] Total protein
[4] Albumin
[5] Cholesterol
[6] Triglyceride
[7] Sodium
[8] Potassium
[9] Calcium
[10] Phosphorus
[11] Vitamin A
[12] Vitamin E
[13] Copper
[14] Selenium
[15] Osmolality

[a,b,c,d] Means (in same row) significantly different ($P < 0.05$)

Table 4. Desert tortoise blood chemistry profiles and osmolality from Harcuvar Mountains, Arizona, 1991. NA = not available.

	MAY 30 $\bar{x} \pm$ SD (n)	JULY 4 $\bar{x} \pm$ SD (n)	SEPTEMBER 26 $\bar{x} \pm$ SD (n)
BUN[1] mg/dl	1.0 ± 2.2 (7)	2.0 ± 2.3 (8)	4.3 ± 7.4 (12)
CREA[2] mg/dl	NA	0.5 ± 0.1^{c} (8)	0.2 ± 0.1^{c} (12)
TP[3] g/dl	3.4 ± 0.2^{b} (7)	3.7 ± 0.3^{b} (8)	3.4 ± 0.5 (12)
ALB[4] g/dl	1.9 ± 0.1^{d} (7)	1.9 ± 0.2^{c} (8)	$3.2 \pm 0.7^{c,d}$ (12)
CHOL[5] mg/dl	73.1 ± 16.7 (7)	93.5 ± 26.3 (8)	91.6 ± 63.2 (12)
TRI[6] mg/dl	38.0 ± 51.3 (7)	12.5 ± 9.7 (8)	62.3 ± 127.2 (12)
Na[7] mg/dl	124.6 ± 3.9^{a} (7)	143.2 ± 10.2^{a} (8)	133.6 ± 6.0^{a} (12)
K[8] mEq/l	3.5 ± 0.5^{a} (7)	5.2 ± 0.5^{a} (8)	4.3 ± 0.3^{a} (12)
Ca[9] mg/dl	10.4 ± 1.1 (7)	10.7 ± 0.8 (8)	10.2 ± 1.9 (12)
P[10] mEq/l	$0.8 \pm 0.8^{b,d}$ (7)	2.2 ± 1.2^{b} (8)	2.3 ± 1.4^{d} (12)
VIT A[11] μg/ml	0.2 ± 0.1^{b} (7)	$0.4 \pm 0.07^{b,c}$ (8)	0.2 ± 0.06^{c} (12)
VIT E[12] μg/ml	$6.4 \pm 4.1^{b,d}$ (7)	1.3 ± 0.7^{b} (8)	1.3 ± 1.3^{d} (12)
Cu[13] ppm	0.7 ± 0.2 (4)	0.6 ± 0.2 (7)	0.6 ± 0.1 (11)
Se[14] ppm	0.05 ± 0.008 (7)	0.05 ± 0.01 (6)	0.04 ± 0.009 (9)
OSMOL[15] mOs/kg	NA	252.2 ± 20.1^{c} (8)	274.5 ± 19.9^{c} (12)

[1] Blood urea nitrogen
[2] Creatinine
[3] Total protein
[4] Albumin
[5] Cholesterol
[6] Triglyceride
[7] Sodium
[8] Potassium
[9] Calcium
[10] Phosphorus
[11] Vitamin A
[12] Vitamin E
[13] Copper
[14] Selenium
[15] Osmolality

[a,b,c,d] Means (in same row) significantly different ($P < 0.05$)

Table 5. Desert tortoise hematology profiles from Little Shipp Wash, Arizona, 1991. NA = not available.

	APRIL 4 $\bar{x} \pm SD$ (n)	JULY 2 $\bar{x} \pm SD$ (n)	SEPTEMBER 24 $\bar{x} \pm SD$ (n)
Hb[1] g/dl	8.6 ± 1.3[c] (6)	9.5 ± 0.8 (5)	11.1 ± 2.2[c] (8)
PCV[2] %	20.5 ± 2.3[c] (7)	22.1 ± 1.6 (6)	24.9 ± 4.9[c] (8)
WBC[3] k/ul	12.1 ± 6.5 (5)	9.2 ± 3.5 (6)	8.9 ± 3.4 (8)
HETR[4] %	74.0 ± 19.8 (5)	69.3 ± 22.7 (6)	73.9 ± 13.2 (8)
LYMP[5] %	7.2 ± 3.8[a] (4)	2.5 ± 1.0[a] (6)	14.5 ± 5.0[a] (8)
MONO[6] %	NA	2.0 ± 1.3 (6)	NA
EOSI[7] %	5.2 ± 4.0 (5)	13.5 ± 14.0 (4)	3.7 ± 3.0 (7)
BASO[8] %	15.0 ± 17.7 (5)	16.8 ± 11.2[b] (6)	8.2 ± 7.2[b] (8)
AZUR[9] %	NA	1.0 ± 0.0 (2)	1.0 ± 0.0 (1)

[1] Hemoglobin
[2] Packed cell volume
[3] White blood cells
[4] Heterophils
[5] Lymphocytes
[6] Monocytes
[7] Eosinophils
[8] Basophils
[9] Azurophils

[a,b,c] Means (in same row) significantly different ($P < 0.05$)

Table 6. Desert tortoise hematology profiles from Harcuvar Mountains, Arizona, 1991. NA = not available.

	MAY 2 $\bar{x} \pm SD$ (n)	JULY 4 $\bar{x} \pm SD$ (n)	SEPTEMBER 26 $\bar{x} \pm SD$ (n)
Hb[1] g/dl	$8.8 \pm 1.0^{a,c}$ (7)	9.7 ± 0.6^{a} (8)	10.2 ± 1.1^{c} (12)
PCV[2] %	21.7 ± 2.1 (7)	22.6 ± 1.7 (8)	21.5 ± 6.7 (12)
WBC[3] k/ul	9.8 ± 6.4 (6)	10.7 ± 3.8 (8)	8.0 ± 4.7 (12)
HETR[4] %	57.5 ± 19.5 (6)	75.5 ± 14.1^{b} (8)	59.6 ± 16.7^{b} (12)
LYMP[5] %	15.3 ± 10.2 (6)	5.7 ± 3.1^{b} (7)	14.6 ± 9.0^{b} (11)
MONO[6] %	24.0 ± 0.0 (1)	2.8 ± 2.5 (5)	NA
EOSI[7] %	4.6 ± 3.6 (5)	6.8 ± 5.8 (5)	1.9 ± 0.9 (9)
BASO[8] %	19.0 ± 21.2 (6)	13.2 ± 12.9 (8)	25.5 ± 18.8 (12)
AZUR[9] %	NA	1.0 ± 0.0 (2)	1.0 ± 0.0 (1)

[1] Hemoglobin
[2] Packed cell volume
[3] White blood cells
[4] Heterophils
[5] Lymphocytes
[6] Monocytes
[7] Eosinophils
[8] Basophils
[9] Azurophils

[a,b,c] Means (in same row) significantly different ($P < 0.05$)

Table 7. Desert tortoise bacteria identified from cloacal and throat swabs and nasal flushes from Little Shipp Wash and Harcuvar Mountains, Arizona, 1990.

LITTLE SHIPP WASH
NOVEMBER 7

Cloacal swab	301	302	303	309	499
Bacillus sp.	P	P	S		S
Escherichia coli		P			
Shigella sp.				M	

Throat swab	302	303	308	309	310	499
Coryenbacteria sp.		H				
Pasteurella testudinis			H	H	H	
Pseudomonas aeruginosa	M					
Streptococcus sp.						P

P = Present S = Slight Growth M = Moderate Growth H = Heavy Growth

Table 7. (continued) Desert tortoise bacteria identified from cloacal and throat swabs and nasal flushes from Little Shipp Wash and Harcuvar Mountains, Arizona, 1990.

HARCUVAR MOUNTAINS
NOVEMBER 9

Cloacal swab	203	205	207	208	210	211	212	213	214	294
Bacillus sp.						S				H
Coryenbacteria sp.					H		H			
Proteus sp.									M	
Pseudomonas sp.	M	H		H				H		
Streptococcus sp.			H							

Nasal flush	207	211	213	217
Pasteurella testudinis	P	P	P	P

Throat swab	202	203	204	205	207	208	209	210	211	212	213	214	215
Coryenbacteria sp.												S	
Escherichia coli	M												
Pasteurella testudinis	H	M	H	M				H	M	H			H
Pseudomonas sp.							H				M		
Staphylococcus sp.					H	H							

P = Present S = Slight Growth M = Moderate Growth H = Heavy Growth

Table 8. Desert tortoise bacteria identified from cloacal and throat swabs and nasal flushes from Little Shipp Wash and Harcuvar Mountains, Arizona, spring 1991.

LITTLE SHIPP WASH
APRIL 30

Cloacal swab	499
Bacillus sp.	S

Nasal flush	301	303	308	309	310	499	500
Pasteurella testudinis	P		P	P	P	P	
Chlamydia-like bacteria		P					P

HARCUVAR MOUNTAINS
MAY 2

Throat swab	204	208	210
Pasteurella testudinis	M		
Pseudomonas sp.		H	H

P = Present   S = Slight Growth   M = Moderate Growth   H = Heavy Growth

Table 9. Desert tortoise bacteria identified from cloacal swabs and nasal flushes from Little Shipp Wash and Harcuvar Mountains, Arizona, summer 1991.

LITTLE SHIPP WASH
JULY 2

Cloacal swab	308	309	310	499	500
Escherichia coli				M	M
Pseudomonas sp.					M
Shigella sp.		M	M		M
Staphylococcus sp.	M	H	H	M	M
Streptococcus sp.	M	H		M	

HARCUVAR MOUNTAINS
JULY 4

Cloacal swab	202	203	205	208	210	211	215	218
Campylobacter sp.							M	
Escherichia coli			H	H	M	M		H
Pasteurella testudinis			H					
Shigella sp.		M						H
Staphylococcus sp.	M	H	H	H	M	M	H	H
Streptococcus sp.	M			H	M	M		

Nasal flush	208	210	211	215
Pasteurella testudinis	P	P	P	P

P = Present S = Slight Growth M = Moderate Growth H = Heavy Growth

Table 10. Desert tortoise bacteria identified from cloacal swabs and nasal flushes from Little Shipp Wash and Harcuvar Mountains, Arizona, fall 1991.

LITTLE SHIPP WASH
SEPTEMBER 24

Cloacal swab	218	219	301	302	303	309	310	499	500	501
Citrobacter sp.					M	S			M	S
Corynebacteria sp.		M	H	H	H	H		H	H	H
Escherichia coli					M				M	
Klebsiella sp.	M			M	M	S			M	
Lactobacillus sp.			H	H	H	H	M	H	H	H
Pasteurella testudinis									H	
Pseudomonas sp.			S		M					
Staphylococcus sp.			H	H	H	M		H	H	H
Streptococcus sp.						S		H		

Nasal flush	303	310	499
Pasteurella testudinis	P	P	P

P = Present S = Slight Growth M = Moderate Growth H = Heavy Growth

Table 10. (continued) Desert tortoise bacteria identified from cloacal swabs and nasal flushes from Little Shipp Wash and Harcuvar Mountains, Arizona, fall 1991.

HARCUVAR MOUNTAINS
SEPTEMBER 26

Cloacal swab	202	203	204	205	208	210	211	215	218	219	220	221
Corynebacteria sp.	H	H	M	M	M	S	S	M	M		M	H
Enterobacter sp.												H
Escherichia coli		M			M			S				H
Klebsiella sp.			M					S			M	
Lactobacillus sp.	H	H			M	S	S	M	M	M	M	H
Pasteurella testudinis	H			S	M						M	
Salmonella sp.												H
Staphylococcus sp.	H	H	M	M	M	S	S	M	M	M	M	H
Streptococcus sp.		H	M	M		S	S					H

Nasal flush	205	208	210	211	215	218	219	220
Chlamydia-like bacteria					P			P
Pasteurella testudinis	P	P	P	P		P	P	

P = Present S = Slight Growth M = Moderate Growth H = Heavy Growth

Parasitology

Fecal analysis indicated that 98% of the tortoises sampled had oxyurid nematode (pinworm) ova (n = 31) (Table 11). This was the only internal parasite detected in 1990 and

Table 11. Desert tortoises with oxyurid (pinworm) ova identified in fecal samples from Little Shipp Wash and Harcuvar Mountains, Arizona, 1990-1991.

LITTLE SHIPP WASH, AZ				HARCUVAR MOUNTAINS, AZ			
11/7/90	4/30/91	7/2/91	9/24/91	11/9/90	5/2/91	7/4/91	9/26/91
301	301	303	301	202	205	218	202
302	302	309	302	203	208		205
303	303	500	303	205			218
308	309		309	211			219
309			500	212			220
							221

1991 analyses. Both populations had more infected animals in fall as compared to spring and summer (59% in fall 1990; 79% in fall 1991).

DISCUSSION

Blood chemistry and hematology

Urea is the principal end product of the catabolism of protein and is excreted almost entirely by the kidneys (Coles 1986). Elevated BUN is an osmotically active way of maintaining water balance (Frye 1981). According to Tietz (1986), elevated BUN is due to a variety of causes such as dehydration, high protein diet, starvation, increased protein catabolism, blockage of the bladder, and kidney disease. Jacobson and Gaskin (1990) reported urea is toxic at high BUN levels (x = 100 mg/dl for ill tortoises).

BUN levels for Little Shipp and the Harcuvars are below the average for healthy free-ranging tortoises (x = 6.0 mg/dl, n = 4) as reported by Jacobson and Gaskin (1990), but within the range (1-30 mg/dl, n = 300) reported by Rosskopf (1982) for healthy captive tortoises. BUN levels were significantly different between the two populations in September 1991. Elevated BUN levels in the Harcuvars in September may be due several ill/dehydrated tortoises (#205, #221). In 1991 BUN levels were lowest in spring and highest in fall. Lower spring BUN levels may be due to available free water.

Creatine is synthesized in the kidney, liver, and pancreas and it is transported to other organs such as the muscle and brain where it converts spontaneously into creatinine (Tietz 1986). An increase in plasma creatinine indicates both acute and chronic renal disease (Tietz

1990). Plasma creatinine is not a sensitive indicator of early renal disease nor is it affected by dietary intake (Tietz 1990).

Creatinine levels for Little Shipp and Harcuvar populations were slightly above the range (0.1-0.4 mg/dl, n = 300) reported for healthy captive tortoises by Rosskopf (1982). Creatinine levels were significantly different between Little Shipp and Harcuvars in September 1991 and between months at Little Shipp.

Plasma proteins occur in a wide variety of chemical compounds such as albumin, globulins, fibrinogen, glycoproteins, and lipoproteins (Coles 1986). Excessive loss of proteins resulting from renal disease, draining wounds, or starvation are reflected in reduced total protein values (Coles 1986). Low total protein levels are often due to decreases in albumin (Coles 1986).

Total protein levels from Little Shipp and Harcuvars were within the range (2.2-5.0 g/dl, n = 300) reported by Rosskopf (1982) for healthy captive desert tortoises. Total protein levels were significantly different between Little Shipp and Harcuvars in July 1991 which indicates the Harcuvar population consumed less plant matter. The Harcuvars had inadequate summer precipitation compared to Little Shipp and thus less forage was available to tortoises. If Harcuvar tortoises took advantage of increased forage there might have been a corresponding increase in dietary protein (Coles 1986).

Albumin affects osmotic pressure and may act as the primary source of reserve amino acids for tissue proteins (Coles 1986). A decrease in total albumin may result from deficient intake of protein, deficient synthesis of albumin, excessive protein breakdown, or direct loss of albumin (i.e. egg laying) (Coles 1986). A decrease in total albumin is often associated with hyperglobulinemia, a disease associated with poor diet and/or poor nutrient absorption (Coles 1986). Overall, albumin levels for Little Shipp and Harcuvar populations were similar. During September 1989, however, albumin was significantly different between the two sites. One possible source of variation could be dehydrated Harcuvar tortoises. This assumption is supported by a corresponding increase in PCV in tortoises with increased albumin levels.

Increased levels of the serum enzyme, SGOT, occur as a result of a wide variety of disease-related tissue damage (Coles 1986). Rosskopf (1982) reported elevated SGOT levels in captive desert tortoises with liver, heart, muscle, intestine, and blood disorders. Jacobson and Gaskin (1990) found elevated SGOT levels in ill free-ranging tortoises

SGOT levels from Little Shipp and Harcuvars populations for 1990 were similar to values (10-100 IU/l; $x = 56 \pm 24$) reported for healthy Mojave tortoises (Rosskopf 1982; Jacobson and Gaskin 1990). SGOT levels were not significantly different between months or sites.

The steroid, cholesterol, is synthesized in all tissues but it is most active in the liver, intestine, and skin (Coles 1986). Cholesterol levels may be used as indicators of liver and thyroid function. Low cholesterol levels are associated with liver disease, hyperthyroidism, anemia, low fat diet, and starvation (Coles 1986).

Cholesterol levels for Little Shipp and Harcuvars were similar to the 83.0 mg/dl level reported for healthy tortoises, and below the 305.0 mg/dl level reported for ill tortoises (Jacobson and Gaskin 1990). Cholesterol levels were significantly different between the two sites in July 1991. High cholesterol levels may indicate vitellogenesis in female chelonians as they mobilize calcium, protein, and lipids for egg yolk production (Frye 1981). Vitellogenesis cannot be discounted because egg laying does occur in July (C. Schwalbe, pers. comm.).

Triglycerides, like cholesterol, are lipids. Triglyceride are structurally different from cholesterol in that they contain a glycerol molecule instead of a four carbon ring (Church and Pond 1982). Lipid energy reserves are primarily triglycerides (Robbins 1983).

Triglyceride levels for Little Shipp and Harcuvar populations had high standard deviations. There was a significant difference in triglyceride levels in May 1991 between the two sites. Elevated levels of triglycerides in Little Shipp tortoises in the spring 1991 may indicate low protein intake as lipids are metabolized to meet energy needs (Robbins 1983). Calcium is important in bone formation, egg production, nerve function, muscle contraction, blood clotting, and cell permeability (Robbins 1983). Almost all blood calcium is found in the plasma (Coles 1986) and is affected by total protein. Increased total protein elevates protein-bound calcium and affects the total serum calcium concentration (Coles 1986).

Calcium levels for Little Shipp and Harcuvars populations were within the range of normal values reported for healthy Mojave tortoises (Rosskopf 1982; Jacobson and Gaskin 1990). Calcium levels differed significantly between sites for May 1991.

Phosphorus is also important in bone formation. A change in the calcium:phosphorus ratio can result in bone diseases such as osteomalacia (Robbins 1983). Phosphorus also influences cell membrane structure and function, protein synthesis, and several enzyme systems (Robbins 1983). An excess of calcium and magnesium can cause a decrease phosphorus absorption (Robbins 1983).

Phosphorus levels from Little Shipp and Harcuvar populations were above the values ($x = 2.5 \pm 0.2$, $n = 9$) reported for healthy free-ranging tortoises (Jacobson and Gaskin 1990). Phosphorus levels were significantly different between the two sites in May 1991 which may be the result of less ingested plant matter by the Harcuvar tortoises.

Sodium and water loss often occurs with diarrhea, vomiting, or renal disease (Coles 1986). Reptiles are unable to concentrate sodium and potassium hypertonically in their urine (Frye 1981). Some species, like the desert iguana, (*Dipsosaurus dorsalis*) have evolved salt glands to excrete excess sodium and potassium (Shoemaker et al. 1972). Extrarenal secretion of these salts reduces their toxic effects and increases the reptile's ability to conserve water (Frye 1981). Desert tortoises do not have salt glands (Dantzler and Schmidt-Nielsen 1966) and must depend on their kidneys for osmoregulation.

Sodium levels in the Little Shipp and Harcuvar populations were similar to values ($x = 136 \pm 0.5$, $n = 9$) reported for heathy free-ranging Mojave tortoises (Jacobson and Gaskin 1990). Sodium levels were significantly different between the two sites in November 1990. Harcuvar tortoises in fall 1990 showed signs of dehydration as sodium levels were low and associated PCV levels were high.

Serum potassium levels may not reflect the true status of body potassium because most potassium is stored in intracellular fluid (Coles 1986). According to Minnich (1970, 1977), increased plasma potassium loads may cause desert tortoises and iguanas to reduce or cease feeding in drought conditions. Desert tortoises also have the capacity to store potassium as precipitated urates (Minnich 1977). These factors may account for the lack of elevated potassium levels in dehydrated tortoises (Minnich 1977; Minnich 1982).

Potassium levels in the Little Shipp and Harcuvar populations were within the range reported by Rosskopf (1982) for healthy captive desert tortoises (2.2-4.5 mEq/l), but below the levels ($x = 6.8$ mEq/l) reported by Minnich (1982) for free-ranging desert tortoises dehydrated 134 days.

Vitamins A is a fat-soluble vitamin present as provitamin A carotenoids, mainly B-carotene, in all green parts of growing plants (McDowell 1989). It is observed in the intestinal tract and stored in large concentrations in the liver to be used during dietary inadequacy

(McDowell, 1989). Vitamin A deficiencies result in vision problems, loss of integrity of the protective lining of mucosal surfaces, reproductive failure, reduced growth, and impaired immunity with an increase in frequency and severity of infections (McDowell 1989). No published information exists on plasma vitamin A levels in desert tortoises.

The highest vitamin A levels were reported at the Little Shipp Wash site in September 1990 and April 1991, following seasonal periods of high rainfall conductive to new plant growth. In 1991 there was a significant difference in vitamin A levels in May and September between the two sites.

Vitamin E is fat-soluble vitamin and a very significant biological antioxidant. It protects cell membranes and preserves cell integrity by avoiding lipid peroxidation (McDowell 1989). A deficiency in vitamin E produces a wide variety of metabolic problems related to its function in the prevention of tissue breakdown. Immunosuppression with a decrease in disease resistance, reproductive failure, myopathies, neuropathies, liver necrosis, and vascular alterations are among the best known diseases produced by vitamin E deficiency (McDowell 1989). Vitamin E is found in green plants and grain, and quickly decreases in concentration as plants mature, or when oxidized by heat (McDowell 1989).

A significant seasonal drop in vitamin E occurred in the Harcuvars in July and September 1991, and less markedly in July 1991 in the Little Shipp Wash site. These drops are likely related to high summer temperatures and reduced rainfall recorded in the Sonoran desert during this time. It is interesting that summertime is usually the season of more severe upper respiratory tract disease (URTD) in captive and wild desert tortoises in Arizona (C. Reggiardo, unpubl. data). Although no published information exists on plasma vitamin E levels in desert tortoises, the levels reported in this study resemble those reported for other Testudinata (Dierenfeld 1989).

Copper is an important mineral necessary for hemoglobin formation, enzyme systems, bone development, and reproduction (Robbins 1983). Its deficiency is associated with anemia, infertility, nervous system disorders, hair pigmentation problems, and lack of resistance to disease (Davis and Mert 1987). Copper uptake is influenced by the presence of molybdenum, iron, calcium, and zinc (Robbins 1983). A significant seasonal drop in copper levels occurred in September 1991 in the Little Shipp population. This marginal copper deficiency may be attributed to lack of food and/or infection (Underwood 1977). Zinc functions in bone development, several enzyme systems, and is required for normal protein synthesis and metabolism (Robbins 1983). Zinc is involved in several mineral interactions. Excess calcium impairs zinc absorption, and excess zinc interferes with copper metabolism and may cause anemia (Robbins 1983). Zinc levels were only available for September 1990 for both sites. No significant difference in zinc levels was detected.

Selenium closely interacts with vitamin E in the prevention of lipid peroxidations in the cell, and its deficiency produces diseases similar to those observed in vitamin E deficiency (Levander 1986). The concentration of selenium in plants depends on the plant species and soil characteristics of a given area (Levander 1986). No significant difference in selenium values occurred between sites and years.

PCV is a measurement of the ratio of the volume occupied by red blood cells to the volume of whole blood. High PCV levels may indicate dehydration while low levels may indicate anemia (Turgeon 1988). PCV levels for Little Shipp and Harcuvar populations were within the range (23-37%, n = 300) reported by Rosskopf (1982) for healthy captive desert tortoises. There was a significantly difference in PCV in September and November 1990 between the two sites. Higher PCV levels in the Harcuvars in fall 1990 may indicate dehydration.

The amount of hemoglobin in the blood indicates oxygen carrying capacity (Coles 1986). In 1990 hemoglobin values were only available for the Harcuvar population in September (x = 11.7%), but were similar to values reported for free-ranging Mojave desert tortoises (Dickinson and Wegge 1991). In 1991 no significant difference was found in hemoglobin values within and between populations.

The major categories of the cellular elements of the blood are red blood cells, white blood cells, and platelets. White blood cells can be subdivided into heterophils, lymphocytes, monocytes, eosinophils, basophils, and azurophils, all of which have specialized functions associated with body defense (Turgeon 1988). Increased levels of white blood cells indicate infection. Heterophils and basophil levels increase in response to inflammatory conditions. Heterophils increase first, and then basophils increase as the disease becomes chronic (Rosskopf 1982). Elevated eosinophil levels are associated with intestinal parasitism (Noble et al. 1989). Differential white blood cell counts in this study were similar to values reported for healthy free-ranging Mojave tortoises (Jacobson and Gaskin 1990). Only lymphocytes were significantly different between the two sites in July 1991. This small difference is unimportant as lymphocyte numbers normally vary.

Osmolality expresses concentrations in terms of mass of solvent (Tietz 1986). In dehydration, where water loss exceeds water gain, there is an increase in osmolality levels (Tietz 1986). Osmolality levels from Little Shipp and Harcuvars were similar to the levels reported by Minnich (1977) for hydrated free-ranging desert tortoises (x = 291 $\pm$ 3.3), but below the levels reported for dehydrated tortoises (x = 334 $\pm$ 3.7). The only significant difference in osmolality occurred in September 1991 where Harcuvar tortoises had slightly higher osmolality levels as compared to Little Shipp. An increase in fall osmolality levels are not uncommon (Nagy and Medica 1986), and an increase of up to 50 mOs\kg has little or no effect on the renal function of desert tortoises (Dantzler and Schmidt-Nielsen 1966).

Bacteriology

Eight of the 18 species of bacteria isolated from Little Shipp and Harcuvar tortoises were reported in free-ranging Mojave tortoises (Fowler 1977). *Pasteurella testudinis* has been isolated from heathy and ill captive tortoises and may be involved in URTD (Snipes and Biberstein 1982, Jacobson et al. 1991). Dickinson and Wegge (1991) found *P. testudinis* in 64% of free-ranging Mojave desert tortoises (n = 28). Although commonly isolated from apparently healthy animals, it is shed in much larger numbers during clinical URTD (C. Reggiardo, unpubl. data) and probably contributes to the clinical syndrome by acting synergistically with other organisms (Jacobson et al. 1991) or with the appropriate nutritional or environmental conditions which help precipitate the disease.

No *Mycoplasma* sp. were isolated from any of the specimens, although the media employed was tested for its ability to support the growth of strains isolated in Florida from tortoises with URTD (Jacobson et al. 1991).

Parasitology

Oxyurids, also known as pinworms, are among the most common and numerous intestinal worms of lizards and turtles (Marcus 1981). Females crawl outside the host's anus and rapidly discharge eggs on the ground. The host can reinfect itself by breathing or ingesting the eggs (Noble et al. 1989). As tortoises share burrows, and are known to eat soil and scat (Esque et al. 1990) continued infection occurs. Though the majority of tortoises at the two sites had pinworms, this condition is not life threatening as these parasites cause little significant disease (Marcus 1981).

CONCLUSIONS

Hematological data indicates that the Harcuvar population was less healthy than the Little Shipp population in fall 1990, and summer and fall 1991. Harcuvar tortoises had generally higher PCV levels in fall 1990 than Little Shipp tortoises which may indicate dehydration. In 1991, Harcuvar tortoises were physiologically stressed in summer and suffered from dehydration and low protein intake in fall. Inadequate summer precipitation and reduced food resources are the probable causes of ill health. In this study, both populations had blood chemistry, differential white blood cell counts, and osmolality levels similar to levels reported for healthy free-ranging tortoises. Eighteen bacteria were isolated from tortoise nasal fossa and cloacae; four of which are potential pathogens. Ninety eight percent of the tortoises sampled had nonpathogenic oxyurid (pinworm) ova in their feces.

Blood levels of BUN, creatinine, total protein, albumin, cholesterol, triglyceride, sodium, potassium, calcium, phosphorus, vitamins A and E, copper, and selenium will be included in future blood chemistry analyses. We will continue to investigate PCV, hemoglobin, and differential white blood cell count data. We will continue bacterial and fecal collections. We will install automatic weather stations at both sites to provide useful information on climate conditions. Blood chemistry data will be interpreted in the light of information from ongoing nutrient studies in the Sonoran desert. This may allow further interpretation of the health studies being conducted.

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Seroepidemiological Studies on Free-Ranging Desert Tortoises (*Gopherus agassizii*) with Upper Respiratory Tract Disease (URTD)

Isabella M. Fuerst, Mary B. Brown and Paul A. Klein

Anatomic, histopathological, microbiological and serological studies have been initiated to identify the responsible infectious agent(s) causing an upper respiratory tract disease (URTD) among free-ranging desert tortoises in the southwestern United States. This disease is associated with high mortality and *Mycoplasma* sp. is suspected to be one of the causative agents of URTD. An ELISA (enzyme-linked immunosorbent assay) was developed in order to screen for antibodies against *Mycoplasma* sp. in the plasm of both clinically sick and clinically healthy desert tortoises. Results of this survey showed a positive correlation between the presence of antibodies against *Mycoplasma* sp. and clinical symptoms and histological findings in sick tortoises. Future studies will refine the ELISA by using monoclonal antibodies against desert tortoise IgG. The ELISA test will then be used for large scale serological screening of both captive and free-ranging desert tortoises.

Occurrence and Treatment of Upper Respiratory Tract Disease at the Desert Tortoise Conservation Center, Las Vegas, Nevada

Janice S. Grumbles, Michael O'Connor, Linda C. Zimmerman, David C. Rostal, Valentine A. Lance and Lori Jackintell

Abstract. Upper Respiratory Tract disease symptoms were observed in 60 tortoises (23 females, 12 males, and 25 of undetermined sex) from the large research pens, the reproduction holding pens, and the Bureau of Land Management holding pens during the period July to October, 1991. Symptoms ranged from mild (serous nasal discharge) to debilitating (purulent nasal discharge and muscle wasting). Symptomatic tortoises were found in pens both with and without supplemental food and water. Neither the frequency nor the duration of handling or bleeding contributed to the development of symptoms. BaytrilR (the antibiotic enrofloxacin) was used for treatment. At the end of 7 treatments, 28 of 45 animals (62%) were asymptomatic, however, 9 of these animals had symptoms recur later. 17 animals (38%) remained symptomatic throughout therapy. Acute handling stress (i.e., bleeding) did not cause an elevation in mean corticosterone levels, but did produce an elevation in circulating white blood cells within 5 minutes.

INTRODUCTION

Numerous tortoises with symptoms of Upper Respiratory Tract Disease (URTD) were observed at the Desert Tortoise Conservation Center beginning in July, 1991. These were tortoises which had cleared quarantine before being placed in research groups. When a symptomatic tortoise was found it was removed from the research group and placed in isolation in the outdoor holding pens. The number of affected tortoises became so high in some research groups that there was concern that research could not be continued with these groups or that results from research within these groups might be erroneous. As a result, after consultation with Dr. Elliott Jacobson (University of Florida), a treatment regime was begun on the isolated animals. Treatment results varied and the underlaying etiology and transmission of this disease became the topic of a meeting called by The Nature Conservancy in Reno this past October. This paper summarizes the results of our retrospective and on-going research in this area.

This study had four main components:

First, to determine the number of symptomatic tortoises which were part of the Drexel/ San Diego Zoo research groups at the Desert Tortoise Conservation Center (DTCC). There was concern, as stated previously, that the number of affected tortoises would be so great that the research in certain groups would have to be curtailed or would be inaccurate.

Second, to determine any predisposing factors in the occurrence of the URTD symptoms especially those which could be modified. In conjunction with this, a handling stress response test on a group of 12 asymptomatic animals was done.

Third, to assess hematological and biochemical parameters associated with the URTD symptoms that might be diagnostic or prognostic in future cases.

Finally, to evaluate the effectiveness of an antibiotic treatment regime for treating symptomatic tortoises.

MATERIALS AND METHODS

Survey for symptomatic tortoises and predisposing factors

The study group consisted of both adult and immature tortoises which are maintained for research at the DTCC. The animals were categorized into 4 major groups for the purposes of comparison:

1) Animals in the supplemented research pens, 2) the non-supplemented research pens, 3) the reproduction holding pens, and 4) the Bureau of Land Management (BLM) holding pens. There are 9 research pens, each 10 acres in size, at the DTCC. Seven of the 9 research pens are supplemented with food and water consisting of irrigated sod and seed stations. Two research pens are non-supplemented and are made up of natural vegetation relying on rainfall for maintenance; there is no supplemental food or water. There are 30-40 animals in each 10-acre research pen, with varying percentages of males, females, and immatures.

The reproduction holding pen group consists of ten 50 foot by 100 foot holding pens, all with supplemental food and water. There are 5 adult animals in each pen, 3 females and 2 males. The last group, the BLM holding pen animals are individually housed tortoises. They are in holding pens similar to the reproduction holding pens but smaller in size. There are males, females, and immature animals housed in these pens. All the holding pens (BLM and the reproduction pens) receive alfalfa hay as well.

Hematologic and biochemical parameters

Blood samples which were collected in September and October, 1991, from symptomatic and non-symptomatic tortoises were compared for differences in hematological and plasma biochemical parameters:

The following hematological parameters were performed: packed cell volume, white blood cell count, and white blood cell differential count. The plasma biochemical parameters examined were: blood glucose, carbon dioxide, total plasma protein, albumin, blood urea nitrogen (BUN), creatinine, uric acid, globulins, albumin/globulin ratio, phosphorous, calcium, the enzymes - alkaline phosphatase, creatinine phosphokinase (CPK), serum glutamic oxalacetic transaminase (SGOT), and the electrolytes - sodium, potassium, and chloride.

The tortoises in this portion of the study were divided into three groups: symptomatic and asymptomatic tortoises from the environmental stress study and a non-treatment group which consists of non-symptomatic tortoises housed individually in the holding pens.

Treatment effectiveness

Tortoises from the research pens which were found to be symptomatic during the period of July to September, 1991 were moved to individual holding pens for isolation purposes. A treatment regime of the antibiotic enrofloxacin (BaytrilR) dosed at 4 mg/kg intramuscularly every other day in conjunction with a 1% BaytrilR solution flush of 0.5cc to each nostril for 7-10 treatments.

Handling stress study

The study group consisted of 12 immature tortoises which were housed individually and maintained under artificial lighting. While the animal was restrained with its neck extended blood samples were taken at 1,5,10,20,30, and 40 minutes via a jugular I.V. catheter. One subsequent sample was taken at 24 hours.

RESULTS AND DISCUSSION

Survey of symptomatic tortoises

In a survey of the large research pens, the reproduction holding pens, and the BLM holding pens, 60 symptomatic tortoises were observed out of 318 tortoises seen (18.9% of the animals surveyed). The breakdown of symptomatic animals was 23 females, 12 males, and 25 tortoises of undetermined sex. The percentage of symptomatic tortoises found is similar to the results Brad Hardenbrook reported in 1991 for the Las Vegas Valley.

Animals were classified as symptomatic even if they were only showing mild symptoms of URTD indicated by the presence of clear, serous nasal discharge. Sixty-three percent of the symptomatic animals occurred in the supplemented research pens, 8% in the non-supplemented research pens, 13% in the reproduction holding pens, and 15% in the BLM holding pens.

Predisposing factors

The smallest percentage of symptomatic animals occurred in the non-supplemented pens, even though these animals would be considered most stressed animals in terms of food and water depravation. It is also interesting to note that the individually housed animals, the BLM holding pen animals had a similar percentage of symptoms as the multiple housed animals in the reproduction pens. It is important to note, however, that 5 of the 8 symptomatic animals in the reproduction group occurred in one pen.

The presence or absence of supplemental food and/or water sources did not predict which pens would develop symptoms as all groups but one were supplemented. One supplemented and one non-supplemented pen were completely free of symptomatic animals. It is possible, however, that the presence of common food stations may promote the transmission of disease among the group when a contagious animal is part of that group.

The frequency of handling and/or bleeding was not significantly different between symptomatic and asymptomatic animals as shown in Table 1. The records from the environmental stress and reproduction studies in which animals are bled repeatedly were compared. The percentages of asymptomatic and symptomatic animals were similar when never bled, or when bled 3 or 4 times. A higher percentage of symptomatic animals were found when bled twice, but a lower percentage was observed at first bleeding.

The duration of recorded bleeding times was not significantly different between symptomatic and asymptomatic animals (Table 1). The effect of handling time duration on the induction of "stress" will be discussed shortly.

Hematologic and biochemical parameters

Jacobson, et al. 1991 reported that plasma sodium, BUN, and SGOT are higher in URTD symptomatic animals and phosphorus is lower. However, in this study, the only significant differences in hematological parameters between symptomatic and asymptomatic animals were found in the percentage of heterophils and the blood urea nitrogen levels.

Table 1. Effects of handling (i.e., bleeding) frequency and duration on the development of URTD symptoms in desert tortoises at the DTCC.

	Number of tortoises (% of total) Symptomatic	Asymptomatic
Number of times bled		
Zero	15 (39.5%)	81 (38.8%)
One	4 (10.5%)	47 (22.5%)
Two	9 (23.7%)	26 (12.4%)
Three	10 (26.3%)	53 (25.3%)
Four	0 (0.0%)	2 (1.0%)
N =	38	209
Duration of bleeding (mins.)		
Mean	14.3	12.1
SE	1.7	0.5
Range	5-36	5-30
N =	24	120

Three groups are shown in Figures 1: symptomatic and asymptomatic animals from the environmental stress study and a non-treatment group which consists of non-symptomatic animals housed individually in the holding pens. When white blood cell counts were compared, symptomatic animals had a higher white blood cell count (6,546) than asymptomatic animals (5,005). The non-treatment group was not significantly different from the symptomatic group (Fig. 1a). Increases in the white blood cell count (leucocytosis) can result from inflammatory processes, tissue trauma, or stress reactions.

The percentage of the white blood cell type, the heterophil, was significantly greaterin the symptomatic group; 18% versus 10% for the asymptomatic and non-treatment groups (Fig. 1b). The number of heterophils often increases with acute or chronic inflammation and with stress.

The blood urea nitrogen level was higher in the symptomatic versus asymptomatic animals as previously reported; 3.2 versus 1.4. However, a surprising elevation, 8.2 was observed in the non-treatment animals (Figure 1c). While elevated BUN levels have been attributed to dehydration and fasting in captive Mediterranean tortoises and in the desert tortoise (Lawrence 1987; Dantzler and Schmidt-Nielsen 1966), this is not likely to be the case with the non-treatment animals. These animals were individually housed with access to supplemental sod and water as well as alfalfa. It is possible that the tortoises' preference for alfalfa (a high quality food source) may have caused the rise in BUN. These animals also had higher glucose, total protein, and albumin levels than either other group. This emphasizes the importance of history (including diet) to interpretation of results.

Treatment effectiveness

The results of this treatment regime are shown in Figure 2. At the end of 7 treatments, 28 of 45 animals or 62% were asymptomatic. 17 animals or 38% still showed symptoms at the end of the treatment period.

Unfortunately, during the subsequent quarantine period, 9 of the asymptomatic animals had recurrent symptoms. None of these animals developed symptoms before 8 days (Fig. 2b). Overall, this indicates that treatment was only effective in 42% of the cases treated.

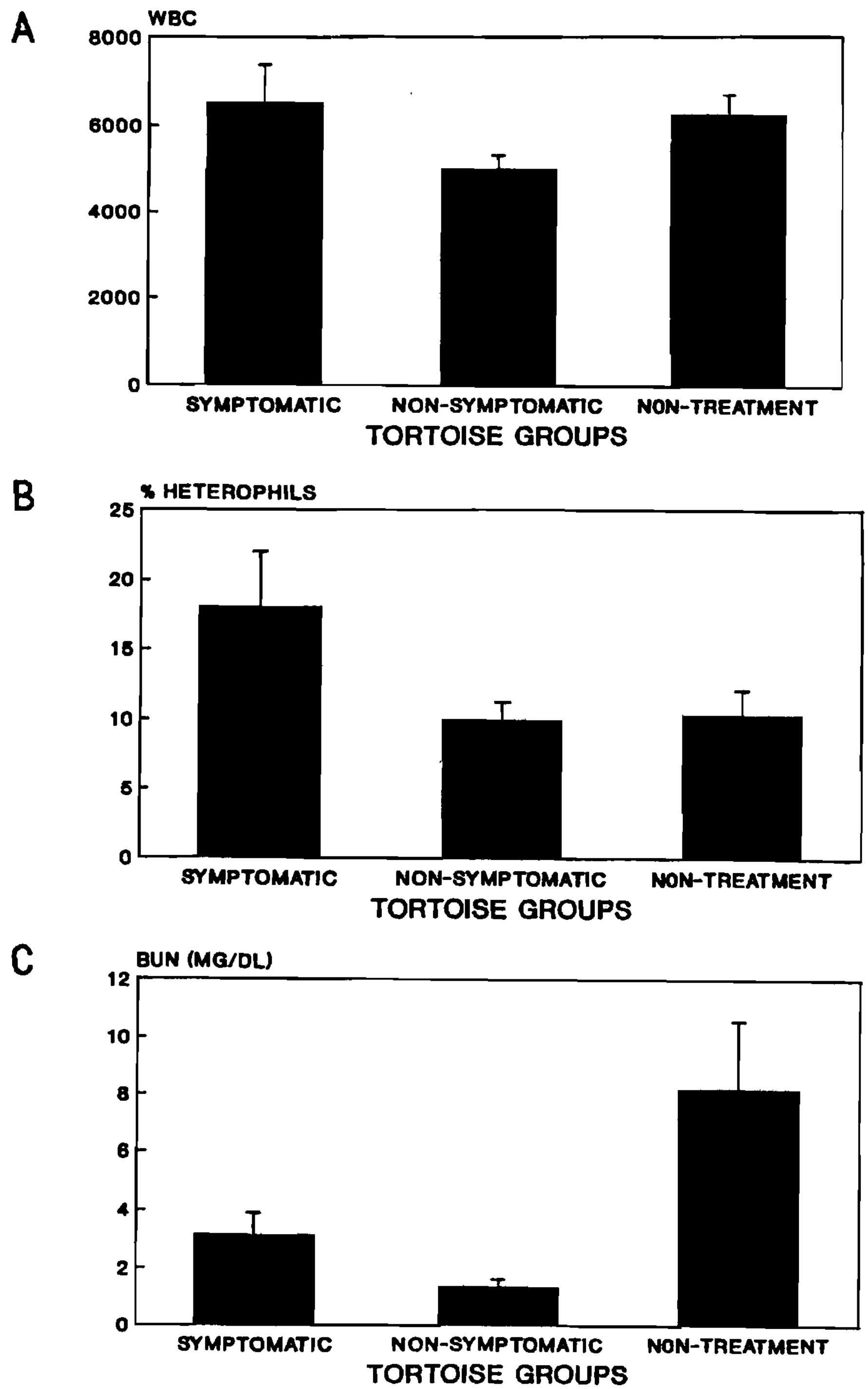

Figure 1. Comparison of blood parameters from symptomatic and asymptomatic desert tortoises from the environmental stress study and a non-treatment group of asymptomatic desert tortoises housed individually (Mean $\pm$ SE). A) White blood cell (WBC) counts were not significantly different among groups. B) Percentage heterophils was significantly greater in the symptomatic group than in asymptomatic or non-treatment groups. C) Blood urea nitrogen (BUN) was significantly higher in the symptomatic and non-treatment groups than in the asymptomatic group.

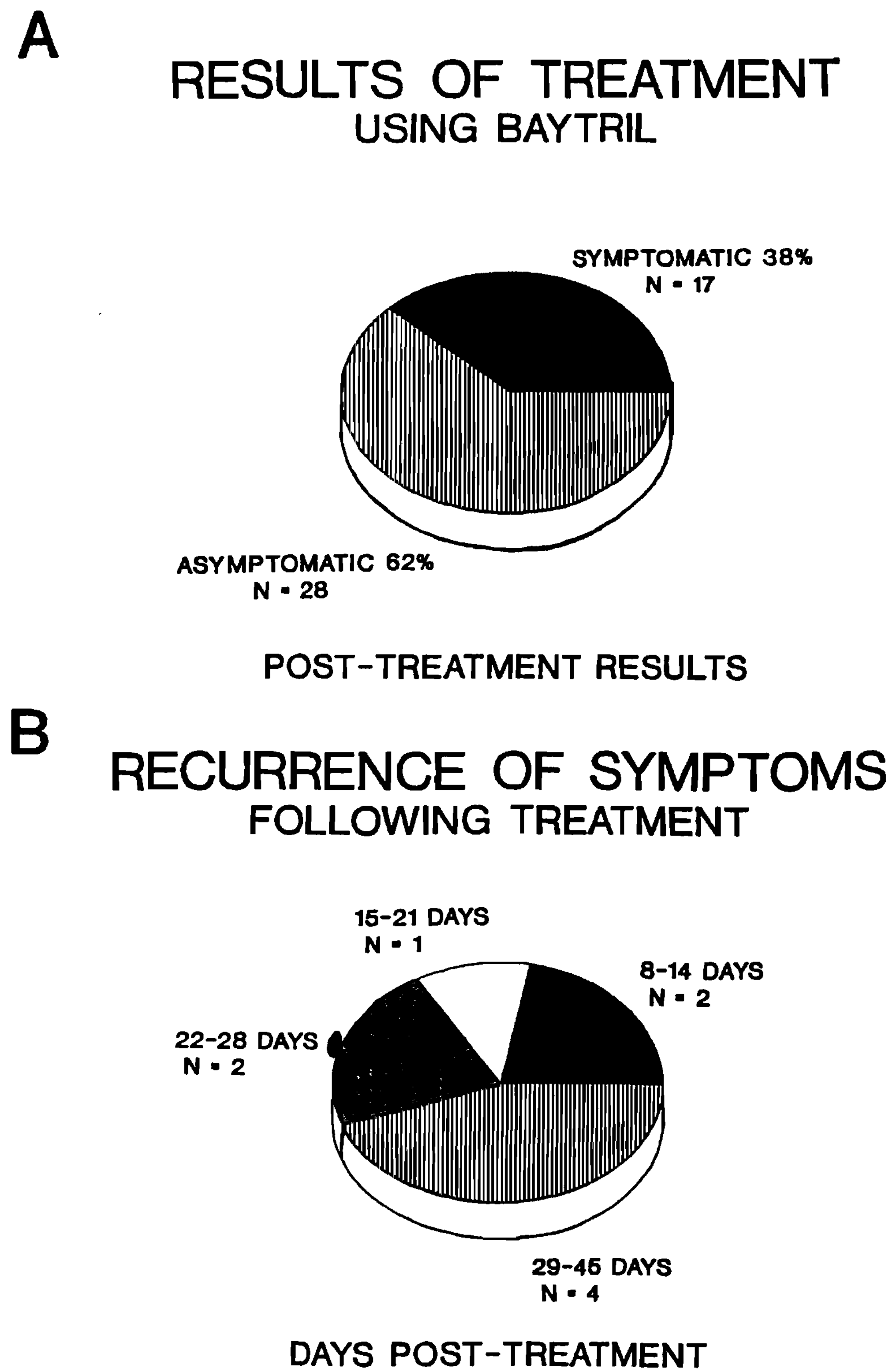

Figure 2. Results of Baytril treatment at the DTCC. A) Results after 7 treatments. B) Time to recurrence of symptoms in treated tortoises. These tortoises were originally asymptomatic at the end of therapy.

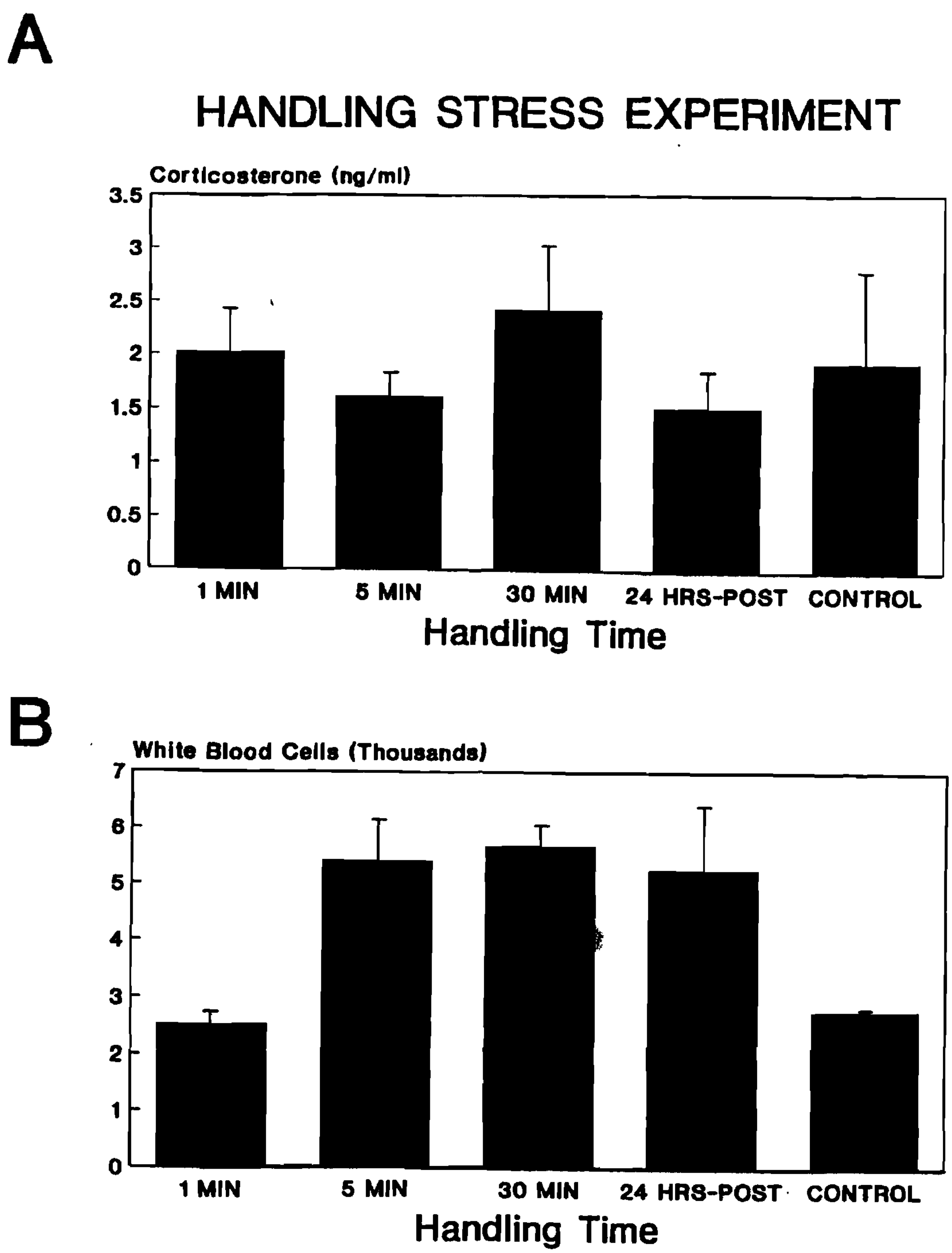

Figure 3. Results of acute handling stress (i.e., bleeding) in a group of 12 immature desert tortoises at the DTCC (mean $\pm$ SE). A) Mean plasma corticosterone levels did not rise during the "stress" period. B) An increase in the number of circulating white blood cells occurred within 5 minutes of "stress" initiation.

Handling stress

The question of how rapidly handling stress will cause elevation in plasma corticosterone levels of tortoises was brought up at the meeting in Reno. As elevated corticosterone levels are an indicator of stress and stress may cause changes in the immune system function (i.e. an increased susceptibility to disease), a preliminary study on handling stress was conducted. The mean corticosterone level did not increase during the sampling period (Fig. 3a). Research done by Lance 1990, has suggested that these initial corticosterone levels were not indicative of a chronic stress level as observed in alligators. Also, please note the large standard error bar in the 30 minute sample (Fig. 3a). This larger error is present as two of the animals did show an elevation in corticosterone by this time period, indicating they were capable of a response. While there was not an increase in mean corticosterone levels, there was an increase in the white blood cell count by five minutes (Fig. 3b). It is not unusual to see this response in reptiles, as handling often causes a sharp rise in catecholamines. Consequently, dilation of capillary beds ensues releasing sequestered white blood cells into the circulation. This is important to bear in mind when interpreting white blood cell count results.

CONCLUSIONS

The following conclusions were drawn from this study:

1) The presence or absence of supplemental food and/or water did NOT influence which tortoises would develop URTD symptoms.
2) There was no correlation between gender and/or age and the development of symptoms.
3) No correlation was observed between handling frequency and the development of symptoms.
4) The only significantly different hematological or biochemical parameters observed in symptomatic animals were increases in the white blood cell count and the percentage of circulating heterophils and an elevated blood urea nitrogen level. However, these did not predict which animals would develop symptoms.
5) Mean plasma corticosterone levels were not observed to increase during a short "stress" period (i.e., blood sampling).
6) An increase in the mean number of circulating white blood cells was observed within the first 5 minutes of blood collection.

Further studies on the determination of stress factors and the influence of these factors on tortoises are already underway.

Symptomatic animals will be left in some research groups (unless they show severe symptoms of the disease) to study the effects of this disease on parameters such as reproduction. This decision was made because tortoises, such as these, seem to represent the desert tortoise population in the Las Vegas Valley.

ACKNOWLEDGEMENTS

We would also like to thank Dr. Robert George for having the biochemical parameter tests and white cell differentials done and for his collaboration on the interpretation of those results.

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Clinicopathologic Evaluations on Desert Tortoises (*Gopherus agassizii*) with Upper Respiratory Tract Disease

Elliott R. Jacobson, Bobby R. Collins, Isabella M. Fuerst, Mary B. Brown, Paul A. Klein and Richard K. Harris

Four groups of three clinically healthy desert tortoises and three desert tortoises with clinical signs of upper respiratory tract disease (URTD) were evaluated in April, July and October 1991, and January 1992. From each tortoise, blood samples were obtained from the supravertebral vein, jugular vein and/or carotid artery for hematologic and plasma biochemical determinations. Hematologic tortoises were euthanatized with an intraperitoneal injection of a concentrated barbiturate solution, the carotid artery catherized and blood collected for immunologic studies. Following euthanasia, swab specimens of the nasal cavity mucosa were obtained for identification of aerobic bacteria and *Mycoplasma* and samples of reproductive organs. One-half of each head and samples of all major organ systems were collected and routinely processed for light microscopic examination. Of the first 6 tortoises examined with clinical signs of URTD, all were found to have lesions in the nasal cavity compatible with this disease. Of the first 6 clinically healthy tortoises examined, three tortoises were found to have pathologic changes of the nasal cavity. Of all the tortoises examined in April and June 1991, the tortoise with the most sever changes in the nasal cavity was originally considered to be clinically normal. Obviously, clinical appearance alone is not sufficient to identify a healthy tortoise.

A Retrospective Study of Upper Respiratory Disease of Captive Desert Tortoises in Arizona

James L. Jarchow

Case histories of 115 captive desert tortoises presented to a veterinary practice in Tucson, Arizona for diagnosis and treatment of upper respiratory tract disease (URTD) a total of 159 times from 1988 to 1992 were reviewed. Each tortoise was a privately owned captive exhibiting a mucous nasal discharge upon initial presentation. In each case routine bacteriological cultures and antibiotic sensitivities were made from swabs of the internal nares prior to treatment. Each tortoise was again examined between 25 and 40 days after the initiation of treatment and then re-examined at or near the end of the study period.

Although the majority of ill tortoises presented were adults, subadult and juvenile tortoises were also represented in significant numbers (Table 1). Seasonal variation in presentations of ill tortoises was evident with progressively more URTD cases presented through successive spring and summer months until a peak was reached in September and October (Fig. 1). Whether this reflected a true seasonal incidence of clinical (overt) URTD or owner procrastination is uncertain.

The majority of nasal cultures yielded *Pasteurella testudinis*. A variety of other potential pathogens were isolated, alone or in combination, less frequently and a small number of ill tortoises exhibited apparently normal (non-pathogenic) nasal flora (Table 2). Each tortoise was placed on a treatment regimen consisting of an appropriate antibiotic (base on in vitro sensitivity) administered by intramuscular injections and irrigation of the nasal cavity with an antibiotic-corticosteroid ophthalmic solution (Gentocin Durafilm, Schering-Plough Animal Health) following completion of the injection series. Each tortoise was maintained at 27-30 °C for the duration of treatment. The number of tortoises that were asymptomatic of URTD 30 days after the initiation of treatment, those that had recurrent episodes of URTD during the three year study period, and those that died during the study period were recorded to evaluate each antibiotic regime (Table 3). Tortoises treated with oxytetracycline had the fewest recurrent episodes of URTD.

Over the course of the study period, 52.2% of the ill, treated tortoises had recurrent episodes of URTD. There was a low incidence of mortality in all but juvenile age groups (Table 4). There were no deaths among those tortoise where *Pasteurella testudinis* was the sole nasal isolate, while mortality reached 20% in those exhibiting bacterial pathogens in addition to *P. testudinis*. Increased mortality in this group may reflect greater debility or immunosuppression.

The frequency of URTD recurrence in treated tortoises, and possibly the relatively low rate of recurrence in those tortoises treated with oxytetracycline, may support the presence of another pathogen, undetected by routine bacterial cultures, such as *Mycoplasma* (Jacobson et al. 1991).

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Jacobson, E.R., J.M. Gaskin, M.B. Brown, R.K. Harris, C.H. Gardiner, J.L. La Pointe, H.P. Adams and C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). J. Wildl. Dis. 27(2):296-316.

Table 1. Age and sex categories of desert tortoises presented with URTD (n=115).

Adults	83	72.2%	males	50	60.2%
			females	33	39.8%
Subadults (90-1000g)	21	18.3%			
Juveniles (< 90g)	11	9.6%			

Table 2. Incidence of bacterial isolates from URTD presentations (n=159).

Pasteurella testudinis	101	63.5%
Pseudomonas spp.	25	15.7%
Beta hemolytic *Staphlococcus*	12	7.5%
Enterobacter spp.	8	5.0%
E. coli	7	4.4%
Normal flora	14	8.8%

others < 3% incidence

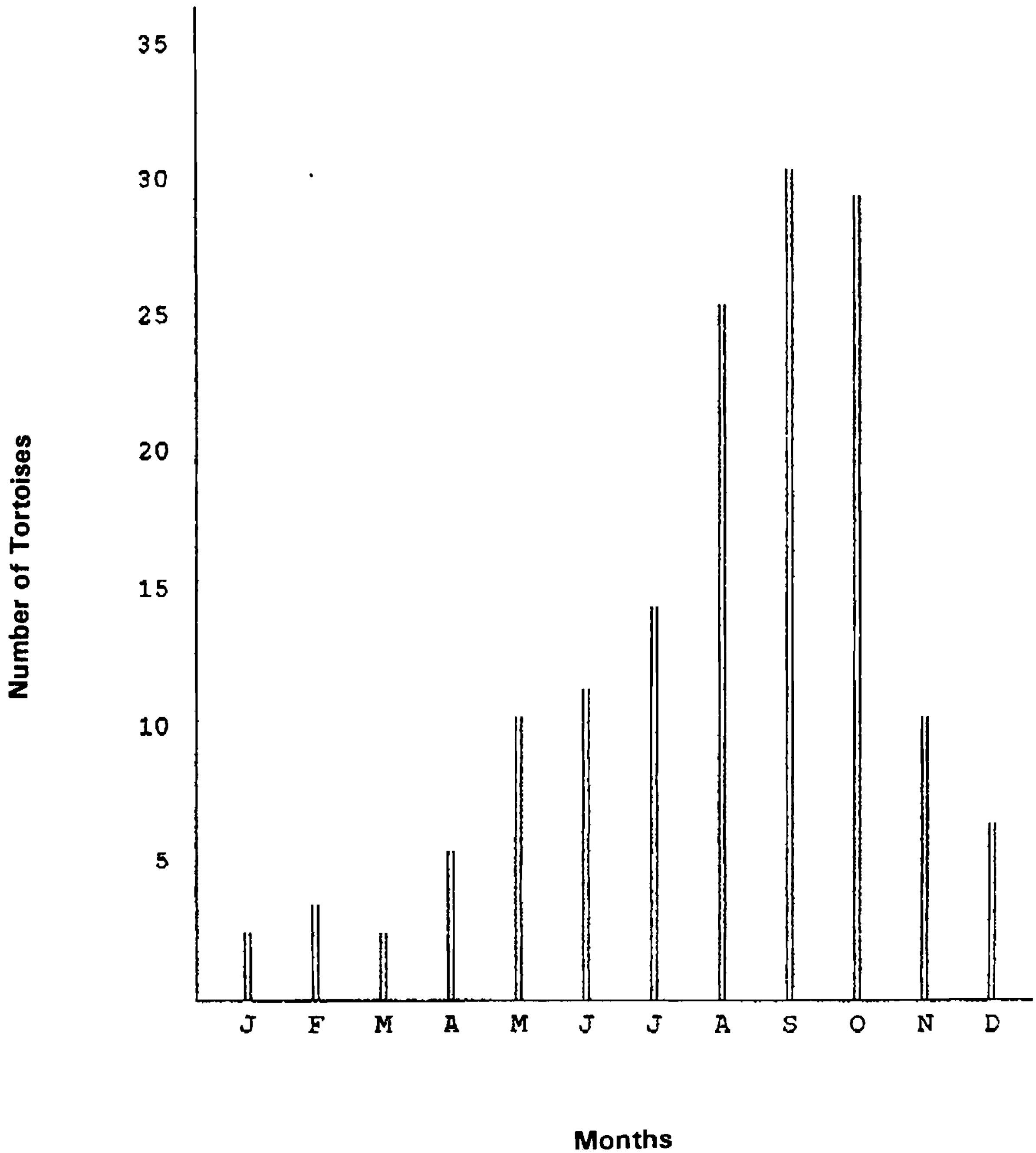

Figure 1. URTD presentations by month.

Table 3. Antibiotic regimes and results.

Antibiotic dosage schedule	n	Asymptomatic at 30 d.	Recurrent URTD	Mortality
amikacin* 5.0 mg/KgBW 1st dose then 2.5 mg/KgBW every 72 hrs; 4-6 doses	9	9 (100%)	6 (66.7%)	0
ceftiofur 2.2 mg/KgBW every 72 hrs; 14 days	57	43 (75.4%)	29 (50.9%)	2 (3.5%)
gentamicin* 2.5 mg/KgBW every 72 hrs; 3-4 doses	27	24 (88.9%)	12 (44.4%)	2 (7.4%)
oxytetracycline 6.0 mg/KgBW every 24 hrs; 14 days	34	28 (82.4%)	7 (20.6%)	1 (2.9%)
trimethoprim + sulfadiazine 25.0 mg/KgBW every 24 hrs (lst 2 doses) then every 48 hrs; 8-10 doses	23	21 (91.3%)	15 (65.2%)	2 (8.7%)

* Nephrotoxic antibiotics: tortoises require diuresis by parenteral fluid administration during treatment regime.

Table 4. Summary of URTD cases, 1988-1992.

	Asymptomatic following treatment	URTD recurrence during study	Mortality
Adults n=83	31 (37.4%)	49 (59.0%)	3 (3.6%)
Subadults n=21	10 (47.6%)	10 (47.6%)	1 (4.8%)
Juveniles n=11	7 (63.6%)	1 (9.1%)	3 (27.3%)
Total n=115	48 (41.7%)	60 (52.2%)	7 (6.1%)

Table 5. Complex URTD infections and mortality.

Pasteurella testudinis (sole isolate)		
n=81		
Asymptomatic after regimen	40	49.4%
Recurrent episodes	41	50.6%
Mortality	0	
P. testudinis with other pathogens		
n=20		
Asymptomatic after regimen	6	30.0%
Recurrent episodes	10	50.0%
Mortality	4	20.0%

Immunological Competence in the Desert Tortoise (*Gopherus agassizii*) and Its Relationship to the Development of Upper Respiratory Tract Disease

Paul A. Klein and Isabella M. Fuerst

The immunological defense systems play a critical role in the ability of all animal species to resist and to recover from infectious diseases. It is possible that failure of the immune system of the desert tortoise to either recognize or to eliminate relevant pathogen(s) may be a major factor in the persistence and spread of the upper respiratory tract disease (URTD) which is afflicting these animals in their natural habitat. Efforts to eradicate URTD would be facilitated by the development of practical and reliable immunodiagnostic tests with which to evaluate immunological competence in the desert tortoise and to identify and monitor populations of infected, uninfected, and carrier tortoises in the wild. As part of a comprehensive immunological study, monoclonal antibodies are being developed which are specific for tortoise immunoglobulin sub-types and for tortoise immune system cell sub-populations. Tortoise immunoglobulins were purified from pooled tortoise plasma by ion-exchange and gel-filtration fusion of spleen cells from immunized mice with the sp2/O myeloma cells were screened by ELISA (enzyme-linked immunosorbent assay) and Western blot for desert tortoise IgG-specific monoclonal antibody production. Two hybridomas have been cloned, one which produces monoclonal antibodies specific for the heavy chain and will be used in immunoassays to monitor captive and free-ranging desert tortoises for exposure to putative URTD pathogens and to study antibody production in immunized healthy and sick desert tortoises.

Health Profiles of Wild Tortoises at the Desert Tortoise Natural Area, Ivanpah Valley and Goffs in California

Kenneth A. Nagy, Ian Wallis and Byron S. Wilson

Male and female radio-telemetered desert tortoises (*Gopherus agassizii*) living in three areas of the Mojave Desert--Desert Tortoise Natural Area near California City, Goffs, and Ivanpah--were sampled for health profiles four times during 1990-1991. The samplings coincided with pre-hibernation (October 1990), and hibernation (February/March 1991), late Spring (May 1991) and Summer (July/August 1991).

Tortoises were weighed upon capture, and then carried to a field laboratory where they were processed. This included a visual check for external symptoms of upper respiratory tract disease and for shell damage, blood sampling from a jugular vein and finally a nasal flush for microbial culture. Biological samples were processed immediately and delivered, within 24 hours, to APL Laboratories in Las Vegas. Health profiles are being determined from laboratory analyses of some 50 parameters.

There were few differences between male and female tortoises, and those which occurred were often weak ($P=0.05$) and confined to one season. There were exceptions: plasma calcium was higher ($P<0.001$) in females than in males in Autumn, Spring and Summer; cholesterol was higher ($P<0.001$) in females in all seasons; packed cell volume was higher ($P<0.01$) in males than in females during Autumn and early Spring.

In contrast, about 65% of all parameters showed differences between sites during one or more seasons. Of the blood parameters, nine (red and white blood cell counts, plasma protein, albumen, globulin, urea, glucose and sodium) varied between sites in three seasons. In most cases, higher values for each of these parameters were found at Goffs and/or Ivanpah relative to DTNA. Site by season interactions were common.

Heavy growth of *Pasteurella testudinis* occurred in 7% of the nasal cultures; 54% were free of the organism. Four of 185 cultures contained *Mycoplasma* sp. Positive cultures were dispersed evenly among males and females and the three sites.

Upper Respiratory Tract Disease (URTD) at the Desert Tortoise Conservation Center in Relation to the Origin and Nutritional Management of Tortoises

O.T. Oftedal, D.L. Freitas and P.S. Barboza

Data on the incidence of overt symptoms of URTD in desert tortoises at the Desert Tortoise Conservation Center were collected in collaboration with personnel from the Nevada Department of Wildlife, U.S. Bureau of Land Management, and the Drexel University research team. The following three management groups were distinguished for this analysis: holding pens ($n = 74$), nutrition pens ($n = 141$) and research pens ($n = 201$). The holding and nutrition pens were essentially equivalent in size (25' x 25' or 5-' x 50'), irrigated regularly, with patches of Bermuda grass (*Cynodon dactylon*) in some enclosures. These two groups differed in the type and amount of supplemental feed offered. Tortoises were provided with some alfalfa and a salad (containing produce, monkey biscuit and rabbit pellets) in the holding pens, while a nutritionally complete experimental diet was provided to animals in nutrition pens twice each week. The seven large research pens contained groups of 23 to 38 tortoises in 10 acres. Artificial or supplemental diets were not provided in the research pens but five enclosures were irrigated and planted with a mixture of legumes and grasses.

The incidence of URTD in the nutrition pens (4%) was significantly lower than either the holding (19%, $P<0.001$) or research (18%, $P<0.0001$) pens. Only singly housed tortoises from the nutrition and holding pens were considered in this analysis to limit any effect of disease transmission. The effect of the original population on the incidence of URTD was assessed by classifying each animal at high or low risk depending on the proportion of symptomatic animals initially collected at its capture site. There were no significant differences ($P>0.05$) in the proportions of high and low risk tortoises between groups. These data suggest that husbandry practices, and especially nutritional management, may influence the appearance of overt symptoms of URTD in the desert tortoise.

Desert Tortoise Research Program: *Pasteurella testudinis*

Kurt P. Snipes and Rick W. Kasten

The gram-negative bacterium *Pasteurella testudinis* has been associated with Upper Respiratory Tract Disease (URTD) in the desert tortoise, but its precise role in URTD pathogenesis remains uncertain. On the basis of previous studies, *P. testudinis* is probably not a primary pathogen that can cause disease in the absence of other predisposing factors. If *P. testudinis* is the etiologic agent ultimately responsible for URTD, it most likely requires some additional stressor(s), such as another microbe (e.g., mycoplasma), to produce disease. The fact remains, however, that *P. testudinis* is more frequently isolated from tortoises with URTD than from healthy tortoise, can be recovered from upper respiratory tract lesions and exudate from those tortoise, and is also isolated from tortoises with apparently unrelated pathologic processes such as stomatitic lesions and other abscesses. For these reasons, it is important to better understand mechanisms by which *P. testudinis* may cause disease and how potentially more virulent strains may be maintained and spread in populations of tortoises.

The primary objectives of the *P. testudinis* study's portion of the Desert Tortoise Research Program are: (1) determine if particular strains of *P. testudinis* are more pathogenic for tortoises than others; (2) if certain strains are more pathogenic, determine why; (3) study the molecular epidemiology; and (4) study the antigenic composition of strains isolated from tortoises with URTD.

Methods being used for the characterization of *P. testudinis* include biochemical, genomic or DNA fingerprinting (ribotyping), sensitivity to the bactericidal effect of normal tortoise serum, and analysis of proteins in the bacterial outer membrane.

Preliminary ribotyping results have revealed a genetically heterogeneous population. Twenty-two distinct ribotypes have been observed in 40 isolates typed to date. Isolates ($n = 13$) from tortoises with URTD have fallen into only three ribotypes so far; an additionally 113 isolates from both ill and healthy tortoises are currently being processed. The ability of certain strains (e.g., from tortoises with URTD) to resist the bactericidal effect of normal serum, an acknowledged virulence factor in other species of *Pasteurella*, has not been demonstrated.

Continuing research on *P. testudinis* will include the attempted confirmation that certain ribotypes represent more pathogenic strains, and if we can define "pathogenic ribotypes," then comparison of traits of those strains with non-pathogenic ribotypes. Such traits to be compared would include interaction with phagocytic cells, ability to scavenge iron from the host, colonization of tortoise upper respiratory epithelium potential production of toxin(s), and possession of immunogenic outer membrane proteins. In addition, we will continue to study the molecular epidemiology of *P. testudinis*, focusing on transmission and reservoirs of strains associated with URTD.

Incidence of Upper Respiratory Tract Disease (URTD) in the Las Vegas Valley: Update of Results from the Desert Tortoise Lawsuit Settlement Collections

Cristopher R. Tomlinson and D. Bradford Hardenbrook

As part of a lawsuit settlement agreement between the U.S. Department of Interior and the City of Las Vegas, State of Nevada, and various development interests, removal of 903 tortoise from approximately 7,000 acres occurred between June 1990 and September 1991 in the Las Vegas Valley. Animals collected became available for use in high priority investigations for the conservation of the species. Collection, handling, and quarantine protocols were developed in addition to federal permit conditions in an effort to gain baseline information while minimizing risks of stress and potential spread of URTD. In compliance with the federal permit, 30 tortoises removed from the site of the Desert Tortoise Conservation Center were released near their points of collection.

Signs of URTD were observed in 125 (14.3%) of the 873 tortoises retained for studies. Most tortoise symptomatic of URTD were collected from five properties located on the west-northwest margins of Las Vegas. The highest incidence of URTD was observed from the Summerlin (27%) and Peccole Ranch (31%) properties. These two properties were located adjacent to Charleston Boulevard (SR159) which is the main route to the Red Rock Canyon National Conservation Area and along which previous releases of captive tortoises have occurred. Only four (2%) of 222 animals collected from the southwest portion of the Valley, displayed signs of URTD.

Four of 10 tortoises determined to be previously released captive animals among the 621 collected from the west-northwest margins of Las Vegas were symptomatic of URTD. None of the three captive released tortoises collected from the southeast portion of the Valley displayed URTD signs.

Nasal cultures were obtained from 369 tortoise to detect the presence of *Mycoplasma* sp. and *Pasteurella testudinis*. Of the 216 animals considered healthy, 102 (39%) tested positive for *Mycoplasma* sp., *Pasteurella testudinis*, or both. In comparison, 90 (83%) of the 108 tortoises symptomatic with URTD tested positive for either or both of these suspected pathogenic microorganisms.

Health Profile Results from the Honda Desert Tortoise Relocation Project

Michael Weinstein

A one-square-mile portion of the Desert Tortoise Natural Area has been divided into four fenced study plots. Seventy-four tortoises were relocated in 1990 from a nearby area and placed with approximately 68 resident tortoises. The four study plots consisted of two containing only resident tortoises, of which one plot was artificially irrigated, and two plots containing both resident and relocated tortoises, of which one plot was artificially irrigated. Each tortoise is a member of one of 6 unique groups or "Cohorts:" (1) resident tortoises inhibiting an irrigated plot by themselves; (2) resident tortoises inhibiting an unirrigated plot by themselves; (3) resident ("Host") tortoises cohabiting an irrigated plot with relocated tortoises; (4) resident ("Host") tortoises cohabiting an unirrigated plot with relocated tortoises; (5) relocated ("Guest") tortoises cohabiting an irrigated plot with Cohort 3 Host tortoises; and (6) relocated ("Guest") tortoises cohabiting an unirrigated plot with Cohort 4 Host tortoises.

External symptoms of Upper Respiratory Tract Disease (URTD) for all tortoises have been monitored approximately once per month from April through September for the past two years. Approximately 50-60 tortoises also have had blood and nasal flush samples taken 2-3 times per year. Blood samples were analyzed for a multitude of parameters, including hematocrit, blood urea nitrogen level, white blood cell and red blood cell counts, hemoglobin, glucose, sodium, potassium, chloride, creatinine, uric acid, protein, albumin, globulin, cholesterol, bilirubin, and several other factors. Nasal flushes were analyzed for types of bacteria and presence of *Mycoplasma*.

Tortoises that show external symptoms of URTD at one time do not necessary show it on others. Tortoises that test positive for *Mycoplasma* at one time do not necessarily test positive for it later. Correlations between *Mycoplasma* test results and external symptoms recorded concurrently are low. However, correlations between tortoises that have ever shown external URTD symptoms and tortoises that have ever tested positive for *Mycoplasma* are considerably higher. An Analysis of Variance (ANOVA) showed this relationship to be statistically significant. External symptoms were noted significantly more frequently for tortoises in non-irrigated plots than for tortoises in irrigated plots. There was no significant difference between Resident, Host, or Guest tortoises in external URTD symptoms. Forty-six tortoises appear to have died so far. ANOVA tests at the 0.05 level showed no significant difference between mortality rates for tortoises in irrigated as opposed to non-irrigated plots. There was, however, a significantly higher mortality rate for relocated (Guest) tortoises than for either Resident or Host tortoises. This higher mortality rate does not appear to be associated with higher rates of predation, nor with food and water availability. There was no significant difference in mortality rate between tortoises with and without external URTD symptoms nor between tortoises that tested positive for *Mycoplasma* and those that did not. Remarkably, significantly fewer of the tortoises that were sampled for blood died than did those tortoises that were never sampled.

Does 10-Year Exclusion of Cattle Improve Condition of Desert Tortoise Habitat?

Harold W. Avery

In 1981 a cattle exclosure was built in the eastern Mojave Desert of California in Ivanpah Valley, by the Bureau of Land Management. The purpose of the exclosure was to facilitate the comparison of vegetation and soil under grazed and ungrazed conditions. In spring and early summer of 1991 measurements of annual and perennial plants and soil parameters were completed inside and outside the Ivanpah Valley exclosure. Measurements of annuals included plant cover, density and plant biomass. Perennial measurements included shrub and perennial grass volume, estimates of total canopy cover, and linear distance between conspecific plants, among other measurements. Soil parameters included bulk density, penetration resistance and hydraulic conductivity.

No difference in annual plant cover (ANOVA $P=0.535$), biomass (ANOVA $P=0.709$) or density (ANOVA $P=0.899$) existed between the grazed and ungrazed plots. Volumes of creosote bushes (*Larrea tridentata*) were greater outside the exclosure than those inside (ANOVA $P< 0.0001$). Likewise, burrobushes (*Ambrosia dumosa*) were larger outside the exclosure than inside (ANOVA $P=0.909$). However, perennial grasses (*Hilaria rigida*) were significantly greater in volume and number inside the exclosure versus outside.

Bulk density of soil was significantly greater outside the cattle exclosure compared to inside (ANOVA $P<0.0001$). These data indicate that the soil is more compacted in the grazed plot compared to the ungrazed plot. There was no difference in hydraulic activity between the grazed and ungrazed plots (ANOVA $P=0.938$), indicating that soil compression in grazed areas is not sufficient enough to reduce the rate of water transit into the soil.

Difference in vegetation and soils are discussed in the context of desert tortoise ecology.

Summer Food Habits of Desert Tortoises in Ivanpah Valley, California

Harold W. Avery

Summer food habits and preferences were determined for free-living desert tortoises in August and early September, 1991 in Ivanpah Valley, eastern Mojave Desert, California. Tortoises were tracked and observed with binoculars to determine plants consumed and number of bites taken of each species. After tortoises completed foraging for the morning or evening, availability of annual plants was determined by counting plants in 20 cm x 50 cm quadrats placed every 20 m along foraging pathways.

Food preferences were determined for tortoises using the Ivlev Electivity Index. Summer annuals available to tortoises included needle grama (*Bouteloua aristidoides*; Grass Family), sixweeks grama (*Bouteloua barbata*; Grass Family), windmills (*Allionia incarnata*; Four-O'Clock Family), Wright's boerhaavia (*Boerhaavia wrightii*; Four-O'Clock Family), California kallstroemia (*Kallstroemia californica*; Caltrop Family), fringed amaranthus (*Amaranthus fimbriatus*; Amaranth Family) and cinchweed (*Pectis papposa*; Sunflower Family). Needle grama, sixweeks grama and immature grama constituted 87% of available annual plants. Tortoises mostly consumed grama grasses (98% of 1,829 total bites observed). Ivlev's Electivity Indices for annual plants indicate that tortoises weakly prefer mature grama grasses and less prefer immature grama grasses and avoid all other species of available annuals. Possible reasons for plant avoidance are discussed within the framework of tortoise feeding ecology.

Comparative Nutritional Ecology of Tortoises and Turtles

Karen A. Bjorndal and Alan B. Bolten

Tortoises and turtles can achieve digestibilities similar to those of mammals, but, as would be expected from their lower metabolic demands, turtles have lower intakes and longer passage times. In a series of studies on free-feeding turtles on foliage diets, digestibilities for cell walls ranged from 15 to 90% and for energy from 20 to 80% with intakes from 1.2 to 3.5 g dry matter per kg live mass per day (Bjorndal 1980, 1982, 1985, 1986, 1987, 1989; Hamilton and Coe 1982; Bjorndal and Bolten 1990). Turtles lack the ability to mechanically reduce particle size of their food; the large particle size of the digesta affects the dynamics of digestive processing (Bjorndal et al. 1990).

Characteristics of the fermentations have been described for a few species of turtles (Bjorndal 1979, 1987; Guard 1980; Bjorndal and Bolten 1990; Bjorndal et al. 1991) and are similar to those described in other vertebrates. The fermentation region in all reptiles studied (see review in Zimmerman and Tracy, 1989) is the hindgut, except for the freshwater turtle *Pseudemys nelsoni* in which 79% of VFA production is in the small intestine (Bjorndal and Bolten 1990). The nutritional ramifications of shifting the fermentation into the small intestine could be great and require further study. It would seem that *P. nelsoni* has lost the major advantage of a hindgut fermentation--the opportunity for the host animal to digest and absorb dietary protein and soluble carbohydrates before the digesta enters the fermentation region. The most apparent benefit to *P. nelsoni* is the increase in the volume of the fermentation vat. Herbivorous reptiles fit the relationship of mass of fermentation contents to body mass described by Parra (1978) for mammals (Troyer 1984; Bjorndal and Bolten 1990). *Pseudemys nelsoni* fits the relationship only if the mass of small intestine contents is included. Gut morphology does not necessarily constrain digestive processing in turtles; there is greater flexibility in digestive processing than would be predicted from gut morphology alone.

Digestive processing is quite variable in those turtles that ingest a range of plant species. Most tortoises are generalist herbivores, feeding on fruits, flowers and foliage. *Geochelone carbonaria* and *G. denticulata* are South American tortoises that ingest a diet comprised of many species with a wide range of composition (Moskovits and Bjorndal 1990). Feeding trials conducted with these tortoises on three diets (two fruits and one foliage) demonstrated flexibility in digestive processing (Bjorndal 1989). Tortoises feeding on guava fruits had high intakes, rapid transit times (3 days) and little cell wall fermentation. On a diet of lantana foliage, tortoises had low intakes, slow (9 day) transit times and extensive cell wall fermentation. Similar flexibility in digestive processing has been demonstrated in two species of freshwater turtles *P. nelsoni* and *Trachemys scripta* feeding on two aquatic plants: hydrilla and duckweed (Bjorndal and Bolten in prep.).

Feeding trials conducted with single-species diets do not address the greater complexity of diet interactions and digestive processing in animals feeding on natural, mixed diets. Adult *T. scripta* ingest approximately 20% animal matter and 80% plant matter (Parmenter 1980). To assess the interactions of this mixed diet, feeding trials were conducted in which *T. scripta* were fed duckweed, insect larvae, or a mixed duckweed:larvae diet (77:23 by dry mass). The actual digestibilities of the mixed diet were significantly greater than those predicted from the digestibilities of duckweed diet and larvae diet fed alone (a significant, positive associative effect). The significant increase in digestibility of the mixed diet could be attributed to increased digestion of duckweed, with greatest increase for the cell wall fraction (Bjorndal 1991). By ingesting animal matter with duckweed, *T. scripta* increases energy gain from duckweed by 70% and nitrogen gain from duckweed by 20%. Associative effects deserve greater attention in studies of diet selection and optimal foraging.

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Diet Selection and Habitat Use By the Desert Tortoise in the Northeast Mojave Desert

Todd C. Esque

This report describes results from the 1991 field season. This is part of an integrated, cooperative research project designed to understand diet selection and habitat selection in two populations of desert tortoises in the northeast Mojave Desert. Selection is defined as: the use of resources with frequencies different from those expected at random based on their availability.

The role of diet selection in the ecology of the desert tortoise is not well understood, however, it may have implications in resolving important questions related to: livestock grazing, disease, and baseline health profiles. Habitat use has important management implications. Management agencies must determine what parcels of habitat will be kept, and what parcels of habitat will be lost to other land uses. Habitat use analyses such as these may be used to help us determine reserve boundaries.

Adult male and female tortoises were studied at the City Creek study Plot in Washington County, Utah and the Littlefield Study Plot in Mohave County, Arizona. Diet was described by observing wild tortoises and recording the species name for every bite the tortoises ate. Above ground biomass and frequency of spring annual vegetation was estimated by species within each subhabitat at the two sites. Habitat use was measured by plotting localities throughout the year and also using behavioral observations of tortoises. Selection of diet or habitat use was determined by comparing use to availability. Chi-squared analysis was used to test the hypothesis that tortoises used resources (plant species or subhabitat patches) with greater or lesser frequency than would be expected at random. Home ranges of desert tortoises were determined using the minimum convex polygon. Geographic Information System (GIS) was used to analyze habitat use. Habitat selection was determined by comparing the area of each subhabitat used by tortoises with the area of each subhabitat available to tortoises.

Tortoises sampled a large proportion (>30%) of the flora, however, only a small proportion of the species were eaten with great frequency (Fig. 1 and Table 1). Tortoises showed preference and avoidance for both native and exotic annual plant species. Woody perennial plants did not occur in the diet to a great extent.

Habitat use analyses, to date, do not indicate strong selection for any subhabitat type except Transition at City Creek, Utah. However, it is clear from seasonal patterns of habitat use that wintering dens play an important role in site selection. GIS surveys show that tortoises in the N. St. George population use travel corridors that appear to be based on topography.

Tortoises selected less individual plant species at City Creek, Utah and Littlefield, Arizona in 1990 than in 1991 (Fig. 2a,b,c,d). The greater diversity of plants available in 1991 may have provided tortoises with an opportunity for selection not present in other years. A wild mustard (*Lepidium flavum*) was a preferred species at both sites in 1991. Woolly Daisy (*Eriophyllum wallacei*) was avoided at City Creek in both years, but it was rare at Littlefield. Big galleta grass (*Hilaria rigida*) appeared to be highly preferred, but that was because it was rare at City Creek and only occurred once on vegetation surveys. Exotic annual plants were present in the diet as preferred and avoided species, but their selection index shifts by year and location. It will be interesting to note possible relationships of diet preference to nutrition

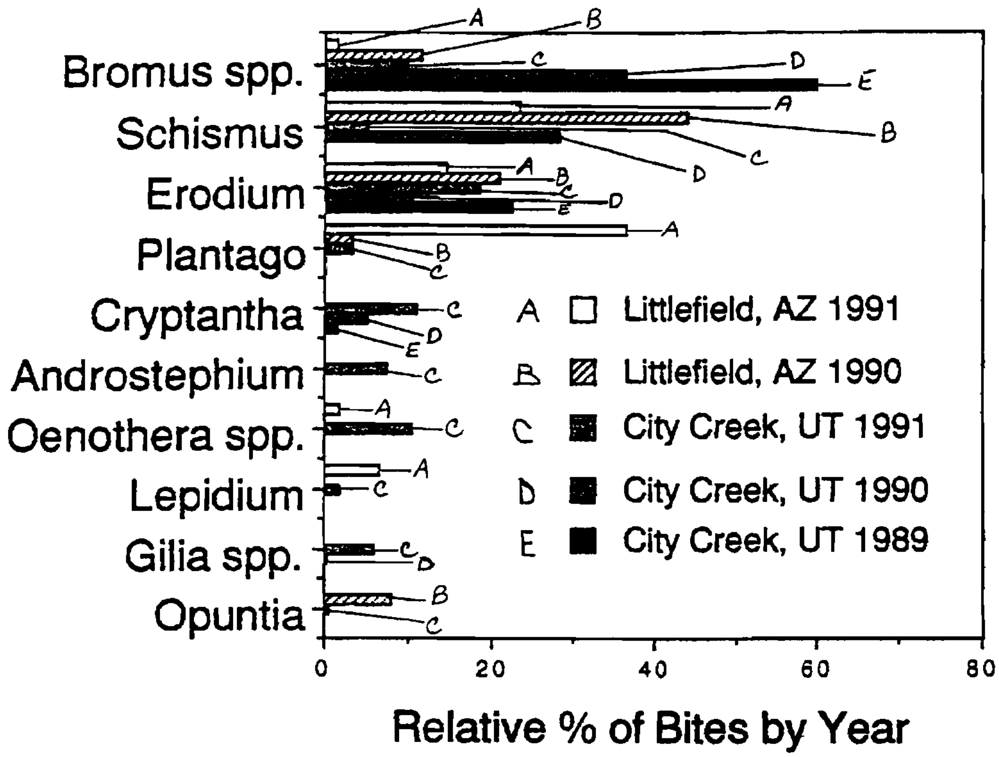


Figure 1. Diet of desert tortoises in the Mojave Desert. These species represent >5% of the relative proportions of diets in respective years.

Table 1. Plants found in desert tortoise diet at City Creek, Utah (1989, 1990, 1991) and Littlefield, Arizona (1990, 1991) that were <5% of the relative percentage of percentage of bites in a given year.

Abronia fragans	*Chorizanthe rigida*	*Crypthantha virginensis*
Eriastrum eremicum	*Eriophyllum wallacei*	*Helianthus anomalus*
Lesquerella tenella	*Opuntia erinacea*	*Rafinesquia neomexicana*
Androstephium breviflorum	*Chorizanthe thurberi*	*Descurainia pinnata*
Eriogonum fasciculatum	*Euphorbia parryi*	*Heterotheca villosa*
Mirabilis sp.	*Oryzopsis hymenoides*	*Salsola iberica*
Aristida purpurea	*Coleogyne ramossisima*	*Dithyrea wislizenii*
Eriogonum inflatum	*Gaura coccinea*	*Hilaria rigida*
Monoptilon belliodes	*Pectocarya recurvata*	*Schismus barbatus*
Bromus rubens	*Cryptantha angustifolia*	*Echinocerus engelmannii*
Eriogonum maculatum	*Gilia leptomeria*	*Krameria parvifolia*
Oenothera pallida	*Phacelia ivesiana*	*Stephanomeria exigua*
Bromus tectorum	*Cryptantha micrantha*	*Ephedra nevadensis*
Erioneuron pulchellum	*Gilia* sp.	*Langloisia setossisima*
Oenothera primiveris	*Plantago insularis*	*Streptanthella longirostirs*
Ceratoides lanata	*Cryptantha nevadensis*	*Erodium cicutarium*
Eriogonum thomasii	*Gutierrezia* ssp.	*Lepidium flavum*
Opuntia basilaris	*Plantago patagonica*	*Thysanocarpus curvipes*
Yucca utahensis		

Figure 2. Diet selection of desert tortoises in the northeast Mojave Desert for plants that occurred >9 times in use or availability data. (2a - City Creek, Utah 1990, b - City Creek,, Utah 1991, 2c - Littlefield, Arizona 1990, 2d - Littlefield, Arizona 1991).

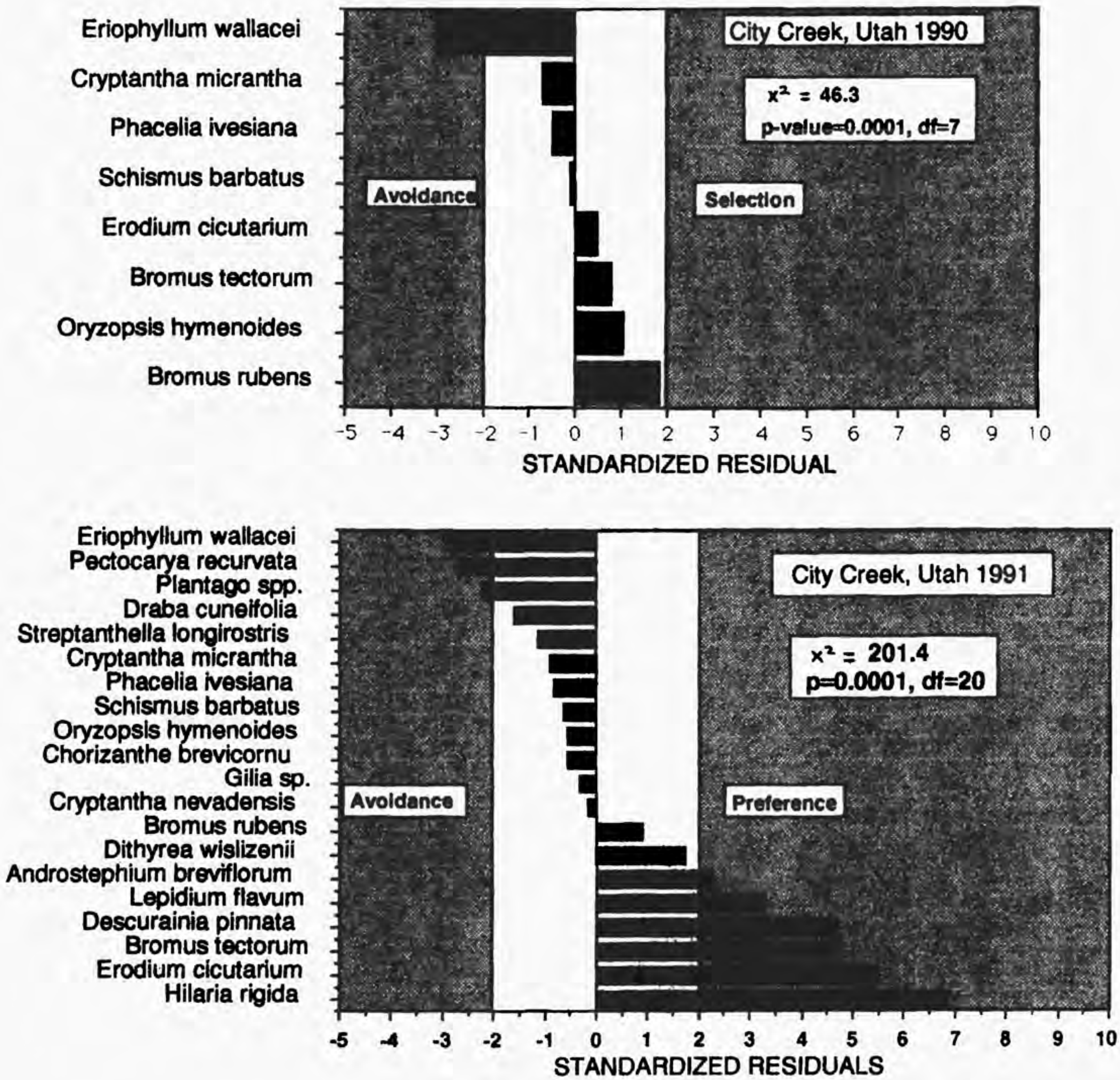
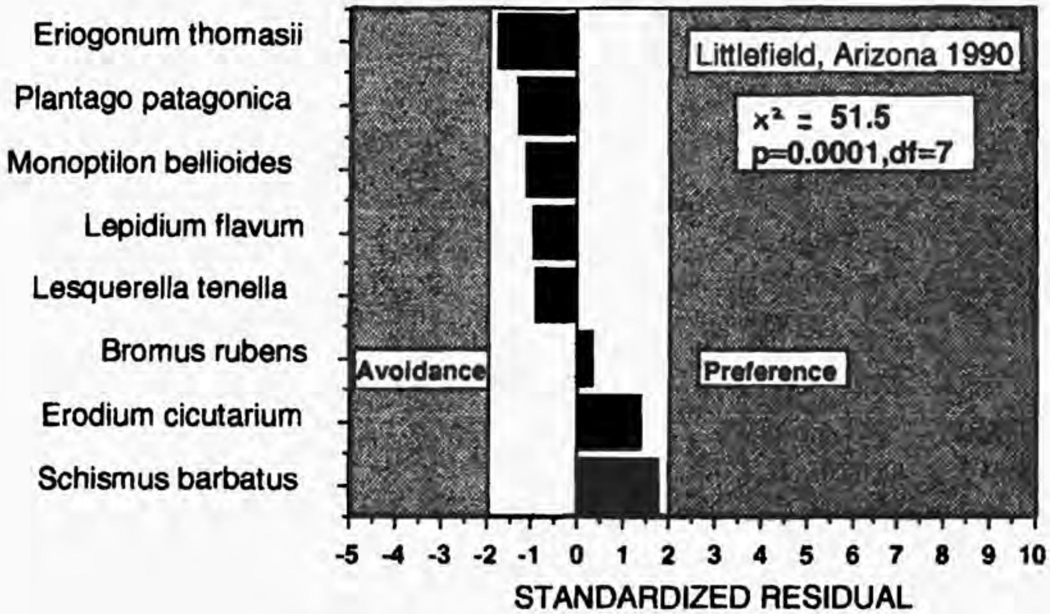


Figure 2b.



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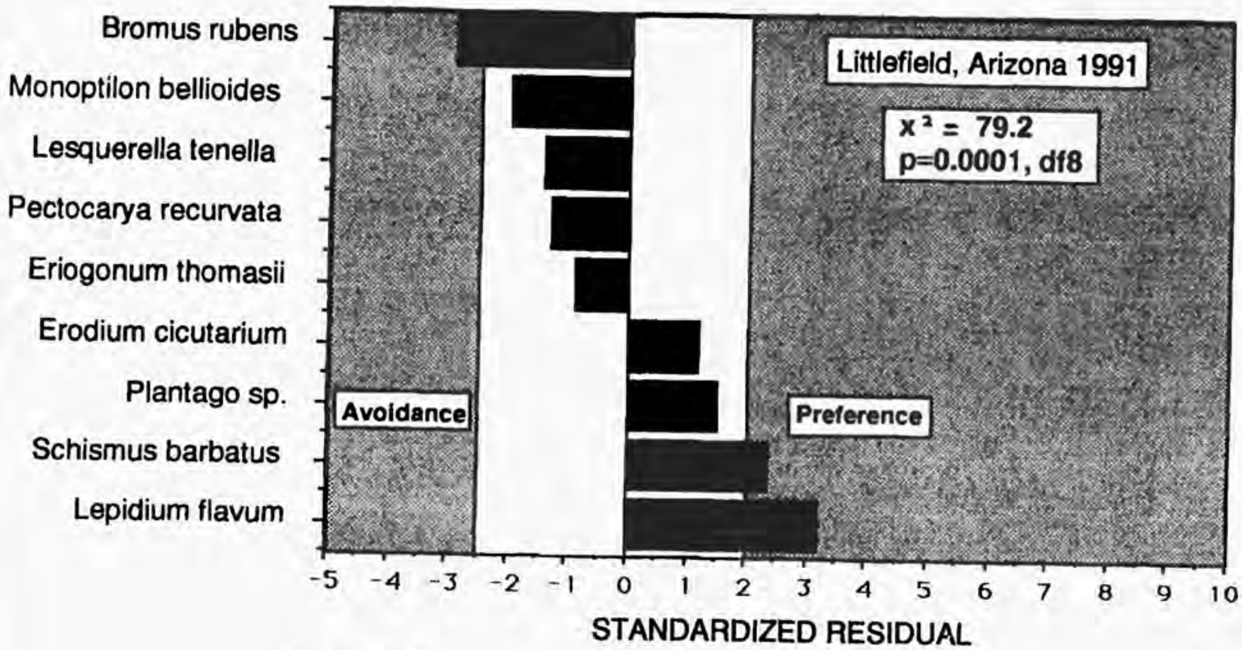

Figure 2d.

of selected plants as those data become available.

The number of feeding observations by subhabitat type did not reveal a strong trend in subhabitat selection. Methods used to determine habitat selection may have oversimplified habitat use by desert tortoises. Home range distributions clearly occur in a pattern that avoids large expanses of rock except in natural corridors. Further analyses will be necessary if we are to understand the mechanisms behind the patterns observed. Variables of particular interest are: seasonality of use, nutrition of available plants, and social structures within groups of tortoises.

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Observations on the Feeding Behavior of Desert Tortoises (*Gopherus agassizii*) at the Desert Tortoise Research Natural Area, Kern County, California

W. Bryan Jennings and Clifford L. Fontenot, Jr.

Abstract. Data on the feeding habits and food preferences of two adult desert tortoises (*Gopherus agassizii*) were collected during May and June 1991 at the Desert Tortoise Research Natural Area in Kern County, California. One adult female and one male tortoise were observed for a total of 24 days, during which time they took 8,612 bites from 757 individual annual plants (21 species) and 3,483 bites from 171 individual herbaceous perennial plants (5 species). Both tortoises were highly selective feeders that largely favored relatively rare plant species. Moreover, several of these uncommon species (e.g., *Astragalus layneae*) were restricted to the margins of small (< 2 m wide) washes. Tortoises spent a considerable amount of time foraging along small washes and were successful at locating these uncommon species. Native composites (e.g., *Lygodesmia exigua* and *Stephanomeria parryi*) and native legumes (e.g., *Astragalus layneae*, *A. didymocarpus*, and *Lotus humistratus*) seemed to be important plant groups in tortoise diet (28% bites/19% plants and 27% bites/22% plants respectively). Further, native plant species were consumed more frequently than non-natives (88% bites/70% plants vs. 12% bites/30% plants respectively).

INTRODUCTION

Desert tortoise (*Gopherus agassizii*) populations have, over the past few decades, been rapidly declining (Berry 1984). Factors that have been implicated in this on-going decline include: chronic respiratory diseases (i.e., Upper Respiratory Tract Disease Syndrome); illegal collecting; raven predation on juveniles; and habitat loss and alteration (Luckenbach 1982; Bureau of Land Management 1988). Upper Respiratory Tract Disease Syndrome has been particularly devastating to tortoise populations at the Desert Tortoise Research Natural Area in eastern Kern County, California (Avery and Berry 1991; Jacobson et al. 1991). Although indirect evidence suggests that disease-carrying domesticated desert tortoises released into the wild are responsible for this outbreak, research shows that a dietary link to the susceptibility of diseases may exist (Jacobson et al. 1991). For many decades, the plant communities in the western Mojave Desert have been altered by human-related activities such as livestock grazing (Berry 1978) and off-road vehicle use (BLM 1988). Invasions by introduced plants following livestock grazing in the arid southwestern United States are well documented (D'Antonio and Vitousek 1992). These unnatural habitat disturbances have resulted in the rampant spread of mediterranean exotics such as filaree (*Erodium cicutarium*), split-grasses (*Schismus* spp.), brome grasses (*Bromus* spp.), and native weeds such as fiddleneck (*Amsinckia tessellata*) (Robbins et al. 1951). Succession in desert plant communities by mediterranean annuals has also been documented in other desert regions containing declining tortoise populations (Esque et al. 1990 and 1991). If tortoises depend upon certain native plant species to maintain their proper health, and these particular species become either reduced in abundance or competively excluded by invasive species of inferior dietary quality, then tortoise populations may become more susceptible to diseases (Jacobson et al. 1991).

In 1991, the Bureau of Land Management sponsored a preliminary study of tortoise food habits at the Desert Tortoise Research Natural Area. The purpose of the project was to identify which plant species tortoises feed upon, determine if they are selective feeders, and observe their feeding habits.

METHODS

The study site was located within sections 1, 11, and 12 of Township 31 S, Range 38 E at the Desert Tortoise Research Natural Area in Kern County, California. At an elevational range of 850-915 m, the vegetational community was generally dominated by creosote bush (*Larrea tridentata*), burro-bush (*Ambrosia dumosa*) and goldenhead (*Acamptopappus sphaerocephalus*). An adult male (279 mm CL at the midline) and female (238 mm CL at the midline) desert tortoise were observed for a total of 24 days between 3 May and 14 June 1991. These particular animals were selected because they were part of an on-going health and disease profile study. The tortoises were located early in the day, using radio-telemetry equipment, when they were about to emerge from their respective cover sites (burrow, shrub, etc.) for daily activity.

Once a tortoise emerged from its cover site, it was then followed at distances of 4-8 m. This distance was determined to be effective at minimizing disturbance to the tortoises caused by our presence, yet close enough to clearly observe feeding habits and behavior. When a tortoise was observed feeding, the following data were recorded: (1) species of plant; (2) number of bites; (3) condition of the plant e.g., whether it was succulent (containing water) or dry (containing no water).

When the tortoise retreated to cover at midday and at the end of the day, 15 X 50 cm rectangular quadrats were positioned lengthwise at intervals along feeding routes. Quadrat sites were selected either randomly or placed in front of a spot where a plant was fed upon. We used 102 quadrats for the feeding routes of the female tortoise and 127 quadrats were used for the male. The plants within each quadrat were then identified to species, counted, and determined to be either succulent or dry. Nomenclature for plant species follows Munz (1974).

To determine if tortoises are selective feeders, the frequency of occurence for each plant species along tortoise feeding routes was compared to the frequency of occurence in tortoise diet using a R x C test of independence (Sokol and Rohlf, 1981).

RESULTS

Female Tortoise. - Once the female tortoise emerged in the morning, she would typically warm up in the sun for a short time (ca. 10-30 minutes), then start feeding. Her feeding patterns were often repeated. She would emerge from a cover site and head nearly straight for her next cover site while feeding along the way on selected plants. While traveling, she would move her head from side to side apparently scanning ahead for potential food plants. Although she seemed to select plants by visually cueing in on them, she would occasionally sniff individual plants before either choosing to feed upon or continue foraging.

The female tortoise fed upon 11 species of annual and 2 species of perennial plants taking 4,697 bites from 306 individual plants (Table 1). The three most-eaten species of plants were: *Lygodesmia exigua*, 2,069 bites (44.0%); *Astragalus layneae*, 1,011 bites (21.5%); and *A. didymocarpus*, 870 bites (18.5%). Moreover, the female tortoise never passed any of the aforementioned species without consuming the entire plant. Of the 306 plants sampled by the female tortoise, 291 (95.1%) were succulent while the remaining 15 (4.9%) were dry (Table 1).

A comparison of the relative abundance of succulent annuals along the feeding routes of the female tortoise with diet reveals that she was a very selective feeder (x^2 = 465.1, d.f. = 15, P = 0.0001; Table 2 and Fig. 1). Nearly 40% of her diet consisted of plants that were not detected in the vegetation samples (Fig. 1). Personal observations confirm that her favorite plants are locally uncommon. Although, these plant species grow in restricted areas, hence, tortoises are able locate them.

The female tortoise spent a considerable amount of time traveling and foraging along "small" (< 2 m wide) washes. Many of her more-preferred plants grew almost exclusively in or along these same washes (e.g., *Astragalus layneae, Camissonia boothii, Mentzelia eremophila,* and *Cryptantha circumcissa*). Moreover, all seven of her burrows (permanent and pallet burrows) were located within 3 m of a small wash. She tended to avoid the wide washes (> 2 m wide) and would only occasionally cross them.

Male Tortoise. - The male tortoise exhibited feeding patterns similar to those of the female tortoise. He would emerge from a cover site and warm up for ca. 10-30 minutes, then he would initiate feeding activity. The male characteristically moved his head from side to side and seemed to locate food items by sight. Occasionally, he would sniff a plant or the ground. As was the case for the female tortoise, his feeding routes extended between consecutive cover sites. He would feed on selected plants while heading directly for his next cover site.

The male tortoise fed upon 20 species of annuals and 5 species of perennial plants taking 7398 bites from 622 individual plants (Table 3). The five most-eaten species of plants were: *Erodium cicutarium*, 1,442 bites (19.5%); *Astragalus layneae*, 1,281 bites (17.3%); *Mentzelia eremophila*, 1,253 bites (16.9%); *Stephanomeria parryi*, 939 bites (12.7%); *Chorizanthe brevicornu*, 882 bites (11.9%). Like the female, the male tortoise never passed some species without consuming the entire plant (e.g., *Astragalus layneae; A. didymocarpus; Mentzelia eremophila; Lygodesmia exigua; Glyptopleura marginata; Camissonia boothii;* and *Stephanomeria parryi*). Of the 622 plants sampled by the male tortoise, 601 (96.6%) were succulent while the remaining 21 (3.4%) were dry (Table 3).

The male tortoise was also a highly selective feeder (x^2 = 139.5, d.f. = 8, P=0.0001; Table 4 and Fig. 2). Moreover, several of the plant species which were in the diet were not represented in the vegetation samples (Figure 2). The male tortoise also spent a considerable amount of time traveling and foraging in and along small washes. Several species in the diet grew exclusively along the margins of small washes (e.g., *Astragalus layneae, Stephanomeria parryi*, and *Camissonia boothii*).

Both tortoises consumed many of the same species of plants. For example, both tortoises fed almost exclusively on plants which grew in exposed areas such as the intershrub spaces and along washes. Moreover, plants in which the tortoises usually ate the entire plant included: *Mentzelia eremophila, Lygodesmia exigua, Astragalus layneae*, and *Stephanomeria parryi*. The male tortoise tended to eat the seeds and leaves of *Erodium cicutarium* and would

Table 1. Number of bites of annual and perennial plant species taken by the adult female tortoise between 3 May and 11 June 1991 at the Desert Tortoise Research Natural Area, Kern County, California.

	Plant Species	# Bites	% Bites	# Plants	% Plants
	Lygodesmia exigua	2069	44.05	111	36.27
**	*Astragalus layneae*	1011	21.52	55	17.97
	Astragalus didymocarpus	766	16.31	60	19.61
	Cryptantha circumcissa	307	6.54	33	10.78
	Camissonia boothii	129	2.75	12	3.92
*	*Astragalus didymocarpus*	104	2.21	13	4.25
	Malacothrix coulteri	85	1.81	1	0.33
	Mentzelia eremophila	70	1.49	5	1.63
	Erodium cicutarium	48	1.02	7	2.29
**	*Mirabilis bigelovii*	46	0.98	2	0.65
	Calycoseris parryi	31	0.66	3	0.98
	Glyptopleura marginata	20	0.43	1	0.33
*	*Mentzelia eremophila*	4	0.09	1	0.33
*	*Amsinckia tessellata*	4	0.09	1	0.33
	Choizanthe brevicornu	3	0.06	1	0.33
	Totals	4697	100.00	306	100.00

* Plant in a "dry" state
** Herbaceous perennial

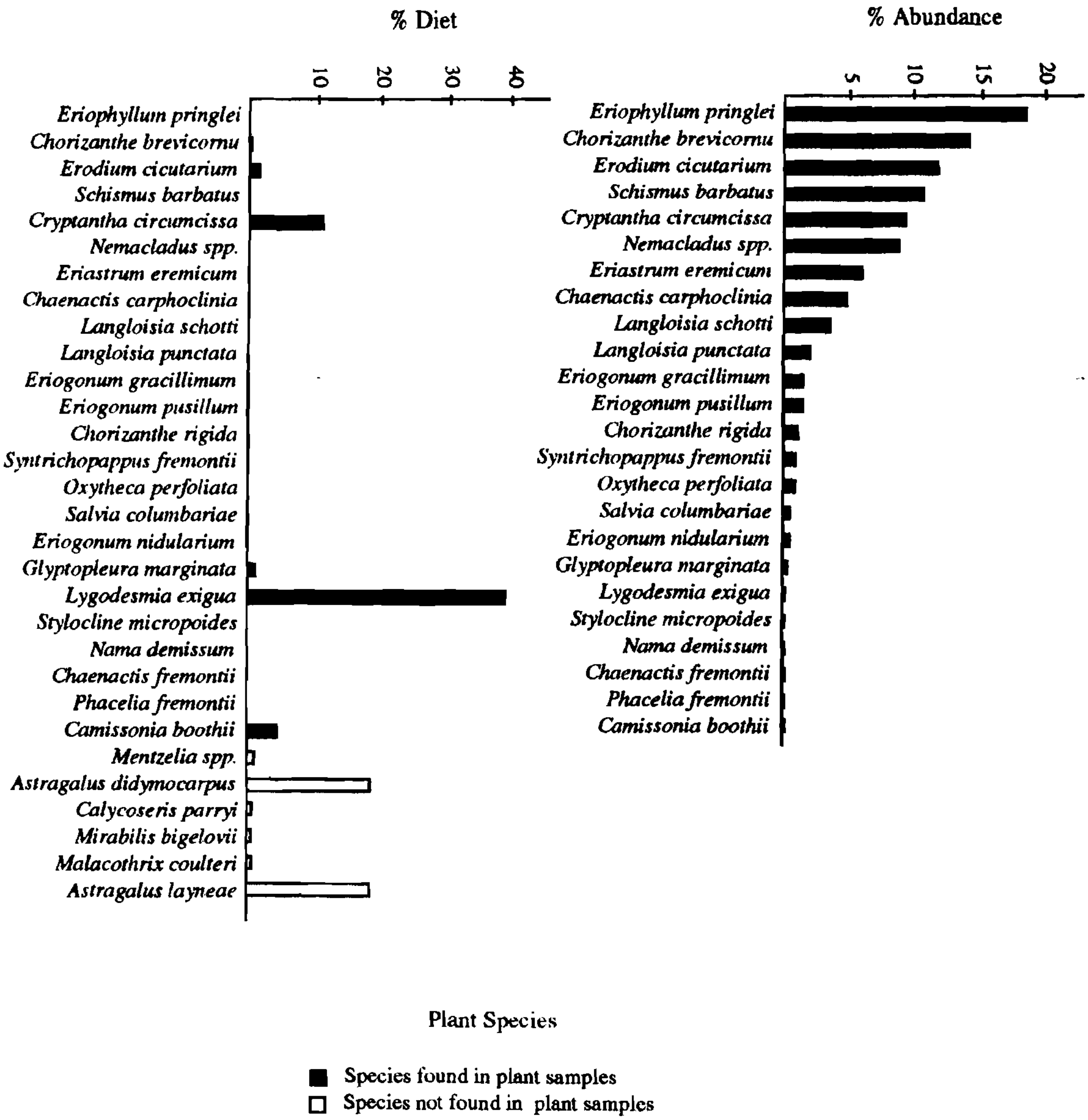

Figure 1. Comparison of relative abundance of plants along the feeding routes of the female tortoise (top graph) with the relative contribution of those plant species to the diet of the female tortoise (bottom graph).

Table 2. A comparison of the availability of succulent annual plants along the feeding routes with diet of the female tortoise.

Plant species	% Abundance	% Diet
Eriophyllum pringlei	17.94	0.00
Chorizanthe brevicornu	13.93	0.69
Erodium cicutarium	11.83	2.41
Schismus barbatus	10.69	0.00
Cryptantha circumcissa	9.54	11.34
Nemacladus spp.	8.97	0.00
Eriastrum eremicum	5.92	0.00
Chaenactis carphoclinia	4.96	0.00
Langloisia schotti	3.44	0.00
Langloisia punctata	2.29	0.00
Eriogonum gracillimum	1.91	0.00
Eriogonum pusillum	1.91	0.00
Chorizanthe rigida	1.34	0.00
Syntrichopappus fremontii	1.15	0.00
Oxytheca perfoliata	1.15	0.00
Salvia columbariae	0.57	0.00
Eriogonum nidularium	0.57	0.00
Glyptopleura marginata	0.38	1.37
Lygodesmia exigua	0.38	38.14
Stylocline micropoides	0.38	0.00
Nama demissum	0.19	0.00
Chaenactis fremontii	0.19	0.00
Phacelia fremontii	0.19	0.00
Camissonia boothii	0.19	4.47
Totals	100.00	58.42

Table 3. Number of bites of annual and herbaceous perennial plant species taken by the adult male tortoise between 3 May and 14 June 1991 at the Desert Tortoise Research Natural Area, Kern County, California.

	Plant Species	# Bites	% Bites	# Plants	% Plants
	Erodium cicutarium	1442	19.49	269	43.25
**	*Astragalus layneae*	1281	17.32	67	10.77
	Mentzelia eremophila	1042	14.08	31	4.98
**	*Stephanomeria parryi*	939	12.69	50	8.04
	Chorizanthe brevicornu	882	11.92	83	13.34
	Amsinckia tessellata	415	5.61	24	3.86
	Camissonia boothii	314	4.24	26	4.18
*	*Mentzelia eremophila*	211	2.85	3	0.48
**	*Euphorbia albomarginata*	188	2.54	12	1.93
	Lygodesmia exigua	142	1.92	5	0.80
	Cryptantha circumcissa	138	1.87	8	1.29
	Lotus humistratus	73	0.99	7	1.13
	Salvia carduacea	71	0.96	1	0.16
*	*Oxytheca perfoliata*	68	0.92	13	2.09
*	*Amsinckia tessellata*	49	0.66	1	0.16
	Chaenactis carphoclinia	30	0.41	4	0.64
*	*Pectocarya recurvata*	29	0.39	2	0.32
	Glyptopleura marginata	24	0.32	4	0.64
	Astragalus didymocarpus	21	0.28	2	0.32
	Nama demissum	12	0.16	1	0.16
**	*Mirabilis bigelovii*	11	0.15	2	0.32
**	*Lomatium mohavense*	7	0.09	2	0.32
	Pectocarya recurvata	3	0.04	1	0.16
*	*Thelypodium lasiophyllum*	2	0.03	1	0.16
	Eriogonum pusillum	2	0.03	1	0.16
*	*Lasthenia chrysostoma*	1	0.01	1	0.16
	Phacelia tanacetifolia	1	0.01	1	0.16
	Totals	7398	100.00	622	100.00

* Plant in a "dry" state
** Herbaceous perennial

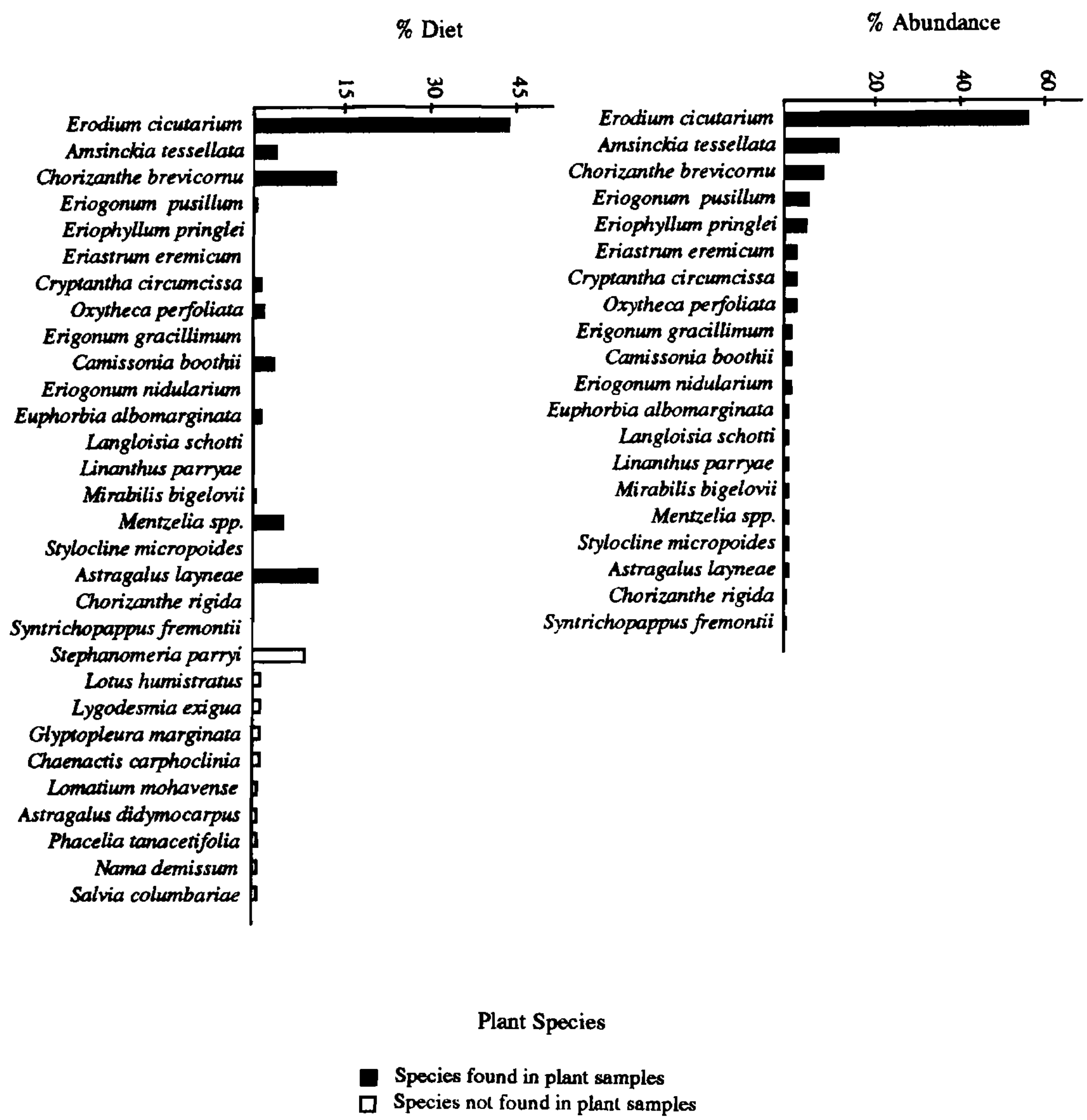

Figure 2. Comparison of relative abundance of plants along the feeding routes of the male tortoise (top graph) with the relative contribution of those plant species to the diet of the male tortoise (bottom graph).

Table 4. A comparison of the availability of succulent annual and perennial plants along the feeding routes with diet of the male tortoise.

Plant species	% Abundance	% Diet
Erodium cicutarium	56.16	43.95
Amsinckia tessellata	12.89	3.92
Chorizanthe brevicornu	8.31	13.40
Eriogonum pusillum	5.16	0.16
Eriophyllum pringlei	4.58	0.00
Eriastrum eremicum	2.87	0.00
Cryptantha circumcissa	2.29	1.31
Oxytheca perfoliata	2.29	2.12
Eriogonum gracillimum	1.15	0.00
Camissonia boothii	0.86	4.25
Eriogonum nidularium	0.86	0.00
* *Euphorbia albomarginata*	0.57	1.96
Langloisia schotti	0.57	0.00
Linanthus parryae	0.29	0.00
* *Mirabilis bigelovii*	0.29	0.33
Mentzelia spp.	0.29	5.07
Stylocline micropoides	0.29	0.00
* *Astragalus layneae*	0.29	10.95
Totals	100.00	88.42

* Herbaceous perennial

rarely take more than 10 bites on a single plant. Curiously, both tortoises tended to decapitate *Camissonia boothii*, discard the inflorescence, and only consume the mid-section of the stem and leaves.

DISCUSSION

In February and March of 1992, the western Mojave Desert was deluged with precipitation. The excessive rains resulted in mass germination of annual plants and flowering of perennial species. Although climatic data are unavailable, winter storms and cold temperatures prevailed throughout February and March, so that tortoise activity did not begin until early April (pers. obs). Tortoises were active from early April to late June; thus, our observations , which were made between early May - mid June, roughly represented the latter half of the spring activity season. Unlike the eastern Mojave and Sonoran Deserts, the western Mojave Desert lacks a summer rainfall component, thus tortoise foraging activities are probably restricted to the spring months.

Although the female tortoise fed on 13 species of plants, 84% of her bites were taken from only 3 species (*Lygodesmia exigua, Astragalus layneae,* and *A. didymocarpus*). As preferred foods became dry, both tortoises switched to other species which were coming into flower. For example, from mid-April to the end of May, the annual legume, *Astragalus didymocarpus*, was in flower, during which time, the female tortoise fed largely upon this species. By June, *A. didymocarpus* were in a dried state, consequently, the female switched her preference to an annual composite, *Lygodesmia exigua*, which was beginning to flower. During the first half of June, the female fed almost exclusively on this species, however, if the female ever encountered an *Astagalus layneae, Calycoseris parryi, Mentzelia eremophila*, or *Mirabilis bigelovii*, she would opportunistically feed upon them. The aforementioned species are uncommon and all have patchy distributions throughout the area.

Although the male tortoise fed on 25 species of plants, nearly 80% of his bites were from only 5 species (*Erodium cicutarium, Astragalus layneae, Mentzelia eremophila, Stephanomeria parryi* and *Chorizanthe brevicornu*). The male also seemed to adjust his preferences as the season progressed. During the month of May while most annuals were still in flower, the male fed chiefly on native annuals (e.g., *Mentzelia eremophila* and *Chorizanthe brevicornu*) and native herbaceous perennials (e.g., *Stephanomeria parryi* and *Astragalus layneae*). By June, the exotic annual, *Erodium cicutarium*, was one of the few annuals that were still in a succulent state, consequently, it was frequently eaten by the male tortoise during this time.

The comparison between plant abundance and tortoise diet was conservative for two reasons. First, only the intershrub space was sampled, thus, plants growing in other microhabitats (e.g., shade of shrubs) were not represented in the samples. And second, several of the uncommon preferred species, tended to have clumped distributions, hence, by sampling the feeding routes, certain uncommon species were counted, whereas, if the habitat were sampled in a completely random manner, they probably would not have been detected.

The results obtained from this study suggest that tortoises are selective feeders. This is consistent with the findings of other studies on desert tortoise foraging ecology (Burge and Bradley 1976; Turner and Berry 1984; Turner et al. 1987; Avery 1992; Esque 1992). Further, many of the most-preferred species (e.g., *Astragalus* spp. and *Stephanomeria parryi*) were the same species which were favored by tortoises at the Desert Tortoise Research Natural Area in the spring of 1973 (K. H. Berry, pers. comm.).

Similarities and differences became apparent between the female and male tortoises with regard to foraging behavior and food choices. Both tortoises seemed to prefer succulent forage over dried forage, native species over exotics, plants which grew in exposed areas rather than under or against shrubs, and both had similar strategies for locating uncommon plants (e.g., travel along small washes). The primary differences between the two tortoises concerned food choices. The disparity between their diets might be ascribed more to the availability of certain species of plants within the home range of a tortoise rather than individual tastes. For example, the annual plant community within the home range of the female tortoise was relatively devoid of weeds and exotics and thus contained a high diversity of native annuals. In contrast, the home range of the male tortoise was largely dominated by *Amsinckia tessellata* (a weedy native) and *Erodium cicutarium* (a non-native weed); the only areas where a diversity of native annuals could be found were in the washes. Hence, nearly all of the plants consumed by the male tortoise, other than *Erodium cicutarium* and *Chorizanthe brevicornu*, were found in the washes. Indeed, the majority of bites taken by the male tortoise were from the exotic, *Erodium cicutarium*. However, it is worth considering a couple of factors which may have had an influence on the diet selection of the male tortoise. First, as already mentioned above, qualitative differences in the annual plant communities existed among the home ranges of both tortoises. And second, both tortoises preferred plants in a succulent state over dried plants. By the end of May, many of the preferred native plants were drying out except for *Erodium*. At this time, the male tortoise began to feed heavily on this species. However, if the male tortoise ever encountered a preferred native species such as *Astragalus layneae*, that was in a succulent state, he would invariably consume the plant in entirety. Thus, it is possible that the male tortoise fed upon a large amount of *Erodium* simply because of the paucity of preferred native species within his home range.

To establish whether these similarities and differences are real, future studies will require larger sample sizes including immatures and juveniles. Furthermore, data should be collected over a period of many years so that foraging behavior could be studied in wet and dry years.

ACKNOWLEDGEMENTS

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Foraging Ecology and Sheltersite Characteristics of Sonoran Desert Tortoises

John R. Snider

Abstract. Sonoran desert tortoises were observed feeding at Little Shipp Wash and the Harcuvar Mountains, Arizona, from May 1991 through October 1991. Eight tortoises were observed at Little Shipp and 12 at the Harcuvars. Sheltersites occupied by tortoises during this study were plotted on topographic maps, flagged for relocation, and the dimensions measured for size comparisons at various times of the year.

Tortoises at Little Shipp Wash fed on 11 plant species during 122 hours of observations. A total of 1174 bites during 1.7 hours of feeding was recorded. Prickly pear cactus fruit (*Opuntia engelmannii*) comprised 29.6% of the bites. Tortoises at the Harcuvar Mountains fed on four plant species, 189 bites were recorded during 92 hours of observations.

Sheltersite usage was similar between the two sites. During the summer tortoises at the Harcuvar Mountains remained on steeper slopes than the tortoises at Little Shipp Wash ($P < 0.05$, n = 46). Slope angles were between 6° and 35° at the Harcuvars and between 5° and 26° at Little Shipp. Only three of 24 active sheltersites at Little Shipp were greater than 200 cm long. Of the 44 sheltersites found at the Harcuvars, none were greater than 200 cm long. No significant differences in sheltersite characteristics were noted during the fall between the two sites ($P < 0.05$, n = 25).

INTRODUCTION

Concern for recent population declines in the desert tortoise (*Gopherus agassizii*) led to the emergency listing of the Mojave (Mohave) desert tortoise on August 4, 1989, as an endangered species (USFWS 1989). The Mojave population, located north and west of the Colorado River, was proposed under regular listing procedures on October 13, 1989, and listed as threatened on April 2, 1990 (USFWS 1990). The Sonoran population includes tortoises south and east of the Colorado River. Both populations are listed as a single entry as a candidate for State endangered or threatened status (AGFD 1988).

An understanding of the health of free-ranging desert tortoises is important in assessing and managing declining populations (Berry 1984). In addition, knowledge of wildlife nutrition is central to understanding the survival and productivity of free-ranging populations (Robbins 1983). Nutrition quality is of importance since insufficient diet quality could cause conditions such as osteoporosis (Jarchow and May 1989), and increase susceptibility to other diseases such as upper respiratory tract disease (URTD; Jacobson and Gaskin 1990).

The objectives of this study are to: 1) relate desert tortoise forage quality and availability to health profiles; 2) determine tortoise food habits, whether it is by preference or availability; and 3) compare forage nutritional quality across seasons and years and between sites. This study will continue to be closely coordinated with the ongoing Arizona

Game and Fish Department health assessment study to compare nutrition quality, food selectivity, and availability to blood chemistries in Sonoran desert tortoises.

METHODS

Weather and Climate

Climate data are based on permanent weather stations in Hillside, Arizona and Aguila, Arizona (NOAA, 1990-1991). We used data on average monthly maximum and minimum ambient temperature and average monthly precipitation.

General Procedures

Two sites were chosen for this study due to the availability of free-ranging tortoises and the representation of Sonoran desert habitat. Little Shipp Wash is located 9.6 km southeast of Bagdad, Arizona and the Harcuvar Mountains site is located approximately 24.1 km northwest of Aguila, Arizona. These sites are located adjacent to Bureau of Land Management (BLM) permanent study plots. There are approximately 50-80 tortoises per square mile (Shields et al. 1990) at each site. While Little Shipp Wash is at a relatively high elevation (788-975 m), the vegetation at both sites is typical of Arizona Upland Sonoran desertsrub with saguaro (*Carnegiea gigantea*), foothills paloverde (*Cercidium microphyllum*), catclaw acacia (*Acacia greggii*), western honey mesquite (*Prosopis glandulosa*) and prickly pear cactus (*Opuntia engelmannii*) dominating the Little Shipp Wash site, and saguaro, foothills paloverde, and ocotillo (*Fouquieria splendens*) dominating the Harcuvar Mountains. Prickly pear cactus is absent at the Harcuvar Mountains.

The initial cohort of radio-instrumented tortoises for this study were available from an ongoing health assessment study. If any unmarked tortoises were encountered during the course of field work, a Telonics, model 125 radio transmitter was attached using 5-minute epoxy gel (Tru-Bond, Chicago, Illinois). Prior to being radioed, tortoises were weighed, measured, and permanently marked with a number by notching the marginals. Gloves were used during the handling of all tortoises to prevent transmission of disease. Both adult (>208 mm median carapace length [MCL]) male and female tortoises were radioed. Any juvenile tortoises found were observed for feeding behavior, but were not radioed.

Feeding observations were made from May 4-October 29, 1991, at Little Shipp and from June 5-October 17, 1991, at the Harcuvars. Morning observations were conducted from 0500 hours MST through 1200 hours MST or until tortoises entered sheltersites. Evening observations were conducted from 1600-2000 hours MST or until it was too dark to successfully watch the animal. Tortoises were located in their sheltersites before daylight via radio telemetry signals. Once the tortoise was located the observer maintained a distance of 10-15 m from the subject and used binoculars for observation. The following information was immediately recorded upon arrival, on a microcassette recorder: location, slope, aspect, cloud cover, wind speed, ambient temperature, ground surface temperature, and temperature at 1 cm above ground. We sought cover behind trees and rocks to avoid detection by the tortoises. As soon as the tortoise emerged, temperatures were taken. All activity was recorded including basking, walking, feeding, resting, agonistic behavior, and courtship. The amount of time spent on each activity was recorded. When a tortoise fed, the observer recorded the exact number of bites, the species (if unknown, the plant was collected for later identification), phenology, and the parts fed on. The distance between each feeding was recorded as well as the total distance the animal travelled. As soon as the tortoise reentered its sheltersite or established a new one, the observation was terminated, and final temperatures were recorded. If at any time the tortoise was disturbed, the observer moved out of sight of the tortoise. Usually after 30 minutes the tortoise resumed activity. A different animal was chosen each day to avoid over-disturbing a single subject. All information recorded was transcribed onto data sheets and then entered into a computer database with double entry verification.

All sheltersites that tortoises occupied were flagged with pink ribbon, plotted on topographic maps, and interior and exterior dimensions taken. Flagging the sheltersites aided in locating additional tortoises for the study as tortoises tend to routinely occupy specific dens. Sheltersite measurements taken included opening width and height, interior width, height, and length, length and width of apron, and height of cover substrate. Composition, percent vegetation cover, soil type, and ground surface temperatures inside and outside were recorded as well as the tortoise number occupying the shelter. Unpaired data were compared using the Mann-Whitney test; the Wilcoxon signed-rank test was used for paired data. Significance was judged at $P < 0.05$. Statistical tests performed for this study assume independence of variables. Alternative procedures accounting for possible correlation among these variables may be informative and will be attempted for the final report.

RESULTS

Weather and Climate

Precipitation and temperature data are summarized for both sites in 1990 and 1991 Fig. 1. Total summer precipitation (April through August) for Little Shipp in 1990 was 17.32 cm as compared to 5.69 cm in 1991. Total summer precipitation for the Harcuvar Mountains in 1990 was 12.41 cm as compared to 2.31 cm in 1991. In addition to less precipitation in 1991 as compared to 1990, temperatures were higher and remained high during spring and summer. Above average spring precipitation (January through March) in 1991 (Little Shipp 24.87 cm; Harcuvars 11.45 cm) encouraged spring annual germination and winter annual growth. High temperatures and below average rainfall in 1991 lead to early curing of spring and summer annuals in the Harcuvar Mountains (Fig. 1).

Feeding Observations

Mid-summer observations were practically void of any feeding activity as tortoises went into aestivation. With some precipitation in late summer (September-October) at Little Shipp, and the abundance of prickly pear cactus (*Opuntia engelmannii*) fruit some feeding observations were made in October. The Harcuvar site remained dry with no summer (June-August) precipitation to provide any late summer greenup of vegetation. Due to a late start (May 1991) we missed the spring feeding bout, and did not record any bite count data from that time period.

Tortoises at Little Shipp consumed 12 species of food during 122 hours of observations. A total of 1174 bites was recorded. Prickly pear fruit comprised 29.64% (348 bites) of the bites (Table 1). One tortoise was observed feeding on bleached tortoise scat. Ninety-eight percent of the feeding was done during October. Ninety-five minutes were spent feeding, 149 minutes walking and 1409 minutes inactive. No other behavior was observed. During the summer (June-August), 255 minutes were spent basking, 115 minutes walking,

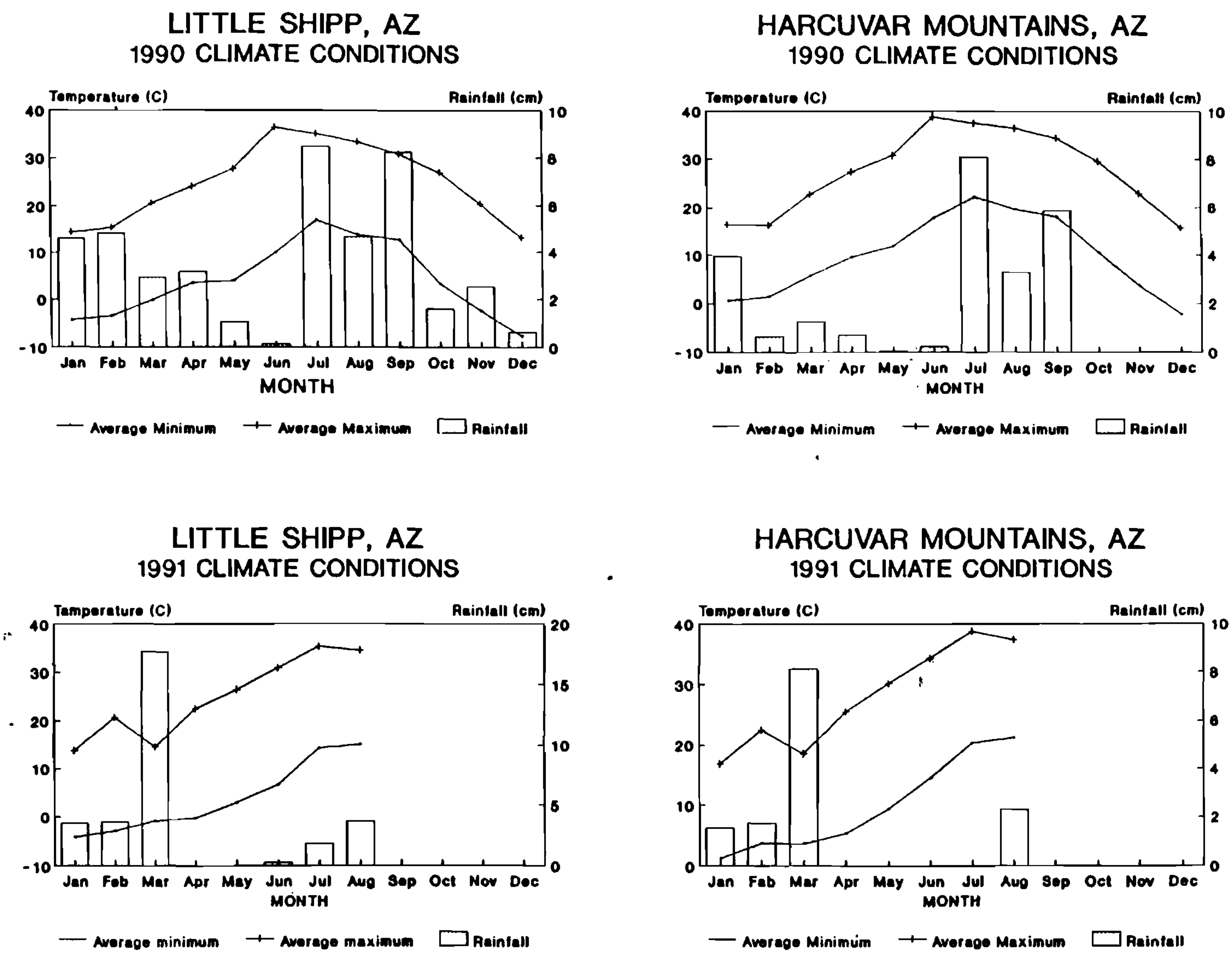

Figure 1. Climate conditions at Little Shipp Wash and Harcuvar Mountains, Arizona, 1990-1991.

Table 1. Food items tortoises fed on at Little Shipp Wash site, Arizona, June-October 1991.

Species	# Bites	% Bites
Aristida purpurea	31	2.64
Ayenia compacta	19	1.62
Erioneuron pulchellum	272	23.17
Euphorbia sp.	163	13.88
Hilaria mutica	234	19.93
Janusia gracilis	15	1.28
Krameria parvifolia	28	2.38
Opuntia engelmannii	348	29.64
Plantago insularis	43	3.66
Sphaeralcea ambigua	14	1.19
Tortoise scat	7	0.60
Total	1174	99.99%

Table 2. Food items tortoises fed on at the Harcuvar Mountain site, Arizona, June-October 1991.

Species	# Bites	% Bites
Schismus barbatus	29	15.34
Plantago insularis	3	1.59
Aristida purpurea	29	15.34
Hilaria rigida	128	67.72
Total	189	99.99%

six minutes feeding and 5070 minutes inactive (Fig. 2). Sixty-five percent of the feeding occurred during the late afternoon and evening hours.

Tortoises at the Harcuvars consumed only four species of food during 92 hours of observations. A total of 189 bites were recorded. Big galleta grass (*Hilaria rigida*) comprised 67.72% (128 bites) of the diet (Table 2). Summer activity consisted of only 10 minutes feeding, 38 minutes walking, and 3986 minutes inactive. Fall (September-October) activity consisted of 11 minutes feeding, 6 minutes walking and 1445 minutes inactive (Fig. 2).

Sheltersite Characteristics

Of the 18 sheltersites found at Little Shipp during the summer, 51% were found on northeast, southeast, and southwest facing slopes. Slope angles were between 6° and 35° ($\bar{x}$ = 18.2°). Elevations ranged from 780 - 975 m (Table 3). All sheltersites were in naturally occurring dens among granitic rocks and boulders. No burrows were constructed by any tortoises and few pallets were used.

Of nine active sheltersites found during the fall at Little Shipp, 33% were located on northeast facing slopes. Slope angles ranged from 5° - 26° ($\bar{x}$ = 14.2°). Elevations ranged from 805 - 963 m ($\bar{x}$ = 857 m), 89% were located in natural granitic rock dens. One tortoise (#309) did move down off the slopes and constructed a burrow along the bank of a wash. At the Harcuvars, 28 active sheltersites were found during the summer, 43% were located on northeast facing slopes at angles between 12° and 36° ($\bar{x}$ = 22.2°). Elevations ranged from 792 - 902 m ($\bar{x}$ = 858 m) (Table 4) 93% were located in dens composed of granitic rock.

During fall, 31% of the active sheltersites found at the Harcuvars, were located on northeast facing slopes (n = 16). Slope angles ranged from 5° - 36° ($\bar{x}$ = 20.2°). Elevations ranged from 780 - 917 m ($\bar{x}$ = 837 m) (Table 4). Pallets comprised 32.5% of the sheltersites used this season. Rocky dens comprised 67.5% of the sheltersites.

Only three active sheltersites were greater than 200 cm long at Little Shipp. Sheltersites averaged 99.7 cm in summer, and 56.9 cm long in fall. Width averaged 40.1 cm in summer and 36.0 cm in fall. Height averaged 23.6 cm in summer and 18.6 cm in fall. At the Harcuvars no sheltersites were found greater than 200 cm and only 5 were greater than 100 cm. Average length of a sheltersite at the Harcuvars during summer was 77.4 cm, and in fall 43.0 cm. Average width and height in summer was 47.4 cm and 22.9 cm, respectively, and in fall 30.9 cm and 16.2 cm, respectively.

Sheltersites were used by more than one tortoise on occasion. One tortoise (#218) was radio tracked to a sheltersite and was found with two unmarked tortoises sharing the same location. Other vertebrates shared sheltersites with tortoises. Researchers, on two separate occasions at the Harcuvar Mountains, observed a gila monster (*Heloderma suspectum*) and a packrat (*Neotoma* sp.) sharing a sheltersite with a tortoise.

DISCUSSION

Feeding Observations

Of the total diet of tortoises at Little Shipp, prickly pear cactus fruit comprised 29% of the bites. Shields et al. (1990), from August 19 to October 25, observed 34 of 39 sightings of tortoises with red stained beaks indicating consumption of prickly pear fruit. This may be due to the high water content of the fruit and its palatability. During observations, tortoises

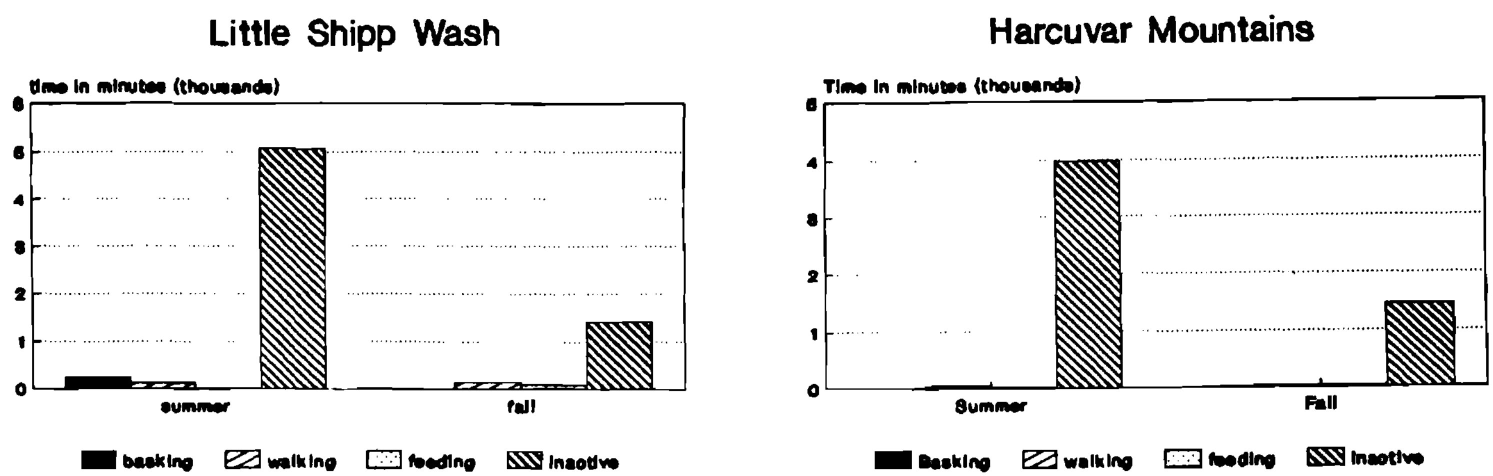

Figure 2. Desert Tortoise activity at Little Shipp Wash and Harcuvar Mountains, Arizona, 1991.

Table 3. Sheltersite profiles from the Little Shipp Wash study site, Arizona, 1991.

	Summer (Jun-Aug) $\bar{x} \pm SD$	Fall (Sep-Oct) $\bar{x} \pm SD$
Slope	18.2 ± 7.4	14.2 ± 8.9
Aspect	5.0 ± 2.7	5.7 ± 2.0
Elevation	2797.8 ± 166.9	2813.3 ± 144.2
Shelter Type[1]	1.0 ± .0	1.1 ± .3
Ground Temp. (°C)	31.9 ± 5.5	29.6 ± 4.3
Shelter Temp. (°C)	30.6 ± 4.5	28.7 ± 2.1
Opening Width (cm)	50.6 ± 21.9	40.4 ± 19.6
Opening Height (cm)	25.0 ± 12.5	21.3 ± 7.3
Interior Width (cm)	40.1 ± 15.5	36.0 ± 21.2
Interior Height (cm)	23.6 ± 13.0	18.6 ± 6.4
Interior Length (cm)	99.7 ± 64.1	56.9 ± 26.6
Apron Width (cm)	69.3 ± 33.0	70.0 ± 10.0
Apron Length (cm)	85.0 ± 54.8	53.3 ± 41.6
Shelter Cov. Sub (cm)	103.1 ± 66.9	78.2 ± 55.8
Soil Type (1)[2]	2.4 ± .7	1.9 ± .9
Soil Type (2)[2]	4.4 ± .7	4.4 ± .7
Shelter Composition[3]	1.3 ± .5	1.2 ± .4
Veg. Species (m)[4]	32.2 ± 20.3	31.7 ± 23.3
Veg. Height (m)	78.2 ± 27.5	158.7 ± 69.8
Veg. Width (m)	152.7 ± 148.2	199.3 ± 98.5
Veg. % Cover	38.9 ± 30.0	90.0 ± 10.0
Time (min)	1196.7 ± 447.1	1271.6 ± 468.9

[1] 1=Sheltersite, 2=Pallet
[2] 1=Sandy, 2=Rocky, 3=Granular, 4=Soft, 5=Hard, 6=Other
[3] 1=Granite Rock, 2=Soil
[4] Vegetation above sheltersite.

Table 4. Sheltersite profiles from the Harcuvar Mountain study site, Arizona, 1991.

	Summer (Jun-Aug) $\bar{x} \pm SD$	Fall (Sep-Oct) $\bar{x} \pm SD$
Slope	22.2 ± 8.6	20.2 ± 8.1
Aspect	5.0 ± 3.0	4.6 ± 2.9
Elevation	2815.8 ± 104.8	2746.4 ± 110.0
Shelter Type[1]	1.1 ± .3	1.4 ± .5
Ground Temp. (°C)	31.6 ± 3.6	29.2 ± 4.2
Shelter Temp. (°C)	30.0 ± 2.4	28.5 ± 3.4
Opening Width (cm)	52.9 ± 25.5	40.8 ± 14.4
Opening Height (cm)	23.1 ± 11.7	19.5 ± 5.6
Interior Width (cm)	47.4 ± 19.4	30.9 ± 12.7
Interior Height (cm)	22.9 ± 12.0	16.2 ± 4.4
Interior Length (cm)	77.4 ± 33.1	43.0 ± 14.3
Apron Width (cm)	41.9 ± 20.8	15.0 ± .0
Apron Length (cm)	44.4 ± 24.2	32.5 ± 7.8
Shelter Cov. Sub (cm)	103.5 ± 69.9	63.7 ± 64.0
Soil Type (1)[2]	1.9 ± .6	2.3 ± .8
Soil Type (2)[2]	3.7 ± 1.3	4.5 ± .7
Shelter Composition[3]	1.0 ± .2	1.2 ± .4
Veg. Species (m)[4]	24.8 ± 21.7	6.2 ± 1.6
Veg. Height (m)	128.1 ± 85.1	161.1 ± 121.2
Veg. Width (m)	159.9 ± 112.7	239.9 ± 227.3
Veg. % Cover (m)	46.5 ± 28.9	68.6 ± 27.2
Time (min)	1121.0 ± 458.4	1141.5 ± 335.6

[1] 1=Sheltersite, 2=Pallet.
[2] 1=Sandy, 2=Rocky, 3=Granular, 4=Soft, 5=Hard, 6=Other
[3] 1=Granitic Rock, 2=Soil
[4] Vegetation above sheltersite.

walked to a prickly pear cactus then circled around it until a fruit was found on the ground. Tortoises did not attempt to feed on fruit still attached to the plant even though it was within easy reach. Tortoises did not solely feed on the cactus fruit but supplemented it with grasses. Observations of cactus fruit feeding was during September and October 1991. The cactus fruit provided adequate foraging possibilities for the tortoises despite the lack of annual grasses and forbs. Shields et al. (1990) also mentions 16 sightings of feeding, 12 of which were grasses. During our field season (excluded spring) tortoises consumed a small amount of grasses. Fluffgrass (*Erioneuron pulchellum*) accounted for 23% of the total bite count which was consumed by one tortoise. During the month of October 1991, unusually high temperatures (>38 °C) prevailed which may have been a limiting factor on the amount of time spent feeding.

Tortoises at the Harcuvar Mountains had less forage species available to them due to lack of precipitation, thus resulting in lower consumption of food. Prickly pear cactus is uncommon in the Harcuvar Mountains and thus tortoises did not have this food source. Lack of precipitation prevented the late summer greenup of vegetation. By September these tortoises appeared weak and dehydrated compared to the Little Shipp tortoises (M. Trueblood, pers. comm.). Big galleta grass accounted for greater than 67% of the total bites taken. Woodman and Shields (1988) observed tortoises feeding six times at the Harcuvars, three of which was big galleta grass. Big galleta grass was the largest component of the scats examined in the Harcuvars (Johnson et al. 1990). Schneider (1981) observed tortoises feeding 21 times, eight times of which was *Schismus* sp. and *Bromus* sp. In this study *Schismus* sp. accounted for 15% of the total bites recorded.

Esque et al. (1990, 1991) observed tortoises feeding on bones and rocks and noted that tortoises were persistent in acquiring those materials. Our observations demonstrated tortoises made no attempts at acquiring bones or rocks in their feeding activity. Since tortoises may eat these materials to supplement dietary minerals (Esque et al. 1990) we suspect Sonoran tortoises may be acquiring these nutrients in their forage. These nutrients could affect the survival of tortoises (Esque et al. 1990). Esque suggests that tortoise carcasses could be an important means of acquiring these minerals. However, Sonoran tortoise populations are widespread and have low population numbers, that tortoise carcasses are relatively uncommon.

Feeding behavior usually resulted while the animal was moving between an original and a new sheltersite. We did not observe any tortoises feeding in a loop fashion (Esque et al. 1990) where a tortoise starts at one point, walks to a feeding area and returns to the original sheltersite. Most of these movements were short in length, usually under 30 m from start to finish. One exceptionally long movement (>100 m) was accomplished by tortoise #309. Woodman and Shields (1988) monitored tortoise movements in the Harcuvars and noted that 40% of them moved at least 300 m in linear fashion.

No agonistic behavior or mating was observed during our field season, though summer and fall are not the time of most frequent encounters. Possibly due to the low population numbers, animal to animal encounters are not as common in the Sonoran as they are in the Mojave desert. Combat between males is more common in spring (Johnson et al. 1990). Summer is a time of inactivity as the data indicates. High temperatures and dry conditions kept most tortoises in sheltersites until early fall.

Sheltersites

Sheltersite characteristics were very similar between the two sites with tortoises using naturally occurring dens among the granitic rock outcrops rather than pallets and burrows. The rocky dens may offer better protection from high summer temperatures (Barrett 1990). Barrett (1990) noted that tortoises in the Picacho Mountains, Arizona, used deeper dens insummer than in winter as compared to tortoises in the Mojave desert that occupy larger dens in winter. After our winter surveys in 1991, we can make some comparisons on seasonal sheltersite usage. Elevation ranges in Arizona for tortoises are from 158 to 1615 m (Barrett and Johnson 1990). We found tortoises and sheltersites between 625 and 1450 m. No significant changes in elevation were noted between summer and fall activity patterns. Cooler and moister northeast slope exposures were preferred over the drier south and west slopes. Slope angles varied but most tortoises remained on steeper ridges. Tortoises in the Sonoran desert tend to avoid the soft-soiled flat valleys (Johnson et al. 1990). Woodman and Shields (1988) found most of the active sheltersites at the Harcuvars on north or east facing slopes, on the ridges and under rocks or boulders. Tortoises will use a number of sheltersites during the year (Johnson et al. 1990). We observed tortoises occupying more than six sheltersites each over the course of the year. According to Johnson et al. (1990), den size influences the length of hibernation. Larger dens provide less temperature fluctuations and enable a tortoise to remain inactive.

CONCLUSIONS

Tortoises at Little Shipp Wash had more forage species available to them and the advantage of some precipitation in late summer, which may have improved feeding conditions. Tortoises at the Harcuvar Mountains faced drought conditions and high temperatures, and had less available forage. Both sites generally had a long summer season with tortoises remaining inactive the majority of the time. Our data for this year is an indication of the amount of time tortoises are inactive during the summer months. Feeding observations should be concentrated during the spring, late summer (after the monsoons) and fall periods. We will increase our sample size at both sites to provide additional data on feeding behavior. We will continue to obtain locations and sheltersite data through the winter to show length of brumation, sheltersite size preferences and locations, and home range size at various seasons. Automatic weather stations will be set up on the study sites to record climate data. Tortoise foraging ecology and forage chemistries will be compared to results of the ongoing health studies in the Sonoran desert. This may allow further interpretation of the health studies being conducted.

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Body Composition and Water Flux Rates of Desert Tortoises at the Desert Tortoise Conservation Center, Las Vegas, Nevada

Brian T. Henen, Linda C. Zimmerman, Michael O'Connor and James Spotila

The body condition and water flux rates of captive tortoises at the Desert Tortoise Conservation Center near Las Vegas ($n=8$, mean body mass ($\pm$SE) = 951 g ($\pm$88)) were measured during August 1991 for general health and ecophysiological comparisons to free-ranging desert tortoises. Total body water values and water flux rates were measured using labeled water (Nagy and Costa 1980; Nagy 1983). Lipid mass and lipid-free mass (lean mass) were measured using the cyclopropane technique (Henen 1991).

These tortoises were 71.6% water (SE= $\pm$0.53), 3.4% lipid (SE= $\pm$0.32), and 25% lipid-free dry mass (SE= $\pm$0.54), corresponding well to measurements for tortoises in field studies at Goffs, California, Barstow, California, and Rock Valley, Nevada respectively, (Henen 1988, 1989, and unpublished data; Minnich 1977; Nagy and Medica 1986). Four of the Las Vegas tortoises were subadults (mean midline carapace length (MCL) = 15.8 cm, SE= $\pm$0.32, range = 15.1-16.4 cm) and four were adults (mean MCL = 188 cm, SE= $\pm$0.21, range = 182-192 cm).

The subadults had lower percent lipid mass (%LM) values (mean = 2.66% of body mass, SE= $\pm$0.31) than the adults at Las Vegas (mean = 4.10%, SE= $\pm$0.32; $t=3.216$, $df=6$, $P<0.01$) and adult female tortoises at Goffs during August 1988 (mean = 4.98%, SE= $\pm$0.22; $t=6.02$, $df=11$, $P<0.005$; Henen 1988, and unpublished data), but %LM did not differ from Goffs females during August 1987 (mean = 2.08%, SE= $\pm$0.21; $t=1.54$, $df=11$, $P>0.10$; Henen 1988, unpublished data). The difference between cohorts at Las Vegas may be due to subadult tortoises, in comparison to adult tortoises, allocating more resources towards growth and having less energy available for storage as lipid. All eight Las Vegas tortoises had higher %LM than the Goffs tortoises measured during August 1987 (adults: $t=5.3361$, $df=11$, $P<0.005$; all: mean = 3.38%, SE= $\pm$0.34, $t=3.33$, $df=15$, $P<0.005$) and lower %LM than the Goffs tortoises measured during August 1988 (adults: $t=2.26$, $df=11$, $P<0.025$; all: $t=4.05$, $df=15$, $P<0.005$). In general, the lipid contents of the captive, Las Vegas tortoises were within the range of values for free-ranging, wild tortoises at Goffs.

The four subadult tortoises had higher percent body water (%BW) values than the adult tortoises (subadults: 72.8% of body mass, SE= $\pm$0.49; adults: 70.5%, SE= $\pm$0.60; $t=3.03$, $df=6$, $P<0.025$). The %BW was not correlated to %LM ($F=1.06$, $df=1,6$, $P>0.25$) and the cohorts did not differ in percent lipid-free dry mass ($t=0.81$, $df=6$, $P>0.20$). Inspection of 95% confidence intervals (Dixon and Massey 1969) indicates that the four subadults (but not the 4 adults or all 8 Las Vegas tortoises) had higher %BW values than wild, subadult tortoises (hydrated and dehydrated) from the Barstow area (Minnich 1977) but were not different from wild, subadult tortoises from Southern Nevada (Nagy and Medica 1986).

Water influx rates of the Las Vegas tortoises were highly variable (15.5 ml/d, SE$\pm$ = 7.18, N = 7). Inspection of 95% confidence intervals indicates that these influx rates were not different from rates from other studies (Minnich 1977; Nagy and Medica 1986).

Some caution should be used with these data because the sample size was relatively small. However, although these tortoises were captive, their body condition measures and water flux rates fall within the ranges measured for free-ranging tortoises.

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Desert Tortoise Diet and Dietary Deficiencies Limiting Tortoise Egg Production at Goffs, California

Brian T. Henen

I observed desert tortoises consuming 13,743 bites of food from June 1986 to July 1989. The bites included annual plants (89.1% of 13,743 bites), perennial plants (6.8%), and soil, scats, crustose lichen and unidentifiable plants or objects (4.1%). The percentage of bites of annuals (A) increased while perennials (P) and other items (O) decreased from spring (A 79.1%; P 11.4%; and O 9.6%) to summer (A 94.4%; P 4.8%; O 0.8%) and autumn (A 99.4%; P 0.6%; and O 0.0%). The tortoises switched from succulent annuals (e.g., *Pectocarya* spp., *Cryptantha* spp., and *Lotus tomentellus*) and perennials (e.g., *Hilaria rigida*, *Opuntia ramosissima*, and *Opuntia basilaris*) during the spring to dry annuals (especially *Schismus barbatus*) as plants dried out during the spring. After summer rains, tortoises consumed primarily dry *Schismus barbatus* and succulent annuals (e.g., *Euphorbia micromera* and *Allionia incarnata*) that germinated from the rain.

Egg production in 1988 and 1989 was lower than during previous years (1983-85: t 2.66, df 26, $P<0.01$; 1986-87: paired t 2.03, df 7, $P< 0.025$) even though lipid reserves increased 41 g from July 1987 to July 1989 (paired $t=10.3$, $df=8$, $P<0.0005$). Simultaneously, body mass and lipid-free mass, which is mostly protein and water, decreased (body mass: paired $t=4.45$, $df=8$, $P<0.005$; lipid-free mass paired $t=5.07$, $df=8$, $P<0.005$). The net production of annual plants during Spring 1989 was also the lowest recorded for the Goffs site (0.0056 g/m^2). The reduced availability of body and dietary protein, water, or both probably limited egg production during 1988 and 1989. This was supported in 1989 by an annual (July 1988 to July 1989) increase in lipid-free mass and body mass for tortoises forgoing egg production (paired $t>5.57$, $df=2$, $P<0.025$) and a significant decrease in lipid-free mass and body mass for tortoises that laid eggs (paired $t>3.80$, $df=5$, $P<0.01$).

Additionally, egg production was correlated to the net production of spring annual plants (semi-log, x: $F_{1,79}=17.5$, $P<0.0005$). Tortoises are very selective eaters (even for Spring 1989: $x^2 = 2747$, $df=6$, $P<0.005$), usually choosing succulent, high-protein annuals when available. These annuals were essentially absent during 1989, so females consumed proportionately less annual plant material in Spring 1989 ($N=4$, total annuals: mean $=36.2\%$, $SE=\pm 18.7$; live annuals: $1.92\pm1.92\%$) than during Spring 1987 ($N=7$, total: mean $=78.2\pm11.8\%$; $t=2.00$, $df=9$, $P<0.05$; live $55.5\pm13.6\%$; Mann-Whitney $U=1$, $df=7,4$, $P=0.006$) and Spring 1988 ($N=6$, total: $86.9\pm5.71\%$; $t=3.08$, $df=8$, $P<0.01$; live $77.3\pm8.80\%$; Mann-Whitney $U=0$, $df=6,4$ $P=0.005$). They also consumed proportionately more perennial material in Spring 1989 ($N=4$, total: $56.5\pm23.6\%$; dead: $12.4\pm6.60\%$; live: $44.1\pm23.0\%$) than during Spring 1987 ($N=7$, total: $12.6\pm9.69\%$, $t=2.04$, $df=9$, $P<0.05$; dead: $2.20\pm2.20\%$, $t=1.82$, $df=9$, $P=0.052$; and live: $10.4\pm4.41\%$, $t=1.58$, $df=9$, $P=0.078$ and MW $U=3$, $df=7,4$, $P=0.021$) and during Spring 1988 ($N=6$, total: $10.2\pm4.41\%$, MW $U=4$, $df=6,4$, $P=0.057$; dead: $0.00\pm0.00\%$, MW $U=3$, $df=6,4$, $P=0.019$; live $10.2\pm4.41\%$, MW $U=6$, $df=6,4$, $P=0.129$, not significantly higher). Subsequently, Goffs tortoises produced the fewest eggs in 1989.

Preliminary Correlations Between Coprophagy, Bacterial and Parasitic Intestinal Loads, and the Growth of Neonatal Desert Tortoises, *Gopherus agassizii*: An Experimental Study

Heather Peck, Davood Soleymani, Michele A. Joyner, David J. Morafka and Manucher Dezfulian

Fecal pellets of adult tortoises are predominant components in the first diets of emergent hatchling tortoises. Fecal samples were drawn from wild adults and juveniles from the Mojave Desert at Fort Irwin, San Bernardino County, California in order to ascertain the contribution of such copraphagy to the intestinal flora and parasite loads of young tortoises.

In addition, four captive treatment groups were established, consisting of eight tortoise neonates (less than one year old). Each set of eight was assigned to its own terrarium. These terraria were placed within an environmental chamber programmed to simulate diel and seasonal cycles. The four groups differed their exposures to adult tortoise feces in their diets. Group A served as a control, receiving no feces. Group B were offered autoclaved sterile feces from captive adult tortoises as a dietary supplement. Group C were provided with untreated fresh feces from wild tortoises at Fort Irwin. Group D was provided with captive adult tortoise feces, as for Group B, but without autoclave sterilization.

The four treatment groups are being subjected to these conditions for a two year period. Their feces are monitored for bacterial, protozoal, and helminth loads. In addition, their growth is being measured in terms of weight, size, and shell shape. Periodic blood panels are conducted to assess health as well.

Combined early sampling of the feces from neonate treatment groups reveals diverse flora of anaerobes. Of 131 isolated strains, 31% have been assigned to the genus *Clostridim* (possibly including the potential symbiont with hemicellulose digesting capacities), *Bacteroides* (23%), nonspore forming bacilli (44%), and Gram-positive cocci (2%). Definite identification of some atypical isolates requires gas liquid chromatographic analysis of microbial metabolic products. Parasites identified from 149 isolated organisms included the protozoan *Entamoeba* sp. (in 49% of fecal samples), ova of oxyurid and ascarid helminths (15.4% and 14.1% respectively), and oocysts typical of *Isospora* and *Eimeria* (21.5%). Ongoing research will attempt to definitively identify these and other parasites and bacteria, assess differences in composition and densities in the feces of different treatment groups and identify potential symbionts.

Preliminary Observation on the Reproductive Cycles of Captive Desert Tortoises (*Gopherus agassizii*)

David C. Rostal, Valentine A. Lance and Allison C. Alberts

Preliminary data were collected on the reproductive cycles of 50 adult desert tortoises (20 males and 30 females) at the Desert Tortoise Conservation Center, Las Vegas, Nevada during the fall 1991. Tortoises (two males and three females per group) were maintained in 15 X 30 m outdoor pens. Each pen contained five artificial burrows and two bermuda grass feeding/watering stations plus natural vegetation. From August 1991 to October 1991, 5 ml heparinized blood samples were collected monthly via jugular puncture. Female reproductive status was monitored using ultrasonography. Male chin glands were measured monthly and secretions were collected for gel electrophoresis.

Mating activity and male combat was observed in all the enclosures during August and September. Ovarian follicular growth was observed in the females between August and October prior to brumation. Follicular growth coincided with elevated plasma calcium levels (an indicator of vitellogenesis). Female plasma testosterone levels also increased from August (mean $\pm$ SE = 1.12 $\pm$ 0.11 ng/ml, n = 30) to October (mean $\pm$ SE = 3.79 $\pm$ 0.26 ng/ml, n = 29). Male testosterone levels were observed to decline from August (mean $\pm$ SE = 243.60 $\pm$ 24.61 ng/ml, n = 20) to October (mean $\pm$ SE = 183.04 $\pm$ 16.81 ng/ml, n = 20) during the fall mating period. Plasma corticosterone levels remained relatively low throughout the fall (male levels ranged from 0.985 to 3.085 ng/ml; female levels ranged from 0.330 to 2.627 ng/ml), although male plasma corticosterone levels were generally higher than females. Male chin gland size was positively correlated with plasma testosterone levels. Initial examination of gel electrophoresis results from 11 male tortoises indicates the presence of at least 10 protein bands. These protein bands range in size from 16,000 to 97,000 daltons.

Based on these preliminary results, the desert tortoise appears to undergo seasonal changes in its reproductive physiology. Males appear to display a pre-nuptial pattern of testicular growth and spermatogenesis during the summer. In the female, vitellogenesis appears to occur primarily during the fall following spring and early summer nesting. Vitellogenesis and follicular growth appears to be complete prior to brumation such that the female is capable of ovulating a clutch of eggs upon emergence from their burrows in the spring. The fall mating period observed during August and September prior to brumation may play a significant role in the mating system of this species.

Influence of Incubation Conditions on Eggs of Desert Tortoises, and Growth Rates and Temperature Selection of Resulting Hatchlings

James R. Spotila, Stanley J. Kemp and Eva Beyer

To examine the influence of incubation conditions on development of embryonic and hatchling desert tortoises (*Gopherus agassizii*), 44 eggs were incubated at 26 °C or 33 °C and 4.0% or 0.4% soil moisture content. None of the eggs hatched following incubation under cool, moist conditions. Hatching success in the other treatment groups was 33% in warm, moist conditions; 50% in cool, dry and 90% in warm, dry incubation conditions. Eggs hatched at a mean time of 73 days when incubated at 33 °C and at a mean time of 125 days when incubated at 26 °C. Sex of hatchlings has not yet been determined. Initial body mass of hatchlings, change in body mass or body mass at 40 days post-hatching were statistically indistinguishable between treatment groups. Temperature selection by hatchlings was measured in a laboratory thermal gradient. Following a six-hour equilibration period, hatchlings from different incubation treatments selected statistically indistinguishable body temperatures (mean = 26.6 °C).

The Importance of Food Quality for Desert Tortoises: Perspectives on Growth of Individuals and Populations

C. Richard Tracy

The opportunities provided by the resource environment, combined with an animal's physiological capacities to digest particular kinds of food, determine the digestive constraints upon bodily growth. In desert tortoises, bodily growth, in turn, ultimately influences the time to sexual maturity. Ultimately the time to sexual maturity can strongly influence the growth, and average size, of entire populations. Using data and analyses from the desert tortoise, we show the relative importance of food quality to population processes. In particular, when tortoises eat forage high in fiber and low in protein, bodily growth rates can be retarded enough to delay age of first reproduction by as much as five years. Delaying the age of first reproduction for desert tortoises can require unreasonably high compensatory fecundities to balance normal tortoise mortality, and therefore, delaying the age of first reproduction can have large negative impacts on the potential for population growth. From our new data and analyses, we can now show how the quality of food available to desert tortoises can determine whether a population grows or declines.

Blood Cell and Serum Chemistry Values for Free Ranging and Captive Neonatal California Desert Tortoises (*Gopherus agassizii*)

Rebecca A. Yates and David J. Morafka

Theses data are the first hematological values comparing naturally occurring neonate desert tortoises (*Gopherus agassizii*) with captive neonate conspecifics. Naturally occurring tortoises were monitored in predator proof exclosures (30 m x 60 m) in the Mojave Desert at Fort Irwin, San Bernardino County, California, U.S.A. Neonates hatched from captive stock, were maintained in an environmental chamber at California State University, Dominguez Hills. Photoperiods, temperature cycles, and diet were controlled and recorded. All neonates were less than 75 days old. Samples were drawn October 10 and 15, 1991 in the field, followed by the collection of captive samples on October 31. Sampling was completed between 0800 and 1300 hrs.

Hematological results include packed cell volume, estimated total white blood cell count, white blood cell differential, thrombocyte estimate and the morphology and identification of parasites. Captive total white cell counts were significantly lower than the values for naturally occurring individuals. Captive animals also demonstrated significantly lower absolute heterophil, lymphocyte, and basophil counts.

Serum chemistry values include blood urea nitrogen, creatine phosphokinase (CPK) and cholesterol. Triglycerides and uric acid values are reported for naturally occurring animals only. Naturally occurring neonates showed significantly lower values for CPK and cholesterol.

These findings are compared to existing hematological data for adult *G. agassizii*, and its three congeners. The significance of contracting values are discussed in ontogenetic, phylogenetic, physiological, and diagnostic contexts.

Thermoregulation by Desert Tortoises (*Gopherus agassizii*) at the Desert Tortoise Conservation Center, Las Vegas, Nevada: Preliminary Results

Linda C. Zimmerman, Michael P. O'Connor, Stanley J. Kemp and James R. Spotila

Abstract. In preparation for further studies of thermoregulation by desert tortoises (*Gopherus agassizii*) in Las Vegas Valley of the eastern Mojave desert, we conducted a pilot study during June - December 1991 at the Desert Tortoise Conservation Center, Las Vegas, Nevada. We devised a methodology for measuring operative temperatures using solid, aluminum alloy models of desert tortoises. In addition, we measured body temperatures of four adults within a ten-acre enclosure. Two temperature-sensitive radio transmitters were affixed to each animal to measure remotely both internal and external body temperatures. External body temperature, which was measured non-invasively, was a quantifiable predictor of internal body temperature. Body temperatures of tortoises were monitored most closely during July and August. During this time, daily minima and maxima differed by as much as 20 °C. Tortoises used burrows primarily during the hottest times of day (generally between 1000 and 1800 h), but typically did not sleep in them at night. During the first week of November, all telemetered tortoises entered the same bank of rock dens where they remained throughout the winter. Here, body temperatures remained fairly constant during any one day and had declined to approximately 15 °C by December. Microhabitat selection, principally use of burrows and epigeal sleeping sites, markedly influenced body temperatures. Physiological and social influences on, and energetic consequences of thermo-

INTRODUCTION

At the Desert Tortoise Conservation Center (DTCC), our goal has been to study salient features of the biology and natural history of desert tortoises so that this information can be applied to the effective management and conservation of the species. One of the most important regulatory processes of desert-dwelling organisms is thermoregulation, i.e., maintenance of body temperature within physiological or ecological boundaries so that thermal modes and extremes in the environment can be taken advantage of, or at least withstood. To ensure that adequate thermal features are available for desert tortoises in any managed, disturbed or marginal habitat, ongoing studies such as this one and others are essential.

A thorough study of thermoregulation involves at least four aspects: 1) Meteorology measurements of features of the physical environment (e.g., wind speed, solar radiation, ambient temperatures), each of which contribute to characteristics of the thermal environment; 2) Operative temperature, interpretation of the thermal environment in terms of the organism; 3) Body temperature, a result of the interaction between animal and environment; and 4) Habitat utilization and behavior, ways in which animals interact with the environment, e.g., microclimate selection (particularly use of burrows in the case of desert tortoises), and the time and space in which foraging or social interactions occur.

In preparation for a larger scale study of thermoregulation by desert tortoises, we conducted a pilot study to verify our methods for measuring the four aspects outlined above. Results of our preliminary studies pertain to three aspects. (1) We explain a methodology developed to model operative temperatures of desert tortoises. (2) We present two types of data related to body temperature: comparison of internal and external body temperatures, and some examples of daily body temperature profiles. (3) We describe some observations on habitat utilization and behavior, although these are largely anecdotal in this preliminary phase of our research.

METHODS

Operative Temperature

Operative temperature can be considered as the equilibrium body temperature a desert tortoise of a particular mass, shape, color and orientation to the sun would attain in a particular thermal microclimate which itself is characterized by particular combinations of wind speed, radiant heat load, and air and ground temperatures. Operative temperature can be calculated or measured using physical models of desert tortoises. Thus, operative temperature models can be considered as thermometers indicating body temperatures in the environment from which tortoises can potentially select and the microenvironments in which those body temperatures occur.

To model operative temperature physically , we experimented with a variety of materials as thermal replicas of desert tortoises. Our prototype models included metal paint cans, formed sheet metal, aluminum salad bowls and foil oven liners, all of which were hollow, plus solid models of tortoises which were cast from an aluminum alloy. In addition, we experimented with a variety of colors including black, gray, brown, green, beige, white, rust, and various combinations of these. (Color *per se* is irrelevant as long as its spectral qualities mimic those of real tortoises.) Prototype models and real tortoise shells (against which models were calibrated) were placed in subjectively identical thermal microenvironments. Thermocouples (24 ga., Cu-Cn), suspended in the models and shells, were connected to a data logger (Campbell Scientific 21X) which recorded temperatures at 15-minute intervals throughout the day. In addition, ground and air temperatures were recorded.

Body Temperature

Four adult desert tortoises were studied in one of the ten acre research pens at the DTCC.

Tortoise Number	Sex*	Body Mass (Kg.)	Carapace Length (mm)
781	F	1.6	217
824	M	2.4	230
873	F	2.9	246
975	F	2.3	226

* F = female, M = male.

To measure body temperature, we used single-channel radio transmitters (AVM Instrument Co., SB2 M-Module) with a frequency range of 150-151 MHz, an external temperature-sensitive sensor and whip antenna. Each tortoise was equipped with two transmitters to measure both internal and external body temperatures.

Each transmitter was affixed to a thin metal plate which was glued with epoxy to the anterior marginal scutes. This unit was covered with silicone sealant. The entire package with potting weighed approximately 110 g. External probes were affixed with super glue in the scapular area, i.e., the skin opposite the neck. Internal probes were inserted into the coelomic cavity through a small hole drilled through the upper medial corner of an abdominal scute. During this procedure, tortoises were anesthetized systemically with Ketamine HCl (Aveco Co., Inc.) and infiltrated locally with Lidocaine HCl (Elkins-Sinn, Inc.). The internal thermal sensor was held in place with dental resin (The Hygenic Corporation, Type II Class I).

Transmitters were calibrated in the lab prior to being used in the field. The correlation between interpulse period (IPP) and temperature was linear and very good (Fig. 1). Thus, in the field, we measured IPP and simply calculated body temperature using the calibration equation for each particular transmitter.

Body temperatures were detected remotely using a hand-held directional antenna and a scanner/receiver (Telonics TS-1/TR2) connected to a digital data processor (Telonics TDP2). In addition, we noted time of day, location of each tortoise and their behavior.

RESULTS

Operative Temperature

With all of the hollow prototype models of different sizes, shapes and colors, we encountered the same problem of a thermal gradient within the model. This outcome was related both to the comparatively large size of adult desert tortoises and to heterogeneity in the thermal environment.

There is a vertical gradient in air temperatures within, essentially, tortoise height (Fig. 2). Because of the comparatively large size of adult desert tortoises, it is not surprising to see a vertical thermal gradient within their shell as well (Fig. 3). For example, at 1000 (a time of day when tortoises were active in June), there was a difference of more than 10 °C between the surface and the bottom of the shell. Accordingly, this prevented measuring true operative temperature. However, solid operative temperature models, cast from a thermally conductive aluminum alloy and painted flat black, produced good results. Comparison of mid-shell and mid-model temperatures (Fig. 4) shows that they closely coincided, unlike in any of our other trials.

Internal and External Body Temperatures

In general, external body temperature was a good predictor of internal body temperature (Fig. 5, a-d). Outlier points were measured when body temperature was rapidly changing, typically shortly after tortoises emerged from or entered burrows.

Body Temperature Profiles

Tortoises were observed on 32-35 days each culminating in an average total of 204 observations per tortoise. We monitored body temperatures most closely in July and August. During this time, body temperatures were highly variable. Throughout this time, body temperatures were lowest (mean = 21.3 °C) at dawn and highest (mean = 41.5 °C) in the evening. Except for brief bouts of activity in the mornings and evenings, tortoises spent most of the day in burrows or rock dens. However, more often than not, tortoises did not sleep in burrows at night. During a total of 14 observations of sleeping sites in July and August, tortoises slept in epigeal sites 80% of the time.

Part of the wide daily range in body temperature during mid-summer was related to whether tortoises slept in burrows at night. For example, on 24 July, Tortoises 781 and 873 slept above ground, while tortoise 975 slept in a burrow. The resulting difference in their body temperatures was 7 °C (Fig. 6). On that same day, tortoises became active *ca.* 700-800 h and then body temperatures steadily increased to a range of 37.3 - 38.4 °C (Fig. 6). At this point, tortoises entered burrows. Tortoise 975 was approximately two m within an artificial burrow (PVC pipe, 2 m long and bisected longitudinally, buried at a 15· angle to the surface), whereas Tortoises 781 and 873 occupied natural burrows which were not very deep. Tortoises emerged from burrows *ca.* 1900-2000 h and a brief period of activity, spent mostly foraging, ensued. At dusk, tortoises became inactive. Once again, Tortoises 781 and 873 slept above ground while Tortoise 975 selected a burrow. Disparity in body temperatures depending upon sleeping site selection is apparent (Fig. 6). Finally, following emergence the next day, body temperature again increased steadily.

Overall, a similar pattern in daily body temperatures was seen in August except that thermal extremes were attenuated (Fig. 7). Tortoises did not get as hot during activity because they retreated sooner and they stayed warmer at night than in July. For example, on 9 August, body temperatures were fairly constant while tortoises were in mid-day retreats (Fig. 7). Tortoises emerged *ca.* 1800 h for a brief period of activity in the evening. This night, as was customary, all tortoises slept above ground. On the following day, as the sun rose and tortoises became active *ca.* 700-800 h, body temperatures gradually increased (Fig. 7).

In late October early November, all four tortoises entered the same bank of rock dens in the northeast corner of the enclosure. Here, their body temperatures remained nearly constant during any one day. By December, body temperatures had gradually declined to approximately 15 °C (Fig. 8).

DISCUSSION

Operative temperature modeling makes it possible to quantify both resource availability (i.e., spatial distribution of thermal microclimates within the environment) and resource utilization (i.e., microhabitat selection by desert tortoises) (e.g., Grant and Dunham 1988). By definition, operative temperature describes the temperature of an isothermal body (Winslow et al. 1937 in Bakken et al. 1985). Accordingly, thermal gradients within hollow prototype models with which we experimented prevented us from measuring true operative temperature. Nonetheless, internal thermal gradients are inherent to adult desert tortoises (Fig. 3) in a heterothermal environment (Fig. 2) and have been measured previously (McGinnis and Voigt 1971). Solid aluminum operative temperature models are advantageous insofar as they will allow us simultaneously to come as close as we can to measuring equilibrium temperatures while accounting for the thermal inertia inherent to large reptiles. As a result, using this methodology for operative temperature modeling, we will be able to quantify the range of body temperatures potentially attainable by desert tortoises and the types of microclimates in which those occur. Such findings will help to ensure that adequate thermal features are available for desert tortoises in any managed, disturbed or marginal habitat.

We consider internal body temperature to be a better measure of true body temperature than external body temperature. However, deep body or core temperature cannot readily be repeatedly measured without using invasive techniques. Accordingly, to measure body temperature non-invasively, we calibrated external body temperature against internal body temperature to quantify their correspondence. We intend to strengthen this relationship with additional data in 1992. At this point, we interpret our results (Fig. 5) as demonstrating that external body temperature is a quantifiable predictor of internal body temperature.

Body temperatures of desert tortoises in mid-summer varied by as much as 20 °C daily (Fig. 6). These preliminary results indicate that desert tortoises appear to avoid thermal extremes instead of regulating body temperature around some thermal set point. This finding contrasts with thermoregulatory patterns documented in other reptilian herbivores which, when possible, maintain a relatively constant body temperature during the day (Christian et al. 1983a; Zimmerman and Tracy 1989).

Microclimate selection influenced body temperature markedly. It will be insightful to explore the energetic consequences of behavioral variation in habitat utilization by desert tortoises. For instance, it is important to document more rigorously thermal and energetic consequences of sleeping site selection. For example, adult Galapagos land iguanas (*Conolophus pallidus*), animals which are ecologically related to desert tortoises insofar as they are large reptilian herbivores, selected cooler sleeping sites during the hot season and warmer sleeping sites during the cool season (Christian et al. 1983b). Epigeal sleeping sites may reduce energy expenditure during a time of day when tortoises are already inactive and during a time of year when warm nighttime temperatures are not necessary to enhance digestion. Another possibility is that cooler sleeping sites mitigate against rapid warm-up in the morning, thus extending activity time during the following day (Huey 1982).

Nutritive and reproductive status influence thermoregulation in reptiles (Hammond et al. 1988). Moreover, a suite of physiological and behavioral performance variables are temperature-dependent in reptiles (Stevenson et al. 1985). Consideration of thermodynamic consequences of microclimate utilization and seasonal patterns of daily body temperature profiles will provide insights regarding mechanistic bases for and ecological importance of thermoregulation by desert tortoises.

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The Desert Tortoise (*Gopherus agassizii*) in St. George Valley: Introduced or Native?

Breck D. Bartholomew and Michael P. Coffeen

For over fifty years the St. George Valley, Utah populations of *Gopherus agassizii* have been considered introduced. The idea that these tortoises are introduced has caused many people to simply overlook the protective measures warranted by their threatened status. In order to determine the origin of these tortoises, we analyzed seven morphological characteristics of *G. agassizii* from the Beaver Dam Slope and St. George Valley and compared them to released captives. The variance of these characteristics was significantly greater for the released captives than the Beaver Dam Slope and St. George Valley tortoises. The morphology of the St. George Valley tortoises did not differ significantly from the Beaver Dam Slope animals. This morphological data, in concert with data on the behavior, biogeography, ecology and demographics of *G. agassizii* from St. George Valley indicate the St. George Valley tortoises are probably native.

Relationships Between Tortoise Population Declines, Levels of Human Use and Impacts to Habitats

Kristin H. Berry

In California, 15 permanent study plots for desert tortoises were established between 1973 and 1980 to monitor population attributes and habitat condition. With two exceptions, each plot was sampled three or more times in the last 10 to 12 years using 60-day spring surveys, and population densities of three size-classes of tortoises were estimated using the Stratified Lincoln Index. For each plot and each sample year, densities were computed for (1) all size classes; (2) only large immature and adult tortoises $\geq$ 140 mm in carapace length (CL); and (3) only subadult and adult tortoises $\geq$ 180 mm CL. The relationships between population densities, sampling years, human use levels and impacts to habitats were evaluated using linear and multiple regression analysis.

In one example, densities of large immature and adult tortoises in the initial sampling year were compared with densities in the latest sampling year, a 10- to 12-year interval, using percent of initial sample. One measure of habitat condition (percentage of introduced annual plants) and two measures of human use (mileage of roads and trails and number of visitor-use days) were compared with population densities. Tortoise populations decreased significantly with (1) increasing mileages of linear disturbances from roads, trails, routes, and tracks ($P<0.01$); (2) increasing numbers of human visitors ($P<0.05$); and (3) increasing percentages of introduced annual plants ($P<0.05$). Study plots with stable or increasing populations have low mileages of linear disturbances and vehicle use, few human visitors, and relatively low percentages of introduced annual plants. Only two of the 15 plots have stable or increasing populations and both are situated in the northern Colorado Desert where disturbance levels are generally lower than elsewhere in the California deserts.

In a separate analysis, relationships between tortoise population status, human use levels, and habitat condition were evaluated using Spearman's coefficient of rank correlation.

Turtles Under Siege: Parallels Between Sea Turtles and Desert Tortoises

Karen A. Bjorndal and Alan B. Bolten

The survival outlook for both desert tortoises and sea turtles is affected by a number of very different factors. Sea turtles face a variety of human-induced threats in each of their life history stages. Many of these threats are the result of human activities directed at sea turtles. However, as direct harvest by humans is brought under control in many areas, the greatest human-induced threats to sea turtles may be the more insidious indirect effects of human activities.

Female sea turtles concentrate on nesting beaches to deposit clutches of eggs. This concentration of reproductive individuals and the extended immature stage (30 to 50 years in green turtles) make sea turtle populations very vulnerable to over-exploitation. Humans can take every egg and every nesting female from a beach every year for 30 to 50 years before the population crash becomes obvious to the harvesters.

Nesting beach habitat is also vulnerable to destruction by humans. Habitat degradation can result from mining sand for construction purposes. Various forms of barriers and sea walls that are erected to prevent beach erosion and to save beach property also serve as barriers to female sea turtles attempting to nest. Artificial lighting on or behind beaches discourage females from coming ashore to nest and disorient hatchlings emerging from nests. Such disorientation from artificial lighting results in the deaths of thousands of loggerhead hatchlings each year in Florida.

Sea turtle eggs are harvested throughout the world, both as a food source and, in some areas, because of their supposed powers as an aphrodisiac. Eggs are also preyed upon by predators introduced by man either as game animals or domestic animals. Introduced dogs, hogs and foxes take high percentages of egg clutches on some beaches. On other beaches, unnaturally high raccoon populations--subsidized by human activities--destroy large proportions of turtle nests.

Once hatchlings have emerged from nests and travelled out to sea, indirect effects of human activities continue to be an important source of mortality. The same physical forces of winds and currents that concentrate little turtles and sargassum in driftlines also collect floating debris and tar. Turtles become entangled in this debris and tar. Also, because turtles are opportunistic feeders at this stage, they ingest tar and debris. Often such entanglement or ingestion is fatal.

After sea turtles leave the pelagic zone and enter the shallow, benthic feeding areas that they will inhabit for the rest of their lives, they are, in many areas, exposed to extensive directed take by fishermen. Turtles are caught by many methods on their feeding grounds--in tangle nets, by harpoons, by skin diving and spear guns, or even with the help of remoras. In the past, sea turtle conservationists thought that such exploitation on feeding grounds would not have a significant effect on a sea turtle population. It was thought that turtles were too dispersed on their feeding grounds and that the capture methods were too inefficient to have a major effect. We now realize that the unrelenting exploitation that occurs in many areas can have devastating effects on sea turtle populations, and that exploitation of turtles on their feeding grounds is an important source of mortality.

Turtles on their benthic foraging grounds continue to be plagued by entanglement in and ingestion of marine debris. Entanglement in discarded monofilament fishing line and fishing nets is a particularly common source of mortality.

Probably one of the greatest sources of mortality, and certainly one of the most visible, is the capture of sea turtles in fisheries that are directed at other species. Incidental capture of sea turtles in shrimp trawls has received the greatest attention in recent years, but there are many other fisheries that are also serious problems. Capture of sea turtles in other trawl fisheries, in driftnets, and in gill nets, as well as on long-lines are important sources of mortality.

Destruction of foraging habitats is an increasing problem. Dredging, destructive fishing practices, pollution, and recreational boaters are only a few of the many sources of degradation of foraging habitats. This situation is made worse by the fact that many sea turtle foraging habitats--coral reefs and seagrass beds, in particular--are notoriously slow to recover from such damage.

The greatest challenge to those individuals interested in the conservation of sea turtles or desert tortoises is to quantify the cumulative effect of these many sources of mortality on the overall mortality rate for the remaining populations of these species. In the case of sea turtles, international cooperation is necessary to develop rational management programs.

The Raven Management Program of the Bureau of Land Management: Status As of 1992

William I. Boarman

Abstract. The common raven (*Corvus corax*) is a major predator on juvenile desert tortoises (*Gopherus* [=*Xerobates*] *agassizii*). In 1988, the Bureau of Land Management (BLM) initiated a program to increase survival of juvenile tortoises by reducing raven predation on tortoises. A final Raven Management Plan and Environmental Impact Statement is scheduled to be released in 1993. In the interim, the BLM will be conducting an experimental program to shoot and live trap ravens. Also, the BLM is coordinating several efforts to survey raven populations in the vicinity of existing or proposed raven attraction sites (e.g., landfills) and is promoting more effective landfill operating methods that will reduce raven use of landfills for food.

INTRODUCTION

The common raven (*Corvus corax*) is a major predator on juvenile desert tortoises in some areas (Berry 1985, 1990). Several lines of evidence support this contention (Boarman in press): i) large numbers of juvenile tortoise shells have been found beneath known raven nests and perches; ii) many shells that show evidence of predation by ravens are found individually throughout the range of the tortoise, many of which are not necessarily associated with raven perches or nests; iii) significant decreases in juvenile representation in the size/age classes have been identified in well studied tortoise populations; and iv) people have observed ravens killing, carrying, and consuming juvenile tortoises. A 1500% increase in the numbers of ravens in the Mojave desert between 1968 and 1988 (BLM, 1990) indicates that raven predation on tortoises has likely increased significantly in recent years. Because ravens make frequent use of food and water subsidies provided by humans (Knight and Call 1980), their population increase can be tied to the increase of anthropogenic food and water sources, such as landfills, agricultural fields, and septage ponds (Boarman in press).

In 1988 the Bureau of Land Management initiated a process to evaluate, design, and implement a program to reduce raven predation on desert tortoises within the California Desert Conservation Area. A pilot program to shoot and poison ravens was implemented in 1989, but was essentially halted by a Temporary Restraining Order filed by the Humane Society of the United States (*HSUS v. Manuel Lujan et al.*, 1989)[1]. A draft Raven Management Plan (Plan) and a Draft Environmental Impact Statement (EIS) were issued for public comment in 1990 and are now being modified. The modified Plan and EIS are scheduled for release in 1993 and will cover the first of a multi-phased program, with each successive phase depending on the findings from previous phases. The initial phase will include: shooting and live-trapping ravens, reducing the availability of food and water subsidies, monitoring for effects of actions on tortoise populations, and research on raven behavior and ecology to find effective means of manipulating raven behavior and populations to benefit tortoises.

In the meantime, the BLM developed an Interim Control Program which was to be implemented in Spring, 1992. The Interim Control Program was designed to collect data essential for finalizing the long-term Plan and EIS while also removing some problem ravens. If fully implemented, the program will: i) evaluate the impacts poisoned eggs may have on non-target species; ii) determine the cost-effectiveness of live-trapping and shooting ravens; and iii) study the movements and home ranges of ravens. Because of insufficient resources, the BLM postponed implementation of the Interim Control Program. The project to experimentally shoot and live trap ravens will be conducted in Spring 1993, focusing on removing most ravens from the Desert Tortoise Natural Area, while also removing individual birds in other areas where there exists strong evidence of recent predation. Implementation of the studies on the non-target impacts of poisoned eggs and on raven movements are pending funding.

In addition to the Interim Control Program, the BLM is actively working with landfill operators and proponents to reduce the availability of anthropogenic food sources for ravens by changing landfill management methods and monitoring raven use of landfills. To reduce the availability of food to ravens at landfills, landfill operators are being asked to cover the solid waste using the methods most effective at ensuring that the garbage remains covered at all times by: i) covering with a minimum of 6 inches of fill at the end of each day, or more frequently if possible; ii) using up-slope or other maximally effective methods of covering the cells; and iii) investigating more effective means of covering if the other methods are insufficient (e.g., synthetic cover material). Coyote-proof fencing should be installed because coyotes are know to dig up garbage, which makes it more accessible to ravens. Sorting areas, where solid waste is exposed for inspection, should be enclosed with screening and kept free of organic matter and standing water whenever people are not present. Ravens should be prevented from accessing any water on site by: i) installing drains at truck washing facilities or, other places where water runoff may collect; ii) placing screen or monofilament line over septage and leachate ponds; and iii) preventing puddles from remaining in place after a rain. We are currently testing methyl-anthranilate, an artificial food-flavoring that acts as a chemical aversion for several birds species, to see if it can be used at landfills.

Monitoring projects are being initiated in association with several landfill projects. The primary purposes of the monitoring efforts are to i) determine how ravens use the area to help develop viable management actions and ii) to monitor for changes in raven numbers, distribution, or behavior as a result of management actions. Because ravens can fly 65 km or more in a single day (Engel and Young 1992), and much farther over the course of a year (E. Knittle, pers. comm.; pers. obs.), a landfill or other major food or water source may affect raven populations over a relatively large area. Therefore, surveys will be conducted at the specific landfills, proposed landfills, or other likely raven concentration sites and on roads within a 50-km radius of the site.

The surveys are designed to ensure that maximum scientific validity will result. The survey routes will be broken into segments, each encompassing only one major land-use type (e.g., agricultural fields, towns, open desert, powerline or other linear corridor, etc.). If possible, specific land-use types will be replicated at least two times. Each individual segment will be covered at different times of the day throughout each month. Data collected for each raven observation will include: time specific location, number of ravens in group, behavior, approximate distance from road and height off ground, and perch type.

All significant raven concentration sites in the area will be located and numbers of birds will be counted at different times of the day throughout each month of the survey. Several times during the year an extra effort will be placed into locating group roosting sites. This primarily involves careful searching and following of ravens very close to and after sunset. When roosts are located they will be censused at least once per month. An attempt will be made to locate all nest sites within the survey area. The area beneath nests, roosts, and commonly-used perch sites will be searched periodically for tortoise shells.

If ravens use the landfill, it may be necessary to conduct a study of raven movements to determine the influence the project has on regional raven populations. A minimum of ten ravens would be affixed with radio-transmitters (with new birds added as old ones are lost to the study) and followed on a regular basis. Periodic aerial surveys would likely be necessary to locate some of the birds. The distance to be searched may easily exceed 80 km from the capture site. Additional birds should be affixed with wing tags to allow for less intensive monitoring of their movements. The study should be conducted for a minimum of three years.

Effective reduction of raven predation on juvenile tortoises requires a multi-faceted program that includes removal of problem birds, alteration of artificial sources of food, monitoring of tortoise and raven populations, and research into raven ecology and behavior. Because we have limited knowledge of raven ecology and behavior and of effective management methods, constant evaluation is necessary, and modifications in the program may be effected as new information becomes available. By coordinating control and monitoring efforts and evaluating the results, a viable management program will emerge.

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Food Habits of Nesting Common Ravens in the Eastern Mojave Desert

R.J. Camp, R.L. Knight, H.A.L. Knight and M.W. Sherman

We studied food habits of nesting common ravens (*Corvus corax*) in the eastern Mojave Desert between 15 - 30 May 1991. Two hundred and twenty six pellets from 39 active nests were analyzed. Vertebrates comprised half of the total weight of raven food items, with mammals being the most important taxa. Although reptiles were unimportant in terms of biomass, they occurred in almost 76% of all pellets. Iguanid lizards were the most common reptile food item, and desert tortoises (*Gopherus agassizii*) were found in pellets from two nests. Invertebrates occurred in 90% of all pellets, and ants and beetles were the most common insect prey. Human refuse occurred in almost a quarter of the pellets.

Modeling Raven Predation on the Desert Tortoise: An Age and Space Structured Approach

Chris Ray, Michael Gilpin, Carl Biehl and Thomas Philippi

Abstract. As populations of the common raven expand across desert tortoise habitat, increases in predation pressure may reduce tortoise population growth. Published observations suggest that raven predation is not spatially uniform, a fact that may be important in determining its ultimate, region-wide effect on tortoise populations. To explore the potential effects of spatially structured raven predation on a dynamic tortoise population, a simple model has been developed. The modeling process points out critical deficiencies in our knowledge of raven predation strategies and tortoise dispersal patterns. However, the model shows that tortoise populations may be able to sustain substantial increases in juvenile mortality before experiencing negative growth. A 25% increase in mortality of tortoises under 5 years old is necessary to reduce a discrete population growth rate from 1.02 to below 1.0. If raven predation primarily affects this class, it may be most efficient to focus research efforts on whether ravens can significantly contribute to losses of this magnitude.

INTRODUCTION

Recent management decisions concerning the common raven (*Corvus corax*) have focused on its increasing role as a predator of desert tortoises (*Gopherus agassizii*) in California (EASCCR 1989). Raven populations in the western Mojave desert appear to be increasing, especially in developed areas, along fences, roads, transmission and power lines, and around landfills (Berry 1985). Evidence of raven predation on tortoises has been documented near nesting and perching sites (Berry 1985; Berry et al., 1986). It has been asserted that predation on juvenile tortoises has been increased over historical levels as a result of increased raven activity in desert tortoise habitat, resulting in a decrease in representation of juvenile tortoises in some current populations (EASCCR 1989).

We are interested in predicting the degree to which raven predation may decrease tortoise population growth. We believe the spatial aspect of this predation will influence its ultimate impact on tortoises. For example, a raven that takes 100% of those juvenile tortoises near its nesting site may have either more or less of an impact than one that takes 10% of juveniles throughout its entire foraging range. Depending on the dispersal rate of juvenile tortoises, more or fewer may wander into a "sink" surrounding a raven nest than would be taken by a bird that forages less efficiently across a larger area. This link between raven foraging strategies and tortoise dispersal behavior is essential to predicting the ultimate effect of raven predation on tortoise population growth. In order to explore the potential effects of spatially structured raven predation on a dynamic tortoise population, a simple model has been developed. In this paper we describe our model, present its predictions, point out some of its limitations and discuss the questions that arose out of the modeling process.

The Model

To introduce a spatial component to the dynamics of a single tortoise population, we divide the population into an array of "cells" linked by dispersal. Each cell has a distinct predation pressure that may differentiate its internal dynamics from other cells. For tractability, we have modeled a linear array of such cells, and have assumed that dispersal occurs only between nearest neighbors.

The internal dynamics of each cell are determined by stage-specificity in both growth and predation. A stage-specific growth model (see Caswell 1989) was derived from demographic data gathered on a population at Goffs, California by Turner et al. (1987), where the stages are composed of individuals that roughly represent the different rates of reproduction, survival and vulnerability to predation experienced by tortoises throughout a lifetime (adapted from Biehl 1990). Seven stages are identified and included in a population projection matrix (Fig. 1). In the absence of predation, this projection matrix results in yearly growth of about 2%.

The spatial aspect of mortality due to predation is implemented differentially across cells by specifying a symmetrical predation rate function across the one-dimensional population transect. The function decreases linearly with distance from its maximum intensity, which is focused on the most centrally located population cells (see top graph in Fig. 2). A separate predation function is defined for each stage class, so that juvenile tortoises may experience higher predation than adults, etc. However, all stages experience the same functional form, if not intensity. This predation model could represent a linear transect running perpendicular to a corridor along which ravens nest and forage, such as a road or powerline. A steeply sloped predation function with a high maximum would mimic local and intense predation, while a shallow slope and maximum would mimic less efficient predation across a larger area. We assume that raven predation pressure is independent of tortoise density; i.e., tortoises do not represent a limiting resource for ravens.

After assignment of an inter-cell dispersal rate, population growth projection is accomplished through iteration of the following: multiplying each cell's population stage vector by the population growth matrix, reducing the resulting population vectors by the stage-specific predation rates for each cell, and dispersing the given fraction of all stages between neighboring cells. Predicting the sensitivity of this model to any one parameter involves exhaustively varying the value of each parameter in turn. The sensitivity of this model has been tested for the following: the maximum (central) predation rate for any stage; the slope of the predation function; the dispersal rate between adjacent cells; and the distribution of ages included in each stage in the population projection matrix.

Model Predictions

Figure 2 is an example of model output. The graphs illustrate the relationship (at time $t = 15$) between three independent variables (tortoise dispersal, predation slopes and maximums) and two dependent variables (population cell stage distribution and growth rate), for an arbitrary choice of independent variable values. At $t = 0$, each population cell contained 100 individuals in the stable stage distribution that would have resulted if raven predation were absent (resembling the outer cells in Fig. 2). With no dispersal, the entire population growth rate would have remained 1.02 (it would be slightly depressed in the presence of dispersal because this model allows dispersal off the "ends" of the transect).

Several general conclusions can be drawn from this model. First, predation on the younger stages is not as effective as predation on the older stages in lowering the population

Stage class transition matrix

	1	2	3	4	5	6	7
1	.696	.000	.000	.908	1.988	2.310	2.642
2	.093	.665	.000	.000	.000	.000	.000
3	.000	.143	.606	.000	.000	.000	.000
4	.000	.000	.232	.748	.000	.000	.000
5	.000	.000	.000	.137	.841	.000	.000
6	.000	.000	.000	.000	.089	.915	.000
7	.000	.000	.000	.000	.000	.032	.947

Figure 1. This seven-stage matrix for tortoise population projection was based on data from a tortoise population at Goffs, California (Turner et al. 1987). The dominant eigenvalue of the matrix (population growth rate) is 1.024.

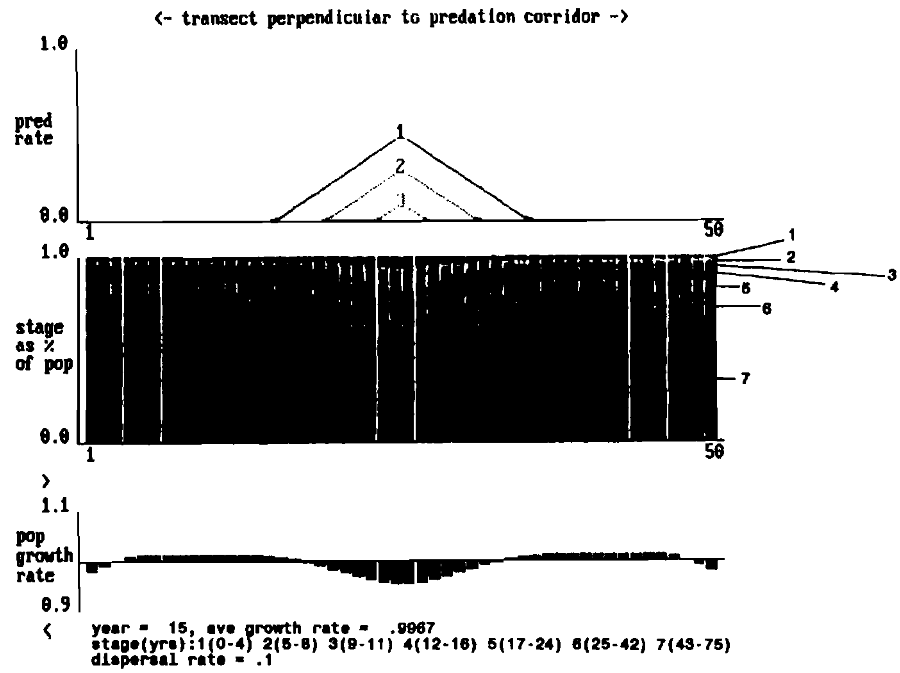

Figure 2. In this example of the predation model output, predation functions for the first 3 tortoise stage classes can be observed in the top graph. Predation on the first class is highest, with a maximum of 50% of these hatchlings taken in the middle of the population transect. The middle graph represents the stage distribution of each population cell. These distributions are not significantly different than they will be at stable stage distribution. The current growth rates of each cell are indicated in the lower graph. The population will eventually relax to a growth rate of 1.01.

growth rate. This will be true as long as desert tortoise demographic parameters are at all similar to those found by Turner et al. (1987). The low survival rate of juveniles to reproductive stages increases the value of reproductive-staged individuals; reproductive values of individuals in the first stage class are less than 5, while those in the fifth class range between 50 and 60 (Biehl 1990). Similar results were obtained by Crouse et al. (1987) for loggerhead sea turtles, which have only qualitatively similar demographic parameters. Second, predation on the youngest stage class decreases the representation of the middle stage classes in the stable stage distribution, while increasing representation of the mature (and sometimes the younger) classes. This effect is created by reduced recruitment to the middle stages and the relatively assured survival of the mature stage class(es). The relatively small decrease in representation of the youngest stage class that can be seen in Fig. 2 is due to the larger percentage of 0-year-olds born to the fractionally larger mature stage class. Third, if predation is applied uniformly across all cells and impacts only the youngest stage class (under 5 years old), it requires a predation rate of almost 25% to push the ultimate growth rate of the population below 1.0, at which point the population declines. Alternatively, predation losses of 15% of the first two stages (under 9 years old) can push the growth rate below 1.0. If the elements of the population projection matrix are uniformly decreased until the yearly population growth is only 1% (to test for sensitivity to errors in the demographic data), a predation rate of almost 15% of the youngest stage class is required to push the growth rate below 1.0.

Model Limitations

This model is bound to misrepresent the potential for raven predation to lower tortoise population growth due to the unavoidable omission of several factors for which we have no data. Two of the most important omissions are those of density dependence in both tortoise population growth and dispersal. Without knowledge of these factors, we cannot make meaningful predictions based on analyses of model sensitivity to the combined effects of non-uniform predation functions and non-zero inter-cell dispersal rates.

Omitting density dependence in tortoise population growth, while allowing dispersal, prevents spatially patchy predation from affecting the population growth rate. If predation reduces growth in every cell, then the average growth of the population is also reduced. If only the ends of the population transect are complete "sinks", then average population growth is reduced by the amount of dispersal into those sinks (if a percent d is dispersed to either side of each cell, then 2d is eventually lost off the ends of the transect, and the population growth rate is depressed by 2d percent). If predation creates additional complete sinks in the midst of the population, those contiguous cells that include at least one growing cell will eventually grow at the rate of the cell with the highest growth rate (minus 2d percent). However, if tortoise growth were density dependent, all cells would eventually reach a carrying capacity, after which the amount of individuals they disperse would be fixed. Cells with pre-immigration growth rates of less than 1.0 would not continually benefit from the exponentially increasing dispersal that drives their growth rates to the maximum in the current model.

It would be straightforward to make cell growth density dependent in this model. However, the form of density dependence, about which we have no knowledge, would so drastically affect predictions of tortoise sensitivity to the predation function that the exercise would be nearly futile. For example, tortoise density dependence could result from reduced female egg production when the number of adults feeding within a cell exceeds some limit.

Alternatively, the growth-limiting factor could be the number of "hiding places" where a hatchling can successfully take refuge from predation. Tortoise population growth would respond very differently to raven predation on hatchlings depending on which of these mechanisms was operating. If the latter mechanism operates, ravens may be simply displacing other predators as a constant mortality factor that depends more on the physical qualities of tortoise habitat than on the biological composition of the community.

The predictive capacity of our model may be further limited by the omission of density dependence in tortoise dispersal. The potential importance of this factor can be visualized using the diagrams in Fig. 3. If tortoises move toward areas of lower density, individuals in the clear region, who would not normally be impacted by predation in the shaded region, will be lost. Raven predation strategy A creates a precipitous decline in tortoise densities across a relatively narrow region, whereas strategy B creates a shallowly sloping tortoise density gradient across a wider region. The degree to which tortoise dispersal is (hypothetically) an inverse function of density gradient determines how effectively each strategy can lower overall population growth. The stronger this relationship, the higher the rate of loss will be from the population cells on either side of predation strategy A relative to those on either side of strategy B. There are of course many strategy variations on this theme, but the general problem remains: we cannot predict overall population decline given spatially differential predation without knowledge of tortoise reaction to spatial population variation.

Our model has also ignored the possibilities of temporal variation in raven predation and of different dispersal capacities of tortoise stage classes. Again, these factors can strongly influence the effectiveness of raven predation. If ravens were using tortoises as a major food source, we would expect them to track tortoise density both spatially and temporally, reducing the impact of tortoise dispersal behavior on the effect of predation. However, if raven activity is concentrated at sites that offer sustained food resources, such as roads and landfills, we would expect tortoise dispersal to remain important. Of course, this importance also depends on the existence of a positive relationship between the dispersal capacity of a stage class and the predation it experiences. If hatchlings are the predominant prey, then considering the dispersal behavior of hatchlings is of major importance. There may still be a need to consider the dispersal behavior of adults, however, as these would be capable of dispersing across corridors of high raven density in order to colonize, recolonize or rescue populations cut off by such corridors.

CONCLUSION

It appears that much research will be necessary to establish the effect of spatially structured raven predation on desert tortoise populations. Even such fundamental variables as the functional form of raven predation over space, the mechanism(s) limiting tortoise density, and tortoise dispersal behavior are relatively unknown. However, the necessity of determining these factors is brought into question by the predictions of a simple model that incorporates only uniform predation across a tortoise population. In order to lower a population growth rate from 1.02 to just below 1.0, a decrease of almost 25% in the survival of tortoises under 5 years old is necessary. Given that over 70% of a tortoise population can be comprised of such hatchlings (Biehl 1990), raven predation would have to account for an extremely large number of tortoise deaths in order to be the sole force behind the decline of

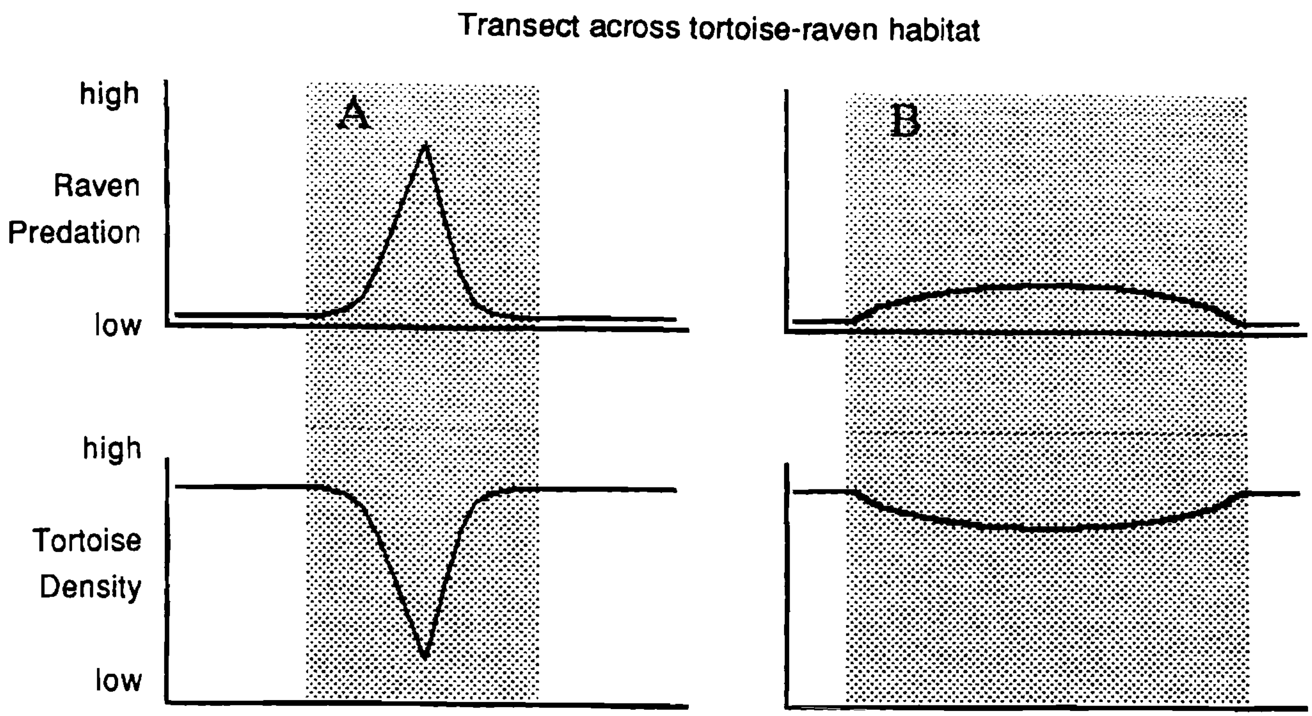

Figure 3. If tortoise dispersal rates are inversely related to the tortoise density gradient, populations under raven predation strategy A will suffer higher losses due to dispersal into the predation zone than will populations under predation strategy B.

a population. It may be most efficient to focus research efforts first on whether or not ravens are capable of approaching this magnitude of predation on desert tortoises.

ACKNOWLEDGEMENTS

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Time-Activity Budgets of Nesting Common Ravens in the East Mojave Desert

M.W. Sherman and R.L. Knight

In spring 1990, we fitted 5 breeding common ravens (*Corvus corax*) with radio transmitters. Raven behavior, habitat use, and movements were recorded continuously during observation periods which totaled 2,174 minutes. Ravens spent 49.8% (SD=15.4%) of their time resting, 28.8% (SD=11.7%) flying, 10.8% (SD=11.7%) feeding, 8.5% (SD=7.9%) in parental care, and 2.1% (SD=2.1%) moving. Fifty-one live-hunting bouts (65%) and 28 scavenging bouts (35%) were observed. Prey type was identified for 72% of the feeding bouts and consisted primarily of lizards, insects and birds obtained by live-hunting, and grain obtained by scavenging. Ravens have a bimodal feeding distribution, feeding primarily between 0500 and 0900 and then between 1200 and 1800. For all non-flight activities ravens spent 51.3% of their time located along human rights-of-way (transmission towers, railroads, telephone poles, and tamarisk trees).

Measuring the Effectiveness of a Tortoise-Proof Fence and Culverts: Status Report from First Field Season

William I. Boarman, Marc Sazaki, Kristin H. Berry, Gilbert O. Goodlett, W. Bryan Jennings and A. Peter Woodman

Abstract. Road kills are an important source of depletion for desert tortoise populations. In 1990, the California Department of Transportation erected a tortoise-proof fence along State Highway 58 between Barstow and Kramer Junction. The California Energy Commission, responsible for licensing thermal power plants in California, Bureau of Land Management, and other agencies initiated a long-term study to determine if the fence will prevent tortoise road kills, and if drainage culverts will accommodate movements of tortoises from one side of the highway to the other. In this paper, we discuss the process used to select the study site and the results of field work performed to collect baseline data.

A series of transects walked within one mile of the highway indicated that human impacts and relative densities of tortoises varied among potential study sites. These data were used to identify the site of a 1 mi^2 permanent study plot. During baseline work on the study site, 44 tortoises were found, 36 tortoises were affixed with radio transmitters, and 3 were equipped with electronic transponders for remote sensing. The remains of 61 tortoises were located along 66 miles of highway edge; these data will serve as a baseline for future surveys to test if the fence is effective at reducing road kills.

INTRODUCTION

Highway traffic has been, and continues to be, an important cause of mortality for the desert tortoise (*Gopherus agassizii;* Berry and Nicholson 1984a), a species state and federally as listed threatened. In addition to gross mortality, roads and highways impact tortoise populations through restriction of movement. This restriction of movement may result in fragmented populations, which may increase the incidence of local extinctions, or increase the potential for inbreeding and inbreeding depression. Both fragmentation of populations and restricted gene flow are more likely to occur with increases in traffic volume, width of highways, and time (e.g., Nicholson 1978). Because there are many roads and highways throughout desert tortoise habitat, the potential for road kills to affect tortoise populations is great, therefore, the mitigation of road kills could help to facilitate the recovery of tortoise populations.

In 1990, California Department of Transportation (Caltrans) erected tortoise-proof fencing along State Highway (Hwy) 58 in a portion of the highway that was scheduled to be widened from two lanes to a four-lane divided highway (Boarman 1991; Boarman and Sazaki, in press). Culverts for flood protection were also installed. Crushed tortoise carcasses have been found along Hwy 58 (Appendix 1 in Boarman 1991), and Bureau of Land Management (BLM) has identified this particular stretch of highway as important tortoise habitat (Bureau of Land Management 1988; Sievers et al. 1988). In 1990, the BLM, California Energy

Commission, Caltrans, U. S. Fish and Wildlife Service, and the California Department of Fish and Game embarked on a cooperative monitoring project to determine the effectiveness of culverts and protective fencing in contributing to recovery of tortoise populations in the area near the fence (Boarman 1991; Boarman and Sazaki in press).

The Review Board for the project developed four study questions (Boarman and Sazaki, in press) that serve as the focus for the long-term project. (1) Is the fence an effective barrier for preventing road kills? (2) Does the fence facilitate "recovery" of the tortoise population near the highway? (3) Do culverts facilitate movements from one side the highway to theother? (4) How do individual tortoises behave when they encounter the fence and culverts? Here we discuss the results of the process to select a permanent study site, and the baseline data collected to address the above questions (see also Boarman 1992).

The Fence and Culverts

The highway traverses slightly rolling terrain consisting primarily of shadscale scrub and creosote bush scrub communities at elevations of 2245 to 2470 ft. The tortoise-proof portion of the fence consists of 24-inch wide, 1/2-inch hardware cloth sunk generally 6 in beneath ground level. The hardware cloth is attached to a 5-ft high, 5-strand right-of-way fence with three barbed wires on top and two un-barbed wires below. The 156 to 206 ft. long culverts are made of 36 to 60 inch, corrugated metal pipe; 54 inch, reinforced concrete pipe; or 10 ft to 12 ft by 6 ft to 10 ft, reinforced concrete boxes. The culverts cross beneath the entire width of the highway and will eventually connect directly to the fence, thus providing an unobstructed pathway between both sides of the fenced highway (Fig. 1).

Study Site Selection

To evaluate the effect of the fence and culverts on tortoise populations along Hwy 58 we established a long-term study plot, approximately 1 mi^{2,} that abuts the edge of the tortoise-proof fence. Because the overall success of the project depends on various characteristics of the specific study site, we designed a two-phased process for evaluating and choosing the site. Phase 1 involved selecting eight candidate study sites, and Phase 2 involved final selection from the alternatives identified in Phase 1. The evaluation criteria for each phase were discussed in Boarman (1991) and Boarman and Sazaki (in press) and included: tortoise density, land status, legal and physical accessibility, presence of culverts, location of fence, size of site, proximity to other roads, right-of-way for All-American Pipeline, similarity of habitat, and human damage to habitat.

Initial Survey for Tortoise Signs and Human Impacts

A series of transects were walked at each candidate site to record: 1) signs of tortoise presence for comparing relative tortoise densities and distributions, and 2) evidence of human impacts on each candidate study site. The data were also used to determine if tortoise densities increased with distance from the highway, as reported by Nicholson (1978).

Methods.--Surveys were conducted for tortoise sign and human impacts between March 20 and 31, 1991. The surveys consisted of a series of strip transects, which were each 10-yds wide and ran the width of each site, parallel to the highway. For each site there were four sets of three contiguous transects (Fig. 1). One set began immediately adjacent to the fence or pipeline right-of-way where it abutted the fence, the second was centered 1/4 mile from the fence, the third 1/2 mile, and the fourth ended 1 mile from the fence.

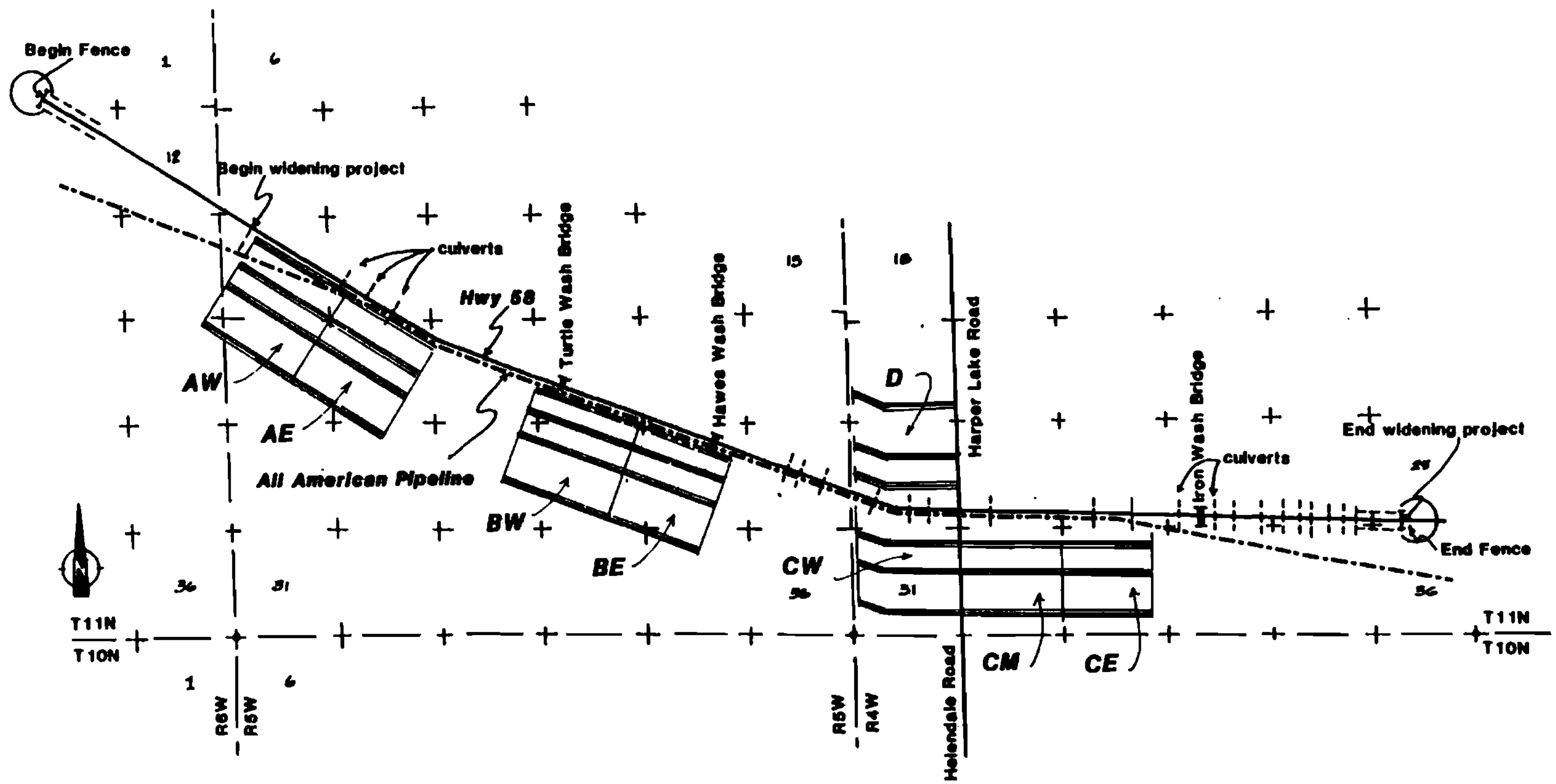

Figure 1. Map showing potential study sites that were surveyed by strip transects for estimates of tortoise density and human impacts.

For tortoise population density, the exact location and characteristics of all tortoise sign (i.e., live animals, shells, tracks, individual or groups of scats, burrows, and pallets) were recorded. Human impacts were evaluated by noting all roads, trails, graded areas, structures, sheep scat, individual tire tracks, campsites, garbage, shooting areas or targets, balloons, and mining pits or markers present on each transect.

For determining if there were significant differences (P = 0.05) among candidate study sites, the total number of tortoise sign along each transect were square-root transformed. The data were entered into a one-factor analysis of variance (ANOVA) with study area being the between groups effect. Pair-wise comparisons among means were made, post-hoc, using the Fisher's Protected Least Significant Difference test. A Kendall Partial Rank-order Correlation Coefficient was estimated to test for an east-west gradient in tortoise sign among sites. This analysis assumes that differences in total corrected sign counts (independent observations of scats, tracks, and burrows) accurately corresponded to relative differences in tortoise density.

Results.--The one-factor ANOVA of the transformed data showed a significant difference among sites (F = 2.544, df = 7, 88, p=0.020; Table 1). Post-hoc analyses indicated that the sites roughly fell into three groups: site AE with the lowest count, site CE with the highest, and all others in between. The seven sites that were south of the highway showed a nearly significant increase in tortoise sign from west to east (= 1.925, p =0.0543, n = 7).

Discussion.--The density of tortoise signs did differ among sites, with a possible increase in densities from west to east. The highest density area, which was significantly higher than the others, was on the eastern-most site. The lowest density was near the west end of the study area.

Table 1. Mean number of tortoise sign found along each 1-mile long transect within each study area. Study areas are arrayed from west to east (with exception of D which was directly north of area CW). N for each area is 12.

Study Area	TCS	Standard Error
AW	2.5	0.74
AE	1.5	0.36
BW	4.1	0.93
BE	3.1	0.66
CW	4.3	0.96
CM	3.6	0.70
CE	7.1	0.23
D	4.9	0.01

Selection Process

To help select the study site, we used the method of Decision Analysis under uncertainty, which was developed by Raiffa (1968) for business management and adapted for wildlife management by Maguire (1986). Decision Analysis provides a framework for evaluating alternative choices in the face of a myriad of uncertainties that affect the outcomes of each alternative decision. The selection of the best available study site is essential for the success of the long-term project, but was dependent on several criteria (listed above), several of which involved uncertain impacts or intensities. It was necessary to consider several factors which often contradicted each other and made the selection process more complicated. The criteria considered were discussed in detail in Boarman (1991) and Boarman and Sazaki (in press). The stability of the land status was one uncertain factor. The extent of habitat heterogeneity and human impacts to the habitat and their respective impact on the outcome of the study were also uncertain. The extent and effects of the other criteria were more certain.

In the final analysis, three factors were most important in selecting the site: presence of culverts, human impacts, and land status. The site (CE) with the most tortoises had the most tenuous land status and the highest potential human impacts. The best sites (AW, BW, and BE)with intermediate tortoise densities had no culverts. Site AE, with the lowest human impacts and most stable land ownership and management status, had significantly fewer tortoises than any other site.

The selected study plot is a combination of study sites AE and AW (Fig. 2). It contains three culverts (two round corrugated metal ones and one large, double, concrete box culvert), has a relatively low level of human impacts, exhibits moderately heterogeneous habitat, is sufficiently large to contain a 1 mi^2 study plot with room for expansion, and is easily accessible for field workers. The All-American Pipeline does skirt the edge of the fence at the northeast end of the site, which may confound the study, but this was also true of all other marginally acceptable sites. The site includes a portion of the low density site AE, but was extended as far as was possible into site AW, which had an intermediate tortoise density. If feasible, the boundaries of the plot will be extended in the future to incorporate more of the higher density tortoise habitat and is less confounded by the All-American pipeline.

Baseline Inventories

Once the study plot was identified, it was prepared in the same manner as the permanent study plots established by the BLM for tracking tortoise population changes (Berry 1984b). The plot was surveyed for live tortoises, and radio transmitters were attached to 36 of them. Passive Integrated Transponders (PIT tags) were attached to three individuals.

Study Plot Location and Characteristics

The study plot is located on the south side of Hwy 58, approximately 7 miles east of Kramer Junction, San Bernardino Co., California (Fig. 2). It consists primarily of rolling hills to the north and relatively flat areas to the south. Vegetation is primarily an association of creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), Mojave saltbush (*Atriplex spinifera*), and Anderson thronbush (*Lycium andersonii*). Creosote is predominant in the northern portion of the study plot and saltbush dominates in the south. A small dry lake bed occurs at the southeast corner of the plot. The plot's substrate primarily consists of coarse sand or gravel with patches of cobblestone in the north and sandy loam in the south.

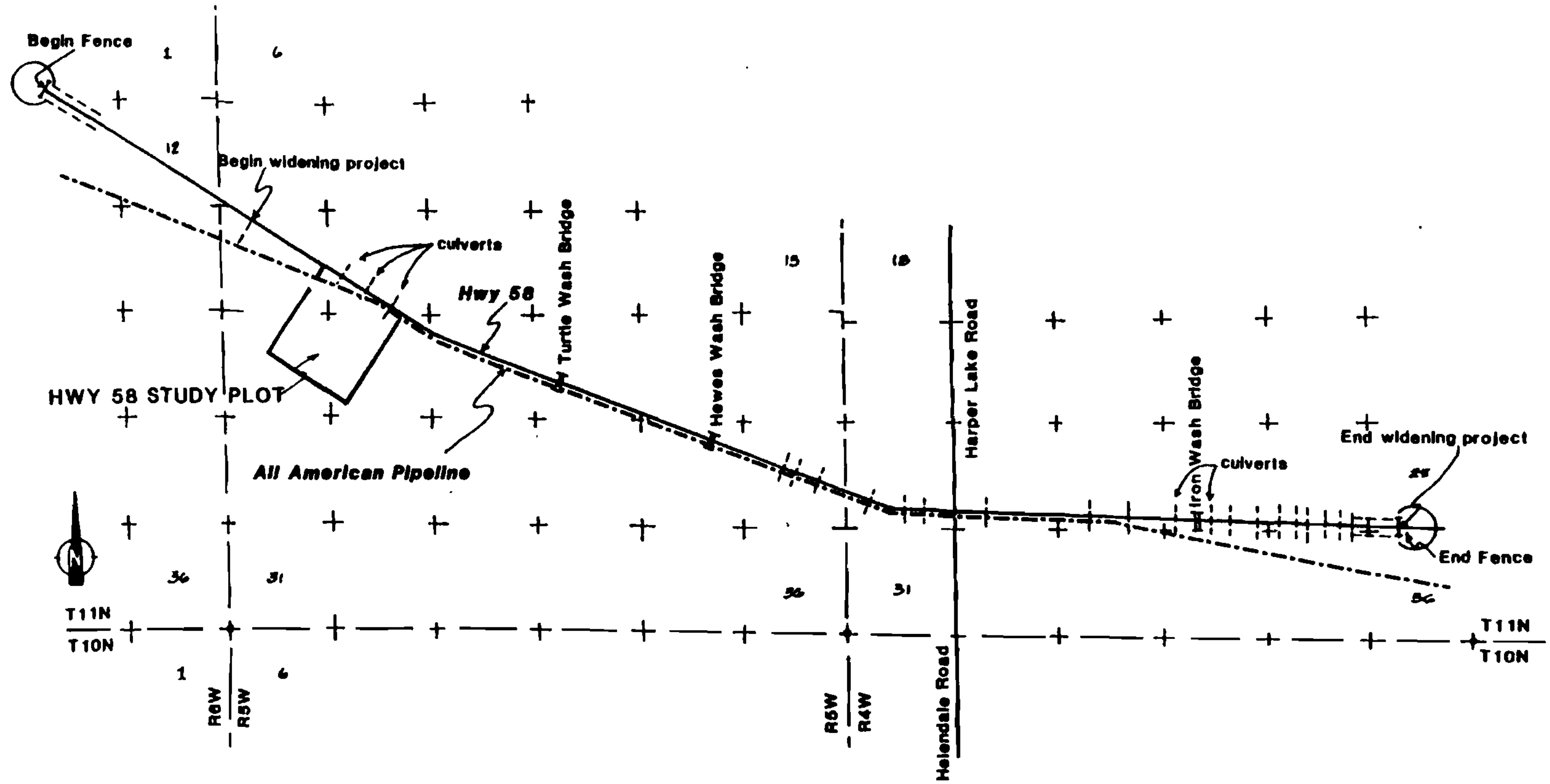

Figure 2. Map of general location of study plot.

Table 2. Size-age class distribution of live tortoise found on the study plot in spring, 1991.

Size-age Class	Unidentified Sex	Males	Females	Total	Percent
Juvenile 1	2			2	4.2
Juvenile 2	2			2	4.2
Immature 1	10			13	27.6
Immature 2	12			12	25.5
Subadult		3	0	3	6.4
Adult 1		1	9	10	21.3
Adult 2		4	1	5	10.6

Site Surveying and Marking

On May 3, 1991, the 1 mi^2 study plot was surveyed and a grid system established that was identical to that used at other BLM permanent study plots (Fig. 3). The northeastboundary of the site was along the highway barrier fence with the sides running at 90° angles southwest for one mile. The plot was surveyed relative to the legal cadastral survey for the area using range poles and reflecting prisms, which reflect infrared light back to the instrument giving a very accurate, distinct measure. A compass bearing, corrected for declination and accurate to 0.25°, was used as a reference angle. A total of 100 quadrats, which were each 528 ft X 528 ft, were surveyed and marked. For marking each quadrat, a four-foot length of 3/8-in rebar was placed in each corner. Ten-ft long 1/2-in diameter, Schedule 125 PVC pipe was placed over each rebar. The quadrats were numbered from 00 in the NW corner of each cadastral section (Fig. 7) and the quadrat number was written on the pole at the northwest corner of each quadrat. An additional five off-plot quadrats were established in the northwest corner where tortoise densities were higher.

Tortoise Surveys

Between April 27 and June 19, 1991, all quadrats were searched at least twice for tortoises. Each quadrat was searched methodically, using a standard pattern of parallel transects as described in Berry (1984b). The experienced field workers first walked the 10-yard wide contiguous transects in one direction then covered the entire plot again by walking similar transects at a 90° angle to the first ones. Every effort was made to rotate search times. However, 60-80% of the quadrats were searched before noon because mornings are usually more successful than afternoons for locating tortoises. All tortoises were marked (Berry 1984b), weighed, sexed, measured, and photographed, and observed for health status using methods described in BLM (1991).

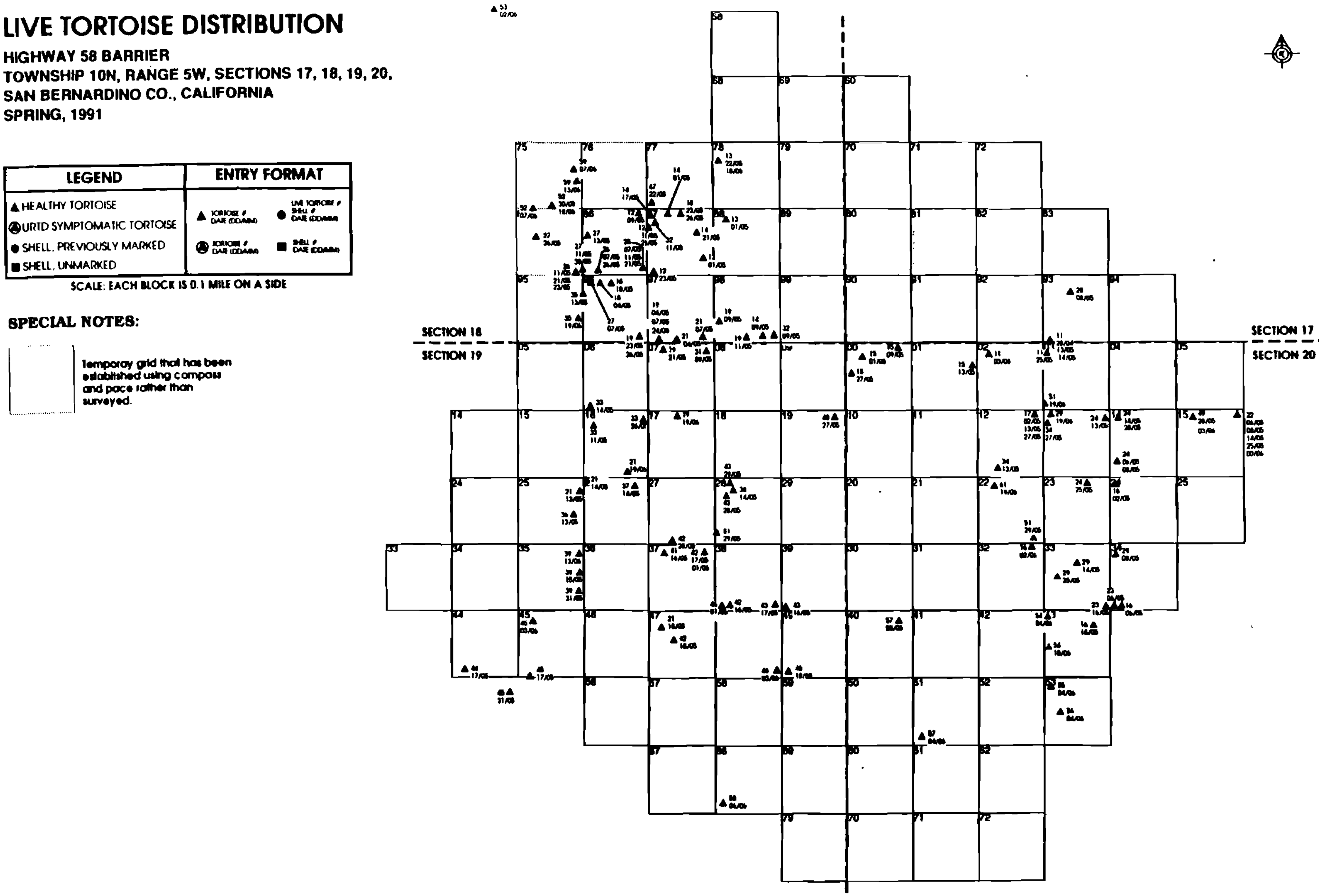

Figure 3. Map showing the layout and numbering system of plot grids and showing all individual tortoise sightings within or near the study site in spring of 1991.

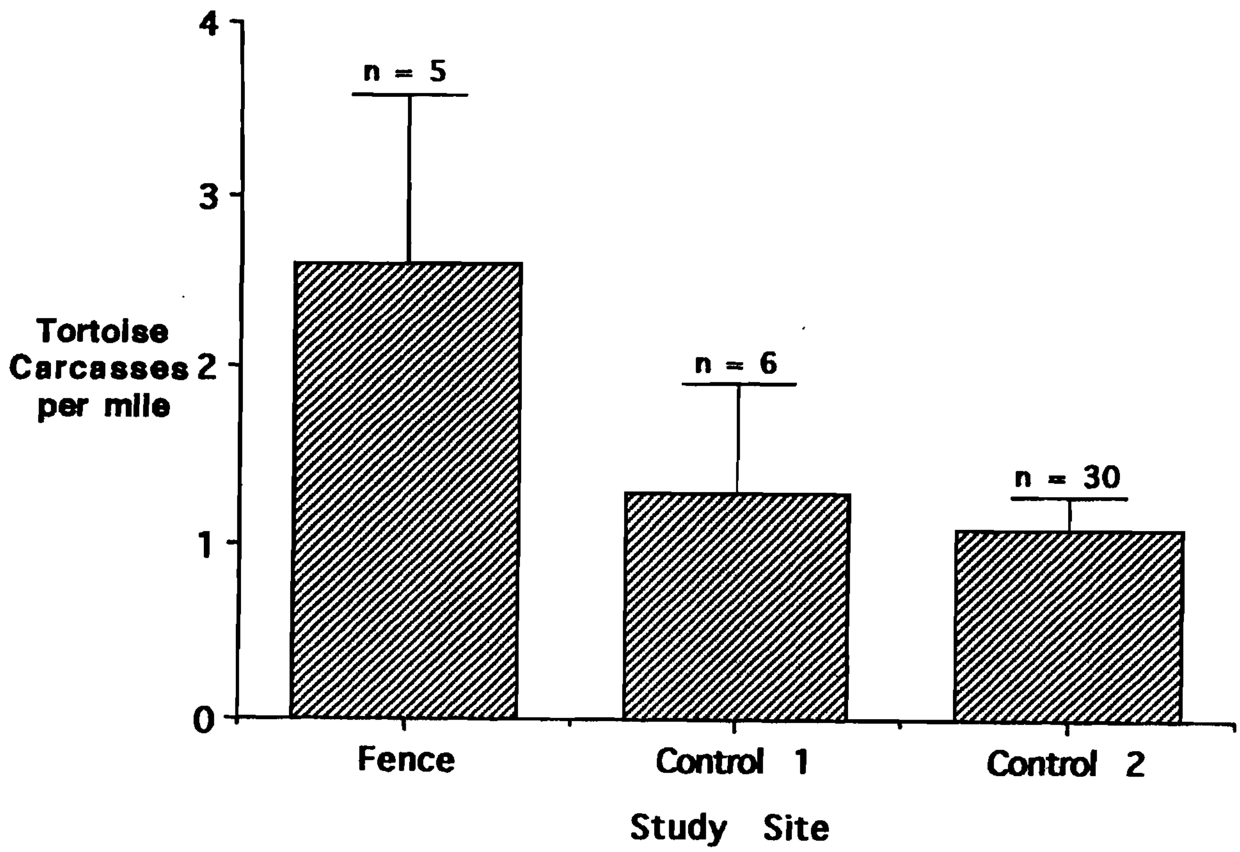

Figure 7. Mean (+ 1 SE) number of shells found per mile along highway edges.

In all, 47 tortoises were located, 44 of which were on the actual study plot (Table 2). Of those 47, 10 were adult females, 8 adult males, and 29 were too young to determine sex correctly. Four animals had wet "beaks" or noses, both of which are possible signs of Upper Respiratory Tract Disease. Three of them were of normal weight for their sex and size, while the fourth was somewhat lighter than expected. Locations of each individual sighting of live tortoises are shown in Fig. 3 and locations of the 65 tortoise carcasses found are shown in Fig. 4.

High-band VHS radio transmitters, made by AVM Instrument Company, Ltd., were attached to 36 animals. Twenty-one were stage two side-car transmitters with removable base plates, five were stage one side-car transmitters also with removable base plates, and 10 were solar-assisted transmitters. The removable base plates allow for easy removal of the transmitters for periodic servicing or replacement. The base plates of the larger two transmitter-types were attached to the 1st left costal scute and the antenna's were run through short sections of PVC tubing epoxied individually to the scutes. The solar-assisted transmitters were attached to the 5th vertebral scute with the flexible antenna in a near-vertical position. Three transmitters became detached from the tortoises, probably due to inadequate mixing or malfunctioning of the epoxy. Two of the transmitters were subsequently re-attached.

PIT tags were attached to three tortoises with 5-min Devcon epoxy. For the adults, the PIT tags were attached to the 10th left marginal scute, oriented parallel to the ground with the most sensitive end of the transducer pointed toward the rear of the animal. For small tortoises where the PIT tag would overlap marginal scutes if attached there, the tags were placed on the pygal scute.

Human Impacts

Several human impacts were present on the site (Fig. 5). The majority of the plot lies south of the All-American and Mojave gas pipelines, but the pipeline right-of-way runs directly through the north-east end, mostly parallel to the barrier fence. Five lightly traveled, dirt access roads run through the plot, although none were known to be used by anyone not associated with this project. A helicopter and patrol plane flew low over the plot on daily inspections of the pipeline. The plot has been subjected to sheep grazing in the past; dry sheep manure was found within 10 of the plot's 100 quadrats. Several mining pits and balloon remains were found scattered throughout the plot. Evidence of shooting included shotgun shells and clay pigeons in two quadrats. Beer cans and a few broken bottles were found within tossing distance of the highway although there were also many scattered throughout the plot. Campsites with old fire pits were found on four quadrats.

Highway Sweeps For Road Kills

The Highway Sweeps project is designed to determine if the barrier fence effectively prevents road kills. A series of transects were walked along the edges of two highways in San Bernardino Co., California. All desert tortoise carcasses or shell fragments found were mapped, recorded, and collected. We compared the results among two controls and the treatment (fenced) site. The first year of the four-year project was intended to: a) test the data collection methods, b) remove old shells and fragments, and c) compare the three study sites. Using the same methods, the sites will be resurveyed in summers of 1992 through 1994.

CARCASS DISTRIBUTION

HIGHWAY 58 BARRIER
TOWNSHIP 10N, RANGE 5W, SECTIONS 17, 18, 19, 20,
SAN BERNARDINO CO., CALIFORNIA
SPRING, 1991

LEGEND	ENTRY FORMAT
▲ HEALTHY TORTOISE URTD SYMPTOMATIC TORTOISE ● SHELL, PREVIOUSLY MARKED ■ SHELL, UNMARKED	▲ TORTOISE # DATE (DD/MM) ● LIVE TORTOISE # SHELL # DATE (DD/MM) TORTOISE # DATE (DD/MM) ■ SHELL # DATE (DD/MM)

SCALE: EACH BLOCK IS 0.1 MILE ON A SIDE

SPECIAL NOTES:

Temporary grid that has been established using compass and pace rather than surveyed.

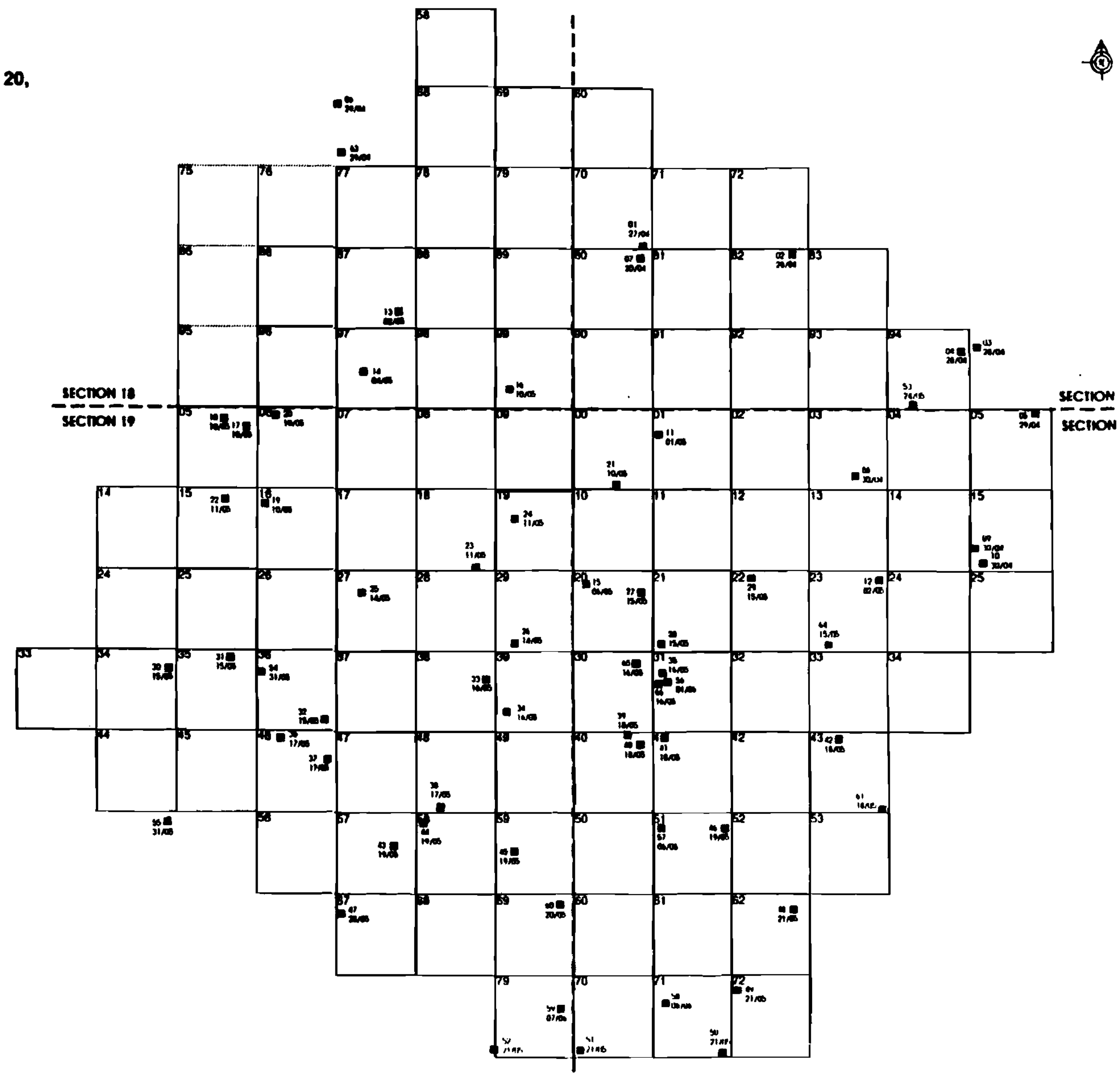

Figure 4. Map of all locations of all tortoise carcasses found within or near the study site in spring of 1991.

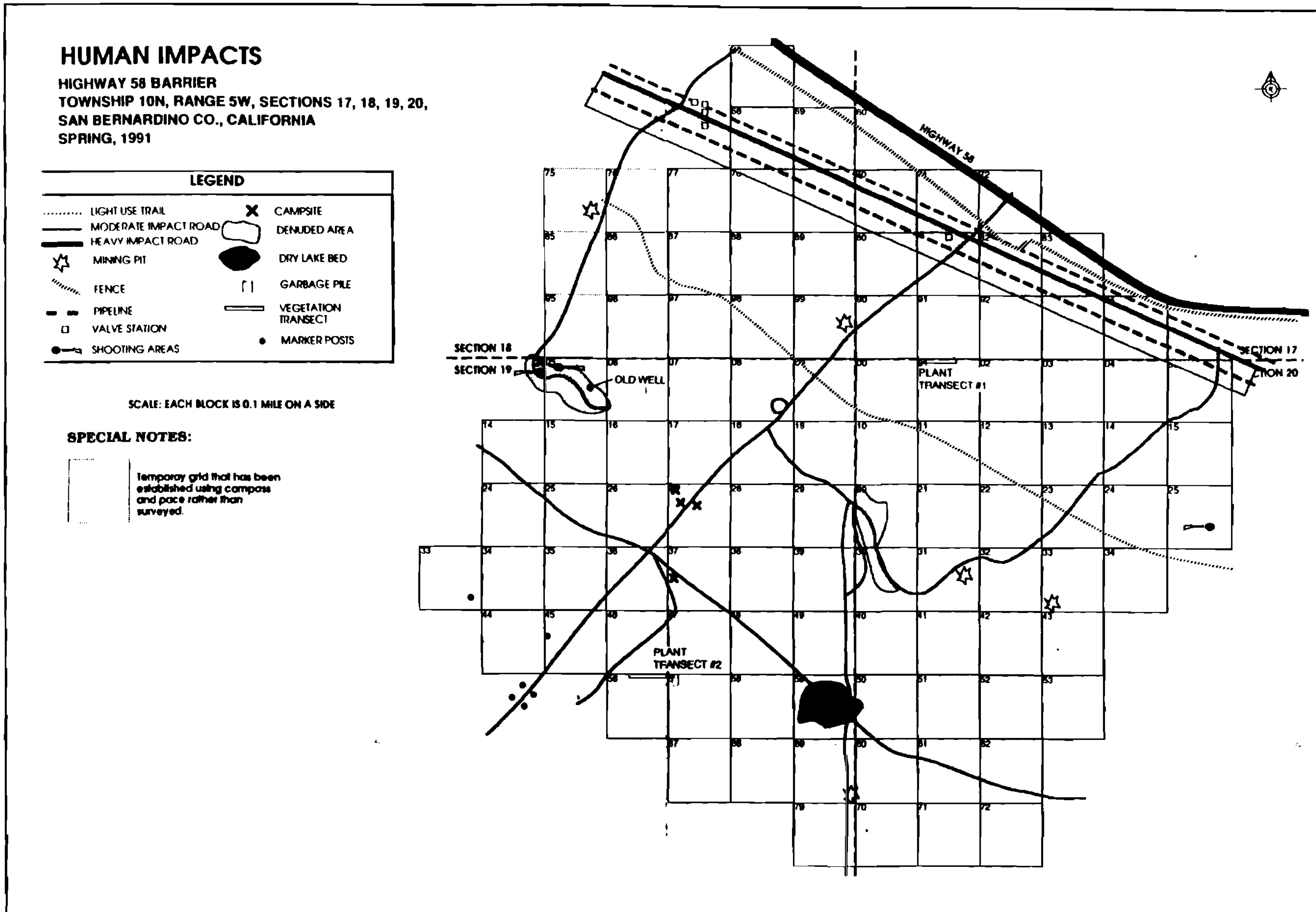

Figure 5. Map of major human impacts recorded on the study plot in spring of 1991.

METHODS

Between February 22 and March 12, 1991, 66 1-mi transects were surveyed along both edges of Hwy 58 and Hwy 395, east and south of Kramer Junction, San Bernardino Co., California (Fig. 6). The general study area was subdivided into three sites: Treatment, Control 1, and Control 2. The Treatment site consisted of both sides of Highway 58 where the tortoise-proof fence was in place. It began approximately 3.6 miles east of Kramer Junction and extended east for 15 miles (30 1-mile transects). Control 1 was along a nearby section of Hwy 58 without a tortoise-proof fence. It began at the western-most end of the Treatment site and ran west along both sides of the highway for three miles (6 1-mile transects). Control 2 was along an unfenced section of Hwy 395. It began 7.7 mi south of Kramer Jct and ran south for 15 miles along both sides of the highway (30 1-mile transects).

Each transect was 10-yd wide and centered 5 yd from the paved roadway. The field worker walked parallel to the highway, at the center of the transect, and scanned the ground for any tortoise remains or signs. If several fragments were found in a cluster less than 7 yd in diameter, we assumed they were from a single animal. A unique carcass number was assigned and the location along the transect was noted and mapped. The physical conditions of the highway edge, including shoulder width, were recorded.

To test for significant differences among the mean number of shells found per mile in each of the three sites, we used a Kruskal-Wallis analysis of variance by ranks test, corrected for ties.

RESULTS

Fragments from 61 tortoises were located; most of the carcasses consisted of a few small fragments. Although the Treatment site was 15-miles long, yielding 30 1-mile transects (15 on each side of the highway), we could only use five of the transects for the analysis. The four transects at both ends of the site were removed to avoid the possible confounding effect of tortoises entering the transect from the non-fenced areas; fragments from seven tortoises were located in these four transects and these shells were not used in further analyses. An additional 21 transects were removed because they were partially or completely obliterated by heavy construction activities associated with widening of the highway. The five remaining transectscontained relatively normal highway-edge habitat, similar to that along the two control sites, and were used for analysis of mean number of shells found per mile.

The mean number of shells found per mile in the Treatment site (2.6 ± 0.980) was roughly twice that found in each of the Control sites (1.3 ± 0.615 and 1.1 ± 0.182; Fig. 7). However, the variance among transects within each site was so great that there was no significant difference among sites (Kruskal-Wallis $H_c = 2.277$, df = 2, $p = 0.3202$).

Width of the highway shoulder in the Treatment site ranged from 6.5 to 131 ft., but 22 of the 30 transects were nearly entirely obliterated by construction. The average shoulder width for the relatively unimpacted transects within the Treatment site was 6.5 ft. The average width of the shoulder along Control 1 was 9.8 ft and for Control 2 was 6.5 ft.

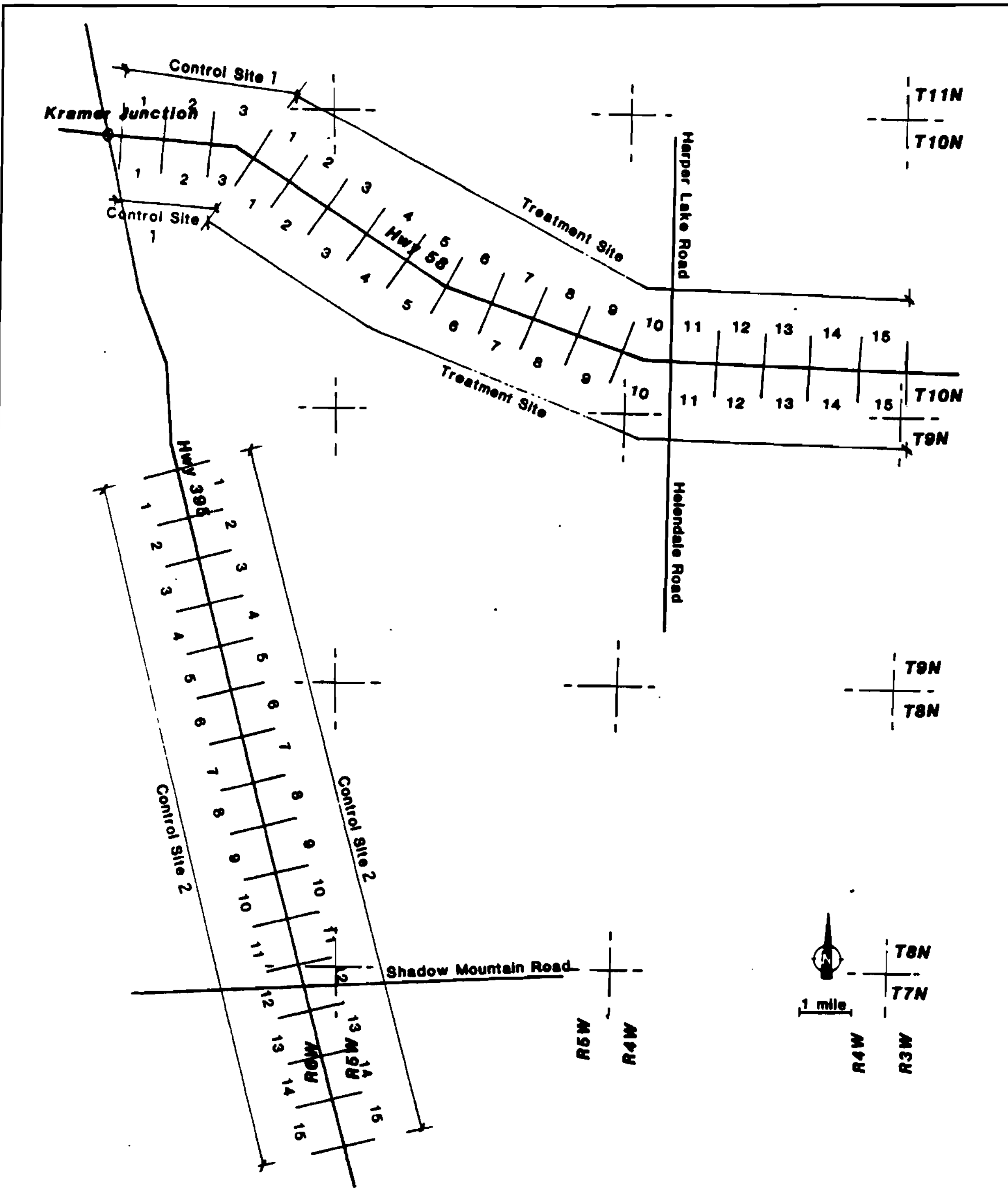

Figure 6. Map showing locations of transects for sweeps of highway edges to search for road killed tortoises.

DISCUSSION

The remains from a total of 61 tortoises were found. All shells found in the surveys were highly fragmented, which is consistent with the hypothesis that the animals were killed by motor vehicles while crossing the road. Additionally, all shell fragments showed evidence of being from dead tortoises exposed to weathering for at least one year prior to being collected (Woodman and Berry 1984). The tortoise-proof fence on Hwy 58 was erected by Caltrans in spring of 1990, so all dead tortoises found most likely died before the fence was in place. Therefore, we assume the sample from the Treatment site largely represents animals killed before the barrier fence was in place.

This is the first detailed study of the rate of tortoise deaths along roads. The only other data available are from Woodman (unpubl. data; see Appendix 1, Boarman,1991). In 1990, he found fragments from 58 tortoises along 17 miles (3.4/mi) of highway right-of-way along the same general stretch of Hwy 58 as covered by our study; 42 of which were considered to be dead for 4 years or less. It is difficult to infer from Woodman's or our data the full impact vehicular traffic has on desert tortoise populations. Nicholson (1978), showed a significant decline in tortoise densities near highways, indicating that highways cause population-level impacts. This relationship was corroborated by our study (Boarman 1991). Detailed and long-term studies on the movements of tortoises near highways are needed to evaluate the causes for the declines noted by Nicholson (1978) and the full impacts of vehicular traffic on individual tortoises and tortoise populations.

Future Plans

The project will run for at least three more field seasons and likely for several years at a less intense rate. The primary activities for spring 1992 were to map home ranges of animals with radio transmitters, attach PIT tags to most animals on the plot, and perform a sweep of highway edges for tortoise carcasses. During the winter of 1992-1993 we plan to deploy the automated-sensing of tortoise use of culverts, which will remain operational for at least 2 years. Spring of 1993 will primarily consist of a resurvey of the tortoise population, some radio-tracking and behavioral observations, sweeps of highway edges, servicing and replacement of transmitters, and reading and maintenance of the automated-sensing apparatus. We will also conduct a survey of the north side of the highway to search for and mark tortoises that have used the culverts, or may use them in the future. Work in the spring of 1994 will emphasize radio-tracking, culverts, population surveys, and a sweep of highway edges. Funds provided by Nevada Department of Transportation and Federal Highways Administration will help to develop the automated-sensing system and to conduct some of the field work in 1993 and 1994.

The Review Board has identified and prioritized several additional tasks that would significantly improve the study. In approximate order of importance, the additional tasks are to: 1) enlarge the study plot to increase sample sizes; 2) establish a new study site with a bridge for determining if tortoises cross under bridges; 3) conduct transects along Hwy 395 to determine densities and distribution of tortoises to validate use of Hwy 395 as a control for thehighway sweeps; 4) extend the study beyond 1994; 5) establish a control plot along Hwy 395; 6)place more transmitters on animals; and 7) place transponders on other animal species to determine if they use culverts.

ACKNOWLEDGEMENTS

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Observation On Burrow Use By Captive Desert Tortoises

Susan J. Bulova

Abstract. Burrow use by captive desert tortoises was observed for six weeks in three 4 ha research pens at the Desert Tortoise Conservation Center, Las Vegas, NV. Patterns of burrow use, including number and type of burrows used and frequency of sharing burrows, were examined and compared between adult and immature tortoises. Burrows (221) were identified and measured, and examined every 1-4 days for occupancy by tortoises. Individual tortoises used 1-9 different burrows and switched 0-12 times. Adults used more burrows and switched more often than did immatures. A higher proportion of artificial burrows than natural burrows was found inhabited at least once. Burrows occupied only during the early morning census (i.e., before activity) faced north, northeast, and south, which is a more limited range of orientations relative to burrows found occupied during the mid-day census. Burrow sharing occurred within and among age groups, and tortoises did not share more frequently with individuals in their own age group. Overall, captive tortoises regularly used several different burrows and utilized the artificial burrows more than expected based on relative availability.

INTRODUCTION

During the active season, desert tortoises (*Gopherus agassizii*) retreat into underground burrows at night and during the hottest parts of the day, thus buffering daily temperature fluctuations (Burge 1977). Knowledge of patterns of burrow use by tortoises is necessary for effective management of wild populations. For example, the number of burrows that tortoises use may be related to individual home-range size and population density. Tortoises may need access to widely spaced burrows to be able to forage over long distances. Social interactions may also influence burrow use. If different individuals will not use the same burrows, then proportionately more burrows must be available to accommodate a given number of tortoises. In this study, I used data from animals held in large outdoor enclosures to examine: 1) the number of different burrows tortoises used over a six week period, 2) the number of times tortoises switched to another burrow on subsequent use, and 3) the sharing of burrows with other tortoises. I also examined the characteristics of the burrows that tortoises used, such as the type of burrow (PVC pipe vs. natural), entrance size, and its compass orientation.

METHODS

I observed tortoises in three research pens at the Desert Tortoise Conservation Center in Clark County, Nevada. I used pen R4, a pen supplemented with grass sod, forbs, and water, and pens R3 and R6, which were unsupplemented (see Ruby 1992). Pens R4, R3, and R6 were 4.5 ha, 4.8 ha, and 3.3 ha, and housed 30, 25, and 32 tortoises respectively. The pens contained both artificial burrows and natural burrows dug by the tortoises. Artificial burrows were constructed of bisected, 1.7 m length PVC pipe of various diameters buried into the ground at a 20° angle.

I attempted to locate and mark every burrow in each of the three pens. I measured the maximum height, maximum width, and compass orientation of the opening of each burrow. From 2 July to 13 August 1991, I performed a census on the burrows in each pen at one to four day intervals. This was done while the tortoises were inactive; all tortoises were found either in burrows or pallets (depressions) or stationary on the surface. Tortoises were inactive in the early morning until approximately 0700 h and during mid-day between 0930-1730 h. I painted large numbers with enamel paint on each tortoise to facilitate identification of individuals inside burrows.

Because of the small number of adult tortoises, I combined the sexes for all analyses. Most of the tortoises were immature (maximum carapace length < 210 mm; Turner and Berry 1984) and were analyzed as one group that included both sub-adults and juveniles. The total number of burrows used by each individual and the number of times each tortoise switched among burrows were compared between the two age classes and among pens using two-way analysis of covariance (ANCOVA). Because I was unable to locate every tortoise during each census, tortoises were observed 1-17 times over varying lengths of time ranging from 1-45 days. The observed number of burrows used increased with greater number of observations, and over a greater number of days, tortoises were located more times. In addition, preliminary examination of the data suggested that adults may have been observed more frequently than were immatures, which is consistent with the finding that immature tortoises are more difficult to locate in the field than are adults (Burge 1977; Berry and Turner 1986). Therefore, I regressed total number of observations on both days observed and age class for each tortoise and computed residuals. These residuals were then used as the covariate in the ANCOVA's described above, and two degrees of freedom were subtracted when computing the mean square error.

I calculated a likelihood ratio x^2 statistic (G2; Fienberg 1989) to determine whether individuals were found sharing more often with their own age group than with the other. Data from the two unsupplemented pens (R3 and R6) were combined for this analysis. R4 was not included to avoid the possible confounding effect of food supplementation.

Finally, I used logistic regression to determine the contribution of burrow height and type (artificial or natural) to the probability of a burrow being used. Differences among pens were accounted for by forcing two dummy variables into the model. I then considered only those burrows used at least once and tested for temporal differences in burrow preference. I determined the contribution of burrow height and type to the probability of a burrow being used only during early morning census or used only during mid-day census using logistic regression. Significance of coefficients in logistic regression equations was tested using the Wald statistic, which is calculated as the square of the ratio of the coefficient to its standard error (Norusis 1989; SPSS Inc. 1989).

RESULTS AND DISCUSSION

The total number of different burrows used by individual tortoises in six weeks ranged from 1-9 (Table 1). In the two-way ANCOVA, adults used more burrows than did immatures ($F = 4.208$, $df = 1, 74$, $p < 0.05$). The number of burrows used did not differ among pens, ($F = 0.138$, $df = 2, 74$, $p > 0.05$), and the pen X age interaction was significant ($F = 3.876$, Individuals varied in the proximity of the burrows that they occupied (Fig. 1). The spatial distribution of the burrows used by a particular tortoise ranged from compact to spread out across the pen. For example, tortoise #738 used only two adjacent burrows whereas tortoise #733 inhabited five different burrows that ranged over most of the length of the pen (Fig. 1). Within the set of burrows it used, each tortoise also occupied burrows at different frequencies. For example, I found tortoise #738 occupying two different burrows across 15 observations; it inhabited an artificial burrow for 13 observations, but I found it only twice in a natural burrow (Fig. 1).

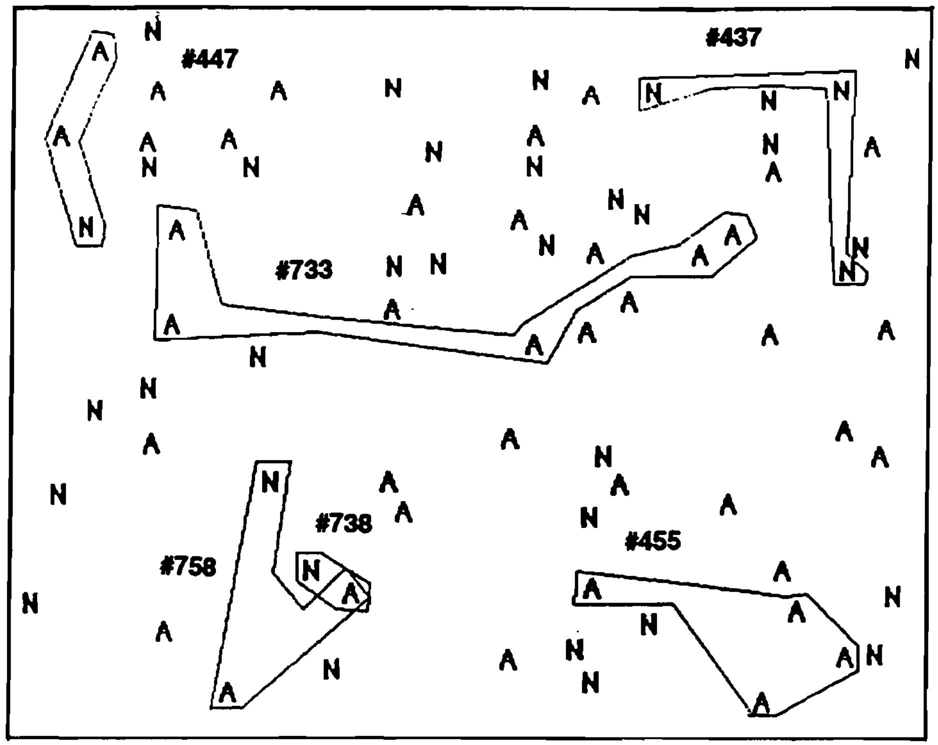

Figure 1. The locations of the burrows used from 2 July through 16 August by six sample tortoises from R6. "A" indicates an artificial burrow and "N" indicates a natural burrow. Tortoise identification numbers are indicated.

Each pen had over 70 burrows, and 68 - 82% were used (Table 3). The probability of a burrow being used was higher for artificial than for natural burrows (Wald statistic = 11.41, df = 1, $p = 0.0007$), and is not influenced by entrance height (Wald statistic = 0.21,df = 1, $p = .6460$). In other words, tortoises used artificial burrows disproportionately more than expected according to their availability. The reason for this disproportionate use is unclear. The artificial burrows were significantly larger than the natural burrows (burrow entrance height: $F = 67.82$, df = 1, 219, $p < 0.01$). Larger tortoises may be excluded from using natural burrows due to size constraints. However, this does not explain differential use by burrow type since use is not influenced by burrow size. Other unmeasured factors such as burrow length or heat buffering capacity may explain the preference for artificial burrows.

The entire range of burrow entrance orientations was available to tortoises, but most of the burrows faced roughly northeast. This discrepancy may be accounted for by the fact

Table 1. Total number of burrows used* per individual tortoise, July - August 1991, Desert Tortoise Conservation Center, NV.

	Pen Number		
Age/Sex Class	R3	R6	R4
Adult Males	6.00 ± 0.82 (4) (5 - 7)	3.50 ± 2.52 (4) (1 - 7)	4.83 ± 2.93 (6) (1 - 9)
Adult Females	3.50 ± 0.71 (2) (3 - 4)	3.33 ± 1.15 (3) (2 - 4)	4.50 ± 1.91 (4) (2 - 6)
Immatures	3.32 ± 1.63 (19) (1 - 6)	4.08 ± 1.53 (25) (1 - 7)	3.31 ± 2.02 (16) (1 - 7)
Total tortoises	25	32	26
Pen Size (ha)	4.8	3.3	4.5

*mean ± s.d (n)
(minimum - maximum)

that most of the artificial burrows were constructed facing between east and north directions. Tortoises did not always select burrow orientations according to their availability; the burrows used only during early morning census faced north, northeast, and south (Fig. 2). Tortoises inhabiting these burrows during the early morning census faced the rising sun. Sun shining into the entrance of the burrow may allow occupants to heat more rapidly and hence length the potential activity period of the tortoise (Huey 1982). Orientations of burrows used during mid-day more closely reflected availability (Fig. 3), suggesting that orientation does not influence burrow choice after the morning activity period. Burrow height and type were notsignificant factors influencing the probability of occupancy for burrows used either during the early morning or mid-day censuses (early morning census only: height: Wald statistic = 0.08, df = 1, p = 0.7763; type: Wald statistic = 0.71, df = 1, p = 0.4001; mid-day census only: height: Wald statistic = 3.75, df = 1, p = 0.0528; type: Wald statistic = 2.53, df = 1, p = 0.1120). Burrow preference did not differ between the two inactive periods with respect to burrow type and entrance size.

I often found more than one tortoise in a burrow, and I observed all possible combinations of cohabitants including immatures together, adults together, and adults with immatures. Of the 13 adults in R3 and R6, three were always found alone, 10 shared a burrow with an immature, and of those 10 adults, three shared with another adult. Moreover, nine of the 44 immatures were always alone, 16 shared with an adult, and 34 shared with another immature (Table 4). I used the G2 test to compare the observed patterns of sharing with the expected frequency of sharing based on the number of animals in each age group. Likelihood ratio x^2 values calculated for each age group in the G2 test were not significant (adults: likelihood ratio x^2 = 0.835, df = 1, p = 0.361; immatures: likelihood ratio x^2 = 0.001, df = 1, p = 0.979). Hence, burrow sharing appeared random with respect to age group. Simultaneous use of burrows has been observed in the field (Burge 1977) but is usually reported for adults only. Burge (1977) mostly found males and females together and never observed females sharing a burrow. I observed burrow sharing both within and among sexes of adults. The discrepancy between my observations and those of field studies may be an artifact of captivity and the high density of tortoises held in the pens.

Table 2. Number of times tortoises switched burrows*, July - August 1991, Desert Tortoise Conservation Center, NV.

	Pen Number		
Age/Sex Class	R3	R6	R4
Adult Males	6.50 ± 0.58 (4) (6 - 7)	4.25 ± 4.79 (4) (0 - 11)	5.50 ± 4.42 (6) (0 - 12)
Adult Females	5.00 ± 2.83 (2) (3 - 7)	4.00 ± 2.65 (3) (1 - 6)	5.25 ± 3.50 (4) (1 - 9)
Immatures	3.47 ± 2.46 (19) (0 - 7)	4.12 ± 2.37 (25) (0 - 11)	3.94 ± 3.40 (16) (0 - 10)

*mean ± s.d (n)
(minimum - maximum)

df = 2, 74, p < 0.05). Tortoises travel throughout their home ranges to reach forage, mates, drinking sites, and mineral licks (Berry, 1986). Thus, the difference in burrow use between age classes may reflect different needs with respect to diet or breeding. Home range information is scarce for immature tortoises, and should be investigated in free-ranging tortoises.

Some tortoises were found in the same burrow at every observation, whereas others switched as many as 12 times (Table 2). In some cases, the number of times a tortoise switched was greater than the number of burrows it used because tortoises returned to previously used burrows. The difference between adults and immatures in number of switches was significant ($F = 3.973$, df = 1, 74, $p < 0.05$). Adults switched more often than did immatures, which is consistent with the above finding that adults also used more burrows. Number of switches did not differ among pens ($F = 0.128$, df = 2, 74, $p > 0.05$) nor was the pen X age interaction significant ($F = 1.599$, df = 2, 74, $p > 0.05$). Therefore, food and water supplementation seemed to have no effect on these aspects of burrow use.

Table 3. Utilization of artificial and natural burrows in three pens, July - August 1991, Desert Tortoise Conservation Center, NV.

	Pen Number								
	R3			R6			R4		
Burrow Type	N	used	unused	N	used	unused	N	used	unused
artificial	46	40	6	39	31	8	51	40	11
natural	25	18	7	37	24	13	23	10	13
total	71	58	13	76	55	21	74	50	24

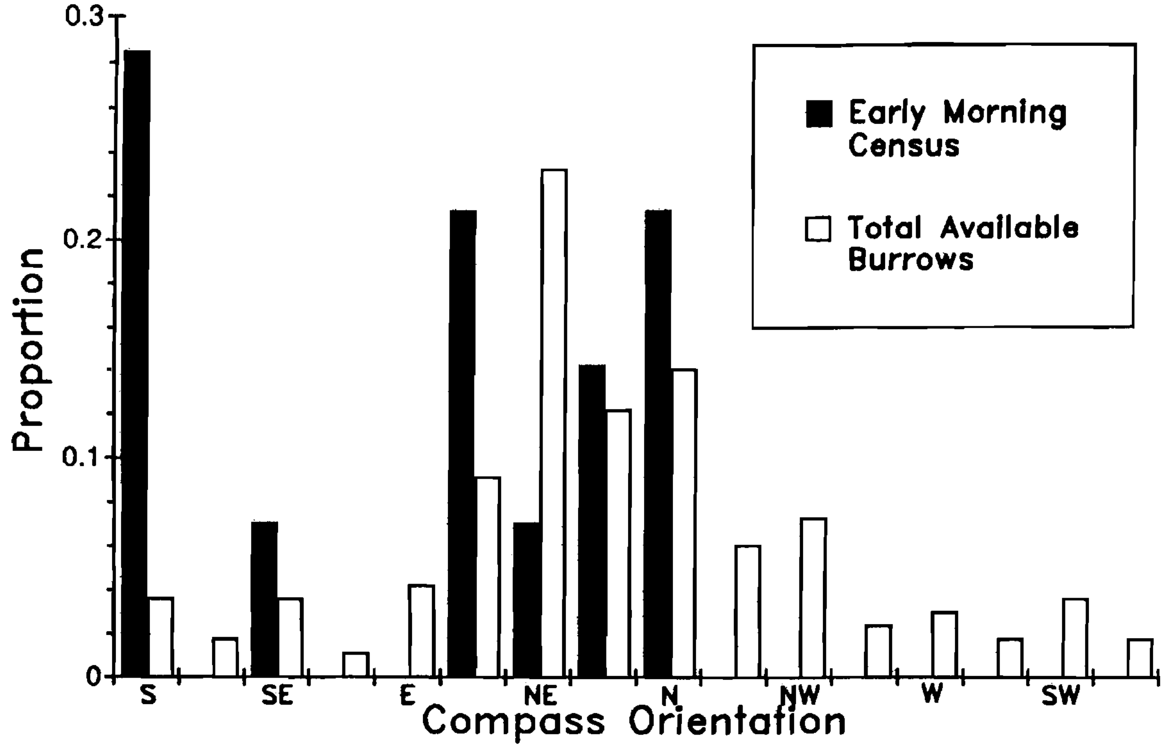

Figure 2. Burrow Orientation: availability vs. use. The proportion of the total number of used burrows and of the burrows used only during early morning census that face in each orientation.

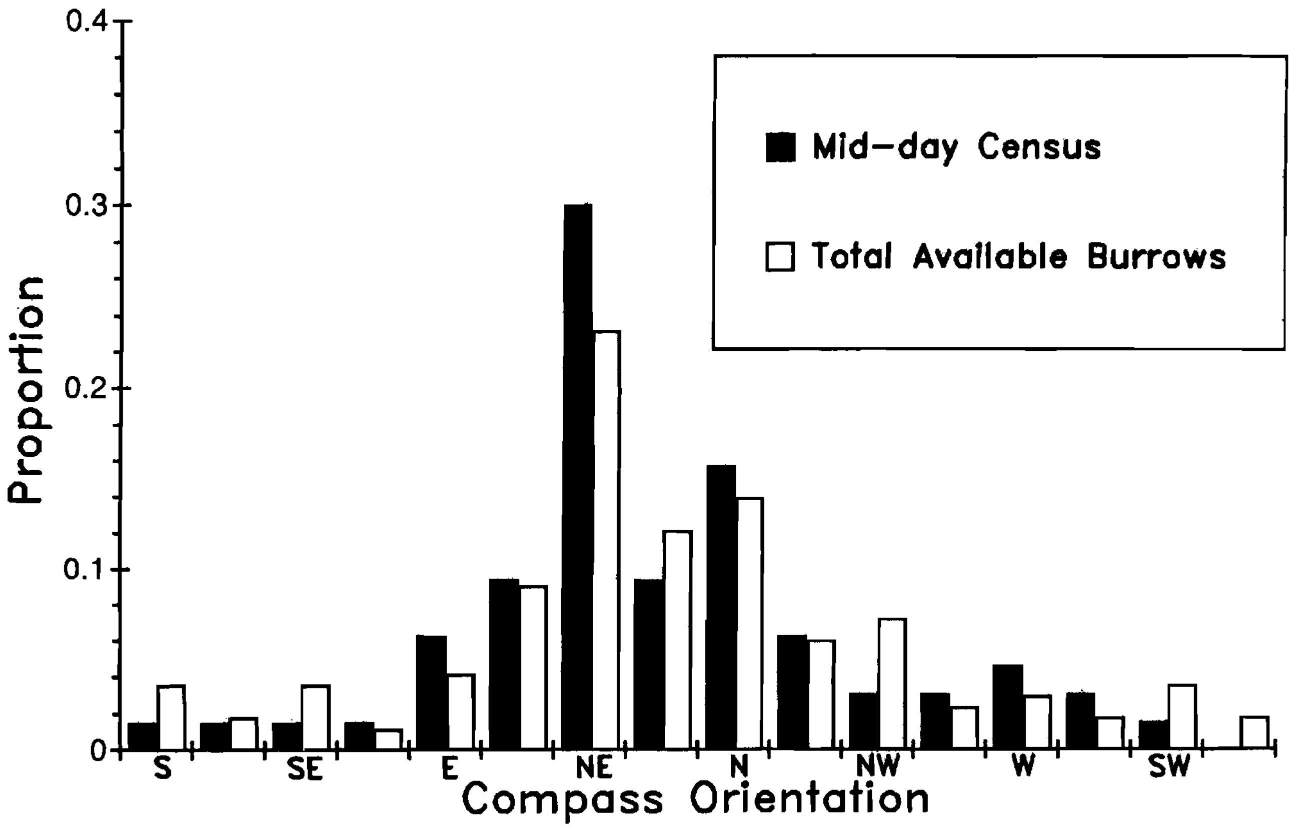

Figure 3. Burrow Orientation: availability vs. use. The proportion of the total number of used burrows and of the burrows used only during mid-day census that face in each orientation.

Burrow sharing has several implications for tortoise ecology and management. In some cases, burrows might be a limiting resource for tortoises, but the number of available burrows needed for a population of tortoises is not necessarily proportional to the number of individuals because tortoises share burrows. In captivity, a tortoise that wanders far from its previous burrow is not necessarily excluded by other inhabitants of nearby burrows. However, cohabitation may promote social transmission of upper respiratory tract disease (URTD; Jacobson et al. 1991) both in the wild and in captivity. Close contact through burrow sharing may increase the potential for infection.

These data were taken during a small part of the tortoises' active season and do not encompass seasonal variation in burrow use. However, I have demonstrated that captive tortoises regularly use several different burrows and tolerate cohabitation. This study indicates the reliance of these captive tortoises on the artificial burrows for shelter and suggests that they prefer them over natural burrows under some conditions. If wild tortoises will use artificial burrows, provision of burrows may be useful as part of a management strategy for introduction or relocation (Baxter and Stewart 1986).

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Demographics and Delayed Sexual Maturity in Blanding's Turtles: Implications for the Conservation and Management of Long-Lived Chelonians

Justin D. Congdon, Arthur E. Dunham and Richard C. van Loben Sels

Examination of both the limits of possible life history traits, and the patterns of covariation of traits can suggest: 1) possible selective factors shaping life histories, and 2) how life history traits of individuals may influence population responses to external disturbances. Life history traits of age at first reproduction (alpha) and longevity covary across many different taxa. The most frequently mentioned benefits attributed to delays in attainment of sexual maturity include increased quality of young produced, increased number of young per reproductive bout, decreased costs associated with reproduction, and decreased risk of mortality as an adult. Theoretically, these benefits combine to result in higher lifetime reproductive success than would be attained by individuals that matured earlier.

The most frequently mentioned costs of delaying sexual maturity are the increased risk associated with death prior to reproduction and possibly for the remainder of the organism's life, and lengthened generation times. An additional, and often overlooked, cost of delaying sexual maturity was pointed out in simulations of stable populations of dinosaurs (Dunham, et.al., 1989). Population simulations of dinosaurs resulted in the conclusion that as age at sexual maturity approaches 20 years, average annual survivorship of eggs and juveniles must approach those reported for adults.

Blanding's turtles (*Emydoidea blandingi*) make an excellent model to test assumptions of the dinosaur model because they are a relatively long-lived turtle. They attain sexual maturity between 14 and 20 years with a mean value of 17.5 years and they have been relatively well studied in terms of nesting fecundity, growth and attainment of sexual maturity, and demography.

We examined data on life history and demographic traits of Blanding's turtles (*Emydoidea blandingi*) collected in southeastern Michigan during 28 years between 1953 and 1991. Actual demographic data were used in conjunction with estimated annual survival of juveniles to construct two life tables, one for a stable population (where $r = 0$). We then held all other demographic parameters constant while allowing one parameter to vary. Results were graphed to display which parameters would result in the most dramatic changes in r (Fig. 1). The population analyses of Blanding's turtles point out that juvenile survival may place important limitations on delaying sexual maturity in particular, and because of the covariation of age alpha with adult longevity, pose a more general constraint on the overall life history features of long-lived organisms. The simulations also indicate that for most late-maturing, long-lived and iteroparous organisms such as Desert Tortoises, options for compensatory changes in the demographics are very limited. Adult survivorship, juvenile survivorship, and age at maturity may be difficult to change because of their already extreme values, whereas clutch size and nest survivorship might be more readily increased. Therefore, long-term disturbances which result in lowering recruitment of older juveniles and adults into the population represent extreme impacts that can be very threatening to populations of long-lived chelonians and successful management strategies may be difficult to implement.

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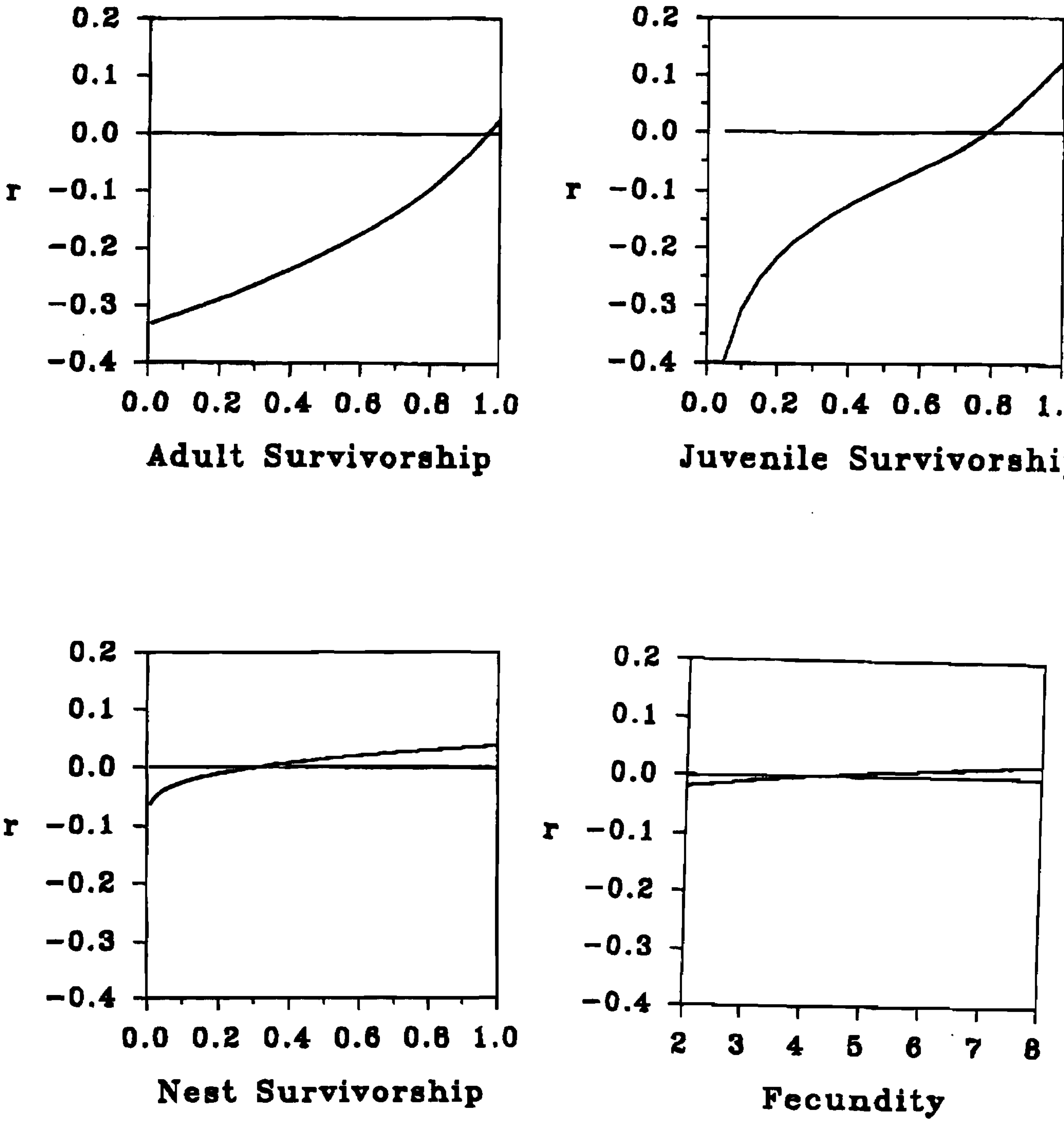


Figure 1. The relatinoships between survivorship of a) adults, b) juveniles, c) nests and d) fecundity to population stability (r = 0) set by long-term mean values for Blanding's turtles on the E.S. George Reserve.

Relocation of the Desert Tortoise: The Honda Project, The Second Year

Michael J. Cornish and Michael Weinstein

In spring of 1990 seventy-one desert tortoises (*Gopherus agassizii*) were relocated to section 8 at the northwest corner of the Desert Tortoise Natural Area (DTNA). The study plot was one square mile subdivided into four quarter square mile fenced plots. The two western plots are irrigated to encourage an enhance plant growth, while the two eastern plots are non-irrigated. Plant surveys were undertaken periodically. The two southern plots contain relocatees while the two northern plots contain only residents. We fitted radio transmitters on most of the relocatees and residents. Transmitters were of three types: two stage 3.6 volt lithium powered units, with either one or two stage transmitters for the adults, and solar/nicad powered units for the smaller animals down to the size of hatchlings.

From March until October, every month, we selected a male, female and juvenile from each of the six cohorts for an intensive eight hour observation period. Three times a year we selected up to 60 tortoises for extraction of 3.7 cc of blood and a nasal culture that was subjected to tests for the URTD research. The remaining tortoises were relocated, weighed, measured and examined for external symptoms. As a result we relocated and examined all tortoise monthly.

New Initiatives for Desert Tortoise Habitat Acquisition and Conservation

Roger A. Dale and Jun Lee

Abstract. The Desert Tortoise Preserve Committee, Inc. achieved substantial gains last year in its efforts to protect the threatened desert tortoise. We are implementing an integrated approach to desert tortoise conservation which includes four main programs: desert tortoise habitat acquisition, public education, liaison and joint ventures with industry and government, and stewardship of the Desert Tortoise Natural Area, located in Kern County, California. Compared to the 30 acres acquired in 1990, the Preserve Committee has acquired by both donation and direct purchase a total of 593 acres of Category I desert tortoise habitat. Public awareness of the threatened status of the desert tortoise continues to be an important focus for the Preserve Committee. In 1991, volunteer tour guides and two full-time naturalists of the Preserve Committee interacted with approximately 2,000 persons who visited the Natural Area. The Preserve Committee is increasingly being recognized as a leader in desert tortoise conservation among government agencies and the corporate community. We are an active participant in government planning forums such as the Western Mojave Coordinated Management Plan and the Desert Tortoise Recovery Plan. Additionally, the Preserve Committee are lead negotiators in mitigation matters which impact the desert tortoise. The Preserve Committee continues to coordinate a proactive stewardship program which includes volunteer work parties which maintain the Natural Area and oversight of government management of the desert tortoise and its habitat.

INTRODUCTION

Nearly 20 years ago a group of concerned citizens formed a small organization in order to undertake an immense mission. Since its inception in 1974 the Desert Tortoise Preserve Committee has worked hard utilizing simple and proven methods to conserve the threatened desert tortoise and its fragile habitat. The Preserve Committee's strategies comprise an effective model for habitat protection and recovery of threatened species. Our mission to preserve the desert tortoise is executed in four main programs: desert tortoise habitat acquisition, public education, liaison and joint ventures with industry and government, and stewardship of the Desert Tortoise Natural Area.

Habitat Acquisition

The Preserve Committee recognizes that habitat loss and degradation are chief causes of desert tortoise population declines. Desert Tortoise habitat is irreparably damaged by intensive human impacts such as land development and off-highway recreational vehicle use. By raising funds and negotiating purchases with individual landowners from within the Desert Tortoise Natural Area, the Preserve Committee ensures that prime desert tortoise habitat is preserved into perpetuity.

During 1991, the Preserve Committee acquired a total of 265 acres of prime desert tortoise habitat within the Desert Tortoise Natural Area. Of the total acreage protected, 140 acres were purchased from individual willing-sellers and 125 acres--valued at $92,500--were donated by The Nature Conservancy. According to Rick Hewett, San Joaquin Valley Representative for the Conservancy, the Preserve Committee's increased capacity to acquire desert tortoise habitat among other issues was the basis for the Conservancy's land transfer. Compared to the 30 acres acquired in 1990, the Preserve Committee's habitat acquisition performance within the Natural Area improved by a factor of nineteen during 1991.

In addition to the generous gift of 125 acres from The Nature Conservancy, the Preserve Committee gratefully acknowledges a considerable gift of a 288 acre parcel in Section 25, which abuts the southern boundary of the Natural Area, from a complex ownership arrangement. Larry Wolfe, Vice President of the Weingart Foundation, and Susan Grimes of the foundation, successfully coordinated with the Preserve Committee multiple donations of ownership interest in this parcel from the Weingart Foundation, the Ruth and Lawrence Harvey trusts, the Yorkshire Family Trust, and the Herbert Berk Trust. This donation comprises a gift amounting to over $200,000. Significantly, this land gift abuts the southern boundary of the Natural Area and is the first step in implementing the Preserve Committee's plans to expand the preserve.

Notably, the Preserve Committee expanded its habitat acquisition in the past year. With the transfer of land and desert tortoise habitat acquisition funds from The Nature Conservancy to the Preserve Committee, we also have succeeded the Conservancy as the sole nonprofit conservation organization in the joint habitat acquisition effort with the Bureau of Land Management and the California Department of Fish and Game. Moreover, due to its enhanced technical expertise, the Preserve Committee is now identified by charitable foundations, corporations, and government agencies as a prominent and equal partner in desert tortoise conservation.

Public Education

Because human activities--positive and negative--are the most significant factors affecting the long term viability of the desert tortoise and its ecosystem, the Preserve Committee continues to expand its educational outreach programs. Annually, we co-sponsor with the Bureau of Land Management full-time naturalists and train volunteer tour guides who provide interpretive services to visitors of the Natural Area. Additionally, Preserve Committee volunteers regularly educate students and the general public about the threatened status of the desert tortoise and positive measures they may take to help save this important denizen of the desert.

This year the Preserve Committee, under a grant from the Bureau of Land Management, will implement a pilot educational program for about 5,500 elementary school students of the San Bernardino School District. This pilot educational program will integrate the Preserve Committee's already successful public awareness campaign with an interactive curriculum.

The Preserve Committee's position as arbiter and facilitator for conservation organizations interested in the desert tortoise, government agencies, and business is undertaken in two approaches: Proactive stewardship and liaison with government and business.

Stewardship

We continue to fulfill a proactive stewardship role to ensure sound government policies that have an effect on the desert tortoise. In addition to providing volunteers to maintain and manage the Desert Tortoise Natural Area, the Preserve Committee, as a public advocate for the desert tortoise, has actively participated in federal, state, and local management planning efforts.

The Preserve Committee provides input to government planning forums which have an impact on the desert tortoise and its habitat. Most recently, the Preserve Committee represented its views as an interested party in public forums related to the Western Mojave Coordinated Management Plan and the Desert Tortoise Recovery Plan. Both of these efforts define the long-term policies of the Bureau of Land Management and are instrumental as planning guidelines for the management of the desert tortoise and its habitat.

When the Preserve Committee, on the other hand, determines that the Bureau of Land Management's policies jeopardize the long-term viability and recovery of the desert tortoise, it takes the lead in advocating more sound management decisions. For example, the Preserve Committee continues to publicly encourage the Bureau to rescind its re-opening of the Rand Mountains and Fremont Valley to Off-highway Recreational Vehicle (ORV) use. Two studies by EnviroPlus Consulting were commissioned by the Preserve Committee to document the adverse impacts of Off-highway Recreational abuses and the Bureau's inability to properly control ORV damages to sensitive desert tortoise habitat. Gilbert and Glenn Goodlett of EnviroPlus Consulting found substantial damage to desert tortoise habitat over the course of two years as a result of the Bureau's re-opening the Rand-Fremont Area. Intensive negotiations to re-close the area to ORV use until a management plan is finalized for the area is currently underway between the Preserve Committee and the Bureau.

Government and Corporate Liaison

Secondly, the Preserve Committee is becoming recognized by both government and business as an effective land agent and steward. In the event that private business entities are required to compensate for desert tortoise habitat loss incurred in their business activities, the Preserve Committee acts as a fiscal agent for mitigation fees and requirements. The Preserve Committee's role in assisting businesses and government agencies with complex regulatory and real estate matters is vital to directing scarce resources to areas identified as critical to the long-term recovery of the threatened desert tortoise. Moreover, the Preserve Committee's ability to negotiate such transactions reduces potential friction and ambiguity between government agencies and businesses with an interest in the Mojave desert.

New Goals for 1992

Looking forward to this year the Preserve Committee is in a strong position to continue its progress in desert conservation efforts. The Preserve Committee in 1992 is working toward the following goals:

1. Raising $500,000 for a revolving habitat acquisition endowment fund;

2. Becoming the primary agent for desert tortoise habitat acquisition compensation matters;

3. Expanding its educational outreach and stewardship programs;

4. Finalizing its designs for an Educational Outreach and Research Center at the Desert Tortoise Natural Area;

5. Increasing its advocacy for the threatened desert tortoise and its habitat.

As a result of the Preserve Committee's effective leadership in desert tortoise conservation, it has recently been approved as a full participating member of the Environmental Federation of California, a fund-raising coalition of about 40 conservation organizations. This is an important, and hard-won, accomplishment which earns the Preserve Committee a seat at the statewide level among the most influential and best organized environmental organizations in California. As a full participating member, the Preserve Committee will have access to millions of corporate and government employees during the Federation's workplace-giving campaigns. Currently, the Environmental Federation of California is the fastest growing workplace-giving federation in the United States.

Already, the Desert Tortoise Council has approved a donation to the Preserve Committee of 40 acres of prime desert tortoise habitat in Ivanpah Valley. We are also undertaking quiet title action to permit acquisition of about 60 acres within the Natural Area. And due to our enhanced capacity to negotiate complex real estate matters, the Preserve Committee is currently investigating ways to protect 700 acres of Category I desert tortoise habitat with the cooperation of Great Western Cities, Inc. and the Luz Development and Finance Corporation. These protected real property assets, in addition to land already owned by the Preserve Committee, would be the foundation for the envisioned revolving habitat acquisition endowment fund.

Finally, in response to the concerns of our members the Preserve Committee is presently evaluating the feasibility of establishing a multi-purpose Educational Outreach and Research Center at the Desert Tortoise Natural Area.

More than ever, the Preserve Committee is considered a full-fledged partner with government, industry, and other conservation organizations. More importantly, though, we have attained new levels of excellence while keeping our fundamental commitment to the public interest. In short, the Desert Tortoise Preserve Committee's mission is the same as it was in 1974: to conserve for posterity the desert tortoise and its natural environment. Thus, last year's accomplishments have been possible due in large measure to almost two decades of minding the public trust.

Special thanks is due to our committed members and our important partners in government, business, and the conservation community. Without your continued support the Desert Tortoise Preserve Committee would be but an honorable dream to preserve a significant symbol of California's natural history, the desert tortoise.

New Techniques in Transporting Desert Tortoises

Ellen M. Engelke, Jack S. Stone and Michael J. Cornish

Current research techniques can require transportation of desert tortoises (*Gopherus agassizii)* from the field into the laboratory. The reliability of the data requires transportation techniques that reduce stress on the tortoise. Our first method was to place tortoises in paper bags and hand-carry them up to 1.5 miles back to the lab station. This put the tortoises in a potentially heat-stressed environment for a period of time. We next tried transporting the tortoises in dishpans enclosed in ice chests secured on top of foam on a modified all-terrain vehicle (ATV). This reduced the exposure to heat and significantly shortened the time spent in transport, but introduced the possibility of large tortoises climbing out of the shallow pans and preventing the sterile isolation environment required by the incidence of URTD. Our third method placed the tortoises in square plastic laundry tubs lined with trash can liners and transported on the ATVs. This method eliminated potential escaping, but the plastic bags introduced new problems. We are now using self-closing plastic containers placed on a cushion of doubly folded egg crate foam padding in a trailer towed by an ATV with the pressure in all tires lowered to 1-2 lbs. These sturdy containers securely hold even the largest tortoise. The sides are translucent white and solid, allowing observation of the animal, reflecting heat rather than absorbing it, and facilitating complete cleaning with a bleach solution. This method significantly reduces the stress tortoises have undergone in past transportation techniques.

Effects of Tortoise Fencing on Indigenous Desert Species

Ellen M. Engelke

Standard 1" poultry netting was used to enclose the one square mile study site in Cantil, California. Designed to prevent desert tortoises (*Gopherus agassizii*) from traveling across study plots, the fence was embedded 18" into the ground and rose 18" above the ground, secured by concrete reinforcing bars every 10 feet. The fence did succeed in retaining the tortoises; however, indigenous species not principal to the study were adversely affected by the fencing material

We observed a total of 555 animals. Juvenile zebra-tailed lizards and horned lizards passed through or over the fence easily; young adult horned lizards and antelope ground squirrels passed through or over the fence with great difficulty as did at least one roadrunner. Large adult zebra-tailed lizards, horned lizards, and a chuckwalla were caught in the fence and had to be extracted. The fence proved particularly hazardous to jackrabbits and adult Mojave rattlesnakes, which were caught in the fence and died.

Head Starting as Halfway Technology: A Case Study with Sea Turtles

Nat B. Frazer

How we define a problem often will determine what we are willing to consider as a solution. When we define the impending extinction of a sea turtle species solely in terms of there being too few turtles, we are tempted to think of solutions solely in terms of increasing the numbers of turtles. Hence, some of what we are doing in our attempts to conserve sea turtles involves "halfway technology," which does not address the causes of or provide amelioration for the actual threats turtles face. Programs such as head starting, captive breeding, and hatcheries may serve only to release more turtles into a degraded environment in which their parents have already demonstrated that they cannot flourish. Furthermore, captive programs may keep turtles from serving important ecological functions in the natural environment, or place them at some disadvantage relative to their wild counterparts once released. Such programs can be contrasted with more appropriate technologies that directly address and correct particular problems encountered by sea turtles without removing them from their natural habitat. For example implementing TEDs (turtle excluder devices) in shrimp trawl nets will reduce mortality of adults and larger juvenile sea turtles, and using LPS (low pressure sodium) lighting on beaches may prevent hatchlings and nesting females from being disoriented. In the final analysis, what is needed are clean and productive marine and coastal environments. Without a commitment to such long-term goals, efforts to protect sea turtles will be futile.

Management Options for Sea Turtles: A Demographic Approach

Nat B. Frazer

Over the past several decades, numbers of nesting female loggerhead sea turtles, *Caretta caretta*, at well-known nesting beaches in both the Atlantic and Pacific Oceans have declined at a rate of between 3% and 7% per year. Long-term (i.e. >20 years) studies by the Georgia Sea Turtle Cooperative (USA) and by the Queensland National Parks and Wildlife Service (Australia) have resulted in the gathering of demographic data on survivorship, fecundity and growth rates (to provide estimates of age at maturity) for these populations. These data are sufficient to produce mathematical computer models of population dynamics which can be used to:

a. assess the probable outcome of alternative management plans for the recovery of these severely depleted populations, and

b. determine the critical stages of sea turtle life history for which more and better information is needed to provide more realistic population models.

The current state of our understanding of sea turtle demography based on the computer models indicates that the most important life stages to protect are the larger juveniles and adults, rather than the eggs and hatchlings that have been the focus of traditional conservation programs. This suggests that one of the most effective means of insuring the recovery of severely depleted populations of loggerhead sea turtles is to deploy TEDS (turtle excluder devices) on shrimp trawl nets.

Satellites and Tortoises at Joshua Tree National Monument

Jerry Freilich and Robert Moon

Desert tortoise (*Gopherus agassizii*) densities and population age structure were examined at two 1-km² permanent study sites at Joshua Tree National Monument, California, chosen for their high tortoise densities. All tortoises found were sexed, measured, weighed and marked. Fifty-seven tortoises were tagged at the first site and 47 at the second. Tortoises and their burrows were located for mapping purposes using Magellan global positioning receivers. Color pictures of the tortoises and burrows were taken on 2" floppy disks using a Canon Xapshot camera. An apple Macintosh database was developed to store tortoise location coordinates and the color, still-video images. The screen display shows tortoise locations as dots superimposed on an aerial photo of the study site. Clicking on a dot brings up specific information and color images of that burrow or tortoises found there. Our system provides a useful bridge between UTM coordinates derived from global positioning devices and the features normally associated with a GIS.

Knowing that we have some high density tortoise "hot spots," we undertook habitat evaluation on a Monument-wide scale, looking for other areas of high density. We use Landsat Thermatic Mapper data together with GAIA (Geographic Access Information and Analysis) software. GAIA allows us to open a Landsat image on the screen of an Apple Macintosh computer. Each 30 m square pixel has a color reflectivity related to features on the ground. We assign false color to each pixel class, then take the computer in the field to ground truth the pixel assignments. GAIA computes statistics on acreages in selected areas. More detailed pixel evaluation is done using IMAGE visual analysis software.

All of these technologies will be demonstrated running on an Apple Macintosh computer. All share the common characters of being high tech but low cost. These solutions will be useful to many tortoise researchers caught in the perpetual squeeze of increasing information needs with fewer dollars.

Studies of Unauthorized Off-Highway Vehicle Activity in the Rand Mountains and Fremont Valley, Kern County, California

Gilbert O. Goodlett and Glenn C. Goodlett

Abstract. In the fall of 1989, the Bureau of Land Management (BLM) placed parts of the Rand Mountains and Fremont Valley of eastern Kern County, California, under a temporary emergency quarantine and road closure to protect the threatened desert tortoise and its habitat. This protective action was lifted on November 21, 1990. Upon re-opening of the area to off-highway vehicle (OHV) use in 1990, the BLM reduced the number of authorized routes of travel to 150 miles. By marking some routes (trails) as "closed" with red Carsonite posts and limiting travel to only those routes marked as "open" with brown Carsonite posts, the BLM established the constraint that unmarked routes were not authorized for vehicular activity.

Shortly after lifting of the closure (December, 1990 to January, 1991), a study of OHV activity (Goodlett and Goodlett, 1991) indicated high unauthorized use levels. In November of 1991, a new monitoring project was initiated to evaluate unauthorized OHV use. Field surveys were conducted November 26, 27, 30 and December 3, 1991. Methods used to evaluate OHV impacts included: driving 105 miles of open routes and recording the number of unauthorized tracks and trails which crossed open routes; walking 39 transects, each of which was 500-feet long, perpendicular to open routes and recording numbers of OHV tracks and trails; raking closed routes and a sample of unmarked trails before Thanksgiving weekend and rechecking them 6 days later after Thanksgiving weekend for new tracks; and recording incidental observations.

A total of 1479 trails were observed to cross 105 miles of surveyed open routes. Of these, 99% were unmarked, and the remaining 1% were marked closed. The signed, closed routes represent a small fraction of the total number of trails being used by OHV enthusiasts.

On each of the 39 transects, a mean of 16 (range = 0 to 99) unauthorized tracks or trails were found, an average of one track or trail every 31 feet. The numbers of unauthorized tracks and trails varied in an inverse proportion to the distance from an open route. Near the edge of an open route (0 - 20 feet), an average of 2.05 (range = 0 to 20) OHV unauthorized tracks and trails per 20 linear feet were found. Further from the trail, the figures declined to an average of 0.51 (range = 0 to 4) per 20 linear feet .

Seventeen signed, closed routes were raked on November 26 and 27, 1991. A total of 107 recent tracks were found on these routes before raking. When raked portions of the trails were rechecked 6 days later after Thanksgiving weekend, 195 new tracks were found, a mean of 11.5 tracks per closed route. On a comparison sample of unmarked trails, 148 tracks (7.4/trail) were recorded before raking and 200 (10.0/trail) after raking.

On Saturday, November 30, 1991, OHV activity was monitored and videotaped. In a high density traffic area, a stationary observer recorded 65

vehicles passing his monitoring site in a 4-hour period. Of these, 25 were traveling on open routes only (38%), 13 traveled on closed routes (20%), and 27 traveled cross-country (42%). An observer driving through the area in a vehicle recorded 164 campers (RVs), 113 mobile motorcycles, and 64 other vehicles during a 5-hour period the same day.

Unauthorized OHV activity was found to be related to open routes. Where open routes existed OHV impacts were found parallel to these open routes. Impacts associated with an open route were projected to extend about 225 ft. on either side of open routes. For the Rand Mountain/Fremont Valley area, this means that 15.6 square miles (26%) of Category 1 desert tortoise habitat has been degraded as a result of the presence of open routes.

INTRODUCTION

Background

The desert tortoise (*Gopherus [Xerobates] agassizii*) was listed by the State of California in June of 1989 as a threatened species (CDFG 1989). A few months later, the U. S. Fish and Wildlife Service listed the species as endangered under an emergency rule, then followed with a permanent listing as threatened on April 4, 1990 (U.S. Fish and Wildlife Service 1990). The tortoise was listed because of rapidly declining populations, habitat loss and fragmentation. The sources for population losses cited include vandalism, vehicle kills, collections, disease, and excessive raven predation.

Declines in tortoise populations are well-documented for the western Mojave Desert (Berry 1990). Vandalism, damage to habitat from sheep grazing and off-highway vehicles, upper respiratory tract disease (URTD), and ravens are particularly critical issues in the Rand Mountains and Fremont Valley.

In fall of 1989 the U. S. Bureau of Land Management (BLM) placed a significant portion of public land in the Rand Mountains and Fremont Valley under a temporary emergency quarantine and road closure to provide increased protection for the desert tortoise and its habitat (U. S. Bureau of Land Management, 1989). The area under quarantine included the Desert Tortoise Research Natural Area (DTNA) and Area of Critical Environmental Concern (ACEC) and West Rand Mountains ACEC. All human activities, except those administratively authorized, were excluded from the DTNA and West Rand Mountains ACEC.

The protective action was lifted on November 21, 1990 (U. S. Bureau of Land Management 1990). According to a BLM media release, "Approximately 150 miles of roads will be opened in the area to provide access. Open routes will be signed with a brown post indicating their open status. Unmarked routes and trails and those marked with a red 'closed' post may not be used by motorized vehicles." This is a "...75 percent reduction in the existing routes." Further, "...camping will be allowed within 100 feet of a road in previously disturbed areas only."

Description of Project

The study area is adjacent to the northeastern part of the DTNA and ACEC, contains the western Rand Mountain ACEC, and has significant habitat for the desert tortoise (U. S. Bureau of Land Management 1980; Sievers et al. 1988). The area is BLM Category 1 desert tortoise habitat, the most important and significant of habitats.

Specific objectives of the study included the following:

1. Investigate the degree of OHV impact on desert tortoise habitat in the study area with specific emphasis on comparing use levels to those documented in the 1990 study (Goodlett and Goodlett 1991).

2. Determine the degree to which public use of the land, much of which is OHV activity, conforms with stated BLM management policies.

3. If significant vehicle activity is occurring and if the vehicle use does not conform to BLM policies, identify the areas of use and document these uses.

4. Study vehicle use levels during a major OHV activity period.

METHODS

Description of Study Site and General Techniques

The survey area was limited to public land administered by the BLM and bounded by the Mojave-Randsburg Road on the south, the DTNA on the west, Red Rock-Randsburg Road on the north, and private land in the Randsburg-Johannesburg area on the east (Fig. 1). An exception to these boundaries included a few open routes to the south of Mojave-Randsburg Road and to the north of Red Rock-Randsburg Road. The area encompassed about 90 square miles, 60 of which are public lands. All land is within Kern County, California.

Four techniques were used to evaluate unauthorized OHV activity. "Unauthorized" OHV activity was defined as recent tracks occurring on unsigned trails that intersect a signed, open route; recent tracks on a signed, closed route; and recent vehicle tracks off routes or trails. This definition is consistent with BLM specifications of authorized OHV activity detailed in a November 1990 news release to the public and outlined in literature available at information kiosks located at major entry points into the area. "Recent" tracks were defined as those where the tread print of the vehicle producing the track was clearly visible. The four techniques included:

(1) driving along open routes and recording the number of unauthorized tracks and trails intersecting the open route;

(2) walking 500-foot long transects which were systematically placed along the driven, open route and were perpendicular to the route;

(3) raking closed trails and a comparison sample of unmarked trails, recording the number of recent tracks, and rechecking the raked portion later; and

(4) observing and recording OHV use and related activity from one stationary and two mobile monitoring stations over Thanksgiving weekend.

Field surveys were conducted by Gilbert Goodlett, Glenn Goodlett, Craig Smith, and Elizabeth Smiley on November 26, 27, 30, and December 3, 1991. Prior to the start of the study on November 11, rain fell in the area. It is not known if the rain erased vehicle tracks prior to that date and no data were collected concerning the durability of vehicle tracks.

Sampling Open, Signed Routes for Evidence of Unauthorized Vehicle Use

We drove 105 miles of open, signed routes and recorded the number of recent OHV tracks on intersecting trails. "Open, signed" routes were those routes clearly marked by the BLM with brown Carsonite signs indicating their status as open to OHV activity and were identified as open to 4-wheeled vehicles on maps located at BLM kiosks at primary entrances to the area. No routes shown as "motorcycle only" were driven.

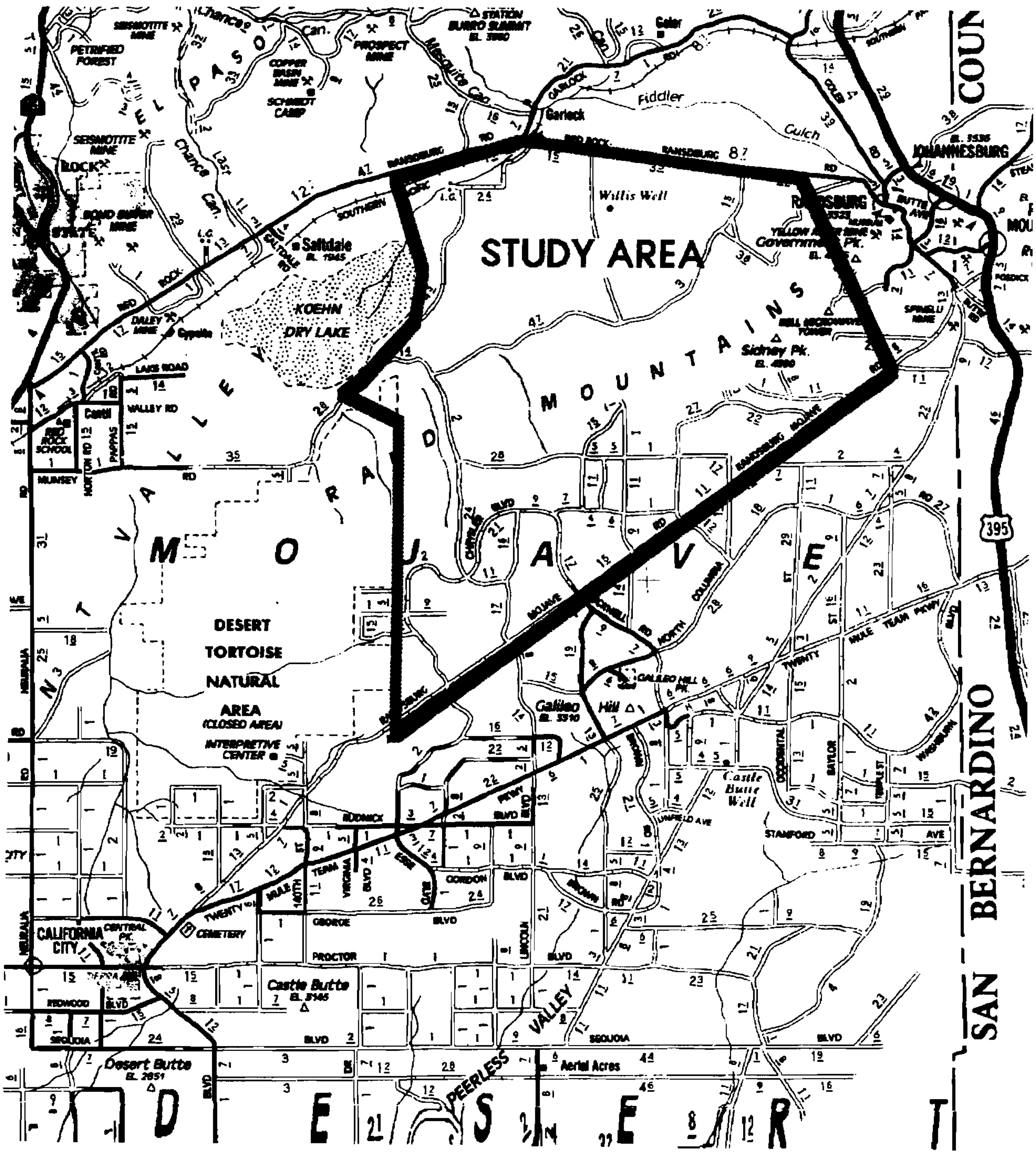


Figure 1. Study area, Rand Mountains and Fremont Valley, eastern Kern County, California.

It was common to find trails that paralleled signed, open routes but often impossible to assess which of the routes was the official open route. Tracks and trails paralleling an open route were not counted in our analysis.

Intersecting trails were placed into two categories: unmarked trails and signed, closed routes. Signed, closed routes were marked with either a red Carsonite signs with the words "CLOSED ROUTE" written vertically on the sign or a rectangular BLM sign mounted on a post that identified the area behind the sign as closed to all vehicular use. Each sign was on or very near the intersection of the closed route with the open route. Data recorded for each category included the number of recent tracks observed on the trail and the width of the trail.

Numbers of unauthorized tracks intersecting open routes were tabulated on a linear mile basis for each open route. The data were then placed in four categories based on numbers of unauthorized tracks per route or route segment per linear mile: 0-20, 20-40, 40-60, and >60. Polygons enclosing each category were drawn on maps of the study area.

Measuring Unauthorized Vehicle Use Adjacent to Open Routes

A total of 39 transects were walked; each transect was spaced at 1.5 mile intervals along open routes (Figs. 2 and 3). These transects were 500 feet long, 30 feet wide, and placed perpendicular to the open routes from which they originated. Transects began at the edge of the route of origin. Distances along transects were measured by calibrated pacing.

Representative videotape footage of each transect was taken of the vicinity of the origin of the transect. The time and date of the transect, weather conditions, geomorphological information, data concerning the trail of origin, and location were recorded on a standard form (Fig. 4). The latitude and longitude of the origin of each transect were recorded to an accuracy of about 200 feet using a portable LORAN navigation device.

Each investigator carried a tally meter to count human impacts. Each transect was divided into four zones, which were measured along the axis of the transect. They were distributed as follows: Zone 0 = 0-20 feet, Zone 1 = 20-100 feet, Zone 2 = 100-250 feet, and Zone 3 = 250-500 feet. Several categories of human impacts were counted, the most significant of which were numbers of trails and tracks. Human impacts in each category were tallied for each zone and summarized on a data sheet. In addition, particularly significant impacts were mapped on a scale drawing of the transect.

Measuring Vehicle Traffic on Closed Routes and Unmarked Routes/Trails

The numbers of recent tracks were counted on every signed, closed route encountered (N = 17) and a systematic random sample of unmarked trails (N = 20). Most of the closed routes were in the southwest 1/4 of the study area (Fig. 1). The sample of unmarked trails was selected in the same geographic area to reduce sample bias. After counting the number of recent tracks, each trail was raked to erase vehicle tracks. Each trail was raked near its intersection with a signed, open route. Several days later, the number of tracks on the raked portions of each trail were tallied.

We raked trails using a conventional heavy-duty yard rake. The raked portion was approximately three feet wide. The length of the raked portion varied and depended on the trail width. For closed trails, the raked area was located near the sign denoting the trail as closed. We raked behind the closed sign only to prevent counting any tracks made by OHV riders who rode up to the sign to read it. For unmarked trails, we raked a similar position except that there were no signs denoting the trail as closed.

Closed trails and the sample of unmarked trails were raked on November 26 and 27.

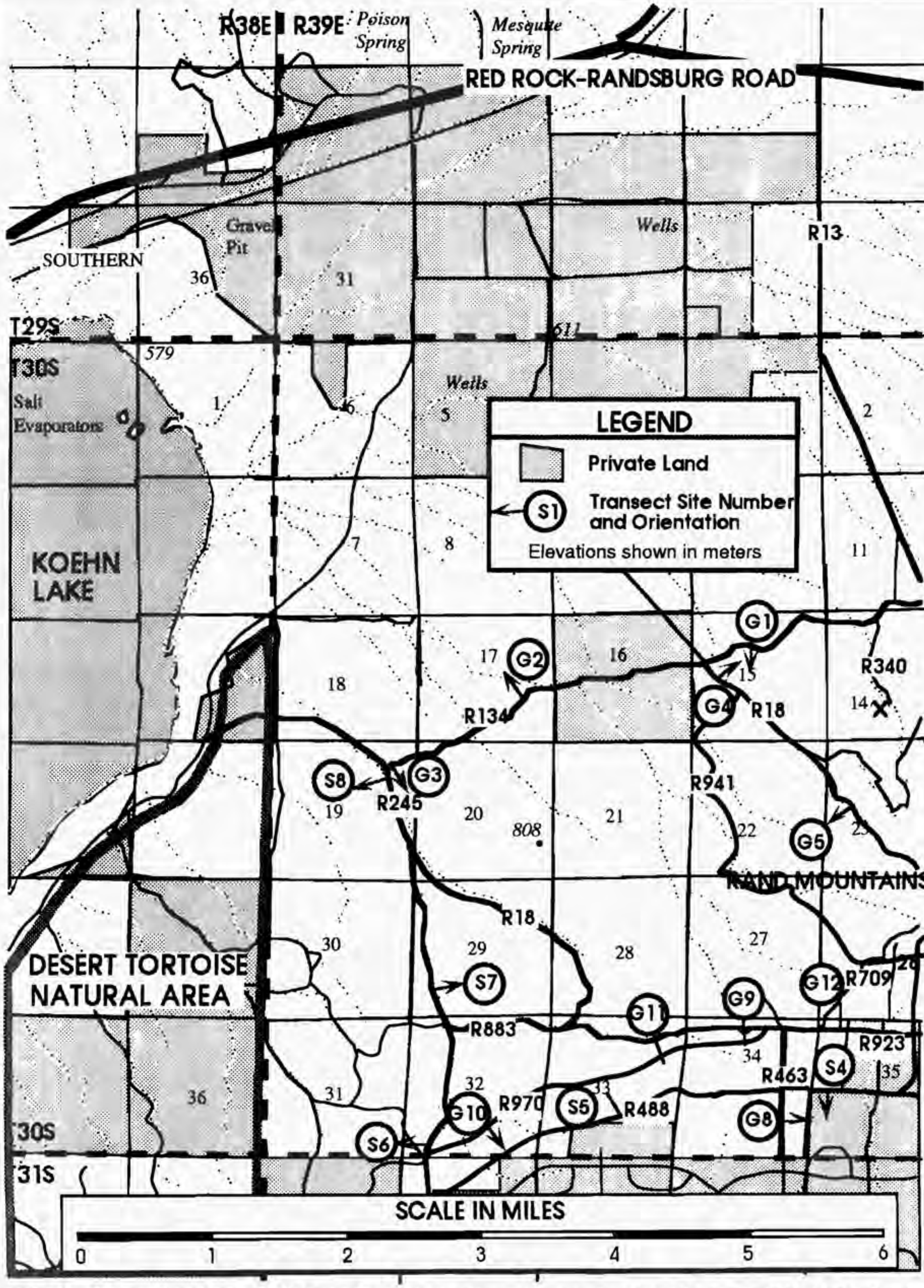


Figure 2. Unauthorized OHV tracks per linear mile per trail in the west half of the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

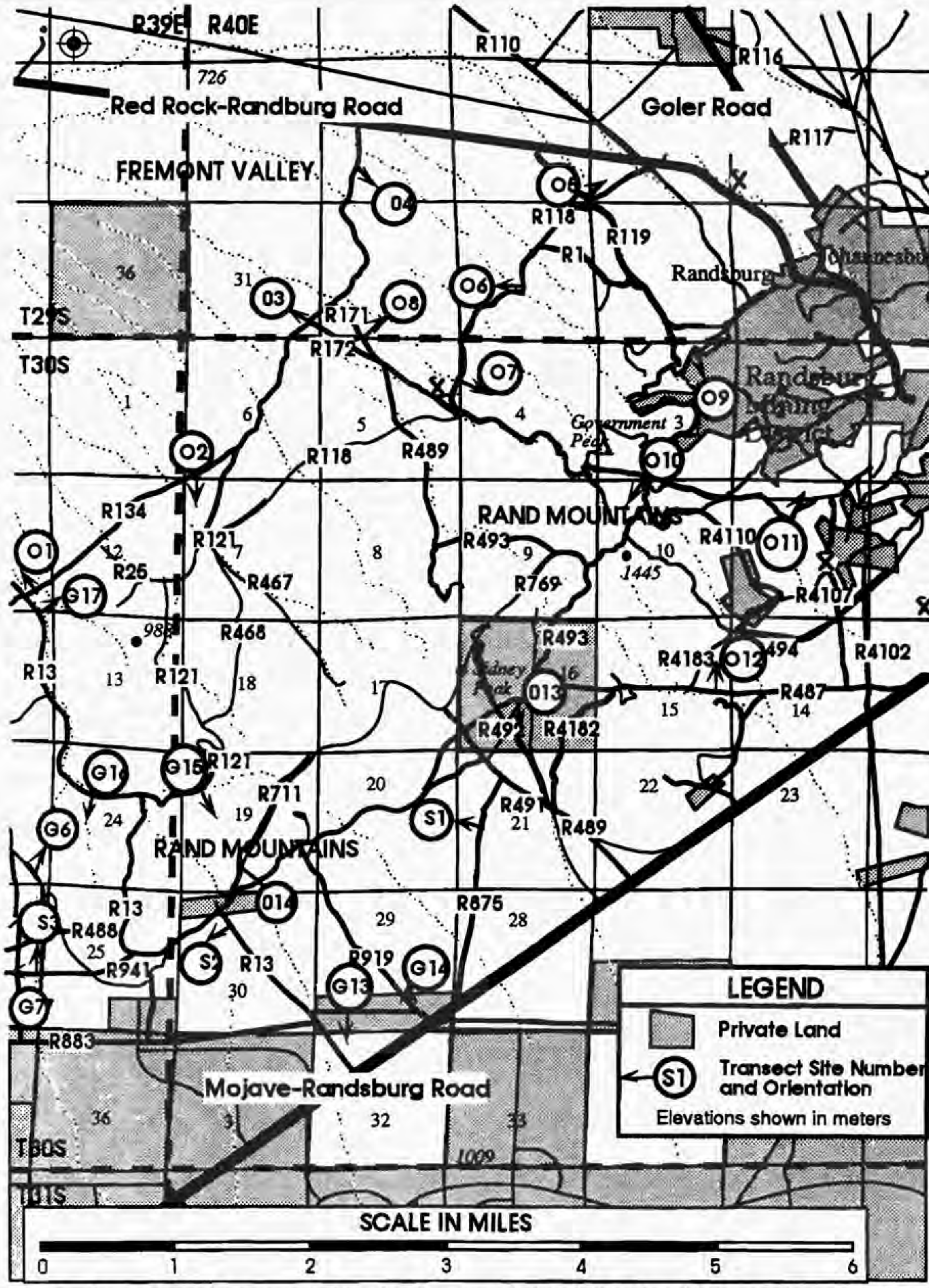


Figure 3. Location of transect sites in the east half of the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

All raked trails were rechecked on December 3 after the Thanksgiving holiday weekend. The number of tracks on the raked portion of each trail was counted. Videotape footage was taken of each trail during each visit.

Other Monitoring of Vehicle Use

Off-highway vehicle use and related activities were monitored on November 30 during the Thanksgiving weekend. Weather conditions were cold and windy with temperatures of about 7 °C and winds exceeding 20 mph. An observation station was operated north of Park "C" on public land at the intersection of open routes R245 and R970 between 1230 and 1630 PST. There, a partially concealed observer (concealed to preclude behavioral bias of OHV enthusiasts), counted the number of vehicles passing the observation point. The observer placed data on vehicles in one of three categories: traveling on an open route, traveling on a closed route, or traveling on an unmarked trail or cross-country. The observation point was selected because it afforded a single point from which all three of these categories of OHV activity potentially could be observed. Its relative proximity to Park "C" indicated a high probability of maximum traffic density which was intended to give a reasonable sample size. The investigator also videotaped activities observed from his vantage point.

Two mobile observation stations were also in operation on November 30. One was assigned with the primary responsibility of counting the number of OHVs, campers, and other vehicles observed using the area and the other videotaped OHV activities, primarily those that were unauthorized. Unlike all other aspects of the survey, the count was not limited to public lands, since most of the RVs were parked on private land south of public land. Only OHVs that were mobile at the time observed were counted, since counting of stationary vehicles located near RVs would be difficult.

Monitors were equipped with video cameras and recorded footage of OHV activity with particular emphasis on capturing evidence of unauthorized activity. The results of vandalism were recorded and noted throughout the study.

Comparisons of Data Collected in December 1990-January 1991 with Data Collected in November 1991

A similar study was conducted from December 1990 to January 1991. The methods used were similar. However, this type of study represents a snapshot in time that is dependent on the specific timing of the study and events during and preceding it. Here, there were significant differences (Table 1).

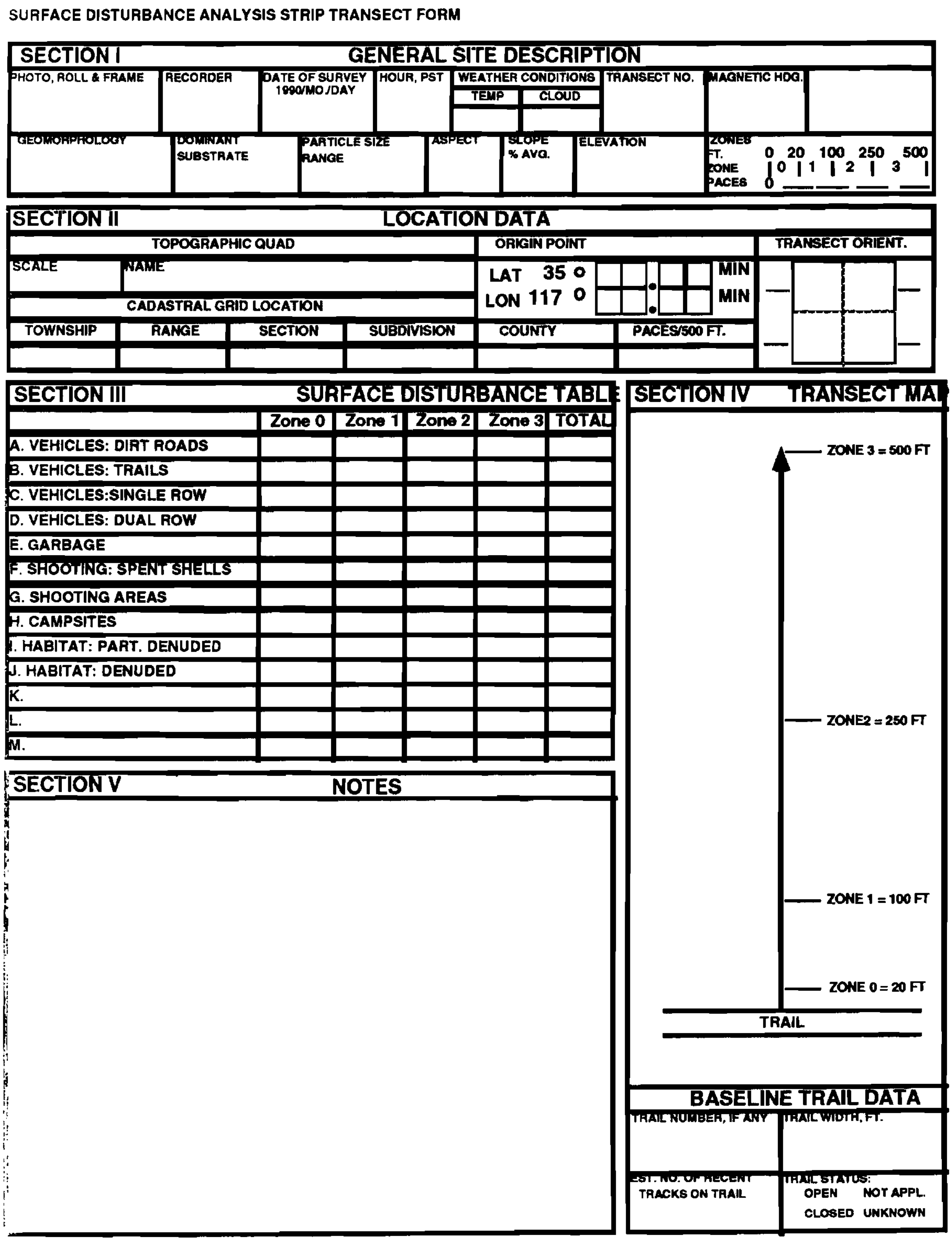
Statistical Methods Used in Data Analysis

Several statistical comparisons are made in this text. A Student's t-test was used for all comparisons at a 95% level of significance.

RESULTS

Changes in Management of Recreational Vehicle Use Between December 1990 and November 1991

Between December of 1990 and November of 1991, BLM added information kiosks at all major entry points into the area and a few prominent locations within the area. These



SURFACE DISTURBANCE ANALYSIS STRIP TRANSECT FORM

SECTION I — GENERAL SITE DESCRIPTION

PHOTO, ROLL & FRAME	RECORDER	DATE OF SURVEY 1990/MO /DAY	HOUR, PST	WEATHER CONDITIONS: TEMP / CLOUD	TRANSECT NO.	MAGNETIC HDG.	

GEOMORPHOLOGY	DOMINANT SUBSTRATE	PARTICLE SIZE RANGE	ASPECT	SLOPE % AVG.	ELEVATION	ZONES
						FT. 0 20 100 250 500; ZONE 0 1 2 3; PACES 0

SECTION II — LOCATION DATA

TOPOGRAPHIC QUAD				ORIGIN POINT		TRANSECT ORIENT.
SCALE	NAME			LAT 35 ° . MIN		
CADASTRAL GRID LOCATION				LON 117 ° . MIN		
TOWNSHIP	RANGE	SECTION	SUBDIVISION	COUNTY	PACES/500 FT.	

SECTION III — SURFACE DISTURBANCE TABLE

	Zone 0	Zone 1	Zone 2	Zone 3	TOTAL
A. VEHICLES: DIRT ROADS					
B. VEHICLES: TRAILS					
C. VEHICLES:SINGLE ROW					
D. VEHICLES: DUAL ROW					
E. GARBAGE					
F. SHOOTING: SPENT SHELLS					
G. SHOOTING AREAS					
H. CAMPSITES					
I. HABITAT: PART. DENUDED					
J. HABITAT: DENUDED					
K.					
L.					
M.					

SECTION IV — TRANSECT MAP

ZONE 3 = 500 FT

ZONE2 = 250 FT

ZONE 1 = 100 FT

ZONE 0 = 20 FT

TRAIL

BASELINE TRAIL DATA

TRAIL NUMBER, IF ANY	TRAIL WIDTH, FT.
EST. NO. OF RECENT TRACKS ON TRAIL	TRAIL STATUS: OPEN NOT APPL. CLOSED UNKNOWN

SECTION V — NOTES

Figure 4. Form used for recording OHV impact data in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

Table 1. Comparison of differences in 1990 and 1991 studies at the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

	1990	1991
Dates of survey	Dec. 13-15, 1990 & Jan. 20,1991	Nov. 26, 27 & Dec. 3.
Recency of precipitation prior to onset of study.	Unknown, not soon before study.	Rain on Nov. 11, 1991, 15 days prior to study.
When were initial sets of tracks created by vehicles?	Unknown, how much unauthorized activity occured before the area was re-opened on Nov. 21, 1990?	Unknown, were all tracks erased by rain on Nov. 11?
Miles of open route surveyed	46.2	105.0; additional area mostly in low vehicle use parts of Fremont Valley
Number of transects	37	39
Locations of transects	Randomly selected	Randomly selected from larger area than 1990. No overlap of specific locations between years.
Number of signed, closed routes where tracks were initially counted	21	17
Locations of signed, closed routes that were surveyed	Baseline	1991 locations were mostly a subset of 1990 locations. Some 1990 closed trails were no longer marked as closed; possibly as a result of vandalism.
Number of signed, closed routes that were raked and rechecked	16	17
Time between raking and re-checking of closed trails.	34 days	6 days
Recreational use level between raking and re-checking of closed trails.	Unknown, how much activity occurred during Christmas and New Years?	Major OHV activity on Thanksgiving weekend.
Use of stationary and mobile monitors counting dynamic use levels	Not used - no data	Used

kiosks include maps of the area showing routes open to motorcycles and 4-wheeled vehicles and hand-out sheets that detail regulations governing the area. The hand-out specifically states, "Vehicle traffic is allowed only on signed open routes marked with brown, numbered sign posts!"

Many new signs marking open routes have been added, eliminating some of the ambiguities that existed in 1990. However, fewer closed routes were located in 1991 versus 1990 (21 and 17, respectively). Some closed signs present in 1990 were no longer present in 1991. We do not know whether the closed signs were removed by BLM personnel or by vandals. Also, some red Carsonite closed signs have been replaced or supplemented with BLM signs stating, "The area behind this sign closed to all vehicle activity," as well as icons representing this idea. The signs were mounted on metal fence posts.

Campsite locations have been established, marked on maps, and delineated on the ground. They were marked with a campsite icon on a brown Carsonite sign; white Carsonite signs were used to mark the boundaries of the camp areas.

Data on Unauthorized Vehicle Use from Open, Signed Routes

A total of 1479 unmarked trails and 4035 unauthorized, recent OHV tracks was observed (Table 2) intersecting 105 miles of signed, open routes. An average of 38 (range = 0 to 194) unauthorized OHV tracks per linear mile of surveyed route were encountered.

Off-highway vehicle impacts were distributed throughout the study area (Figs. 5 and 6). In general, the highest level of impact occurred in the southwestern portion of the study area along the more gently sloping southwestern strike of the Rand Mountains within the Rand Mountains ACEC. Six trails had > 60 unauthorized intersecting tracks per linear mile: R463, R488 (west half), R711, R937, R941, and R970.

Data on Unauthorized Use Adjacent to Open Routes

A total of 85 unauthorized trails and 553 recent, unauthorized tracks was recorded on 39 transects (Table 3). An average of 16 unauthorized trails or tracks crossed each transect, or one track every 31 feet. Numbers of tracks and trails observed on transects ranged from 0 to 89.

Off-highway vehicle impacts varied with respect to the distance from the route of origin (Table 3, Fig. 7). Impacts tallied included unauthorized trails and recent tracks. Close to the origin of the transect at the edge of an open route (0-20 feet), a mean of 2.05 OHV impacts per 20 linear feet were found. Further from the origin, impacts gradually declined to a mean of 0.51 impacts per 20 linear feet beyond 250 feet from the origin trail.

Data on Unauthorized Vehicle Traffic from Closed Routes and Unmarked Routes/Trails

A total of 107 recent tracks (mean = 6.3/closed route) was located on 17 signed, closed trails on November 26 and 27, 1991 (Table 4). After this initial tally, all closed trails intersecting the 105 miles of open route surveyed were raked. These same trails were rechecked after the Thanksgiving weekend on December 3, 1991, 6 to 7 days later. At this time 195 new tracks (mean = 11.5/closed route) were recorded on the raked portions of the closed trails (Table 4).

On November 27 we found 148 recent tracks (mean = 7.4/unmarked route) on a random sample of 20 unmarked trails. After counting the tracks, these trails, like the signed, closed trails, were raked. On December 3, the trails were rechecked and a total of 200 new tracks (mean = 10.0/unmarked route) were recorded (Table 5).

Table 2. Numbers of unmarked trails and recent OHV tracks encountered along open routes in the Rand Mountain and Fremont Valley study area, eastern Kern County, California.

Surveyed Open/signed route	Begin	End[1]	Number of miles surveyed	Number of unmarked intersecting trails[2]	Number of crossing tracks	Recent OHV tracks/ linear mile of open route[3]
R134	R13	Red Rock Rd	4.7	54	61	13
R171	R134	R172	0.6	0	4	7
R172	R171/R489	Ambiguous	1.1	4	5	5
R118	R172	Red Rock Rd	2.4	45	77	32
R119	Red Rock Rd	R172	4.7	94	85	18
R4107	R4110	R487	2.9	43	74	26
R487/488	MoRand Rd	R13	5.9	121	182	31
R711	R488	R769	0.9	56	175	194
R769	R711	Ambiguous	0.7	13	32	46
R491	R488	R331	0.6	13	27	45
R491	R488	R489	0.7	7	9	13
R489	MoRand Rd	R969	1.9	34	38	20
R969	R489	R492	0.4	4	7	18
R492	R969	R489	1.0	18	9	9
R4102	MoRand Rd	Private Land	1.2	13	29	24
R494	Private Land	R4183	1.6	23	34	21
R4110	R494	R769	1.3	15	26	20
R769	R4110	Sydney Peak	1.5	17	51	34
R493	R769	R487	1.2	13	17	14
R969	R493	R492	0.1	0	0	0
R4182	R489	Ambiguous	1.6	10	13	8
R4102	MoRand Rd	R883	2.0	10	10	5
R121	R134	R118	0.7	2	3	4
R118	R121	R807	0.7	1	2	3
R807	R118	R331	0.3	4	2	7
R13	Red Rock Rd	MoRand Rd	9.7	113	431	44
R875	MoRand Rd	R491	1.8	25	67	38
R488	R480/R491	R245	8.3	156	607	73
R245	R488	Koehn Lake Rd	4.7	74	269	57
R134	R245	R13	4.5	34	134	30
R18	R134	R709/R937	3.1	44	142	46
R937	R709/R18	R883	0.9	13	61	68
R883	MoRand Rd	R245	11.1	147	549	49
R970	R245	R883	3.0	86	251	84
R463	R883	Sec.Road	0.9	32	92	102
R9[illegible]9	S. Boundary	R488	0.5	6	15	33
R941	R488	R18	4.8	106	321	67

Table 2 (cont). Numbers of unmarked trails and recent OHV tracks encountered along open routes in the Rand Mountain and Fremont Valley study area, eastern Kern County, California.

Surveyed Open/signed route	Begin	End[1]	Number of miles surveyed	Number of unmarked intersecting trails[2]	Number of crossing tracks	Recent OHV tracks/ linear mile of open route[3]
R110	Boundary	Rail Road	4.6	10	36	8
R113	Garlock Rd	HWY 395	3.5	6	39	11
R115	HWY 395	R116	1.9	8	26	14
R116	Goler Rd	HWY 395	1.1	5	23	21
TOTALS			**105.0**	**1479**	**4035**	
MEAN						**38**

1. Where the end of the route was reported as "ambiguous", the end of the route could not be determined.
2. Unmarked, intersecting trails were unsigned established trails that intersect the indicated open route. These routes are not open to OHV use according to BLM management policies.
3. Number of recent OHV tracks/ linear mile of open route is the number of unauthorized, intersecting OHV tracks encountered on a particular open route divided by the number of linear miles surveyed. It represents an average of the density of unauthorized OHV use for that particular open route.

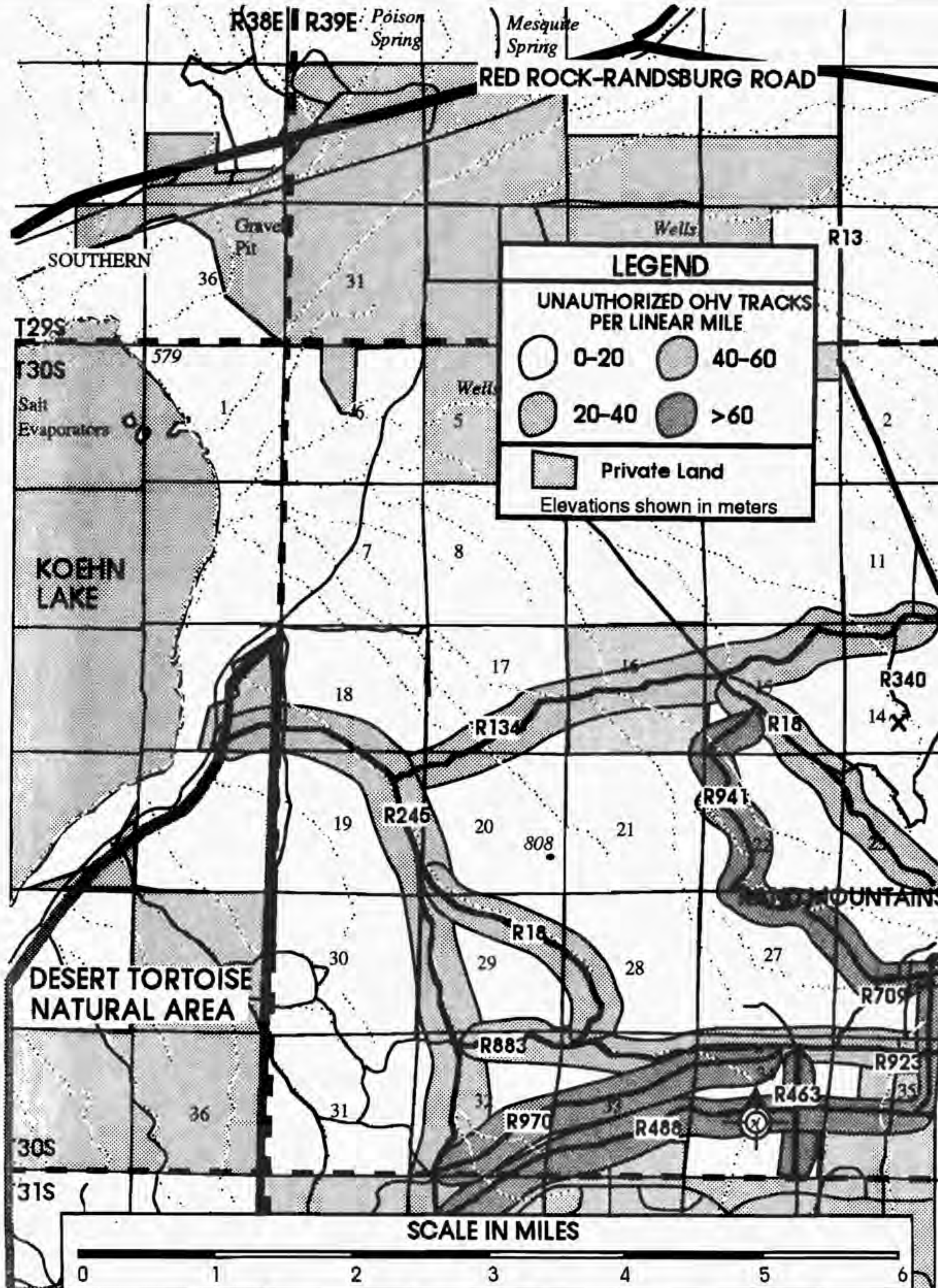


Figure 5. Numbers of unauthorized OHV tracks per linear mile per trail in the west half of the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

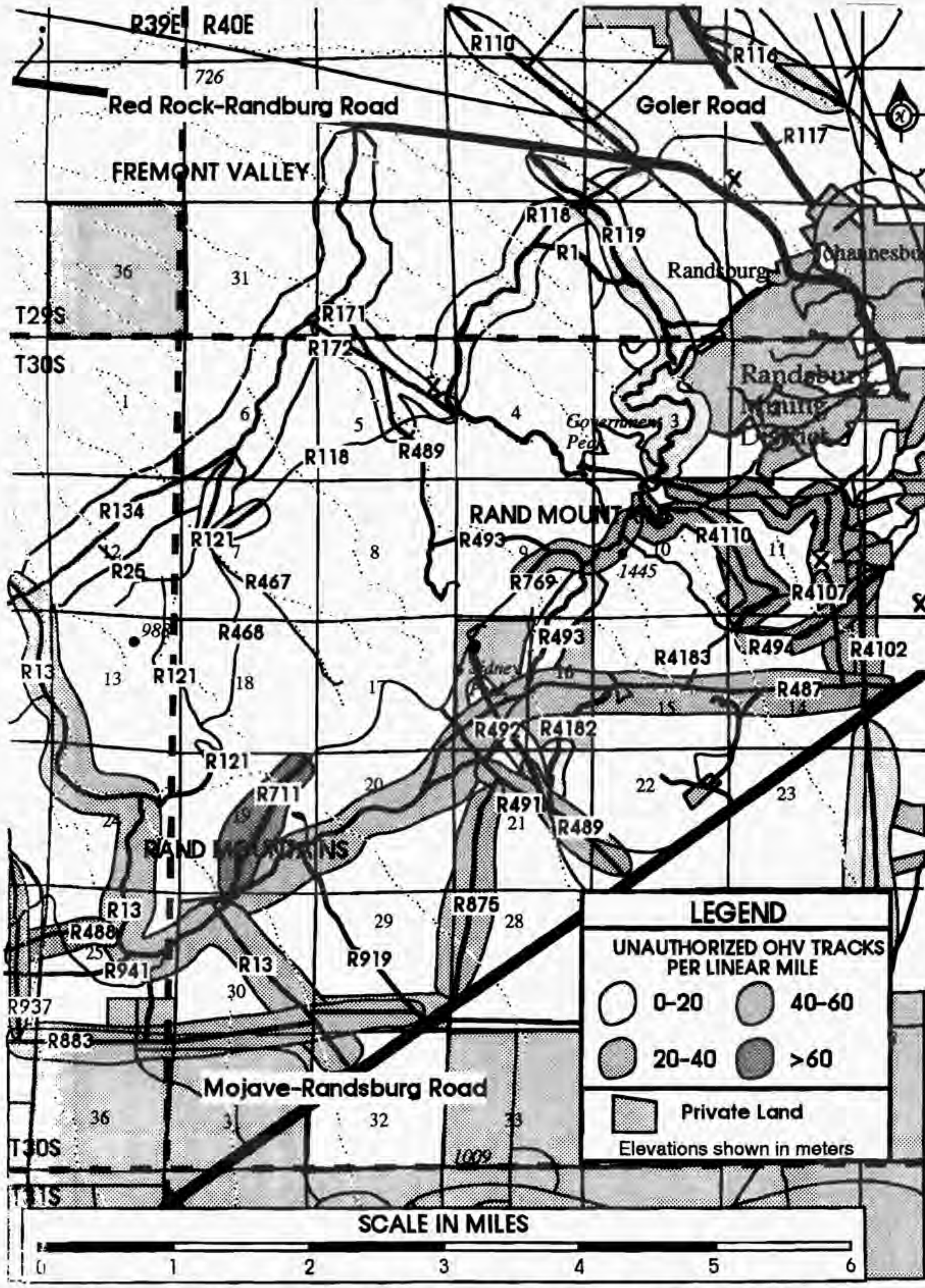


Figure 6. Numbers of unauthorized OHV tracks per linear mile per trail in the east half of the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

This figure shows the relationship between the average number of impacts per 20 linear feet versus distance from the transect origin (edge of open route). Impacts are most concentrated near the open route and gradually decline as the distance from the open route is increased. Zone definitions are: Zone 0 = 0 to 20 feet; Zone 1 = 20 to 100 feet; Zone 2 = 100 to 250 feet; and Zone 3 = 250 to 500 feet.

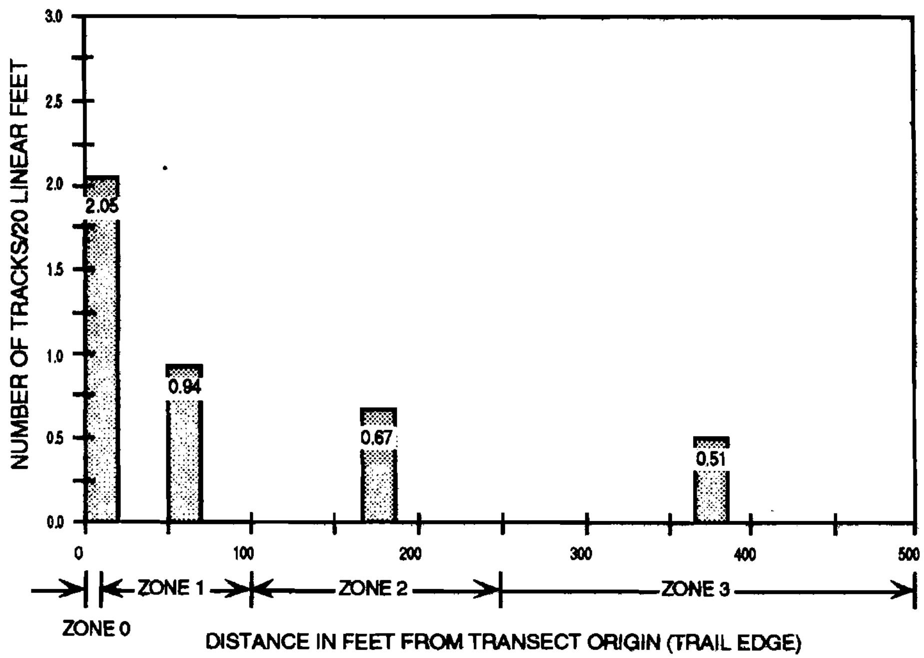


Figure 7. Relationship between unauthorized OHV activity and perpendicular distance from open routes, Rand Mountains and Fremont Valley study area, eastern Kern County, California.

Table 3. Counts of unauthorized tracks and trails occurring on thirty-nine, 500-foot long transects in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

		ZONE 0 0-20 feet		ZONE 1 20 to 100 feet		ZONE 2 100 to 250 feet		ZONE 3 250 to 500 feet		TOTAL	
Transect	Route association	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks
S1	R875		2	1		1	1			2	3
S2	R13							1	5	1	5
S3	R941				1						1
S4	R488		1	2	7	1	4		1	3	13
S5	R488				1	6	35	4	17	10	53
S6	R245			3	8		1	2	26	5	35
S7	R245					2	21		1	2	22
S8	R245	1	5			3	6		2	4	13
O1	R134			1						1	
O2	R134			1	4					1	4
O3	R13	1							1	1	1
O4	R134							1		1	
O5	R119							1	1	1	1
O6	R118				1			1	7	1	8
O7	R118					1		1	1	2	1
O8	R171										
O9	R119	1						1	9	2	9
O10	R119		1			1	4			1	5
O11	R4107	1	8							1	8
O12	R487	1	2							1	2
O13	R487							1	1	1	1
O14	R711	1	19	2	19	1	1	6	50	10	89
G1	R134				1						1
G2	R134		7	1	10					1	17
G3	R134		5		3			1	16	1	24
G4	R18		2		2	2	2	1	4	3	10
G5	R18										
G6	R18	1	4			2	7	3	18	6	29
G7	R937			2	13	2	5		1	4	19
G8	R463			3	27	1	10		1	4	38
G9	R970					1	8	1	9	2	17
G10	R970					1	12		3	1	15
G11	R883				3	1	7	1	14	2	24
G12	R883				2	1	7	1	9	2	18
G13	R883	1	4						4	1	8

Table 3 (cont). Counts of unauthorized tracks and trails occurring on thirty-nine, 500-foot long transects in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

		ZONE 0 0-20 feet		ZONE 1 20 to 100 feet		ZONE 2 100 to 250 feet		ZONE 3 250 to 500 feet		TOTAL	
Transect	Route association	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks	Vehicles: Trails	Vehicles: tracks
G14	R883					1	13	2	3	3	16
G15	R13		7	1	12		2			1	21
G16	R121		1		3	1	11	1	3	2	18
G17	R13			1	4					1	4
TOTALS		**8**	**68**	**18**	**121**	**29**	**157**	**30**	**207**	**85**	**553**
ZONE TOTALS		76		139		186		237		638	
MEAN IMPACTS/ TRANSECT		2.054		3.757		5.027		6.405			
IMPACTS/ 20 LINEAR FEET		2.054		0.939		0.67		0.512			

Table 4. Counts of recent tracks on 17 signed, closed trails before and after raking in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

Closed route number	Open route association	Latitude	Longitude	11/26/91 Number of recent tracks on closed trails (raked)	12/3/91 Number of tracks on raked portion of closed trail
1	R487	35º19.50	117º41.80	0	0
2	R13	35º18.22	117º43.68	10	10
3	R487	35º18.43	117º42.98	5	37
4	R13	35º17.59	117º42.95	5	4
5	R487	35º18.39	117º43.35	7	30
6	R875	35º17.84	117º41.83	2	1
7	R711	35º18.50	117º43.38	13	8
8	R875	35º18.01	117º41.84	0	0
10	R875	35º18.40	117º41.82	1	0
12	R875	35º19.22	117º41.54	0	0
14	R245	35º16.41	117º49.25	17	40
16	R245	35º17.42	117º49.04	8	7
18	R245	35º19.11	117º49.82	16	14
20	R245	35º19.15	117º49.91	12	11
22	R883	35º17.42	117º43.51	2	9
24	R883	35º17.43	117º43.56	4	9
26	R883	35º17.37	117º48.97	5	15
TOTALS				**107**	**195**
MEANS				**6.3**	**11.5**

Table 5. Counts of recent tracks on a sample of 20 unmarked trails before and after raking in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

Unmarked route number	Open route association	Latitude	Longitude	11/27/91 Number of recent tracks on unmarked trails before raking	12/3/91 Number of tracks on raked portion of unmarked trail
1	R13	35º17.47	117º42.84	3	6
2	R13	35º17.58	117º42.92	13	9
3	R13	35º17.89	117º43.35	0	13
4	R13	35º18.12	117º43.58	11	41
5	R488/13	35º18.10	117º43.85	17	6
6	R941	35º17.87	117º44.15	8	8
7	R941	35º17.72	117º44.71	8	4
8	R941	35º17.74	117º44.89	10	12
9	R488	35º17.67	117º45.27	0	0
11	R488	35º17.30	117º45.27	5	6
12	R488	35º17.23	117º45.59	6	7
13	R488	35º17.08	117º45.97	6	8
14	R488	35º17.03	117º46.19	23	20
15	R488	35º16.98	117º46.60	2	3
16	R488	35º16.66	117º47.31	5	5
17	R488	35º16.58	117º47.61	6	6
18	R488	35º16.52	117º48.14	0	7
19	R488	35º16.29	117º48.87	9	13
28	R245	35º17.35	117º49.01	11	19
30	R245	35º19.31	117º50.09	5	7
TOTALS				**148**	**200**
MEANS				**7.4**	**10**

No statistically significant difference was found in the number of new tracks on closed trails as compared to a sample of unmarked trails (mean = 11.5 and 10.0, respectively). There was also no statistically significant difference in the number of tracks originally found on both closed routes and unmarked routes prior to raking (mean = 6.3 and 7.4 respectively).

Other Data on Vehicle Use

A stationary monitor observed 65 vehicles during a 4-hour period. Twenty-five vehicles (38% of those observed) traveled on open routes only. This activity is authorized. Forty vehicles (62% of those observed) traveled on signed, closed routes (13) or on unmarked routes/cross country (27). This activity is not authorized. A mobile monitor driving in the area counted the 341 OHVs, campers (RVs), and other vehicles (Table 6).

Monitors recorded unauthorized use of unmarked routes and signed, closed routes by OHV enthusiasts on videotape. Examples of vandalism also were recorded on videotape, including signs that had been shot, run over, or removed. In one case, a closed route sign was hidden with the remnants of a vehicle seat on top of it. We did not count the number of vandalized sites encountered.

Comparisons of Data Collected in December 1990-January 1991 with Data Collected in November 1991

Comparison of OHV Use on Unmarked Routes

In both the 1990 and 1991 studies, the numbers of unsigned, intersecting trails and unauthorized tracks were tallied by individual route with specific beginning and ending points. A valid comparison of these data can only be made if the same routes or route segments are compared. Even for the same routes, the origin and ending points of data collection differed between 1990 and 1991. These end points were recorded in both years. We then selected routes or route segments from both years that maximized the between-year overlap and calculated the degree of overlap (Table 7).

In 1991, 105 miles of open route were surveyed while in 1990, 46 miles of route were surveyed. Between these two years, about 33 miles of surveyed open route overlapped. For 1990, the concurrent data set represents 83% of the selected data set (32.7/39.2) while for 1991, the concurrent data set represents 65% of the selected data set (32.7/50.1). In comparison between years, there was little difference in the mean numbers of recent OHV tracks per linear mile while the number of unmarked intersecting trails showed a dramatic increase in 1991 by a factor of 2.

Comparison of Transect Data

During both years, a relationship existed between open routes and unauthorized activity. The density of unauthorized activity was high near an open trail and gradually declined as the perpendicular distance from the open route increased (Fig. 8).

The transect data from 1990 (Goodlett and Goodlett, 1990) and 1991 were regressed using a linear regression and a second order polynomial regression (Fig. 9). A linear regression projects that impact levels will reach 0 at 500 ft (1990 data) and 475 ft (1991 data).

A more realistic situation is probably represented by a second order polynomial regression because the asymptotic relationship emulates the physical reality of always having some level of unauthorized vehicle activity associated with an open route. In this case, impact levels never reach 0. Instead, they reach a minimum value at about 275 ft. from the transect

Table 6. Observations of vehicle use recorded by a mobile monitor for a 5-hour period on November 30, 1991 in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

Vehicle type	Number observed	Percent of total
Off-highway vehicles (OHVs)	113	33.1%
Campers (RVs)	164	48.1%
Other vehicles	64	18.8%
TOTALS	**341**	**100.0%**

Table 7. Comparisons of 1990 and 1991 analysis of OHV activity on unmarked routes in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

	1990	1991		1990	1991	1990	1991
Surveyed Open/signed route	Number of miles surveyed	Number of miles surveyed	Miles of overlap between 1990 & 1991	Unmarked intersecting trails/mile	Unmarked intersecting trails/mile	Recent OHV tracks/ linear mile of open route	Recent OHV tracks/ linear mile of open route
R121	1.8	0.7	0.7	4.4	2.9	28.3	4.3
R13	6.7	9.7	6.7	7.6	11.6	34.9	44.4
R134 (west)	5.2	4.7	4.7	4.2	11.5	37.7	13.0
R134 (east)	2.0	4.5	2.0	2.5	7.6	20.0	29.8
R18	1.5	3.1	1.5	3.3	14.2	18.7	45.8
R245	5.5	4.7	4.7	4.9	15.7	40.5	57.2
R4102	1.3	1.2	1.2	4.6	10.8	35.4	24.2
R4182	0.5	1.6	0.5	2.0	6.3	8.0	8.1
R488	7.8	8.3	5.0	4.7	18.8	33.7	73.1
R883	5.2	11.1	5.2	6.7	13.2	79.4	49.5
R919	1.7	0.5	0.5	6.5	13.3	85.9	33.3
TOTALS	**39.2**	**50.1**	**32.7**				
MEAN				**5.3**	**13.0**	**41.9**	**45.0**

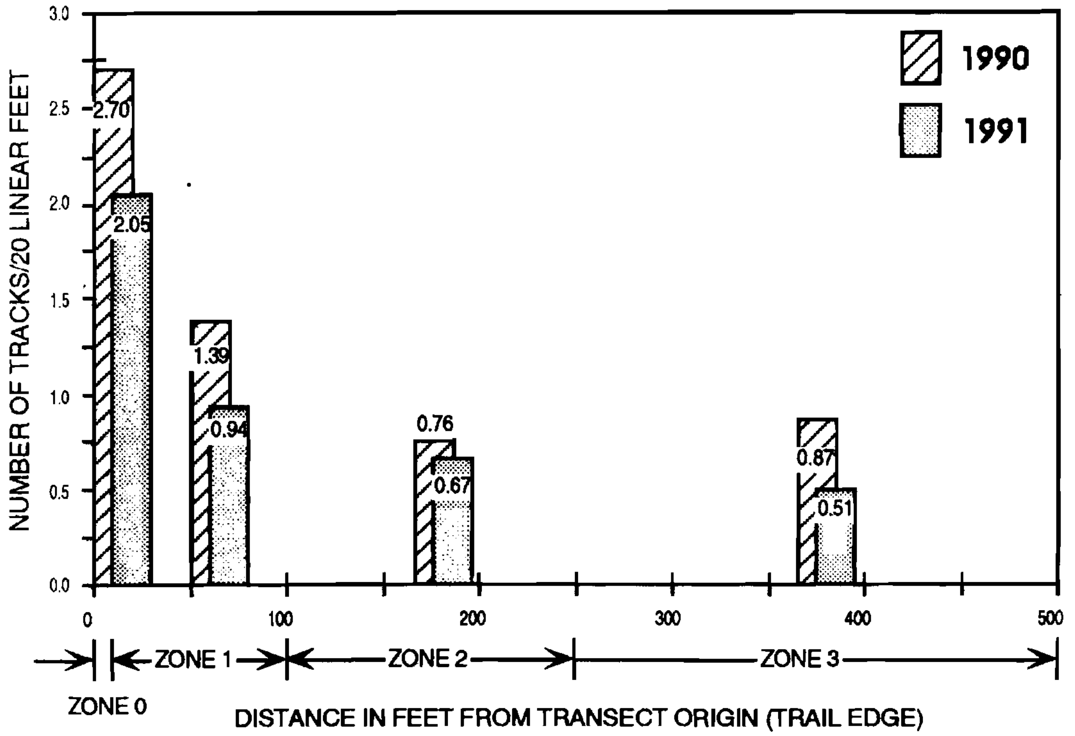


Figure 8. Relationship between levels of unauthorized vehicle use and distance from an open route for 1990 and 1991 in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

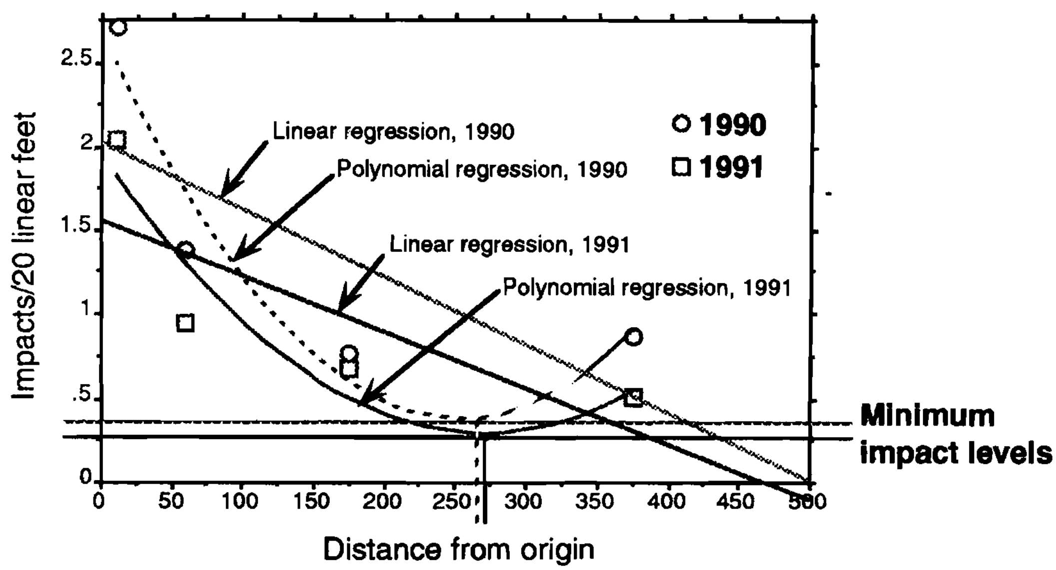


Figure 9. Comparison of 1990 and 1991 regression analysis of transect data in the Rand Mountains and Fremont Valley study area, eastern Kern County, California.

origin (edge of trail) for both 1990 and 1991 data. Thus, a single open trail on the average represents a band of impact 550 ft wide with the open trail in the center.

According to the BLM, a route structure of 150 miles of trails has been established in this area consisting of about 60 square miles of public land. If each trail represents a band of influence 550 ft wide, the 1990 and 1991 data sets reveal a total of 15.6 square miles of degraded desert tortoise habitat, representing 26% of the total area of public land in the Rand Mountains and Fremont Valley.

Comparison of Closed Trails

In 1990, 237 tracks were found on 21 closed routes (mean = 11.3 tracks/closed route). In 1991, 107 tracks were found on 17 closed routes (mean = 6.3 tracks/closed route). Both years, closed routes were raked and rechecked later. However, these data are not comparable from year to year since a month passed in 1990 before rechecking of raked trails and in 1991 only a few days passed before rechecking. These few days in 1991 were during a high use period, the Thanksgiving weekend.

Closed Trails Versus Unmarked Routes

In 1990, 93% of unauthorized trails located while driving open routes were unmarked. In 1991, 99% of unauthorized trails were unmarked. A total of 1479 trails were unmarked while 17 were marked closed. Unmarked trails represent the vast majority of unauthorized trails found in the area.

DISCUSSION AND CONCLUSIONS

Levels of Unauthorized Vehicle Use and Effects on Tortoises and Tortoise Habitat

Bureau of Land Management instructions governing OHV activities are not being followed by many OHV enthusiasts. As a result, significant degradation of tortoise habitat is occurring. Unauthorized activity is continuing at levels inconsistent with the objective of protection of desert tortoise habitat and other natural values.

Unauthorized use is high. From trail and track mapping, an average of 38 unauthorized tracks per linear mile was recorded. A more accurate estimate of unauthorized activity is derived from the data set of 39 transects. On the average, one unauthorized track was encountered every 31 linear feet. Unauthorized impacts over a major OHV holiday weekend (Thanksgiving) are also high. We found 195 new tracks on closed routes (N = 17) and 200 new tracks on a sample of unmarked trails (N = 20) over a 6-day period. This represents an intensive, negative impact to the habitat of a federally listed species.

Again in 1991, a relationship was established between open routes and unauthorized OHV activity. Impacts are highest close to the open route and gradually decline as the distance from the open route is increased. At the 250 to 500 ft interval from the open route, unauthorized activity was observed at a rate of one impact every 40 feet. This suggests that the presence of an open route may induce negative impacts for substantial distances from the route edge and that these impacts are difficult to control. The 1990 and 1991 data sets project the band of impact to be about 550 feet wide. Using the band of influence concept, we predict that the existence of open routes in this area has resulted in degradation about 15.6 square miles of 60 square miles of desert tortoise habitat on public land. These effects are cumulative and dependent on the historical and future use levels in the area. Thus, the current level of habitat degradation is a function of the previous use levels. The degradation is greater than it was in the past and is less than it will be in the future assuming that current levels of use continue.

Marking routes as "closed" is an ineffective measure against trespassing. A comparison of closed routes (N = 17) and a sample of unmarked routes (N = 20) showed no significant difference in the number of tracks observed over Thanksgiving weekend. Both signed, closed routes and unmarked routes were used equally.

Study Recommendations

We have pointed out the limitations of comparing 1990 and 1991 data, because the study techniques are static and completed at essentially a single point in time. The data gathered at this point in time are dependent on events occurring prior to the study. If the BLM wishes to gather data more frequently, a dynamic monitoring program should be developed. A dynamic monitoring program can be simply implemented by establishing monitoring stations at randomly selected locations in the study area. Locations should be selected that include: 1) signed, closed trails and a sample of unmarked trails for raking and rechecking; 2) a sample of transect sites; and 3) a specific set of short routes that can be driven for recording unauthorized tracks and trails. These locations could be checked on a periodic basis, perhaps bimonthly. Some checks should be associated with major holidays, whereas others could be focused on low use periods.

Initiation of such a monitoring program would provide the BLM with invaluable data on unauthorized use levels in the area. These data could be used to assist in the development of management policy most beneficial to the area.

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Results of Seven Desert Tortoise Plot Surveys and One Mortality Survey in Arizona, Fall 1991

Scott Hart, A. Peter Woodman, Steve Boland, Scott Bailey, Paul Frank, Gilbert Goodlett, Dave Silverman, Dan Taylor, Mike Walker and Peggy Wood

Seven one-square-mile study plots were surveyed for desert tortoises from August through October 1991. Four 60-day surveys (West Silverbell Mountains, San Pedro Wash, Wickenburg Mountains, and Hualapai Foothills) were funded by the Bureau of Land Management and two 60-day (Granite Hills, Little Shipp Wash) and one 36-day survey (Eagletail Mountains) were funded by Arizona Game and Fish Department. Topography, temperature regime, soil and boulder composition, vegetation, sheltersite type, slope orientation preferences, and population demographics varied considerably among plots. Numbers of tortoises found ranged from 15 at Wickenburg to 82 at Little Shipp Wash. The male:female sex ratio was significantly skewed towards females at the Silverbells (0.51:1), was skewed towards females at four others (range 0.56:1 to 0.89:1), and towards males at the Hualapais (1.46:1) and Wickenburg (2.00:1). Adult and subadult tortoises were significantly larger on the four northern plots. No tortoises under 216 mm MCL were found at Wickenburg, none under 170 mm at San Pedro, and only one between 140 and 240 mm at the Eagletails. The cause and implications of these findings are unknown. At San Pedro and Hualapai Foothills, a high number of adult tortoise deaths have occurred in the past four years (11 and seven, respectively) and their high carcass:live tortoise ratios (0.26:1 and 0.21:1) indicate potential population declines. No signs of URTD were found. Studies in three years (two successive) at Little Shipp, Granite Hills, and the Eagletails indicate that these populations appear stable. Findings of a mortality survey throughout the Maricopa Mountains indicate that the high mortality, discovered during the 1990 plot survey, occurred throughout the range.

Building Conservation Partnerships to Conserve Turtles

Michael W. Klemens

There is tremendous competition among various organizations and programs for each available conservation dollar. Funding agencies wish to receive the maximum return in terms of concrete conservation action and positive public relations (i.e. "bang for the buck"). In order to generate both the support and funds needed for turtle conservation, it is necessary to form broad coalitions among a wide variety of government agencies, non-government agencies, corporations, foundations, academic institutions, and individuals. The Turtle Recovery Program, which is the implementation arm of the IUCN Action Plan for tortoise and freshwater turtle conservation, provides a case study of this approach. The Turtle Recovery Program places special emphasis on building equitable collaborative partnerships between western institutions and their equivalents in the developing world.

Distribution of Desert Tortoise Sign Adjacent to Highway 395, San Bernardino County, California

Edward L. LaRue, Jr.

Abstract. Between November 1991 and January 1992, desert tortoise (*Gopherus agassizii*) sign, including scat, burrows, and carcasses were observed on 17 study plots along the eastern side of Highway 395 between Adelanto and Red Mountain, southwestern San Bernardino County, California. Each plot was 305 m (1000 ft) perpendicular to Highway 395 and 174 m (570 ft) parallel to it, or about 5.3 ha (13.1 ac). Plots were surveyed by transects placed at 9 m (30 ft) intervals, for 20 transects per plot, effecting 100% coverage of each plot. When found, the distance between the tortoise sign and Highway 395 was recorded. Disturbances observed on each of the surveyed transects were also recorded.

Cumulatively, on the 17 plots, there were 142 tortoise scat, 38 burrows, and 20 carcasses found. Spatial distribution of scat and burrows indicated that the numbers of scat and burrows steadily increased with increasing distance from the highway. The correlation coefficient for the number of scat and burrows relative to the distance from the highway was $r = 0.92$, $P < 0.0005$ and $r = 0.89$, $P < 0.0005$, respectively, indicating a linear relationship between the amount of sign and the distance from the highway. The correlation coefficient for carcasses ($r = 0.56$, $P = 0.025$) indicated a less predictable relationship between the number of carcasses and the distance from the road. Four of 38 burrows (10.5%) and 15 of 142 scat (10.6%) were found within 91 m (300 ft) of the highway, whereas 12 of 20 carcasses (60%) were found within the same 91 m interval.

Disturbances and their frequencies of occurrence on the 340 transects surveyed on the 17 plots included off-highway vehicle traffic (98% occurrence; i.e. off-highway vehicle traffic was detected on 332 of 340 transects); presence of sheep scat (81%); canine sign, including tracks, digs, and scat (65%); established dirt roads (51%); human foot prints (18%); Caltrans erosion ditches (16%); horse sign, including tracks or scat (10%); trash dumping (7%); rifle shells (3%); shotgun shells (3%); and miscellaneous ground disturbances (1%).

INTRODUCTION

Few studies have been performed to determine the impacts of established roads and highways on adjacent tortoise populations. In 1977, Nicholson surveyed for tortoise sign along 10 paved roads in the western Mojave Desert that included Interstates 15 and 40, Highways 395 and 58, and secondary roads, including Shadow Mountain Road and Barstow Road (Nicholson 1978). Her study indicated, generally, that there was an increase in tortoise sign with increasing distance from the road. She concluded that paved roads and vehicular traffic have a detrimental effect on tortoise populations within 1 km (3,281 ft) of a road. She identified two potential impacts, including mortality resulting from vehicular collision and removal of tortoises by passing motorists, as adversely affecting tortoises. The Bureau of Land Management (BLM) has found 48 tortoise carcasses along Highway 58 between Kramer Junction and Barstow (BLM 1991).

The BLM is presently conducting a study along Highway 58 that is designed to determine the effects of fencing on tortoise populations in adjacent areas (Boarman 1993). The study's preliminary findings indicate that, prior to fencing the highway, numbers of tortoise sign increase with increasing distance from the highway. In the Rand Mountain-Fremont Valley area, Goodlett has found that there is a "band of influence" approximately 275 ft wide (84 m) adjacent to unimproved roads where off-highway vehicle traffic is more common than in areas farther out than 275 ft (Goodlett and Goodlett 1991).

The Nicholson and BLM studies are similar to one another because they surveyed for tortoise sign at distinct intervals adjacent to paved roads. BLM's study, for example, surveyed for tortoises at the fence line, which is within 61 m (200 ft) of the highway, at 402 m (1/4 mi), 805 m (1/2 mi), and 1610 m (1.0 mi) distant from Highway 58. The present study is different from these two studies in that a continuous area, beginning at the shoulder of the highway and ending 305 m (1,000 ft) out from the road, is surveyed, so that all scat, burrows, and carcasses found within that area are located relative to the highway. A primary assumption of this study is that tortoises use of an area can be determined by the presence of their sign (i.e., scat and burrows), and that tortoises are either absent or not commonly found in areas where their sign is not found. This assumption is fundamental to United States Fish and Wildlife Service (USFWS) tortoise survey protocol, which is designed to determine the presence or absence of tortoises in an area, and makes the assumption that they are absent from the area if sign is not found (USFWS 1992).

Previous tortoise surveys performed by the author where tortoise sign were found (Tierra Madre Consultants 1991a, 1991b, 1992) seem to indicate that few, if any, tortoise scat and burrows are found within approximately 91 m (300 ft) of well-traveled highways. In one case in Helendale, California, (Tierra Madre Consultants 1991a), National Trails Highway (old State Route 66) passes through the middle of an 80-acre parcel, whose southeast corner coincides with the northwest corner of the adjacent 80-acre parcel (Fig. 1). The 80-acre parcels were surveyed on consecutive days, and the spatial distribution of tortoise sign found on those parcels is shown in Fig. 1. Two collapsed, inactive burrows were found 43 m (140 ft) and 104 m (340 ft) from the highway, and the nearest intact, active burrow was approximately 213 m (699 ft) south of the highway. Tortoise burrows found on the adjacent 80-acre parcel, which was not bisected by the highway, were randomly distributed throughout that parcel, had more intact tortoise burrows (82 versus 9), more tortoises (16 versus 4), and more tortoise scat (214 versus 82). Surveys, such as this one, seem to indicate that tortoises are impacted by well-traveled highways.

METHODS

<u>Study plots</u>. The 17 study plots were chosen along the eastern side of Highway 395 because electrical power lines and associated maintenance roads occur on the western side of the same stretch of highway. The plots were chosen to avoid unimproved roads, residences, and dry washes, which may affect the spatial distribution of tortoise sign (Baxter 1988; Tierra Madre Consultants 1991c). The locations of the 17 plots are shown in Figure

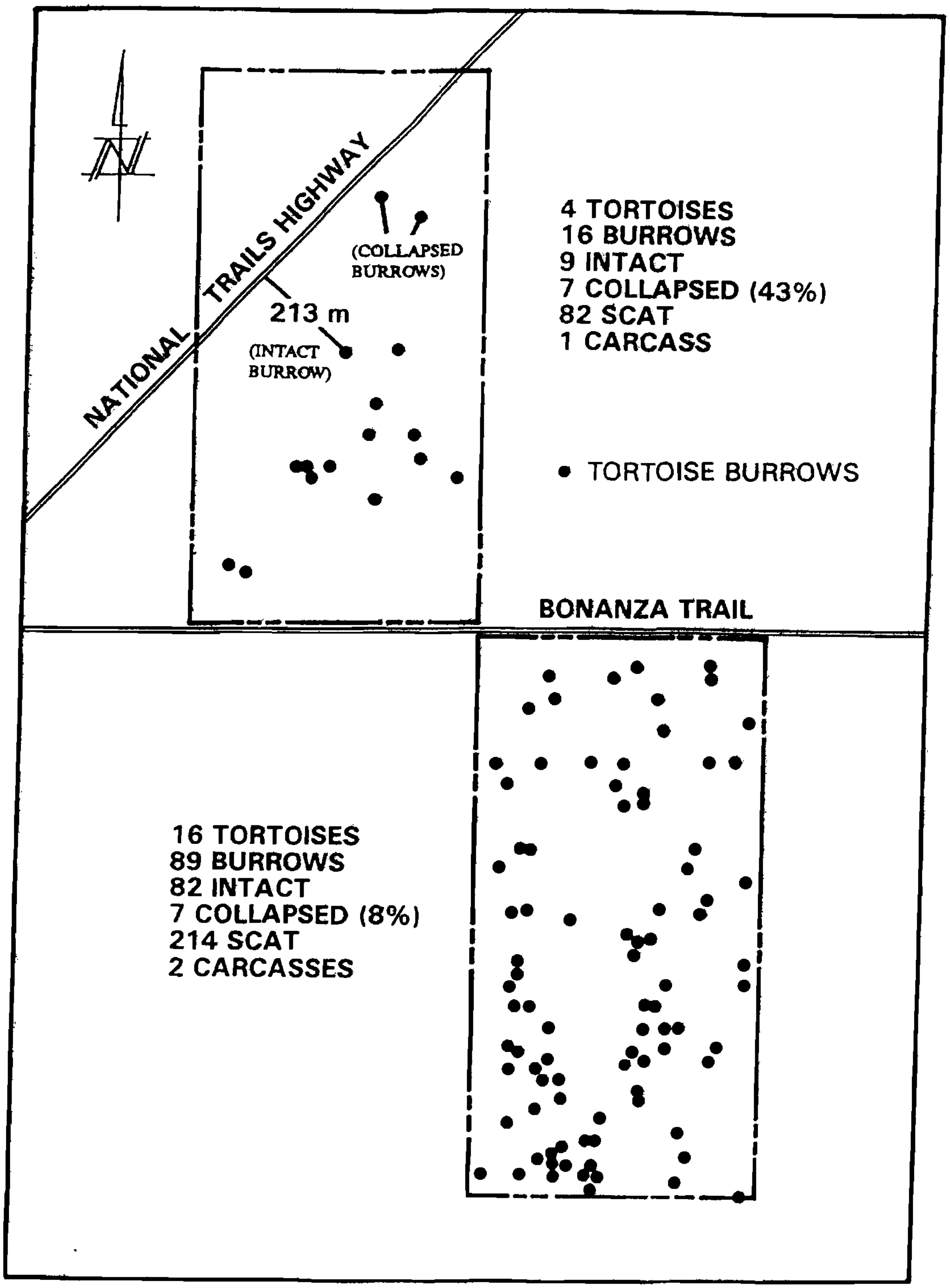

Figure 1. Spatial distribution of desert tortoise sign found on the two 80-acre parcels near Helendale, California.

2. Plots were not chosen south of #1 in the vicinity of Adelanto, north of #17 in the Randsburg/Johannesburg area, or between #11 and #12 in the Kramer Junction area because human disturbances not associated with the highway (residences, businesses, mining activities, etc.) are relatively more common in those areas and may have affected the distribution of tortoise sign.

The 17 plots were surveyed between 22 November 1991 and 12 January 1992. For each plot, 20 transects, spaced at 9-m (30-ft) intervals, perpendicular to Highway 395, beginning at the vegetated side of the highway [approximately 3.6 m (12 ft) to 4.6 m (15 ft) east of the pavement], and extending 305 m (1,000 ft) to the east, were surveyed. The lengths of transects and the distances between transects were paced. Every third or fourth transect was paced to ensure that the survey marker [a 3 m (10 ft) PVC pole] remained 305 m from the roadside. The plots were surveyed for an average of 1.96 hours (range 1.66 hours to 2.30 hours). A constant pace during each transect was sought, and the amount of tortoise sign present may have slowed the total time for some plots (i.e. data recordation slowed the pace).

<u>Tortoise sign</u>. The distance between each tortoise scat, burrow, and carcass and Highway 395 was recorded. Additionally, the relative age of the scat ("this year" versus "not this year") and age class (based on the relative size of the scat: juvenile, subadult, adult) was recorded. Width, height, depth, and general condition of each burrow ("poor," "fair," "good," "excellent" as per BLM criteria) were determined and recorded. Each accumulation of tortoise bones was recorded as one tortoise carcass. Once found, the area around the initial find was searched for additional bones. Bones found on other transects, or on the same transect, that were not found with the initial search were recorded as a second carcass.

<u>Statistics</u>. Bill Boarman, Hal Avery, and Jeff Lovich, of the BLM, indicated that 17 plots and the amount of tortoise sign found was sufficient to perform statistical analysis (pers. comm., February 1992). They also made recommendations for those analyses. A regression analysis was performed on the data using Lotus 1-2-3 (Lotus 1990). The independent variable (x) was the amount of tortoise sign found at a given distance from the road, and the dependent variable (y) was the distance from the road at which the sign were found. The distance from the highway at which tortoise sign were found was regressed on the amount of tortoise sign, which resulted in the regression coefficients and equations given in the results section of this report.

<u>Disturbances</u>. Detectable disturbances were recorded for each transect, yielding a "percent occurrence" for each of 13 disturbances observed during this study. The disturbances included off-highway vehicle traffic (OHV); evidence of sheep grazing, usually scat; evidence of domestic canine use, usually tracks and digs, occasionally scat; presence of unimproved dirt roads; human foot traffic; Caltrans erosion ditches; evidence of horseback riding, usually tracks, occasionally scat; trash dumping, not including windblown litter; common ravens observed; rifle shells present; shotgun shells present; area burned; and miscellaneous ground disturbances, such as excavated pits or trenches. Disturbances were not recorded to distinguish between a single occurrence and many occurrences on a given transect; e.g. a single rifle shell and 40 rifle shells on two different transects were both recorded as "present."

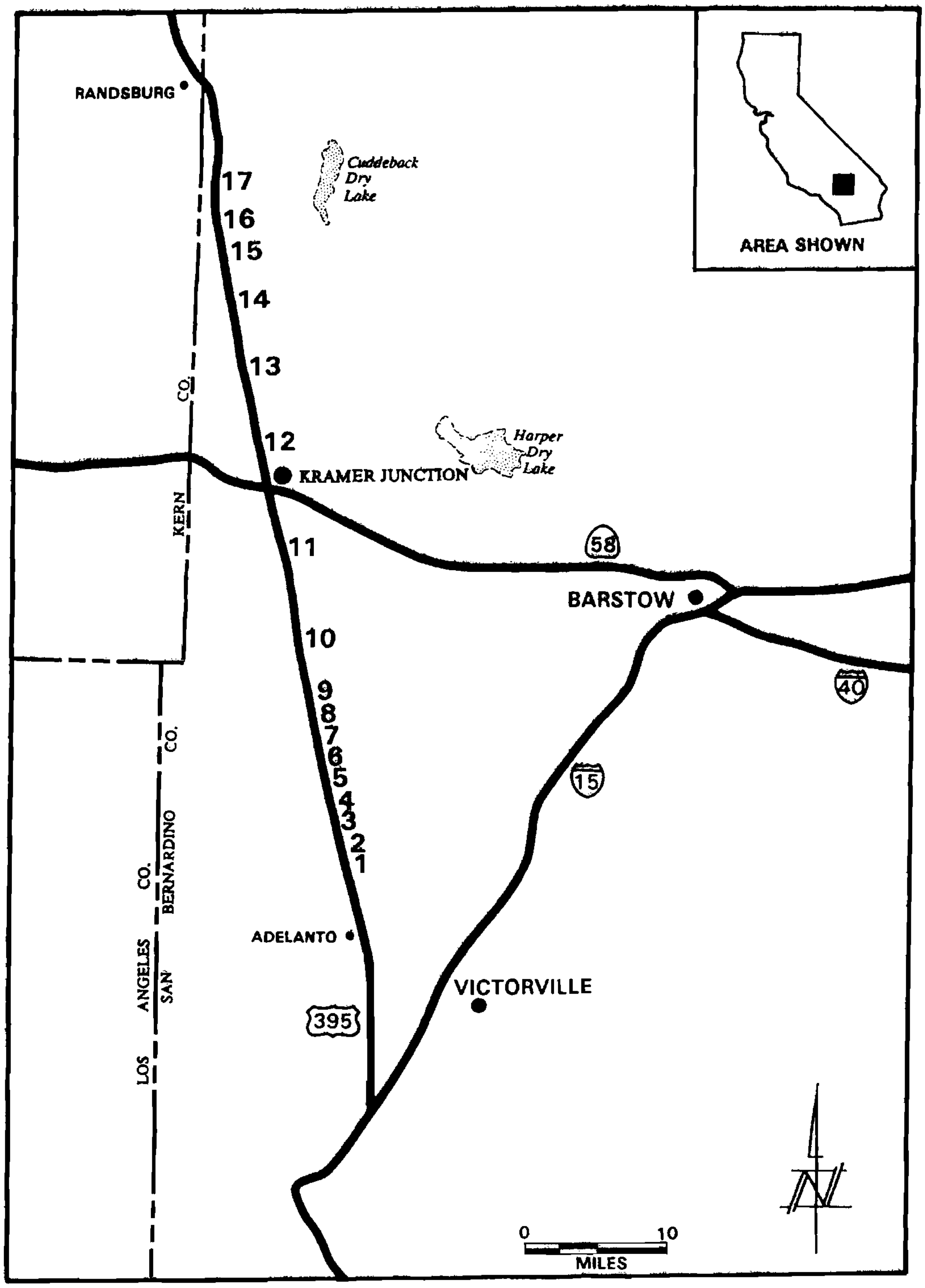

Figure 2. Locations of 17 study plots along the eastern shoulder of State Route 395.

RESULTS

Tortoise sign. Cumulatively, 142 tortoise scat, 38 burrows, and 20 carcasses were observed on the 340 transects surveyed. The most tortoise sign (16 scat, 5 burrows, and 2 carcasses) was observed on the plot 2.9 miles north of Shadow Mountain Road (Fig. 3, #8), although 16 scat, 2 burrows, and 4 carcasses were found near the north end of the study area (Fig. 3, #15), and 15 scat, 5 burrows, and 2 carcasses were found near the south end of the study area (Fig. 3, #2). The plot 3.3 miles north of Kramer Junction (Fig. 3, #12) yielded the fewest amount of tortoise sign, 1 scat and 1 carcass. Tortoise carcasses were found on 8 of 11 plots (73%) south of Kramer Junction, and on 2 of 6 plots (33%) north of Kramer Junction.

Prior to this study, I suspected that little or no tortoise sign occurs within about 90 m (300 ft) of a well-traveled highway, such as Highway 395. The null hypothesis was that tortoise sign is found randomly throughout the area. The experimental hypothesis was that the tortoise sign is not randomly distributed, but that the highway would have some negative impact on the numbers of tortoises immediately adjacent to the highway.

The spatial distribution of the tortoise sign is shown in Fig. 4. Fifteen (15) of 142 scat (10.6%) and 4 of 38 burrows (10.5%) were found within 91 m (300 ft) of the highway, whereas 12 of 20 carcasses (60.0%) were found within the same area. One of 38 burrows (2.6%) and three of 142 scat (2.1%) were found within 61 m (200 ft) of the highway, whereas 11 of 20 carcasses (55.0%) were found within the same 61 m interval. Two of 142 scat (1.4%) and no burrows were found within 30.5 m (100 ft) of the highway, and 6 of 20 carcasses (30.0%) were found in that area. Similar numbers of scat and burrows were found within 91 m (10.6% of the scat and 10.5% of the burrows) and 61 m (2.6% of the scat and 2.1% of the burrows) of the highway.

The four burrows found within 91 m (300 ft) of the highway were intact and apparently active: two of them "good" and two of them "excellent." Two of these four burrows were on the same plot, and, based on the sizes of the burrows, belonged to the same tortoise. One of these two burrows was in the side of a Caltrans erosion ditch, which diverts runoff from Highway 395 into adjacent areas. The only two scat found within 30.5 m (100 ft) of the highway were on the same plot and of similar size, and were likely deposited by the same tortoise. These two scat were in the vicinity of a Caltrans erosion ditch, which concentrates water in a small area and may attract tortoises into that area.

The frequency distributions for tortoise scat, burrows, and carcasses relative to the highway are shown in Fig. 5. The graph shows a step-wise increase in the numbers of tortoise scat and burrows as the distance from the highway increases. Most of the carcasses (11 of 20) are found within 60 m (197 ft) of the highway, although there is not an apparent trend between numbers of carcasses and distance from the highway.

Regression analyses were performed to determine if there is a correlation between the amount of sign and the distance from the road at which the sign occurs. The distance from the highway (y) was regressed on numbers of scat (s), burrows (b), scat and burrows combined (s + b), and carcasses (c) found along each transect, resulting in the following equations, coefficients, and significance levels:

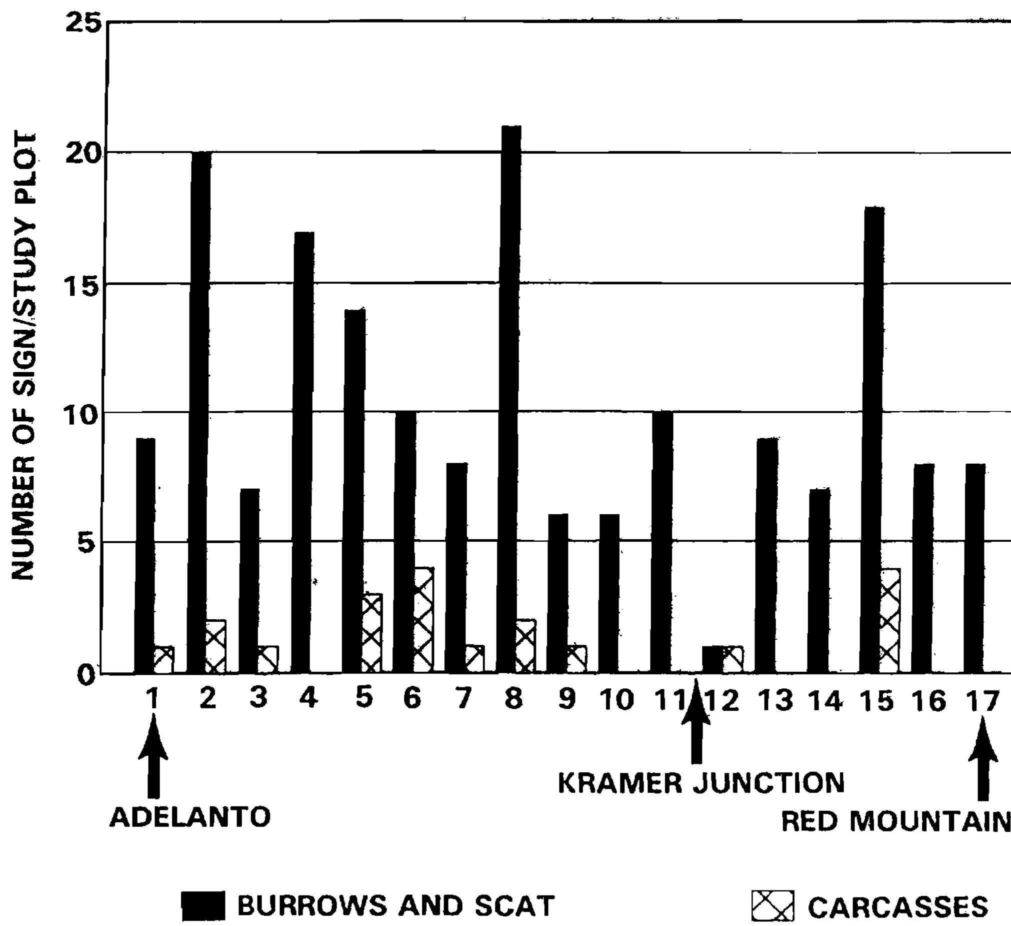

Figure 3. All sign found on the 17 plots, beginning south near Adelanto, and extending north to near Red Mountain, California.

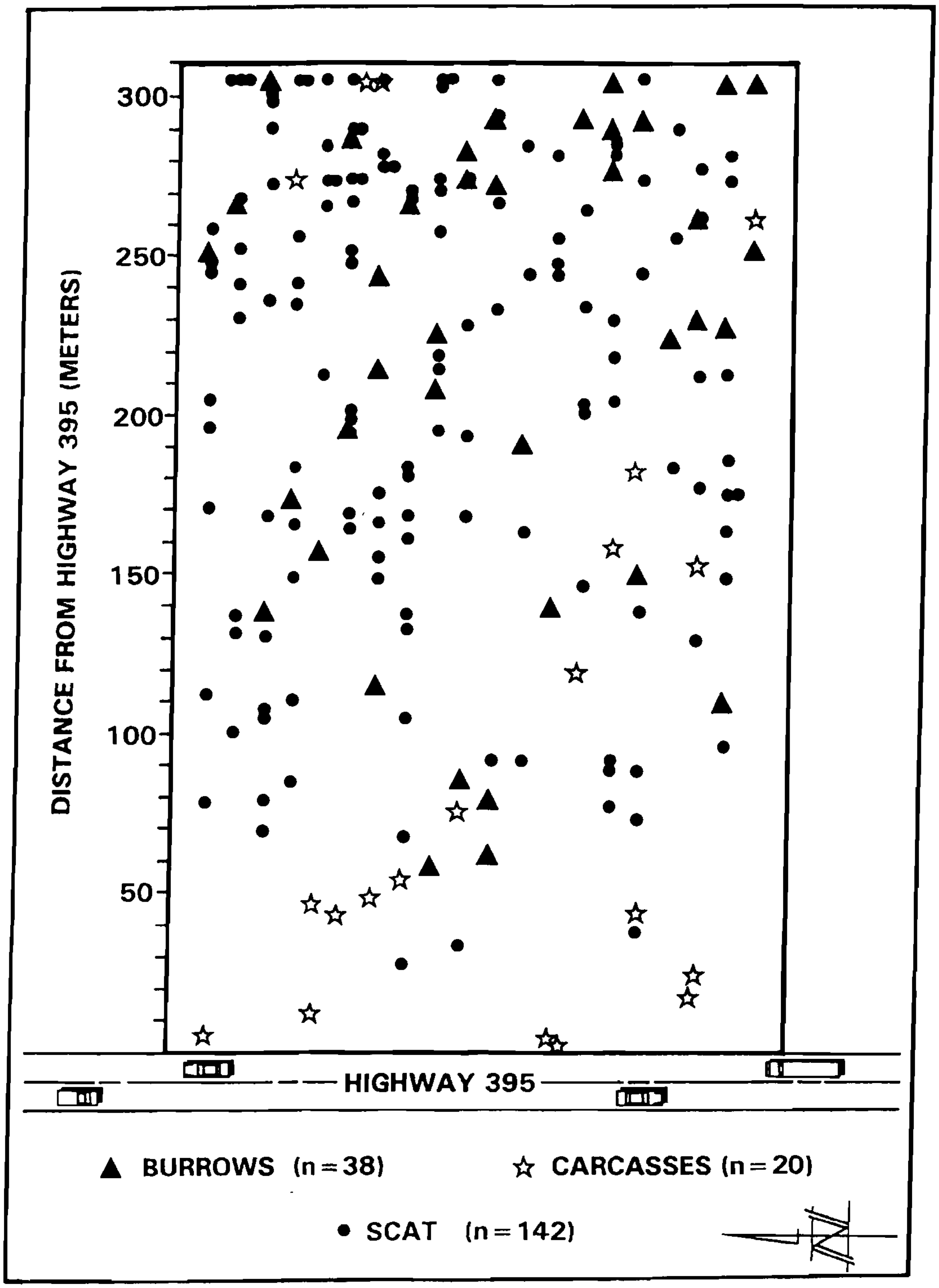

Figure 4. Spatial distribution (scattergram) of desert tortoise sign found on all 17 study plots along State Route 395.

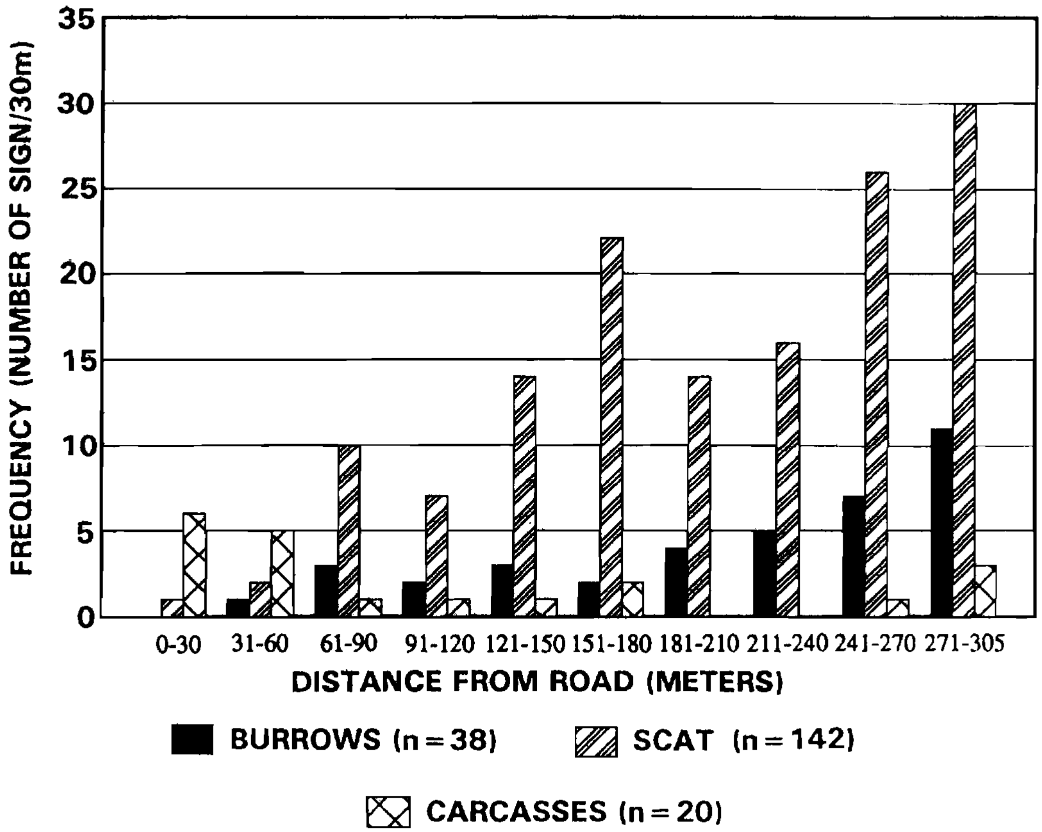

Figure 5. Frequency distribution of all sign found on 17 study plots relative to the distance from the road at which the sign was found.

Independent variable	Regression equation	Regression coefficient
Scat	$y = 10.0s + 41.3$	$r = 0.92, P < 0.0005$
Burrows	$y = 25.4b + 71.5$	$r = 0.89, P < 0.0005$
Scat and burrows	$y = 5.7s + 14.6b + 41.5$	$r = 0.94, P < 0.0005$
Carcasses	$y = -24.9c + 217.7$	$r = 0.56, P = 0.025$

The regression coefficients and level of significance were sufficiently high to indicate that there is a predictable relationship between the number of "living tortoise sign" (scat and burrows) and the distance from the road at which "x" amount of sign would be expected. For example, using the regression equation for scat, one would expect to find about 20 scat at about 241 m (790 ft) from the highway [241.3 m = 10.0(20) + 41.3], and only one scat 51 m (168 ft) from the highway [51.3 = 10.0(1) + 41.3]. For scat, burrows, and scat and burrows combined, these analyses indicate that there is a linear relationship between the amount of living tortoise sign and the distance from the road at which it occurs: the farther one goes from the road, out to 305 m, the more living tortoise sign one encounters.

During March 1991, the BLM removed 33 tortoise carcasses from alongside Highway 395, beginning seven miles south of Kramer Junction and extending 15 miles south of there (to 22 miles south of Kramer Junction) (Boarman et al. in press). Therefore, eight months prior to the present study, the BLM had removed all carcasses from the shoulder of 395 on nine of 11 plots occurring south of Kramer Junction (Figure 3, #2 through #10). Therefore, even more carcasses occurred along the shoulder of Highway 395, south of Kramer Junction, than were found during this study. Boarman said that 13 new carcasses were removed from the same stretch of Highway 395 15 months after the initial removal, indicating that 13 roadkills had occurred during those 15 months (Boarman et al. 1993).

The correlation coefficient between the numbers of carcasses and the distance from the road for this study was $r = 0.56$, with a significance level of $P = 0.025$. Therefore, there does not appear to be a linear relationship between the number of carcasses and the distance from the road at which they occur. The relationship would be even less linear if the BLM had not removed the carcasses; i.e., more carcasses would be found along the shoulder of the highway than were found during the present study.

Caltrans indicated that the Average Daily Trips (ADT) for 24 hours along Highway 395 south of Randsburg was 3,600 in 1991. The ADT at the northern end of Adelanto was 10,000 and the ADT at Kramer Junction was 7,000. This indicates that the stretch of highway between Kramer Junction and Randsburg is used about half as often as the stretch between Kramer Junction and Adelanto. Tortoise carcasses were found on 8 of 11 plots (72.7%) south of Kramer Junction, and on two of six plots (33.0%) north of Kramer Junction. More tortoises may have been killed south of Kramer Junction because of more traffic, or because more tortoises occur in those areas and there are consequently more carcasses, regardless of vehicle collisions.

Disturbances. The prevalence of disturbances throughout the 17 plots is shown in Table 1. No single disturbance was observed on all transects, although four of them: OHV traffic, sheep grazing, canine sign, and dirt roads were observed on more than half of the transects. Even though dirt roads were consciously avoided during the present study, they were still present on more than half (51%) of the surveyed transects. This is because the dirt road was not observed until after the plot survey was begun. In one case, a plot was abandoned when the first tortoise sign observed was a crushed tortoise carcass several meters from a dirt road. No similar observations were made for the 17 plots that are included in this study.

Table 1 shows the prevalence of disturbances on the two plots (Fig. 3, #2 and #8) where the most scat and burrows were observed (Most sign), the two plots (Fig. 3, #10 and #12) where the least number of scat and burrows were observed (Least sign), and the prevalence of disturbances on all 17 plots (All plots). Table1:

	Percent Occurrence		
Disturbance	Most Sign	Least Sign	All Plots
OHV traffic	100%	100%	98%
Sheep grazing	50%	90%	81%
Dirt roads	23%	70%	51%
Canine sign	75%	58%	65%
Caltrans erosion ditch	30%	30%	16%
Human foot traffic	20%	25%	18%
Miscellaneous ground disturbance	0%	33%	1%
Common ravens observed	3%	13%	7%
Horse sign	3%	13%	10%
Trash Dumping	10%	5%	7%
Rifle shells	5%	8%	3%
Area burned	0%	0%	1%
Shotgun shells	5%	3%	3%

Sheep grazing, dirt roads, and miscellaneous ground disturbance (an old railroad bed at Site #12) are much more prevalent on the plots where the least amount of tortoise sign were observed. Human foot traffic, common raven observations, horseback riding, and rifle shells are slightly more prevalent on those two plots. Domestic dog sign, trash dumping, and shotgun shells are somewhat more prevalent on the two plots where the most tortoise sign were observed.

DISCUSSION

Desert tortoise spatial distribution. When surveys are performed at distinct intervals adjacent to a given roadway, the density of tortoise sign decreases as one approaches that roadway (Nicholson 1977; BLM, in press). The present study indicates that within 305 m of Highway 395, there is a predictable decrease in the amount of tortoise sign as one approaches the highway, which implies that the highway is negatively affecting tortoises immediately adjacent to it. This study found evidence of only one living tortoise within 30.5 m (100 ft) of the highway. Tortoises, as evidenced by the locations of their scat and burrows, occur within 305 m of Highway 395, but they are more common away from the highway than immediately adjacent to it. If the assumption is correct that tortoises only occur in areas where tortoise sign is found, then tortoises may seldom be found within 30.5 m (100 ft) of the highway, and Highway 395 may serve as a barrier to tortoises occurring to the east and west.

During the 17th Annual Desert Tortoise Council Symposium, Dr. Peter Brussard said that one of the eight management areas identified in the Recovery Plan for the desert tortoise (the Fremont/Kramer Management Area) is proposed to occur along Highway 395 in the area of this study. Highway 395 bisects the proposed Fremont/Kramer Management Area. If tortoises do not often approach Highway 395 there is a limited mix of genes between tortoises occurring east and west of the highway. If this assumption is true, the Fremont/Kramer Management Area may actually consist of two distinct populations, effectively separated by Highway 395. The BLM Highway 58 study and others may show how often tortoises approach well-traveled roads. These studies may either support the conclusion that the highway effectively fragments a given population into two separate populations, or may refute that idea and show that there is a mix of genes between tortoises occurring on either side of a given highway.

If no tortoises were killed by vehicles on Highway 395, one would expect to find a random distribution of carcasses between the highway and 305 m east of it. Tortoises do occasionally approach Highway 395 as evidenced by the number of crushed carcasses found during this study. The BLM has shown that many tortoises have been killed by vehicular collision along Highway 58 (BLM 1991). Boarman (1993) has shown that as many as 13 tortoises may have been killed along Highway 395 between March, 1991 and June, 1992. Many of the tortoise carcasses found along Highway 395 during the present study had been crushed, as evidenced by their unnatural disarticulation. I believe that more carcasses occur between 0 and 61 m (200 ft) of the highway (55% of those found) than between 61 m and 305 m because the tortoises were trying to cross the road and were killed by vehicles. Tortoise carcasses persist in nature for many years (Kristin Berry, pers. comm.), and those found between 61 m and 305 m on the study plots likely include mostly tortoises that have died naturally and a few that have been killed by vehicular collisions.

Effects of disturbances on tortoise densities. Within the 17 study areas, it appears that certain disturbances, such as foot traffic, horseback riding, canine sign, and certainly Caltrans erosion ditches are more prevalent immediately adjacent to Highway 395 than farther out from the highway. The highway serves as a focal point for people walking through the desert or those traveling by horseback. Motorcycles and all-terrain vehicles may ride parallel to the highway on established and unestablished routes. Vehicles stop on the shoulder of the highway and passengers leave their cars, often with their pets, to go into adjacent desert areas. Dumping is most often associated with unimproved roads, which in turn are more common along major highways than in open, untraveled desert areas. Ravens are known to congregate along highways, using distribution towers for nesting, and may travel in straight lines alongside a highway (Knight and Kawashima, in press). There are unknown variables, such as heavy vehicle vibrations in adjacent areas, that may affect the prevalence of tortoise sign adjacent to Highway 395. Any one or all of these disturbances may result in fewer tortoises immediately adjacent to Highway 395.

Figure 6 shows the results of the disturbance analysis that was conducted for the two 80-acre parcels in Helendale, California. Five of the 10 disturbances observed on the 80-acre parcel bisected by National Trails Highway were observed on 100% of the transects surveyed; only sheep grazing and OHV tracks were observed on all transects on the southern parcel. Horse sign, dog sign, foot traffic, and trash dumping appeared to be associated with National Trails Highway, and were more prevalent on the northern parcel than the southern one. Figure 1 shows that there is an obvious difference in tortoise density between these two parcels. I believe that the difference is due to the presence of the well-traveled highway through the northern parcel. Human disturbances and accessibility associated with the highway have reduced the prevalence of tortoises on the northern parcel, relative to the southern one, and have resulted in fewer tortoise sign and more collapsed burrows on the northern parcel.

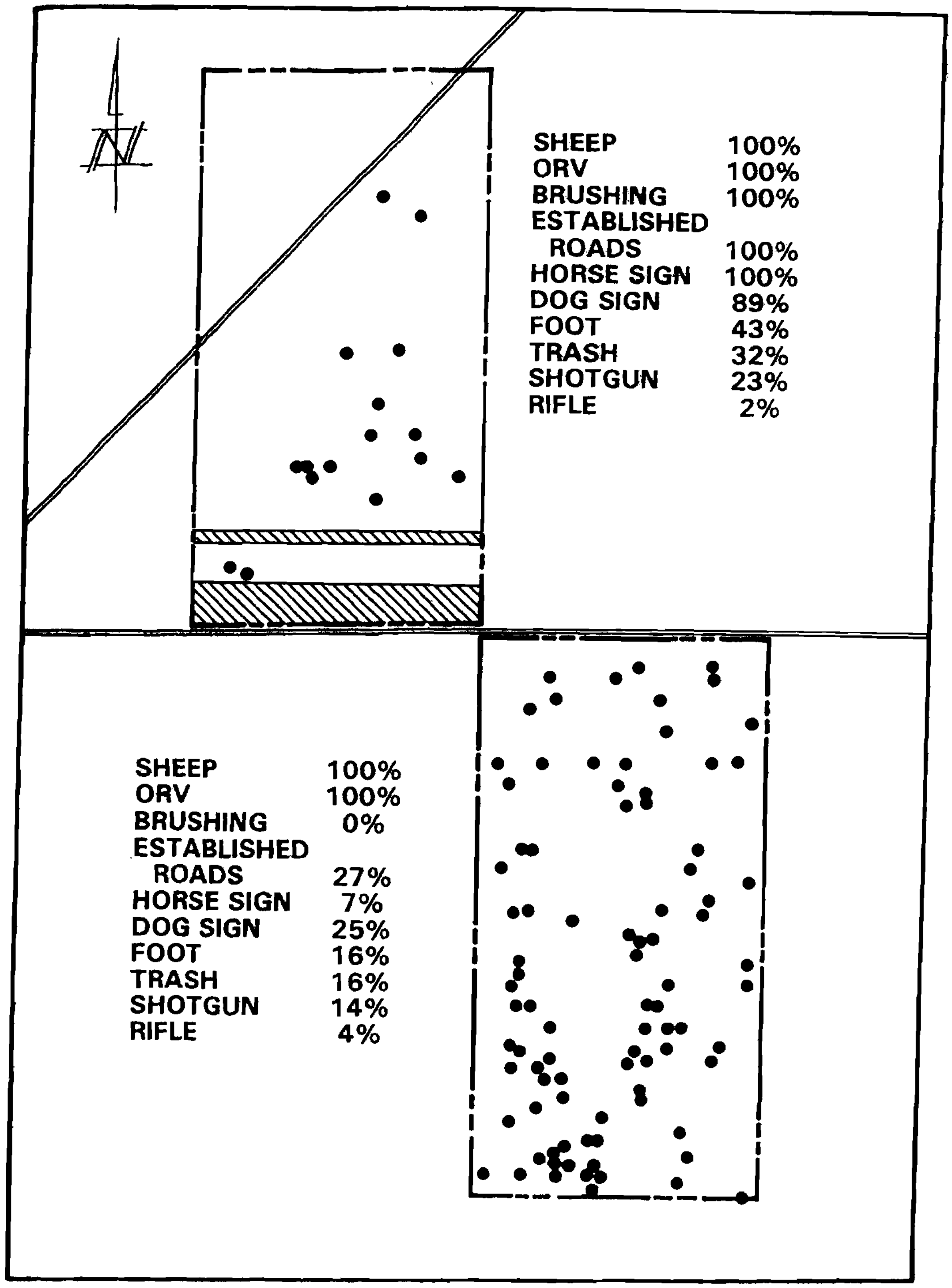

Figure 6. Prevalence of disturbances on the two 80-acre parcels near Helendale, California.

There have long been plans to widen Highway 395, and tortoise-proof fences may be constructed along either side of the widened highway. I suspect that the prevalence of disturbances adjacent to the widened highway will decrease if tortoise-proof fences are installed. Human encroachment into adjacent areas, particularly OHV traffic, human foot traffic, and canine sign, would likely be reduced if a tortoise-proof fence is attached to a barbed wire fence. It is strongly recommended that Caltrans conduct baseline disturbance analyses so that disturbances prior to fencing and after fencing can be compared. Caltrans should also determine if the installation of the tortoise-proof fence encourages tortoises to come closer to the road. Those tortoises that are trying to cross the road would likely wander the fenceline until they were given access to the other side by means of a culvert or other underpass structure. Still, if disturbances are minimized in areas adjacent to the highway, and those disturbances were responsible for the lesser amount of tortoise sign, then one would expect that more tortoise sign would be found closer to the road after the fences are installed. Data collected during the present study may serve as baseline information to answer such a question, although it is recommended that Caltrans collect more data over a longer period of time so that the effects of tortoise-proof fences can be more accurately determined.

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Natural Recovery Rates of Desert Tortoise Habitat from Anthropogenic Effects

Jeffery E. Lovich

Large areas of desert tortoise habitat in the Mojave and Colorado Deserts have been negatively affected by urbanization, off-highway vehicle use, domestic livestock grazing, agriculture, construction of roads and utility corridors, and military training activities. Secondary contributions to degradation include the proliferation of exotic plant species and a higher frequency of anthropogenic fire. Effects of these impacts include alteration or destruction of macro- and micro-vegetation elements, establishment of disclimax plant communities, destruction of soil stabilizers, soil compaction, erosion, and pollution.

Eight published estimates of recovery times are available for various impacts in the deserts of southern California. Estimates are based on return to pre-disturbance levels of perennial plant biomass, cover, density, community structure, or soil characteristics. Natural recovery rates depend on the nature and severity of the impact but are generally very slow. Recovery to predisturbance plant cover and biomass may take from 50-300 years while complete ecosystem recovery may require over 3,000 years. The recovery of annual plant communities has not been studied. Efforts to restore degraded plant communities have generally experienced poor results due to the harsh conditions of the desert environment. Recent revegetation successes in the Colorado Desert may be applicable to restoration efforts in the Mojave. The success and rate of recovery is enhanced by protecting seedlings from herbivores, using low cost underground irrigation systems, and establishing habitat islands instead of restoring larger areas.

Desert Tortoise Climate and Disease

Charles H. Lowe

Gopherus agassizii is one of several reptilian community associates that live in a diverse array of environments on the Southwest tropical to temperate S - N axis of thornforest - thornscrub - desertscrub. Within the framework of controlling Southwest regional climate, model-predictions on tortoise population health and disease across the species' range are discussed. Local tortoise populations and habitats under recent climate and weather are analyzed, and some current field methods for obtaining desert tortoise health related data sets are discussed.

Conservation of Amphibians and Reptiles

Russell A. Mittermeier and John L. Carr

(The following is an abstract of material presented in two lengthier contributions (Mittermeier et al. 1992; Mittermeier and Carr 1993) that should be consulted for additional details.)

Amphibians and reptiles are of great importance to people for a variety of reasons, and therefore worthy of significant conservation attention. There is a tremendous amount of aesthetic and cultural interest in amphibians and reptiles throughout the world, both historically and currently, in both traditional and modern societies. Various groups of amphibians and reptiles are of significance to science as subjects of research, important to herpetology and to biology generally. Amphibians and reptiles also function in natural ecosystems in an incredible diversity of ways, many of which we are only beginning to comprehend. And lastly, amphibians and reptiles have had and remain of great economic value, with potential for continuing value if the resources are managed wisely.

The greatest threat to amphibian and reptile populations is habitat loss, with the greatest potential and current impact in tropical regions, where it is estimated over 80% of all amphibian and reptile species live. Included with habitat loss are various forms of pollution that degrade natural environments and thereby impinge on amphibians and reptiles. Other threats include hunting for subsistence or commercial purposes, including the pet trade, exotic animal introductions, and indirect causes such as inappropriate levels of tourism and fishing by-catch.

A number of amphibian and reptile extinctions have been recorded over the last several hundred years, but many others will go unrecorded because of the paucity of our knowledge of tropical herpetofaunas in particular. Currently, about 5.5% of amphibian and reptile species are considered threatened or endangered. Reptilian groups that have received special attention by herpetologists interested in conservation, i.e., turtles and crocodilians, are overrepresented among the ranks of the endangered and threatened. Herpetofaunal groups having received little attention, such as snakes and anurans, are probably grossly underrepresented. Conservation organizations, both governmental and nongovernmental, have generally focused little of their financial resources on amphibians and reptiles in proportion to their significance as part of the global vertebrate fauna (approximately 25%).

Priorities in the conservation of amphibians and reptiles fall into several categories, including research, taxonomic and geographic priorities. Research priorities should include taxonomic and systematic studies that enrich our understanding of the diversity and distribution of amphibians and reptiles, especially in the tropics, as well as those aspects of their ecology that are important considerations for management of populations or protected areas. Taxonomic priorities should emphasize species or groups that are known to be endangered or threatened, in addition to taxonomically unique species such as those representing monotypic families. Geographic priorities include an emphasis both on critical ecosystems and particularly diverse countries. A number of tropical ecosystems have been identified that by themselves account for a disproportionate share of the globe's biodiversity, including amphibian and reptile species, and that are presently extremely threatened by human intervention. There are also a number of countries, megadiversity countries, that by themselves account for a large portion of world biodiversity, including many endemic species. The significance of these countries is the amount of biological wealth for which they hold responsibility in the political sense - without attention to these few countries significant biodiversity losses may ensue no matter what may happen in other countries.

Among the conservation actions required are preparation of action plans for either taxonomic groups or geographic areas (e.g. Stuart and Adams 1990; TFTSG, 1991; Thorbjarnarson 1992). Action plans are needed in order to channel limited financial and manpower resources toward priority goals. Among conservation activities required in order to conserve amphibians and reptiles are recovery projects for populations of individual species, establishment and maintenance of protected areas, sustainable use projects, public awareness campaigns, and professional training. Attempts should be made to integrate herpetofaunal conservation efforts into broadly based, ecosystem-level conservation, management, or development projects.

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Effectiveness of Mitigation for Reducing Impacts to Desert Tortoise Along an Interstate Pipeline Route

Thomas E. Olson, Karen Jones, David McCullough and Martin Tuegel

Abstract. The Kern River pipeline was constructed in 1991, covering 393 km of desert tortoise (*Gopherus agassizii*) habitat in Utah, Nevada, and California. Construction occurred during every month of the year. Mitigation measures designed to reduce impacts to tortoises were developed by Dames & Moore in consultation with agency personnel. Major elements of the mitigation plan included preconstruction surveys, monitoring for tortoises during construction, seasonal construction windows, worker education, and limits placed on access and vehicle speed. Some measures were effective and readily implemented, such as the preconstruction surveys and the worker education program. Others were ineffective and difficult to enforce, including low speed limits. Seasonal windows that limited construction to the tortoises' active season appeared to result in substantially more potential encounters between tortoises and equipment. Possible changes in mitigation for future projects include provision for flexibility in monitoring staffing levels, and development of information about the status of tortoises relocated during different seasons of the year.

INTRODUCTION

In 1991, the Kern River Gas Transmission Company (Kern River) natural gas pipeline was constructed. The pipeline route was approximately 1,040 km long from southwestern Wyoming to an intertie point with another natural gas pipeline near Daggett, San Bernardino County, California. From southern Utah to the intertie point, the Kern River pipeline crossed approximately 393 km of desert tortoise habitat (Fig. 1).

Due to a number of potential causes (including loss of habitat, livestock grazing, an upper respiratory tract disease, and increased predation on juveniles by common ravens, *Corvus corax*), apparent declines in tortoise population numbers have been noted (Berry 1985; Woodman and Juarez 1988; FaunaWest Consultants 1989; Luke et al. 1991). In response to those declines, the desert tortoise was designated as a state threatened species in California in 1989. Subsequently, the Mojave population of the tortoise was designated as a federal threatened species (United States Department of the Interior 1990a).

Because the proposed Kern River pipeline route traversed habitat of the desert tortoise, the project proponent (Kern River) completed endangered species consultation with the United States Fish and Wildlife Service (USFWS) and obtained a 2081 incidental take permit from the California Department of Fish and Game (CDFG). Federal and state biological opinions that were developed during the consultation processes included terms and conditions with which Kern River was to comply before, during, and following construction of the pipeline. Among the terms and conditions was an on-site mitigation program focused on preconstruction surveys, as well as monitoring during construction for tortoises (United States Department of the Interior 1990b).

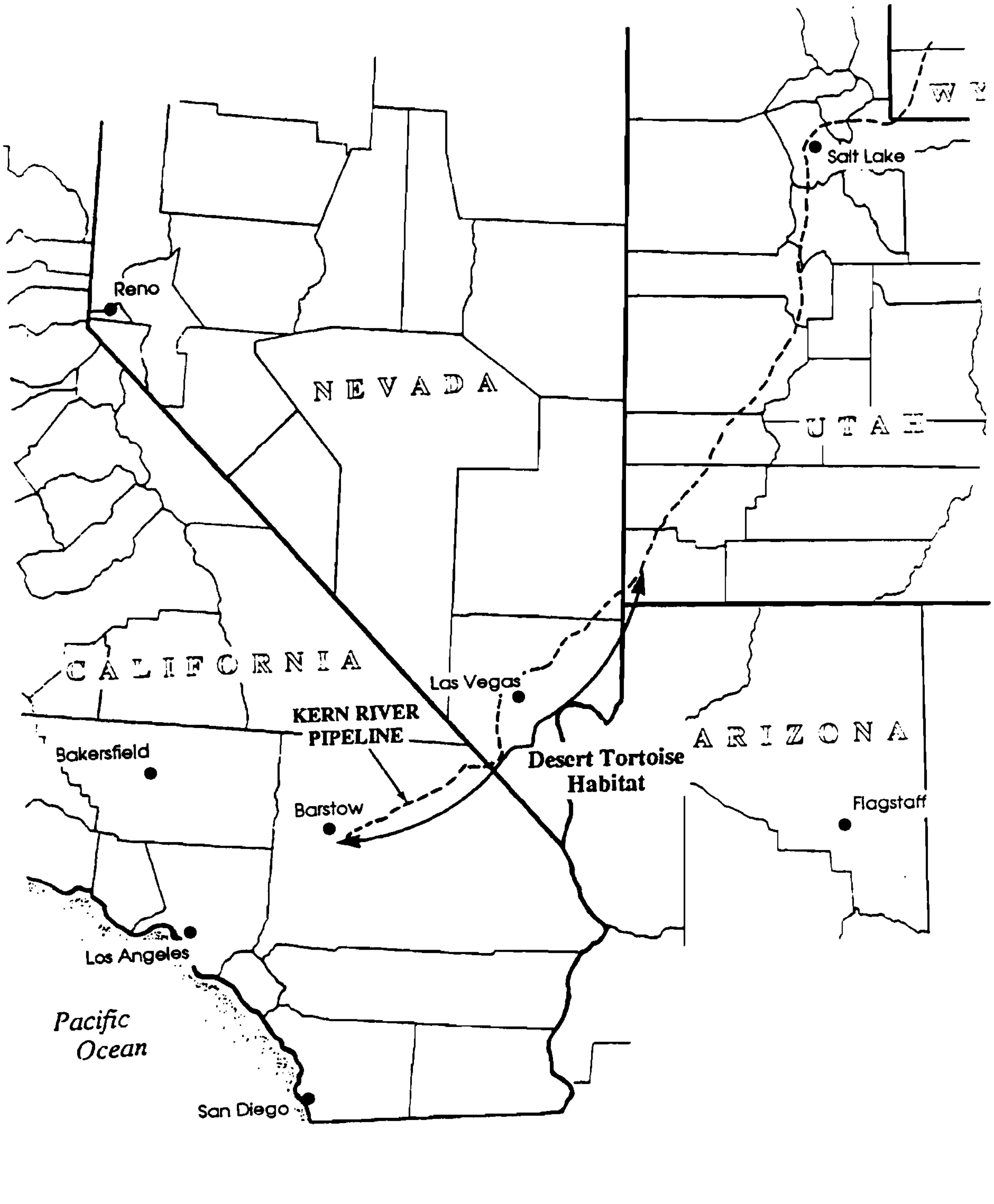

Figure 1. Location of Kern River natural gas pipeline route, Utah, Nevada, and California, 1991.

In this paper we generally discuss the effectiveness of the major components of the on-site mitigation program. Because the Kern River pipeline was one of the first large-scale projects to occur following federal listing of the entire Mojave population of desert tortoise, this information could be useful for the development of future mitigation programs. Because another paper describes survey and monitoring results (such as numbers of tortoises observed, moved, and incidentally taken) (Olson et al., 1992), the discussion within this paper will focus on the effectiveness of mitigation measures in a mostly non-quantitative basis.

Study Area

The Kern River pipeline route traversed 393 km of desert tortoise habitat, including 26 km in Utah, 215 km in Nevada, and 152 km in California. The easternmost extent of tortoise habitat along the pipeline route was in Washington County, southern Utah. The route continued through tortoise habitat to the terminus at an interconnect with another pipeline near Daggett in San Bernardino County, California.

The predominant vegetation type was Mojave creosote bush scrub. Other types included desert saltbush scrub, blackbrush scrub, and Joshua tree woodland. The quality of the habitat traversed along the 393 km of pipeline route varied in quality as indicated by estimated tortoise densities and Bureau of Land Management (BLM) tortoise habitat categories. General ranges of densities (very low to very high) were estimated from 1990 survey results using a methodology developed by U.S. Fish and Wildlife Service (United States Department of the Interior 1990c) and based on Berry and Nicholson (1984). Along the portion of the route that traversed tortoise habitat, tortoise densities varied from very low to very high, with low and moderate densities occurring most frequently. Highest densities occurred west and south of Las Vegas, Nevada. Habitat categories developed by BLM (United States Department of the Interior1989) include Categories 1 (highest quality tortoise habitat) to 3 (lowest quality habitat that still supports tortoises), as well as undesignated habitat (areas in which tortoises and sign have not been observed and areas containing unsuitable habitat, such as cultivated agricultural fields, residential and commercial areas, and highly disturbed areas). Category 3 was the most frequently traversed habitat category.

On-Site Mitigation Program

The on-site mitigation program for the Kern River pipeline project was developed by Dames & Moore based on terms, conditions, requirements, and stipulations within several environmental documents, including primarily the biological opinions issued by USFWS (United States Department of the Interior 1987; 1990b) and CDFG (1991). The program included information from previous tortoise monitoring projects such as Olson and Wear (1989). It included five major components: 1) preconstruction surveys; 2) monitoring for tortoises during construction; 3) mitigation measures that directly involved construction personnel (construction-related mitigation); 4) monitoring by Dames & Moore of compliance with construction-related measures; and 5) post-construction review of construction-caused disturbance to tortoise habitat.

The on-site mitigation program began with preconstruction surveys and continued through monitoring during reclamation and cleanup. The time periods associated with on-site mitigation exclusive of post-construction review of disturbance included 4 April 1991 to 3 July 1991 for Utah, 7 January 1991 to 30 April 1992 for Nevada, and 11 March 1991 to 6 December 1991 for California. The time period for Nevada was extended in length due to construction of ancillary facilities.

Preconstruction Surveys

Surveys to remove tortoises from, and collapse tortoise burrows in, all pipeline construction zones were conducted prior to the start of construction. The objective of the surveys was to relocate tortoises from active burrows within the construction zones in an efficient, systematic manner. A detailed description of the survey methodology, including timing, is in Olson et al. (1992).

Monitoring During Construction

All phases of pipeline construction, from initial clearing and grading to cleanup and reclamation were monitored for desert tortoises. Tortoises observed above ground in or near construction zones were monitored. When necessary, tortoises were relocated to reduce the likelihood of lethal incidental take. Similar to preconstruction surveys, monitoring during construction is described in more detail in Olson et al. (1992).

Construction-related Mitigation

Several measures within the mitigation program designed to reduce incidental take of tortoises directly involved construction personnel (Table 1). Those measures fit into four categories: 1) seasonal construction restrictions (construction windows); 2) worker education; 3) measures to reduce direct incidental take of tortoises (lethal take or injury); and 4) measures to reduce disturbance to tortoise habitat.

<u>Seasonal Construction Restrictions (Construction Windows)</u>

The federal biological opinion (United States Department of the Interior 1987; 1990b) included two different seasonal construction restrictions (construction windows). The original biological opinion (United States Department of the Interior 1987) limited pipeline construction to the tortoises' inactive season (specifically 1 November to 1 March). In the revised biological opinion (United States Department of the Interior 1990b), that construction window remained for the Utah and Nevada portions of the pipeline route. However, for the California portion of the route, construction was limited to the tortoises' active season (15 March to 15 June). The difference in construction windows reflected different views held by resource agency biologists regarding the season of year in which incidental take of tortoises is least likely to occur. Due to delays in pipeline construction, the seasonal restrictions were removed. Pipeline construction occurred during every month of the year.

<u>Worker Education Program</u>

The worker education program that was implemented required all visitors and workers affiliated with pipeline construction activities to attend a presentation about the desert tortoise. The presentation covered topics such as current distribution and abundance of tortoises, possible reasons for population declines, measures developed for this project that were intended to reduce impacts to tortoises, and protocol to follow if a tortoise was encountered. Presentations to large groups were made in classroom situations. Most construction workers attended presentations given to smaller groups in the field. Handouts that summarized information were distributed during presentations. Wallet-sized cards documenting attendance at a worker education presentation were distributed.

<u>Measures to Reduce Direct Incidental Take</u>

Mitigation measures developed and implemented to reduce direct incidental take (lethal take and injury) of tortoises during construction of the pipeline focused on the following

Table 1. Mitigation measures implemented to reduce impacts to desert tortoise that involved construction personnel, Kern River pipeline, Utah, Nevada, and California, 1991.

Mitigation Measure Category	Description of Measure
Seasonal construction restrictions (construction windows)	• Initially, construction restricted in Nevada and Utah to 1 November to 1 March; in California to 15 March to 15 June (restrictions later removed)
Worker education program	• Presentation and handout given to all visitors and workers
Measures to reduce direct incidental take	• Speed limit in construction zone and on access roads • Contain litter • Work only with monitors present • Movement of construction vehicles only with escort vehicles • Ride-along spotters • Only authorized vehicles in construction zone and on access roads
Measures to reduce habitat disturbance	• Restriction of vehicle access, vegetation clearance • Cleanup of fluid spills • Restriction of spoil material

measures. A 20-mile-per-hour (mph) speed limit was imposed on all vehicles in the construction zone, as well as on access roads to the construction zone. The speed limit was subsequently reduced to 15 mph following several lethal incidental takes in Nevada and California.

Additional measures involving vehicles were also implemented along with the reduced speed limit. Construction vehicles were required to travel from checkpoints to the construction zone in groups escorted by a tortoise monitor's vehicle. Construction vehicles that travelled frequently within the construction zone and on access roads (such as pipe trucks) were to include a passenger (spotter) whose responsibility was to look for tortoises. In an attempt to reduce the number of vehicles, only authorized private vehicles were allowed on access roads and in the construction zone. Ride-sharing in company vehicles and buses was encouraged.

In addition to the speed limit, two other measures that applied throughout the duration of the project were containment of litter and a prohibition on work with equipment unless a biological monitor was present. The latter measure was implemented to limit direct incidental take caused by encounters with equipment. The objective of litter containment was to reduce the likelihood of common ravens (predators of hatchling and juvenile tortoises) being attracted to the project area. Specifically, litter items were to be placed in garbage containers with secured covers. The containers were to be emptied on a daily basis.

Measures to Reduce Habitat Disturbance

Three measures were developed to reduce disturbance to desert tortoise habitat. Construction vehicles and equipment were restricted to the approved construction zones (including the pipeline right-of-way and extra work staked in the field). Vegetation clearance/ disturbance was to be contained to those staked areas. This included restriction of spoil material to the approved construction zones. Spilled vehicle fluids, including gasoline, diesel, motor oil, hydraulic fluid, and coolant were to be cleaned up as soon as practicable.

Monitoring of Compliance With Construction-Related Measures

Dames & Moore's environmental monitors monitored compliance with the above measures by construction personnel. Incident reports were prepared for each occurrence of non-compliance. Those reports were presented to Kern River's environmental inspector the following morning and were accompanied by a discussion of methods to avoid a continuation of the non-compliance.

Post-Construction Review of Construction-Caused Habitat Disturbance

Disturbance to tortoise habitat was documented during pipeline construction and subsequent cleanup and reclamation. Habitat disturbance occurred in the pipeline right-of-way, as well as in approved and unapproved extra work spaces. Extra work spaces were areas outside of the pipeline right-of-way needed for pipeline construction due to reasons such as concern for slope stability and additional pipe protection at wash crossings. Following completion of the pipeline, this documentation was compiled and area of habitat disturbance beyond that in the right-of-way was calculated. The general consistency and accuracy of the documentation was verified during a January 1992 helicopter flight over desert tortoise habitat traversed by the pipeline.

RESULTS AND DISCUSSION

The five major components of the on-site mitigation program were reviewed following construction to assess the relative effectiveness of specific measures at reducing impacts to desert tortoise. The relative effectiveness of the measures is summarized in Table 2 and described below.

Preconstruction Surveys

The preconstruction surveys conducted along the Kern River pipeline route comprised one of the most effective mitigation measures. Two sets of preconstruction surveys were conducted for each segment of the route. This resulted in a very high proportion of burrows in construction zones being detected and examined for the presence of tortoises prior to any disturbance to the habitat. Included in the total of 1889 burrows collapsed throughout the project (Table 3), only 12 (0.6%) were excavated during construction monitoring. The remaining 99.4% were found during the preconstruction surveys.

Fifty-four tortoises were removed from burrows prior to collapse. As such, preconstruction surveys were responsible for reducing potential incidental take by a maximum of 54. Preconstruction surveys allowed biologists to locate, examine and collapse burrows (and relocate tortoises, when necessary) in a systematic, thorough, unhurried manner.

Monitoring During Construction

Monitoring for tortoises during construction of the pipeline was an effective measure. Given the relatively high level of tortoise activity during a large portion of the construction period, the potential existed for a lethal incidental take total greater than the observed 29. A majority of the 401 tortoises relocated (Table 3), were moved during construction to avoid incidental take.

Monitoring of the open trench reduced the potential incidental take by 35 (the number of tortoises removed from the trench). A difficulty associated with this type of monitoring was adequate access to obtain a clear view of the trench. The presence of a large, continuous spoil pile and the need for compliance with safety standards made monitoring of the open trench difficult. Removal of tortoises using a swimming pool net with extendable (to 6.7 m) handle was a quite efficient method.

The staffing level for monitors depends on a number of factors, including quality of tortoise habitat, level of tortoise activity, and number and type of equipment being used. Monitoring supervisory personnel should be allowed the flexibility to adjust staffing levels as necessary.

Construction-related Mitigation

The effectiveness of construction-related mitigation measures varied (Table 2). Clearly, the most effective measures included the worker education program and the prohibition of unauthorized vehicles in the construction zones. The former measure improved the effectiveness of other measures, such as prohibition of work with equipment unless a monitor was present. Of the ineffective measures, the speed limit (a potentially valuable measure) was the most difficult to enforce. On future projects, this may be somewhat offset by greater emphases placed on reducing the number of vehicles on the right-of-way and access roads. Ride-sharing and busing should be used to the extent possible.

Table 2. A summary of the relative effectiveness of on-site mitigation measures, Kern River pipeline, Utah, Nevada, and California, 1991.

Mitigation Measure	Relative Effectiveness	Comments Regarding Effectiveness
Preconstruction Surveys	Effective	• Relocation of tortoises from burrows reduced potential incidental take.
Monitoring During Construction	Effective	• Monitoring of open trench difficult, but necessary to reduce take (35 tortoises removed from trench).
Construction-related Mitigation		
• Seasonal construction restrictions (construction windows)	Ineffective	• Construction during tortoises' active season results in more potential encounters with equipment. • Difficult to restrict large-scale construction projects to a specific construction window.
• Worker education program	Effective	• Presentations given on a daily basis at checkpoints along access roads ensured that nearly all construction workers attended.
• Speed limit in construction zone	Ineffective	• Difficult to enforce. Incidents of non-compliance throughout project.
• Containment of litter	Partially effective	• Unsuitable containers used. Containers emptied on infrequent basis.
• Work only when monitors present	Effective	• Relatively few incidents of non-compliance.
• Movement of construction vehicles only with escort vehicles	Ineffective	• Varying work schedules of construction personnel made escorting difficult.
• Ride-along spotters	Ineffective	• Difficult to assess effectiveness. Few tortoises observed by spotters.

Table 2. Concluded.

Mitigation Measure	Relative Effectiveness	Comments Regarding Effectiveness
• Only authorized vehicles in construction zone and on access roads	Effective	• Assisted in reducing number of vehicles in construction zone.
• Restriction of vehicle access, vegetation clearance	Partially effective	• Construction zone and access roads well marked. Minor incidents of non-compliance quite frequent.
• Cleanup of fluid spills	Partially effective	• Approximately 80% of spills cleaned up soon after spill. Biological monitors often not informed of spills.
• Restriction of spoil material	Partially effective	• Numerous minor incidents of non-compliance.
Monitoring of Compliance with Construction-related Measures	Effective	• Meetings among monitors, pipeline inspectors, and construction personnel important for reinforcing need to comply with measures.
Post-construction Review of Construction-caused Habitat Disturbance	Effective	• Post-construction review necessary due to use of extra work space. Could result in adjustment to monetary compensation.

Table 3. Summary of desert tortoise encounters along the Kern River pipeline route, Utah, Nevada, and California, 1991.

		Number of Tortoises			Number of
Portion of Route	Length (km)	Observed	Relocated	Incidentally Taken	Burrows Collapsed
Utah	26	72	8	1	68
Nevada	215	653	286	21	1129
California	152	953	107	7	692
TOTALS	393	1678	401	29	1889

Monitoring of Compliance with Construction-related Measures

Although not quantifiable, this was an effective measure for reducing incidental take of tortoises and tortoise habitat. The presence of biological monitors, as well as daily meetings among monitoring, Kern River, and construction supervisory personnel served as constant reminders of the mitigation measures. Regularly scheduled daily meetings should be emphasized.

Post-construction Review of Construction-caused Habitat Disturbance

Because the addition of many extra work spaces was necessary during construction of the pipeline, actual area of habitat disturbance was greater than that projected prior to construction. As such, the post-construction review of habitat disturbance was very useful. Large-scale projects such as the Kern River pipeline are likely to require extra work spaces, ultimately resulting in adjustments to monetary compensation/land acquisition agreements. A post-construction review (including for large-scale projects, if possible, aerial review/photography) is necessary to accurately assess the potential agreement adjustments.

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Behavioral Differences Between Captive Tortoises at Different Stress Levels

Douglas E. Ruby

Desert animals frequently confront stressful situations such as high temperatures, limited food and sparse water resources. Understanding how demanding conditions are countered by behavioral mechanisms provides insight into animals' ability to cope with man-made change. Considering the longevity of tortoises and the harsh desert environment, one might predict that desert tortoises respond to stress by reducing activity and "waiting out" the unfavorable conditions.

Four ten-acre pens were established at the Desert Tortoise Conservation Center in Las Vegas, Nevada. Each pen had approximately the same mix of adult and grass or an alfalfa and rye grass mix (supplemented) and two pens were not supplemented (deprived). Pens were gridded at 40 meter intervals. Individual animals were observed during June and July 1991 for 30 minute focal periods during daily activity. Data were collected at 5 minute intervals: distance traveled during 5 minutes; number of feeding bouts (mouthful of food) per 5 minutes; and location by quadrant. The number of feeding bouts measures feeding effort and not caloric intake. A total of 149 focals were analyzed for variation between stress level, month and hour. Home ranges were calculated for each month and both months combined. The length of activity period was measured in both ways. The times when animals were observed entering or leaving burrows during focal observations were recorded. Simultaneous surveys of activity were run in all four pens during the morning activity period on two separate dates.

During June, animals in the supplemented pens moved further and eat more than animals in the deprived pens between 0800-0900 and 1000-1100. During July, no comparisons between treatments were significantly different. Animals in the deprived pens appeared to increase their activity and feeding rate from June to July. Supplemented animals maintained a longer activity period in the morning during June but not during July. Animals in both treatments emerged after sunrise or were already out of burrows at sunrise but supplemented animals stayed out longer than deprived animals (about 1,030 vs. 1,000 min). This additional time meant the total distance moved and amount of feeding effort per day was greater in the supplemented animals. Supplemented animals presumably maintain longer activity periods because better availability of water and food modified their energy and water budgets to permit such activity. It appears that July daily temperatures impose greater stress which was reflected in reduced activity during this month, even in the supplemented animals. Animals in the deprived pens had significantly larger home ranges when calculated over both months, although individual monthly averages were not different between and within treatments. Animals in the deprived pens apparently utilized different areas in July than they did in June.

Examination of Desert Tortoise Burrows Using a Miniature Video Camera

Mari Schroeder

The necessity to look for live desert tortoise in the western Mojave Desert during the winter of 1992 required the examination of tortoise burrows during field surveys. Until now, the accepted method of examining desert tortoise burrows utilized fiber-optic scopes. Because some tortoise burrows have been found to extend in excess of 30 feet, the fiber-optic scope needed to examine these burrows must be highly specialized. The prohibitive cost plus the limited visibility of long fiber-optic scopes provided the impetus for the development of an alternative method of examining tortoise burrows. The new method developed by Chambers Group personnel consists of a miniaturized or miniature video camera that is hooked up to a standard camcorder with an approximately 30-foot long cable. The camera itself, which is the size of a thumb, is contained inside a protective housing that also contains lights. The cable is reinforced and contained within a protective cover to allow for the flexibility and rigidness required to negotiate inside burrows. Materials selected for the protective housing on the camera and cable are durable enough to withstand repeated use in the dirt and the application of sterilization agents. Actual field use of the video camera has resulted in high resolution pictures of tortoises inside burrows and less harassment to tortoises due to the increased visibility. Based on the affordable cost of the camera unit, the high resolution pictures received from the instrument, and the permanent documentation of tortoises inside burrows, the Chambers Group feels that this is a viable alternative to the fiber-optic system for examination of desert tortoise burrows.

Experiences With Captive Desert Tortoises at the University of Nevada, Las Vegas (UNLV)

Richard C. Simmonds and Frances R. Taylor

Thirty two tortoises were acquired after listing as a threatened species by the U.S. Fish and Wildlife Service (Act), and six tortoises were acquired prior to the listing (pre Act). The tortoises have been housed in the Central Animal Facility (CAF) at UNLV. The pre-Act animals were received at various times prior to 1990 and were randomly caught without regard to whether or not they displayed symptoms of upper respiratory tract disease (URTD). The Act animals were all received in October 1990 and were all considered by the Nevada Department of Wildlife (NDOW) as having exhibited symptoms of URTD.

Tortoises were generally housed in groups, with Act animals being housed separately from pre-Act animals. Diet consisted of various amounts of collared greens, broccoli, carrots, alfalfa and bean sprouts, squash, and, occasionally, bananas fed 3 times per week or daily. Alfalfa hay and water were available ad lib except when the animals were in hibernation. Ambient room temperatures ranged from about 70°F to 85°F. Humidity was not controlled. Light cycles were 12:12, light:dark. The animals were handled only as required for cleaning (once per week) or weighing.

No treatments were administered to any animal as the original goal of the planned research was to evaluate the physiological status of animals with and without symptoms. Due to the unexpected death of the principal investigator, the planned studies were not completed.

As of October 1991, 18 Act (56%) and 4 (66%) pre-Act animals were still alive (at this time the 18 Act animals were transferred to either NDOW or the Desert Tortoise Conservation Center). During their stay in the CAF, all but one of the Act animals were observed with URTD symptoms while only one of the six pre-Act animals was ever observed with such symptoms. Symptoms in all cases were very erratic, with any individual animal appearing to be disease-free about as much as it appeared to be diseased.

Single culture results were available on 31 of the 32 Act tortoises. Six were positive for both *Pasteurella* and *Mycoplasma*, nine for *Pasteurella* only, and none for *Mycoplasma* only. Fourteen were negative for both organisms.

Of the 32 Act animals, 8 gained weight, 11 loss weight, 11 had no weight change, and weights were unavailable for the other 2. As of October 1991, 14 (44%) had died. Of the 6 pre-Act animals, 4 have loss weight and 2 have had no significant weight changes. As of October 1991, 2 (33%) had died (neither ever showed URTD symptoms).

During the 1990/1991 winter, 16 tortoises were allowed to hibernate and were housed in cardboard boxes without food or water at ambient temperatures of about 40 °F. Fourteen other animals were housed in a group and maintained at ambient temperatures of approximately 76 °F, provided food and water, and encouraged to remain active. Twelve (75%) of the hibernated group, but only 6 (43%) of the active group survived through October 1991 (Table 1).

Survival in captivity, under the conditions provided in the UNLV CAF, appeared to be somewhat dependent on whether or not the tortoises had ever displayed URTD symptoms, with those showing symptoms being more likely to die, and dependent upon whether or not the animals were allowed to hibernate, with those remaining active being more likely to die.

Table 1. Summary of survival and microoragnism infection data for desert tortoises housed at UNLV Fall 1990 - Fall 1991 where: n is the number of animal; P, M, and P&M are respectively *Pasteurella* and *Mycoplasma* infections; ND = not determined.

GROUP DESIGNATION (n)	PERCENT POSITIVE (n) P	M	P&M	SURVIVAL TO FALL 1991
PRE-ACT TORTOISES* (6)	ND	ND	ND	4 (66%)
ACT TORTOISES [ACTIVE]** (16)	19%(3)	0	6%(1)	6 (37%)#
Males (9)	33%(3)	0	11%(1)	4 (44%)
Females (0)	-	-	-	
Unknown Sex (7)	0	0	0	2 (29%)
ACT TORTOISES [HIB.]** (16)	36%(6)	0	31%(5)	12 (75%)
Males (7)	43%(3)	0	43%(3)	6 (86%)
Females (6)	50%(3)	0	33%(2)	5 (83%)
Unknown Sex (3)	ND	ND	ND	1 (33%)

* = Of these 6 tortoises, only 1 ever exhibited symptoms of URTD

** = Of the 32 Act tortoises, all but 1 was observed with URTD symptoms.

Behavioral Responses By Desert Tortoises (*Gopherus agassizii*) to Roadside Barriers: A Preliminary Study

James R. Spotila, Douglas E. Ruby, Stanley J. Kemp and Linda C. Zimmerman

Abstract. The response of desert tortoises to barriers was tested in behavioral trials with small pens made of different types of construction materials. The amount of time spent near each barrier, the type of contacts between the tortoise and the barrier and the efforts to escape from the pen were monitored during 30 minute trials. Tortoises spent most of the time walking around the pens investigating the barrier. Some solid barriers provoke less interest and do not elicit as much contact as barriers with openings or made of wire. Tortoises behave differently between solid and non-solid barriers. Barriers such as chicken wire provoke a lot of fence fighting activity and are undesirable as barriers.

INTRODUCTION

Causes of mortality in adults of long-lived species are particularly damaging to the ability of the population to maintain sufficient numbers (Congdon et al. 1987; Congdon and van Loben Sels 1991). One factor contributing to increased mortality in desert tortoises (*Gopherus agassizii*) is increases in vehicular traffic through the tortoise habitat (increases in both numbers of roads and number of cars per road). Previous studies (Nicholson 1978) indicate that population levels drop sharply near roadways and power line transects. Thus, the need for roadside barriers which prevent tortoises from crossing in front of traffic but do not impair natural migration has become more urgent. Fusari (1982) tested three types of fencing and concluded that visual cues beyond the fence and the mesh size of the fence affected the tortoises' response. This study attempted to test tortoises with a wider range of barrier choices and quantify their initial behavioral responses.

METHODS AND MATERIALS

Initial responses by desert tortoises to different types of barriers were tested in a systematic way using behavioral trials. A series of 11 square pens 4.6 m x 4.6 m (15' x 15') were constructed at the Desert Tortoise Conservation Center in Las Vegas, Nevada. Walls were made of common construction materials: railroad ties, cement block, silverized insulation, aluminum sheeting, wooden corral fence, chain link fence, chicken wire fence, 1 cm (1/2") mesh fence. One pen consisted of a sloped trench approximately 0.6 m deep and 0.5 m wide dug into the substrate and lined on the steep side with 1 cm mesh fence. Each pen was tested five times with different adult animals for 30 minute periods during September 1991. Animals were removed from their home pen and tested during the morning or afternoon activity periods when other tortoises were active. The Test animals were confined in pens constructed of corrugated plastic sheeting for at least six months prior to testing. Thus, the animals were familiar with man-made barriers but the specific types of barriers used in testing were unfamiliar. The test animals were used for three barrier trials on different days during the experiment. Fifty-two trials were run. One trial where the animal did not move during the 30 minutes was discarded. Three trials were run on each of two pens with the same barrier material but with the material buried at the bottom in one pen. After three trials, no differences were noticed and the trials were combined.

During each trial, the following data were collected: time spent near (less than 1 body length) the barrier to the nearest minute, number of contacts with fence (nose touch, head contact or through the fence, foot contact or through the fence, head and foot through the fence), number of pushes against fence and number of attempts to climb the fence or escape. Head through the fence, foot through the fence, or head and foot through the fence were identified from other contacts by efforts of the tortoise to raise its body higher against the fence. Representative samples of trials were videotaped.

Frequencies of response were tested by analysis of variance (ANOVA) for variation among pen types as a separate type and grouped into two types of barrier pens: solid and non-solid.

RESULTS

Animals within a barrier pen spent nearly the entire 30 minute trial exploring the pen and searching the perimeter. Although tortoises spent at least half of the trial time within a body length of the barrier (Fig. 1), there was a significant variation in the amount of time animals spent near a barrier (Table 1). Animals typically spent more time walking or standing near non-solid barriers than solid barriers. Three barriers were least attractive: the silverized insulation and aluminum sheeting were reflective and bright in appearance and the railroad ties seemed to smell unattractive to the tortoises. Barriers with openings (like the wooden corral) or wire fences attracted more efforts by the tortoises to explore or contact the barrier.

The number of contacts by nose, head or foot for each barrier type are shown in Fig. 2. Each of these types of contact varies significantly between pens (Table 1). The frequency of the contacts differs primarily depending upon whether the barrier is solid or not. Chicken wire barriers attracted the most contacts in every category except head thrusts, where it was surpassed by the chain link fence barrier. Attempts to push against or climb the fence also varied significantly among the pens (Table 1) and were highest for chicken wire (Figure 2). No escapes were successful although one animal nearly climbed over the log cabin barrier.

A major difference among the tested barriers is whether they are solid or non-solid with openings through which tortoises can see (Table 2). All but one type of contact (nose against or through fence) was significantly different. Analysis of variation within these two groups indicated that tortoises reacted to all solid barriers in the same way (Table 3a) but non-solid barriers were treated with significant variation in the number of foot contacts and pushes (Table 3b). The variation among no-solid barriers occurred because a barrier through which the tortoise can place its head generated much more contact between the tortoise and the barrier. Barriers such as the 1 cm mesh have openings too small for the tortoises' heads and the animals treated the barrier similarly to a solid barrier after a few initial contacts by nose. Barriers such as chicken wire and chain link fencing have large openings through which tortoises could place both head and foot simultaneously. Tortoises attempted to push through these barriers and continued to push through even when their initial efforts failed. We observed a noticeable difference in the number of head and foot contacts versus the number of pushes for chain link fence and chicken wire fence. The chicken wire apparently

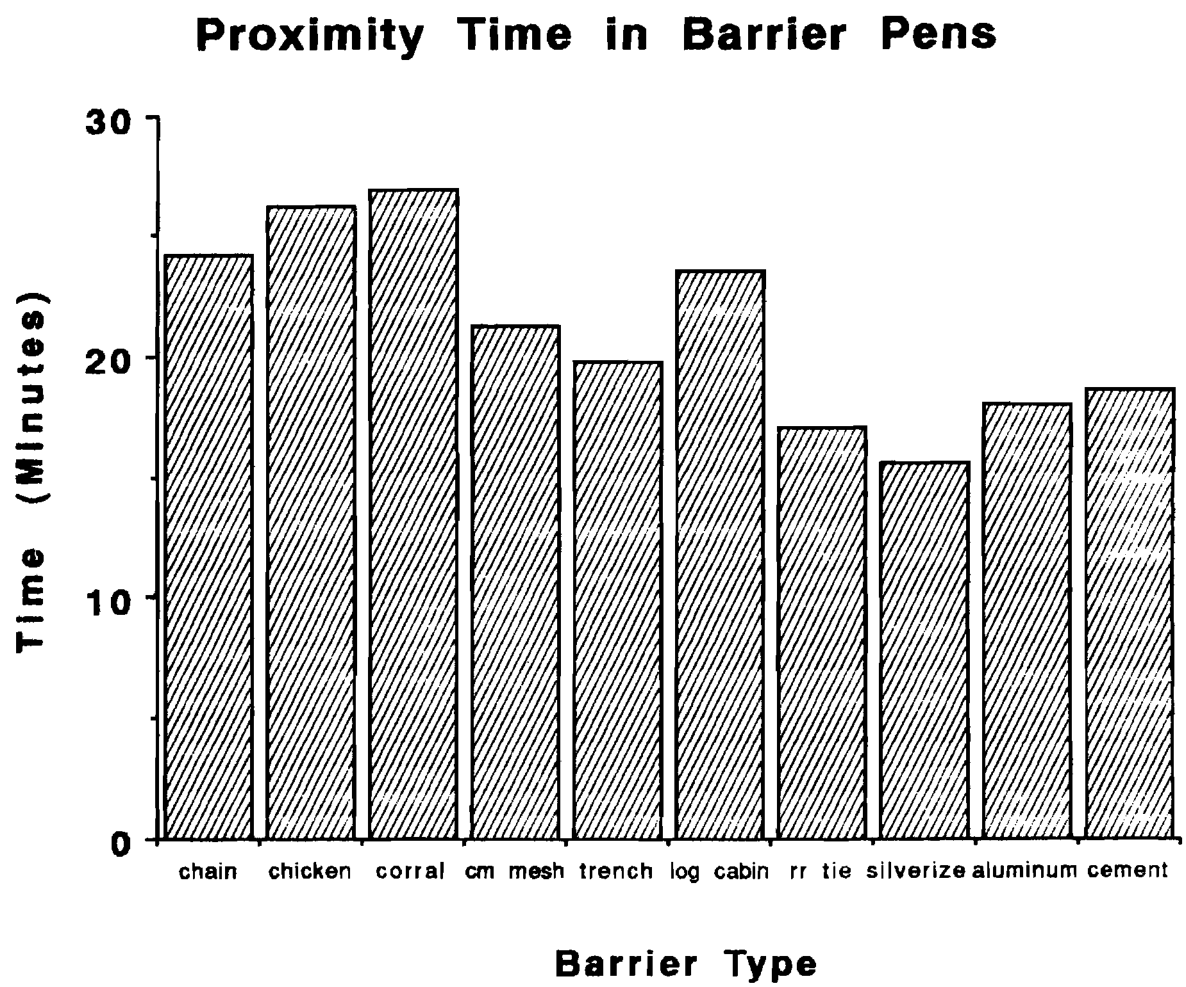

Figure 1. Mean length of time spent near barrier during 30 minute trials. N = 5 for each barrier type except cm mesh where N = 6.

Table 1. Analysis of variance of the frequency of behaviors among barrier pen types during 30 minute time trials. All barrier pen types included.

Behavior	df	F	P
Proximity near fence (in minutes)	9,42	3.23	0.0047
Nose through fence	9,42	2.66	0.015
Foot through fence	9,42	9.38	0.0001
Push against fence	9,42	5.33	0.0001
Head through fence	9,42	3.70	0.0017
Head and foot through fence	9,42	1.88	0.08
Climb fence	9,42	1.65	NS

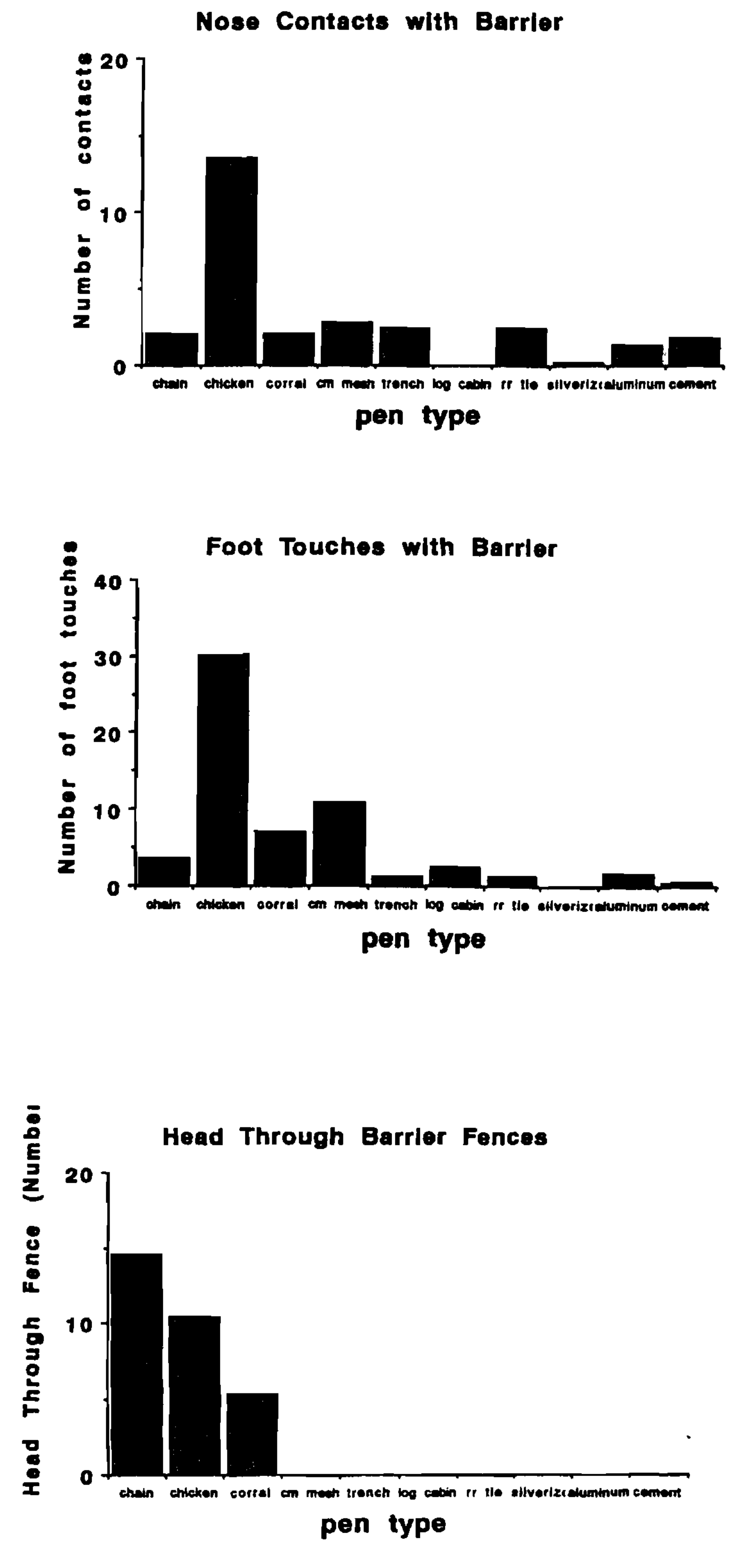

Figure 2. Mean number of contacts with barrier in 10 types of barrier pens. N = 5 trials in each graph except cm mesh where N = 6.

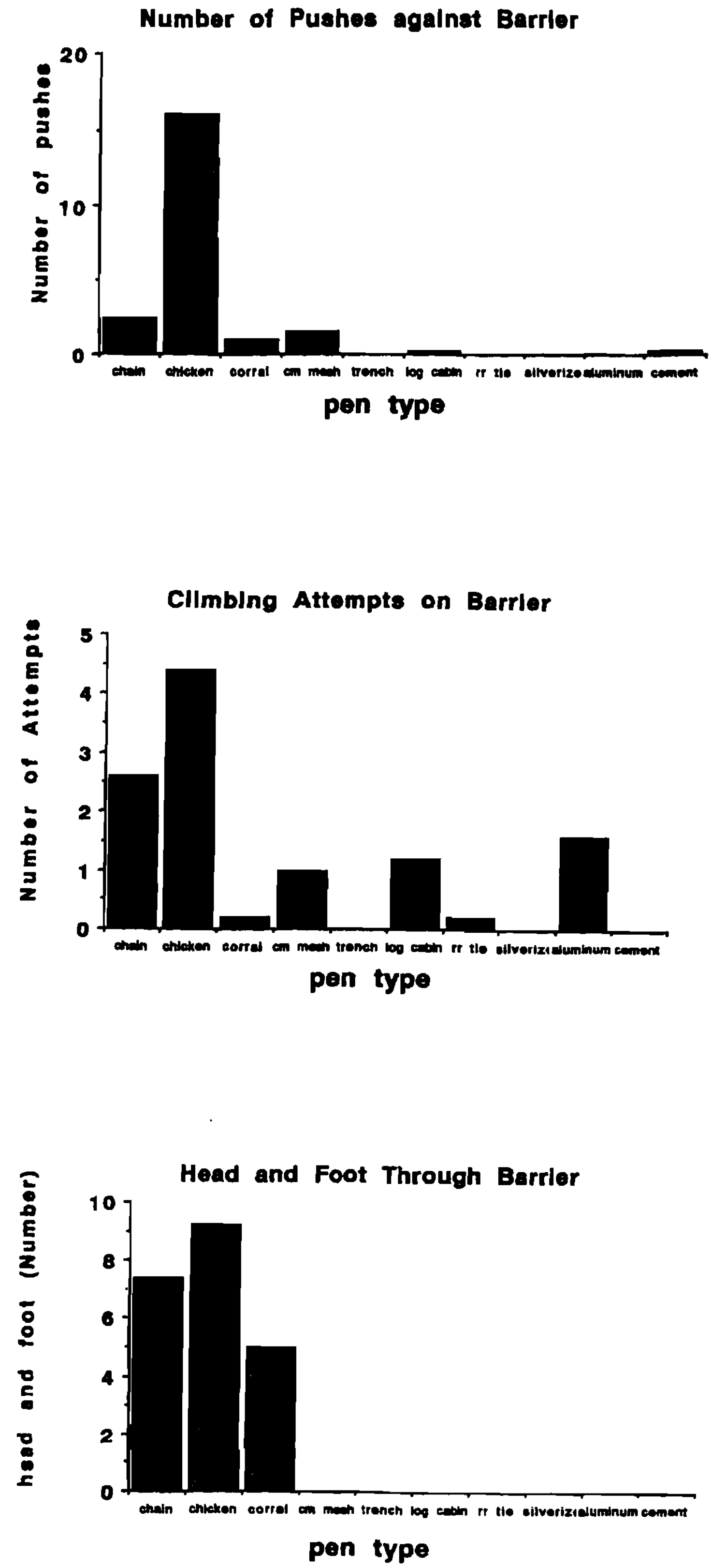

Figure 2 cont. Mean number of contacts with barrier in 10 types of barrier pens. N = 5 trials in each graph except cm mesh where N = 6.

Table 2. Comparison between solid and non-solid walls in the frequency of behaviors in pens during 30 minute time trials

ANOVA df = 1,50

Behavior	F	P	Solid	Non-solid
Proximity to fence (min)	15.60	0.002	18.77 ± 5.47	24.52 ± 4.63
Nose on or through fence	4.78	0.3	1.39 ± 1.99	5.00 ± 8.91
Foot through fence	21.01	0.0001	1.26 ± 2.03	12.91 ± 13.99
Push against fence	8.74	0.004	0.09 ± 0.39	5.05 ± 9.36
Head through fence	14.26	0.0004	0.0	7.24 ± 10.72
Head + foot through fence	9.49	0.003	0.0	5.14 ± 9.35
Climb fence	4.33	0.04	0.48 ± 1.61	2.0 ± 3.56

Table 3. Analysis of variance in the frequency of behaviors during 30 minute time trials.

a) within solid types of barrier pens

Behavior	df	F	P
Proximity to fence	5,25	1.35	NS
Nose through fence	5,25	1.5	NS
Foot through fence	5,25	1.08	NS
Push against fence	5,25	0.70	NS
Head through fence	5,25	0.0	--
Head and foot through fence	5,25	0.0	--
Climb fence	5,25	0.99	NS

b) within non-solid types of barrier pens

Behavior	df	F	P
Proximity to fence (min)	3,17	1.86	NS
Nose through fence	3,17	2.51	0.09
Foot through fence	3,17	6.63	0.003
Push against fence	3,17	4.68	0.01
Head through fence	3,17	2.24	NS
Head and foot through fence	3,17	1.02	NS
Climb fence	3,17	1.49	NS

attracted the most pushes because the thinner wire is not well perceived by the tortoises who continued their efforts to push through.

DISCUSSION

This study expands previous experiments with barriers by demonstrating that Fusari (1982) was correct in pointing out the importance of visual space behind the barrier (solid versus non-solid barriers). Fusari (1982) noted a strong difference in the frequency of nose touches and pushing behavior between chicken wire compared to hardware cloth and solid metal. We found that all solid barriers were treated similarly. We did not observe any behavior that would recommend one type of solid barrier over another as a barrier or directional device. Relative cost and esthetics are more likely to determine which type of solid barrier is chosen.

However, 1 cm (1/2") mesh fence was treated similarly to solid barriers because the mesh is smaller than the tortoises' head and prevented protrusions. This type of fence has advantages of allowing smaller animals such as small lizards, snakes and insects through but appears to discourage contacts after a tortoise has attempted a few contacts. Barriers such as chicken wire, chain link or wooden corrals which contained large enough openings for the tortoise to place either its head or foot through attracted large numbers of contacts as tortoises attempted to negotiate through the barrier. Tortoises seemed to recognize the chain link fence as an effective restraint while they did not with chicken wire fence.

We assume that frequent attempts to climb over, push or climb through a barrier make it ineffective in humanely directing tortoises away from obstacles or hazards. Chicken wire evokes the greatest exploration / escape reaction from tortoises and therefore is not an effective barrier since tortoises can easily become ensnared. Thus, these types of barriers seem to be less effective. Our trials were not long enough to indicate whether tortoises would habituate to the openings and realize that they cannot get through. Further work will investigate this possibility, and the reaction of tortoises to directional changes.

ACKNOWLEDGEMENTS

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Movements and Survival of Desert Tortoises (*Gopherus agassizii*) Following Relocation from the Luz Solar Electric Plant at Kramer Junction

Glenn R. Stewart

Abstract. Between December 1985 and May 1987, 24 tortoises were removed from the construction site and relocated to a study site about 5.6 km to the northeast. Beginning in May 1987, 14 of these were monitored with radio transmitters for at least 3.5 months. During 1987 and 1988, 28 resident tortoises were identified on the study site and 10 of these were monitored for at least 2.75 months.

The distances moved by relocatees were not significantly different from those of residents. Eight of the nine relocatees monitored for at least 18 months settled within 1,000 m of their initial release points, and four of the nine settled within 10 days of their release dates. The three relocatees that immediately dispersed, including two that moved over 5,500 m in the first 30 to 60 days, may have been searching for home. However, the directions and distances recorded for most relocatees did not indicate a clear homing tendency.

Tortoises tended to gain weight during 1987 and lose weight during 1988, 1989, and 1990. Total mortality rates for the relocated and resident tortoises were not substantially different (4/14 = 28.6% vs. 2/10 = 20%). The most important factors predisposing tortoises to mortality probably were drought conditions and Upper Respiratory Disease. Poaching caused the loss of at least as many tortoises as did all other factors combined.

INTRODUCTION

The removal of tortoises from a project site and relocation to another area of suitable habitat would seem to be an appropriate mitigation measure when severe impacts or habitat destruction by the project are expected. However, there is little information on what actually happens to wild tortoises that have been relocated. Some studies have been conducted on Hermann's tortoise (*Testudo hermanni*) in Italy (Chelazzi and Francisci 1979, 1980; Chelazzi and Delfino 1986), and the gopher tortoise (*Gopherus polyphemus*) in Georgia (Landers, unpubl. data), Florida (Diemer 1984; Burke unpubl. data), and Mississippi (Lohoefener and Lohmeier, 1986). A limited relocation of desert tortoises was conducted at the Twentynine Palms Marine Corps Base by Stewart and Baxter (1987). Berry (1973, 1974, 1975a, 1975b) reported on an extensive desert tortoise relocation project, but most field work was terminated after 15 to 18 months. Reviewing much of the existing data, Berry (1986) concluded that studies on relocation efforts should run for at least two to four years, and that these studies should evaluate not only the survival and movements of the relocatees but also their interactions with the host population. Construction of the LUZ Solar Electric Generating Station (SEGS) in the Western Mojave Desert at Kramer Junction, San Bernardino County, California (Fig. 1) provided an opportunity for such a study..

SEGS construction required the destruction of about 5 km^2 of desert tortoise habitat

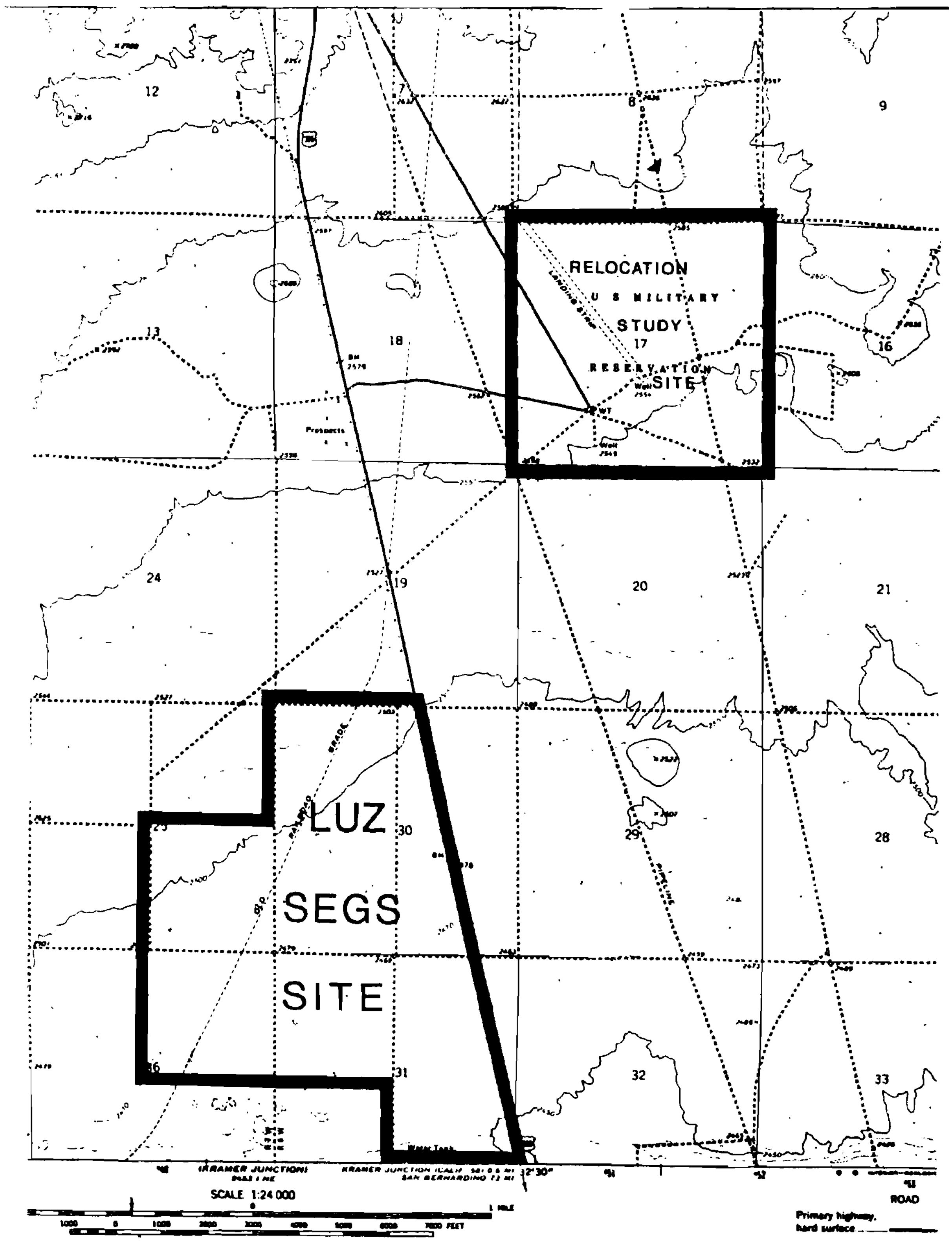

Figure 1. Locations of the LUZ Solar Electric Generating Station (SEGS) site and relocation study site. Grid interval = 1.61 km.

between December 1985 and July 1987. Prior to initial construction activities at the SEGS site in 1985, eight tortoises were removed (Baxter and Stewart 1986). Sixteen additional tortoises were removed in 1986 and four in 1987. Of these 28 tortoises, 24 were relocated to the study site, and 16 ultimately were equipped with radio transmitters and monitored (Appendix 1).

The SEGS site was an area of essentially flat ground sloping gently to the southeast with no well-developed washes. The perennial vegetation was a nearly uniform stand of Mojave saltbush (*Atriplex spinifera*). The relocation study site was a 2.6 km^2 plot of land located 5.6 km north-northeast of the SEGS site and 1.6 km east of U. S. Highway 395 in San Bernardino County (Fig. 1). This property (Section 17, T 11N, R 6W) formerly was a U. S. Military Reservation, but now is owned by the State of California and managed by the California Department of Fish and Game (CDFG). It is designated as the "West Mojave Ecological Reserve." The topography here is slightly rolling with a gentle slope to the south and two major washes. Much of the southern half of the site is dominated by saltbush, but creosote bush (*Larrea tridentata*) occurs in the southeastern and southwestern corners. It becomes increasingly abundant in the north and along the washes. The study site is traversed by several roads and an old 1.3 km long by 30 m wide dirt landing strip. The landing strip is mostly free of perennial vegetation, but has some very large creosote bushes along its edges due to water drainage from the compacted soil.

Sheep have been grazed regularly on both sites during the spring months. However, a sheep-proof fence was installed along the perimeter of the study site in June 1987. The bottom of the 1.2 m tall hog-wire fence was raised 15 to 20 cm above the ground to permit the passage of tortoises.

The purpose of the intensive phase of the study, begun in 1987, was to monitor the movements and survival of the relocated tortoises, and to evaluate the effectiveness of the relocation effort. Also, an attempt was made to obtain some comparable data on tortoises residing at the relocation site, and to document the interactions of relocated and resident tortoises.

METHODS AND MATERIALS

Study Site Preparation: Prior to the introduction of relocated tortoises, Uptain and Karl (1987) established a 10 X 10 grid on the 2.6 km^2 study site. Grid points were marked using 0.9 m rebar stakes covered with 3 m segments of PVC pipe. Uptain and Karl (1987) also searched the site in April for resident tortoises, processing and marking all 21 encountered. These workers, however, did not weigh the tortoises or identify them with painted numbers. Appendix 2 presents a roster of the 28 resident tortoises occurring on the site, including the seven additional tortoises found by relocation personnel.

Tortoise Treatments: The first eight tortoises (four females and four males) removed from the SEGS site were excavated from hibernation burrows between 12 and 15 December 1985. They were weighed with a Chatillon spring scale (0-6 kg), measured with calipers for median carapace length (MCL), and marked using a standard shell notching code (Berry 1984). The letters "LUZ" and a number corresponding to the shell notching code also were painted in black on a yellow background on a posterior vertebral scute. The painted mark was protected by a coat of epoxy resin. Following this processing, the tortoises were placed individually in closed cardboard boxes lined with newspapers and stored in an abandoned water tank at the southern edge of the SEGS site until field work was completed on 15

December. The tortoises were then transported in their boxes to a home garage in the city of Lake Matthews, Riverside County, California where they were stored until 27 December. At that time, they were transported to Edwards Air Force Base (EAFB) and placed in an artificial hibernaculum constructed in the natural habitat.

On 23 February 1986, three females escaped from the hibernaculum. The remaining female and four males were then placed in closed cardboard boxes lined with newspapers and stored in an isolated corner of the basement of the Science Building at Cal Poly University, Pomona, Los Angeles County, California until they could be released at the relocation study site a month later. In late May 1986, one of the escaped females was found by a motorist at El Mirage Dry Lake, 53 km south-southeast of EAFB. This tortoise (L5 F) was relocated to the study site in early June 1986.

The treatments of primary concern relate to the 15 tortoises that were relocated to the study site during the week of 4 May 1987. The first of these tortoises (L11) was removed from the SEGS site on 2 November 1986, placed in a closed cardboard box lined with newspapers, and stored in the basement of the Science Building at Cal Poly, Pomona. Between 15 and 18 December 1986, 13 additional tortoises were excavated from hibernation burrows at the SEGS site and treated in the same way. On 19 December, all 14 tortoises were processed in the laboratory. Weights and MCL measurements were recorded and identification markings were applied as described previously.

After processing, the 14 tortoises were returned to their individual closed boxes and hibernated in the dirt-floored basement of a house in Pomona. On 11 March 1987, a 15th tortoise (L25 F) was brought in from the SEGS site, processed, and placed in the same basement. In mid-April 1987, all 15 tortoises (three males and 12 females) were taken to the basement of the Science Building at Cal Poly where they were kept for about 10 days.

On 24 April 1987, the 15 tortoises were taken to the roof of the Science Building and placed in three open 2.3 m^2 enclosures. They were provided with dishes of water and a diet of lawn clippings and romaine lettuce. The tortoises remained in these enclosures until the days of their releases. Thirteen of the tortoises were weighed immediately after their removal from the Science Building basement, and again on 28 April and 1 May. Approximately one week prior to their release, the females were X-rayed to determine if they contained shelled eggs.

On 1 May 1987, radio transmitters (150 MHz; TELONICS, Mesa, Arizona) were applied to 12 of the 15 tortoises (three males and nine females). Each transmitter weighed about 50 g and was equipped with a 46 cm antenna. The transmitters and their antennae were affixed to the carapaces of the tortoises using a combination of silicone sealant and epoxy resin. Transmitters were mounted on the posterior vertebral scutes of males and on the anterior costal scutes of females. On both sexes, the antennae were curved around the carapaces at the level of the costal scutes. In addition, a white tag bearing in black ink the phone number of the Long Beach office of the CDFG was affixed to the carapace of each tortoise and covered with epoxy resin. The tortoises were weighed again following the application of the transmitters and antennae.

On 4, 6, and 8 May 1987, groups of five tortoises (one male and four females each) were transported to the relocation study site in individual closed boxes. The male and three females of each group were equipped with transmitters. Tortoises of the first group were released at mid-morning on 4 May at alternate central site gridposts. Each tortoise was placed facing a direction different from those of its closest neighbors. Just before sundown on 6 May, tortoises of the second group were placed in existing burrows scattered through the central and northeast portions of the site. The last group of tortoises was released on 8 May at central site gridposts in a manner similar to the first group. Immediately following the morning releases, study personnel observed one or two individuals in each of these groups through binoculars for an hour or more to check for orientation behavior (head movements, sniffing, direction of locomotion, etc.).

Monitoring: On 54 of the 57 days following the release of the first group (through 30 June 1987), the locations of each transmittered tortoise were recorded at least once daily. Thereafter, tracking efforts were reduced. About 50 days of field work were carried out in the remainder of 1987 and a total of 57 days in 1988. In early November 1988, 11 tortoises (see Appendices) were captured to replace transmitters that were due to expire during the 1988-89 hibernation period. These tortoises were extracted from their hibernation burrows, brought to the laboratory for the transmitter replacement, and returned to their burrows the following day. Between February and November of 1989, tortoises were monitored for an additional 21 days.

The relocation site was checked six times in 1990. There were three surface visits between late February and mid-March, an over flight in a CDFG plane on 26 May and, in July, two searches for the purpose of removing all functioning transmitters from relocated and resident tortoises. The July searches were not exhaustive, but all radio signals that could be detected on or near the study site were tracked down and most of the tortoises that had working transmitters probably were found.

As additional tortoises were encountered on or near the relocation site in 1987 and 1988, they were processed in the field and monitored along with the others. These included three relocatees not initially equipped with transmitters (L5 F, L7 F, and L23 F; see Appendix 1) and 11 residents (see Appendix 2). Also, L26 M was found at SEGS III on 16 May 1987 by Uptain and Karl (1987), temporarily held on the SEGS site in a box at room temperature, and released at the relocation site with a transmitter on 24 May 1987.

Most transmittered tortoises were located at least once each field day in 1987 and 1988. Fewer attempts were made in 1989 to locate each tortoise each field day. Tortoise locations were recorded on data sheets and later plotted on grid maps of the relocation site or U. S. Geological Survey (USGS) 7.5 Minute Series quadrangle maps.

Social interactions of tortoises were noted when observed, but time did not permit extended observation of encounters. Weights of most tortoises were taken every one to two weeks from May through July 1987, and every four to six weeks through November 1987. Generally, tortoises were weighed less frequently in 1988 and 1989. Few weights were taken in the late summer and fall due to the dehydration that would result from accidental urination, and no weights were taken during the winter months (December - February).

Data Management: To examine the pattern of early movements, the locations of the first 12 transmittered relocatees were plotted sequentially for the first seven to 10 days on the study site grid map and adjacent parts of the USGS Saddleback Mountain quadrangle map. In addition, the distances and directions to the locations of these tortoises at the end of three days were measured. Long term movements were examined by measuring the distances to the last known locations of the 14 relocatees, and eight of the ten residents (no final location data are available for CP16 M and CP25 M), that were monitored for at least 2.75 months but not more than 18 months. (Eighteen months was used as a cutoff for these data because this was the beginning of the hibernation period in 1988 and the relatively small number of observations recorded in 1989 did not indicate significant changes in the locations of the tortoises.)

In all cases, distances were recorded as straight line measurements between the release points (or capture points of residents and relocatees later equipped with transmitters) and their later locations. Directions were taken as the angles of the tortoises' later locations relative to their initial points and a hypothetical home point on the SEGS site in Section 36, T 11N, R 7W of San Bernardino County. The home point is an approximation of the center of the area from which 13 tortoises were removed in December 1986. The bearing from the release point to the home point was arbitrarily established as 0° in the direction analysis. The relocatees listed in Table 1 (three day movements) and Table 2 (long term movements) are different for the following reasons: L5 F and L7 F were released in 1986 but not equipped with transmitters until 1987 and 1988, respectively; L23 F was released in early May 1987 but not equipped with a transmitter until a month later; L26 M was not captured and transmittered until late May 1987; and the transmitters of L22 F and L25 F failed in less than two months.

Because of the small sample sizes, males and females could not be compared statistically. Pooled means for distances traveled by relocatees and residents were calculated and compared with two-sided Student's t-tests (Simpson et al. 1960). Circular statistics were employed to analyze the direction data. Mean angles (Zar 1984) were calculated for both relocatees and residents relative to their initial points and the home point. Rayleigh's z-test and the V-test were used to test the significance of mean angles (Zar 1984). In all statistical tests, the 0.05 level of confidence was required to accept the results as statistically significant. Valid statistical comparisons of tortoise weights were impossible due to the small sample size and large number of uncontrolled variables.

RESULTS AND DISCUSSION

Movements and Orientation Behavior

Early Movements and Behavior: For the first few minutes after their release, the eight relocatees observed carefully tended to sit quietly while partly withdrawn into their shells. During the first hour, however, they were seen to sniff the ground, air, and surrounding vegetation. Some also fed on annual plants, such as *Schismus barbatus*, the principal grass species on the relocation site. Linear distances traveled in the first hour of observation ranged from 0 to 25 m. Directions of these initial movements appeared to be random.

Seven to 10 days after their release, nine of the 12 transmittered relocatees remained on or near the gridded relocation site. Three made irregular circles (e.g. L12 F and L17 F; Fig. 2), four tended to move in straight lines for several hundred meters (e.g. L14 F and L18 M; Fig. 3), and two made more erratic movements.

Three tortoises immediately embarked on long distance movements off the relocation site (Figs. 4 and 5). L22 F zigzagged south for four days, made a circle between days five and seven, then headed southwest. When its transmitter failed on the eighth day, it was 1,468 m from its release point on a bearing of 347° relative to "home." L20 F moved southeast for three days, then moved steadily southwest for seven days where it was found at the eastern edge of U. S. Highway 395. At this location, it was 2,737 m from the release point on a bearing of 355° relative to "home." On the same day, L20 F was picked up and released at a different point on the relocation site. From there it moved steadily west with only slight deviations. During the next four days, it traveled 1,856 m to the eastern edge of U. S. 395. From that point it was transported 260 m west of the highway and allowed to continue. After

Table 1. Straight line distance (m) and direction (° relative to "home") moved by 12 transmittered relocatees 3 days after relocation.

TORTOISE	(m)	(°)	Dates
L12F	544	269	5-4/5-7-87
L13M	1007	268	5-6/5-9-87
L14F	741	110	5-8/5-11-87
L15M	463	118	5-4/5-7-87
L16 F	278	166	5-4/5-7-87
L17F	116	331	5-6/5-9-87
L18M	417	127	5-8/5-11-87
L20F	810	272	5-4/5-7-87
L21F	289	102	5-6/5-9-87
L22F	938	340	5-8/5-11-87
L24F	660	75	5-6/5-9-87
L25F	984	116	5-8/5-11-87

mean distance = 604 m (SD ±299 m)

mean angle = 63° (not significant)

Table 2. Distance (m) and direction (° relative to "home") moved to final locations by 14 transmittered relocatees monitored for 3.5 to 18 months and 8 transmitted residents monitored for 2.75 to 18 months.

RELOCATEES				RESIDENTS			
Tortoise	(m)	(°)	Dates	Tortoise	(m)	(°)	Dates
L5F*	255	24	5-7-87/11-6-88	CP6F	315	301	6-30-88/11-6-88
L7F*	110	41	5-5-88/11-6-88	CP9M	185	288	5-8-87/11-6-88
L12F	435	286	5-4-87/11-6-88	CP14M	1130	71	5-8-87/11-6-88
L13M	2859	50	5-6-87/9-22-87	CP20M	1620	212	5-19-87/8-5-87
L14F	935	106	5-8-87/11-6-88	CP21M	795	95	5-8-87/7-13-88
L15M	850	54	5-4-87/11-6-88	CP24M	1128	90	5-8-87/11-6-88
L16F	1812	62	5-4-87/8-29-87	CP27M	245	255	10-5-87/9-3-88
L17F	130	301	5-6-87/11-6-88	CP29M	470	90	5-31-88/11-6-88
L18M	960	122	5-8-87/9-14-87				
L20F	6768	52	5-4-87/4-14-88				
L21F	480	120	5-6-87/8-19-87				
L23F	420	198	5-6-87/11-6-88				
L24F	1272	40	5-6-87/11-6-88				
L26M	250	75	5-22-87/11-6-88				

mean distance = 1,253 m (SD ±1,758 m) mean distance = 736 m (SD ±519 m)

mean angle = 61° (not significant)

*relocated in spring 1986

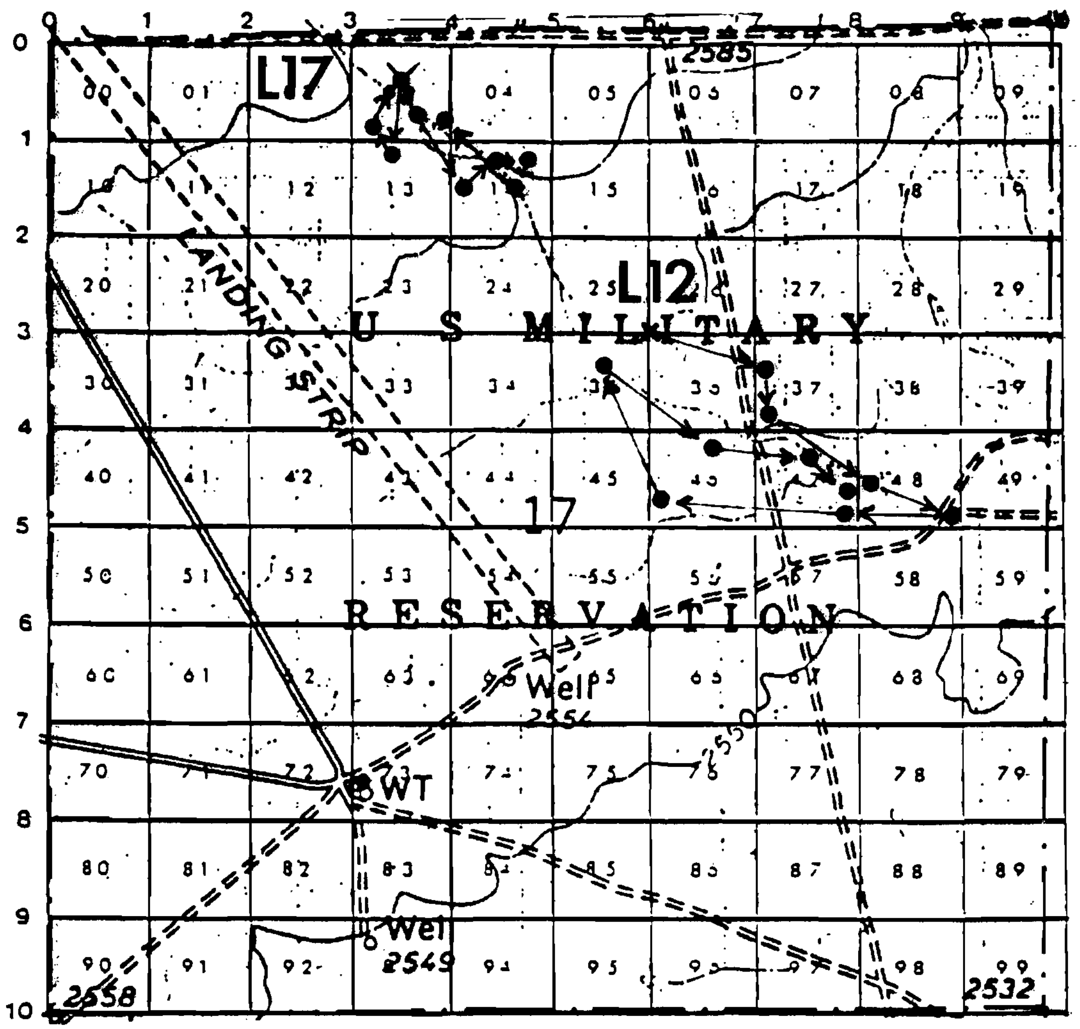

Figure 2. Movements of L12 F and L17 F during the first 9-10 days after relocation (L12 f: 5/4-5/14/87; L17 F: 5/6-5/15/87). X is the release point, arrows show direction of movement. Grid interval = 161 m.

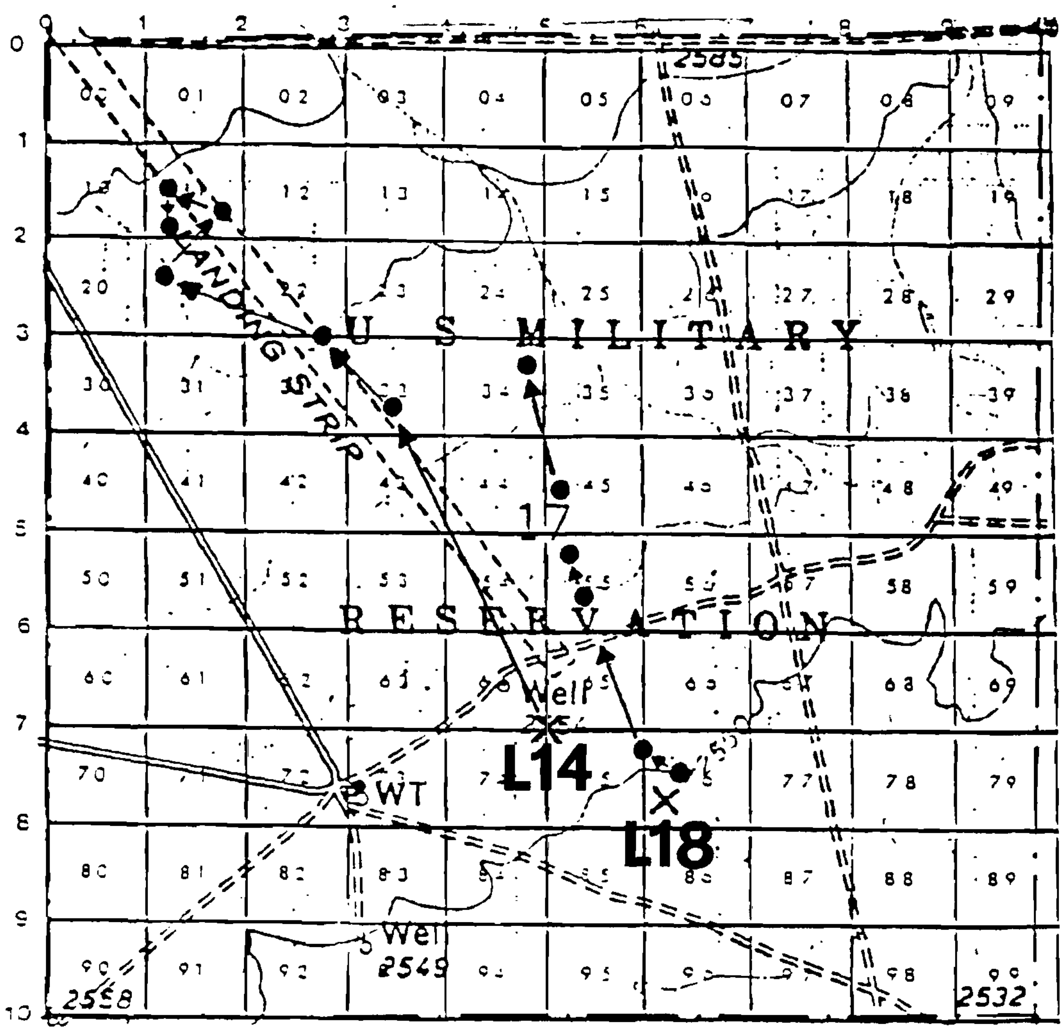

Figure 3. Movements of L14 F and L18 M during the first 10 days after relocation (5/8-5/18/87; L14 F stayed in grid section 11 from days 6-10; L18 M stayed in grid sections 55 and 45 from days 3-9). **X** is release point, arrows show direction of movement. Grid interval = 161 m.

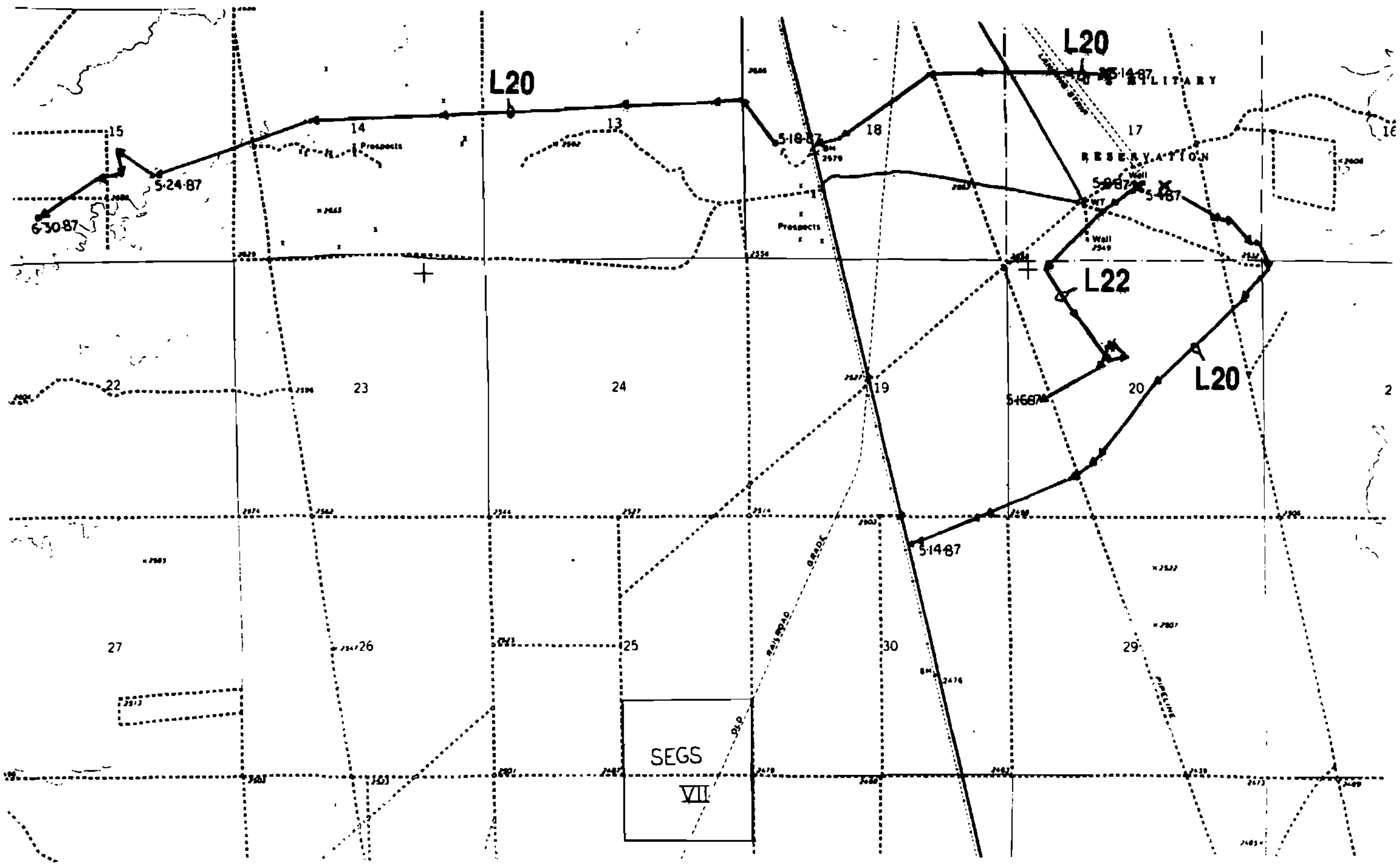

Figure 4. Long distance movements of L20 F and L22 F following relocation. **X** is release point, arrows show direction of movement. Grid interval = 1.61 km.

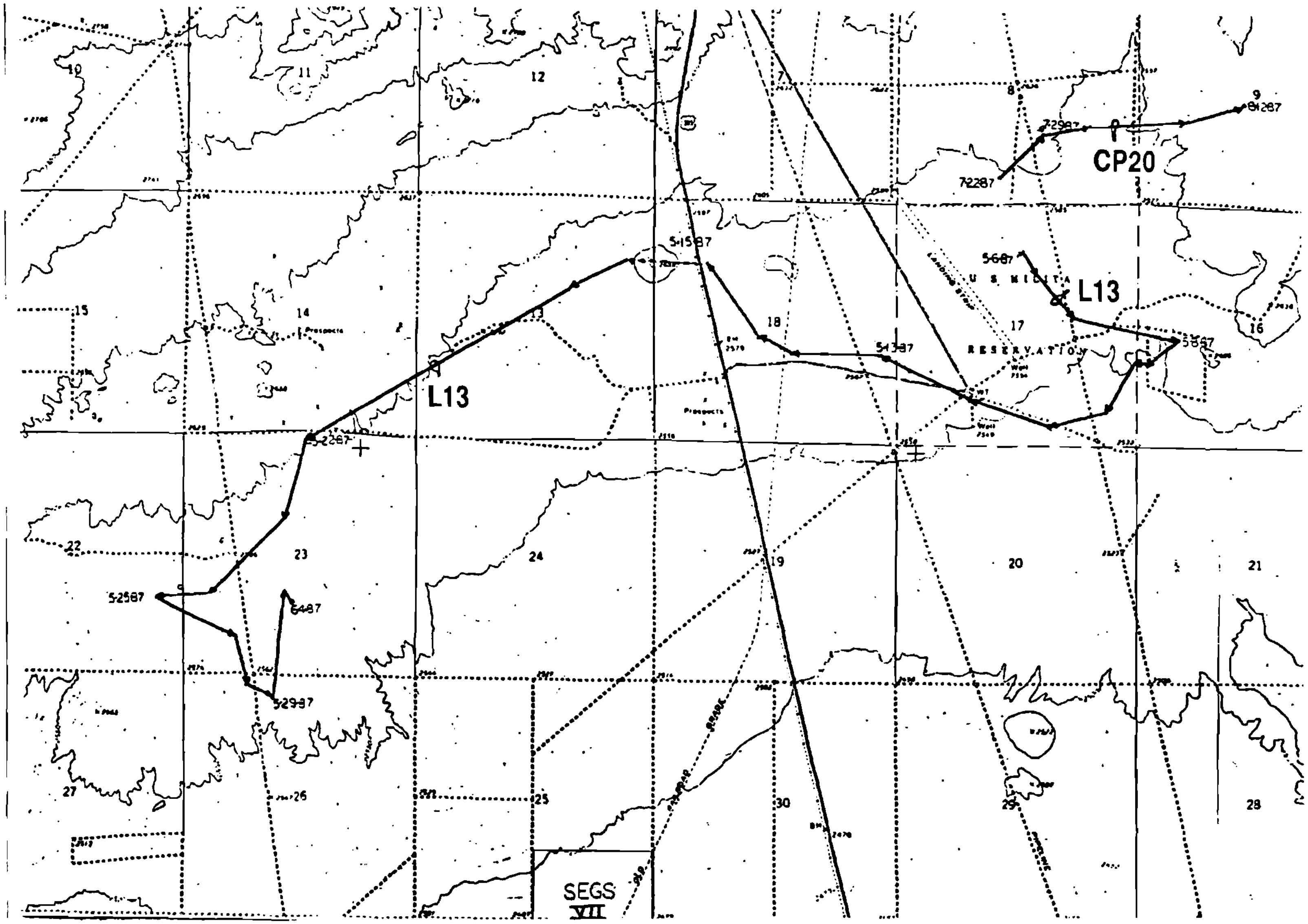

Figure 5. Long distance movements of L13 M following relocation and CP20 M following a two month sedentary period. X is release point, arrows show direction of movement. Grid interval = 1.61 km.

another 43 days, it had reached a location 6,650 m west of its second release point. By early July 1987, L20 F had settled down in a new area, and it remained there until it disappeared in April 1988.

During the first two days after its release, L13 M moved southeast a distance of 1,210 m. Then it abruptly doubled back. Nine days after its release it was close to the eastern side of U. S. 395 and 2,056 m due west of the release point. During the next seven days, it crossed the highway and moved 2,973 m to the southwest. Finally, during the following 13 days, L13 M moved in an irregular circle to the south and temporarily settled down in an area about 5,500 m southwest of the release point. Later in the summer, L13 M returned erratically to the northeast and disappeared in September at a point 2,859 m west of its release point. One resident tortoise (CP20 M) also made a long distance move. After being relatively sedentary for two months, it moved 1,620 m in 21 days (Fig. 5).

Three Day and Final Locations: By three days after their release, there was a wide range of variation in the distances traveled by the 12 relocated tortoises (Table 1). For example, L17 F covered only 116 m while L13 M moved l,007 m. The mean angle calculated for the direction of movement relative to "home" (0°) was not significant - i.e., there was no mean direction for the sample ($P > 0.05$). There also was a wide range of variation in the distances moved by relocatees and residents after approximately three to 18 months (Table 2). Thus, the difference between the mean distances of relocatees (1,253 m, SD ±1,758) and residents (736 m, SD ±519) was not significant ($P > 0.05$). If the long distance movements of L13 M and L20 F are deleted, the mean distance for the relocatees was only 659 m (SD ±518). The mean angle for the final locations was not significant ($P > 0.05$).

Of the six relocatees for which there are appropriate data (L12 F, L14 F, L15 M, L17 F, L24 F, and L26 M), four (L12 F, L14, F, L17 F, and L24 F) evidently had settled by 10 days after their release because they still were within 160 m of their seven to 10 day locations at the end of 18 months. Eight of the nine relocatees monitored for at least 18 months settled within 1,000 m of their initial release points. It is notable that L5 F and L7 F, the only individuals monitored from the group of six relocated in 1986, remained on the site for most of the study period (see Appendix 1).

The behavior noted in relocatees within the first hour of their release was similar to that described by Berry (1974). Berry (1974, 1975a, 1975b) also reported considerable variability in the movement patterns of relocatees during the first few days after their release. Some individuals settled, some circled, others moved in straight lines for long distances, and still others apparently moved at random. Berry (1974), Burge (1977) and Medica et al. (1982) all observed that resident tortoises may move several hundred meters in a day, often in straight lines. The latter authors reported that one male moved 3.1 km in 16 days. The function of such long distance movements is not known, but it is clear that long distance and straight line movements are not necessarily the result of being in unfamiliar territory. They also are made by tortoises that already have established activity areas. The utilization of activity areas by tortoises is well-documented (Berry,1986; Chelazzi and Carl, 1986; Geffen and Mendelssohn 1988). In the desert tortoise, activity areas may be as large as 70 to 80 ha (Turner et al. 1981; Medica et al. 1982) or more (Berry 1986).

The two relocatees (L20 F and L13 M) that moved very long distances (over 5,500 m) in the first 30 to 60 days following their release, and L22 F, whose transmitter failed after eight days, may have been searching for home. However, the directions and distances recorded for most relocatees after three days and after 3.5 to 18 months did not indicate a definite homing tendency. Chelazzi and Francisci (1979, 1980) and Chelazzi and Delfino

(1986) demonstrated homing ability in Hermann's tortoise (*Testudo hermanni*) over distances up to 1.5 km. Lohoefener and Lohmeier (1986) reported that three of 18 relocated gopher tortoises (*Gopherus polyphemus*) homed over a distance of 1.5 km in one season. However, other examples of homing in tortoises are few in number, generally over no greater distances, and mostly anecdotal in nature (Berry 1986).

Berry (1974, 1975b, 1986) believed that some of her relocated desert tortoises showed a tendency to orient toward home, but the data were equivocal and complicated by the fact that the relocatees were temporarily kept in holding pens at a location different from their home site. As there is some evidence of Type II (sun-compass) orientation in tortoises (Berry 1986), a better performance by relocated tortoises in the present study would be expected if they had been making a real effort to home. However, it is possible that handling procedures may have impaired the relocatees' homing ability.

Weights and Mortality

Weights of Relocatees Before and After Artificial Hibernation: During their artificial hibernation in Pomona, December 1986 to April 1987, all tortoises lost weight. Except for L22 F and L18 M, weight losses were minimal (mean loss for 11 = 1.5%). L22 F lost 256 g (7.2%) and L18 M lost 421 g (11.9%) of body weight. During the following week in which the tortoises had access to unlimited amounts of food and water, most gained weight (mean gain for 10 = 7.7%), but L16 F, L19 F, and L18 M continued to lose up to another 1.1%. However, there was no apparent correlation between the weight changes of tortoises during captivity and their later weights or survival.

Weight Changes in the Field: While there is so much variation within the small samples of relocated and resident tortoises relative to the amount and direction of both short and long term weight changes that no statistical evaluation of the data is possible, some observations and interpretations can be presented. During the period from May through July 1987, which represents the first three months following their release, seven of the 13 new relocatees lost weight (five females and two males), four gained weight (two females and two males), and two females showed no change. Of the two residents monitored during this time, one gained weight and one declined slightly. L5 F, which had been on the site for a year, also declined slightly.

The greatest weight loss (13.6%) in a relocatee during the May through July 1987 period was exhibited by a female and the greatest gain (18.9%) by a male. Substantial weight losses in females (>10%) during this period may be indicative of egg laying. Although none of the 12 relocated females X-rayed in the laboratory in late April 1987 showed evidence of producing eggs, three of the four females exhibiting substantial losses (L16, L17 , and L21) are known to have laid eggs. The fourth female known to have laid eggs (L24) showed a 5.1% weight gain. Since field observations and rainfall data from nearby Edwards Air Force Base (EAFB) indicate that a significant rain occurred at the study site in June 1987, it is possible that this female was able to obtain enough water at that time to more than compensate for a weight loss due to egg laying. Following egg laying, weights tended to stabilize or increase, but the weight of L21 F continued to decline and it was found dead on 19 August 1987. After a major weight recovery, the weight of L16 F again declined and it was found dead on 29 August 1987. All six of the relocatees that were weighed again in May 1988, including L5 F, gained weight compared to May 1987.

Comparing tortoise weights from one fall to the next gives an indication of how well the tortoises fared during the course of each year - 1987, 1988, and 1989 (Table 3). During

Table 3. Fall to fall weight changes of tortoises in the field: 1986 to 1989.

Tortoise	Wt. g Dec. 1986	Wt. g Sep./Oct. 1987	Wt. g Nov. 1988	Wt. g Aug./Oct. 1989	Dec. '86- Sep./Oct. '87 Diff. g	Diff. %	Sep./Oct. '87- Nov. '88 Diff. g	Diff. %	Nov. '88- Aug./Oct. '89 Diff. g	Diff. %
L5F	2690*	3530	3190	-----	+840	+31.2	-340	-9.6	-----	-----
L7F	2840*	-----	2980	2265	-----	-----	-----	-----	-715	-24.0
L12F	3290	3650	3610	3015	+360	+10.9	-40	-1.1	-595	-16.5
L13M	3540	3655	-----	-----	+115	+3.3	-----	-----	-----	-----
L14F	2390	2585	2250	2510	+195	+8.2	-335	-13.0	+260	+11.6
L15M	2940	2650	2990	2565	-290	-9.9	+340	+12.8	-425	-14.2
L17F	2640	2855	2750	-----	+215	+8.1	-105	-3.7	-----	-----
L18M	3540	3515	-----	-----	-25	-0.7	-----	-----	-----	-----
L20F	3190	3655	-----	-----	+465	+14.6	-----	-----	-----	-----
L23F	1940	2650	2510	2120	+710	+36.6	-140	-5.3	-390	-15.5
L24F	1940	2255	2300	1920	+315	+16.2	+45	+2.0	-380	-16.5
L26M	-----	3275	3070	2715	-----	-----	-205	-6.3	-355	-11.6
CP6F	-----	-----	2070	1665	-----	-----	-----	-----	-405	-19.6
CP16M	-----	-----	3750	3215	-----	-----	-----	-----	-535	-14.3
CP25M	-----	-----	2190	1990	-----	-----	-----	-200	-----	-9.1
Mean	2813	3116	2805	2398	+303		-311		-407	
SD	±565	±524	±556	±496						

*Weights in December 1985

1987, seven of the nine new relocatees that were monitored gained weight. L5 F also gained relative to its fall 1985 weight. The two tortoises that lost weight were males. During 1988, L5 F. and five of the seven new relocatees monitored lost weight. One of the tortoises that gained was a male and one was a female. Finally, of the six new relocatees monitored through 1989, five lost weight. L5 F showed a decline and was found dead in July. L7 F, which was relocated with L5 F in 1986, also lost weight, as did the three residents that were monitored. Weight losses of the residents were of about the same magnitude as those of the relocatees. Only L14 F gained weight in 1989.

A comparison of the initial capture weights and final fall weights of six relocatees, five monitored for at least 32 months (December 1986 - August 1989) and one monitored for 46 months (December 1985 - October 1989), shows that four lost weight (three females and one male) and two gained (both females; Table 4). However, only in L7 F and L15 M did the losses exceed 10%. Five of these six tortoises were weighed again in July 1990 when their transmitters were removed. Four had continued to decline somewhat, but L15 M had gained 18.9%.

Beatley (1974) discussed the relationship between seasonal rains and the growth of annual plants. This relationship is one that, based on the rainfall data from EAFB, suggests moderate production of tortoise forage in the spring of 1987, good production in the spring of 1988, and poor production in the springs of 1989 and 1990. The EAFB rainfall data also indicate some late summer and early fall rains. Thus, observed weight gains in spring months probably were due to the availability of adequate amounts of forage, and the observed recovery or stabilization of weights during summer and early fall months probably was made possible by the opportunistic utilization of rain water (Nagy and Medica 1977; Medica et al. 1988). The tendency for tortoises to lose weight from late 1988 to mid-1990 likely was due to the prevailing drought conditions.

Berry (1974) predicted that desert tortoise weights should increase in the spring and decrease through the summer and fall, with fluctuations superimposed on this general curve by egg laying, drinking, and defecation. Of the 11 resident tortoises that she monitored in the Western Mojave Desert from spring to fall in 1972, eight lost weight, two gained, and one stayed the same. In six of the eight weight losers, the losses exceeded 10% (maximum 16.9%). The weight gainers increased by 20% and 28.6%. The three relocatees in Berry's study also lost weight, though not as much as the residents. Turner et al. (1981, 1984) and Medica et al. (1982) described weight changes in a population of desert tortoises in Ivanpah Valley of the Eastern Mojave Desert, California. In the late spring of 1980, a good forage year, males tended to gain 6-7% in weight while females tended to lose 5-6%. Weight losses in females were associated with egg laying, and some females recovered weight after laying. In the same season of 1981, a poor forage year, both sexes tended to lose weight through June, and weight losses in females went up to 20.5%. No weights were recorded in either year after June.

Weight changes of relocated and resident tortoises in the present study were about the same as found in the above studies. Significantly, relocated tortoises performed in a manner similar to residents.

Mortality Rates: Only transmittered tortoises can give reliable data on mortality and survival rates. Due to early transmitter failures on two of the relocatees (L22 F and L25 F), only 14 relocated tortoises, counting L5 F and L7 F (see Table 2) were potentially available for monitoring for at least 3.5 months during 1987. Of these 14 tortoises, two died in August 1987 (LI6 F and L21 F), one had a transmitter failure in September (L18 M), and two

Table 4. Initial capture weights and final weights of 6 relocated tortoises monitored for at least 32 months (December 1986 to August 1989) and 5 relocated tortoises monitored for at least 43 months (December 1986 to July 1990).

Tortoise	Wt. g Dec. 1986	Wt. g Aug./Oct. 1989	Dec.'86-Aug./Oct.'89 Diff. g	Diff. %	Wt. g July 1990	Aug./Oct.'89-July'90 Diff. g	Diff. %
L7F	2840*	2265	-575	-20.3	2200	-65	-2.9
L12F	3290	3015	-275	-8.4	-----	-----	-----
L14F	2390	2510	+120	+5.0	2500	-10	-0.4
L15M	940	2565	-375	-12.8	3050	+485	+18.9
L23F	1940	2120	+180	+9.3	2050	-70	-3.3
L24F	1940	1920	-20	-1.0	1860	-60	-3.1
Mean	2557	2399	-158				
SD	±557	±386					

*Weight in December 1985

presumably were poached, one in September (L13 M) and one the following spring (L20 F). Thus, only nine relocatees were available for monitoring during 1988 (see Table 2 and Appendix 1). No losses occurred among these tortoises during that year and the same nine tortoises were available for monitoring in 1989. However, L5 F died in June 1989 and on 23 May 1989 L17 F was discovered to have symptoms of Upper Respiratory Disease (URD). L17 F was removed from the study site on 6 June 1989 and was later confirmed by Walter Rosskopf (pers. comm.) to have URD.

If the URD tortoise is counted as a mortality, then during the course of the principal 29 month (May 1987 to October 1989) period of monitoring relocated tortoises the total mortality rate was 4/14 or 28.6%. Annualized mortality rates for the relocatees during the three study years were: 1987 - 2/14 (14.3%), 1988 - 0/9 (0%), and 1989 - 2/9 (22.2%).

No transmitter failures or deaths are known to have occurred among the 11 resident tortoises monitored for various lengths of time during the same 29 month period, but four may have been poached in 1987 and 1988 (see Appendix 2 and below). Ten residents were monitored for at least 2.75 months, but because residents were not monitored as consistently as relocatees, the data for them are not easily compared. Nevertheless, it is important to note that one resident (CP29 M) was found dead on the study site in late February 1990 and another (CP6 F) in early June 1990. Thus, a total mortality rate for residents monitored during the study can be calculated as 2/10 (20%). In July 1990, one of the two residents located (CP9 M) appeared extremely emaciated and may not have made it through the summer.

Turner and Berry (1986) estimated annual mortality rates for desert tortoises in the Eastern Mojave Desert population at Goffs, California between the years 1977 and 1984. The values they calculated for adults ranged from 3% to 11% in females and 6% to 16% in males. In the Ivanpah Valley population studied by Turner et al. (1984), mortality rates for females and males in a good year were 4.2% and 4.7%, respectively. In a poor year, they were 19.2% and 16.7%. Considering that the samples of relocatees and residents in the present study were very small, and that the tortoises were subjected to severe drought conditions, the mortality rates observed are consistent with those cited above.

Mortality Factors: It is impossible to determine the cause of mortality for any of the dead tortoises. L16 F and L21 F were found on their backs, dried and partly dismembered (heads, some limbs, and viscera missing). Photos of CP6 F, provided by Marc Sazaki, show it in the same condition. All three of these tortoises evidently had been utilized by scavengers (probably kit foxes, coyotes, or ravens), and the carcass of CP6 F had been pushed or pulled along the surface for some distance. The remains of L5 F were found in and around a burrow it had been known to frequent, and there were tooth marks on some bones and carapace scutes. However, it is not known if these tortoises were initially killed by predators or if they died from other causes and subsequently were scavenged. The carcass of CP29 M was upright, in an advanced stage of decomposition, and did not appear to have been preyed upon or scavenged.

Factors that may have predisposed the relocated tortoises to mortality include the stresses of captivity (transportation, artificial hibernation, repeated handling), being returned to an unfamiliar location, drought conditions, and URD. Since one tortoise is known to have contracted URD, it is possible that this disease was a predisposing factor in some of the other mortalities observed (e.g.CP29 M).

Poaching: Two clear cut cases of poaching of transmittered tortoises were documented in this study, and it is believed that at least five other transmittered tortoises may have been poached as well (see Appendices 1 and 2). On 12 August 1987, the transmitter of CP20 M was found lying on the ground in an isolated location about 1 km northeast of the relocation study site. The transmitter obviously had been forcibly removed from the tortoise and the tortoise was missing. Human footprints were seen ranging over an area of about 1 ha in the vicinity of the transmitter. The second clear cut case of poaching involved CP28 M. This tortoise was equipped with a transmitter on 8 May 1988 near the west side of the study site. It evidently was picked up on 26 May 1988, just before the Memorial Day weekend. About five weeks later, the Long Beach Office of CDFG informed the author that a tortoise bearing CDFG identification and the number CP28 was seen in the possession of a motorist passing through an agricultural inspection station at the Idaho border.

Social Interactions

Courtship and Mating: Courtship and/or mating was observed on at least 20 occasions. Most of these encounters were observed for only a short time, but they ranged from simple approaches of females by males, with characteristic head bobbing, to actual mounting. Since the encounters were observed from a distance, no attempt was made to determine in which cases the males actually achieved intromission.

A majority of the courtship/mating encounters involved male residents interacting with female relocatees, and most of the remaining cases involved male and female relocatees. This distribution of observed courtship/mating encounters is due to the disparate sex ratios in the populations of relocatees and residents, and especially in the samples of relocatees and residents that were transmittered. Fourteen of the 22 adult relocatees were females (M : F = 1 : 1.75) while 16 of the 26 sexually mature residents, counting one subadult, were males (M : F = 1.60 : 1). Only four of the 16 transmittered relocatees were males and only one of the 11 transmittered residents was a female (see Appendices 1 and 2).

Agonistic Behavior: Eight instances of agonistic behavior were noted. They ranged from actual fights to chases. Chases may have been the end result of fights, but agonistic encounters usually were not observed in their entirety. All agonistic interactions were male-male encounters, and all except one were between residents. In July 1987, a portion of a confrontation between resident male CP9 and relocated male L26 was observed. CP9 was seen to chase L26 from the east-central part of the study site under the boundary fence 200 m to the southeast. At that point, the observation was terminated. L26 was the smaller of the two tortoises (see Appendices 1 and 2), but it returned to the study site within a few days. Both of these males continued to occupy the east-central part of the study site through the fall of 1989. While contact was lost with L26, presumably due to transmitter failure, CP9 was still in its usual area when located for transmitter removal in July 1990. The limitation of observed agonistic encounters primarily to resident males is due, again, to the relatively small number of relocated males.

Burrow Sharing: Well over 100 instances of burrow sharing were observed in 1987 and 1988. The vast majority of these instances involved two groups of tortoises, one comprised of two and the other of three relocated females, which regularly used certain burrows in preference to others. On some occasions, the burrow that evidently was preferred would be occupied by only one female while, on other occasions, it would be shared with one or both of the neighboring females. Sometimes burrow preference shifted back and forth between different burrows so that sharing among the same tortoises occurred in different burrows on different days. Tortoises also traded burrows. Resident males occasionally were found together with single relocated females, or in the burrows of females when the females were elsewhere.

Berry (1986) reviewed social behavior in desert tortoises. Males usually court and attempt to copulate with every female encountered. They know where females have their burrows and are able to locate females while, at the same time, avoiding encounters with other males. All age classes and both sexes exhibit agonistic behavior, but most agonistic encounters are between males. In such encounters, the larger individual usually is the aggressor and the dominant. Observations on social interactions in the present study were entirely consistent with this review. However, there is little information on burrow sharing in desert tortoises. Patterson (1971) described it in captives, and Woodbury and Hardy (1948) reported that deep hibernation dens in Utah often contained several tortoises.

Effectiveness of this Relocation Effort

Number Remaining Through Time: One way to evaluate the success of a relocation effort is to look at how many of the relocated animals remained on or near the relocation site after a period of time. Of the 16 tortoises available for monitoring, three immediately dispersed, two died within four months, and the transmitters of two more failed by the fall of 1987. At the end of seven months, this left nine (56.3%) in the study area that could be monitored. The same nine individuals remained in the area in the fall of 1988, after 18 months. Two died in 1989 (counting one removed with URD), leaving seven (43.8%) after 29 months. Between October 1989 and late July 1990, another transmitter failed and one tortoise was presumed poached. After 39 months, then, five (31.3%) remained in the study area. Note that these are minimum estimates of numbers remaining because it is possible that one or more of the tortoises whose transmitters failed could still have been present but undetected.

In view of the severe drought conditions that prevailed from late 1988 through 1990, these results compare favorably with those described by other researches. Three researchers working with the gopher tortoise (*Gopherus polyphemus*) in the southeastern United States reported generally similar percentages of tortoises remaining at relocation sites: Burke (unpubl. data) - 26/75 (34.7%) after one year; Landers (unpubl. data) - 32/79 (41.5%) after three years; Diemer (1984) - 7/24 (29.2%) after five years. Lohoefener and Lohmeier's (1986) studies with gopher tortoises are not comparable, and there are few comparable studies on desert tortoises. Stewart and Baxter (1987) reported that, over a two year period, 10 out of 11 desert tortoises marked and relocated a distance of about 450 m were recaptured, and that seven (63.6%) of them remained on the relocation site. However, some of these tortoises probably were relocated within their original activity areas. Berry (1986) reported that, of 12 desert tortoises taken from three different sites and relocated to a single site, six (50%) remained within 0.5 to 1.5 km of the relocation site for 0.5 to 12.5 months. In another relocation effort involving 31 tortoises taken from one site and moved 27.4 km, 10 (32.3%) remained within 1.3 km for one month to six years (Berry 1986).

Assimilation of Relocatees into Host Population: Berry (1986) suggested that a more biologically sound approach to measuring the success of a relocation effort is to look simultaneously at survival of the relocated and host populations, and at assimilation of the relocatees into the host population. She expressed concern that relocatees might disrupt the existing social system and/or cause the combined populations to exceed the carrying capacity of the relocation site.

While data on the host population in this study are very limited, they indicate that, considering known mortalities, survival rates of transmittered relocatee and residents monitored to July 1990 were not substantially different (71.4% and 80%, respectively). Because of the fortuitous, complementary imbalance in the sex ratios of relocatees and residents, it is unlikely that there was any disruption of the existing social system of the host population. In fact, most of the females probably were assimilated into the social system and improved it. Berry (1986) stated that, next to hatchlings and juveniles, female relocatees may be expected to have the lowest potential for disturbing the existing social structure. At least two of the four monitored males also remained with the resident population, evidently harmoniously, for 29 months or more.

So far as carrying capacity is concerned, it is difficult to say what impact the relocatees may have had. Sheep grazing and off-road vehicle activity clearly have degraded the habitat in the study area, and undoubtedly they have reduced tortoise carrying capacity from what it was 10 or 15 years ago. Still, the mortality rates observed among both relocatees and residents during the study period do not seem excessive when viewed in terms of the drought. While the drought, in effect, probably reduced the habitat's carrying capacity in the short term, there is no evidence that the relocation necessarily exceeded the habitat's carrying capacity over the long term.

Comments and Recommendations: This relocation project was not planned. It evolved under the selective forces of the San Bernardino County Planning Department, Desert Tortoise Council (DTC), California Department of Fish and Game (CDFG) and, most importantly, California Energy Commission (CEC). Most tortoises literally had to be excavated from their hibernation burrows shortly before SEGS sites were graded. The CDFG property was the only place available to relocate these tortoises.

In spite of this, the project did meet most of the criteria that Berry (1975b) felt were important for the success of a relocation effort: The relocation site was in an area where tortoises already occurred; the habitat there fairly closely matched the habitat from which the tortoises were taken; the relocated and resident tortoises were part of the same gene pool; and disturbance of the host population's social structure probably was minimal due to the sex ratios of the respective populations. An advantage the relocation site had over others that have been used for desert tortoises is that it was somewhat protected by the sheep exclusion fence, gates, signing, and designation as an ecological preserve. However, it was not large enough to contain those tortoises that tended to disperse.

I agree with Berry (1975b, 1986) in recommending that relocation projects should be undertaken with careful advance planning to ensure that the above criteria are met as closely as possible. If it is not likely that a majority of these criteria can be met, then a proposed relocation probably should not be undertaken. It is unlikely that these criteria can be met in cases were large numbers of tortoises (100 or more) would be relocated. Also, I recommend that the collection and release of tortoises be carried out during spring months so as to minimize the handling and stress of the relocatees. Further, it would be advisable to have a qualified veterinarian examine the intended relocatees to certify, in so far as possible, that they are free of URD and other potentially contagious diseases.

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Encouragement for the study came from the DTC, CDFG, and CEC. Marc Sazaki of the CEC supported the project with his interest and enthusiasm from the time the CEC became involved in 1986. Jim St. Amant and Frank Hoover of the CDFG were very helpful in getting the fence erected around the relocation site, and in other aspects of the project's early stages in 1987. Betty Burge supervised construction of the hibernaculum at EAFB. The cooperation of Mike Phillips and Chris Rush of EAFB is gratefully acknowledged.

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Appendix 1. Roster of Tortoises Relocated from LUZ SEGS III-VII.

No.	Sex	MCL* (mm)	Wt* g	Date Removed	Date Relocated	Freq. 150 MHz	Comments
L1	M	274	3790	12-15-85	3-24-86	-------	Found dead on site 4-20-87 by Uptain and Karl
L2	F	238	2390	12-15-85	-------	-------	Escaped from Edwards AFB late Feb. 1986
L3	M	295	4340	12-15-85	3-24-86	-------	Not seen after March 1986
L4	F	238	2590	12-15-85	--------	-------	Escaped from Edwards AFB late Feb. 1986
L5	F	265	2690	12-15-85	6-3-86	.020, .850	Escaped EAFB Feb. 1986; recaptured El Mirage 5-21-86; transmittered 5-22-87; new transmitter 11-9-88; scattered remains on site 10-2-89
L6	M	268	3390	12-15-85	3-24-86	-------	Last seen on site 5-6-87
L7	F	246	2840	12-15-85	3-24-86	.180	Seen on site 4-19-87 by Uptain & Karl; transmittered 5-5-88; on site 7-31-90, transmitter removed
L8	M	231	1940	12-15-85	3-24-86	-------	Not seen after March 1986
L9	F	241	2890	7-30-86	7-31-86	-------	Relocated 3.2 km NW SEGS V; not tracked
L10	F	238	2490	7-30-86	7-31-86	-------	Relocated 3.2 km NW SEGS V; not tracked
L11	F	252	3040	11-2-86	5-4-87	-------	Not seen after release
L12	F	268	3290	12-18-86	5-4-87	.690, .880	New transmitter 11-9-88; last seen on site 11-10-89; presumed poached
L13	M	277	3540	12-18-86	5-6-87	.510	Last seen 2 km W of site 9-22-87; presumed poached
L14	F	237	2390	12-18-86	5-8-87	.870, .890	New transmitter 11-9-88; on site 7-31-90, transmit. removed

Appendix 1. Roster of Relocated Tortoises (contd.)

No.	Sex	MCL* (mm)	Wt* g	Date Removed	Date Relocated	Freq. 150 MHz	Comments
L15	M	253	2940	12-18-86	5-4-87	.430, .900	New transmitter 11-9-88; on site 7-17-90, transmit removed
L16	F	253	2840	11-18-86	5-4-87	.920	Dead 0.8 km W of site 8-29-87
L17	F	250	2640	12-18-86	5-6-87	.820, .930	New transmitter 11-10-88; URD symptoms 5-23-89; removed 6-6-89
L18	M	259	3540	12-18-86	5-8-87	.470	Last seen on site 9-14-87; presumed transmitter failure
L19	F	252	2890	12-18-86	5-8-87	--------	Not seen after release
L20	F	266	3190	12-18-86	5-4-87	.630	Last seen 5.8 km W of site 4-14-88; presumed poached
L21	F	242	2440	12-18-86	5-6-87	.750	Dead 0.5 km N of site 8-19-87
L22	F	259	3540	12-18-86	5-8-87	.800	Last seen 0.8 km S of site 5-16-87; transmitter failed
L23	F	234	1940	12-18-86	5-6-87	120, .940	Transmittered 6-4-87; new transmit 11-10-88; on site 7-31-90, transmitter removed
L24	F	223	1940	12-18-86	5-6-87	.840, .950	New transmitter 11-10-88, 0.5 km W ofsite; same location 7-17-90, transmit. removed
L25	F	249	2700	3-11-87	5-8-87	.550	Last seen 0.8 km N of site 6-23-87; transmitter failed
L26	M	256	3000	5-16-87	5-24-87	.040, .970	New transmitter 11-10-88; last seen onsite 10-2-89; presumed transmt. failure
L27	unk	52	31	5-16-87	5-23-87	--------	Juvenile; not seen after release
L28	unk	65	60	5-17-87	5-23-87	--------	Juvenile; not seen after release

*MCL and weight at first capture

Appendix 2. Roster of Tortoises Resident on or Near Relocation Site.

No.	Sex	MCL* (mm)	Wt* g	Date of • Ist Capture	Freq. 150 MHz	Comments
CP1	F	233	--------	4-13-87	--------	Not seen after first capture
CP2	M	260	--------	4-13-87	--------	Not seen after first capture
CP3	F	246	--------	4-13-87	--------	Last seen on site 5-8-87
CP4	F	245	--------	4-14-87	--------	Not seen after first capture
CP5	F	243	--------	4-15-87	--------	Last seen on site 5-8-87
CP6	F	228	--------	4-15-87	.260	Transmittered 6-30-88; on site 11-6-88; found dead on site 6-1-90 by Marc Sazaki
CP7	M	273	--------	4-16-87	--------	Last seen on site 5-8-87
CP8	M	239	--------	4-19-87	--------	Not seen after first capture
CP9	M	286	--------	4-19-87	.360, .790	Transmittered 5-24-87; new transmitter11-11-88; on site 7-31-90, transmitter removed
CP10	M	286	--------	4-19-87	--------	Not seen after first capture
CP11	F	237	--------	4-19-87	--------	Not seen after first capture
CP12	F	272	--------	4-20-87	--------	Not seen after first capture
CP13	F	245	--------	4-20-87	--------	Not seen after first capture
CP14	M	292	--------	4-21-87	.450, .910	Transmittered 6-19-87; new transmitter 11-11-88; on site 7-17-90, transmitter removed
CP15	F	210	--------	4-21-87	--------	Not seen after first capture
CP16	M	280	--------	4-22-87	.280	Transmittered 9-30-88; last seen on site 11-10-89
CP17	F	268	--------	4-23-87	--------	Not seen after first capture
CP18	M	272	--------	4-23-87	--------	Not seen after first capture

Appendix 2. Roster of Resident Tortoises (contd.)

No.	Sex	MCL* (mm)	Wt* g	Date of• 1st Capture	Freq. 150 MHz	Comments
CP19	M	258	--------	4-23-87	--------	Not seen after first capture
CP20	M	276	--------	4-24-87	.060	Transmittered 5-19-87; last seen 1 km NE of site 8-5-87; poached
CP21	M	253	--------	4-24-87	.200	Transmittered 8-28-87; last seen 50 m W of site 7-13-88; presumed poached
CP22	NUMBER NOT USED			--------	--------	-------------
CP23	unk	130	465	5-7-87	--------	Last seen on site 5-7-87
CP24	M	192	1300	5-8-87	.090, .390	Transmittered 5-22-87, 160 m W of site; new transmitter 11-10-88; last seen same location 3-28-89
CP25	M	221	2190	5-18-87	.140	Initial capture 0.8 km W of site; transmittered 5-5-88; on site 11-6-88; last seen 0.3 km W of site 8-22-89
CP26	M	131	470	6-2-87	--------	Not seen after first capture
CP27	M	225	2235	10-5-87	.240	Transmittered 10-8-87; last seen on site 9-3-88; presumed poached
CP28	M	--------	3365	5-3-88	.160	Transmittered 5-5-88; last seen 5-25-88, poached and taken to Idaho
CP29	M	--------	2245	5-31-88	.220	Transmittered 6-7-88; on site 11-10-89; dead on site late Feb. 1990; possible URD

*MCL and weight at first capture

• Numbers CP01 - CP21 recorded by Uptain and Karl (1987)

Improvements in Radio Tracking of Desert Tortoises

Jack S. Stone and Michael J. Cornish

After two years of tracking desert tortoises (*Gopherus agassizii*) in Section 8 of the Desert Tortoise Natural Area, Fremont Valley, western Mojave Desert, new methods were developed to address specific problems encountered.

There was difficulty receiving a signal when tracking tortoises that were deep within a burrow, primarily due to reduced signal output from the AVM Instrument Company 1 & 2 stage Tortoise Sidecar Telemeters. This problem has not been fully overcome, because of the expense involved in replacing approximately 100 telemeters with newer, improved design telemeters available from AVM. Other causes of reduced signal were a radio shadow effect, antenna grounding on the walls of the burrow, and possible signal canceling when more than one telemetered tortoise was in a burrow.

Also, we continue to be plagued by frequency crowding of our transmitters. We have a large number of transmitters crowded into a 2 Mhz spread. Although each animal has a stated, discrete frequency; environmental conditions cause frequency drift, resulting in frequency overlap, leading to the tracking and recovery of animals close in frequency. An improvement would be to spread the telemeter frequencies over a wider range.

Problems were also encountered with the AVM SM1 Solar Transmitters used exclusively on hatchling and juvenile tortoises. Intense ambient light overcharged the nickel-cadmium battery, eventually destroying it. To overcome this problem, see instituted the use of a new design; and AVM solar transmitter with a partially occluded solar panel. Also, we will be testing another new AVM design; a zinc oxide cell-powered telemeter that utilizes atmospheric oxygen as a catalyst.

In our second year, we implemented the use of Telonics scanner-coupled receivers, allowing us to locate animals more quickly and efficiently.

Despite the problems cited, we have been remarkably successful in tracking and collecting data from a relatively large number of study animals, although at times due to these problems, intense effort was required to locate them.