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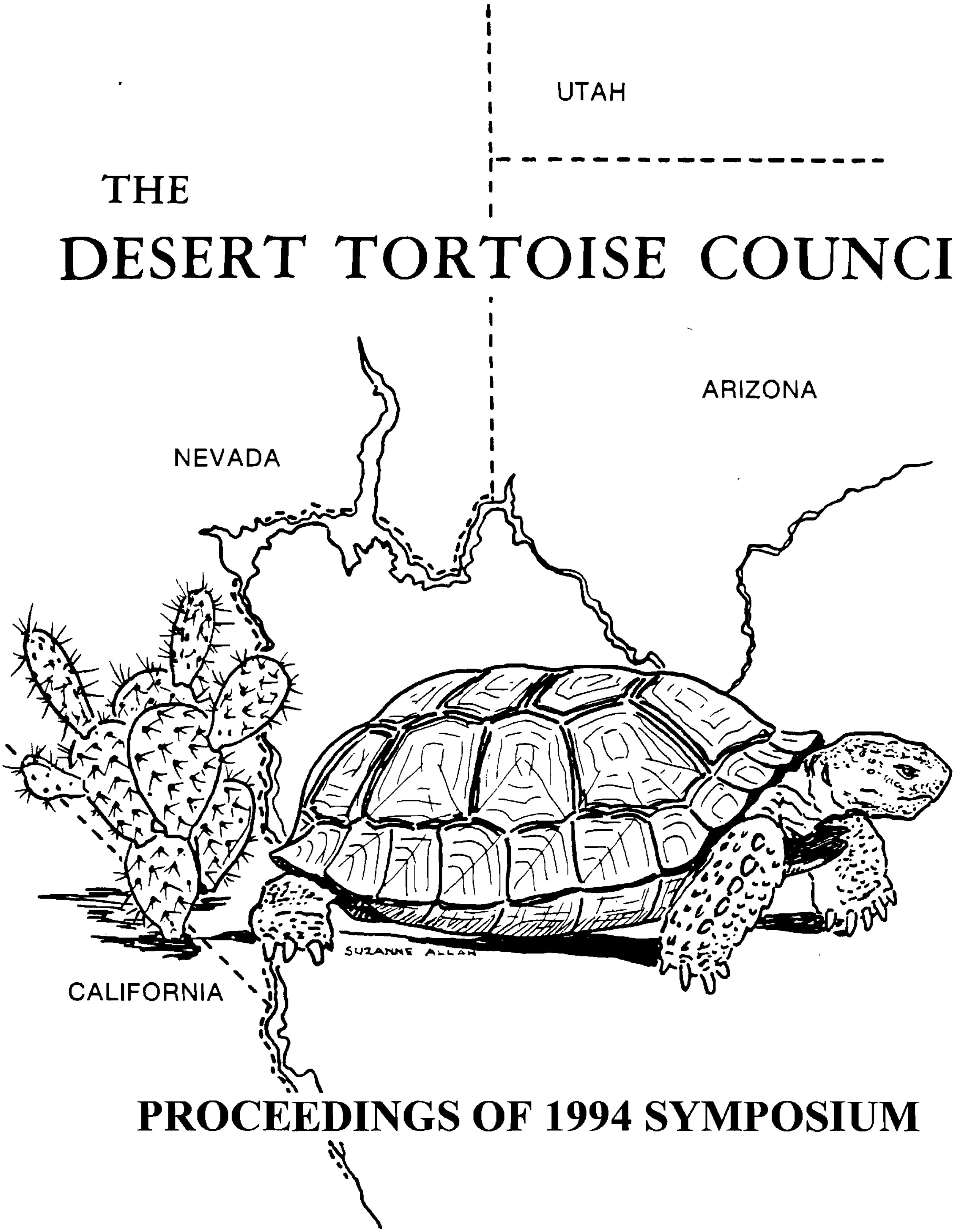

PROCEEDINGS OF 1994 SYMPOSIUM

DESERT TORTOISE COUNCIL

PROCEEDINGS OF 1994 SYMPOSIUM

A compilation of reports and papers presented at the 19th annual symposium

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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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The Wildlands Project Mission Statement for the North American Wilderness Recovery Project

Dave Foreman, The Wildlands Project, Tucson, Arizona

The Wildlands Project was established to help protect and restore the ecological richness of North America through the establishment of a connected system of reserves. We argue that existing National Park, Wildlife Refuge, Wilderness Area, and other preserve systems have failed to protect biological diversity because of fragmenttion and because areas have been selected for scenic and recreational considerations instead of habitat considerations. We propose the design and establishment of an international system of reserves (wilderness recovery networks) from Panama to Alaska based on a core wilderness/buffer zone/connecting corridor model. We base our proposal on the needs of large predators and other wide-ranging, sensitive species.

Health Studies Of Sonoran Desert Tortoises

Vanessa M. Dickinson

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.

Tortoises were sampled for health characteristics in three collection periods in 1993. Tortoises were captured and fitted with radio transmitters in 1990 with additional captures in 1993. 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 swabs, and fecal samples.

Little Shipp and Harcuvar tortoise populations exhibited the effects of site, sex, and season on hematology, clinical chemistry, electrolyte, osmolality levels, and bacteria. Parasites showed no effect of site, sex, or season. Eight bacteria, two of which were potential pathogens, were isolated from tortoise cloacae. One potential pathogen, *Pasteurella testudinis*, was detected in nasal aspirate. *Mycoplasma*-like colonies were isolated from the majority of tortoise nasal aspirate at both sites (91%). The identity of the *Mycoplasma*-like colonies is in question. An enzyme-linked immunosorbent assay (ELISA) for detecting *Mycoplasma agassizii*, the causative agent of Upper Respiratory Tract Disease (URTD), indicated three positive tortoises and four suspect tortoises in the Harcuvars (n = 19), and three suspect tortoises at Little Shipp (n = 24). No clinical signs of URTD were observed in tortoises at either site. Ninety-six percent of the tortoises sampled had nonpathogenic pinworm ova in their feces (n = 28).

INTRODUCTION

Concern for 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 (U.S. Fish and Wildlife Service [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 (Arizona Game and Fish Department [AGFD] 1988).

Understanding health of free-ranging desert tortoises is important in assessing and managing populations (Berry 1984). However, relatively little is known regarding desert tortoise physiology. Desert tortoises tolerate large temporary imbalances in their water, salt, and energy budgets (Dantzler and Schmidt-Nielsen 1966; Minnich 1977, 1982; Nagy and Medica 1986). Hematological and clinical chemistry values are available from several studies of captive and wild Mojave desert tortoises (Minnich 1977; Rosskopf 1982; Nagy and Medica 1986; Dickinson and Wegge 1991; Christopher et al. 1992a, 1992b, 1993; Dickinson and Reggiardo 1992a; Dickinson 1993a) and two studies of wild Sonoran tortoises (Dickinson and Reggiardo 1992b; Dickinson 1993b). Bacteriological culture results are available from many captive and wild Mojave tortoise 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; Christopher et al. 1992a, 1992b, 1993; Dickinson and Reggiardo 1992a; Dickinson 1993a) and two wild Sonoran tortoise studies (Dickinson and Reggiardo 1992b; Dickinson 1993b).

Primary objectives of this ongoing five-year study are to (1) establish baseline data on hematological, biochemical, bacterial, and parasitic values in two populations of desert tortoises, and (2) compare physiological variations due to site, sex, and season.

METHODS

Study sites

Two tortoise populations were studied in the Sonoran Desert; one from Little Shipp Wash, Yavapai County, Arizona (Schneider 1981), and the other from the Harcuvar Mountains, La Paz County, Arizona (Woodman and Shields 1988) (Figure 1). USFWS, Bureau of Land Management (BLM), and AGFD personnel selected these two sites in 1990 based on the knowledge of suitable wild tortoise populations and characteristic Sonoran Desert vegetation. Both study sites are 1 km from permanent desert tortoise study plots used for population and habitat monitoring.

Little Shipp Wash is 9.6 km southeast of Bagdad, Arizona. Elevations range from 788-975 m. Predominant plant species include little-leaf palo verde (*Cercidium microphyllum*), saguaro (*Carnegia gigantea*), ocotillo (*Fouquieria splendens*), mesquite (*Prosopis juliflora*), cat-claw acacia (*Acacia greggii*), fairy duster (*Calliandra eriophylla*), flat-topped buckwheat (*Eriogonum fasciculatum*), and Engelmann's prickly pear (*Opuntia engelmannii*) (Dickinson and Snider 1992). Grasses and forbs include red brome (*Bromus rubens*), Indian wheat (*Plantago insularis*), purple three-awn (*Aristida purpurea*), big galleta grass (*Hilaria rigida*), and slender janusia (*Janusia gracilis*) (Dickinson and Snider 1992). The Little Shipp Wash site is managed by the State of Arizona for multiple use including cattle grazing, hunting, and outdoor recreation.

The Harcuvar Mountain site is 24.1 km northwest of Aguila, Arizona. Elevations range from 792-1006 m. Harcuvar Mountain vegetation is characterized by saguaro, ocotillo, little-leaf palo verde, cholla (*Opuntia* sp.), fairy duster, flat-topped buckwheat, red brome, and Indian wheat as well as a small population of Joshua trees (*Yucca brevifolia*) (Dickinson and Snider 1992). The occurrence of prickly pear cactus is rare (Dickinson and Snider 1992). The Harcuvar Mountains are managed by the BLM for multiple use including cattle grazing, hunting, and outdoor recreation.

Physical parameters and rainfall

Climate data were based on automatic weather stations (Model System 10, Rainwise, Inc., Bar Harbor, ME) located at each site, and from permanent weather stations at Hillside and Aguila, Arizona (National Oceanic Atmospheric Administration [NOAA] 1992-1993). The automatic stations collected the following data at one point every hour: date, time, ambient temperature, humidity, rainfall, soil temperature, soil moisture, and average wind speed. Rainfall was recorded as the total for the hour. Soil moisture probes (Irrometer Company, Inc., Riverside, CA) recorded soil moisture in centibars on a scale of 0-200, where 0-10 indicated saturated conditions, and 100-200 indicated dry conditions. Monthly maximum and minimum values were averaged for all on-site weather variables. Since the automatic weather stations had occasional mechanical problems and were not operational for some periods in 1992 and 1993, permanent weather station data (NOAA 1992-1993) were obtained as a substitute for the missing periods. Data on average monthly maximum and minimum ambient temperature and average monthly rainfall were used from permanent weather stations.

General procedures

Three trips (April [spring], July [summer], September [fall]) were made to each site in 1993 to collect samples, and affix radio telemetry units to additional tortoises. Populations were compared by examination of blood and tissues taken from adult ($>$208 mm median carapace length [MCL]) tortoises encountered at each site. All radio-tagged adult tortoises were weighed, measured, marked if necessary, and a blood sample was taken. Swabs for bacteriological culture were taken and a fecal sample was obtained if possible.

Each adult tortoise was outfitted with a radio transmitter for recapture and tissue sampling in successive seasons and years. Model 125 transmitters (Telonics, Mesa, AZ) were affixed with 5-minute gel epoxy (Tru-Bond, Chicago, IL) to the anterior marginal scutes of adult tortoises. A maximum sample size of 15 radio-tagged tortoises was attempted at each site.

Tortoises were anesthetized using ketamine hydrochloride (15 mg/kg body weight) injected intramuscularly into the left rear leg using a 25-gauge x 5/8" needle, 20 minutes prior to the collection of blood and tissue. After tissue samples were taken, tortoises were rehydrated at the axillary notch with 1-2% body weight of equal parts Normosol (Abbott Laboratories, Chicago, IL) and 2.5% dextrose and 0.45% sodium chloride (Abbott Laboratories, Chicago, IL) to replace any fluids voided during handling. 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.

Sample collection

Blood samples (6 ml) were drawn by jugular venipuncture using 22-gauge x 3/4" needles. Packed cell volume (PCV) was determined in duplicate in the field using microcentrifugation. Two air-dried blood smears were made and sent to APL Veterinary Laboratories, Las Vegas, Nevada, for differential white blood cell (WBC) counts. An aliquot (0.6 ml) of whole blood was placed in a lithium heparin-coated microtainer for hemoglobin and fibrinogen determination. The remaining whole blood was put into a lithium heparin vacutainer and mixed for five minutes. Plasma was collected by centrifuging for five minutes. Plasma was placed in cryogenic vials (Whatman LabSales, Hillsboro, OR) and immediately frozen in liquid nitrogen. Four aliquots of plasma were assembled and mailed on dry ice to appropriate laboratories for analysis. The first aliquot (1.0 ml) was sent to Animal Diagnostic Laboratory, Inc., Tucson, Arizona, for blood chemistry determinations with a 550 Express Analyzer (Ciba-Corning, Oberlin, OH). Plasma was analyzed for 22 blood values: glucose, blood urea nitrogen (BUN), creatinine, uric acid, bile acid, total protein, albumin, aspartate aminotransferase (AST; SGOT), alanine aminotransferase (ALT; SGPT), alkaline phosphatase (ALP), calcium, total bilirubin, direct bilirubin, indirect bilirubin, cholesterol, triglyceride, chloride, sodium, phosphorus, potassium, carbon dioxide, and osmolality. A second aliquot (1.5 ml) was sent to Carlos Reggiardo, Arizona Veterinary Diagnostic Laboratory, University of Arizona, Tucson, Arizona, for analysis of copper, selenium, zinc, vitamin A, and vitamin E. A third aliquot of plasma (1.0 ml) was sent to Valentine Lance, San Diego Zoo, California, for analysis of corticosterone, estradiol, and testosterone. A fourth aliquot of plasma (0.5 ml) was collected and sent to Isabella Schumacher, Department of Infectious Diseases, University of Florida, Gainesville, Florida, for an enzyme-linked immunosorbent assay (ELISA). This test detects the antibody response of desert tortoises to *Mycoplasma agassizii*, the causative agent of Upper Respiratory Tract Disease (URTD). All plasma samples were kept in a liquid nitrogen tank prior to transfer to a dry ice mailing container. Samples on ice were express mailed to the respective laboratories within 24 hours of collection. Samples on dry ice were mailed to the laboratories within 2-3 days of collection.

One cloacal swab was taken from each tortoise and stored with Transtube (Medical Wire and Equipment Co., Dover, NJ). Swabs were placed on ice and sent to Animal Diagnostic Lab, Inc. for routine cultures. Cloacal swabs were used to make plates for gram stain and microscopic evaluation. Plates were incubated at room temperature and at 37^{o}C. Bacterial cultures were completed using blood agar, MacConkey agar (gram negative bacteria), Selenite agar (*Salmonella, Shigella*), Hektoen agar (*Salmonella, Shigella*), and Campylobacter agar (*Campylobacter*). Bacteria observed were classified as gram positive or gram negative and identified to species, if possible.

The nasal fossa of each tortoise was flushed with 0.25 ml of 0.9% sodium chloride (Abbott Laboratories, Chicago, IL) for recovery of bacteria from the upper respiratory tract. Saline aspirated from each nasal fossa was placed in a cryogenic vial containing 1.0 ml of tryptic soy broth (MicroBio, Tempe, AZ). The vial contents were slowly mixed and then immediately frozen in liquid nitrogen. Samples were sent to the University of Arizona Veterinary Diagnostic Laboratory for *Mycoplasma* and *Pasteurella* sp. cultures, and *Chlamydia* sp. isolation attempts. *Mycoplasma* sp. cultures isolated by the University of Arizona Veterinary Diagnostic Laboratory were sent to the Department of Infectious Diseases, University of Florida, Gainesville, FL, for genetic typing.

Fecal samples were collected and placed on ice. Fecal samples were kept on ice and express mailed to Animal Diagnostic Lab, Inc. within 24 hours of collection. Fecal samples were analyzed for parasites by direct microscopic examination and fecal flotation.

Statistical analyses

Data were summarized by calculation of means (x) and standard deviations (SD). Data were tested for normality with multivariate analysis of variance (MANOVA) probability plots (SPSS Inc.; Norusis 1988). Most variables were normally distributed and were analyzed with parametric tests. Tests for significance between sites and sexes were analyzed by two-tailed *t* tests (T-TEST, SPSS Inc.; Norusis 1988). As blood characteristics differ in response to sex (Dickinson 1993a, 1993b), and the proportions of males and females at both sites were not equal, sites were analyzed by comparing Little Shipp males with Harcuvar males, etc. Seasonal variation was analyzed by a one-way ANOVA (ONEWAY, SPSS Inc.; Norusis 1988). Variables without complete data sets were not statistically analyzed. Significance was judged at $P < 0.05$. Statistical tests performed for this study assume independence of blood variables. Multiple *t*-tests increase the probability of a Type I error and recommend the use of repeated measures of variance (RM-ANOVA, SPSS Inc.; Norusis 1988). These data (1993) did not satisfy the assumption of multivariate normality. RM-ANOVA will be attempted for the final report on five years of data which may indicate correlations among variables. This procedure may result in some differences in the analyses as compared to the annual reports.

RESULTS

In 1993, 11 tortoises were sampled at Little Shipp, and eight at the Harcuvars. Three study tortoises died in 1993; two males at Little Shipp (303, 499) and one male in the Harcuvar Mountains (202) (Table 1). Tortoise 303 was sampled once (April), tortoise 499 was sampled twice (April, July), and tortoise 205 died before the April sampling. The cause of death for tortoise 303 was predation, possibly by a mountain lion (*Felis concolor*). Tortoise 499 was found dead on its back wedged between rocks, and the cause of death of tortoise 202 remains unknown. Analysis of clinical chemistry, bacteria, and parasites for tortoises 303 and 499 did not indicate the cause of death. Tortoise weights and MCL are summarized in Table 2. No significant differences in tortoise weights and MCL were detected between sites, sexes, or seasons.

Physical parameters and rainfall

Rainfall and temperature data were summarized for Little Shipp Wash and the Harcuvar Mountains for 1992-1993. The NOAA weather station at Aguila, Arizona, is 24 km from the Harcuvar Mountains, while the NOAA station at Hillside, Arizona, is 19 km from Little Shipp Wash. Total 1993 rainfall (January-December) for Little Shipp was 55.6 cm as compared to 54.8 cm in 1992. Total 1993 rainfall (January-December) was not available for the Harcuvars from NOAA. Available data (January-April) indicated that 14.0 cm of rain fell in the Harcuvars as compared to 17.3 cm for the same period in 1992. At Little Shipp, the average maximum temperature was 23.6^{o}C during spring (March-May), 32.9^{o}C during summer (June-August), and 28.8^{o}C during fall (September-October). At the Harcuvars only average maximum temperature (25.4^{o}C) during spring was available. Average winter rainfall for both sites in 1993 facilitated spring annual germination. Temperatures from the automatic weather stations were 3-6 degrees lower than those reported by NOAA.

Hematology

Hematological comparisons are summarized in Table 3. Harcuvar male tortoises had significantly higher WBC levels than Little Shipp tortoises. This was the only significant hematological difference between sites. No sex differences in hematology were detected in Little Shipp and Harcuvar Mountain tortoises. Seasonal differences in hematology occurred in the following: WBC estimate, heterophils, lymphocytes, monocytes, eosinophils, and fibrinogen (Figures 4-5). July changes in WBC levels were largely the result of changes in proportions of heterophils, which were highest in July. Heterophils and fibrinogen showed increases in July, while lymphocytes, monocytes, and eosinophils showed increases in September. The high heterophil levels in July are from four individual tortoises. These same four tortoises showed positive or suspect results with the ELISA test. Heterophils may not be a good indicator of tortoises suffering from URTD as other tortoises with similar ELISA results showed no increases in heterophil levels. No significant differences in basophils and azurophils were observed between sites, sexes, or seasons.

Slight polychromasia was observed in two male tortoises: one from Little Shipp in July (503), and one from the Harcuvars (203) in September. No anemia, anisocytosis, or hemoparasites were observed in the blood smears from any tortoise at any time.

Clinical chemistry

Plasma biochemical values are summarized in Table 4. Values for parameters with significant sex differences are indicated in Table 6. Analyses of steroid levels were not available for this report (Lance in prep.).

Organics

Little Shipp male tortoises had significantly higher levels of BUN, triglycerides, and vitamin A than Harcuvar males. Harcuvar males had significantly higher levels of carbon dioxide compared to Little Shipp males. Female Harcuvar tortoises had higher albumin levels than Little Shipp females. Sex differences in organics were detected in cholesterol and triglycerides at both sites with females having higher levels of each. In the Harcuvars, females had significantly higher levels of calcium and total protein than males. Seasonal differences in organic clinical chemistry occurred in creatinine, total protein, triglycerides, calcium, total and indirect bilirubin, bile acid, and vitamins A and E (Figures 6-9). Most of the organics (total protein, triglycerides, calcium, total and indirect bilirubin, bile acids) had higher levels in April. Only creatinine showed a higher level in July. Vitamins A and E were higher in September.

Enzymes

AST, ALT, and ALP values are summarized in Table 5. Little Shipp males had significantly higher levels of ALT than Harcuvar males. The only sex difference occurred at Little Shipp where males had significantly higher levels of AST than females. No differences in enzyme levels were observed among seasons (Figure 7).

Electrolytes and osmolality

Plasma electrolytes and osmolality values are summarized in Table 5. Analyses showed only two significant differences between sites in 1993. Higher chloride levels were reported for Harcuvar males compared to Little Shipp males, and Harcuvar females had higher levels of sodium compared to Little Shipp females. Sex differences occurred in only one value, phosphorus, with females at both sites having higher levels than males. Seasonal differences occurred in sodium, potassium, phosphorus, chloride, and osmolality (Figures 10-11). Sodium and osmolality levels were highest in April, while potassium, phosphorus, and chloride were higher in July.

Bacteriology

Eight species of bacteria, two of which were potential pathogens, were isolated from 118 tortoise cloacal swabs in 1993 (Tables 7-9). Little Shipp tortoises had the following nonpathogenic bacteria: *Entero-Klebsiella* sp. (17%), *Escherichia coli* (6%), *Pseudomonas* sp. (24%), *Shigella* sp.(9%), and *Staphylococcus* sp. (36%). Potential pathogens in Little Shipp tortoises included small percentages of *Campylobacter* sp. (2%) and *Salmonella* sp. (3%). Harcuvar tortoises had similar results for nonpathogenic bacteria: *Entero-Klebsiella* sp. (10%), *Escherichia coli* (17%), *Pseudomonas* sp. (23%), *Shigella* sp.(13%), and *Staphylococcus* sp. (35%). Harcuvar tortoises had only one potential pathogen, *Salmonella* sp. (2%), isolated from cloacal swabs.

Two species of bacteria were isolated from tortoise nasal aspirate in 1993 (Table 10). Of 43 nasal flushes, 39 (91%) tortoises had *Mycoplasma*-like colonies, and seven (16%) tortoises had *Pasteurella testudinis*. Eighty-three percent of Little Shipp tortoises and 100% of Harcuvar tortoises had *Mycoplasma*-like colonies in their nasal aspirate. No *Chlamydia*-like agents were isolated from any tortoise at any time.

Of the 43 plasma samples sent for ELISA, four (9%) samples tested positive for *M. agassizii* antibodies, nine (21%) tested suspect, and 30 (70%) tested negative (Table 10). At Little Shipp, three tortoises (302, 310, 502) tested suspect for *M. agassizii* antibodies. Tortoise 310 was suspect in April and July, but tested negative in September. In the Harcuvar Mountains, three tortoises (203, 211, 218) tested positive and four tortoises (203, 208, 219, 222) tested suspect. Changes in ELISA results also occurred in Harcuvar tortoises. For example, tortoise 218 tested positive in April, negative in July, and then tested positive in September. Tortoise 203 tested suspect in April, positive in July, and then tested negative in September. Correlations between the ELISA results and hematology and clinical chemistry results indicated that tortoises that tested positive or suspect for *M. agassizii* had lower cholesterol and higher AST levels as compared to tortoises that tested negative from the same site and sampling period. No clinical signs of URTD were observed in tortoises at either site.

Parasitology

Twenty-eight fecal samples were analyzed for the presence of parasitic worms and ova. Of these, only one (4%) tortoise was negative for parasites. Little Shipp tortoise 310 tested negative for parasites in April but later tested positive in July and September for oxyurid nematode (pinworm) ova. The remaining 27 (96%) tortoises were positive for pinworm. These 28 fecal samples were from 13 individual tortoises; nine from Little Shipp and four from the Harcuvars. Pinworm was the only internal parasite detected in 1993 fecal analyses. No significant differences in numbers of ova occurred between site, sex, or season. The mean number of eosinophils for tortoises with intestinal parasites was 51.0 k/ul as compared to 31.8 k/ul in tortoise 310 that did not have parasites. Considering the small sample size of tortoises without parasites, it is not realistic to consider a relationship between parasitism and eosinophil numbers.

DISCUSSION

Physiological Variations Due to Site, Sex, and Season

Site differences

The higher levels of WBC estimates observed in Harcuvar tortoises can be explained by the high numbers of heterophils in tortoise 208 (female). Tortoise 208 had consistently higher numbers of heterophils in all three seasons, but showed no sign of disease. Hart et al. (1991) reported an increase in heterophils in response to inflammatory disease in free-ranging Aldabra giant tortoises (*Geochelone gigantea*). The suspected inflammation in tortoise 208 can not be explained by ELISA and nasal aspirate results. Though tortoise 208 tested suspect for *M. agassizii* antibodies in April and July and had *Mycoplasma*-like colonies in all three sampling periods, other tortoises with similar results did not have elevated heterophil levels. Both sites showed variations in hematology throughout the year, which may be common in reptiles (Dugay 1970). Dugay (1970) found frequencies of WBCs varied in reptiles in response to factors including sex, age, vitellogenesis, geography, pathological condition, ecological effects and season.

Little Shipp tortoises ingested more food than Harcuvar tortoises as indicated by higher levels of BUN, glucose, triglycerides, vitamin A, and potassium. The mean values for glucose in this study were twice as high as those reported for California desert tortoises (Rosskopf 1982) and gopher tortoises (Taylor and Jacobson 1982). High levels of urea and osmolality have been reported in starved, dehydrated, and aestivating tortoises (Balinsky et al. 1967, Baze and Horne 1970). Little Shipp tortoises were not dehydrated as there was no corresponding increase in PCV or osmolality. Dehydration was also not apparent in Harcuvar tortoises despite the elevated spring chloride levels.

Male tortoises at Little Shipp had significantly higher levels of ALT as compared to male Harcuvar tortoises, with higher levels at both sites found in the fall. Taylor and Jacobson (1982) also found higher levels of SGPT (ALT) in gopher tortoises in the fall but could not explain why this occurred. High levels of ALT are usually associated with liver, heart, and kidney disease (Tietz 1987), but no evidence of these diseases was seen in this study.

Sex differences

In this study, higher levels of total protein, calcium, cholesterol, triglycerides, and phosphorus were observed in female tortoises from both sites and are consistent with previous findings (Dickinson 1993). Significantly higher levels of total proteins, lipids, and cholesterol were observed in gravid female Mediterranean tortoises (*Testudo graeca* and *T. hermanni*) in August (time of oviposition) as compared to males (Lawrence 1987).

Taylor and Jacobson (1982) associated vitellogenesis with higher levels of total protein and cholesterol in female gopher tortoises (*Gopherus polyphemus*). Calcium, phosphorus, and cholesterol are important in egg production, and values appear to increase during vitellogenesis in female tortoises in spring (Woodbury and Hardy 1948). Higher levels of sodium reported for Harcuvar females cannot be explained.

Male tortoises at Little Shipp had significantly higher levels of AST as compared to females. Christopher et al. (1993, 1992b) found male Mojave desert tortoises had twice the mean value than females. Little Shipp and Harcuvar male tortoises had highest AST levels in the spring. This may be correlated with male aggression and subsequent injury during the mating season. Little Shipp and Harcuvar AST mean values were above the range reported by Rosskopf (1982) for healthy Mojave desert tortoises.

Seasonal differences

In this study, a seasonal peak in heterophil numbers in July was associated with one tortoise which did not show signs of disease. Inflammation in tortoises in the summer was indicated by a July increase in fibrinogen levels. Taylor and Jacobson (1982) found seasonal variations in WBC and monocyte levels in gopher tortoises with the greatest variation in the spring. A study of Mediterranean tortoises found an increase in lymphocytes during the active period and an eosinophil response in October (Lawrence and Hawkey 1986). Seasonal variations in WBC types in snakes and lizards have been reported by Dugay (1970) and Saad and El Ridi (1988). The spring peak in number of monocytes is similar to the seasonal variation reported in gopher tortoises (Taylor and Jacobson 1982).

In this study, spring peaks in triglycerides, calcium, and total protein were likely due to female tortoises preparing for egg laying. Seasonal trends in total protein, cholesterol, and lipids (triglycerides) were observed in female Mediterranean tortoises (Lawrence 1987). Another possibility for a summer drop in triglyceride and vitamin levels is energy reserves were metabolized during aestivation. Seasonal decreases in vitamin E levels have been reported for other Testudinata during the summer (Dierenfeld 1989). A July increase in creatinine levels may not be important as levels are not high enough to indicate kidney disease. Seasonal changes in total and indirect bilirubin with higher levels seen in April may indicate some type of inflammation. In this study, the mean values for total and indirect bilirubin values in the spring were four times higher those reported for Mojave desert tortoises (Christopher et al. 1993).

Bacteriology

Potential pathogens isolated in this study were *Campylobacter* sp. and *Salmonella* sp. *Campylobacter* sp. can be commensal or pathogenic in animals (Coles 1986). *Salmonella* sp. is frequently cultured from reptile abscesses (Frye 1981; Marcus 1981). All eight species of bacteria isolated from cloacal swabs from Little Shipp and Harcuvar tortoises were reported in free-ranging Sonoran tortoises in 1991 and 1992 (Dickinson and Reggiardo 1992b; Dickinson 1993a, 1993b).

One potential pathogen, *P. testudinis*, was isolated in tortoise nasal aspirate. *P. testudinis* has been isolated from healthy and ill captive tortoises and may be involved in URTD (Snipes and Biberstein 1982, Jacobson et al. 1991). Dickinson and Reggiardo (1992b) found *P. testudinis* in 46% of nasal aspirate from free-ranging Sonoran desert tortoises. Although commonly isolated from apparently healthy animals, *P. testudinis* occurs in larger numbers during clinical URTD (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.

Mycoplasma-like colonies were isolated from the majority of Little Shipp and Harcuvar tortoises and may not be pathogenic. The identity of the *Mycoplasma*-like colonies is questioned as they did not ferment glucose and grew faster than mycoplasmas when cultured at the University of Florida (M. Brown, Department of Infectious Diseases, University of Florida, Gainesville, FL, pers. comm.). Genetic typing and subsequent *Mycoplasma* species identification of the colonies was therefore not possible (M. Brown, pers. comm.). An alternative test to culturing *Mycoplasma* is a polymerase chain amplification (PCR) of a specific gene sequence. *Mycoplasma* has been isolated from lesions in the nasal cavity of Mojave desert tortoises with URTD (Jacobson 1993).

ELISA results indicated three tortoises tested positive and seven tortoises tested suspect for *M. agassizii* antibodies. Results of a recent transmission study (Brown, unpubl.) indicated *M. agassizii* as the causative agent of URTD in desert tortoises. Desert tortoises with URTD have been described as having anemia, lower hemoglobin and phosphorus levels, and higher levels of sodium, urea, and AST (Jacobson and Gaskin 1990). Of the ten tortoises in this study with positive or suspect ELISA results for *M. agassazii*, only higher AST levels were found. AST appears as a result of a wide variety of disease-related tissue damage (Tietz 1987). In this study a decrease in cholesterol was associated with positive or suspect ELISA results, a phenomenon that is not reported in the literature. Despite ELISA results indicating URTD, none of the ten "ill" tortoises showed clinical signs of the disease.

Parasitology

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). According to Marcus (1981) they are among the most common and numerous intestinal worms of lizards and turtles. The host can reinfect itself by breathing or ingesting the eggs (Noble et al. 1989). Tortoises share burrows and have been documented eating soil and scat (Esque et al. 1990), activities which may contribute to continued reinfection.

CONCLUSIONS

Little Shipp and Harcuvar tortoises had a majority of hematological and biochemical values similar to levels reported for healthy free-ranging Mojave tortoises. Both populations exhibited effects of sex and season in hematology, clinical chemistry, electrolytes, osmolality, and bacteria. Eight bacteria, two of which are potential pathogens, were isolated from tortoise cloacae. Two bacteria were detected in nasal aspirate, with *Mycoplasma*-like colonies isolated from the majority of tortoises at both sites. An ELISA for the detection of *M. agassizii* antibodies indicated three positive and seven suspect tortoises. ELISA test results for positive and suspect tortoises were inconsistent across seasons. No clinical signs of URTD were observed in tortoises at either site. Ninety-six percent of the tortoises sampled had nonpathogenic pinworm ova in their feces.

Differences in hematological, biochemical, bacteriological, and parasitic values in Sonoran desert tortoises will continue to be investigated. The incidence of *M. agassizii* in Sonoran desert tortoises will also continue to be investigated. The identity of the *Mycoplasma-* like colonies will be investigated with a PCR test and continued culture of nasal aspirate. Physiological parameters will be interpreted with information from ongoing nutrient studies in the Sonoran desert. This may allow further interpretation of the health studies being conducted on the Sonoran population of the desert tortoise.

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TABLE 1. STATUS OF RADIO-TAGGED ADULT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993).

	MALES				FEMALES			
Site	Initial No. of Tortoises	Tortoise Number	Date Missing	Date Dead	Initial No. of Tortoises	Tortoise Number	Date Missing	Date Dead
LITTLE SHIPP WASH, ARIZONA	6	303		6/93	6			
		499		8/93				
Subtotal				2			0	0
HARCUVAR MOUNTAINS, ARIZONA	8	202		4/93	4			
		204	9/92					
		205	4/92					
		220	7/93					
Subtotal			3	1			0	0
TOTALS	14		3	3	10		0	0

TABLE 2. WEIGHT AND MEAN CARAPACE LENGTH (MCL) OF DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993)

SITE: LITTLE SHIPP WASH, ARIZONA

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
WEIGHT (kg)				
Male	3.2 ± 0.7 (3)	3.0 ± 0.6 (3)	3.3 ± 0.8 (4)	3.2 ± 0.7 (10)
Female	3.3 ± 0.7 (5)	3.3 ± 0.7 (4)	3.3 ± 0.6 (5)	3.3 ± 0.6 (14)
Combined	3.3 ± 0.6 (8)	3.2 ± 0.6 (7)	3.3 ± 0.6 (9)	3.3 ± 0.6 (24)
MCL (mm)				
Male	264.0 ± 14.9 (3)	253.0 ± 18.0 (3)	269.2 ± 24.8 (4)	262.8 ± 19.4 (10)
Female	256.8 ± 18.7 (5)	261.7 ± 23.2 (4)	260.6 ± 22.4 (5)	259.6 ± 19.8 (14)
Combined	259.5 ± 16.7 (8)	258.0 ± 20.0 (7)	264.4 ± 22.4 (9)	260.9 ± 19.3 (24)

SITE: HARCUVAR MOUNTAINS, ARIZONA

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
WEIGHT (kg)				
Male	3.4 ± 1.2 (2)	2.9 ± 1.2 (3)	2.8 ± 0.8 (3)	3.0 ± 0.9 (8)
Female	2.9 ± 0.5 (4)	2.5 ± 0.4 (3)	2.7 ± 0.4 (4)	2.7 ± 0.4 (11)
Combined	3.1 ± 0.7 (6)	2.7 ± 0.8 (6)	2.7 ± 0.5 (7)	2.8 ± 0.7 (19)
MCL (mm)				
Male	261.5 ± 34.6 (2)	249.7 ± 30.8 (3)	248.7 ± 34.6 (3)	252.2 ± 28.6 (8)
Female	247.5 ± 13.5 (4)	242.3 ± 6.4 (3)	249.5 ± 14.5 (4)	246.8 ± 11.6 (11)
Combined	252.2 ± 20.0 (6)	246.0 ± 20.3 (6)	249.1 ± 22.4 (7)	249.1 ± 20.0 (19)

ALL SITES COMBINED

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
WEIGHT (kg)				
Male	3.2 ± 0.8 (5)	2.9 ± 0.9 (6)	3.1 ± 0.8 (7)	3.1 ± 0.8 (18)
Female	3.2 ± 0.6 (9)	3.0 ± 0.7 (7)	3.0 ± 0.6 (9)	3.1 ± 0.6 (25)
Combined	3.2 ± 0.7 (14)	3.0 ± 0.7 (13)	3.1 ± 0.7 (16)	3.1 ± 0.7 (43)
MCL (mm)				
Male	263.0 ± 20.3 (5)	251.3 ± 22.7 (6)	260.4 ± 28.8 (7)	258.1 ± 23.8 (18)
Female	252.7 ± 16.3 (9)	253.4 ± 19.8 (7)	255.7 ± 19.1 (9)	254.0 ± 17.6 (25)
Combined	256.4 ± 17.8 (14)	252.5 ± 20.3 (13)	257.7 ± 23.0 (16)	255.7 ± 20.3 (43)

TABLE 3. HEMATOLOGIC VALUES FOR DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993)

SITE: LITTLE SHIPP WASH, ARIZONA

$\bar{x} \pm SD$ (n)	April	July	September	Seasons Combined
PCV (%)	25.0 ± 3.0 (8)	23.6 ± 2.4 (7)	25.7 ± 4.0 (9)	24.8 ± 3.2 (24)
Hemoglobin (g/dl)	9.9 ± 1.5 (8)	10.2 ± 1.2 (6)	10.9 ± 1.6 (9)	10.3 ± 1.5 (23)
Fibrinogen (mg/dl)	111. 2 ± 45.8 (8)	148.3 ± 7.5 (6)	145.6 ± 17.4 (9)	134.3 ± 33.0 (23)
WBC estimate (k/ul)	6.5 ± 2.2 (8)	10.4 ± 5.0 (7)	8.2 ± 2.2 (9)	8.3 ± 3.5 (24)
Heterophils (k/ul)	427.7 ± 231.7 (8)	879.0 ± 490.3 (7)	421.0 ± 178.6 (9)	556.8 ± 367.1 (24)
Lymphocytes (k/ul)	105.1 ± 49.9 (8)	67.1 ± 34.9 (7)	162.8 ± 36.5 (9)	115.7 ± 56.2 (24)
Monocytes (k/ul)	6.1 ± 5.8 (8)	3.1 ± 6.7 (7)	33.4 ± 22.3 (9)	15.5 ± 19.9 (24)
Azurophils (k/ul)	9.4 ± 12.2 (8)	0.0 ± 0.0 (7)	0.0 ± 0.0 (9)	3.1 ± 8.1 (24)
Eosinophils (k/ul)	25.9 ± 16.0 (8)	5.4 ± 7.9 (7)	95.5 ± 73.2 (9)	46.1 ± 59.7 (24)
Basophils (k/ul)	75.7 ± 39.9 (8)	88.1 ± 67.2 (7)	102.8 ± 76.2 (9)	89.5 ± 61.8 (24)

SITE: HARCUVAR MOUNTAINS, ARIZONA

$\bar{x} \pm SD$ (n)	April	July	September	Seasons Combined
PCV (%)	26.8 ± 2.5 (6)	27.7 ± 2.5 (6)	24.2 ± 2.1 (7)	26.1 ± 2.7 (19)
Hemoglobin (g/dl)	11.1 ± 1.2 (6)	11.6 ± 1.0 (6)	10.1 ± 1.2 (7)	10.9 ± 1.2 (19)
Fibrinogen (mg/dl)	131.7 ± 16.0 (6)	148.3 ± 9.8 (6)	127.1 ± 7.6 (7)	135.3 ± 14.3 (19)
WBC estimate (k/ul)	5.1 ± 1.8 (6)	10.7 ± 6.2 (6)	9.3 ± 7.8 (7)	8.4 ± 6.1 (19)
Heterophils (k/ul)	262.7 ± 161.4 (6)	838.0 ± 579.6 (6)	524.9 ± 627.1 (7)	540.9 ± 535.7 (19)
Lymphocytes (k/ul)	90.2 ± 41.2 (6)	107.7 ± 44.8 (6)	176.8 ± 132.9 (7)	127.6 ± 92.0 (19)
Monocytes (k/ul)	26.6 ± 18.0 (6)	7.3 ± 12.5 (6)	17.3 ± 16.4 (7)	17.1 ± 16.9 (19)
Azurophils (k/ul)	7.9 ± 3.1 (6)	0.0 ± 0.0 (6)	0.0 ± 0.0 (7)	2.5 ± 4.1 (19)
Eosinophils (k/ul)	12.8 ± 8.0 (6)	3.7 ± 4.5 (6)	96.9 ± 40.8 (7)	40.9 ± 50.2 (19)
Basophils (k/ul)	106.5 ± 74.2 (6)	110.0 ± 78.5 (6)	109.8 ± 127.0 (7)	108.8 ± 92.8 (19)

TABLE 3. (CONTINUED) HEMATOLOGIC VALUES FOR DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993)

SITE: ALL SITES COMBINED				
$\bar{x}$ ± SD (n)	**April**	**July**	**September**	**Seasons Combined**
PCV (%)	25.8 ± 2.8 (14)	25.5 ± 3.2 (13)	25.0 ± 3.3 (16)	25.4 ± 3.0 (43)
Hemoglobin (g/dl)	10.4 ± 1.4 (14)	10.9 ± 1.3 (12)	10.5 ± 1.5 (16)	10.6 ± 1.4 (42)
Fibrinogen (mg/dl)	120.0 ± 36.6 (14)	148.3 ± 8.3 (12)^	137.5 ± 16.5 (16)	134.8 ± 26.0 (42)
WBC estimate (k/ul)	5.9 ± 2.1 (14)	10.5 ± 5.3 (13)^	8.6 ± 5.2 (16)	8.3 ± 4.7 (43)+
Heterophils (k/ul)	357.0 ± 214.8 (14)	860.1 ± 510.5 (13)^	466.5 ± 420.9 (16)	549.8 ± 443.7 (43)
Lymphocytes (k/ul)	98.7 ± 45.3 (14)	85.8 ± 43.5 (13)	168.9 ± 88.5 (16)^	121.0 ± 73.4 (43)
Monocytes (k/ul)	14.9 ± 15.9 (14)	5.1 ± 9.6 (13)	26.4 ± 21.0 (16)^	16.2 ± 18.5 (43)
Azurophils (k/ul)	8.8 ± 9.2 (14)	0.0 ± 0.0 (13)	0.0 ± 0.0 (16)	2.9 ± 6.6 (43)
Eosinophils (k/ul)	20.3 ± 14.4 (14)	4.6 ± 6.3 (13)	96.2 ± 59.4 (16)	43.8 ± 55.1 (43)
Basophils (k/ul)	88.9 ± 56.8 (14)	98.2 ± 70.4 (13)	105.8 ± 97.8 (16)	98.0 ± 76.7 (43)

^ Significantly different from other months

\+ Significantly different between sites (males and females analyzed separately, see text for details)

TABLE 4. PLASMA BIOCHEMICAL VALUES FOR DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993)

SITE: LITTLE SHIPP WASH, ARIZONA

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
Glucose (mg/dl)	119.1 ± 31.1 (8)	176.4 ± 35.3 (7)	152.0 ± 19.6 (9)	148.2 ± 36.0 (24)
BUN (mg/dl)	0.4 ± 0.5 (8)	0.4 ± 0.5 (7)	0.0 ± 0.0 (9)	0.2 ± 0.4 (24)
Creatinine (mg/dl)	0.2 ± 0.05 (8)	0.3 ± 0.1 97)	0.2 ± 0.1 (9)	0.2 ± 0.1 (24)
Uric Acid (mg/dl)	5.1 ± 1.2 (8)	5.9 ± 1.5 (7)	5.0 ± 1.2 (9)	5.3 ± 1.3 (24)
Bile Acid ((µmol/l)	10.8 ± 9.2 (8)	0.6 ± 1.1 (7)	2.5 ± 4.2 (9)	4.7 ± 7.2 (24)
Total Protein (g/dl)	3.9 ± 0.6 (8)	4.2 ± 0.6 (7)	3.3 ± 0.4 (9)	3.8 ± 0.7 (24)
Albumin (g/dl)	1.4 ± 0.2 (8)	1.4 ± 0.2 (7)	1.3 ± 0.1 (9)	1.3 ± 0.2 (24)
AST (IU/l)	90.1 ± 36.5 (8)	103.7 ± 58.7 (7)	112.4 ± 58.4 (9)	102.5 ± 50.8 (24)*
ALT (IU/l)	3.5 ± 1.5 (8)	2.7 ± 2.2 (7)	8.4 ± 5.1 (9)	5.1 ± 4.3 (24)
ALP (IU/l)	65.7 ± 28.8 (8)	102.3 ± 58.0 (7)	89.7 ± 33.1 (9)	85.4 ± 41.7 (24)
Calcium (mg/dl)	13.2 ± 1.6 (8)	9.0 ± 4.4 (7)	12.5 ± 1.9 (9)	11.7 ± 3.2 (24)
Cholesterol (mg/dl)	171.6 ± 107.1 (8)	120.7 ± 63.4 (7)	135.9 ± 61.9 (9)	143.4 ± 79.5 (24)*
Triglycerides (mg/dl)	250.6 ± 285.5 (8)	35.6 ± 25.4 (7)	239.7 ± 218.7 (9)	183.8 ± 226.0 (24)*
Total bilirubin (mg/dl)	0.6 ± 0.5 (8)	0.2 ± 0.04 (7)	0.1 ± 0.,1 (9)	0.3 ± 0.4 (24)
Direct bilirubin (mg/dl)	0.03 ± 0.01 (8)	0.02 ± 0.01 (7)	0.2 ± 0.4 (6)	0.1 ± 0.2 (21)
Indirect bilirubin (mg/dl)	0.6 ± 0.5 (8)	0.1 ± 0.04 (7)	0.1 ± 0.1 (9)	0.3 ± 0.4 (24)
Copper (ppm)	--	--	0.3 ± 0.2 (3)	0.3 ± 0.2 (3)
Selenium (ppm)	--	--	0.03 ± 0.01 (6)	0.03 ± 0.01 (6)
Vitamin A (µg/ml)	0.4 ± 0.1 (8)	0.2 ± 0.1 (7)	0.4 ± 0.1 (9)	0.3 ± 0.1 (24)
Vitamin E (µg/ml)	7.6 ± 0.9 (8)	6.2 ± 0.8 (7)	11.2 ± 4.2 (9)	8.5 ± 3.4 (24)
CO_2 (mEq/l)	27.3 ± 14.7 (8)	28.4 ± 7.8 (7)	33.1 ± 4.5 (9)	29.8 ± 9.8 (24)

-- Test not performed

* Significantly different between sexes

TABLE 4. (CONTINUED) PLASMA BIOCHEMICAL VALUES FOR DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993)

SITE: HARCUVAR MOUNTAINS, ARIZONA				
$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
Glucose (mg/dl)	130.3 ± 20.8 (6)	179.5 ± 58.9 (6)	103.7 ± 24.7 (7)	136.1 ± 48.3 (19)
BUN (mg/dl)	0.8 ± 1.6 (6)	2.7 ± 2.3 (6)	0.1 ± 0.4 (7)	1.2 ± 1.8 (19)
Creatinine (mg/dl)	0.2 ± 0.04 (6)	0.4 ± 0.1 (6)	0.1 ± 0.1 (7)	0.2 ± 0.1 (19)
Uric Acid (mg/dl)	4.1 ± 1.8 (6)	5.3 ± 1.2 (6)	3.5 ± 1.8 (7)	4.2 ± 1.7 (19)
Bile Acid (µmol/l)	6.8 ± 2.7 (6)	0.2 ± 0.4 (6)	9.0 ± 14.5 (7)	5.5 ± 9.3 (19)
Total Protein (g/dl)	3.8 ± 0.6 (6)	4.2 ± 0.4 (6)	3.4 ± 0.4 (7)	3.8 ± 0.6 (19)*
Albumin (g/dl)	1.5 ± 0.3 (6)	1.5 ± 0.2 (6)	1.3 ± 0.1 (7)	1.4 ± 0.2 (19)
AST (IU/l)	88.3 ± 17.6 (6)	69.8 ± 18.3 (6)	102.0 ± 64.2 (7)	87.5 ± 41.7 (19)
ALT (IU/l)	2.7 ± 1.2 (6)	2.0 ± 2.2 (6)	6.9 ± 3.2 (7)	4.0 ± 3.2 (19)
ALP (IU/l)	95.3 ± 53.1 (6)	113.3 ± 76.2 (6)	110.0 ± 56.5 (7)	106.4 ± 59.3 (19)
Calcium (mg/dl)	13.4 ± 1.6 (6)	11.0 ± 2.1 (6)	12.9 ± 1.7 (7)	12.5 ± 2.0 (19)*
Cholesterol (mg/dl)	172.5 ± 85.4 (6)	137.2 ± 78.0 (6)	139.4 ± 79.5 (7)	149.2 ± 78.0 (19)*
Triglycerides (mg/dl)	266.0 ± 266.5 (6)	25.3 ± 11.0 (6)	221.1 ± 221.0 (7)	173.5 ± 217.0 (19)*
Total bilirubin (mg/dl)	0.4 ± 0.2 (6)	0.1 ± 0.02 (6)	0.1 ± 0.1 (7)	0.2 ± 0.2 (19)
Direct bilirubin (mg/dl)	0.1 ± 0.2 (6)	0.04 ± 0.01 (6)	0.02 ± 0.00 (4)	0.1 ± 0.1 (16)
Indirect bilirubin (mg/dl)	0.3 ± 0.3 (6)	0.1 ± 0.02 (6)	0.1 ± 0.1 (7)	0.2 ± 0.2 (19)
Copper (ppm)	--	--	--	--
Selenium (ppm)	--	--	0.03 ± 0.00 (7)	0.03 ± 0.00 (7)
Vitamin A (µg/ml)	0.2 ± 0.1 (6)	0.2 ± 0.1 (5)	0.3 ± 0.04 (7)	0.3 ± 0.1 (18)
Vitamin E (µg/ml)	9.6 ± 0.8 (6)	6.4 ± 0.7 (5)	8.6 ± 1.7 (7)	8.3 ± 1.7 (18)
CO_2 (mEq/l)	41.3 ± 3.9 (5)	37.4 ± 8.8 (6)	33.4 ± 4.4 (7)	36.9 ± 6.6 (18)

-- Test not performed

* Significantly different between sexes

Table 4. (continued) Plasma Biochemical Values for Desert Tortoises at Two Sites in the Sonoran Desert (April 1993 - September 1993)

SITE: ALL SITES COMBINED

$\bar{x} \pm$ SD (n)	April	July	September	Seasons Combined
Glucose (mg/dl)	123.9 ± 26.8 (14)	177.8 ± 45.5 (13)	130.9 ± 32.6 (16)	142.8 ± 41.8 (43)
BUN (mg/dl)	0.6 ± 1.1 (14)	1.5 ± 1.9 (13)	0.1 ± 0.2 (16)	0.7 ± 1.3 (43)+
Creatinine (mg/dl)	0.2 ± 0.05 (14)	0.4 ± 0.1 (13)^	0.1 ± 0.1 (16)	0.2 ± 0.1 (43)
Uric Acid (mg/dl)	4.7 ± 1.5 (14)	5.6 ± 1.4 (13)	4.3 ± 1.6 (16)	4.8 ± 1.6 (43)
Bile Acid (μmol/l)	9.1 ± 7.2 (14)^	0.4 ± 0.8 (13)	5.3 ± 10.2 (16)	5.1 ± 8.1 (43)
Total Protein (g/dl)	3.8 ± 0.6 (14)^	4.2 ± 0.5 (13)	3.4 ± 0.4 (16)	3.8 ± 0.6 (43)
Albumin (g/dl)	1.4 ± 0.2 (14)	1.4 ± 0.2 (13)	1.3 ± 0.1 (16)	1.4 ± 0.2 (43)+
AST (IU/l)	89.4 ± 28.9 (14)	88.1 ± 46.6 (13)	107.9 ± 59.2 (16)	95.9 ± 47.1 (43)
ALT (IU/l)	3.1 ± 1.4 (14)	2.4 ± 2.1 (13)	7.7 ± 4.4 (16)	4.6 ± 3.8 (43)+
ALP (IU/l)	78.4 ± 42.0 (14)	107.4 ± 64.3 (13)	98.6 ± 44.4 (16)	94.7 ± 50.7 (43)
Calcium (mg/dl)	13.3 ± 1.5 (14)^	9.9 ± 3.5 (13)	12.7 ± 1.8 (16)	12.0 ± 2.7 (43)
Cholesterol (mg/dl)	172.0 ± 94.8 (14)	128.3 ± 67.9 (13)	137.4 ± 67.6 (16)	145.9 ± 78.0 (43)
Triglycerides (mg/dl)	257.2 ± 267.0 (14)^	30.8 ± 20.0 (13)	231.6 ± 212.5 (16)	179.2 ± 219.5 (43)+
Total bilirubin (mg/dl)	0.5 ± 0.4 (14)^	0.2 ± 0.03 (13)	0.1 ± 0.1 (16)	0.3 ± 0.3 (43)
Direct bilirubin (mg/dl)	0.1 ± 0.1 (14)	0.03 ± 0.01 (13)	0.1 ± 0.3 (10)	0.1 ± 0.2 (37)
Indirect bilirubin (mg/dl)	0.4 ± 0.5 (14)^	0.1 ± 0.04 (13)	0.1 ± 0.1 (16)	0.2 ± 0.3 (43)
Copper (ppm)	--	--	0.3 ± 0.2 (3)	0.3 ± 0.2 (3)
Selenium (ppm)	--	--	0.03 ± 0.01 (13)	0.03 ± 0.01 (13)
Vitamin A (μg/ml)	0.3 ± 0.1 (14)	0.2 ± 0.1 (12)	0.4 ± 0.1 (16)^	0.3 ± 0.1 (42)+
Vitamin E (μg/ml)	8.4 ± 1.3 (14)	6.3 ± 0.7 (12)	10.1 ± 3.5 (16)^	8.4 ± 2.8 (42)
CO_2 (mEq/l)	32.7 ± 13.5 (13)	32.6 ± 9.2 (13)	33.2 ± 4.3 (16)	32.8 ± 9.2 (42)+

-- Test not performed
* Significantly different between sexes
^ Significantly different from other months
+ Significantly different between sites (males and females analyzed separately, see text for details)

TABLE 5. PLASMA ELECTROLYTES AND OSMOLALITY VALUES FOR DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993)

SITE: LITTLE SHIPP WASH, ARIZONA

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
Sodium (mEq/l)	139.2 ± 6.8 (8)	135.0 ± 5.9 (7)	131.9 ± 3.0 (9)	135.2 ± 6.0 (24)
Phosphorus (mEq/l)	3.0 ± 1.6 (8)	6.0 ± 4.3 (7)	3.1 ± 1.4 (9)	3.9 ± 2.8 (24)*
Potassium (mEq/l)	4.6 ± 0.5 (8)	4.7 ± 0.6 (7)	4.4 ± 0.5 (9)	4.6 ± 0.5 (24)
Chloride (mEq/l)	95.0 ± 2.4 (8)	108.1 ± 8.2 (7)	103.4 ± 3.2 (9)	102.0 ±7.2 (24)
Osmolality (mOs/kg)	305.5 ± 29.1 (8)	265.4 ± 17.3 (7)	279.6 ± 11.4 (9)	284.1 ± 25.6 (24)

SITE: HARCUVAR MOUNTAINS, ARIZONA

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
Sodium (mEq/l)	144.2 ± 6.0 (6)	140.5 ± 4.4 (6)	136.3 ± 6.8 (7)	140.1 ± 6.5 (19)*
Phosphorus (mEq/l)	2.6 ± 1.9 (6)	4.1 ± 2.6 (6)	3.1 ± 2.1 (7)	3.3 ± 2.2 (19)*
Potassium (mEq/l)	4.6 ± 0.9 (6)	4.7 ± 0.7 (6)	4.0 ± 0.4 (7)	4.4 ± 0.7 (19)
Chloride (mEq/l)	95.5 ± 5.4 (6)	111.7 ± 3.8 (6)	107.7 ± 9.1 (7)	105.1 ± 9.4 (19)
Osmolality (mOs/kg)	294.8 ± 13.0 (6)	287.5 ± 16.3 (6)	265.9 ± 13.4 (7)	281.8 ± 18.6 (19)

SITE: ALL SITES COMBINED

$\bar{x}$ ± SD (n)	April	July	September	Seasons Combined
Sodium (mEq/l)	141.4 ± 6.7 (14)^	137.5 ± 5.8 (13)	133.8 ± 5.4 (16)	137.4 ± 6.6 (43)+
Phosphorus (mEq/l)	2.8 ± 1.7 (14)	5.1 ± 3.6 (13)^	3.1 ± 1.7 (16)	3.6 ± 2.6 (43)
Potassium (mEq/l)	4.6 ± 0.7 (14)	4.7 ± 0.6 (13)^	4.2 ± 0.5 (16)	4.5 ± 0.6 (43)
Chloride (mEq/l)	95.2 ± 3.8 (14)	109.8 ± 6.5 (13)^	105.3 ± 6.6 (16)	103.4 ± 8.3 (43)+
Osmolality (mOs/kg)	300.9 ± 23.5 (14)^	275.6 ± 19.8 (13)	273.6 ± 13.8 (16)	283.1 ± 22.5 (43)

* Significantly different between sexes
^ Significantly different from other months
\+ Significantly different between sites (males and females analyzed separately, see text for details)

TABLE 6. VALUES FOR PARAMETERS WITH SIGNIFICANT SEX DIFFERENCES FOR DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT (APRIL 1993 - SEPTEMBER 1993). NS - NOT SIGNIFICANT

$\bar{x}$ ± SD (n)	Cholesterol (mg/dl)	Triglyceride (mg/dl)	Phosphorous (mEq/l)	AST (IU/l)	Total protein (g/dl)	Calcium (mg/dl)	Sodium (mEq/l)
LITTLE SHIPP WASH							
Male	79.4 ± 16.0 (10)	22.5 ± 14.8 (10)	1.7 ± 0.2 (10)	133.1 ± 53.6 (10)	NS	NS	NS
Female	189.1 ± 74.9 (14)	299.0 ± 236.5 (14)	5.5 ± 2.8 (14)	80.6 ± 36.7 (14)	NS	NS	NS
HARCUVAR MTNS.							
Male	80.2 ± 31.6 (8)	10.5 ± 4.2 (8)	1.4 ± 0.7 (8)	NS	3.4 ± 0.5 (8)	10.9 ± 0.9 (8)	136.4 ± 6.1 (8)
Female	199.3 ± 60.9 (11)	292.0 ± 219.2 (11)	4.7 ± 1.8 (11)	NS	4.1 ± 0.4 (11)	13.6 ± 1.8 (11)	142.8 ± 5.6 (11)

TABLE 7. BACTERIA IDENTIFIED FROM CLOACAL SWABS FROM DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT, SPRING 1993.

LITTLE SHIPP WASH
APRIL 27

Cloacal swab	301	302	303	309	310	499	501	502
Campylobacter sp.						L		
Enterobacter-Klebsiella	L		H			MH		
Escherichia coli		L						
Pseudomonas sp.	L	L	H	L		MH	MH	
Staphylococcus sp.	H	MH	H	H	H	P	H	H

P=Present (1-7 colonies) S=Slight Growth (<1+) L=Light Growth (1+) M=Moderate Growth (2+) MH=Moderately Heavy (3+) H=Heavy Growth (4+)

TABLE 7. (CONTINUED) BACTERIA IDENTIFIED FROM CLOACAL SWABS FROM DESERT TORTOISES AT TWO SITES IN THE SONORAN DESERT, SPRING 1993.

HARCUVAR MOUNTAINS
APRIL 29

Cloacal swab	203	208	211	218	219	221
Enterobacter-Klebsiella		M			L	
Escherichia coli				P		MH
Pseudomonas sp.	L				L	MH
Shigella sp.	L	L				MH
Staphylococcus sp.	H	H	H	MH	MH	MH

P = Present (1-7 colonies) S = Slight Growth (< 1+) L = Light Growth (1+) M = Moderate Growth (2+) MH = Moderately Heavy (3+) H = Heavy Growth (4+)

TABLE 8. BACTERIA IDENTIFIED FROM CLOACAL SWABS FROM DESERT TORTOISE AT TWO SITES IN THE SONORAN DESERT, SUMMER 1993.

LITTLE SHIPP WASH
JUNE 29

Cloacal swab	301	302	309	310	499	502	503
Enterobacter-Klebsiella	M	M		L			
Escherichia coli					M		
Pseudomonas sp.	M	M	H		M		S
Shigella sp.	L		M	L			
Staphylococcus sp.	H	H	H	MH	H	H	H

HARCUVAR MOUNTAINS
JULY 1

Cloacal swab	203	208	211	219	222	223
Enterobacter-Klebsiella	L	MH				
Escherichia coli				S	M	MH
Pseudomonas sp.	L	MH			M	MH
Salmonella sp.					M	
Shigella sp.					M	M
Staphylococcus sp.	H	H	H	H	H	H

P=Present (1-7 colonies)   S=Slight Growth (<1+)   L=Light Growth (1+)   M=Moderate Growth (2+)   MH=Moderately Heavy (3+)   H=Heavy Growth (4+)

TABLE 9. BACTERIA IDENTIFIED FROM CLOACAL SWABS FROM DESERT TORTOISE AT TWO SITES IN THE SONORAN DESERT, FALL 1993.

LITTLE SHIPP WASH
SEPTEMBER 21

Cloacal swab	301	302	309	310	500	501	502	503	508
Diptheroid sp.					H		H		
Enterobacter-Klebsiella		M	M		L	H		M	
Escherichia coli				L					P
Pseudomonas sp.		M	M	L	L	H			
Salmonella sp.		L						L	
Shigella sp.			M		L	MH			
Staphylococcus sp.	MH	H	H	L	H	L	H	H	H

P-Present (1-7 colonies) S=Slight Growth (<1+) L=Light Growth (1+) M=Moderate Growth (2+) MH=Moderately Heavy (3+) H=Heavy Growth (4+)

TABLE 9. (CONTINUED) BACTERIA IDENTIFIED FROM CLOACAL SWABS FROM DESERT TORTOISE AT TWO SITES IN THE SONORAN DESERT, FALL 1993.

HARCUVAR MOUNTAINS
SEPTEMBER 23

Cloacal swab	203	208	211	218	219	221	223
Enterobacter-Klebsiella					M		
Escherichia coli			L	L		H	H
Pseudomonas sp.			L	L	M	H	MH
Shigella sp.				L	L		
Staphylococcus sp.	H	H	H	H	H	H	MH

P=Present (1-7 colonies) S=Slight Growth (<1+) L=Light Growth (1+) M=Moderate Growth (2+) MH=Moderately Heavy (3+) H=Heavy Growth (4+)

TABLE 10. BACTERIA IDENTIFIED FROM NASAL FLUSHES FROM DESERT TORTOISE AT TWO SITES IN THE SONORAN DESERT, 1993.

Site	Tortoises Sampled ID	n	Tortoises w/positive/suspect ELISA for *Mycoplasma agassizii* ID	n	Tortoises w/cultured *Mycoplasma*-like colonies ID		Tortoises w/cultured *Pasteurella testudinis* ID	
APRIL 1993								
LITTLE SHIPP WASH, AZ	301 310 302 499 303 501 309 502	8	302 (suspect)[1] 310 (suspect)	2	301 310 302 499 303 501 309[2]	7	301	1
HARCUVAR MOUNTAINS, AZ	203 218 208 219 211 221	6	203 (suspect) 208 (suspect) 218	3	203[2] 218 208[2] 219[1] 211[2] 221	6		0
JULY 1993								
LITTLE SHIPP WASH, AZ	301 499 302 502 309 503 310	7	310 (suspect) 502 (suspect)	2	301 502 302 503 309[2] 499	6	301 499	2
HARCUVAR MOUNTAINS, AZ	203 219 208 222 211 223	6	203 219 (suspect) 208 (suspect) 222 (suspect) 211	5	203[2] 219[2] 208[2] 222 211[2] 223	6	219 223	2

[1] "Suspect"; not a clear positive test

[2] *Mycoplasma*-like colonies cultured in three seasons

TABLE 10. (CONTINUED) BACTERIA IDENTIFIED FROM NASAL FLUSHES FROM DESERT TORTOISE AT TWO SITES IN THE SONORAN DESERT, 1993.

SEPTEMBER 1993										
Site	Tortoises Sampled ID		n	Tortoises w/positive/suspect ELISA for *Mycoplasma agassizii* ID	n	Tortoises w/cultured *Mycoplasma*-like colonies ID		n	Tortoises w/cultured *Pasteurella testudinis* ID	n
LITTLE SHIPP WASH, AZ	301	501	9		0	309[2]	503	7	301	2
	302	502				310	508		501	
	309	503				500				
	310	508				501				
	500					502				
HARCUVAR MOUNTAINS, AZ	203	219	7	218	1	203[2]	219[2]	7		0
	208	221				208[2]	221			
	211	223				211[2]	223			
	218					218				

[2] *Mycoplasma*-like colonies cultured in three seasons

Risk Associated with Long-distance Movements by Desert Tortoises

Marc Sazaki, William I. Boarman, Glenn Goodlett and Tracy Okamoto

Abstract. Since 1991, we studied desert tortoises (*Gopherus agassizii*) to determine the effectiveness of tortoise barrier fences in the western Mojave Desert. We attached small radio transmitters to 54 permanently marked desert tortoises and conducted carcass surveys for these and other tortoises along 24 km of fenced and 24 km of unfenced highway.

Fifteen (28%) of our transmitter-affixed study animals made relatively straight-line movements of 0.8 to 15.5 km during April-June in 1992 and/or 1993. Six (40%) of these long distance movers were immature animals at the start of each study period. Eight (53%) were subadults, while only one was an adult.

Carcass surveys along 24 km of State Highway 58 that had barrier fencing showed that no tortoises perished along this stretch of highway whereas 18 carcasses were found along a comparable stretch of State Hwy 395 without barrier fencing.

Our study results indicate a high proportion of tortoises in the study area made long distance movements and virtually no tortoises were killed along a stretch of highway with a barrier fence. We have not documented that tortoises were killed on the road as a result of long-distance movements during the study, but tortoises probably increase their risk of being killed on roads while making such movements, particularly where major highways remain unfenced.

INTRODUCTION

Animals are generally believed to make long-distance movements to satisfy various life requisites including: foraging, locating mates and suitable habitat for mating, egg laying, rearing of young, and hibernation. Such movements in a relatively pristine environment may represent an adaptive advantage to individual species, in spite of any exposure to increased risk of natural mortality. Expanding human development into natural habitats places animals under additional mortality risk, especially animals engaged in long-distance movements.

During 1990, a jointly sponsored study was initiated by the Bureau of Land Management, California Energy Commission, California Department of Fish and Game, California Department of Transportation, and the U.S. Fish and Wildlife Service to assess the effectiveness of a tortoise fence barrier erected by the California Department of Transportation along a portion of State Highway (Hwy) 58 between Mojave and Barstow, California. The purpose of the fence was to prevent desert tortoises (*Gopherus agassizii*), a state and federal listed "threatened" species, from being hit and killed by vehicles in an area considered to be important tortoise habitat.

The study goal was to address four questions that would serve as the focus of this anticipated long-term project. First, is the fence an effective barrier for preventing tortoises from being killed on the road? Second, does the fence facilitate "recovery" of the tortoise population near the highway? Third, do culverts facilitate movements from one side of the highway to the other. And fourth, how do individual tortoises behave when they encounter the fence and culverts? The overall project background and study design is fully described in Boarman, et al. (1993) and Boarman and Sazaki (1994).

In 1992 and 1993, we noted that during April through June, some of the tortoises affixed with transmitters exhibited what we characterized as net linear or long-distance movements. Net linear movement was the straight-line distance between a given tortoise's location at the start and end of the tracking period each year. We considered these movements outside the bounds of typical activity areas or home ranges, which were more or less established by the majority of known tortoises on our square-mile study plot. In this report we describe these long-distance movements. We discuss the implications of nearby heavily traveled highways posing additional mortality risk to tortoises in the general area of our study plot.

Also, we discuss general results of surveys for dead tortoises conducted on the stretch of highway with a tortoise barrier fence located adjacent to our study plot versus a similar but unfenced stretch of highway in the vicinity. This discussion provides for a preliminary examination of the potential for tortoises traveling long-distances to encounter, attempt to cross, and become killed on highways that act as mortality sinks for the species.

METHODS

All tortoises included in the study were assigned unique numbers for identification and marked systematically by writing the tortoise number on a white paint spot applied to the forth right costal scute and by notching the marginal scutes according to a coding scheme used on BLM permanent study plots in the Mojave Desert (Berry, 1988). In addition, passive integrated transponder (PIT) tags were attached to most tortoises found on or near the study plot and radio transmitters were affixed to the tortoises we intended to track for home range determinations. Methods used to attach PIT tags and transmitters were provided in Boarman (1991).

Attempts were made to locate each transmitter-carrying tortoise two to four times per week during each spring season. Each time a tortoise was found, its location was mapped and its behavior was observed for a minimum of five minutes and noted. At least twice during the spring season, each tortoise was checked for discernable identification marks, weighed, sexed, measured, photographed, and observed for health status using methods outlined in BLM (1991). Aerial-tracking flights were conducted each year to search for tortoises that exhibited long-distance movements or tortoises that had become lost to our ground-based tracking efforts.

Tortoises tracked to the edge of unfenced highways were safely carried across in the direction in which they were traveling to reduce the likelihood of their being killed; thus, for purposes of the highway mortality aspects of the study, these animals were eliminated from further analysis.

Surveys for carcasses were conducted 2 -18 July, 1992 and 13-16 July, 1993. Twenty-four km long transects were surveyed along both edges of the highway east and south of the Highway 58 and Highway 395 junction. Each carcass survey transect was 10 m wide and centered approximately 5 m from the paved roadway. The Highway 58 route was fenced and the carcass survey began approximately 5.8 km east of the junction and extended east for 24 km. The Highway 395 route was not fenced and the survey began 12.3 km south of the junction and ran south for 24 km. Each observer walked parallel to the highway, at the unpaved edge of the graded shoulder, and scanned the ground for any tortoise remains or signs. If several tortoise fragments were found in a cluster generally less than 7 m in diameter, it was assumed they were from a single animal. After locating the remains of a tortoise and prior to any disturbance for closer examination, data were recorded and the remains were photographed. 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. The final step was to collect and bag each group of tortoise remains for later analysis. Similar data were also collected on other dead vertebrate species found on the transects. The species of all carcasses found on the unpaved shoulder were identified, times since death were estimated, and the locations of the carcasses were mapped.

RESULTS

We detected several instances where tortoises made long-distance movements as estimated by determining the straight-line distance between the two most distant locations at which each tortoise was located over the study period. We defined long-distance movement to be greater than or equal to 0.8 km. Also, this movement was obviously external to the normal, seasonal activity area or home range of individual tortoises, as suggested by our tracking results.

In 1992, eight animals made such linear movements (Table 1) (Figs. 1-3): three females, two males, and three unknown because they were too small to be sexed. All were subadult or immatures. The maximum distance moved by these tortoises was 7.0 km. Tortoise #78 was first found and marked on May 26 about 0.4 km east of

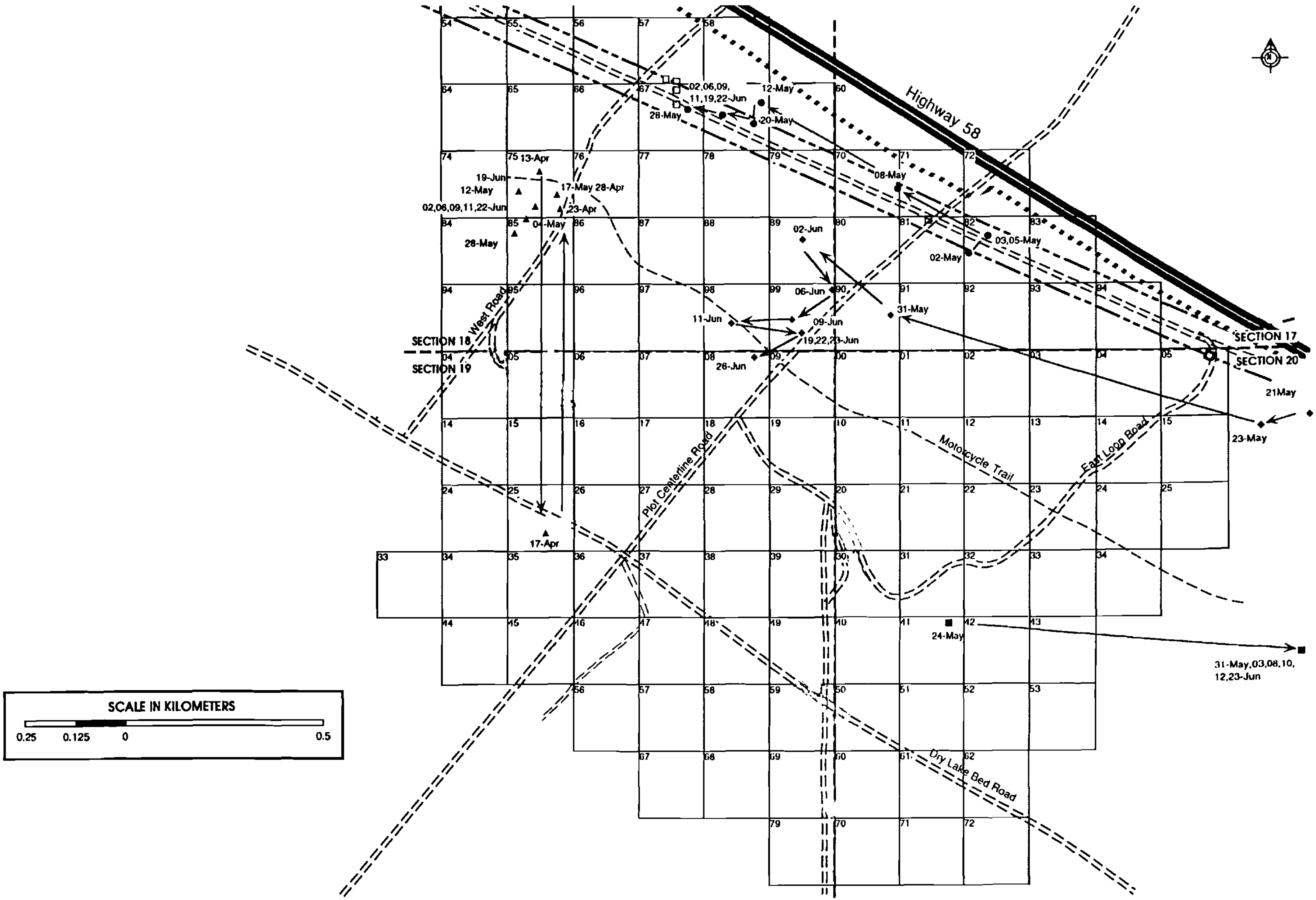

Figure 1. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1992. Various sightings indicated by day and month (▲=Tortoise #52 --- ●=Tortoise #23 --- ♦=Tortoise #75 --- ■=Tortoise #77).

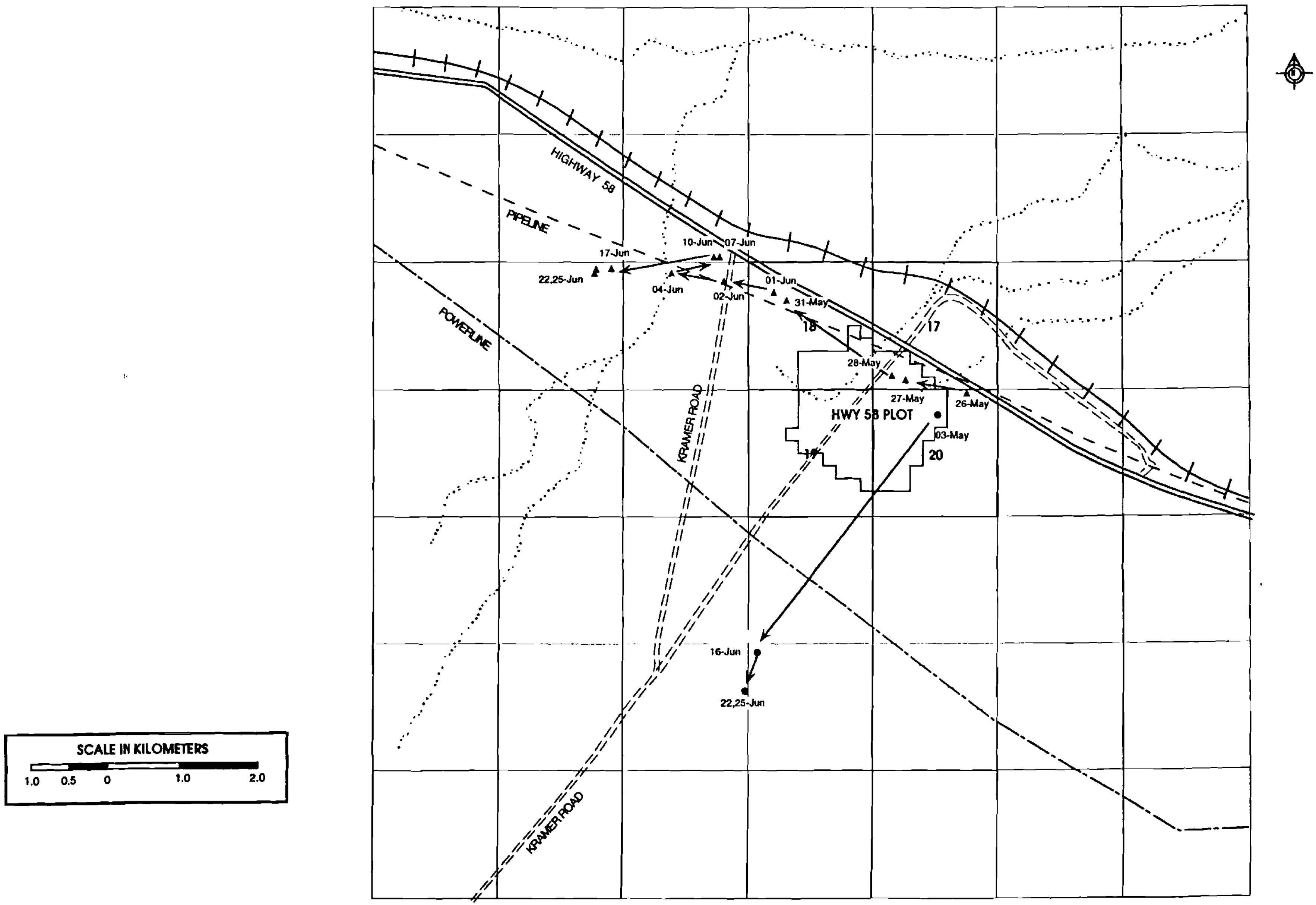

Figure 2. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1992. Various sightings indicated by day and month (▲=Tortoise #78 --- ●=Tortoise #32).

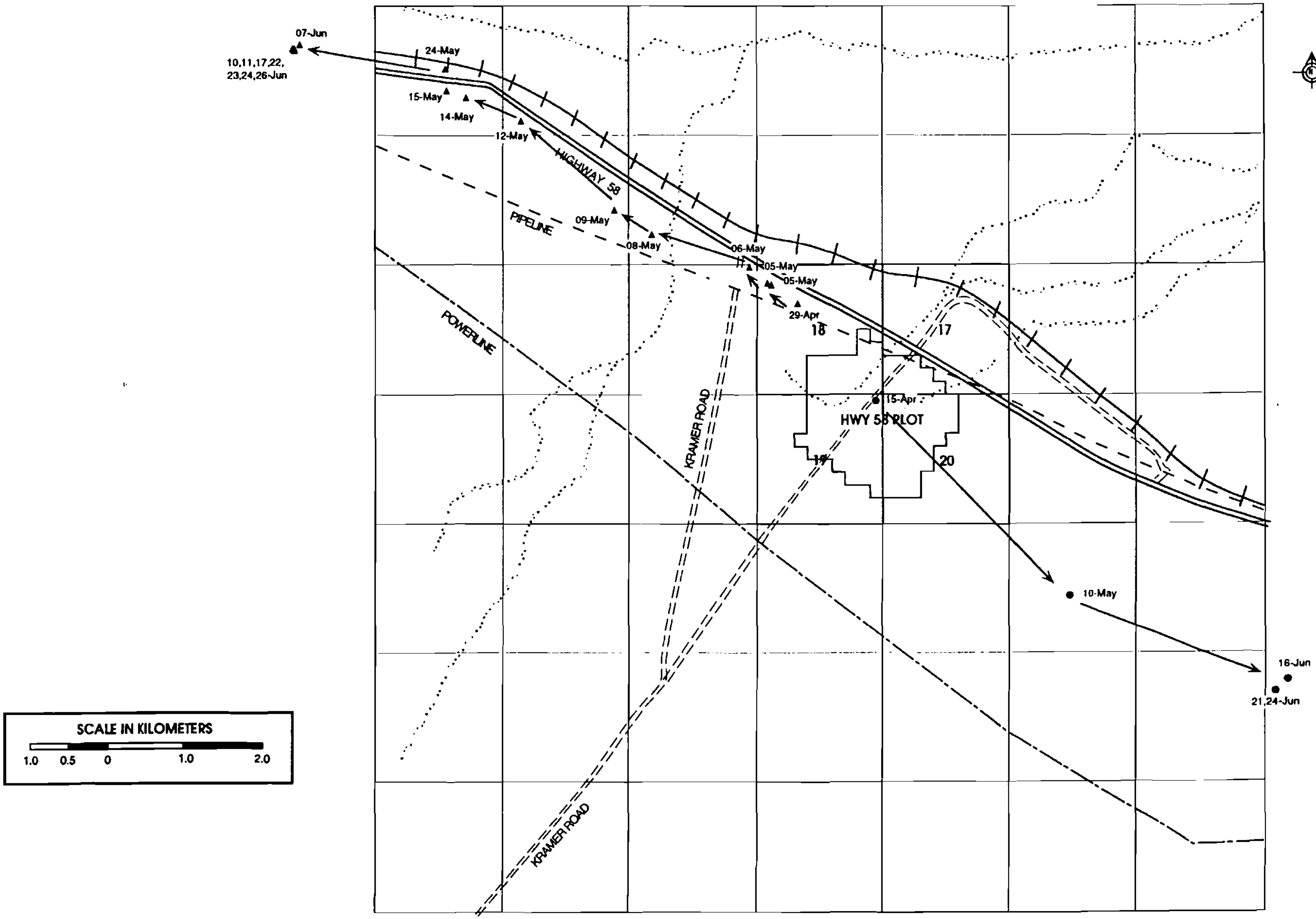

Figure 3. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1992. Various sightings indicated by day and month (▲=Tortoise #72 --- ●=Tortoise #15).

Table 1. Long-distance ($\geq$ 0.8 km) linear movements of desert tortoises at the Highway 58 tortoise barrier study plot during April - June, 1992.

Tortoise ID #	Sex	Size/Age Class	Size MCL[1] (mm)	Linear Distance[2] (km)
15 Female	Subadult	191	6.2	
23	Unknown	Immature 2	142	0.8
32	Male	Subadult	202	4.5
52	Unknown	Immature 2	162	4.6
72	Unknown	Immature 2	163	7.0
75	Female	Subadult	201	1.8
77	Female	Subadult	199	0.8
78	Male	Subadult	183	5.0

1 - MCL = Midline Carapace Length
2 - Linear distance = straight-line distance between two most distant points.

Table 2. Long-distance ($\geq$ 0.8 km) linear movements of desert tortoises at the Highway 58 tortoise barrier study plot during April - June, 1993.

Tortoise ID #	Sex	Size/Age Class	Size MCL[1] (mm)	Linear Distance[2] (km)
48	Unknown	Immature 2	157	1.6
62	Unknown	Immature 1	123	7.0
77	Female	Subadult-Adult 1	208	2.6
88	Unknown	Immature 2	151	2.9
91	Female	Subadult	193	5.0
111	Male	Adult 1	214	13.3
114	Female	Subadult	200	15.5
123	Female	Subadult	183	4.5

1 - MCL = Midline Carapace Length
2 - Linear distance = straight-line distance between two most distant points.

the study plot. By June 25, it had crossed through the plot and was about 3.5 km to the west when the tracking period concluded. This tortoise was classified as a transient because it traveled completely through the study plot.

Four of the tortoises (#15, 32, 52, and 72) were not found again after the 1992 tracking season, three (#23, 75, and 78) stayed in the vicinity of their final 1992 locations throughout the 1993 season, and one (#77) moved to a new location in 1993.

In 1993, eight tortoises made long-distance movements (Table 2) (Figs. 4-8), ranging from 1.6 to 15.5 km. Tortoise #77, a long-distance mover in 1992, repeated as a long-distance mover in 1993. Four of the eight tortoises were females, one was a male, and the remaining three were too small to make sex determinations. All the tortoises making long-distance movements in 1993, except for one adult male, were subadult or immatures at the start of the tracking season. One subadult female grew into an adult 1 age class before the end of the 1993 tracking period. The sex composition of long-distance movers was similar in both years.

Tortoise #111 and 114 were transients in 1993, and made the longest movements, 13.3 and 15.5 km respectively. Overall, the majority of long-distance movements by individuals of known sex were made by females (7 versus 3 males). Two tortoises made excursions out of their respective activity areas and subsequently returned before the end of the tracking period. Tortoise #52 (Fig. 1) did so in 1992 and tortoise #77 (Fig. 4) did it in 1993.

Field investigators carried tortoise #72 safely across Hwy 58 in 1992, and tortoise #111 across Hwy 395 in 1993. Both tortoises appeared to be attempting to cross these highways at the time. After its initial encounter and processing by field investigators, tortoise #114 passed under a gate in the Hwy 58 fence. This tortoise was found on the highway side of the fence apparently attempting to get back onto the study plot side. The tortoise was captured and released on the study plot side of the fence. Subsequently, it moved off the plot to the south.

Tortoise carcass surveys revealed that after an attempt to remove all prior evidence of dead tortoises was made in 1991, remains were found of one tortoise in 1992 and none in 1993, along the 24 km fenced section of Hwy 58 (Table 3). The remains of the one tortoise found along the fenced portion of Hwy 58 was judged to have been overlooked in 1991, based on a shell disintegration assessment devised by Woodman and Berry (1984). Along the 24 km unfenced section of State Highway 395, remains of 14 desert tortoises were collected in 1992, and 5 in 1993.

DISCUSSION

In a paper describing likely reasons for long-distance movements by freshwater turtles on the Savannah River Plant in South Carolina, Gibbons (1986) considered whether there could be any applicability of the movement patterns of these populations to the management of the desert tortoise. He was particularly interested in relocation of tortoises to avoid the impacts of human related development. He suggested four long-distance movement phenomena including mate-seeking movement by males, nesting site selection, movement in response to adverse environmental conditions, and movement to hibernacula. Gibbons also stated that no information was available to suggest that desert tortoises were actually exhibiting long-distance movements for these reasons, but until more study could explain this aspect of desert tortoise behavior, successful relocation of tortoises as a management tool would lead to uncertain results.

Regardless of the reasons that desert tortoises make long-distance movements, many investigators have noted this phenomenon. In the western Rand Mountains northeast of California City, Kern County, California, Berry (1975) studied the movements of twenty-five translocated desert tortoise in the early 1970's. Of the seven tortoises affixed with transmitters, three exhibited straight-line movements from 1.26 to 1.44 km. Berry utilized aerial tracking to assist in making these determinations.

Burge (1977) monitored desert tortoises near the base of the Spring Mountains southwest of Las Vegas, Nevada, to determine daily and seasonal activity, distances traveled, and home range. She found that single trip distances did not exceed .434 km. Included in her study were ten tortoises affixed with transmitters. Four of these tortoises were only tracked for two to nine months of the fifteen month study period. Burge (1977) offered no

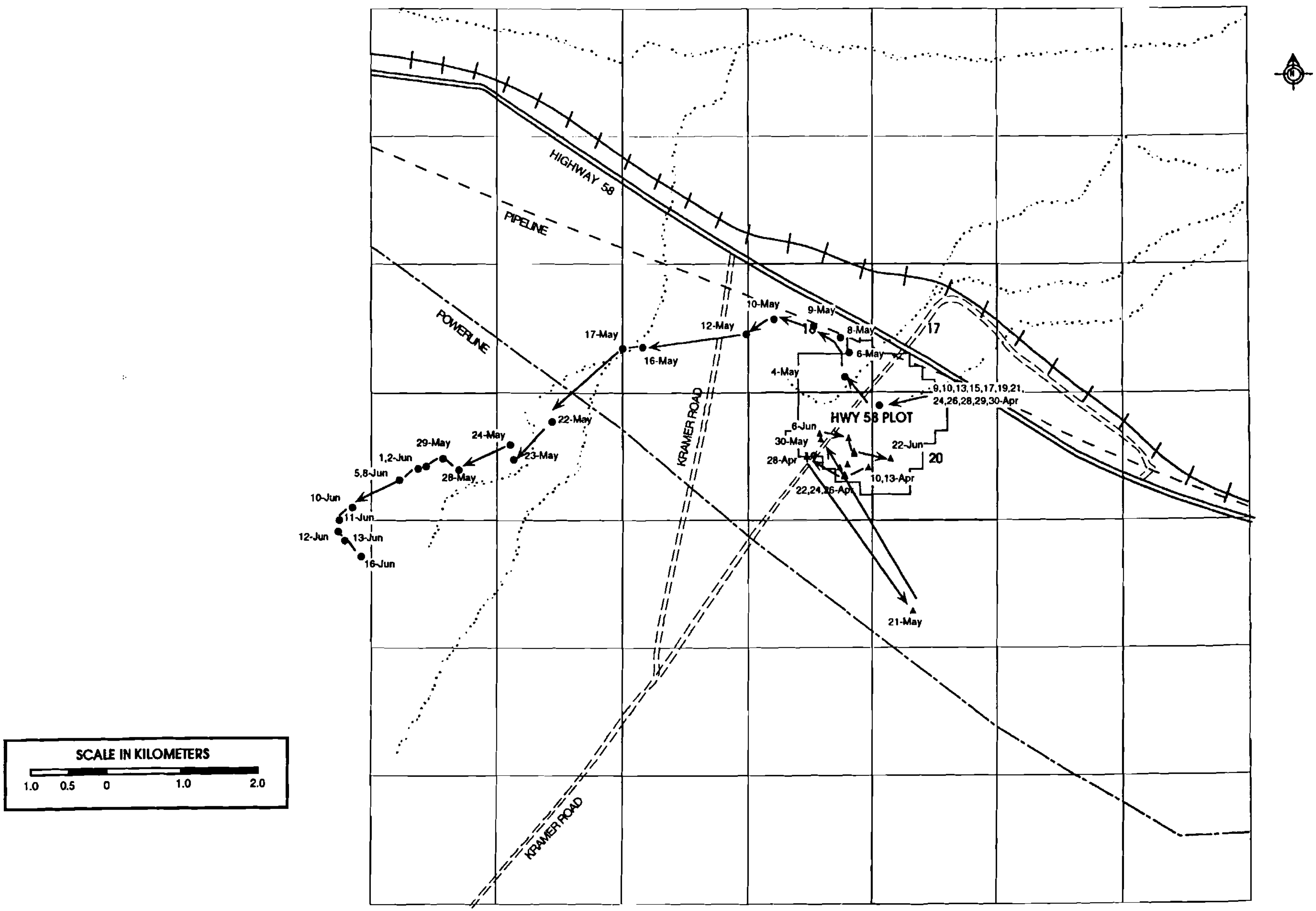

Figure 4. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #77 --- ●=Tortoise #62).

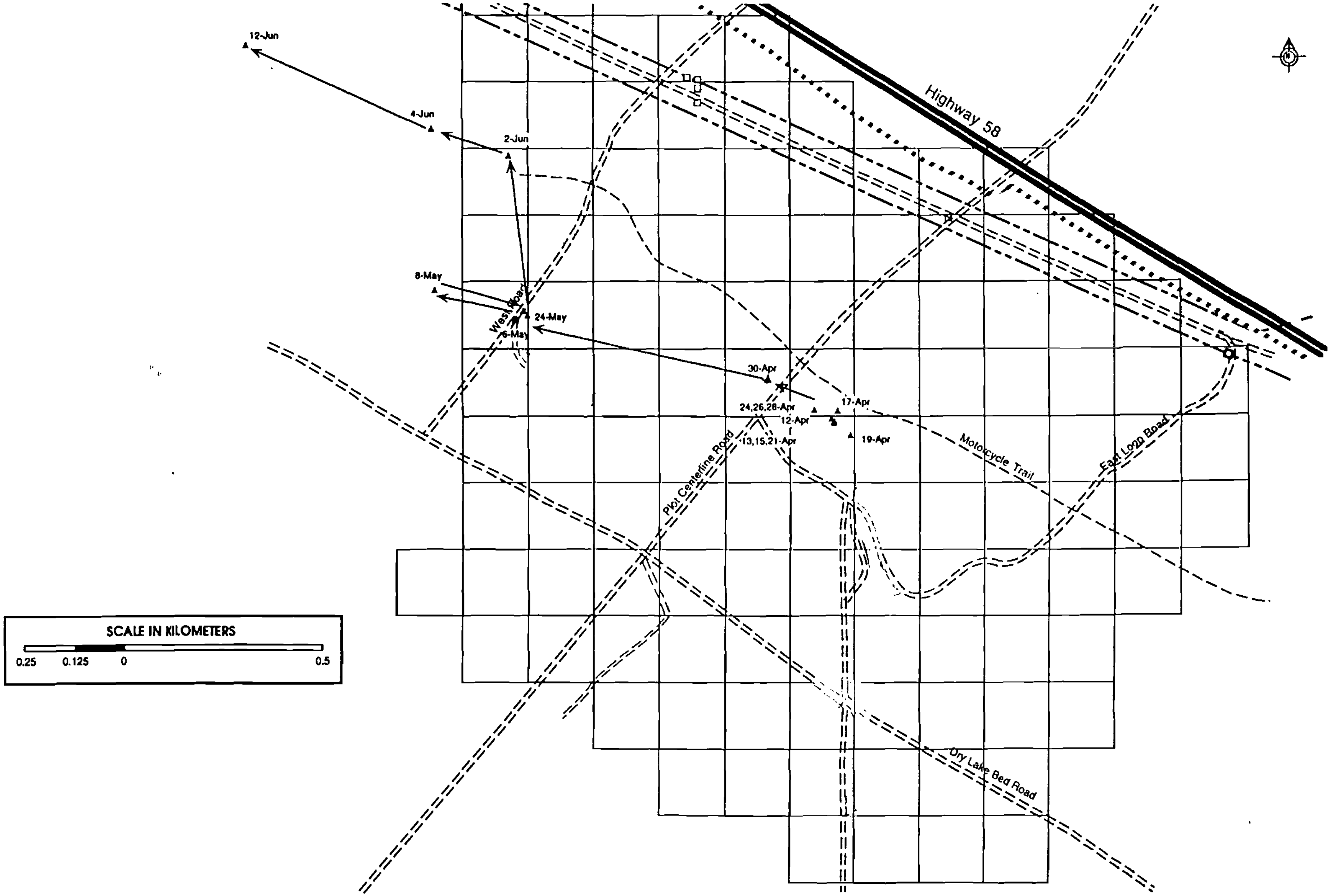

Figure 5. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #48).

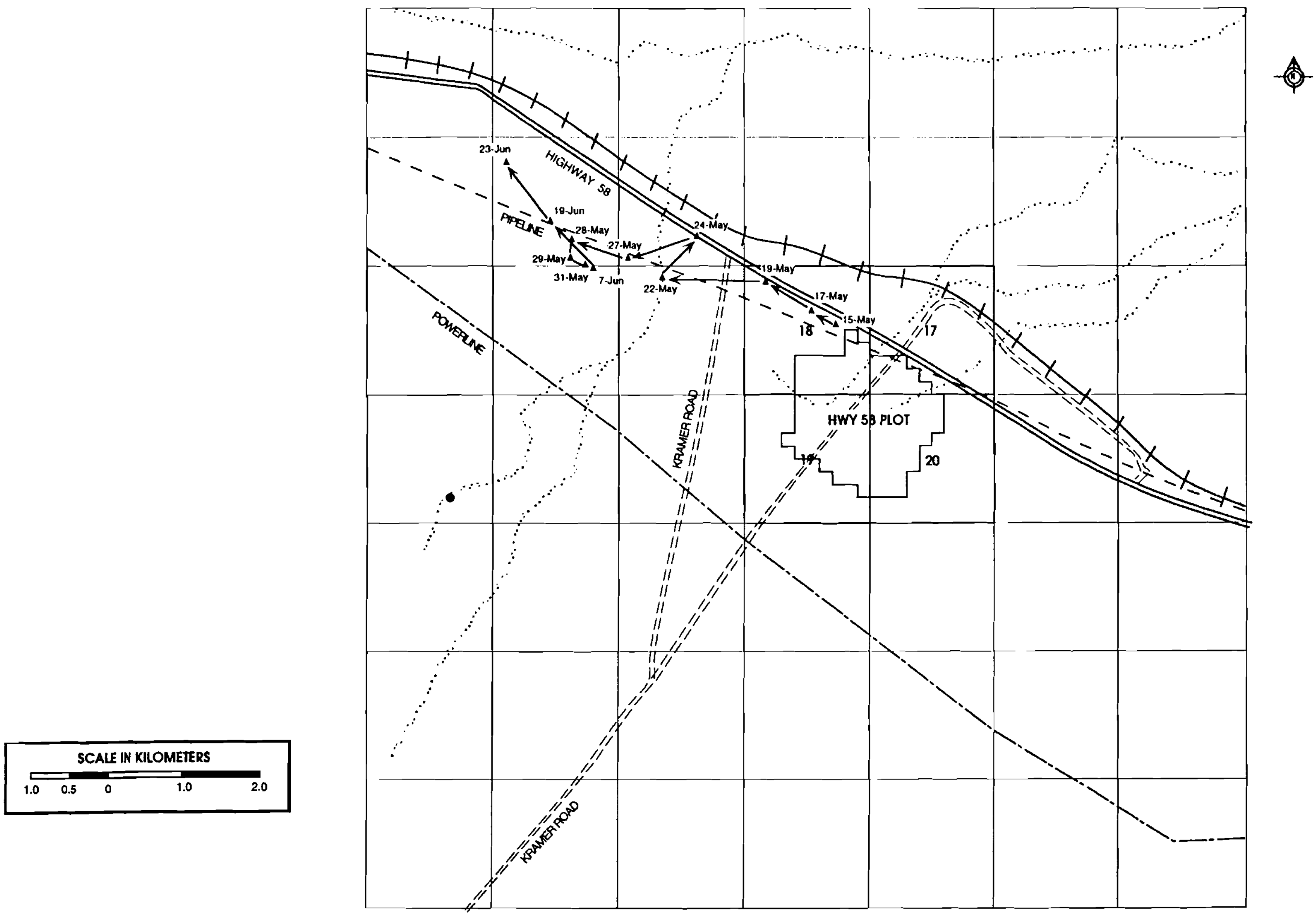

Figure 6. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #123).

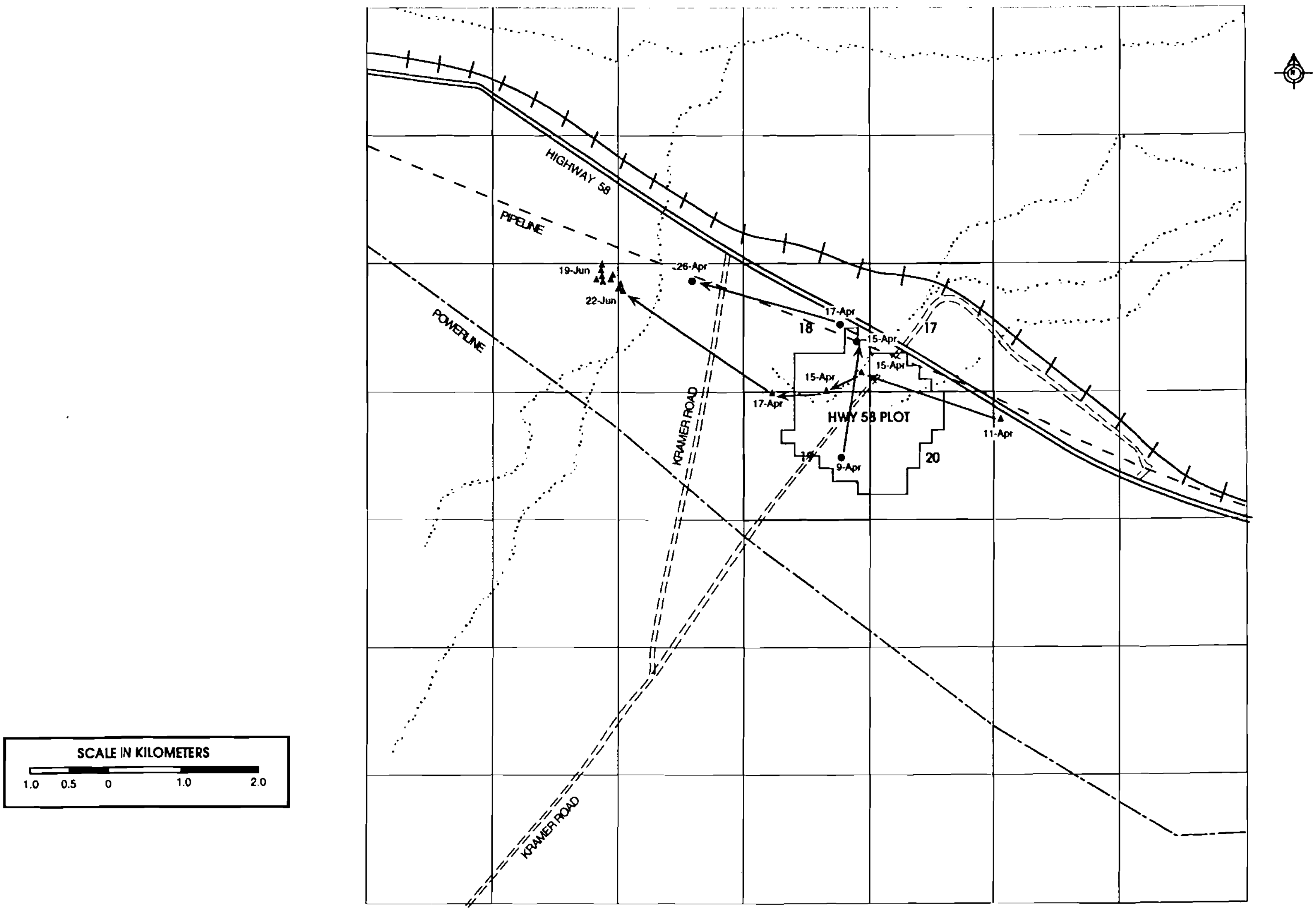

Figure 7. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #91 --- ●=Tortoise #88).

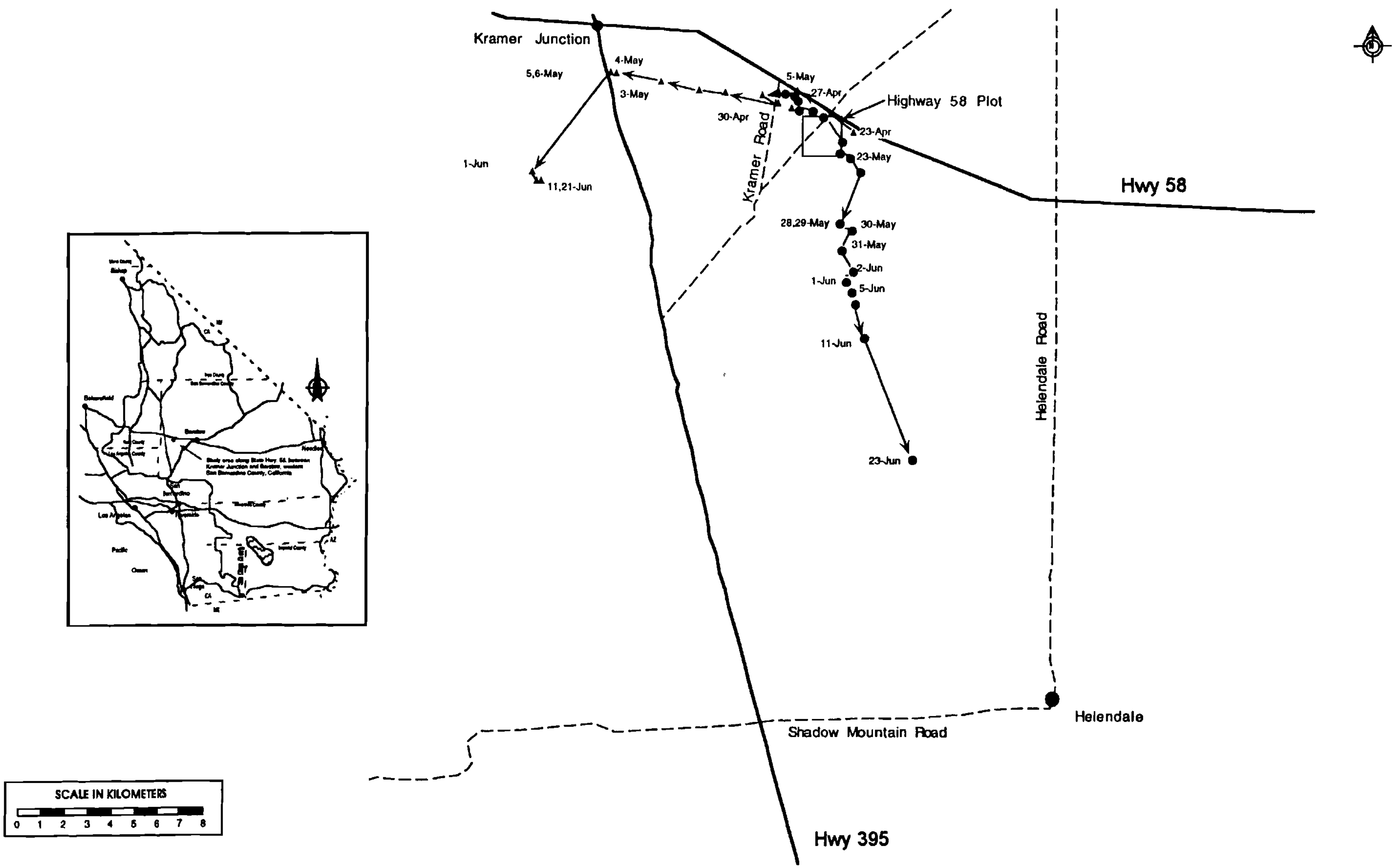

Figure 8. Long-distance movement by desert tortoises at the Highway 58 study plot during April-June, 1993. Various sightings indicated by day and month (▲=Tortoise #111 --- ●=Tortoise #114).

explanation for not tracking these tortoises for the entire study. Tracking them may have been discontinued due to transmitter failure, or because these tortoises moved beyond the range of the telemetry equipment being used. Aerial tracking was not done.

Table 3. Desert Tortoise carcasses (remains) found along 24 km stretches of fenced State Highway 58 and unfenced State Highway 395 in 1992 and 1993.

	1992	1993
Hwy 58 Fenced	1[1]	0
Hwy 395 Unfenced	13	5

1 - Presumably overlooked in 1991, based on condition of shell fragments.

During the mid-1970's, while studying the Beaver Dam Slope desert tortoise population in Arizona, Hohman (Personal Communication, 1994) was unable to locate an adult female two weeks after its last sighting because of a weak transmitter signal. After an extensive systematic ground search, she assumed the transmitter had failed and gave the animal up for lost. Two years later another investigator found this tortoise about 6.4 km from where Hohman had last detected it. The tortoise was reportedly healthy and the transmitter was functioning properly.

In researching desert tortoise physiology in the Mojave Desert, Peterson (1994) reported that four of his thirty-three study animals near the Desert Tortoise Natural Area exhibited long-distance movements over one to twenty-four month periods. The distances traveled by these adult tortoises were 1.6, 1.6, 4.6, and 5.6 km with the only male of the group traveling the intermediate distance. The tortoises included in Peterson's study were preselected as adults by design. Two of the tortoises were found dead. At least three of these long-distance movers were located either by investigators not associated with Peterson's study, or found by taking advantage of donated aerial reconnaissance flights.

It appears in general that individuals who have studied various aspects of desert tortoise biology usually defined and delineated a study plot for mapping purposes. Except for the Berry study cited above, the scope of their searches for study animals was intentionally limited to suit the needs of their projects. Time and effort necessary to track an occasional wayward tortoise presumably would have been considered too costly.

Conversely, from 1985-1987 Stewart (1992) investigated a desert tortoise relocation effort associated with a solar power plant at Kramer Junction, San Bernardino County, California. Tortoises were collected at the power plant site prior to construction and moved to a site 5.6 km to the northeast. Stewart's objective was to see if any of the relocated tortoises would return to close proximity of their original burrow sites. This required tracking beyond the limits of the square mile relocation site. The study's field investigator tracked the relocated tortoises as well as resident tortoises and found that 7 of 14 relocatees exhibited long-distance movements greater than 0.8 km while 3 of 8 residents did the same. One of the relocatees traveled 6.8 km, whereas the longest distance traveled by a resident was 1.6 km. Two of the tortoises that were about to cross Hwy 395 were carried safely across by a field investigator.

To our knowledge, EG&G (1993) documented the longest non-linear journey undertaken by a desert tortoise. A tortoise that was residing on a work site at the Yucca Mountain Project in Nevada was relocated to an alternate burrow approximately 5 km away from its established hibernaculum. After emerging from hibernation, it traveled a total of 30 km in a circuitous route away from its relocation burrow. It returned about 95 days later and established itself in a different burrow within 2.5 km of its initial relocation burrow. The distance this tortoise traveled before reversing its general direction of travel was about 10.5 km. The tortoise, of unknown sex, was 178 mm (mid-carapace length) long.

Our study demonstrates that a conspicuous number of the tortoises we tracked on the Hwy 58 study plot exhibited long-distance movements within the range of similar movements reported by other researchers. Aerial tracking aided us in locating tortoises that had moved off the plot. This aspect of our study design and a concerted effort to continue tracking tortoises that moved off the plot were extremely important in allowing us to document this behavior.

Some of the tortoises on the Hwy 58 study plot could be considered residents in the sense that over the three years of study to date, they remain on the plot. This includes two tortoises that took long-distance journeys, but returned to their established activity area or local home range. Other tortoises that were classified as long-distance movers in 1992 did not make similar movements in 1993.

A few tortoises appear to have been transient tortoises that were included in our study because after first being encountered off-plot and affixed with a transmitter, they traversed the study plot over the springtime tracking period, travelling well beyond its boundary. Of course, this characterization is only relative to our study plot and may be important in understanding the dynamics of some of our study questions; but in terms of examining the phenomenon of long-distance movements, it is probably unimportant.

The propensity for some tortoises to embark on long-distance movements may only occur irregularly at some time in their lives. At this time, our data are insufficient to determine if these movements represented dispersal events or relatively uncommon movements within a broad "lifetime" home range. Nevertheless, this activity has potentially life-threatening consequences for tortoises when heavily traveled highways and roads are encountered.

Nicholson (1978), Boarman (1992), and LaRue (1992) describe apparent tortoise depletion zones that extend out 1 km, 0.8 km and 0.3 km respectively along well traveled highways in various parts of the Mojave Desert in California. The results of their work suggest that highway road kills may account for this depletion. Considering our findings as well as incidental observations made by other tortoise researchers, the effects of roads and highways on tortoise populations may be more pervasive than suspected because of long-distance movers.

As Gibbons (1986) has suggested, if the biology of the animal were better understood, then appropriate management strategies could be devised and implemented to protect and preserve the species, eventually leading to its recovery. Because desert tortoise populations are threatened with extinction, it is important to understand the nature of long distance movements, the level of risk caused by the movements, and ways of reducing those risks. We suggest that until reasons for these long-distance movements are determined and can be factored in, the most immediate and appropriate management prescription to effectively deal with tortoises suffering road kill losses along heavily used highways is to install effective barrier fences along such highways.

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Reproduction In A Sonoran Population Of The Desert Tortoise

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Abstract: Ten desert tortoises were monitored with radio telemetry between 12 September 1991 and 12 September 1993 to collect baseline reproduction data for Sonoran Desert tortoises. Eggs were detected by palpation in 1992 and by palpation and radiography in 1993. Two of eight tortoises were determined to be gravid in 1992, and eight of 10 in 1993. Radiography revealed that palpation was only 50% effective in 1993. Mean clutch frequency was 0.78 clutches/female, and clutch size averaged 5.7 eggs/gravid tortoise. Oviposition occurred before and during the summer monsoon season in both years, from early June to early August.

Even though Mojave and Sonoran Desert tortoise populations are known to differ genetically, morphologically, and ecologically (Lamb *et al.*, 1989; Lowe, 1964; Luckenbach, 1982; Weinstein & Berry, 1987), reproductive biology has only been reported from observations of captive animals and from studies in the Mojave Desert (Johnson *et al.*, 1990; Turner *et al.*, 1984, 1986). No reproduction data have been reported from the Sonoran population.

METHODS

We monitored ten adult female tortoises with radio telemetry between 12 September 1991 and 12 September 1993 in the western foothills of the Mazatzal Mountains, about 30 mi northeast of Mesa, Maricopa County, Arizona. Vegetation at the study site is classified as the paloverde-mixed cacti series (Brown *et al.*, 1979) in the Arizona Upland subdivision of the Sonoran Desert (Turner and Brown, 1982). Arroyos dividing many steep, rocky slopes characterize the topography, and boulders up to approximately 5-m diameter occur on these slopes. Gravid tortoises were determined in 1992 by palping anterior to the rear legs for presence of eggs. We radiographed the tortoises in the field between 12 June and 12 September 1993 with a MinXray 210 portable X-ray machine (13 mA and 63 kV peak) powered with a Honda gasoline generator. The X-ray machine was mounted on a tripod, with the X-ray source 28 inches (71 cm) above the radiograph cassettes. We used rare earth intensifying cassettes and Kodak Ektascan M film with a 0.5 sec exposure or Fuji Medical RX-U film with a 0.4 sec exposure. Radiographs were developed with an automatic processor at the Arizona Health Sciences Center. We determined palpation efficacy by comparing palpation and radiograph results. All means are presented + 1 standard error (SE).

RESULTS AND DISCUSSION

Two of eight (25%) telemetered adult female tortoises were determined by palpation to be gravid in 1992. We used these results to schedule field radiography in 1993. The lack of large decreases in body masses during both springs indicate that tortoises did not lay eggs before the summer laying period.

Radiography revealed that seven of the 10 telemetered tortoises were gravid in 1993; another tortoise laid eggs (suspected due to weight loss and confirmed by the presence of eggshell fragments in the burrow on 12 December 1993) before the initiation of radiography. Eggs were initially detected by palpation in only four of the eight gravid tortoises (50%) in 1993. Failure to detect eggs by palpation appeared to be due to small clutches in early development, tight shell closure preventing effective palpation, or both.

Mean annual clutch frequency was 1.0 clutch/female (SE = 0.0); no tortoise laid more than one clutch. Clutch sizes ranged from 3-9 eggs (mean = 5.7 + 0.92 eggs) per clutch per gravid female. Oviposition occurred between 6 June and 7 August 1993, just before and during the beginning of the summer monsoon season. Only three nests were positively identified in 1992 and 1993, and these occurred below boulders and/or vegetation on northerly slopes of 20-30% grade. Tortoises known to have laid eggs in 1993 tended to remain at a single burrow following oviposition. Since only two nests were positively identified, we cannot state conclusively that post-gravid tortoises were guarding their nests, but this behavior has been reported in the literature (Barrett and Humphrey, 1986).

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Estimating Sizes Of Sonoran Populations Of The Desert Tortoise With Program Capture

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Abstract: Few population studies of the desert tortoise have considered the effects of invalid assumptions on abundance estimates. The primary assumptions common to most estimators of population size include population closure; permanent, correctly recorded marks; and constant and equal capture probabilities. Most of these assumptions can be met in studies of the desert tortoise, but equal capturability has been shown to be problematic for many taxa, including tortoises. Unequal capture probabilities confound most commonly used estimators (e.g., Lincoln-Petersen). Simulations showed that Program CAPTURE's Jackknife and Darroch estimators are robust to variations in capturability. Mean capturability during a given study determines which estimator is most appropriate for that population.

Numerous statistical models have been developed for the estimation of animal abundance (Seber, 1982), as well as several software packages to facilitate these analyses (Lebreton *et al.*, 1993). Biologists have often looked at this assortment of estimators and software packages simply as alternatives from which to choose, even though each model is based on a specific set of assumptions (Skalski and Robson, 1982). Several studies have estimated Sonoran Desert tortoise population sizes using variations of the familiar Lincoln-Petersen method (Lincoln, 1930; Petersen, 1896), with either a single season divided into two sample periods *a posteriori* (e.g., Holm, 1989; Shields *et al.*, 1990; Wirt, 1988), or by using pooled data from two consecutive seasons (Hart *et al.*, 1992; Woodman *et al.*, 1993). Methods used in the Mojave Desert also include the Stratified Lincoln Index (Overton, 1971), Schnabel (1938) method, Schumacher-Eschmeyer (1943) method, and others (see Turner and Berry, 1984). Few studies have considered the effects of invalid assumptions on the resulting estimates, even though several have noted failings in these assumptions (Hart *et al.*, 1992; Holm, 1989; Schneider, 1980, 1981; Turner and Berry, 1984; Woodman and Shields, 1988).

Otis *et al.* (1978) provide a framework for the following review of the general assumptions in abundance estimation models. First, the population must be demographically and geographically closed. Demographic closure means that births, deaths, immigration, and emigration do not occur during the study. Open models allow the relaxation of this assumption, but still require geographic boundary closure (White *et al.*, 1982). Some closed models, such as the Lincoln-Petersen method, may still be valid with either unknown additions to or deletions from the population, but are invalid if both effects occur during the study (Skalski and Robson, 1992). Failure of this assumption leads to overestimates of the true population size due to an inflated ratio of unmarked to marked individuals.

Tortoise longevity allows subadult-adult populations to be considered demographically closed within a given sampling season. Mortality is low for mature tortoises in healthy populations, and slow growth rates prevent significant recruitment into these size classes within a single season. Most Sonoran Desert tortoise populations may also be considered geographically closed due to small home ranges (Bailey, 1992; Barrett, 1990). Demographic closure will begin to break down as the number of seasons included in a given analysis increases, however; insufficient data exist to evaluate long-term site fidelity.

The remaining assumptions are required by both open and closed abundance estimation models. The most important assumption requires each animal to have a constant and equal capture probability during each trapping occasion (Otis *et al.*, 1978). This assumption may fail due to three sources of variation: temporal differences in capturability between sample periods; behavioral responses to capture, such as trap-shyness and trap-happiness; and individual heterogeneity (i.e., innate differences in capturability between individuals). If heterogeneity is present in the population, individuals with higher capture probabilities will be marked earlier and caught more often than those with low capturability, resulting in an underestimate of the ratio of unmarked to marked individuals and, thus, the true population size (Pollock *et al.*, 1990). Similar results occur when animals are trap-happy, while trap-shy animals produce overestimates due to the opposite effect (Pollock *et al.*, 1990).

Larger tortoises are easier to find than smaller ones (Shields, 1980), so it has been common practice to compute estimates separately for the subadult-adult size classes ($>$180 mm median carapace length [MCL]) and the juvenile-immature size classes ($<$180 mm MCL) (e.g., Hart *et al.*, 1992; Holm, 1989; Schneider, 1980; Shields *et al.*, 1990). Schneider (1980) provides evidence for unequal capturability for tortoises within size classes, possibly due to differences in home range and activity patterns, but this problem has since received very little attention. Hart (1993) presented preliminary data suggesting differences in capturability between sexes. Individual tortoises may also be differentially subject to capture depending on the complexity of the habitat in their home ranges, especially in topographically diverse areas with varying concentrations of boulders.

Additionally, marks must be permanent and recorded correctly at each trapping occasion (Otis *et al.*, 1978). Failure of these assumptions leads to overestimates because of the loss of marks. Notching the marginal carapace scutes provide permanent marks for large tortoises, but notches may be obscured by growth between recaptures in young individuals. Correctly recording identification numbers is simply a matter of working carefully.

Otis *et al.* (1978) developed Program CAPTURE for estimating the abundance of closed animal populations, and White *et al.* (1982) provide a companion primer to the original monograph. CAPTURE includes several estimators allowing the relaxation of the equal capturability assumption; the models and estimators in the most current version (Rexstad and Burnham, 1991) are summarized in Table 1. The program also includes a model selection procedure that chooses the best estimator for the data based on a series of goodness-of-fit tests. Unfortunately, the model selection procedure has low power and performs poorly with small sample sizes and capture probabilities (Menkins and Anderson, 1988; Otis *et al.*, 1978), such as those typically found for Sonoran Desert tortoises.

Table 1. Abundance estimators included in Program CAPTURE (from Rexstad and Burnham, 1991).

Model	Key Word	Source of variation in capturability	Reference	
M_0	Null	Constant	Otis *et al.*,	1978
M_t	Darroch	Time	Otis *et al.*,	1978
	Chao-M_t	Time	Chao,	1989
M_h	Jackknife	Heterogeneity	Otis *et al.*,	1978
	Chao-M_h	Heterogeneity	Chao,	1989
M_b	Zippin	Behavioral	Otis *et al.*,	1978
M_{bh}	Removal	Behavioral and heterogeneity	Otis *et al.*,	1978
M_{th}	Chao-M_{th}	Time and heterogeneity	Chao *et al.*,	1992
M_{tb}	M_{tb}-Burnham	Time and behavioral	Rexstad and Burnham	1991
M_{tbh}	no estimator	Time, behavioral, and heterogeneity	Otis *et al.*,	1978

Any model can only approximate a natural population, and it is impossible to know with absolute certainty which particular model provides the best approximation. As discussed, the only assumption that may be a problem in abundance estimation is equal capturability. Several statistical tests have been developed to directly test the assumption of equal capturability (e.g., Carothers, 1971, 1979; Cormack, 1966; Eberhardt, 1969; Leslie, 1958), but these tests have been shown to have very low power (Roff, 1973). Small sample sizes also contribute to poor performance of these tests (Burnham, pers. comm.).

METHODS

Since it is impossible to know the true capturability pattern of a given population, and data from desert tortoise population studies are insufficient for Program CAPTURE's model selection procedure, we compared the performance of several estimators under different capturability patterns in computer simulations. The objective was to analyze the robustness of the estimators so that a particular estimator could be selected to give reliable results in the absence of powerful statistical tests of the assumptions.

Several models may be eliminated from consideration a priori based on a knowledge of desert tortoise natural history and sampling procedures. Since tortoises are hand captured, there should be no trap effects in capturability in a systematic sampling program. Any individuals sensitive to handling will be able to resume their normal activity between samples, because it takes several days to systematically cover a study plot. Therefore, we eliminated Models M_b, M_{bh}, M_{tb}, and M_{tbh} (Table 1); we also eliminated Model M_0 as unrealistically simple (Otis *et al.*, 1978). Individual heterogeneity may be present, as well as temporal variation in capturability between sample periods, so we compared the Jackknife, Chao-M_h, Darroch, Chao-M_t, and Chao-M_{th} estimators (Rexstad and Burnham, 1991; Table 1) under various capturability patterns and population sizes. Statistical derivation of these estimators may be found in the references listed in Table 1.

Simulations were run for populations under the assumptions of Models M_h, M_t, and M_{th}, as well as M_0 with equal and constant capturability for comparison, at three levels of mean capturability: "high" (approximately 20%), "moderate" (approximately 15%), and "low" (approximately 10%). Details of simulation procedures may be found in Murray (1993). Characteristics of good estimator performance include low bias, high confidence interval coverage (near 95%), and small average interval lengths (i.e., high precision).

As mentioned in the introduction, if individual heterogeneity is present, Lincoln-Petersen estimates will underestimate the true population size. In an effort to determine whether heterogeneity is a likely factor in desert tortoise capturability, we counted the number of individuals in the 1990 subadult-adult cohort marked in 1990, 1991, and 1992 on two Arizona Game and Fish Department (AGFD) and Bureau of Land Management (BLM) study plots: Eagletail Mountains (Eagletails), Maricopa County and Little Shipp Wash (Little Shipp), Yavapai County (AGFD, unpubl. data). Low numbers of unmarked tortoises in this cohort in 1992 indicate that the total number of marked individuals is a near complete census (see Table 3). We compared these numbers with the 1990 Lincoln-Petersen estimates (Shields *et al.*, 1990) to see if they underestimated the population. We discarded new tortoises in these size classes in 1991 and 1992 that would have been smaller than 180 mm MCL in 1990 based on an estimate of 15 mm growth per year (see Hart *et al.*, 1992; Woodman *et al.*, 1993) so that the final totals would not be biased by recruitment.

RESULTS

Simulations

Estimator performance (including robustness to alternate capturability patterns) varied primarily according to the mean level of capturability, so model selection should be based on the actual capture probabilities estimated in a particular study. Best results were obtained with five sample periods. Darroch produced the most reasonable estimates when capture probabilities were relatively high under Model M_t, and it also produced reasonable results under Models M_h and M_{th} with "high" capture probabilities (18-21%). Therefore, since we cannot test for unequal capturability, Darroch is a reasonable estimator for general use when mean capture probabilities are $>18\%$. Estimate bias ranged from 0.3-9.0% underestimation, and percent coverage ranged from 86.3-94.8%, with 64.3% in a single simulation.

As capture probabilities decrease, most of the estimators' performances decline. Jackknife generally performed best overall with "moderate" mean capturability (15-16%), especially when heterogeneous capturability was present in the population (with or without time variation). With variation in capturability, bias ranged from -7.4% to +14.1%, and confidence interval coverage ranged from 69.1-92.5%. Therefore, Jackknife is recommended for general use when mean capturabilities approximately equal 15%.

Finally, even though bias was relatively high in most cases (2.7-26.2% underestimation), Jackknife is recommended for very low levels of mean capturability (10-11%), since it produced the best results for all combinations of capturability pattern and population size. Confidence interval coverage ranged from 74.1- 94.7%. These recommendations are summarized in Table 2. A more detailed account of the results may be found in Murray (1993).

Table 2. Suggested model selection for desert tortoise population estimation in Arizona (Program CAPTURE, five sample periods).

Estimated mean capture probability (p)	Recommended model
High (> 18%)	Darroch
Moderate ($\approx$ 15%)	Jackknife
Low ($\approx$ 10%)	Jackknife

Individual Heterogeneity

The 1990 Lincoln-Petersen estimate for the Eagletails plot underestimates the known marked population by 6.1%, but this figure is deceptively large due to the small size of the population (Table 3). The point estimate was only two less than, and the confidence interval easily includes, the known marked population. The Little Shipp plot contains a relatively large population, however, and the Lincoln-Petersen method underestimates the known marked population by 10.5% (Table 3). The Lincoln-Petersen 95% confidence interval barely includes the known number of tortoises in this cohort.

Table 3. 1990 Lincoln-Petersen estimates for two desert tortoise study plots compared with the total number of adults and subadults marked from 1990-1992.

Population	Estimate[b] (95%CI)	Number new tortoises (1990 cohort) marked[a]			Total marked	Estimate difference
		1990	1991	1992		
Eagletails	31 (26-36)	28	2	3	33	-6.1%
Little Shipp	85 (70-100)	68	17	10	95	-10.5%

[a] From AGFD, unpubl. data.
[b] From Shields *et al.* (1990).

DISCUSSION

The Lincoln-Petersen underestimate for the 1990 Little Shipp plot would be expected if heterogeneity were present in the population. It is likely that tortoises have heterogeneous capture probabilities under the survey protocols used in recent population studies (see Hart *et al.*, 1992; Shields *et al.*, 1990; Woodman *et al.*, 1993); unequal plot coverage ensures that tortoises in areas visited less often will have lower capture probabilities than those in areas with more emphasis.

The Lincoln-Petersen method has been the most frequently used abundance estimator in desert tortoise population studies, especially in Arizona (Hart *et al.*, 1992; Holm, 1989; Shields *et al.*, 1990; Wirt, 1988; Woodman *et al.*, 1993). As previously discussed, model selection carries important ramifications for the validity of population estimates. Buck and Thoits (1965) found considerable bias in their Lincoln-Petersen estimates of fish in a pond. A complete census was conducted by draining the pond after the recapture samples were taken. They ruled out recruitment and mortality based on their data, so the bias was attributed to unequal capturability between fish. Eberhardt (1969) found that unequal capturability occurs for several species across taxonomic groups, and Roff (1973) showed that the available tests for this assumption are unreliable. Cormack (1968) pointed out that it is impossible to test for unequal capturability in a population of unknown size because of the possibility of some individuals having zero catchability.

The inability to directly test the equal capturability assumption does not mean, however, that researchers may not compute valid abundance estimates based on other sources of information. Cormack (1968) emphasized that all information, both biological and statistical, must be used in choosing the most appropriate estimator. The results of this study provide a basis for selecting models that will produce biologically meaningful abundance estimates. Murray (1993) also discusses other aspects of monitoring desert tortoises including sampling procedures and study plot size, density estimation, population trend analysis, and survivorship and recruitment estimation.

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Fighting Wildfire In Desert Tortoise Habitat: Considerations For Land Managers

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Abstract. We describe our experience as biologists/resource advisors working with firefighting personnel to reduce the risk of impacts and disturbances to desert tortoises and their habitats. Pre-fire season planning is essential preparation for risk assessment and identifying sensitive areas of habitat between biologists/resource advisors and fire managers. Having resource advisors present at the onset of fire operations can prevent potentially destructive activities related to the logistics of having vehicles in habitat and providing for the needs of groups of fire suppression personnel. Rehabilitation of road heads in tortoise habitat is a useful means of deterring further long-term degradation of habitat in some cases. We provide two appendices for use in the field: 1) an outline of fire management activities to be used by fire managers, and 2) an outline of a shift briefing used to educate firefighters at the scene of a fire. These prescriptions for action and education were developed for use in the northeast Mojave Desert of Utah and Arizona. These procedures are not universal in application and should be tailored to local needs and consideration of other resource values than tortoises. The Sonoran Desert of Arizona differs substantially in physiography, and plant species composition and fuel loads. Therefore, we should consider habitat characteristics and habitat use by tortoises in the Sonoran Desert of Arizona specifically to assess the possible effects of fire suppression activities and to minimize adverse impacts to desert tortoises and their habitats.This approach could be useful for protecting other sensitive species and habitats in a variety of areas.

INTRODUCTION

Wildfires have the potential to drastically alter desert landscapes, reduce the ability of habitats to support wildlife, and kill wildlife directly by exposure to smoke and excessive heat (Humphrey 1974, Stubbs et al. 1985, Simons 1989, O'Leary and Minnich 1981). There are risks to desert tortoises and their habitats associated with fire suppression activities. Vehicles can crush live tortoises or destroy nests and burrows. Vehicles also can create tracks that become trails for off-road vehicle enthusiasts. These potential risks must be considered during fire suppression activities. In the interest of conserving habitat for tortoises and other desert wildlife, it is useful to predict years of high fire incidence and prepare resource advisors and firefighters for the special considerations of suppressing fires in tortoise habitat. Through this cooperative approach, between resource advisors and fire suppression personnel, it is possible to reduce risks, to tortoises and their habitats, that may arise from wildfire suppression. The recent listing of the Mojave population of the desert tortoise as a threatened species protected by the Endangered Species Act (USDI Fish and Wildlife Service 1990), and the delineation of critical habitat has created the need for federal agencies to consider the potential impact of fire suppression activities on desert tortoises and their habitats (USDI Fish and Wildlife Service 1994). Policy for fighting wildfires on federal lands in relation to desert tortoises and their habitats has only been considered formally by federal agencies in areas that have special designations such as the Desert Tortoise Natural Area in the Mojave Desert of southern California (U.S. Bureau of Land Management and California Department of Fish and Game 1988).

Role of Biologists in Fire Suppression

There are two levels of involvement for biologists in fire suppression: as the Resource Advisor (RA) and as a monitor. All official fire operations conducted by federal agencies have a designated Incident Commander (IC). The IC is responsible for all field operations on fires. RA's act as liaison between the IC and the agency manager. The RA provides input directly to the Incident Commander about locations of tortoise habitat in relation to the fire operation, identifies areas that are particularly sensitive to disturbance such as research areas or high density tortoise areas, and provides information to fire fighting personnel about desert tortoise natural history that can be used to minimize further impacts to tortoise populations and their habitats (e.g. how to identify tortoises and their cover sites, where cover sites occur, and what aspects of the habitat are important to tortoises). The RA does not set specific control objectives or determine firefighting tactics - those are the responsibilities of the IC. It is essential that biologists do not give conflicting orders in potentially dangerous situations and that they work through the chain-of-command. Monitors work directly with fire crews and support personnel to ensure that guidelines are followed and impacts minimized. Monitors may provide shift briefings for firefighting personnel, survey potential campsites for tortoises or tortoise coversites, and walk in front of fire engines to spot tortoises and other objects of concern. Monitors ensure that tortoises and their habitat are protected from specific suppression actions but do not direct suppression efforts.

Preseason

Fire management begins during the winter when habitat managers meet with fire specialists to develop a firefighting policy. Objectives and restrictions of fire management are determined. The policy identifies areas of concern such as desert wildlife management areas, research plots, and critical habitat. Levels and methods of fire suppression are addressed. By meeting prior to the fire season, biologists and fire specialists may avoid conflicts associated with fire suppression.

During the pre-fire season meeting fire management personnel develop an understanding of the importance of quick, effective action against fires in desert tortoise habitat, and biologists become aware of the tactical and logistical considerations of firefighting. A tortoise education program and shift briefing are developed and should be tailored to local conditions and needs (Appendix II).

Fire Season

Local fire crews receive a desert tortoise education program during their regular early season fire training. We have provided firefighters with a shift briefing specific to the agency where they work, similar to the information contained in Appendix II. It is crucial that firefighters understand how their actions can impact the environment and how impacts can be reduced. During the fire season biologists are on call and available as resource advisors or monitors on fires. It is a safety requirement that biologists have the necessary protective clothing and equipment in order to be able to go out on the fireline. Biologists may also need to attend fire training to become qualified to work on the fire as a resource advisor.

Fire Suppression

Throughout the year the Fire Management Officer monitors fuel loads and weather, and accordingly adjusts firefighting forces and equipment location. Standard suppression techniques were developed for forest fires, therefore some modifications are likely to be appropriate for desert conditions. The Incident Command System (ICS) is the standard management structure used by state and federal agencies (National Wildfire Coordinating Group 1983). It is a strictly regimented command and control system, where roles are defined for all participants.

The Incident Commander is responsible for all logistics and operations related to fires. On small fires the IC may be a local fire crew foreman. On larger fires, an incident management team may be brought in to work for the IC. Sometimes these teams have little or no experience working in the desert. These teams receive their mandate from the local agency manager, and it is imperative that the importance of the mission (including all information related to desert tortoises) be conveyed from the agency manager to the IC. The IC is then responsible for relaying that information (e.g. possibly using the RA or monitor to convey information) and emphasizing its importance to subordinate personnel in the ICS.

Logistics coordinators provide important support services that may impact tortoises and their habitat. The location and design of camps, and any rules of behavior for personnel, are important considerations to reduce impacts to tortoises. Biologists work with Camp Managers to identify camp areas. Campsites should be located outside of desert tortoise habitat, or in locations that are already so disturbed that further use will not cause additional harm to tortoises or the habitat. If it is necessary to establish a camp in desert tortoise habitats the sites should be inventoried for tortoise presence to avoid harm to tortoises. Personnel activities may be contained within these previously disturbed areas and nearby sensitive areas may be designated and delineated as off-limits.

Logistics coordinators also assist suppression efforts with Ground Support. The RA should work with the Ground Support Team to establish rules for vehicle use such as travel restrictions, parking, and speed limits. Drivers are specifically told how to park in relation to the roads and to turn around on desert roads with a minimum of off-road impact. In a fire situation, people tend to hurry. By informing fire personnel of the presence of tortoises and driving rules, fewer tortoises may be run over.

The most important suppression activities occur in Operations, where firefighters attempt to halt the spread of the fire. Hand crews are used to build and hold the fire lines, attend to hot spots, and support fire engine crews. Fire engine crews can patrol roads or lay hose along fire lines. If necessary, fire engines may be driven off-road, preceded by a monitor or firefighter on foot to guide the driver of the vehicle around tortoises and other objects of concern. Local units should go off-road first because of their prior knowledge of the area whenever possible.

Desert wildfires can, under high fuel loads or during high winds, move very fast and present difficult control problems. These problems are exacerbated when suppression forces are insufficient to meet the need of controlling the fire. Helicopters and fixed-wing aircraft may be used for a variety of missions to support ground forces. Helicopters can transport personnel into roadless areas, provide a reconnaissance platform, and deliver water from buckets. Large, surplus military bombers can be used to drop fire retardant, but they are being replaced by small, single-engine aircraft that can work from dirt landing strips and, reduce turnaround time. All aircraft landing and fueling areas within habitat must be surveyed and monitored for presence of desert tortoises prior to use to reduce chances of tortoises being killed.

Fire retardant can be important in controlling the spread of fires. There are several options for fire retardant (e.g. foam, water, slurry). A fugitive retardant slurry (FRS) may be preferred over water, foam, or the traditional iron oxide phosphate retardant slurry. FRS can be more effective than water-chemical reactions, and does not evaporate as easily. Foam is a surfactant (like soap) that reduces the surface tension of water that is applied on fires. Slurries of iron oxide stain the ground and remain visible in the desert for extended periods of time. At present the effects of these fire retardant agents on the health of individual desert tortoises are not known. Retardant is most effective when ground crews are available to provide suppression support in keeping the fire from burning through or around the retardant.

Sometimes fire is fought with fire. Under certain conditions, the best and perhaps only opportunity to contain a fire is to set backfires along control lines to remove fuel. Because of the intensity of backfires, the areas where they are attempted can be the most denuded. However, under high wind conditions, or high fuel loads, roads and handlines may not retard the advance of a fast-moving fire. In some circumstances, backfiring is used to protect larger areas of habitat.

Fires burn erratically, leaving patches of unburned fuel called islands or fingers. Traditional fire suppression techniques call for the "burning out" of these unburned areas to reduce the chance of the fire flaring up and spreading across control lines. However, in desert habitats these islands and fingers are not as much of a threat as they are in timber fires. Due to their value as undisturbed habitat in largely burned areas we do not allow "burning out" in deserts. These habitat islands may be extremely important in the recovery of habitat as seed stock, recovering root crowns and refugia for tortoises that will eventually re-populate burned areas.

Tracked vehicles may also be used to suppress fires; however, due to their long-lasting impacts on desert soils and vegetation, they are restricted to improving roads or constructing lines where a short distance of line might save a large area from fire. Tracked vehicles have not been used in desert tortoise habitat of the Arizona Strip, Arizona and Utah since 1980. If used, tracked vehicles must be preceded by a qualified monitor.

Post Suppression

Impacts secondary to the fires themselves may continue long after the fire is out (Esque et al. 1994). Roads that were created by fire suppression machinery may open up previously untraveled areas to off-road vehicle enthusiasts. We suggest that fire crews obliterate their tracks to reduce the temptation of the public to drive down those tracks. In some cases it is possible to re-vegetate the junctions of roads and heavily used fire access trails. Re-vegetation with perennial plants can be expensive; however, by re-vegetating a short distance from the road-head these sources of future disturbance can be hidden from view and therefore less likely to be used (Carolyn Miller - Joshua Tree National Monument, pers. comm.).

CONCLUSIONS

The ideas conveyed in this article were developed as guidelines for fighting fires in desert tortoise habitat in the northeast Mojave Desert of Arizona and Utah. We have found these guidelines useful through several fire seasons on the Arizona Strip of northern Arizona and recently in southwestern Utah, but they may not be universal in application. We stress the importance of tailoring such guidelines for local conditions, and in consideration of other resource values as well as that of the desert tortoise. The physical nature of desert tortoise habitat in the Sonoran Desert of Arizona is very different from that of the Mojave Desert. Because of these differences, many of the stipulations for fire suppression activities may differ in Sonoran habitats of Arizona. Biologists working for land management agencies in the Sonoran Desert of Arizona should consider habitat characteristics and habitat use by tortoises to assess the possible effects of fire suppression activities and to minimize adverse impacts to desert tortoises and their habitats.

We have learned that on-site education for firefighters can be an effective tool to minimize disturbances to habitat and tortoises as a result of fire suppression activities. Individuals charged with briefing firefighters about desert tortoises and habitats should be provided with an information package that they can use for guidelines. We believe this approach can be used to establish guidelines for other sensitive wildlife and plant species, as well as sensitive habitats.

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Appendix I. A Hierarchy for Fire Suppression Activities in Desert Tortoise Habitats.

I. Preseason

A. Resource Manager meets with Desert Tortoise Biologist and Fire Management Officer (FMO).

1. Discuss objectives of fire suppression.

2. Identify areas of concern (e.g. Critical Habitat, Areas of Critical Environmental Concern, Research Study Areas).

3. Determine level and methods of suppression. Full suppression of desert wildfire requires quick initial attack by hand crews, fire engines, and aircraft. Plan for sufficient number of crews and fire engines; consider contract helicopter and single engine air tanker.

4. List key contacts to serve as Resource Advisors (RA), and monitors.

5. Discuss restrictions on fire suppression.

B. Identify water sources (for aerial water drops by aircraft) and arrange for their use.

C. Identify locations for base camp and staging areas. Survey potential base camp and staging areas for tortoise presence.

D. Determine locations of natural and man-made barriers to fire.

E. Conduct annual road maintenance just prior to fire season improve access and create barriers to fire.

F. Organize an educational package for individuals who will be presenting shift briefings at fires and distribute the packages to appropriate individuals.

II. Fire Season

A. RA's and monitors should be on call 24 hours. These individuals must be trained and issued full protective gear. Training may be on site, prior to the actual fire activity, or the individual may attend a fire training seminar.

B. Local fire suppression forces are briefed on desert tortoise considerations for fire suppression during their regular early season fire training. Briefings include a discussion of tortoise ecology, legal status, fire suppression goals and restrictions (Appendix II).

C. Fire Management Officer (FMO) monitors fuel load and weather conditions and adjusts initial attack preparedness level according to fuel and weather.

III. Fire Suppression

A. Fire suppression is a dangerous business. Tortoise considerations are secondary to issues of human safety. Fire organization adheres to a strict chain-of-command. The resource advisor helps define goals and objectives for fire suppression efforts and informs the Incident Command (IC) of any restrictions, but does not get involved in specific suppression tactics. Tortoise biologists/monitors ensure that tortoises and sheltersites are protected/avoided but do not give specific directions on locations of fire lines. On small fires the IC may be a local fire crew foreman. For example, some areas have determined that the cutoff when further personnel are called in is 10 acres (BLM - Dixie Resource Area, Unpublished fire plan).

B. It is important that biologists not interfere in fire suppression operations. RA's/monitors are a resource to provide input and assistance. If tortoise considerations are not being observed, issues are discussed with IC and FMO. It would be inappropriate and counter productive for the RA's to give conflicting orders.

C. Small fires should be handled by local forces.

D. For more complex fires, an organized fire management team is brought in. The IC should be informed by the RA that tortoise considerations have high priority. IC relays through subordinates the importance of following the guidelines provided by RA. RA makes an awareness presentation at shift briefings (Appendix II).

E. IC and RA evaluate suppression resources, tortoise habitat and population considerations. After considering these factors, IC develops a plan for fire suppression.

F. Hand crews should be used to build and defend fire lines. Engines can be used for support from roads. Wherever practical, fire engines remain on roads and lay fire hose along hand lines. If fire engines need to go off-road then they must have a crew member or monitor walking in front of the engine to avoid tortoises and shelter sites. Use local units to go off road first.

G. Hot fires may require aerial support from helicopters or fixed-wing aircraft using slurry (fugitive retardant most preferred, iron oxide least preferred), foam, or water retardants.

H. If it appears that it may be necessary to use tracked vehicles then order and stage them at a site previously cleared by the RA/monitor - heavy equipment should be used as a last resort and optimized where a short distance of fire line will prevent large area from burning. Tracked vehicles must be accompanied by qualified RA/monitor.

I. Backfires can be used from roads or lines where necessary. Fingers, or islands of unburned habitat must not be burned out as a fire suppression measure. Scratch lines should be patrolled.

IV. Post Suppression

A. Notify appropriate agencies of damage or injury to desert tortoises or tortoise habitats.

B. Begin rehabilitation of fire lines, especially lines created by tracked vehicles. Obliterate vehicle tracks that leave roads to prevent those tracks from becoming trails and roads.

C. Begin consideration of any rehabilitation of burned area that may be necessary (e.g. seeding, perennial plantings).

D. Begin vegetation monitoring where appropriate. Establish paired plots inside/outside burn.

E. Conduct post-fire critique. Evaluate effectiveness of suppression activities and identify successes and failures of desert tortoise mitigation efforts. Revise procedures as necessary.

Appendix II. Shift Briefing for Fire Suppression Forces in Desert Tortoise Habitats.

INTRODUCTION

Key points and issues: With proper organization and consideration, ecosystem management responsibilities can be built into fire management plans to consider the effects of firefighting activities on desert tortoises and other federally listed species. Firefighting is a hazardous activity with very explicit objectives and goals that are established only in terms of communication with a Resource Advisor (RA) at the request of land managers. When conservation of desert tortoises (and other federally listed species) is a consideration, firefighters need to know that tortoise habitat is a priority. The value of desert resources may not be immediately apparent to firefighters whose background is primarily in timber. Some ecosystems depend on fire; however, Mojave Desert ecosystems are not currently thought to be as fire-tolerant as they once might have been. Exotic grasses now dominate the annual plant communities of many desert areas. These exotic plant species can carry fires very well in some years. This can result in the conversion of desert habitat to habitats dominated by exotic annual species which, in turn, burn more easily and may increase the size of exotic dominated areas.

Background and Situation

This fire is burning in the habitat of desert tortoises, a species listed as Threatened with extinction by the U.S. Fish and Wildlife Service and protected by the Endangered Species Act (ESA). The ESA states that activities undertaken by federal agencies must not result in the "take" of designated Threatened or Endangered species or their habitats. According to the ESA we must not: harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct with an organism under ESA protection. Wherever federal agencies administer desert tortoise habitats, they are responsible for conserving the habitat of desert tortoises and recovering tortoise populations. To that end, management agencies are managing all human activities such as grazing, mining, and off-road vehicles in a restrictive manner in desert tortoise habitats. It is also a priority for management agencies to reduce the degradation of habitat from wildfire. Desert tortoises are not the only consideration here - management agencies are responsible for managing ecosystems with many resource values (list local emphasis). Areas designated as Critical Habitat, proposed Desert Wildlife Management Areas, study areas and desert tortoise population centers should be delineated for firefighters in the immediate area of the fire at this time.

Heat, smoke, and fire suppression activities can kill or injure desert tortoises, may destroy eggs in nests, and can destroy habitat. Mojave Desert shrubs burn well and may take years to recover to their former condition after being burned. The loss of shrubs can stress desert tortoises because shrubs protect tortoises from excessive exposure to sunlight and predators.

Desert tortoises are herbivorous reptiles meaning that they primarily eat plants. The plants that tortoises depend on for the majority of their diets are annual plants. Individually, desert tortoises are selective in their diet choice (e.g. individuals each have a suite of favorite plants). But as a species desert tortoises are generalists, using a wide variety of desert vegetation. Fire can result in a short-term loss of forage.

Fires in the desert may be followed by an invasion of exotic annual grasses. Annual grasses can invade fire disturbed areas in as little as one growing season. Dense stands of exotic grasses burn more easily and therefore more frequently than desert shrub communities. Fires in annual grass dominated communities can also spread into previously unburned areas. The result of this cycle is that areas dominated by annual grass can increase in area. There is some evidence that these desert habitats ultimately return to shrub communities through succession. However, as annual grass monocultures increase in size, it becomes increasingly unlikely that tortoise populations can survive in these disturbed habitats.

Tortoise Facts

Key points and issues: describe tortoises and shelter sites so that firefighters can recognize and avoid interactions with tortoises. As time permits, add any interesting facts or stories. Be concise and remember that the objective of the education session is to prevent take of tortoises and habitat on this specific fire. Discussions of tortoises on a rangewide basis should be saved for informal discussions in the base camp. These firefighters have a job to do and will be anxious to get to the action.

Describe desert tortoise shelter site types from a local perspective - burrows, dens, and pallets - their shapes and locations. Describe desert tortoises - color, size, and shape - and any local characteristics that would help novices notice and identify tortoises or their shelter sites. Use photos, diagrams, handouts, models, etc.

Operational Approach

Key points and issues: The overall goal is to fight fire safely and efficiently, minimizing the size and impacts of suppression activities. Describe the relationship of RA to IC. Describe the strategy to fight fire without creating take.

The overall goal of this fire suppression effort is to safely and efficiently minimize fire size and the impacts of fires to tortoises from suppression actions. The RA will brief the Incident Command (IC) on tortoise considerations and advise on preferred strategies. IC has the authority to take actions that are deemed appropriate to ensure the safety of firefighters and the public, and reduce threats to equipment and private property.

Tortoise monitors will be assigned, where necessary, to work directly with units. On the line, monitors have the authority to direct crews to avoid tortoises and their nests and sheltersites, but will not direct the suppression action. When working with support units, monitors have authority to ensure avoidance of tortoises and their nests and sheltersites when developing base camp facilities and staging areas. Use of predetermined and inventoried areas is encouraged.

RA and monitors will work through the chain-of-command to accomplish their mission. It is inappropriate for them to give conflicting orders directly to personnel in the field. In order to minimize habitat disturbance and the chance of take from suppression actions we recommend the following strategy: Simultaneous use of hand crews to construct and hold fire line, fire engines to hold roads and lay hose to support hand crews, and aerial retardant from fixed-wing aircraft (either large tankers or single engine air tankers) and helicopters. Fugitive surfactant retardant (FSR) is preferred over iron-oxide. FSR can be more effective than water-chemical reactions, and does not evaporate as easily. Foam is a surfactant (like soap) that reduces the surface tension of water that is applied on fires. Slurries of iron oxide stain the ground and remain visible in the desert for extended periods of time. Retardant is most effective when fire crews are present to follow-up on suppression activities, and ensure that the fire cannot burn through or around the retardant. At present the effects of these fire retardant agents on the health of individual desert tortoises are not known.

Where necessary, fire engines may be driven off-road, preceded by a crew member, ensuring the vehicle does not crush any tortoises, or shelter sites. If it appears that it may be necessary to use tracked vehicles, then order and stage them at a cleared site - tracked vehicles should be used as a last resort where short distance of line will prevent large areas from burning. Tracked vehicles must be accompanied by qualified RA/monitor.

Rehabilitate lines from tracked vehicles completely. Backfire can be used from roads or lines where necessary. Do not burn out habitat fingers or islands - use scratch lines and patrol them around the edges. These islands and fingers become essential habitat features to the recovery of the area.

Restrictions

Minimize off road travel. Wheeled vehicles will be preceded by crew member to observe, and tracked vehicles require qualified monitors. On-road travel should be restricted to speeds that allow drivers to distinguish obstacles such as a rock and tortoises. Minimize disturbances at turn-around points. After fire, obliterate all vehicle tracks from the point where they leave the road to prevent that track from attracting future vehicle use.

Firefighters should note location and condition of desert tortoises and carcasses, but should not attempt to touch or move them unless the animal is in immediate danger from fire or is on a road that is receiving traffic use. Firefighters should be encouraged to provide notes to tortoise RA/monitors. We have found that many individual firefighters are interested and like the opportunity to participate in this manner. Firefighters will not leave trash on the line. Around camp, trash receptacles will be available and emptied regularly.

Question and Answer Period

Questions should be prioritized according to what is needed to be known immediately. We have found that these groups usually have further questions of general interest about tortoise biology. Time permitting these can be answered later.

Recovery Of A Desert Community After Fire In The Northern Mojave

Philip A. Medica, Mary B. Saethre and Richard B. Hunter

Abstract. Flora and fauna were censused in 1987, 1990, and 1993 on a burned area and nearby control to examine fire effects and recovery. The 1985 lightning-caused fire was followed by drought in 1988 to 1991.

1987 was a good year for annual plant growth (burn = 74 g/m^2), but in 1990 there was no germination. Winter precipitation in 1993 was twice that of 1987, and nearly twice as many species but lower biomass was recorded (46 g/m^2) than 1987. On the control, biomass was 52 g/m^2 in 1987, 0 in 1990, and 65 g/m^2 in 1993. Exotic species *Bromus rubens, Erodium cicutarium*, and *Amsinckia tessellata* were abundant in 1987 and 1993.

Shrubs and bunch grasses died or died back in 1990 followed by increases in cover and live volume in 1993. Growth from 1990 to 1993 was proportionally greater on the burn where total cover increased from 1% to 5% compared to 13 to 17% on the control. Grasses made up 88% of the perennial plants in the burn and 37% in the unburned transect. Crown and root sprouters, *Ephedra nevadensis*, *Lycium andersonii*, and *Stipa speciosa,* prospered after the fire. On the control in 1990, 97% of the bunch grasses died due to drought compared to only 60% on the burn where competition for resources was lower. *Hymenoclea salsola* invaded the edges of the burned area by 1993.

Rodents on the burn in 1987 were dominated by *Dipodomys merriami* while *Perognathus longimembris* was most common on the undisturbed area. Species diversity on the control was higher although numbers captured at both sites were similar. In 1990 decreases occurred at both sites, although the burn appeared to provide better forage as this area had more animals, even though plant cover was lower. 1993 results were similar to 1987; however, *Chaetodipus formosus* replaced *P. longimembris* as most common on the control.

No adult *Uta stansburiana* were observed on the burn during August 1987 while five were captured on the control. Hatchlings numbered 32 on burn and 33 on control. Similar results occurred in 1988, although 4 adults were captured on the burn in the summer compared to 11 on the control. Fewer adults in spring 1990 (11) affected hatchling production on the burn, with less than half as many (15) as on the control (36). Population size of adults on the control (38) appeared to be unaffected by the drought, but fewer hatchlings were produced than in 1988. In 1993 adult and hatchling numbers were back to 1988 levels on the burn while the control had numbers twice that of 1988.

The burned area appeared to be impacted by the drought as subsequent recovery of vertebrates was hindered, apparently by lack of plants for cover, forage and insect supply. Other sites nearby that were disturbed over the past 40 years by blasting, blading, and compacting have been slow to recover, possibly because soil fertility was depleted by those activities. By comparison, the burned area's revegetation and recovery has been rapid.

INTRODUCTION

Most studies covering fire effects on wildlife and related habitat have focused on areas commercially used for timber harvesting or traditionally used in large herbivore grazing. Also of special concern are habitats where game animals are abundant (Wood 1988; Masters *et al.* 1993; Bartos *et al.* 1994). Indeed, many of the timber related papers deal with the nuisance of increased rodent abundance associated with the surge in growth of annual plants subsequent to harvest and prescribed burning (Ream 1981).

Information related to fire in the desert southwest has mainly covered short-term vegetational changes after fires to control weedy species on grazing land - land that has usually had over a century of disturbance from grazing and no longer maintains native assemblages of plants or vertebrates (Martin 1983; White and Currie 1983). Although some virgin desert burns have been followed for short term succession studies (Christensen and Muller 1975; Keeley *et al.* 1981; McLaughlin and Bowers 1982; Johnson and Strang 1983; Cave and Patten 1984; Wirtz *et al.* 1988), most occurred in Sonoran or Chihuahuan deserts or southern California chaparral (see Minnich, these proceedings). Most agree that arid regions tend to burn sporadically, usually after one to two years of high rainfall when standing biomass is high (Simons 1991).

The results presented here are part of a larger monitoring program at the Nevada Test Site undertaken since 1987 by the Basic Environmental Compliance and Monitoring Program (BECAMP). This study was designed to determine effects of fire on the local plants and animals by characterization of site recovery over time as compared to a relatively undisturbed site nearby. Vegetational measurements were limited to annual (ephemeral) plant species germination and growth, and perennial shrub and grass survival, cover, and growth. Vertebrate sampling consisted of describing the rodent population structure, density, and diversity of species, and documenting population size, survival, and reproduction in the lizards inhabiting the area.

METHODS

The study site is located in a burned area at an elevation of 1288 m in Yucca Flat on the Nevada Test Site (NTS), Nye Co., NV (Figure 1). The NTS is approximately 105 km northwest of Las Vegas, NV. A lightning-caused fire on June 24, 1985 ignited an area of ~35 ha. This site and a site 500 m away in undisturbed habitat were first studied in 1987 with sampling repeated in 1990, and 1993 (Table 1). Lizards were resampled in 1988 to corroborate unusual results from 1987.

PRECIPITATION: Daily and monthly precipitation data were available from a National Oceanic and Atmospheric Administration (NOAA) station located in Yucca Flat approximately 8.5 km east of the burned area. Records of rainfall at this location are available back to 1969.

ANNUAL PLANTS: Annual plant sampling was performed between mid-April and mid-May in 1987, 1990, and 1993. All annuals were harvested from inside 20-0.025 m^2 quadrats randomly selected along a 50 meter tape. Plants were placed in envelopes or small bags according to species. After harvesting the twenty quadrats, the areas one meter and then 10 meters on either side of the 50 meter tape (100 m^2 and 1000 m^2) were searched for less common species. Specimens were collected for identification but not biomass calculation as

Table 1. Sampling dates at the Yucca Flat burn and control area.

	YEAR			
SUBJECT	1987	1988	1990	1993
Annual	30 April	Not Done	11 April	11 May
Perennial	15 July	Not Done	16-23 July	16 July
Rodent	14-17 July	Not Done	14-16 August	7-9 July
Lizard	25-31 August	28 March - 5 April and 15-26 August	3-11 April and 6-13 August	23,26-29 April 23-26 August

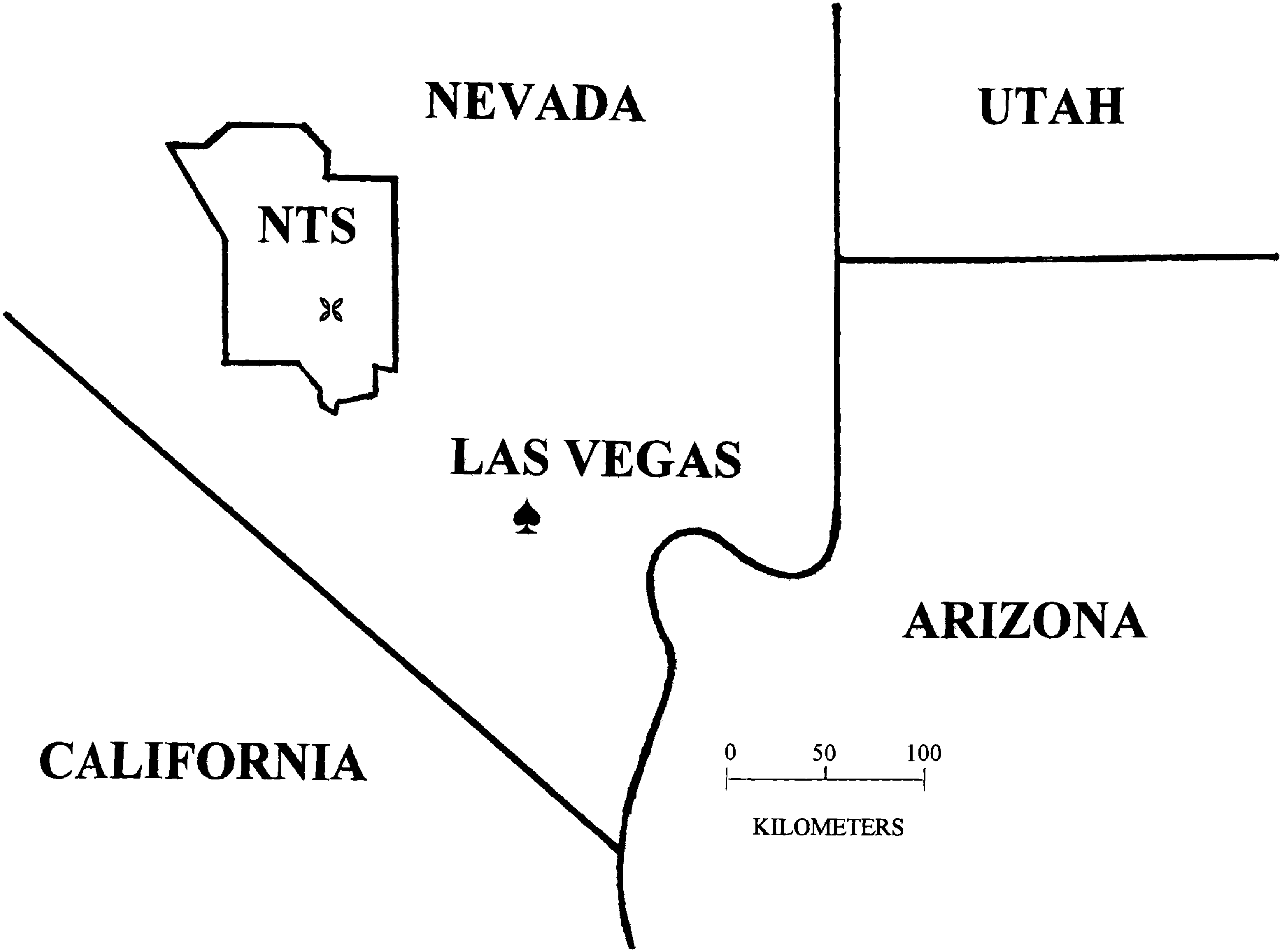

Figure 1 - Location of study site on the Nevada Test Site, Nevada.

species encountered in the larger quadrats were deemed too scarce to significantly affect the biomass of annuals at a site. Plants were identified, dried (three days at 150°C), and weighed to the nearest milligram to determine density, weight per plant, and weight per square meter. Taxonomy followed Munz (1974) and/or Cronquist *et al.* (1977), with synonymy following Kartesz and Kartesz (1980).

The average density (number of plants per quadrat) and biomass (g/m^2 per quadrat) were calculated for each species collected at a site along with standard error of the mean (se). Only the most common species had realistic standard errors.

PERENNIAL PLANTS: The method of measuring shrubs changed only slightly between years of sampling. In 1987, a 200 m transect site was selected with about 90 meters in an unburned section and 110 m in the burned area. Resulting values of number, cover, and volume were adjusted to 100 m^2 for standard comparisons. Five-foot steel fence posts were installed to permanently mark the ends and to divide the line into four 50-m segments. In all years, a 50 m measuring tape was laid slackly over the top of vegetation, allowing the ends to pull away from the stakes. The end quadrats (0 and 49) were therefore slightly longer than 1 m and the others (1 to 48) somewhat shorter.

Plants were measured in a belt along the tape: each plant with a base within one meter of the tape was considered "in" and its location along the tape and distance and direction from the tape were recorded. By clearly indicating the location, the status of individual plants could be followed.

- Data recorded in all three years included greatest live height, greatest live width and the live width perpendicular to it, number of crowns, percent of plant consisting of dead wood, reproductive state (flower buds, flowers, or fruit), dormant or vegetative, and percent of canopy removed by grazing animals. In 1990 and 1993 dead shrubs and grasses were also measured. When numerous seedlings occurred in a clump, those of similar size were counted and a representative individual was measured.

Cover for each plant was calculated as the product of the two radii and π. Volume (m^3) of each shrub was calculated by multiplying height by cover (an elliptical cylinder). Biomass (kg) was determined for each plant by multiplying volume by an updated regression coefficient determined for NTS shrubs (Hunter and Medica 1989).

LIZARDS: An 8 x 8 staked grid was erected in the center of the burned area and another similar grid was set up in undisturbed habitat upslope and west of the burned area. Stakes were set at 15-m intervals for a total of 105 m per side (1.1025 ha). The inner 6 x 6 grid (0.5625 ha) at each site was sampled for lizards, particularly the side-blotched lizard, *Uta stansburiana*. Lizards were sampled twice a year: in the spring before or during egg-laying and again in the summer after hatchlings emerged. The methodology for censusing *Uta* populations was taken from Tinkle (1967) and Medica *et al.* (1971): one to two searchers walked systematically through the study sites, with both sites walked simultaneously. Lizards were captured by noose or hand and placed in a numbered vial. A numbered marker was left at the point of capture. The entire plot was searched at least once and a second pass was made if lizards were still active. Lizards were weighed to the nearest 0.05 grams and measured (snout-vent and tail length in mm). Females were palpated to determine presence, number, and approximate size of yolk follicles or eggs. Lizards were toe-clipped with a unique number and given a unique paint pattern for easy identification on subsequent encounters. After processing, lizards were released at capture locations. On subsequent days, lizards observed with paint patterns were considered 'recaptured' and the location and paint pattern were recorded.

Density Estimation: Spring and summer adult and summer hatchling densities and standard error were estimated using the following formulas (Seber 1982:138). Using the Seber estimate and the plot size, an estimate of density plus or minus a hypothetical standard error (SE) was calculated.

SMALL MAMMALS: Small mammals were trapped on the two sites for three consecutive nights. Nocturnal mammals were captured in Sherman live traps (8 x 9 x 30 cm) set to capture animals over 5 g (approximately the weight of a juvenile *Perognathus longimembris*). The study plots each consisted of the 8 x 8 staked grid (64 stations) used for the lizard study. Two traps were set at each station (128 total traps) to provide more opportunities for capture within the short trapping period. Traps were baited in the early evening (1800+ hours) with a mixture of rolled oats and birdseed. Half-cylinder shades made of sheetmetal were placed over traps to prevent hyperthermia from direct sunlight. Traps were checked shortly after sunrise and closed for the day. On the last day, all bait was removed from the traps and poured into plastic bags. No bait was left on the plots to avoid supplementing normal food sources.

Each rodent was permanently marked. Kangaroo rats (*Dipodomys* spp.) and the occasional lagomorph were ear tagged. All other rodents, including squirrels, were toe-clipped with no more than one toe amputated per foot. Species, capture status (new or recapture), animal number, sex, reproductive condition, and grid location were recorded on field data sheets along with any pertinent notes (Hunter and Medica 1989). Bait was removed from cheek pouches and each animal was weighed to the nearest gram and released at the point of capture.

Density Estimation: The first night of the three nights of trapping was considered a preliminary trap night. The population size and standard error of the most commonly trapped species were estimated using the same equations as for lizards (Seber 1982:138) with data from the second and third nights of trapping. Calculations gave an estimate of population in number per plot plus or minus the hypothetical standard error (SE). To estimate density in number of animals per hectare ± standard error, N* and SE were both divided by the plot size in hectares, including a 7.5 m wide perimeter (adjusted grid size). Estimated standard errors of zero resulted when all of the animals captured on the last day were previously marked (no new animals), or when all of the previously marked animals were captured on the last day. Because the variances are hypothetical and no degrees of freedom could be assigned, statistical tests for differences between estimated densities were not possible.

An overall "naive density" (N/ha) was estimated for all animals captured on a site by dividing the total number of individuals captured by the adjusted grid size.

Species Diversity Index: The numbers of individuals in each species captured at a site were used to calculate a Shannon's species diversity index (H'). The Shannon formula (Zar 1984:33), was used as a species diversity index at each site. A high value for H' indicates that a relatively large number of common species are residing at a location and a high diversity exists.

This index is useful in comparing disturbed with undisturbed areas or changes over time at the same site. A t-test and calculated degrees of freedom described by Zar (1984:146) were used to compare the species diversity at the disturbed site with its control in the same year or to compare the same site between different years.

RESULTS

PRECIPITATION: Winter and annual rainfall in 1989 through 1991 were lower than the 25 year average for winter (119±62 mm) and annual (180±75 mm) precipitation (Figure 2). Both plants and animals responded to the drought situation by either higher mortality or lack of germination in plants and lower densities in rodents and lizards. This indicates that while trying to relate the resulting date to recovery from the fire this was confounded by the lack of rainfall.

ANNUALS: The most direct fire effect on the annual plants was the incineration of standing dead plants and seed bank. Plants had likely fruited and dropped seeds prior to the fire. Two years after the fire (1987), the average number of ephemerals/m^2 on the burned area (1110) was almost half that on the control area (1931). However, average biomass in grams/m^2 was greater on the burned area (74.25 as compared to 52.04), indicating that annuals did not grow at equivalent rates on both sites.

1987 was not a particularly good year for annual plants on the NTS probably because the preceding winter was relatively dry. Both sites had similar numbers of species collected from the small quadrats (9 on the burn and 7 on the control). Most annuals on the NTS in that year were small and sparsely distributed (Hunter and Medica 1989), consequently, searching the 1000 m^2 quadrats did not recover many more species (2 on the burn and 5 on the control).

Table 2. Annuals harvested from the Yucca Flat burned area and control in 1987. Errors are ± 1 standard error.

	BURNED AREA		UNDISTURBED	
SPECIES	n/m² g/m²	mg/plant	n/m² g/m²	mg/plant
Bromus rubens	720 ± 168 22 ± 4	49 ± 11	1803 ± 474 43 ± 9	35 ± 6
Erodium cicutarium	240 ± 73 13 ± 4	60 ± 16	101 ± 88 8 ± 6	50 ± 16
Malacothrix glabrata	64 ± 17 3 ± 1	54 ± 14	0 ± 0 0 ± 0	-
Chaenactis stevioides	40 ± 16 2 ± 1	32 ± 13	14 ± 3 0.09 ± 0.08	11 ± 7
Amsinckia tessellata	27.3 ± 9.6 22 ± 11	668 ± 147	2.7 ± 2.7 0.7 ± 0.7	309
Astragalus lentiginosus	7.3 ± 3.4 12 ± 10	1592 ± 1376	5.3 ± 5.3 0.11 ± 0.11	25
Descurainia pinnata	7.3 ± 5.7 0.16 ± 0.13	37 ± 29	2.7 ± 2.7 0.08 ± 0.08	37
Phacelia fremontii	1.8 ± 1.8 0.02 ± 0.02	8	0 ± 0 0 ± 0	-
Mentzelia albicaulis	1.8 ± 1.8 0.07 ± 0.07	31	0 ± 0 0 ± 0	-
Camissonia kernensis	0 ± 0 0 ± 0	-	2.7 ± 2.7 0.06 ± 0.06	28
Other: 100 m² and 1000 m²	*Bromus tectorum* *Cryptantha circumscissa* *Euphorbia albomarginata* *Delphinium* spp. *Oenothera* spp.		*Eriophyllum pringlei* *Sysimbrium altissimum*	

Bromus rubens, *Malacothrix glabrata*, and *Erodium cicutarium* were the most abundant species on the burned area while *B. rubens* was by far the most abundant on the unburned area, accounting for most of the plants/m² as well as biomass (Table 2). Weedy annuals such as *Erodium cicutarium*, *Bromus rubens*, *B. tectorum*, and *Sysimbrium altissimum* were successful in 1987 on the NTS while reproduction of native annuals was relatively unsuccessful (Hunter and Medica 1989). However, on burned and shrub removal plots, native annuals grew larger and had a greater input into seed reserves (Hunter and Medica 1989).

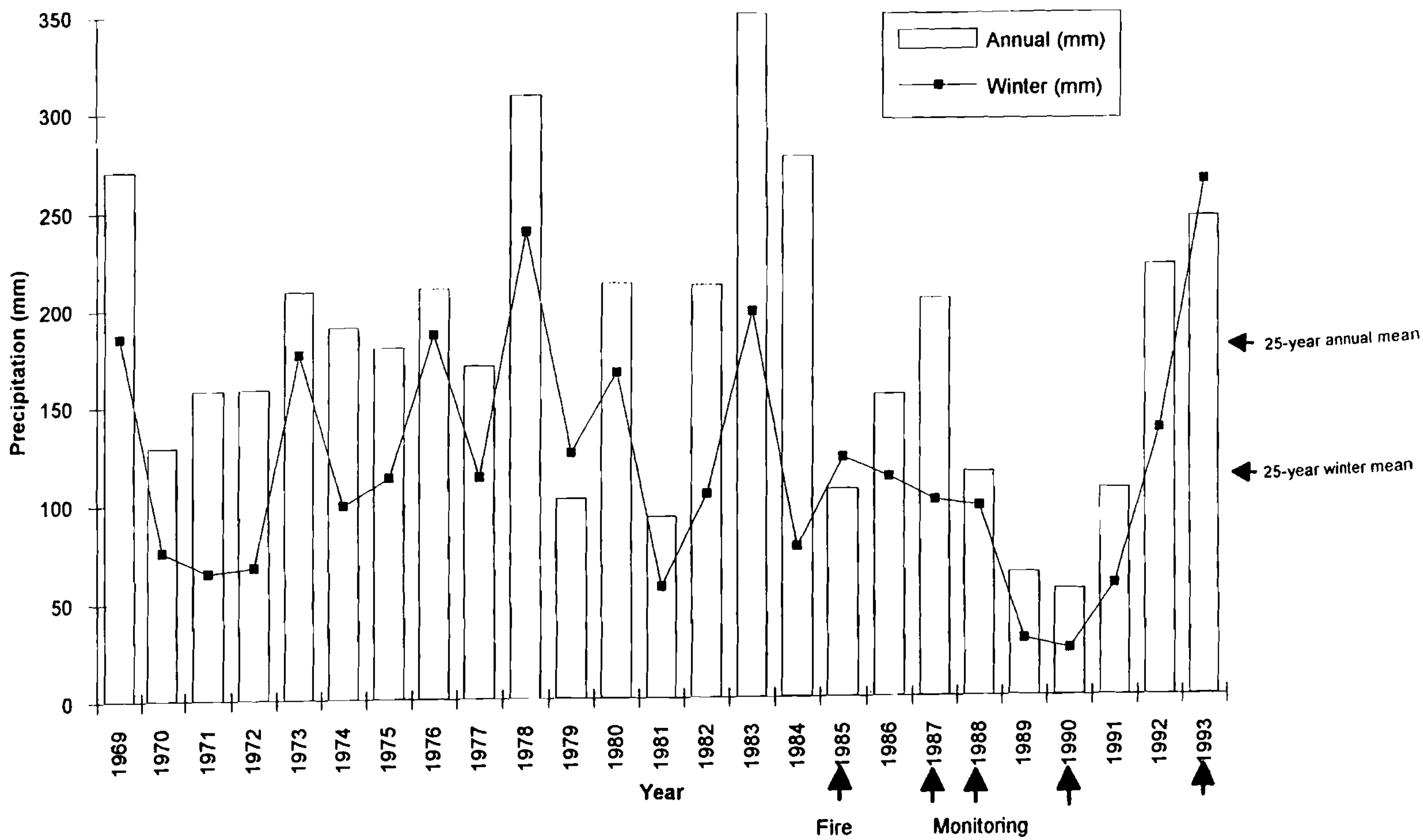

Figure 2 - Annual (January through December) and winter (September through March) precipitation in Yucca Flat, Nye Co., NV, 1969 through 1993.

When the burn and control sites were sampled in 1990, no live annuals were found on either site within the 1000 m^2 quadrats. This year had the lowest winter rainfall since recording began at the Yucca Flat NOAA station in 1969 (Figure 2). None of the other sites sampled in Yucca Flat in 1990 had annuals (Hunter 1994a).

1993 was the second consecutive year of above average winter precipitation and as such, the display of annual plants was better than average. Species of native annuals were far more numerous than previous years and the number of species collected on the burned and control areas more than doubled (25 and 26 respectively) from 1987 numbers. Mean number of plants/m^2 was the same as in 1987 on the burned area (1118 ± 374 in 1993) and decreased by nearly 1/2 on the control (1028 ± 429/m^2 down from 1931). In 1993, mean biomass (g/m^2) was relatively greater on the control area (64.73) than on the burn (45.84) but this was not statistically significant. This may be attributed to the weedy annuals on the burned area, although not present in fewer numbers, being smaller in size (Table 3). Small size may be due to a lack of soil water in April, when temperature is best for growth, even though a lot of rain fell in January and February of that year (Hunter, personal observation).

Table 3. Annuals harvested from the Yucca Flat burned area and control in 1993. Errors are ± 1 standard error.

	BURNED AREA		UNDISTURBED AREA	
SPECIES	n/m^2mg/plant g/m^2	n/m^2 g/m^2	mg/plant	
Erodium cicutarium	700.0 ± 294.6 20.29 ± 6.90	44 ± 12	317.5 ± 172.0 16.24 ± 6.43	92 ± 56
Eriogonum maculatum	75.0 ± 129.7 0.50 ± 0.69	14 ± 13	240.0 ± 356.1 1.28 ± 0.98	16± 8
Chaenactis stevioides	73.3 ± 36.9 6.46 ± 5.71	121 ± 130	77.5 ± 53.4 4.53 ± 3.25	85 ± 49
Mentzelia albicaulis	58.3 ± 33.7 2.26 ± 1.52	39 ± 13	7.5 ± 8.1 0.55 ± 0.80	73 ± 86
Phacelia fremontii	50.0 ± 49.2 0.90 ± 1.05	18 ± 12	2.5 ± 5.0 0.17 ± 0.43	69

Table 3. Annuals harvested from the Yucca Flat burned area and control in 1993. Errors are ± 1 standard error.

Amsinckia tessellata	41.7 ± 23.3 11.34 ± 6.59	280 ± 105	22.5 ± 21.9 23.78 ± 21.62	1282 ± 959
Descurainia pinnata	21.7 ± 18.0 0.36 ± 0.42	16 ± 14	22.5 ± 25.3 0.12 ± 0.14	6 ± 6
Gilia transmontana	21.7 ± 17.3 0.90 ± 0.76	45 ± 15	12.5 ± 14.1 1.11 ± 1.53	81 ± 67
Bromus rubens	20.0 ± 25.0 1.02 ± 1.44	51 ± 36	187.5 ± 172.6 11.14 ± 8.84	71 ± 36

Salsola australis	16.7 ± 16.6 0.18 ± 0.18	11 ± 2	2.5 ± 5.0 0.30 ± 0.06	12
Cryptantha circumcissa	11.7 ± 10.2 0.92 ± 1.52	105 ± 177	50.0 ± 23.7 2.23 ± 1.71	54 ± 51
Gilia sinuata	5.0 ± 10.0 0.23 ± 0.47	47		
Malacothrix glabrata	5.0 ± 5.5 0.11 ± 0.13	21 ± 15	15.0 ± 16.1 0.55 ± 0.80	31 ± 24
Astragalus lentiginosus	3.3 ± 4.6 0.06 ± 0.08	18 ± 4	7.5 ± 8.1 0.22 ± 0.25	30 ± 10
Camissonia kernensis	3.3 ± 4.6 0.16 ± 0.30	49 ± 83	40.0 ± 44.4 0.67 ± 0.72	20 ± 10
Chaenactis fremontii	3.3 ± 6.7 0.06 ± 0.13	19		
Eriogonum nidularum	3.3 ± 6.7 0.03 ± 0.05	8	10.0 ± 20.0 0.07 ± 0.14	7
Sysimbrium altissimum	3.3 ± 4.6 0.03 ± 0.04	8 ± 7	100 m^2	
Oxytheca perfoliata	1.7 ± 3.3 0.03 ± 0.06	18	7.5 ± 10.9 0.24 ± 0.41	27 ± 2
Lupinus flavoculatus		2.5 ± 5.0 1.83 ± 3.66	732	
Streptanthella longirostris		2.5 ± 5.0 0.07 ± 0.15	29	

Table 3. Annuals harvested from the Yucca Flat burned area and control in 1993. Errors are ± 1 standard error.

Other (100 m^2 and 1000 m^2)	*Bromus tectorum* *Chorizanthe thurberi* *Lomatium nevadense* *Lupinus shockleyi* *Eriogonum reniforme* *Phacelia vallis-mortae* *Rafinesquia neomexicana* *Stephanomeria paryi*		*Bromus tectorum* *Chorizanthe brevicornuata* *Eriogonum deflexum* *Phacelia vallis-mortae* *Stephanomeria paryi*	
Total	1118.3 ± 373.6 45.84 ± 12.47	0.07 ± 0.81	1027.5 ± 429.4 64.73 ± 29.28	0.14 ± 0.81
Average species/quad.	4.54 ± 0.83		5.13 ± 0.81	

One notable change from 1987 on the burned area was the near disappearance of *Bromus rubens*. In that year, *B. rubens* made up 93% of the number/m^2 and 83% of the biomass/m^2. In 1993 these percentages decreased to 2% for both number and biomass. Preliminary results from *Bromus* removal plots indicate this species may not fare well in the absence of cover (Hunter 1994b). Since this species also declined on the control area in a good year, it seems that prolonged drought will affect propagation of *Bromus rubens*.

The dramatic increase in plant biomass on the control from 1987 may be due to drought kill of shrubs (see Figure 5) and a subsequent decrease in competition for water. Prior to 1990, *Bromus rubens* and *B. tectorum* on the NTS were increasing in prevalence (Hunter 1991). With the drought and decrease in *Bromus*, native annuals appeared to come back with large increase in species present at these two sites (Tables 2 and 3). While *Bromus* may inhibit germination of native species, variations in species richness is generally attributed to dynamic weather patterns.

PERENNIALS: Cover two years after the fire was less than 1 m^2/100 m^2 (1% cover) on the burned area and nearly 20 times greater on the unburned area (Figure 3). Ten species were enumerated on the control transect and six on the burn. Although Joshua trees (*Yucca brevifolia*) are present in the area, only one was encountered on the 200 m transect, in the burned section. The area is more characteristic of transition type desert than either Mojave or Great Basin.

The three most common species of plants enumerated and measured on the unburned area in 1987 - *Stipa speciosa*, *Hymenoclea salsola*, and *Grayia spinosa* - were not most common on the burned area with the exception of *S. speciosa*. This bunch grass was the most common on both sites, accounting for 88 % of the plants on the burned transect and 37 % on the control.

Lycium andersonii and *Ephedra nevadensis* comprised the bulk of the remaining plants on the burn in 1987, with *E. nevadensis* accounting for 31 % of the cover (m^2) on the burn transect (Figure 3). In contrast, *Grayia spinosa* made up 32% of cover on the unburned transect. These results are not surprising considering the nature of the vegetation involved: *E. nevadensis*, *L. andersonii*, and *Stipa speciosa*, although burned above ground, will regenerate as crown sprouts from below ground and would be expected to recover rapidly following a low intensity fire.

Recovery after the fire was hindered by the severe drought conditions from 1989 through 1991, with death or dieback of shrubs a widespread occurrence. Death of grasses was not as severe on the burn, with 60 % mortality as compared to 97% on the undisturbed area. In 1990, *Ephedra nevadensis* showed little change from 1987 on the burn but did grow slightly. This species actually showed a decline on the control area. Volumewise, *Lycium andersonii* grew on both sites between 1987 and 1990, but fared better on the undisturbed site. This was not due to grazing on the burned area where green plants on disturbed areas are prone to grazing (Hunter 1994c). It may be that the crown sprouts on the burned area were not vigorous in that small shoots were supporting large root systems.

Perennials in 1993 saw a three-fold increase in cover on the burned section of the transect from approximately 1.4 in 1990 to 5.2 m^2/100 m^2, after relatively little change from 1987 to 1990 (Figure 4). *Lycium andersonii* and *Ephedra nevadensis* continued to thrive on the burn, and in 1993, *Hymenoclea salsola* successfully invaded the burned area and surpassed *E. nevadensis* in providing the most cover.

A second seedling perennial plant, *Ericameria cooperi*, also did well on the burned area, appearing for the first time in the 1990 census. By contrast, *Grayia spinosa* appeared to be severely affected by the drought and showed little recovery even on the control (Figure 5). Growth on the burned area was proportionately greater than on the control as cover on the control increased from 13.4 to 16.7 m^2/100 m^2. This was most likely due to less competition from other perennials on the burn.

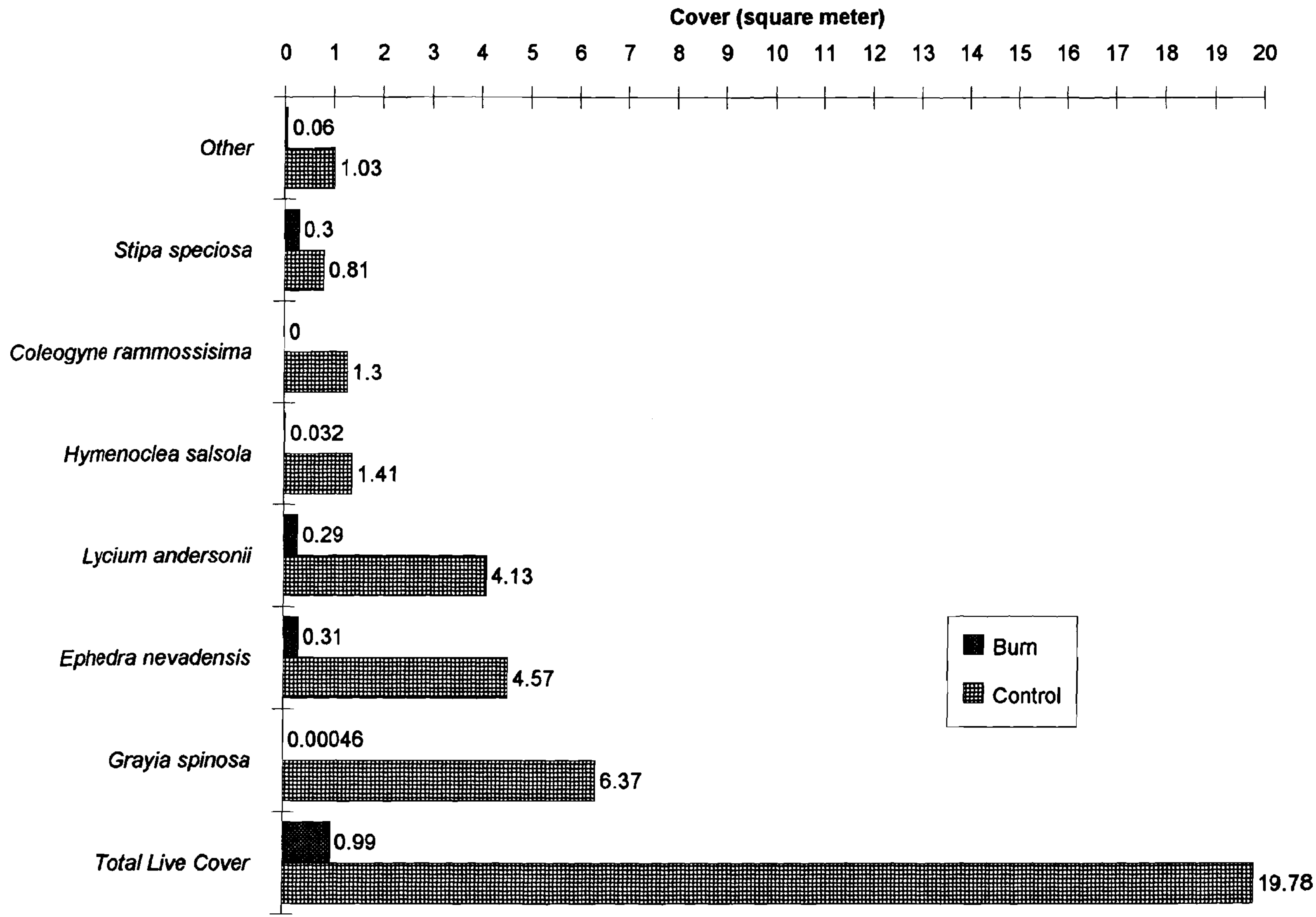

Figure 3 - Cover in m²/100 m² of perennial plants at the Yucca Flat burned area and control in 1987.

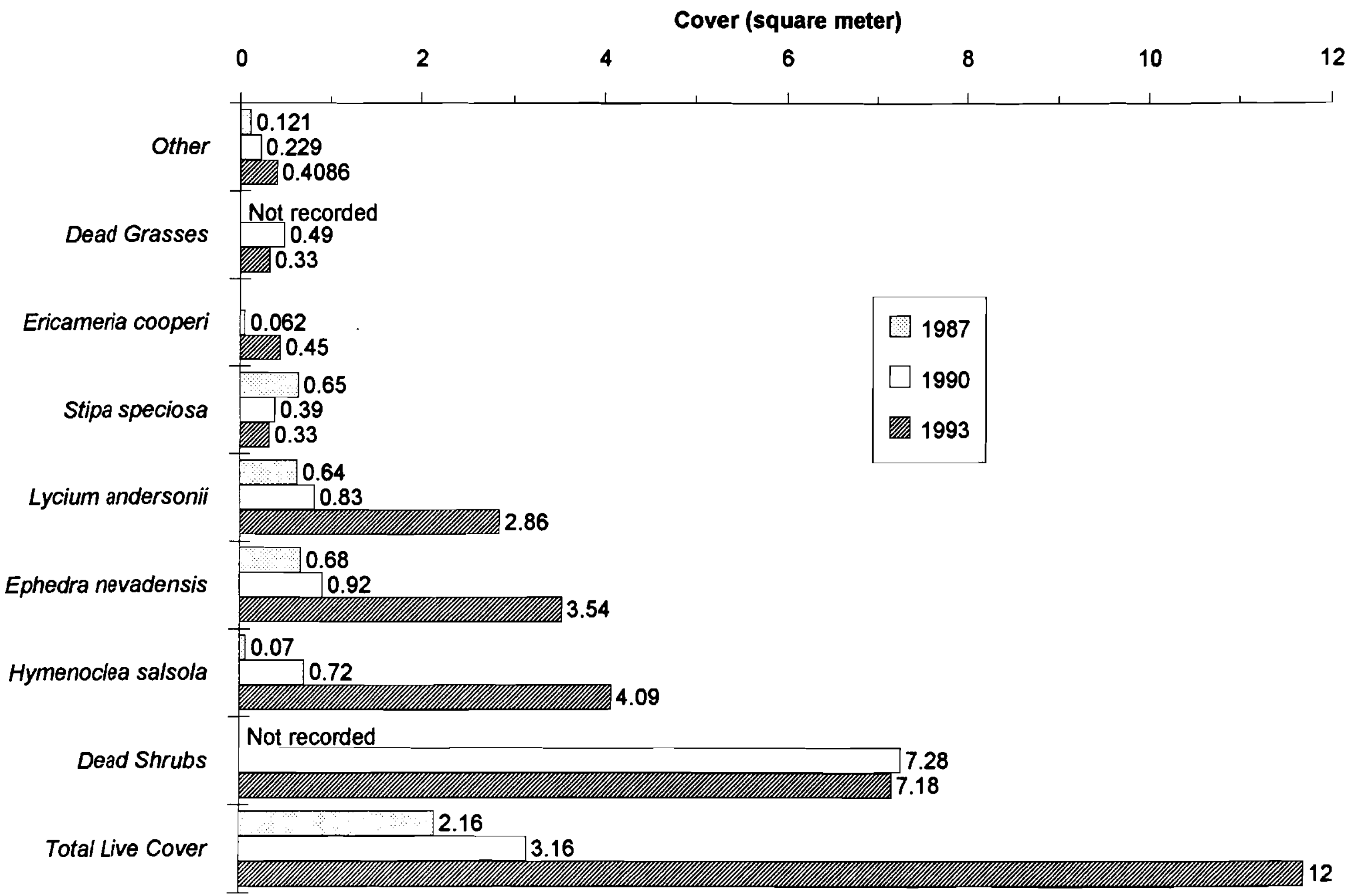

Figure 4 - Cover in m² of perennial plants at the Yucca Flat burned area in 1987, 1990, and 1993. Sampled area was 226 m².

Lizards: *Uta stansburiana* (side-blotched lizards) are ubiquitous over the NTS and were the most abundant lizard at both sites in this study. Other lizards present included *Cnemidophorus tigris* (western whiptail), *Phrynosoma platyrhinos* (desert horned lizards), and *Gambelia wislizenii* (leopard lizard). *Sceloporus magister* (desert spiny lizard) was present off the control plot where it was observed while walking transects (Medica *et al.* 1994).

The most significant impact of the fire appeared to be an indirect effect on the number of adult *Uta stansburiana* surviving from spring to summer due to the loss of vegetative cover. The burn and control areas were sampled in 1988 to reconcile the lack of adults on the burn in August 1987 (Medica 1988). The plots were not constructed until the summer of 1987 and therefore no spring census could be made to determine adult populations. In four years of study, adults were absent on the burned area during the summer only in 1987. However, adults were present in very low densities as compared to spring and control censuses (Tables 4a and 4b).

Table 4a. Numbers of individuals and estimated densities (n/ha ± 2 SE) of adult *Uta* in spring. ND = not done.

	BURNED AREA			UNBURNED AREA		
YEAR	TOTAL	FEMALE	DENSITY	TOTAL	FEMALE	DENSITY
1987	ND		ND			
1988	28	1854 ± 7	31	22	59 ± 9	
1990	11	912 ± 3	38	22	71 ± 9	
1993	24	1243 ± 0	63	39	121± 13	

Table 4b. Numbers of individuals and estimated densities (n/ha ± 2 SE) of adult *Uta* in summer.

	BURNED AREA			UNBURNED AREA		
YEAR	TOTAL	FEMALE	DENSITY	TOTAL	FEMALE	DENSITY
1987	0	0 0	5	2	10 ± 4	
1988	4	4 9 ± 5	11	9	30 ± 18	
1990	3	1 5 ± 0	18	12	43 ± 14	
1993	2	0 4 ± 0	15	11	50 ± 35	

The only direct effect of the fire on the lizard *Uta* population appeared to be ethological. Lizards present on the burned area invariably were found basking at the mouths of rodent burrows and utilized burrows as escape cover. This behavior has been noted at other disturbed sites on the NTS where shrub and bunch grass cover is negligible. Use of rodent burrows was less prevalent on undisturbed areas. Here, *uta* generally used grass clumps or shrubs for escape cover.

Numbers of hatchlings caught during the summer censuses were not different between the two plots in 1987 and 1988, although estimated densities were higher on the control (Table 5).

Summer density of adult + hatchling *Uta* showed a strong positive correlation with winter precipitation (Figure 6), indicating the importance of adequate rainfall within this desert ecosystem. Slopes of the two regression lines were not significantly different (t_4 = 1.10, p = 0.183). The ratio of summer hatchlings to spring adult females (a measure of reproductive output) also showed a positive relationship to precipitation for both sites (Figure 7). This relationship, rather than linear, is more likely asymptotic where above a certain rainfall, no additional lizards could be supported. A successful reproductive year then must not depend only on sufficient adult populations but more importantly on adequate winter rainfall. The slopes of the regression lines were also not statistically different (t_2 = 0.201, $p > 0.50$), nor was elevation (t_3 = 0.184, $p > 0.50$), indicating that reproductive output (number of hatchlings produced per female) was the same on both plots after adjusting for rainfall.

Table 5. Numbers of individuals and estimated densities (n/ha ± 2 SE) of hatchling *Uta* in summer.

	BURNED AREA			UNDISTURBED AREA		
YEAR	TOTAL	FEMALE	DENSITY	TOTAL	FEMALE	DENSITY
1987	32	1666 ± 13	33	14	75 ± 23	
1988	56	32109 ± 15	59	21	216 ± 98	
1990	15	929 ± 7	36	16	129 ± 70	
1993	69	41112 ± 10	114	52	265 ± 45	

Small mammals: The rodent assemblage on the burn plot was also indirectly affected by the fire. The number of *Perognathus longimembris* (little pocket mouse) captured on the burned area in 1987 was less than on the control, while the number of *Dipodomys merriami* was greater (Table 6). *P. longimembris* prefers to forage near shrubs rather than open areas and was consequently not as abundant in any year on the burned area. *D. merriami* (Merriam's kangaroo rat), however, does well in open areas and clearly fared well on this burned site. The densities for *P. longimembris* in 1987 were not as clear: the estimate on the burn was 37 ± 22 (N ± 2 SE) and 31 ± 4 on the undisturbed area. This was probably due to the low percentage of animals recaptured and a large number of new captures on the last day of trapping on the burn site. Densities of *D. merriami* followed the relative number captured in 1987: 37 ± 4 on the burn and 15 ± 3 on the control. Densities of the other kangaroo rat present, *D. microps*, were 3.7 ± 1.4 on the burn and 6.2 ± 2.8 on the control. This animal does not thrive in areas of the NTS where perennial vegetation has been removed and would therefore be expected to be present at lower numbers on the burned area. Overall, there were more animals captured on the burn in 1987.

The number of captured animals decreased on both sites in 1990 with approximately 75 % less animals captured. More animals were captured on the burned area again. The relative decrease in density for *Dipodomys merriami* (down to 13 ± 0 on the burn) was lower on the control (down to 11 ± 2). *Dipodomys microps* was not captured at either plot in 1990 and decreased or disappeared from all other sites studied in Yucca Flat that year (Saethre 1994). 1993 saw an increase in number of animals captured at both sites, with the control area nearly doubling from 1987. Only slightly more animals were captured on the burn on 1993 as compared to 1987. *D. merriami* estimated density on the burned area was 52 ± 6 and 37 ± 4 on the control. *D. microps* density increased at both sites from 1987: 10 ± 0 (burn) and 13 ± 2 (control).

Species diversity was higher on the undisturbed site in 1987 (t_{76} = 2.478, p = 0.0154) but not in 1990 during the drought, when several species were not captured (t_{36} = 1.560, p = 0.128). In 1993, both sites had high diversity and were not significantly different (t_{220} = 1.858, p = 0.0645). Animal numbers at the two sites also reached an all time high. The burned area during the drought could have had a better seed reserve available for caching by rodents due to the annuals present after the fire. Shrubs and grasses may also have had a greater water reserve in stems than on the undisturbed area (Hunter 1987).

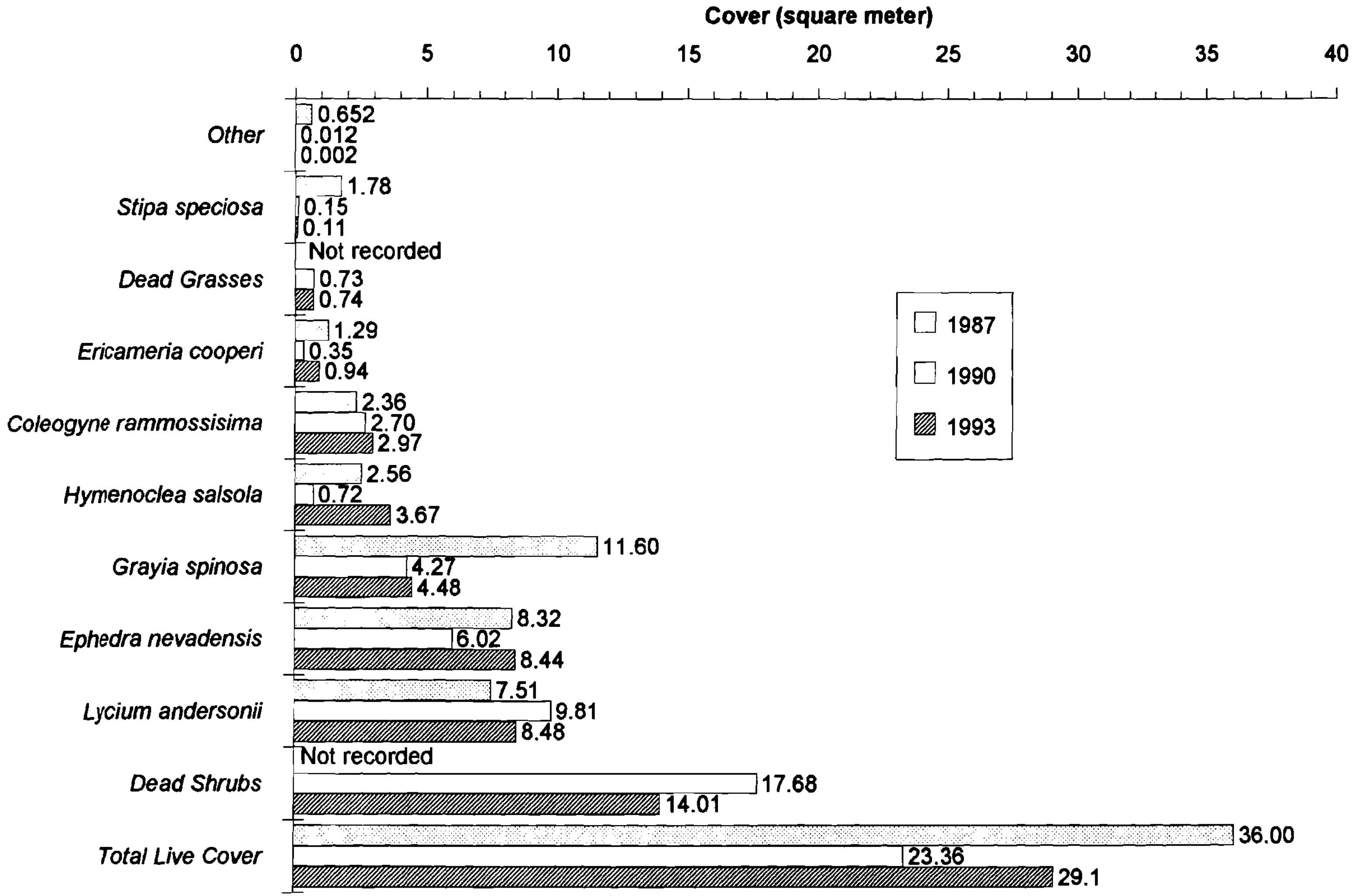

Figure 5 - Cover in m² of perennial plants at an undisturbed site in Yucca Flat in 1987, 1990, and 1993. Sampled area was 174 m².

The distribution of species captured at both sites changed drastically over the three years studied. On the burned area, the relatively long-lived *Perognathus longimembris* made up a significant portion of the captured population in 1987 but slightly less in 1990. This species made up a marginal proportion of the rodents in the burned area assemblage in 1993 (Figure 8). Since the drought, this species has virtually disappeared from other BECAMP plots studied in Yucca Flat (Saethre 1994, in press). The burned area did, however, support a significantly greater number of species in 1993 as compared to 1987, possibly at the expense of the little pocket mouse.

Table 6. Number of individual small mammals captured on the Yucca Flat burn and undisturbed plots in 1987, 1990, and 1993.

	BURNED AREA			**UNDISTURBED AREA**		
SPECIES	1987	1990	1993	1987	1990	1993
Chaetodipus formosus	--- ---	1	4	---	61	
Dipodomys merriami	52 18	67	19	14	49	
D. microps	5 ---	15	9	---	17	
Perognathus longimembris	32 6	5	43	2	6	
P. parvus	--- ---	1	---	---	1	
Onychomys torridus	2 1	12	4	---	6	
Peromyscus maniculatus	--- ---	---	---	---	1	
Ammospermophilus leucurus	--- ---	7	3	---	6	
Sylvilagus audubonii	--- ---	---	2	---	---	
TOTALS	91 25	108	84	16	147	
TRAP SUCCESS %	45.3	14.6	47.7	38.8	7.0	64.1
H'	0.4049	0.3074	0.5302	0.6108	0.1636	0.6255
N/ha	63.19	17.36	75.00	58.33	11.11	102.08

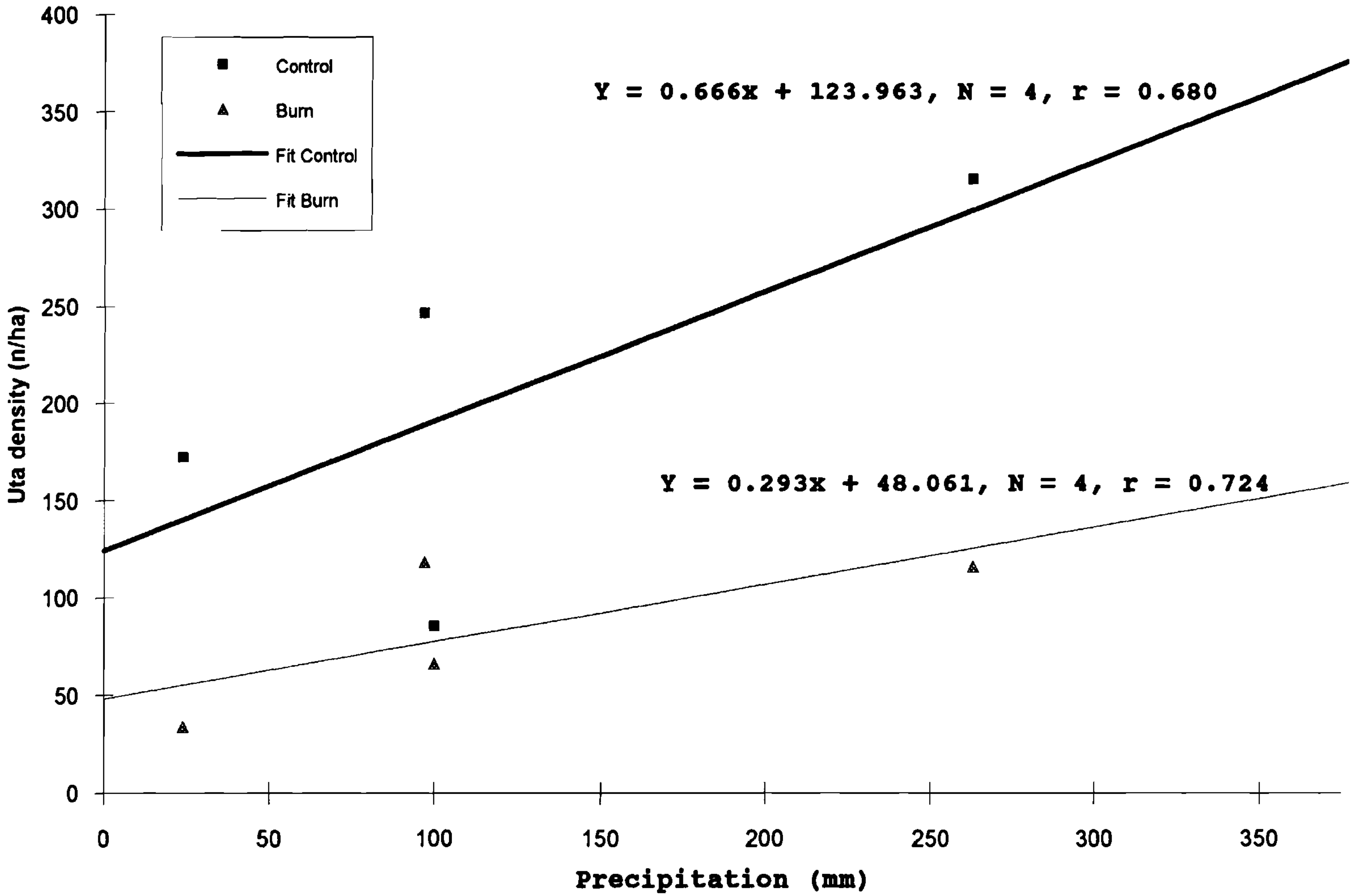

Figure 6 - Relationship of summer adult *Uta* + summer hatchlings density and winter precipitation.

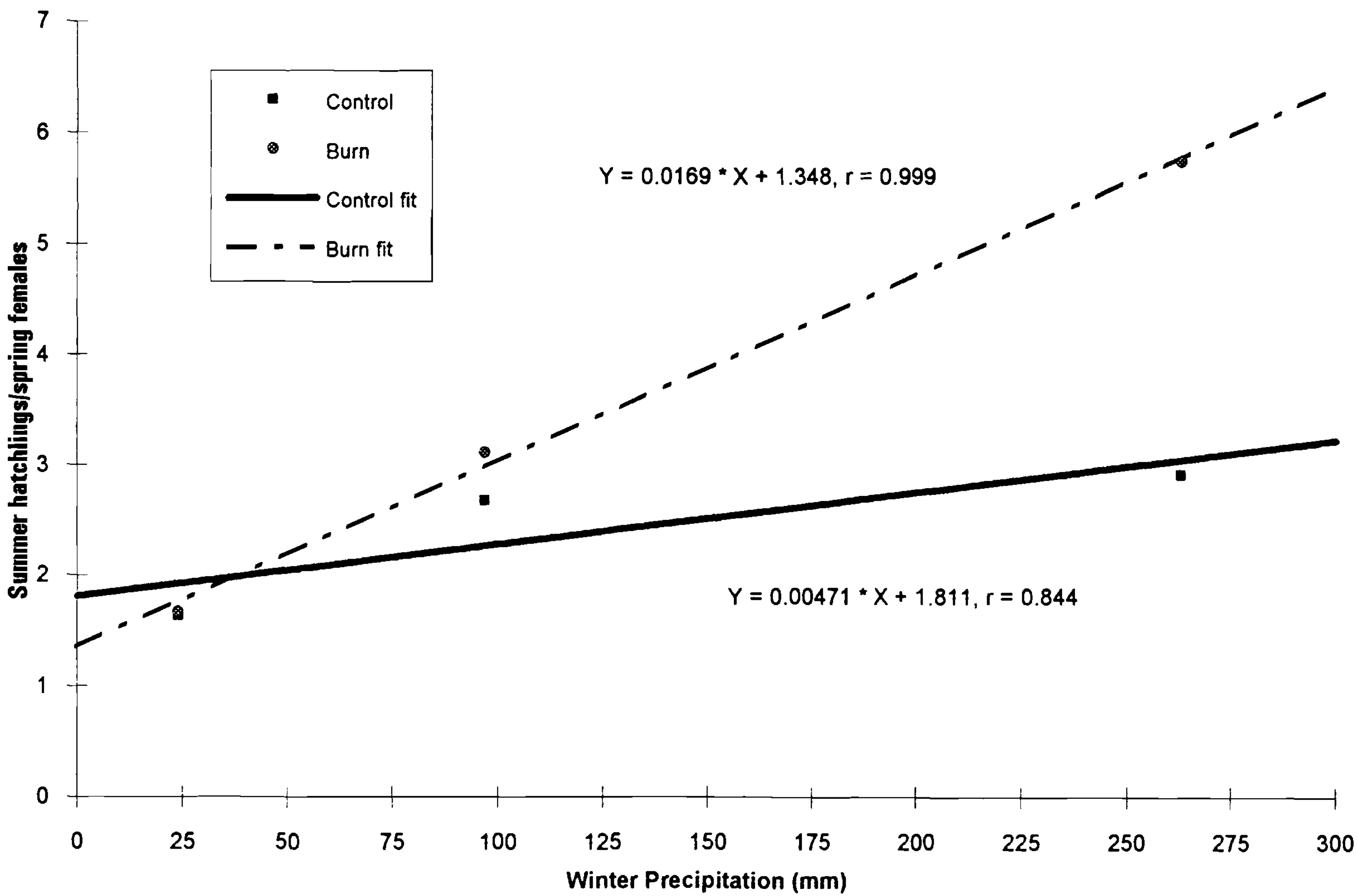

Figure 7 - Relationship of winter precipitation and summer hatchlings/spring adult females on the burned and undisturbed areas.

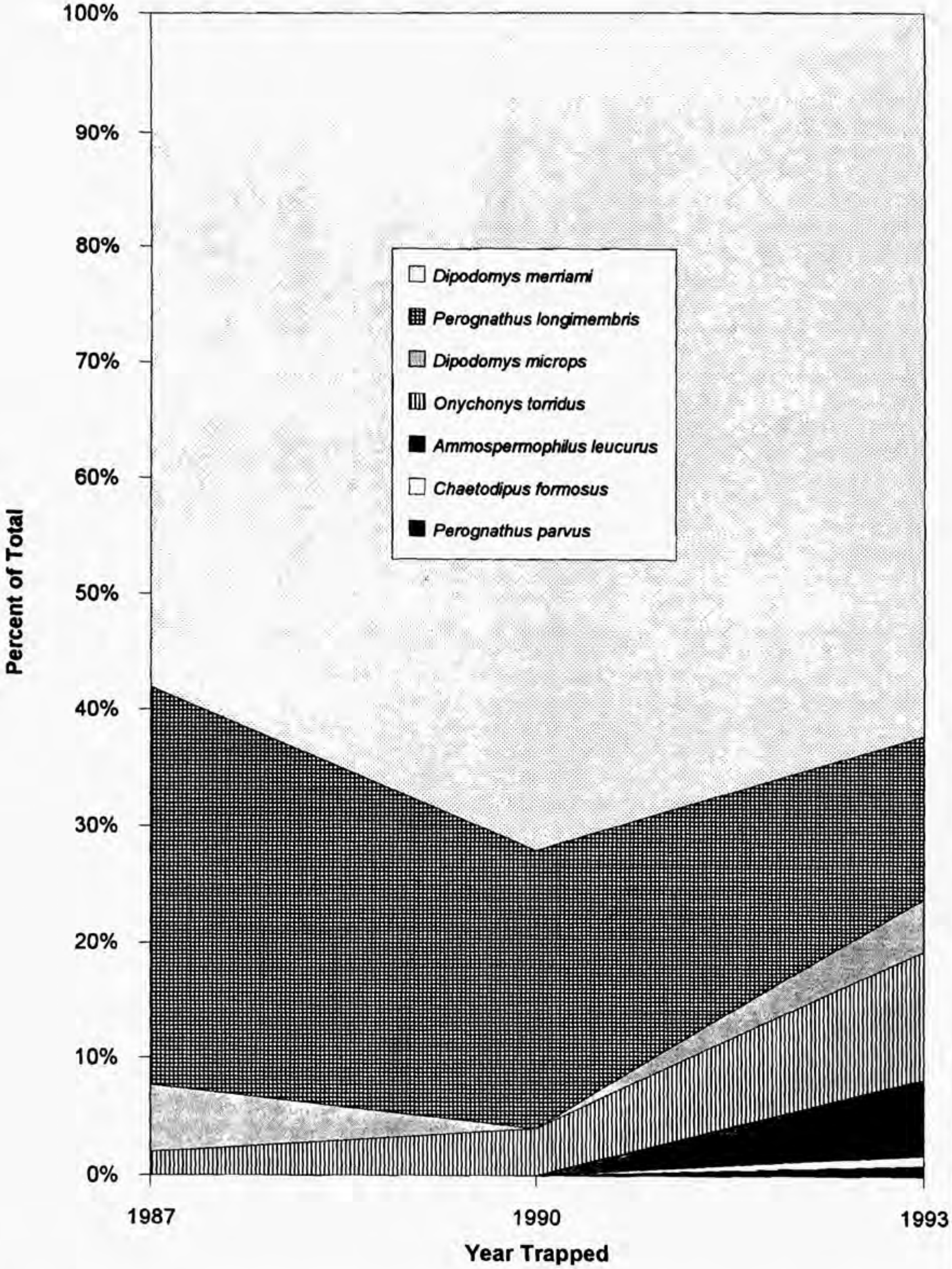

Figure 8 - Distribution of rodent species captured at the burned area in Yucca Flat in 1987, 1990, and 1993.

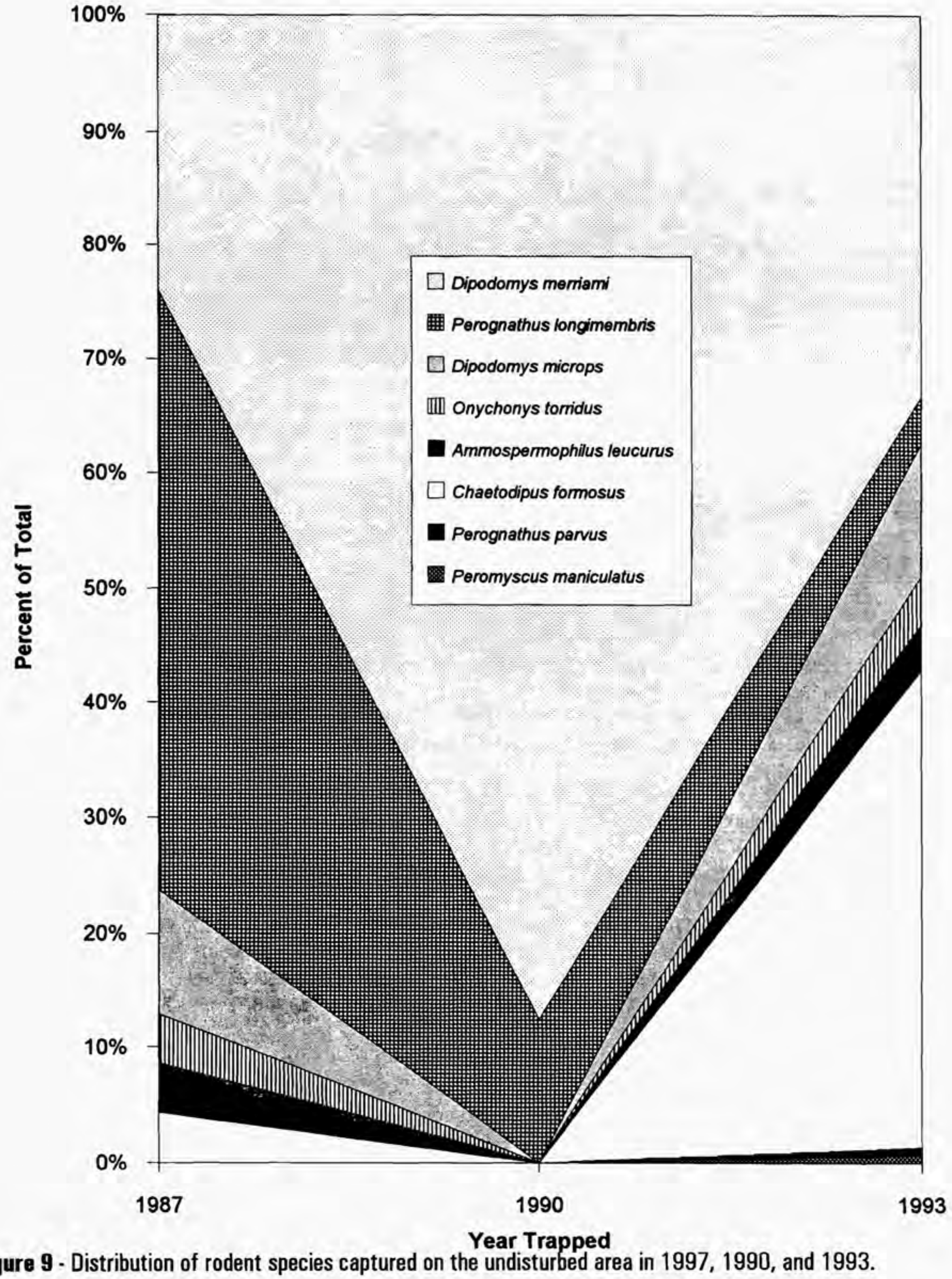

Figure 9 - Distribution of rodent species captured on the undisturbed area in 1997, 1990, and 1993.

At the undisturbed plot, *P. longimembris* was replaced almost entirely by the long-tailed pocket mouse, *Chaetodipus formosus* (Figure 9). This species is regularly found in high abundance at areas to the south of Yucca Flat but has increased in number and moved into other areas in recent years. Most of the species present before the drought but not captured in 1990 were again present in 1993 at approximately the same percent with the exception of *Onychomys torridus* (grasshopper mouse) and *Ammospermophilus leucurus* (antelope ground squirrel). The carnivorous *O. torridus* may have increased due to the abundance of insects on the burned area.

DISCUSSION AND CONCLUSIONS

The burned area in western Yucca Flat is revegetating more quickly than other areas nearby that have been disturbed by testing activities. Nuclear testing over the past 40 years has involved blading, compacting, blasting, and burning activities. The sites affected by testing have been slow to recover, due to removal of surface soils and seed reserves in addition to soil sterilization by intense heat and irradiation. Opportunistic and short-lived species such as Russian thistle (*Salsola australis*), four-winged saltbush (*Atriplex canescens*) and cheese bush (*Hymenoclea salsola*) successfully invade and inhabit severely disturbed sites such as craters, drill pads, and blast areas. Recovery through succession to native vegetation is not apparent after 30+ years.

Fires such as the one at the Yucca Flat study site kill above ground vegetation, but seed caches from rodents are left intact and soil fertility may even be enhanced (Christensen and Muller 1975). Heat from fire has also been well documented in breaking seed dormancy. Thus, sites such as this one have the opportunity to recover, with only abiotic effects such as precipitation governing the rate of recovery. Lack of competition from other perennials on the burned area undoubtedly led to the better performance of bunch grasses. Only one perennial species demonstrated any pattern of vegetation recovery: *Hymenoclea salsola* appeared to be more vigorous at the edge of the burned area.

The most common reason for prescribed burning is to reduce perennial shrubs and promote an increase in growth of grasses and annual forbs (Bunting *et al.* 1987). At a sagebrush/grassland site similar to the NTS site, grass and forb production on a burned site was greater than on an unburned site while sagebrush cover was effectively reduced for 30 years (Harniss and Murray 1973). The burned area in Yucca Flat showed a similar pattern with greater relative abundance of bunch grasses (namely *Stipa speciosa*) and greater production of annuals in 1987, although annual plant biomass was greater on the unburned area in 1993.

Because these sites were not sampled immediately after and yearly since the fire, it is difficult to characterize the successional flora as temporary, permanent, or fire dependent species (see Keeley *et al.* 1981). Information about individual species characteristics could be used to make some assumptions on this. It is likely that any "fire annuals" were already absent by the time measurements were made.

Loss of vegetation is likely the driving force behind the lower densities of lizards on the burned area as reduced vegetation is associated with lower insect abundance and reduced lizard fecundity on the NTS (Turner *et al.* 1982) as well as in other desert ecosystems (Dunham 1980). Lower live perennial cover, as well as litter (both under shrubs and dead grass clumps) and insect supply associated with vegetation, would not support as many animals as on the undisturbed area. Life history of *Uta stansburiana* on the NTS has been well documented (Turner *et al.* 1969; Turner *et al.* 1970; Medica and Turner 1976; Turner *et al.* 1982). Medica and Turner (1976) found that *Uta* on the southern portion of the NTS laid between one and seven clutches between April and July. Clutch size in these lizards depended not only on body size of females but also on environmental conditions, with smaller lizards producing fewer and smaller sized clutches. The drought placed an added burden on lizards, which likely led to lower reproductive output in the *Uta* population at both sites in 1990.

Predation by larger lizards or birds was the likely cause of the decrease in adult *Uta* from spring to summer at the burn. Lack of cover presents an added risk of succumbing to predation. The lack of Joshua trees at the burned area is probably the reason that no *Sceloporus magister* have been recorded here. Destruction of suitable habitat by fire has been attributed to a decrease in a similar species (Lee 1974), and on the NTS this species is most often observed on Joshua trees, fences, and telephone poles.

Small mammal assemblages change predictably with changes in cover and vegetation regime (Price 1978; Reichman and Price 1993) and rodent responses to fire have been well represented in the literature (Boggs *et al.* 1991; Cook 1959; Ream 1981; Simons 1991). All agree that the modification of vegetation structure favors granivory specialists such as *Dipodomys merriami*, with mammalian succession responding to changes in vegetation structure (Hall and Willig 1994). Wirtz *et al.* (1988) concluded that recovery of a rodent community to prefire equivalence took four to six years and depended on the composition of prefire plant and animal species. This fits in well with the small mammal results presented here, although yearly data is not available for our sites. Increased risk of predation by birds is also a common result and is a likely factor in controlling small mammal populations.

The reason for a continued loss of *Perognathus longimembris* at either site is not clear. That the drought was a factor in the decrease from 1987 to 1990 is obvious. It may be that this species is not as opportunistic as *Chaetodipus formosus* and was edged out by this slightly larger pocket mouse.

The greatest factor influencing the natural recovery of this burned site appears to be adequate precipitation. The drought compounded the fire effects in that herbs were slow to gain in abundance and perennials that survived the fire grew slowly. Perennials which might have germinated from seeds most likely did not survive through the low rainfall periods. There has been essentially no perennial germination except perhaps for bunchgrasses.

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Postfire Succession In Desertscrub Communities Of Southern California

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Abstract. Above normal precipitation and increases in herbaceous cover in 1978-84 and 1992 resulted in widespread burning in creosote bush scrub in the Mojave Desert of California. Analysis of burns near Victorville, Palm Springs and Joshua Tree National Monument shows that long-lived dominant shrubs and arboreal succulents *Larrea tridentata, Ambrosia dumosa, Opuntia spp.* and *Yucca brevifolia* are replaced by short-lived pioneer shrubs. In low deserts the dominant early successional species is *Encelia farinosa*. At the intermediate altitudes of Mojave Desert successional species are *Hymenoclea salsola, Gutierrezia microcephala, Encelia virginensis, Salazaria mexicana,* and *Acamptopappus schaerocephalus*. Above 1400 m in Joshua Tree *Coleogyne ramosissima* scrub is replaced by *Hymenoclea salsola* and *Salazaria mexicana, Hilaria rigida* and *Stipa speciosa* recovering by resprouting from meristems and root-matts, respectively. Similar successions after anthropogenic disturbances in the Mojave Desert indicate that stand regeneration times range from many decades to centuries. The recent outbreaks of fire may be an anomaly because climatic drought, limited stand productivity, and fuel accumulations may result in long fire intervals at spans compatible with long-lived perennial shrubs. Alternatively, recent burning may also represent the beginning of increasing fire activity and degradation of creosote bush scrub due to invasion of exotic annual cover, in particular *Bromus rubens, Schismus barbatis,* and *Brassica tournfortii*.

INTRODUCTION

A succession of wet years between 1976 and 1985 resulted in increased herbaceous cover and widespread burning in desertscrub of southern California (Tratz and Vogl, 1977; Brown and Minnich, 1986;). Desert shrubs in California and Arizona appear to have a low tolerance to burning, and adaptations to fire in this vegetation have not been strongly developed (Rogers and Steele, 1980; McLaughlin and Bowers, 1982; Rogers, 1986; Brown and Minnich, 1986). Consequently, fires may cause longstanding changes in the structure and species composition of these communities.

The outbreak of fires in desertscrub has been attributed to the spread of exotic grasses and forbs which have increased available fuel and fuel continuity (Beatley 1966; Rogers and Steele, 1980; McLaughlin and Bowers, 1982; Brown and Minnich, 1986; Rogers and Vint 1987). Since fire is being provoked by newly introduced species, there is concern that exotic invasions may encourage directional changes in fire regime and in desert scrub vegetation. This paper summarizes research on fire and

FIRE BEHAVIOR

Bureau of Land Management and Forest Service fire reports indicate that in creosote bush scrub fires are propagated by the annual layer. Flames are usually carried by strong winds, are fast moving, and low in intensity (flame heights $<$ 1-2 m). Flames are carried by exotic species, notably *Bromus rubens*, *Schismus barbatus*, and *Brassica tournefortii*, which form a continuous, cured layer of flashy fuels. (A glossary of common names of species is given on Table 1.) Native dicots as well as the exotic *Erodium cicutarium* provide only limited fuels because they are either scarce, or shatter into fine parts which fall to the ground or blow away. Individual fires usually occur in afternoon hours, and seldom survive a single night of cooler temperatures, higher humidities, and low wind speeds.

Table 1. Common names of important species in the southern California deserts.

SPECIES	COMMON NAME
ANNUALS	
Brassica tournefortii	Moroccan Mustard
Bromus rubens	Red Brome, Foxtail Grass
Erodium cicutarium	Filaree, Storksbill
Schismus barbatus	Schismus, abumashi
BUNCHGRASSES	
Hilaria rigida	Galleta grass
Stipa speciosa	Purple Needle Grass
EVERGREEN SHRUBS	
Ephedra nevadensis	Mormon Tea
Larrea tridentata	Creosote Bush
SUBSHRUBS	
Acamptopappus sphaerocephalus	Goldenhead
Ambrosia dumosa	Burrobush
Coleogyne ramosissima	Blackbrush
Encelia farinosa	Brittlebush
Encelia actoni	Acton Brittlebush
Eriogonum fasciculatum	California Buckwheat
Grayia spinosa	Spiny Hopsage
Gutierrezia microcephala	Matchweed
Haplopappus cooperi	Cooper Goldenbush
Hymenoclea salsola	Cheesebush
Lycium andersonii	Boxthorn, Wolfberry
Lycium cooperi	Boxthorn, Wolfberry
Salazaria mexicana	Bladder Sage
Salvia mojavensis	Mojave Sage
Viguiera deltoidea	Goldeneye
DROUGHT DECIDUOUS MICROPHYLLOUS WOODLAND AND WASH SPECIES	
Acacia greggii	Catclaw
Justicia californica	Chuperosa
Cercidium floridum	Palo Verde
Dalea spinosa	Smoke Tree
Hyptus emoryi	Desert Lavender
Olneya tesota	Desert Ironwood
Prosopis juliflora	Mesquite
Prosopis glandulosa	Honey Mesquite
STEM SUCCULENTS	
Opuntia bigelovii	Jumping Cholla
Opuntia acanthocarpa	Buckhorn Cholla
Opuntia echinocarpa	Silver Cholla
LEAF SUCCULENTS	
Yucca brevifolia	Joshua Tree
Yucca schidigera	Mojave Yucca

The pattern of fire damage is often species-specific due to individual species' morphologies. The evergreen *Larrea tridentata* tends to scorch rather than burn because of its relatively tall stature, spreading branch habit, high foliar fuel moisture, and low dead fuel content of its canopy. *L. tridentata* are occasionally consumed during intense burns, but may sustain only light char marks at the root axes in light burns. Drought-deciduous subshrubs, such as *Ambrosia dumosa*, *Hymenoclea salsola*, *Eriogonum fasciculatum*, *Encelia virginensis*, *Salazaria mexicana*, *Lycium andersonii* and *Coleogyne ramosissima* burn to the ground because of their small stature, proximity of canopies with ground fuels, finely divided branching habits, and abundance of small leaves (high fuel continuity). Stem-succulents in such genera as *Opuntia* and *Echinocereus* are scorched because of their high fuel moisture, but high flame temperatures apparently destroy cell walls, resulting in eventual uncontrolled desiccation of stems. The arboreal leaf-succulents *Yucca schidigera* and *Y. brevifolia* are often destroyed because flames arising from ground fuels are propagated into the canopy by persistent dead leaves along their trunks.

After fire, the above-ground canopy in desert scrub communities is typically denuded, and the reestablishment of cover and biomass to preburn levels is achieved only after several decades. In the landscape, burns are defined by conspicuous gaps in cover that can be seen from a distance, especially among the more arboreal or very dominant species such as *Larrea tridentata*, *Yucca brevifolia* and *Coleogyne ramosissima*. Fire lines are accompanied by discrete shifts in the composition of less prominent species.

SUCCESSIONAL PATTERNS

The desertscrub of southern California is marked by diverse species changes along climate and altitude gradients. As a consequence, plant successions vary greatly from place to place, depending upon the available pool of colonizing and long-term successional species. This review describes four studies at the following localities: Snow Creek, Palm Springs, the Mojave Desert north of the San Bernardino Mountains, and Joshua Tree National Monument. In these studies, site sampling was conducted along fire boundaries so that burned vegetation was compared with nearby unburned vegetation. The method assumes that prior to fire, the vegetation on the burn site was similar to that sampled offburn. The differences between and on- and off-burn vegetation permits the estimation of postfire species response, as well as changes in stand species composition and physiognomy.

Snow Creek (O'Leary and Minnich, 1981)

In June 1973, the first known fire to penetrate creosote bush scrub in southern California occurred at Snow Creek on the northern rim of the San Jacinto Mountains. The fire moved through dense cover of *Bromus rubens*, *Avena barbata* and *Schismus barbatus* following a wet El Niño winter of well-spaced rains. Native annuals *Malacothrix glabrata*, *Lupinus bicolor*, *Cryptantha intermedia*, *Lotus tomentellus*, *Lasthenia chrysostoma*, and *Camissonia pallida* were too scattered to carry flames. The fire was pushed by high winds in association with marine air spilling through San Gorgonio Pass, typical of the region during early summer.

The offburn plot was dominated by *Larrea tridentata* with moderate cover of *Prosopis glandulosa*, *Opuntia echinocarpa*, and *Hymenoclea salsola* (Table 2). The burn resulted in an increase in *Hymenoclea salsola*, which both resprouted and established numerous seedlings. *H. salsola* is a weedy colonizer and a relatively short-lived shrub that occurs in naturally disturbed areas in creosote bush scrub (Vasek *et al.,* 1975a,b). High fire mortality resulted in a sharp decline in the cover of *Larrea tridentata* and *Opuntia acanthocarpa*. The fire was severe enough to defoliate nearly all *L. tridentata*. Resprouts normally grew from the main stems, near the root axis, and within the canopy to smallest stems experiencing nonlethal cambium damage. Stems rarely emerged from subsurface roots. *O. acanthocarpa* was incinerated partly because of its small size and partly due to the presence of its flammable spines which propagate the flames along their stems. Surviving individuals were unburned or lightly seared. Little regeneration from fallen unburned joints was apparent.

Table 2. Perennial cover (percent) in the Snow Creek drainage.

Species	Off burn 1983	Off burn 1994	On burn 1983	On burn 1994
Larrea tridentata	10	27	2	0
Opuntia acanthocarpa	4	0	2	0
Hymenoclea salsola	5	5	10	17
Prosopis glandulosa	5	0	0	0
Encelia farinosa	1	0	1	0
Total Cover	25	32	15	7

A second burn in 1982 caused further species changes. Resampling of the original site in 1994 (Table 2) revealed that the second burn extirpated remaining *Larrea tridentata* and *Opuntia acanthocarpa*, leaving an almost monotypic stand of *H. salsola*. Widely scattered juvenile *O. acanthocarpa* had established vegetatively from fallen joints. *L. tridentata* had established a few seedlings (11 ha^{-1} on burn and 5 ha«MDSU»$^{-1}$ off burn) since our first sampling in 1986. The similarity of seedling densities across the burn boundary indicates that its establishment is not dependent on autogenic successional processes. Offburn *L. tridentata* cover had increased substantially since 1986.

Time-series ground photographs of the site show that herbaceous cover was continuous and heavy until 1988, but thinned significantly during the drought of 1988-1990. Herbaceous cover rebounded during normal and above-normal precipitation years after 1990. The photographs reveal several changes in the species composition of the herb layer. *Bromus rubens* was the dominant herb in 1983, but *Brassica tournefortii* was dominant in 1988. During the drought, *B. tournefortii* and *B. rubens* formed a thin cover with considerable bare ground. In 1991, the "March miracle" year, the site had abundant cover of wildflowers, particularly *Lasthenia chrysostoma*. *Erodium cicutarium* and *Schimus barbatis* were relatively more abundant than *B. rubens* and *B. tournefortii* than during the pre-drought years. *B. tournefortii* again became the dominant herb at the site by 1992. Field estimates in 1994 indicate that the herbaceous layer was nearly contiguous and dominated by *Brassica tournefortii*, *Bromus rubens*, *Erodium cicutarium*, and *Schismus barbatus* (Table 3). The herb layer cover could easily carry another fire at any time.

Table 3. Estimated cover of annuals (percent) in the Snow Creek drainage.

Species	Off burn	On burn
Brassica tournefortii	6	11
Bromus rubens	22	35
Erodium cicutarium	17	16
Erigeron	2	2
Schismus barbatus	12	6
Total	59	70

Palm Springs (Brown and Minnich, 1986)

In 1980 and 1983, unprecedented heavy rains and heavy growth of exotic annual vegetation carried three large burns across extensive stands of creosote bush scrub on the east flank of the San Jacinto Mountains. Precipitation at Palm Springs (mean, 138 mm) averaged 215 percent of normal between 1978 and 1980, and 161 percent of normal in 1983.

Four sites were sampled located on lower portions of alluvial fans of the San Jacinto Mountains. Creosote bush scrub was dominated by *Larrea tridentata*, *Ambrosia dumosa*, and *Encelia farinosa*, typical of the lower Sonoran Desert. Wash species (*Acacia greggii*, *Justicia californica*, *Hyptus emoryi*) and cacti (*Opuntia acanthocarpa*, *O. bigelovii*) were occasional on all the sites (Table 4). The fires were carried by high winds of 10-20 ms^{-1}, high ambient temperatures (35-40°C), and in relative humidities ranging from 10-25%. Flames were carried by a subcontinuous cover of herbs dominated by *Bromus rubens* and *Schismus barbatus* (Table 5). The flames reduced herbaceous cover to a low stubble, indicative of a fast, moving low intensity fires. *Larrea tridentata* was mostly scorched, but local stands were burned during high winds. *Encelia farinosa* was also scorched because its pencil-thick branches support an umbrella of leaves with few stems beneath. *Ambrosia dumosa* was burned to the ground because its finely divided, dense branches maximize fuel continuity, surface to volume ratio, and rapid pyrolysis. The cacti scorched, although the dense spines of *Opuntia bigelovii* carried flames through its stems. The wash species were typically too tall to be burned, but above-ground canopy was fire-killed due to fatal cambium damage to the primary stems.

Table 4. Perennial cover (percent) at Blaisdell Canyon (Palm Springs)

Species	Off burn 1983	Off burn 1994	On burn 1983	On burn 1994
Larrea tridentata	6	7	0	0
Ambrosia dumosa	6	6	1	0
Encelia farinosa	6	3	5	18
Opuntia acanthocarpa	0	0.3	0	0.6
Total Cover	18	16	6	19

Resprouting was uncommon among most perennials except for the wash species. *Larrea tridentata*, *Ambrosia dumosa*, *Encelia farinosa*, and the cacti all suffered heavy or total mortality, similar to congeners or conspecific taxa in Arizona (Rogers and Steele, 1980; Malanson and O'Leary, 1982; Tratz and Vogl, 1977). Burned shrubs resprouted less than scorched ones, indicating that resprouting rates are fire intensity dependent (White, 1968; Cable, 1972).

By 1983, postfire succession was dominated by abundant recruitment of *Encelia farinosa*. Replicate sampling of the Blaisdell site shows little change in postfire succession between 1983 and 1994 (Table 4) except that *E. farinosa* cover increased by 3-fold. There were no *L. tridentata* seedlings. The lack of establishment is not related to seed availability because it is capable of long distance seed dispersal by wind, and living populations occur within 100 m of the site. Poor recruitment of *Larrea tridentata* and *Ambrosia dumosa* may be related to inadequate precipitation, season of precipitation, and accumulation of organic matter (Zedler, 1981; Vasek, 1980).

Time-series ground photographs show that herbaceous cover and species composition at the Blaisdell Canyon site had also changed significantly since 1983. In 1988 *Brassica tournefortii* became the dominant fuel on the site, but was mixed with *Bromus rubens* and dense, low cover of *Schismus barbatus*. In 1990, two years of severe drought (annual precipitation, 30 cm) resulted in virtual denudation of the herbaceous layer on the site, as scarce annual cover was blown off the site. The "March miracle" rains of 1991 resulted in thin cover of *Erodium cicutarium*, *Schismus barbatus*, and scattered wildflowers similar to the Snow Creek site, but no establishment of *Bromus rubens* and *Brassica tournefortii*. Perhaps rains came too late that year for germination of seed cashes of these species. Dense cover of *B. tournefortii* mixed with *E. cicutarium* and *Schismus barbatus* developed after heavy rains in 1992 and 1993. *Bromus rubens* has been extinct from the site since the 1988-1990 drought. This grass is known for almost complete germination of the annual seedbank, typical of many grasses. Apparently, the scarce rains of 1989 and 1990 caused germination of seedlings which later died before reaching seed production. In 1994 annual cover, mostly *S. barbatus*, decreased to 8% after the dry winter (Table 5).

Table 5. Estimated cover of annuals (percent) at Blaisdell Canyon.

	Off burn		On Burn	
Species	1983	1994	1983	1994
Bromus rubens	21	0	17	0
Schismus barbatus	16	7	7	7
Erodium cicutarium	6	0.3	2	0
Chaenactis fremontii	5	0	6	0
Euphorbia polycarpa	11	1	6	1
Aristida adscensionis	0	0	2	0
Chorizanthe brevicornu	0	0	2	0
Malacothrix glabrata	1	0	0	0
Plantago Insularis	3	0	0	0
Total cover	65	8	42	8

Microphyllous Woodlands.

Although there are no formal studies on fire in microphyllous woodlands of southern California, we have observed that *Olneya tesota*, *Cercidium floridum*, *Prosopis juliflora*, and *Dalea spinosa* are all strong resprouters after fire. Such sprouting behavior may be a generalized adaptation to flash flood disturbances which are recurrent in their habitat along washes and alluvial fans (Tratz 1978; Zedler, 1981). Furthermore, microphyllous woodland species have hard seeds that require scarification for germination after flash flooding. Hence, these taxa recruit heavily after flash floods (Zedler, 1981), but seldom between such perturbations. After runoff episodes, these leguminous phreatophytes extend deep taproots and follow the soil moisture front to the water table, which provides secure long-term moisture (Rundel *et al.,* 1982; Nilson *et al.,* 1983). These shrubs seldom establish at other times because soils are seldom wetted to depth by natural rainfall.

It is highly unlikely that fires will encourage recruitment of microphyllous woodland species, despite their ability for seed scarification, because the probability is low that rare burns will be followed by flash floods required for successful recruitment. On the other hand, the impact of rare fires on this community will be minimized by the strong sprouting habit of the dominant species.

The Mojave Desert near Victorville

Beginning in 1976, several fires burned *ca.* 10,500 ha of creosote bush scrub in the desert ranges and alluvial fans of the Mojave Desert between the San Bernardino Mountains, Victorville and Barstow. Again, these blazes were phased with persistent heavy precipitation between 1976 and 1985 (Table 6). In 1976 and 1977 two fires spread down the northern escarpment of the San Bernardino Mountains into Lucerne Valley. Other fires burned portions of the Granite Mountains, the Sidewinder Mountain, and Stoddard Mountain between 1979 to 1983.

Table 6. Annual Precipitation at Victorville (cm)[1].
(Source: USDC, 1987)

Year	Total	Percent of Normal
1976-77	21.1	166
1977-78	32.7	257
1978-79	22.8	180
1979-80	24.3	191
1980-81	7.4	58
1981-82	15.3	120
1982-83	32.7	257
1983-84	9.4	74
1984-85	17.1	135

1. July 1 to June 30.

Perennial cover and species composition shifts along a decreasing precipitation gradient northward from the San Bernardino Mountains. Offburn transects show that the dominant shrubs at all sites were *Larrea tridentata* and *Ambrosia dumosa*. Associated species at Lucerne Valley were *Hilaria rigida*, *Eriogonum fasciculatum*, *Stipa speciosa*, *Lycium andersonii*, *Ephedra nevadensis*, *Hymenoclea salsola*, and *Yucca schidigera* (Fig. 1). *H. salsola* was the only abundant subshrub at four sites in the desert ranges west of Victorville. Total shrub cover decreased from 58% at Lucerne Valley to 23% west of Victorville.

Larrea tridentata mortality rates ranged from 53 to 91 percent, except on a very light burn at Stoddard Mountain where no mortality occurred. *A. dumosa* and other subshrubs were burned to the ground because of their finely canopy morphologies. Burned stem succulents *Opuntia acanthocarpa* and *O. ramosissima* also experienced heavy mortality.

In Lucerne Valley, several shrubs are strong resprouters including *Ephedra nevadensis*, *Lycium andersonii*, and *Hymenoclea salsola*. *Y. schidigera* resprouted as "pups" emerging from primary lateral roots near fire-killed arboreal stems. These taxa, however, are rarely stand dominants. Several species were never seen to resprout, because they apparently lack adventitious buds including *A. dumosa*, *Eriogonum fasciculatum*, *Salazaria mexicana*, *Gutierrezia microcephala*, *Grayia spinosa*, *Acamptopappus sphaerocephalus*, and *Salazaria mexicana*.

Postfire succession is characterized by the replacement of *Larrea tridentata* and *Ambrosia dumosa* by opportunistic colonizers of fluvial or aolean disturbances, and are characterized by long distance seed dispersal by wind: *Encelia actoni*, *Hymenoclea salsola*, *Eriogonum fasciculatum*, *Salazaria mexicana*, and *Gutierrezia microcephala*.

Postfire succession in the more arid desert ranges to the north involved few perennial species. Again, *Larrea tridentata* and *Ambrosia dumosa* suffered heavy mortality. *Yucca schidigera* mostly resprouted, but the cover of this stem-succulent was less than on offburn transects due to the reduced stature of sprouting individuals. There was scarce recruitment of *Hymenoclea salsola*.

Annual herbaceous cover at three sites in the spring of 1992 ranged from only 10 to 49%, in spite of heavy rains the previous winter (Table 7). *Bromus rubens* and *Erodium cicutarium* were dominant at each site. The most abundant native wildflowers were *Amsinkia tessellata*, *Phacelia distans*, *Machaeranthera tortifolia* and *Propidocarpum gracile*.

Table 7. Estimated cover of annuals (percent) at three sites in the Mojave Desert (April, 1992).

Species	Kiowa		Lucerne Valley		Sidewinder	
	off	on	off	on	off	on
Amsinkia tessellata	5	1	0	0	18	10
Bromus rubens	43	21	11	5	14	25
Eriogonum inflatum	0	3	0	0	0	0
Erodium cicutarium	1	3	4	5	4	2
Phacia distans	0	1	1	0	0	0
Total	49	29	16	10	36	37

Joshua Tree National Monument

Desertscrub vegetation on the high plateau of Joshua Tree National Monument was also hit by large fires between 1978 and 1982, during a time when precipitation was above normal for nearly a decade (Table 8). The blazes moved across Joshua Tree woodland in basins, and blackbrush scrub growing on steep well-drained slopes at Quail Mountain, Quail Wash, Hidden Valley and Lost Horse Valley. Smaller fires struck nearby areas between 1984 and 1987.

Table 8. Annual Precipitation at Twentynine Palms (cm)[1]. (Source: USDC, 1987)

Year	Total	Percent of Normal
1975-76	11.5	114
1976-77	14.1	140
1977-78	23.0	228
1978-79	13.8	137
1979-80	22.3	221
1980-81	11.2	111
1981-82	5.3	52
1982-83	12.2	220
1983-84	21.7	215
1984-85	18.1	179
1985-86	13.2	131

1. July 1 to June 30. Period of record, 1935-1987.

In contrast with the fires in creosote bush scrub at lower elevations of the Mojave and Sonoran Deserts, the Joshua Tree National Monument blazes were propagated by native perennial shrubs and bunch grasses, particularly *Hilaria rigida* in Joshua Tree woodland and *Coleogyne ramosissima* in blackbrush scrub. These dominants and associated species produce a continuous perennial layer due to the cooler, more mesic climate of the plateau than in desert lowlands. Fuels produced by exotic annual herbs appear to be insignificant.

Wildfire is not unprecedented on the monument, as smaller burns occurred in Lost Horse Valley after wet winters in 1942, 1967, and 1968.

The correlation between these fire incidence and heavy rainfall in Joshua Tree woodland and blackbrush indicates that fuel build-up and fire probability is maximized by spurts of rapid growth and fuel accumulation which increase short-term fire probability in the region. Fire occurrence does not seem to be related to fuel build-up over long succession times. I have observed decreases in shrub cover and biomass in these communities due to dieback from drought, especially in *Hilaria rigida*. Although biological decomposition is minor in desertscrub, it is possible that dried fuels are shredded by wind action, and blown away. Saltation of fuels along the ground further breaks down undecomposed litter into nonflammable size particles. Perhaps these organics are then utilized by microfauna.

The patterns of postfire succession in Joshua Tree woodland and blackbrush scrub are distinct.

Joshua Tree Woodland

The most conspicuous vegetation change in Joshua Tree woodland was the destruction of *Yucca brevifolia*. This tall stem-succulent was typically burned or scorched because persistent leaf blades along the bole and primary branches propagated the flames through the entire canopy. *Y. brevifolia* resprouted by sending up "pups" from its primary root axes. Resprouting rates at 15 sample sites, however, averaged only 17% of stems, and seldom exceeded 33% of stems (Table 9). Joshua Trees on the monument do not exhibit vigorous sprouting seen in populations growing with chaparral at Cajon Pass, and with pinyon forest in the eastern San Bernardino Mountains. Another 14% of *Y. brevifolia* directly survived the fires with some green canopy (Small resprouting pups are easily distinguished taller, surviving trees). More than half of *Y. brevifolia* were fatally damaged in all but one of the sample sites, and stands were totally destroyed at 6 sites. Resprouts were most frequent where the frequency of surviving stems was also greatest. This indicates that resprouting rates of *Y. brevifolia* are inversely related to fire intensities.

Chronosequence sampling of burns between 1942 and 1984 (Fig. 2) show that postfire successional patterns in the understory is dominated by the rapid establishment of *Hilaria rigida*. This perennial bunch grass sends up numerous stems from subsurface rhizomes in a tuft-like configuration. These tufts establish in high densities from a subsurface root network. *H. rigida* cover was almost 10% within two years after fire, and comparable to offburn plots (25%) after 10 years. Most other shrubs established by resprouting including *Ephedra nevadensis*, *Lycium cooperi*, *Hymenoclea salsola*, and *Stipa speciosa*. As a consequence, these species also attained preburn cover within *ca.* 10 years after fire. Two stem succulents, *Opuntia echinocarpa* and *O. ramosissima* established scattered seedlings in older stands. *Yucca brevifolia* recruitment appears to be slow and continuous. No seedlings or saplings were seen in burns < 10 years old and recruitment densities are typically < 10 ha^{-1} in older burns. *Y. brevifolia* may reach preburn densities and stature only after successional times of a century or longer. Indeed, a large gap in *Y. brevifolia* may still be seen in the 1942 burn.

Blackbrush Scrub

In contrast with Joshua Tree Woodland, fires in blackbrush scrub cause a drastic transformation in the postburn species composition. On Joshua Tree National Monument, blackbrush scrub grows on steep, well-drained slopes, especially in areas of metamorphic and volcanic bedrock. Stands form contiguous cover but seldom exceed 0.5 m height. Fire reports indicate that flames move through blackbrush scrub only in high winds. Hence, fires are usually brief and cover small areas. Fires always denude the shrub layer, leaving only scorched yuccas and skeletons of *Juniperus californica*. The removal of the dark cover of *Coleogyne ramosissima*, exposure of lighter colored substrate, and species replacements of brighter green shrubs result in sharp fire boundaries that can be seen from a distance. The burn scars persist for decades.

Table 9. Yucca brevifolia and Y. schidigera resprouting and mortality rates (percent) in Joshua Tree National Monument.

Site	stems	Frequency Unburned[1]	Resprout[2]	Resprout rate (%)	Survivor-ship (%)
HID	2	2	6	27	36
NWE	11	2	2	18	36
QM-1	6	0	0	0	0
QM-2	21	2	2	10	19
SHP-1	23	3	3	13	27
QW-N	8	0	1	13	13
QW-S	16	0	1	6	6
QW-2	12	0	0	0	0
QW-3	9	0	2	22	22
JUN-1	1	0	0	0	0
JUN-2	11	1	0	0	9
SHP-2	2	0	1	50	50
LHV	12	3	3	0	25
RAN-1	22	11	6	27	77
RAN-2	9	1	3	33	44
Total/ ave.	179	25	31	17	31

1. All or portions of the canopy are green after the fire.
2. Resprout frequency/total frequency

Offburn field samples reveal that *C. ramosissima* (blackbrush) make up nearly half of the total shrub cover (Fig. 3). Other species growing with it include *Hilaria rigida*, *Stipa speciosa*, *Ephedra nevadensis* and *Viguieria deltoidea*, with an open arboreal layer of *Yucca brevifolia*, *Y. schidigera*, and *Juniperus californica*.

Onburn field sampling of burns 8-12 years old (Fig. 3) reveal that *Coleogyne ramosissima* was fire-killed and replaced by a diversity of subshrubs and perennial bunch grasses. *Hymenoclea salsola* and *Lycium cooperi* resprouted vigorously. *Stipa speciosa* sent out new stems from meristems well-protected from flames in the interior of the plants. *S. speciosa* in burns were often larger than those offburn, due possibly to the addition of soil nutrients from the ash, giving a "pampas grass" like aspect to the burned landscape. Weedy species adapted to frequent disturbance established numerous seedlings, including *Hymenoclea salsola*, *Salazaria mexicana*, *Viguiera deltoidea*, as well as scattered *Happlopappus cooperi* and *Salvia mojavensis*. Partially damaged *Juniperus californica* survived the burn. Most *Yucca schidigera* resprouted, while scarce *Y. brevifolia* sustained heavy mortality. The few *Coleogyne ramosissima* on the sample sites were found on local unburned "fire islands." This shrub is a nonsprouter and the lack of recruitment during early succession suggests that its eventual establishment requires considerable time.

EXOTIC ANNUALS, FIRE, AND FUTURE VEGETATION CHANGES IN DESERTSCRUB

Postfire succession studies in desertscrub support the secondary succession model proposed by Vasek (1979-80, 1980) in which long-lived poorly competitive species with low reproductive capacities are replaced by highly competitive short-lived species with high reproductive capacities. These colonists typically grow along washes, sandy sites, and steep slopes subject to recurrent fluvial and aeolian disturbances, instead of the open desert bajadas. These shrubs are also capable of long distance seed dispersal by wind. Although mature desertscrub ecosystems appear to be "early successional," i.e, minimal cover, bare ground, limited soil organic matter, etc., the establishment of pioneer shrubs in burns is evidence that some kind of habitat modification is essential to their establishment, perhaps the removal of resident plants or soil nutrient enrichment from ash.

The greatest short-term impact of desert fires in California is the destruction of *Larrea tridentata*. High *L. tridentata* mortality was also found by Dalton (1962), White (1968, 1969), Cable (1972), Wright (1972) and Rogers and Steele (1980) in Arizona. Although *L. tridentata* is also capable of long distance wind dispersal of seed, seedling establishment is limited even in during favorable weather (Vasek (1980). Moreover, *L. tridentata* requires about 18 years to reach reproductive maturity (Chew and Chew, 1965). Barbour (1969) found that germination and survival of *L. tridentata* in laboratory tests were rare events. No species exhibited immediate fire-stimulated reproduction from refractory seed characterized by long-term dormancy and seed viability as with many species in the fire-prone chaparral of coastal southern California (Keeley, 1989).

The tendency for burns to be colonized by short-lived pioneers has been reported for several anthropogenic disturbances in the eastern Mojave Desert. In pipeline construction, the removal of creosote bush scrub dominated by long-lived *Larrea tridentata*, *Ambrosia dumosa*, *Hilaria rigida*, and *Ephedra californica* encouraged invasion of short-lived *Hymenoclea salsola*, *Gutierrezia microcephala*, and *Eriogonum fasciculatum*. The cover of long-lived shrubs was below undisturbed control plots after 12 years (Vasek *et al.,* 1975a).

Several studies of succession after historic anthropogenic disturbances in the Mojave Desert suggest that pioneer species persist for several decades and recruitment of long-lived species to levels of undisturbed stands requires long periods of time. Vasek *et al.* (1975b) describe an incomplete recovery of *Larrea tridentata* and *Ambrosia dumosa* beneath pylons of power transmission lines constructed 33 years before the study. These areas still had greater cover of short-lived *Hymenoclea salsola*, *Salazaria mexicana*, and *Sphaeralcea ambigua* than control sites. Streets abandoned for 30 years in southern Nevada were colonized by *Hymenoclea salsola*, *Salazaria mexicana*, and *Stipa speciosa*. *L. tridentata* were still 20 times as abundant in undisturbed sites (Wells, 1961). Abandoned fields in the northeastern Mojave Desert were invaded by *Sphaeralcea ambigua*, *Hymenoclea salsola*, and *Gutierrezia microcephala*. After 65 years, on-field *L. tridentata* cover was one third that on off-field controls (Carpenter *et al.*, 1986). Postfire succession of creosote bush scrub in the Mojave Desert may require a century or more to complete.

A new fire regime?

While wildland fire is a rare event in the southern California deserts, it is imperative to examine whether the present outbreak is an anomaly or portends a new fire regime in southern California desertscrub. Since postfire successions of desertscrub communities appear to require a great amount of time, relatively little burning (long fire return times) might result in directional changes in the abundances of desert perennials. The answer to this question, of course, will be difficult to establish due to natural temporal fluctuations in precipitation and future role of exotic species.

It can be argued that the recent outbreak of fires may be an ephemeral event in desertscrub ecology because burning is phased with a rare period of unusually heavy precipitation. Time-series ground photographs at Snow Creek and Palm Springs show that the annual build-up of fuels correlates with annual precipitation. Large fuel build-up during wet years may be spaced by long-hiatuses of nonflammability in the herb layer during droughts. Moreover, even abundant exotics such as *B. rubens* may suffer may setbacks or even local extinctions during severe drought. In addition, fires burn only small portions of the desert with each outbreak. Hence, climatic drought, limited stand productivity, and fuel accumulations produce fire intervals within the adaptive limits of long-lived perennial shrubs, and the reestablishment of mature phases of creosote bush scrub, Joshua Tree woodland, and blackbrush scrub.

On the other hand, it can be argued that southern California desertscrub perennials are now experiencing directional change in species composition due to the ongoing invasion of exotic herbs. Alien species, by annually forming cured groundcover, can produce short fire recurrences which breach desertscrub successions before long-lived species achieve dominance. This would require that the build-up of flashy exotic fuels may be reaching levels greater than formerly provided by native annuals. Under this scenario, recent fires represent the beginning of a period of increasing fire activity.

Early fire history and the timing of alien invasions.

One method to test whether exotic herbs are causing new rates of fire disturbance is to determine whether extensive burning took place in previous wet periods. This question requires: 1) the determination when exotic species first become abundant in the desert; and 2), the analysis of fire history since that time.

Naturalization of exotic species

Exotics introduced to California during the Franciscan Mission period in the late 18th century, including *Avena fatua*, *Brassica nigra*, *Hordeum spp.*, and *Festuca spp.* spread only into mesic coastal areas of California (Heady, 1988). The Franciscan introduction *Erodium cicutarium* undoubtedly spread into the deserts long before California Statehood, but this herb readily decomposes and is not a significant source of fuel in arid habitats. Other common exotics were introduced to California only in the late 19th century, and did not reach the deserts until the 20th century.

Table 10. Botanical collections of Bromus rubens in the Mojave Desert before 1940.

Collection/Herbareum[1]	Year	Location
Parish (RSA)	1887	Fort Tejon
Jepson 5468 (JEPS)	1913	New York Mountains
Epling (LA)	1925	Palmdale
Abrams 11709 (LA)	1927	Head of Antelope Valley
Wolf 1546 (RSA)	1928	South side of Antelope Valley
Epling (LA)	1930	Argus Mountains (Death Valley)
Duran 3420 (RSA, UC)	1933	Between Mojave and Palmdale
Duran M40 (UC)	1933	Silver Canyon, White Mountains
Clokey, Anderson 6518 (UC)	1935	North of Barstow
Axelrod 286 (UC)	1935	Deep Creek, San Bernardino Mtns.
Jepson 18348 (JEBS)	1937	Mitchells Cavern
Beal 299, 304 (JEBS)	1937	Providence Mountain
Yates 6496 (UC)	1937	Antelope Valley
Jepson 19692, 19754 (JEPS)	1940	Panamint Mountains

1. RSA, Rancho Santa Ana Botanical Garden. Claremont, California.
2. JEPS, Jepson Herbareum. University of California, Berkeley.
3. LA, University of California, Los Angeles.
4. UC, University of California, Berkeley.

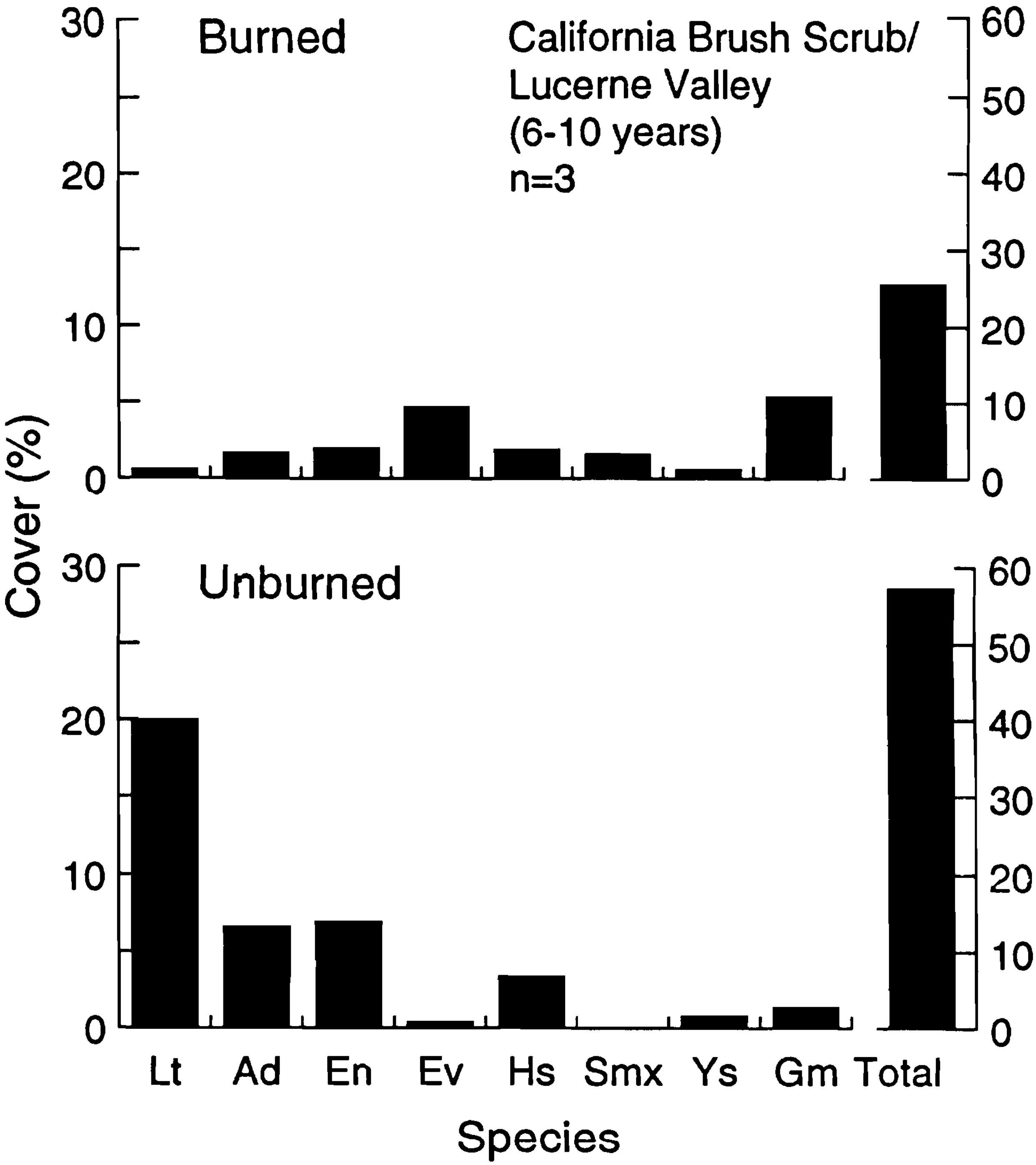

Figure 1a. Perennial cover by species at Lucerne Valley for burns 6-10 years old. Lt, *Larrea tridentata*; Ad, *Ambrosia dumosa*; En, *Ephedra nevadensis*; Ev, *Encelia actoni* (E. virginensis); Hs, *Hymenoclea salsola*; Smx, *Salazaria mexicana*; Ys, *Yucca schidigera*; Gm, *Gutierrezia microcephala*.

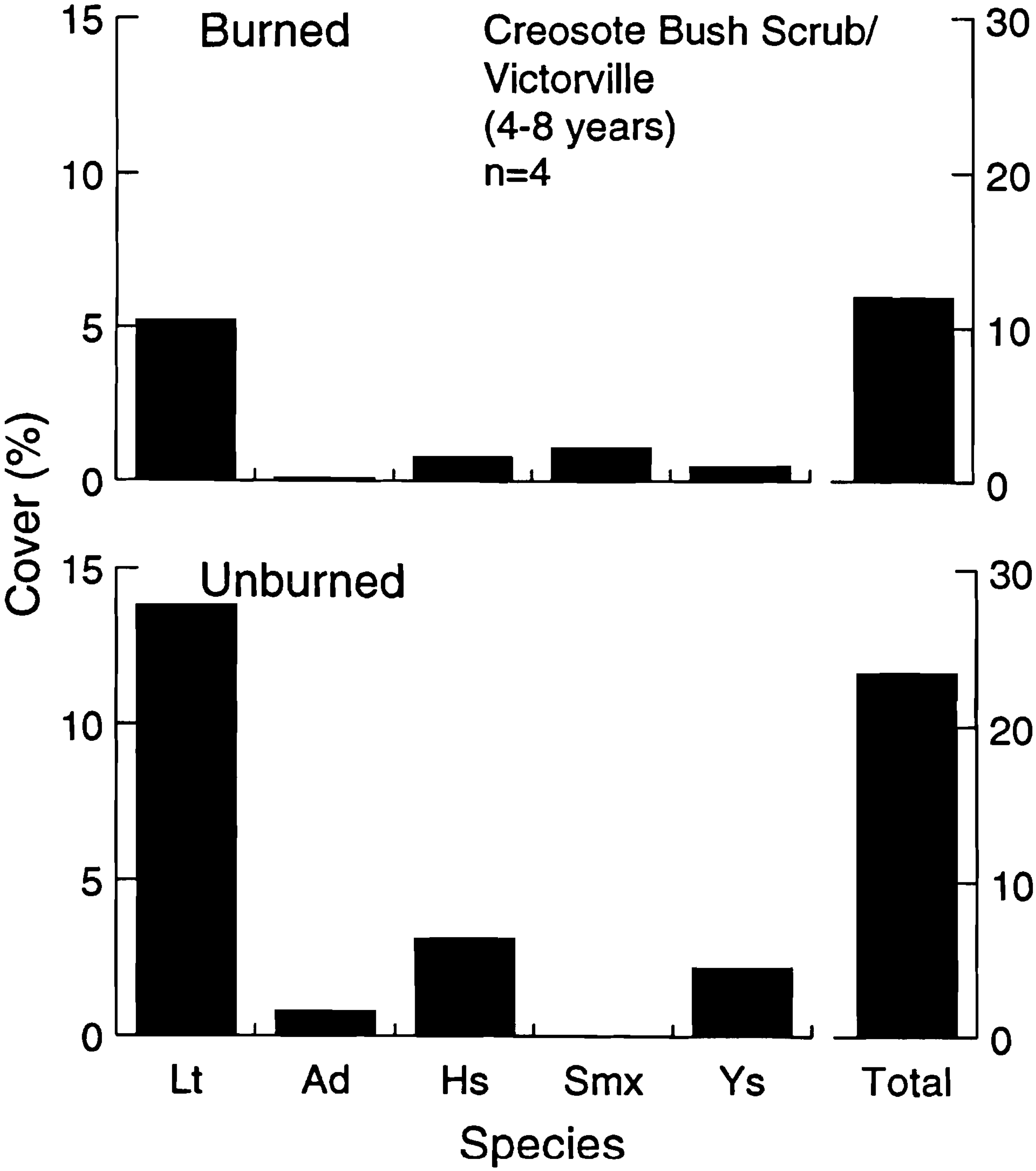

Figure 1b. Perennial cover by species near Victorville for burns 4-8 years old. Lt, *Larrea tridentata*; Ad, *Ambrosia dumosa*; Hs, *Hymenoclea salsola*; Smx, *Salazaria mexicana*; Ys, *Yucca schidigera*.

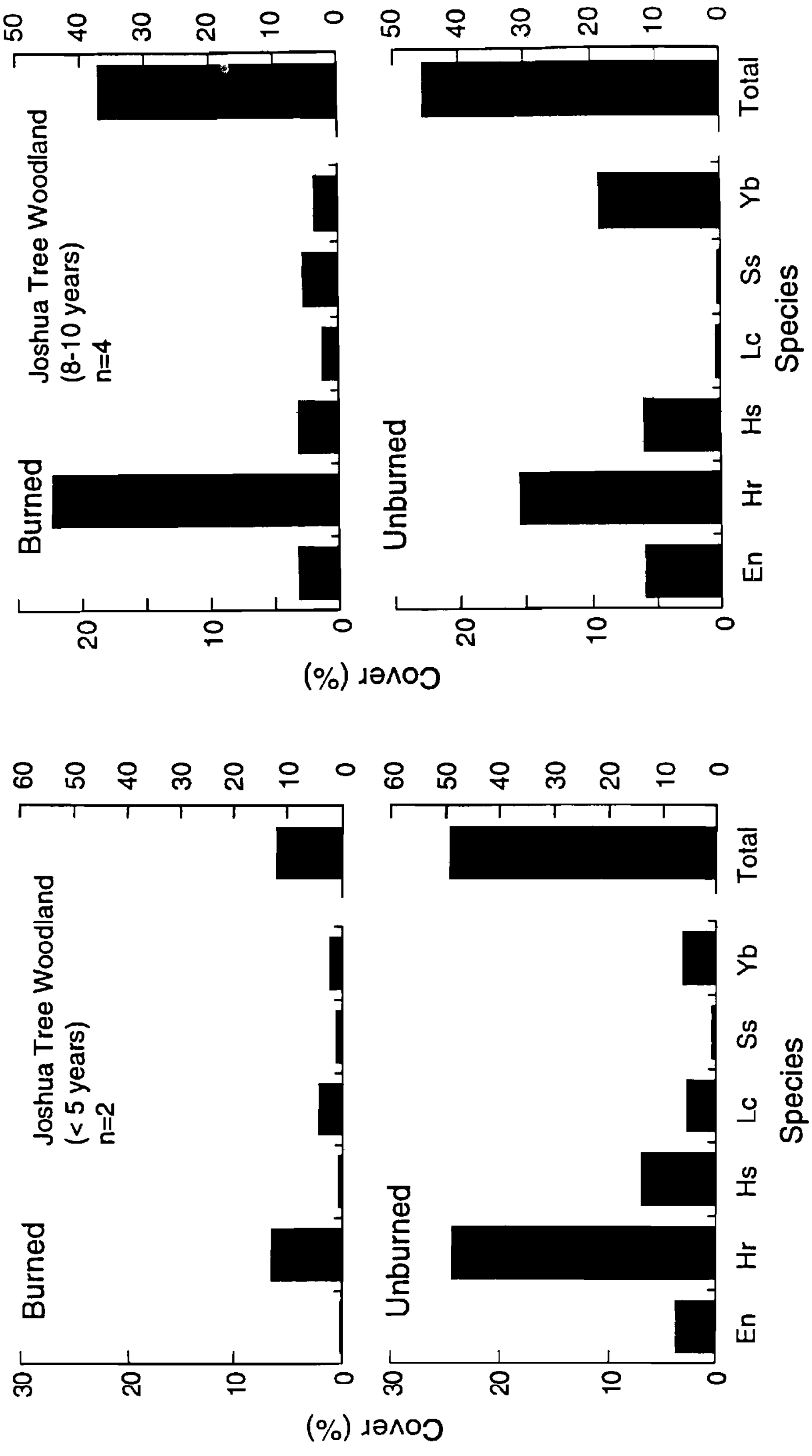

Figure 2a,b. Perennial cover by species in Joshua Tree woodland for burns: a) < 5 yr; b) 8-10 yr; c) 20 yr; and d) 41 yr. En, *Ephedra nevadensis*; Hr, *Hilaria rigida*; Hs, *Hymenoclea salsola*; Lc, *Lycium cooperi*; Ss, *Stipa speciosa*; Yb, *Yucca brevifolia*.

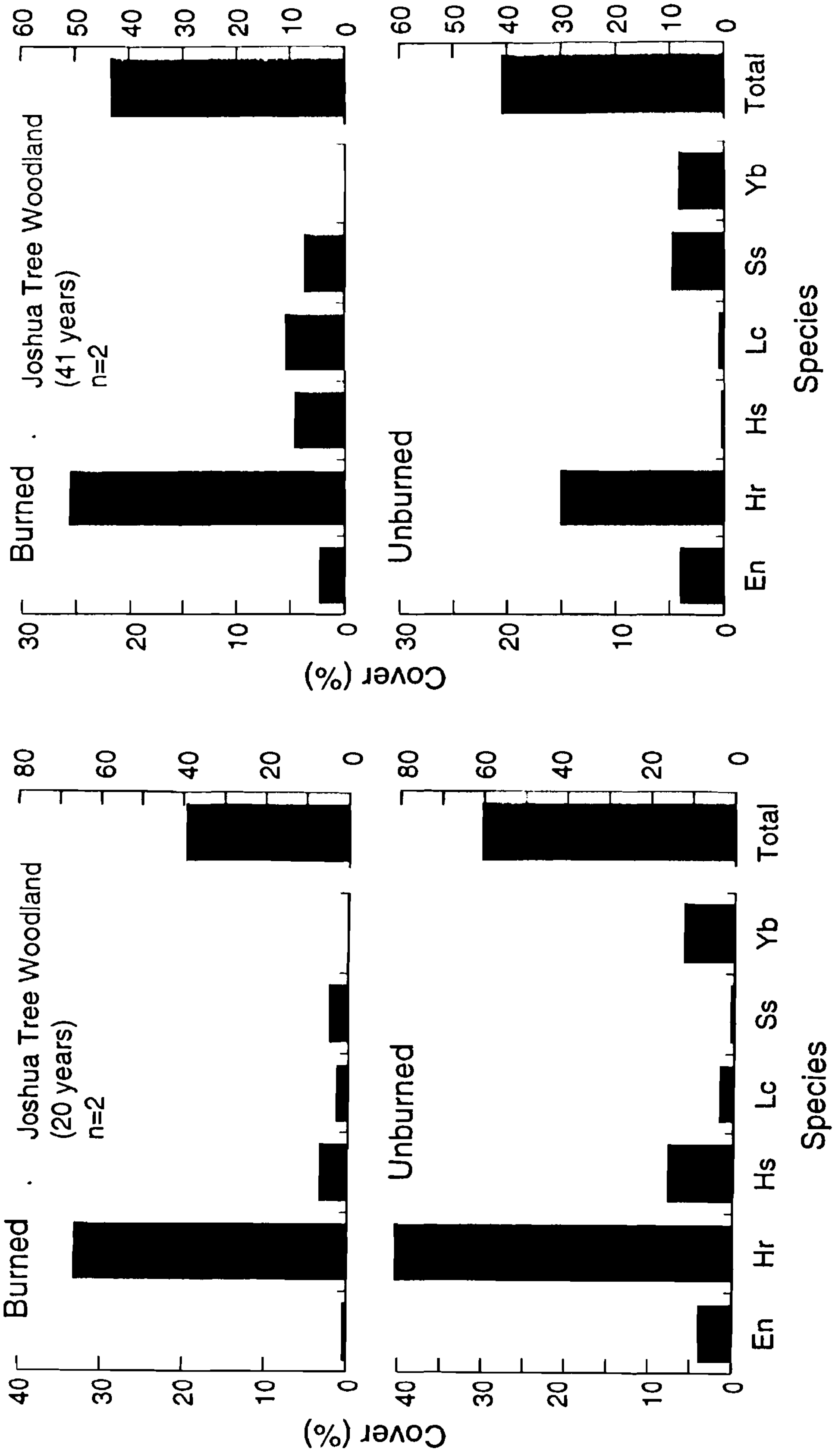

Figure 2c,d. Perennial cover by species in Joshua Tree woodland for burns: a) < 5 yr; b) 8-10 yr; c) 20 yr; and d) 41 yr. En, *Ephedra nevadensis*; Hr, *Hilaria rigida*; Hs, *Hymenoclea salsola*; Lc, *Lycium cooperi*; Ss, *Stipa speciosa*; Yb, *Yucca brevifolia*.

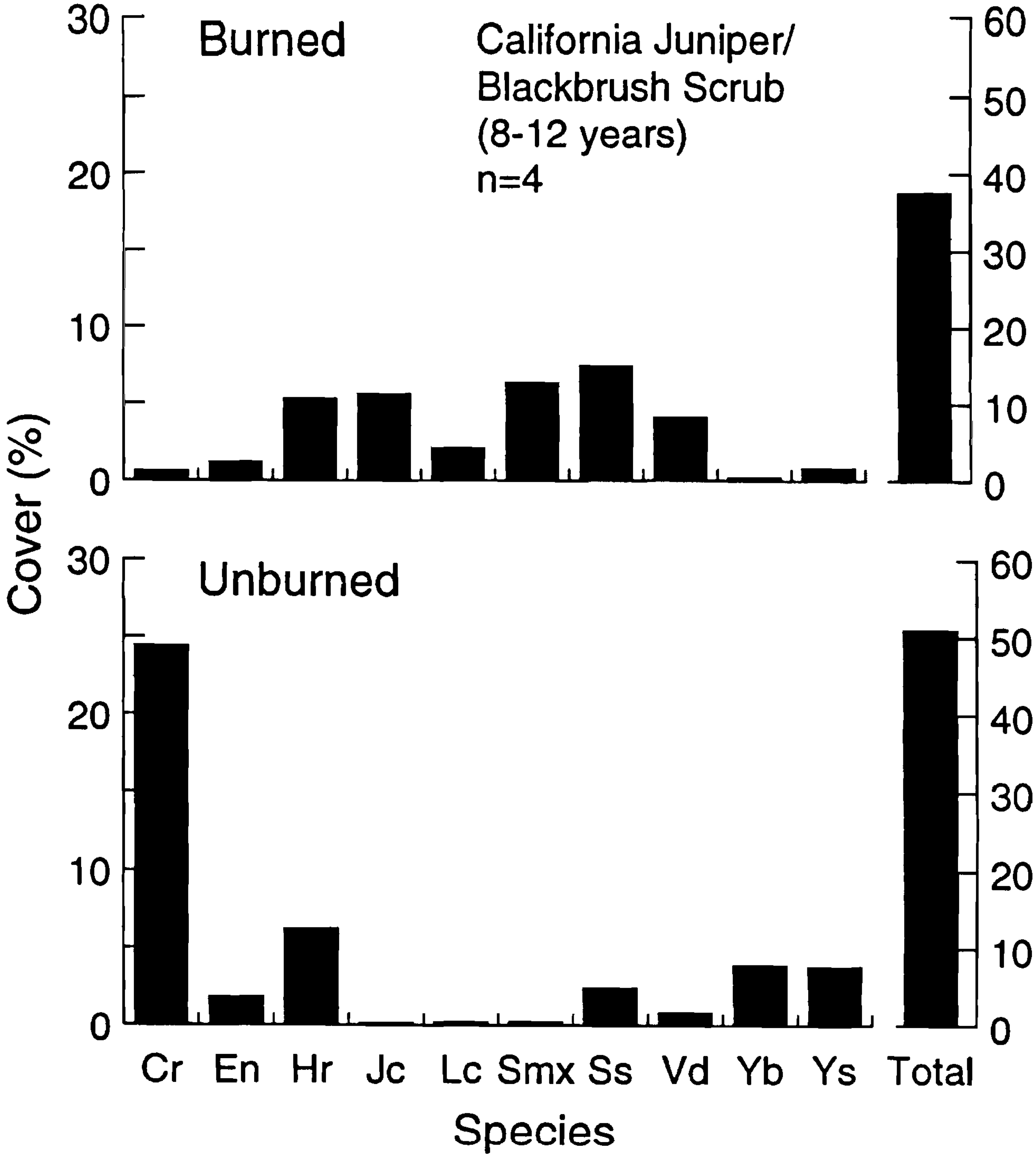

Figure 3. Perennial cover by species in blackbrush scrub for burns 8-12 years old. Cr, *Coleogyne ramosissima*; En, *Ephedra nevadensis*; Hr, *Hilaria rigida*; Jc, *Juniperus californica*; Lc, *Lycium cooperi*; Smx, *Salazaria mexicana*; Ss, *Stipa speciosa*; Vd, *Viguiera deltoidea*; Yb, *Yucca brevifolia*; Ys, *Yucca schidigera*.

This is seen in botanical collections of the most important desert exotic fuel *Bromus rubens* (Table 10). Except for a single report in 1913 in the New York Mountains, earliest herbarium specimens in the Mojave Desert date to 1925. Most reports before 1930 come from the southern and western margins of the Mojave Desert in Antelope Valley and Palmdale. Collections during the 1930's extend *B. rubens* into the central desert near Barstow, Mitchells Cavern, Providence Mountains, and the Panamint Mountains. In a botanical collection (University of California, Berkeley), Duran (3240) states in 1933 that it was "a common grass...on roadsides and on cleared land." Thus, characteristic of pioneers, *B. rubens* first invaded disturbed sites and later the open desert. This grass may still be increasing in density. Vasek (personal communication) states that *B. rubens* was not very common in the Mojave Desert in the 1950's, but had developed dense stands by 1978. *B. rubens* had proliferated at Yucca Flat only by 1986 (data presented at the Tortoise Conference).

These data indicate three trends about *Bromus rubens*: 1) it is still expanding its range; 2) it established first along waste places, then occupied open range. 3) it produced dense cover only in recent decades.

Bromus rubens has been since joined by other exotics. Schismus barbatus was introduced to southern Arizona in 1935 and had become widespread in California only by 1959 (Hitchcock, 1935; Munz, 1959). *Brassica tournefortii*, which was first discovered near Palm Springs in the 1960s, and spread rapidly across the lower deserts in 1970s and 1980s and reached Sonora in recent years (Andrew Sanders, personal communication). In the Mojave Desert, I recently saw populations along roadsides as far north as China Lake in October 1992.

Fire history before 1976

Although fire records did not exist for most desert regions until very recently, early fire history can be reconstructed from historical time-series aerial photographs. Desert fires can be mapped because 1) *Larrea tridentata* (and other arboreal species such as *Yucca brevifolia*) are readily identifiable at scales larger than 1:20,000. Because it is fire-killed, the elimination of stands over discrete areas produces large gaps with distinct boundaries.

Examination of 1938, 1944, 1953, 1970 aerial photos at Victorville, San Gorgonio Pass, and Palm Springs reveal no burns in these areas. The only fire at this early date occurred in 1942 near Hidden Valley in Joshua Tree National Monument, which was carried mostly by the native *Hilaria rigida*.

The period 1934-45 was characterized by unusually heavy precipitation (Table 11) and the potential for the development of dense herbaceous cover. The absence of desertscrub burns during this period indicates that: 1) native annuals produced limited fuels and 2) exotics were not yet extensive in the region, as indicated by botanical sheets.

Table 11. Annual precipitation (cm) and Palm Springs, 1934-45. (Source: California, 1980)

Year	Total	Percent of Normal
1934-35	21.8	158
1935-36	15.6	113
1936-37	30.5	221
1937-38	12.8	93
1938-39	17.6	128
1939-40	22.6	164
1940-41	30.0	217
1941-42	20.6	149
1942-43	30.0	217
1943-44	28.4	205
1944-45	10.1	73

THE FUTURE

Current trends suggest that the indefinite continuation of recent burning rates may result in changes in species composition of creosote bush scrub over portions of the Mojave Desert due to selective elimination of taxa with long generation times such as *Larrea tridentata*, *Ambrosia dumosa*, and *Opuntia spp*. Perhaps, short-lived pioneer shrubs will proliferate with repeated disturbances.

The potential for vegetation change will depend on the regional climate. Desertscrub adjacent to the southern California coastal ranges in the southwestern Mojave Desert and western Sonoran Desert should be most effected because of high mean annual precipitation, plant productivity and fuel accumulation rates in these areas. The percentage of years with sufficient fuels to carry fire should be correspondingly greater than in more arid deserts. Indeed, the hyperarid sections of the Sonoran and Mojave Deserts may be little effected because herbaceous fuel build up is limited even during the wettest years.

Since 1986 drought has caused a decline in herbaceous cover, with little burning in the deserts. But heavy rains associated with the El Niño of 1991-94 has increased fuels and renewed burning, especially in the Mojave Desert between Palmdale and Hesperia. In the meantime *Bromus rubens* and other exotics have expand their ranges for another 7 years. Only time will tell whether recent events will portend another outbreak of fire in the California Deserts.

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The Habitat Conservation Planning Process in Washington County, Utah

Scott C. Belfit, Marilet A. Zablan, Richard A. Fridell, Todd C. Esque, and Marshall Topham

Abstract. The Washington County Habitat Conservation Planning process was initiated to resolve conflicts between urban development and desert tortoise (*Gopherus agassizii*) habitat in the Upper Virgin River Recovery Unit. The resulting Habitat Conservation Plan (HCP) was developed by a 15-member interdisciplinary Steering Committee over a 3.5 year period. The HCP supports a permit application for take of the species over a 20-year period. Scientific guidance was provided through agency-funded inventories, study plots, research projects, and by a technical advisory committee comprised of several local biologists. Primary mitigation for proposed development of 12,459 acres of desert tortoise habitat is the acquisition of State and private lands for inclusion in a 60,818-acre conservation reserve. Design criteria in the Draft Desert Tortoise Recovery Plan were considered during the reserve design process. The HCP budget provides for enforcement, fencing, monitoring, environmental education and administration for the term of the permit. Although initially proactive, the Steering Committee's public relations effort was not maintained throughout the planning process. Over 40 law enforcement contacts were made in response to concerns over non-compliance with the Endangered Species Act during this planning process.

INTRODUCTION AND BACKGROUND

Washington County, Utah is one of the fastest growing counties in the country, with an 83% increase in human population from 1980 (26,125) to 1990 (48,560) (Washington County HCP Steering Committee 1994). Growth projections to the year 2010 vary from 80,543 to 138,692 (Washington County HCP Steering Committee 1994). Most of the County's development has centered around the city of St. George, and desert tortoise habitat in the area includes some of the most desirable real estate because of its scenery, water availability, and local preferences.

The northeastern periphery of the Mojave Desert tortoise population, federally listed as threatened, extends to the vicinity of St. George, Utah (Figure 1). Due to its unique attributes, the desert tortoise population occurring in this area has been classified in the Draft Desert Tortoise Recovery Plan (Fish and Wildlife Service [FWS] 1993) as a distinct recovery unit (Upper Virgin River Recovery Unit) by the Desert Tortoise Recovery Team (DTRT) for purposes of management and recovery.

The 1982 amendments to the Endangered Species Act of 1973 (ESA) in Section 10(a)(1)(B) (Exceptions) provided for the issuance of take permits to developers and others causing incidental mortality or harm (take) to a listed species in the course of clearing or developing habitat. A primary requirement of permit applicants is provision of an HCP that specifies, among other things, "what steps the applicant will take to minimize and mitigate the impacts of such taking" (FWS 1988). For a thorough explanation of the requirements for an ESA Section 10(a)(1)(B) permit, see FWS (1985 and 1988), Webster, (1987), Arnold (1991) and Houck (1993). The purpose of this paper is to document the HCP process and elements of the development phase of the Washington County HCP.

The Plan

On October 1, 1990, the Washington County Commission established the Washington County Desert Tortoise Habitat Scoping Committee to conduct a feasibility study on habitat conservation planning. This group recommended that the County proceed with the HCP process by creating a 15-member Washington County HCP Steering Committee (Steering Committee) representing the broad spectrum of local conservation and development interests. Local government officials and interest groups supported the concept, and the Steering Committee was formed. Its first official meeting was held January 29, 1991 and its last on February 24, 1994 when the plan was

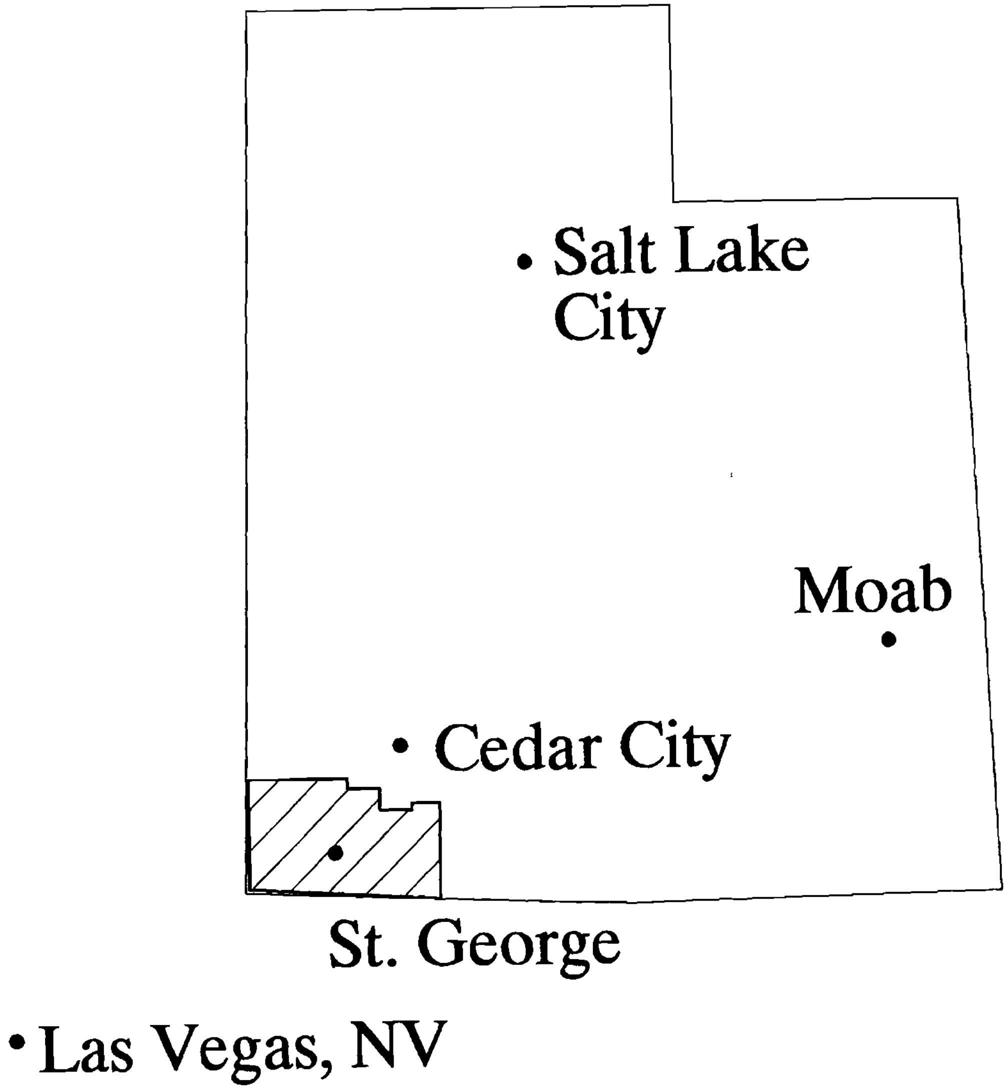

Figure 1. Location of Washington County, Utah

approved for submittal to FWS. The group was on hiatus between April 1, 1992 and July 15, 1992 due to disagreements concerning the size of the conservation reserve. The HCP was submitted to FWS in May, 1994 and if approved by December, 1994, it will have taken 4 years and 3 months to complete. In the early stages of plan development, there were three subcommittees, and decisions were made by majority vote. Later, Steering Committee decisions became consensus-based, and a total of 11 subcommittees (3-6 members each) were formed to provide specific technical products.

Start-up funds for plan development came from a grant to the Steering Committee from the State of Utah. Local governments, private developers, and Section 7 funds (generated as compensation for habitat disturbance resulting from a pipeline project) also contributed to the budget. The available funds from all sources totalled $760,622. An environmental consulting firm received a contract to provide support services to the Steering Committee.

The HCP requests a 20-year permit and is County-wide in geographic scope. The permit application is to take desert tortoises and their habitat only, within the Upper Virgin River Recovery Unit. However, a reserve was designed to benefit other species associated with the Mojave Desert.

A technical advisory committee (TAC) provided scientific support to the Steering Committee by collecting and evaluating biological information on the desert tortoise and other species of concern. The TAC's primary task was to review a series of reserves proposed by the Steering Committee. They incorporated the results of 997 one-mile-long desert tortoise transects, two standard one-square-mile study plots, a soil and vegetation survey (BLM 1990) and results of ongoing scientific research (Esque 1994) into their reviews. Members of the TAC kept in contact with the DTRT and desert tortoise biologists from other states to ensure that the HCP benefitted from the most current information on reserve design theory, disease, genetics and other relevant biological topics.

The reserve design process was iterative, with the TAC reviewing a series of proposals presented by the Steering Committee. See Washington County HCP Steering Committee 1992a and 1992b; Doyle 1993; and Washington County HCP Steering Committee 1994 for details of these iterations. Figure 2 gives locations of place names used in this discussion. Generally, the TAC was highly critical of the impacts inherent in the initial proposals. Their primary concern was that the reserves proposed by the Steering Committee were not responsive to reserve design criteria used by the DTRT (FWS 1993). The proposed reserves were small (confined between Utah Highway 18 and Interstate Highway 15), fragmented by proposed development, and included unmanageable inholdings. The current proposal (Figure 3), submitted to FWS in May, 1994, resulted from the Steering Committee incorporating many of the TAC's suggestions into the design. This plan is more responsive to the biological requirements of the species than previous draft plans. However, the TAC has expressed concerns over the amount of development in several areas including Padre Canyon, Red Cliffs, Leeds, and Hurricane, outlined in this proposal.

The plan includes conservation of a core area centered around the City Creek Desert Tortoise Study Plot (City Creek), includes most of Paradise Canyon, provides for habitat connectivity between Paradise and Padre Canyons, and establishes a reserve in the vicinity of the cinder knolls at Hurricane. It incorporates 43,488 acres of the remaining 55,947 acres of habitat into a 60,818-acre multispecies reserve (Washington County HCP Steering Committee 1994).

While land acquisition and establishment of a reserve constitutes the primary mitigation for take, numerous other conservation measures are proposed to enhance the reserve's effectiveness in recovery of the species (see Washington County HCP Steering Committee 1994). The budget contains line items for hiring a staff to administer the HCP and to facilitate consolidation of the reserve. Other HCP-funded mitigation includes land management planning, fencing, purchase of some grazing permits, desert tortoise population monitoring, environmental education, law enforcement, translocation, and conservation of ESA-listed threatened and endangered species other than the desert tortoise. The total HCP budget for the 20-year permit period is projected to be $ 9,055,000.

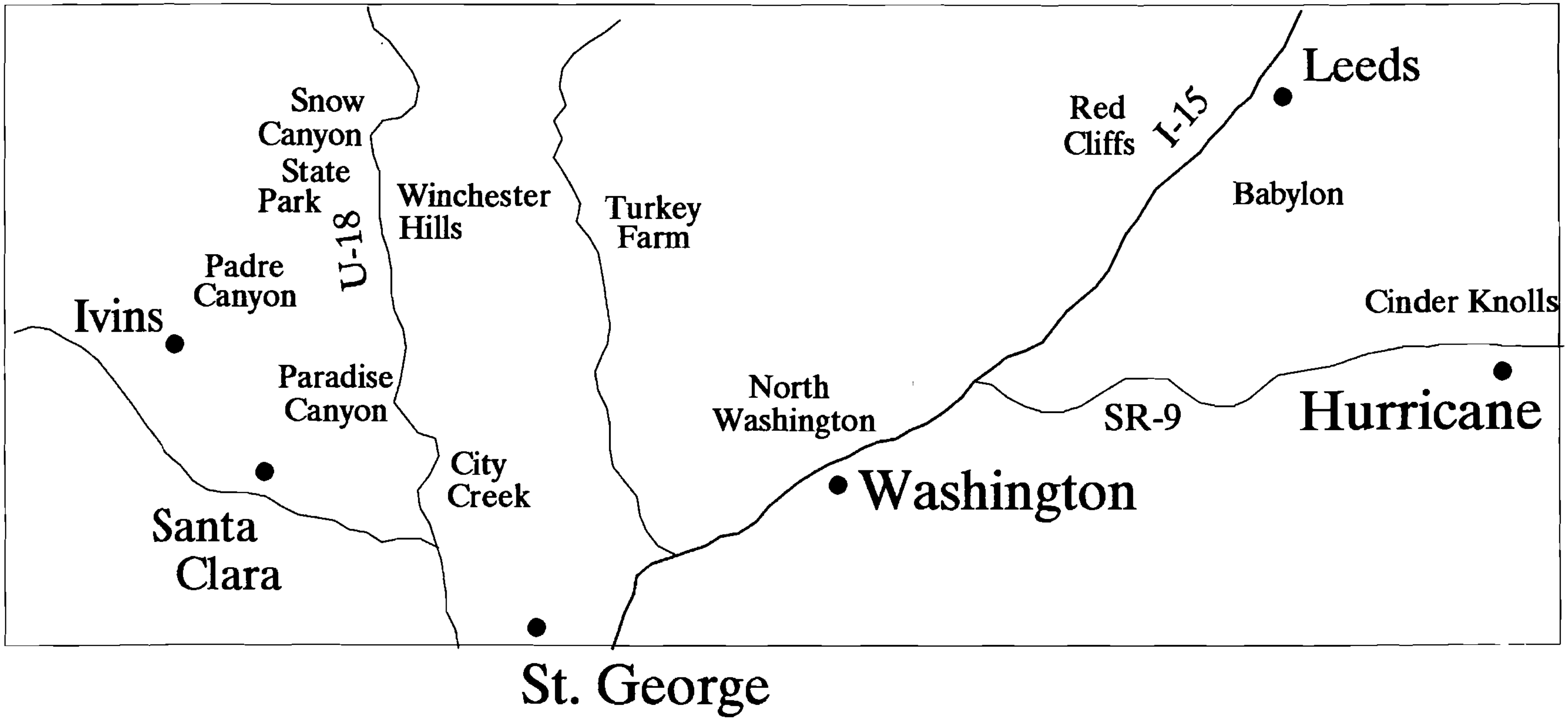

Figure 2. Place names used in Washington County Habitat Conservation Plan (HCP).

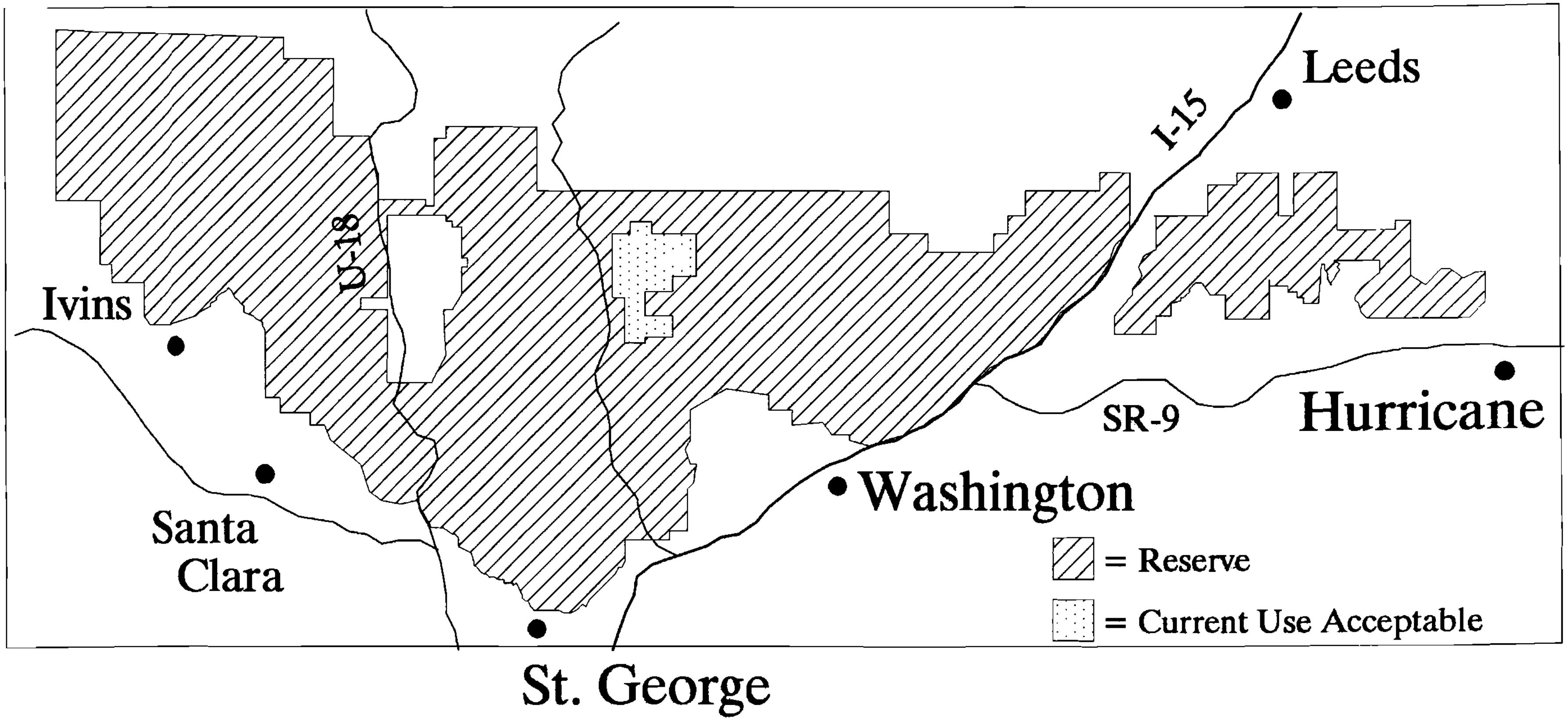

Figure 3. Proposed Desert Habitat Reserve, April 1994
Washington County Habitat Conservation Plan
(Not to scale).

Public Relations and Law Enforcement

During the first 18 months of the HCP planning process, a strong positive public relations campaign (consensus-based) generated support for the HCP with production of a videotape, brochures, and numerous media releases. During the last 2 years of the process, public relations efforts were dropped by the Steering Committee and strong anti-conservation stories have led the media coverage. Some Steering Committee members provided individual perspectives to the media; however, their views were not always consistent with views of other members.

Due to alleged violations of the ESA involving unpermitted urban development in desert tortoise habitat, a law enforcement effort was coordinated between resource management agencies in early April, 1992. The goal was to provide a higher profile presence while making contacts and gathering information. From April 15 to June 15, 1992, Utah Division of Wildlife Resources conservation officers conducted over 40 inquiries, including contacts with 18 developers and property owners. Five of the contacts resulted in in-depth law enforcement investigations. FWS took the lead on 3 cases involving take of habitat, and investigations are ongoing.

CONCLUSION

ESA Section 10(a)(1)(B) provides a legal mechanism with which to resolve conflicts between rapidly expanding development and dwindling endangered species habitat. Previous initiatives to develop HCPs provided a framework for developing a workable process for the Washington County HCP effort (Bean *et al.* 1991). As more communities utilize this process and share their experiences, costs and time invested in future efforts can be reduced.

The development phase of the Washington County HCP took over twice as long as had been anticipated. Public support for the process declined in response to cessation of the Steering Committee's consensus-based public relations program. This frustrated both developers who faced potential construction delays, and conservationists who observed continuing habitat degradation which could have been prevented by implementation of HCP provisions (e.g., fencing and enforcement).

The early availability of sound scientific data was a key factor in enabling the planning process to move forward. Existing agency data bases, ongoing studies, TAC input, and the willingness of the Steering Committee to fund additional inventories will enable the FWS to expeditiously review the permit application.

Given the controversy stemming from the perceived high value of much of the property in Washington County, the cost in time and money of developing this HCP was also high. The costs of completing this project 10 years ago would have been a small fraction of costs incurred in the current effort. In fact, some properties which are proposed for the reserve were previously in Federal ownership. The challenge for the future is for communities, agencies and conservation groups to predict resource conflicts early enough to enable timely affordable solutions to be achieved.

ACKNOWLEDGMENTS

The plan development phase of the Washington County HCP would not have reached this stage (submission to FWS) without the generous donation of time and effort by all members of the Scoping and Steering Committees. Scott Hirschi initially chaired the Steering Committee and was later replaced by Steven E. Snow. Any success of this HCP will be due in large part to their efforts. We are grateful for thorough and timely reviews of an early draft of this paper by Debbie J. Pietrzak, C. Richard Tracy, and Leo D. Lentsch.

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Progress Report on Proposed Mojave Desert Educational Outreach Center San Bernardino County, California

Roger Dale, Desert Tortoise Preserve Committee, Inc., San Bernardino, California

Abstract: During the past two years the Desert Tortoise Preserve Committee has been actively engaged in a planning process to establish a permanent visitor center in the Mojave Desert. The Committee's original plan was to develop a permanent visitor center and research facility at the Desert Tortoise Natural Area (DTNA) in Kern County, California. Based on a series of feasibility analyses and considerable public input, the initial concept has been revised to separate the public education and research components of the overall project. Whereas the DTNA is still considered an appropriate location for the research aspects of the program, the Committee believes that it is not the optimal location for a public visitor center for the following major reasons: (1) The DTNA's remote location would not provide maximum exposure to the general public for the Committee's educational outreach efforts; and (2) Construction of a major facility and the resulting increase in visitor use at the DTNA would likely have a negative impact on the area's sensitive desert tortoise habitat.

The Committee's current plans are to develop the educational outreach center along Interstate 15 at Zzyzx in San Bernardino County. This location would provide immediate access to approximately 20 million highway travelers per year and would enable the facility to have an expanded role in public education, not only focussing on desert tortoise conservation but on the broader issues of land use management throughout the Mojave Desert. The Committee has recently completed architectural and engineering studies for this site, as well as evaluations of the market and financial feasibility of the proposed project. These studies have culminated in the preparation of an overall master plan for the center. The entire planning process for the center is being conducted in cooperation with the Bureau of Land Management, which presently owns the site and is a potential joint-venture partner for the facility. The Committee has a targeted completion date for the project of 1997. The proposed research facility at the DTNA is still under consideration by the Committee but is being given lower priority at this time.

Background

The Desert Tortoise Preserve Committee, Inc. was founded in 1974 to provide support in the stewardship of desert tortoise habitat, particularly at the Desert Tortoise Natural Area (DTNA) in Kern County, California. The Committee's major program areas include land acquisition, habitat stewardship, and public education. Much of the Committee's work on these programs has been done in coordination with the Bureau of Land Management (BLM). The Committee's efforts have historically been focussed at the DTNA where the Committee provides various visitor interpretive services, stewardship through a cooperative management agreement with the BLM, and a naturalist program each spring.

Four years ago the Committee set a long-term goal of establishing a permanent visitor center at the DTNA to expand upon the interpretive facilities which are currently available at the Natural Area (a kiosk and the Committee's motorhome, the "Tortoise Discovery Center"). Two years ago the Committee initiated a formal planning process for this goal and commissioned a series of architectural, engineering, and economic studies to refine the concept. During this process, the Committee has attempted to solicit as much public input as possible from the following sources:

- The Preserve Committee's own members;
- Various government agencies including the BLM, the National Park Service, and the California Department of Fish and Game; and
- Representatives of existing educational facilities in the desert including:
    - The Living Desert in Palm Desert, California;
    - The Anza Borrego Visitor Center in the Anza Borrego State Park; and
    - The Arizona-Sonora Desert Museum in Tucson, Arizona.

Needs Assessment

After assessing the public input and reconsidering the basic needs that the proposed facility was intended to address, several issues became clear which caused the Committee to re-evaluate its initial plan of locating a large building facility at the Desert Tortoise Natural Area:

1) The Committee seriously questioned the appropriateness of constructing a major facility at the DTNA. Both the initial construction activity and the ongoing traffic from increased visitation would likely result in unacceptable impact levels to desert tortoise habitat.

2) The Committee also realized that the DTNA was not an optimal location for a public education facility due to its remote locale. In order to fully achieve its educational outreach objectives, the Committee realized that it would need a site that would be accessible and visible to a larger number of diverse desert users, not just people who are already interested in or concerned about the desert tortoise.

3) The initial round of studies also suggested that the Committee needed to adopt a broader theme for the project rather than focussing specifically on the desert tortoise. In this regard, the Committee selected a name for the facility which reflects a more general programmatic treatment of the Mojave Desert.

The expanded scope of the project is significant for several reasons. First, it will enable the Committee to reach a larger audience and to develop an educational program that emphasizes the inter-relationships of the various land uses and management policies in the Mojave Desert which ultimately impact the desert tortoise. Secondly, the broader program will provide the Committee access to a larger pool of potential funding sources for the project. Given that the total capital cost of the project is projected at $5.4 million, the availability of funding is a critical consideration.

Site Selection Process

Based on its refined set of objectives, the Committee began the process of identifying potential sites for the center. Given its concern about achieving maximum exposure to desert visitors, the Committee focussed on available sites along Interstate 15 (I-15) in California.

The Committee closely coordinated the site selection process with the BLM since, as indicated previously, the BLM is a potential joint venture in the project and is also a major landowner in the California desert. In this regard, the discussions with BLM included full consideration of long-range plans for the management of Federal lands along various segments of I-15.

As a result of its site selection efforts, the Committee is now focussing its planning efforts on a specific site located along I-15 northeast of Barstow, California and just south of Baker, California. The exact location is the southeasterly quadrant of the I-15/Zzyzx Road interchange. The Committee has selected this site based on the following characteristics:

- The site provides immediate access to approximately 20 million highway travelers per year;
- The site's location provides visitor access to both the East Mojave Desert and the West Mojave Desert;
- The site offers spectacular scenic values and a sense of remoteness due to the lack of urban development in the vicinity; and
- Based on preliminary discussions with the BLM (the landowner), the site is potentially available for this project. Moreover, there are currently no long-range plans for other land uses in the immediate vicinity which would degrade the site's scenic values in the future.

Site Planning Process

The preliminary round of architectural and engineering studies was not conducted at a site-specific level and was in fact already completed by the time the Committee had selected the Zzyzx Road location as its highest priority site. It was therefore necessary to revisit the feasibility analyses and refine the findings to reflect the unique characteristics of the Zzyzx Road site.

Throughout the planning process, the architectural and engineering team has worked with the guiding principal that the built form of the facility should not only be compatible with its surroundings, but should enhance its environment by articulating a sense of purpose. Building on this theme, the design team refined the general findings from its draft studies to produce a very specific set of recommendations for the Zzyzx Road location. Three major architectural recommendations resulted from the finalized design studies:

1) The facility should provide 12,000 net square feet of total building area;

2) The overall site should encompass a property endowment totalling at least one square mile in order to ensure an atmosphere of remoteness; and

3) The facility should include three distinct programs each occupying a separate building and unified by a common outdoor courtyard.

The three program categories are education, visitor services, and administration. The major facilities associated with each of these program areas area as follows:

- **Educational Facilities:** Live animal exhibits, multimedia and interactive displays, and a mobile touring program.
- **Visitor Facilities:** Telecommunications equipment, cafe and dining areas, gift shop, outdoor sightseeing areas, traveler informational resources, and temporary animal holding area (to receive unwanted captive desert tortoises in order to prevent their release into the wild).
- **Administrative Facilities:** Administrative office space, research and archival library, and community conference room.

Capital Campaign

The design team's work also included detailed construction cost estimates. Based on these estimates the Preserve Committee has established the following capital campaign goals:

- Raise $3.6 million for building fund;
- Raise $1.0 million operating endowment; and
- Raise $800,000 for fixtures and equipment.

Thus, the capital requirements for the overall project total $5.4 million in 1994 dollars.

Economic Feasibility Analysis

As a crucial component of the overall planning process, the Preserve Committee has prepared an economic feasibility analysis for the proposed facility. The economic study consists of two elements:

1) A market analysis to determine potential visitation levels at the proposed facility, and to determine the potential revenue generation from visitor use; and

2) A financial feasibility analysis which evaluates annual costs and revenues from operation of the facility, and projects the net cash flows which would accrue to the Preserve Committee.

The major findings of the economic analysis are summarized below.

Potential Visitation and Revenue Generation

- Total annual traffic passing by the Zzyzx Road site is projected at approximately 9.3 million trips (in both directions) in 1997. By 2000, total annual traffic passing by the site is projected to increase to nearly 10 million trips.

- 43,500 vehicles could potentially be attracted to visit the site in 1997. In 2000, the total number of vehicles stopping at the facility is projected at 48,800. These projections are based on very conservative capture rates of the total traffic volumes passing the site.

- 230,000 visitors are projected to be attracted to the facility in 1997. Total visitation in 2000 is projected at approximately 320,000 persons.

- $973,000 in total operating revenue is projected for the facility in 1997. Total operating revenue in 2000 is projected at approximately $1.4 million. These amounts include nominal admission fees, and visitor expenditures on food/beverages, souvenirs, and special attractions. The revenue projections are given in 1994 dollars.

Projected Overall Cash Flow from Facility Operations

- A net loss of $65,200 from overall operation of the facility is projected for the first year of operation (1997). This net deficit would consist of three components:

    - A net loss of $144,200 from museum operations;
    - Net income of $51,500 from retail sales; and
    - Net rental income of $27,500 accruing to the Preserve Committee from a restaurant concessionaire.

- In 2000, the Preserve Committee's operating loss from overall operation of the facility is projected at $15,700, consisting of the following components:

  - A net loss of $126,100 from museum operations;
  - Net income of $72,000 from retail sales; and
  - Net rental income of $38,400 from a restaurant concessionaire.

The projected operating losses indicate that in order for the facility to be financially feasible, the Preserve Committee would need to secure supplemental funding of approximately $15,000 per year once stabilized operations are reached. This supplemental funding could potentially come from the following sources: 1) An operating endowment established as part of the capital campaign for the facility; 2) Membership dues/donations from a non-profit organization (separate from the Preserve Committee) established specifically to support the facility; or 3) Annual operating grants secured by the Preserve Committee to support operation of the facility.

Given the magnitude of the overall operating budget projected for the facility, the projected deficit of $15,700 is relatively insignificant, representing only 2.0 percent of total annual expenditures. Thus, it is very likely that the deficit could be avoided without supplemental funding, by adjusting the program budget to a level commensurate with projected revenues.

Development of Master Plan for Educational Outreach Center

Based on the finalized design recommendations and economic feasibility analysis, the Preserve Committee has recently completed an overall Master Plan document for the proposed Zzyzx Road facility. This document will be utilized to promote the project to potential funding sources and joint venture partners. The Preserve Committee is currently pursuing a number of major grants for the capital campaign program.

MONITORING RAVEN ABUNDANCE AT YUCCA MOUNTAIN

Eric A. Holt and James M. Mueller

Abstract. We monitored the abundance of ravens (*Corvus corax*) at Yucca and Bare mountains, Nevada, to determine if activities conducted for the Yucca Mountain Site Characterization Project (YMP) caused an increase in raven abundance. Biologists conducted simultaneous road surveys along a treatment (Yucca Mountain) and control (Bare Mountain) route on five randomly selected weekdays every other month. Each survey route was 40 km long and consisted of 50 stops spaced 0.8 km apart. At each stop, one biologist looked for ravens for one minute and recorded information on location and behavior of all ravens sighted. During a 32-month period beginning August 1991, more ($P=0.02$) ravens were observed on the treatment route ($\bar{x}=3.5$) than on the control route ($\bar{x}=2.5$); and more ($P=0.003$) ravens were observed during the post-disturbance period ($\bar{x}=3.6$) than during the pre- disturbance period ($\bar{x}=2.3$). However, because there was no change in the difference between the number of ravens observed on the two routes ($P=0.9$), we concluded that YMP did not cause an increase in raven abundance at Yucca Mountain over this time period.

INTRODUCTION

The Mojave population of the desert tortoise (*Gopherus agassizii*) was listed by emergency rule as an endangered species in August 1989 (54 Fed. Reg. 32326-32330) and by final rule as a threatened species in April 1990 (55 Fed. Reg. 12178-12191). One of the reasons for listing the desert tortoise as a threatened species was speculation that increased raven populations may be causing tortoise populations to decline (55 Fed. Reg. 12186).

The fact that ravens occasionally eat desert tortoises has been known for over 60 years (Miller 1932) and has been confirmed recently (Camp *et al.* 1993). Concern increased in the 1980's when biologists reported finding large numbers of tortoise carcasses that appeared to have been eaten by ravens (Campbell 1983, Esque and Duncan 1985, Farrell 1989). All of these accounts could represent scavenging by ravens rather than predation. However, observations of ravens killing tortoises have also been reported (U.S. Bureau of Land Management 1990, p.20).

The increase in raven populations in the western United States has been documented by Robbins *et al.* (1986) using data collected during the annual Breeding Bird Survey. They concluded that raven populations in the region composed of California, Oregon, Washington, Idaho, and Nevada increased from 1968 to 1979. When analyzed by state, California was the only state in the West that had an increase. When analyzed by strata, the Mojave Desert did not have an increase. Using unpublished data from the Breeding Bird Survey, the U.S. Bureau of Land Management (1990) calculated a 1,528% increase in raven population size in the Mojave Desert between 1968 and 1988. The methodology used for obtaining this figure was not reported. Unpublished reports on raven population increases were reviewed by the U.S. Bureau of Land Management (1990). Increases in raven abundance have been attributed to the construction of utility lines (Engel *et al.* 1992, Knight and Kawashima 1993) and to increases in road-killed animals (Austin 1971, Conner and Adkisson 1976).

The U.S. Department of Energy is studying Yucca Mountain to determine if it is a suitable site for a high-level radioactive waste repository (Nuclear Waste Policy Act of 1982; Nuclear Waste Policy Amendments Act of 1987). Following consultation, the U.S. Fish and Wildlife Service (1990) issued a non-jeopardy biological opinion for the Yucca Mountain Site Characterization Project (YMP). One of the terms and conditions of the incidental take provision for YMP included monitoring the abundance and distribution of ravens.

This paper describes the study we developed to meet this requirement, the results from the first 32 months, the impact of ravens on tortoises at Yucca Mountain, and methods that should be considered for future surveys. The objectives of the study are to determine if YMP causes an increase in raven abundance at Yucca Mountain, to monitor use of YMP facilities by ravens, and to identify where ravens congregate.

STUDY AREA

We monitored raven abundance at Yucca and Bare mountains, Nye County, Nevada. Yucca Mountain is on the southwestern edge of the Nevada Test Site, approximately 160 km north of Las Vegas. Bare Mountain is approximately 16 km west of Yucca Mountain. Bare Mountain was selected as a control site because the vegetation, elevation, topography, climate, and length and types of roads are similar to Yucca Mountain. Both mountains are at the northern edge of the Mojave Desert and the northern extreme of the desert tortoise range (Auffenberg and Franz 1978, Karl 1981). Elevations range from 994 to 1,789 m above sea level. Vegetation associations below 1,220 m are dominated by *Larrea tridentata* and *Ambrosia dumosa*. Above 1,220 m, *Coleogyne ramosissima* is the dominant plant in the transition between the Mojave and Great Basin deserts (Beatley 1976).

METHODS

Most studies to monitor trends in abundance of ravens and other raptors have used one of two types of road surveys: point counts (Robbins *et al.* 1986) or belt transects (Austin 1971, U.S. Bureau of Land Management 1990, Knight *et al.* 1993). We chose to use point counts along roads because it would have been dangerous to search for birds while driving due to the traffic at Yucca Mountain and the rough terrain at both sites.

Beginning in August 1991, biologists conducted simultaneous road surveys along the Yucca Mountain and the Bare Mountain routes on five randomly selected weekdays every other month. Based on anecdotal information that ravens were more active at midday (Kilham 1989), we began surveys four hours after sunrise. Each survey route was 40 km long and consisted of 50 stops spaced 0.8 km apart. The surveyor recorded the time and weather conditions (temperature, wind speed, and cloud cover) at the beginning and end of the survey. At each stop, the surveyor looked for ravens for one minute and recorded the location and behavior of all seen. Binoculars were not used to search for birds, but were used to verify the species of a bird after it was seen or heard. The location of sightings were determined in the field from 1:24,000 topographical maps. In addition, the surveyor recorded the initial behavior of each raven and described any man-made facilities each bird used.

We tested the null hypothesis that YMP did not cause an increase in raven abundance at Yucca Mountain following the methodology of Stewart-Oaten *et al.* (1986). There was no defined start-up point in time for YMP. Construction of a pad for the Exploratory Studies Facility began in November 1992, and this marked the beginning of a substantial increase in human activity at Yucca Mountain. Therefore, we assumed that data collected prior to November 1992 was collected pre-disturbance. To determine whether YMP caused an increase in raven abundance at Yucca Mountain, we first calculated the difference between the number of ravens observed on each route for each survey. This difference was then averaged for each month, and the monthly averages were compared for the pre- and post-disturbance periods using a t test. We compared the number of ravens seen on the two routes and during the two periods using a two-way analysis of variance. Statistical significance was determined using an α-level of 0.1 rather than the traditional α-level of 0.05 to reduce the probability of Type II error (Skalski and Robson 1992, pp. 21-22). Data were analyzed for the period August 1991 to February 1994.

RESULTS

Because there was no change in the difference between the number of ravens observed on the two routes between the pre- and post-disturbance periods ($P = 0.9$), we concluded that YMP did not cause an increase in raven abundance at Yucca Mountain. More ($P = 0.02$) ravens were observed on the Yucca Mountain route ($\bar{x} = 3.5$, SE = 0.3) than on the Bare Mountain route ($\bar{x} = 2.5$, SE = 0.3), and more ($P = 0.003$) ravens were observed during the post-disturbance period ($\bar{x} = 3.6$, SE = 0.4) than during the pre-disturbance period ($\bar{x} = 2.3$, SE = 0.3). Figure 1 shows the monthly inconsistency in the trend of more ravens at Yucca Mountain and during the post-disturbance phase.

DISCUSSION

The increase in raven abundance during the second half of the study may have been a result of increased food availability following above-normal precipitation. Precipitation during the first three months of 1992 was over four times the average for the preceding 43 years (U.S. Natl. Weather Serv., data for McCarran Airport, Las Vegas, Nev.).

The current effect of ravens on the tortoise population at Yucca Mountain is not known. We have not observed any ravens feeding on tortoises. We did find signs of avian predation or scavenging on six of sixty-nine tortoise carcasses we collected (EG&G/EM, unpubl. data). Although we looked under utility poles and three nest sites for carcasses during other field work, we found no carcasses at these sites.

We believe our methods could be improved by starting surveys earlier in the day. Recent studies have shown that ravens become active before sunrise (Engel *et al.* 1992) and exhibit a bimodal activity pattern, foraging in the early morning and then in the afternoon (Sherman and Knight 1992). Because data gathered at different times of the day may not be comparable, we will continue to start our surveys four hours after sunrise.

One alternative to the method we use for monitoring ravens is to use the methods of the Breeding Bird Survey (Robbins *et al.* 1986). The methods of the Breeding Bird Survey differ from ours in four ways: start time (30 min vs. 4 hr after sunrise), time spent at each survey stop (1 min vs. 3 min), number of surveys per year (1 per route vs. 30 per route), and search distance at each stop (400 m vs. an unlimited distance). We believe the latter two items should be modified if this method is being used to monitor abundance of ravens.

First, multiple surveys during equally-spaced periods throughout the year are required if inferences are to be made about raven abundance over the entire year. Since Breeding Bird Surveys in the Mojave Desert are typically conducted in May (Robbins *et al.* 1986), one or more surveys should be conducted during this month so that comparisons with the Breeding Bird Survey can be made.

Second, all ravens seen should be counted, not just those within 400 m. For the Breeding Bird Survey, counts of only a few species of hawks were sufficient to test for trends in populations from 1965-1979, and ravens were sighted only slightly more often than hawks (Robbins *et al.* 1986). The addition of ravens seen beyond 400 m will improve the adequacy of samples for calculating trends. However, to allow comparison with Breeding Bird Surveys, information on whether each raven is within 400 m must be recorded. By using only counts of ravens within 400 m, comparisons to the Breeding Bird Survey can be made, and those routes could be considered controls.

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A Tale Of Two Tortoise 10(A) Permits

Edward L. LaRue, Jr., M.S.

The Church Site federal 10(a)(1)(B) permit was California's first for the lawful incidental take of the desert tortoise (*Gopherus agassizii*), which was federally listed as threatened in 1990. The U.S. Fish and Wildlife Service took 16 months to issue the permit for that five-acre site. It has been two years and 11 months since the U.S. Fish and Wildlife Service received the permit application for the Sunland Communities 10(a) permit, which has still not been issued. The Church Site documents were derived from the Sunland Communities documents; both had the same author. Federal section 7 biological opinions are typically issued in 135 days. There have been approximately 150 issued for tortoises in California, and only one 10(a) permit. Relative to section 10(a), section 7 has the following advantages: (A) it is quicker; (B) it facilitates project completion; (C) it avoids interagency conflicts; and, (D) it is less expensive. Recommendations are made to the U.S. Fish and Wildlife Service to expedite the issuance of small-project 10(a) permits: (A) provide meaningful direction to the private development community; (B) set a time limit for 10(a) permit review; (C) localize the review process; (D) ensure consistency; and, (E) ensure continuity. In accomplishing these recommendations, demonstrate to the private development community that section 10(a)(1)(B) of the Federal Endangered Species Act is functioning efficiently and effectively.

* Documents pursuant to these 10(a) permits were prepared by Ed LaRue while at Tierra Madre Consultants, Inc., Riverside, California. LaRue is now in partnership with his wife at Circle Mountain Biological Consultants, Wrightwood, California.

I. Introduction

A. Church Site

The five-acre parcel located in Yucca Valley, California comprising Phase I of the Good Shepherd Lutheran Church and Valley Community Chapel (Church Site) was surveyed in May 1990 (Tierra Madre Consultants 1990a, 1990b). No tortoise sign was found on Phase I areas, although tortoise sign was found about 250 feet south, on Phase II. Phase I was resurveyed in January 1992, when one tortoise scat was found (Tierra Madre Consultants 1992). A burrow with tortoise egg shell fragments in the opening was found about 150 feet south of the site, indicating that juvenile tortoises could be in the area.

On 4 March 1992 Church trustees met with Ray Bransfield of the Ventura office of the U.S. Fish and Wildlife Service (Service) and Frank Hoover of the Chino office of the California Department of Fish and Game (Department). Trustees were told that they would need California 2081 and federal 10(a)(1)(B) incidental take permits before they could build the two Church facilities. On 8 March 1992, I met with Ray Bransfield, Frank Hoover, Roger Dale and Tom Dodson of Desert Tortoise Preserve Committee (Preserve Committee), and June Lee of Nonprofit Council to discuss how to mitigate and compensate impacts.

The state permit was issued 11 months later, when Department Director Boyd Gibbons signed the Management Agreement on 9 February 1993. The federal permit - California's first 10(a) permit for the desert tortoise - was issued on 30 August 1993, 16 months after the Habitat Conservation Plan (HCP) was formulated.

B. Sunland Communities

The 160-acre site located in western Victorville, California was surveyed in July 1990 (Tierra Madre Consultants 1990c). Thirty-eight (38) tortoise burrows and two tortoises were found. Ten of the 38 burrows (26%) were collapsed, and the site was disturbed by off-highway vehicle use, sheep grazing, hunting and/or target practice, domestic dogs, and other human uses. The nearest tract homes were 1.5 miles to the east and Highway 395 was 1.5 miles to the west.

On 18 October 1990, I met with Ray Bransfield, Frank Hoover, and Alden Sievers of the Bureau of Land Management (Bureau). It was agreed that Sunland Communities would need state 2081 and federal 10(a) permits to mitigate and compensate impacts.

The state permit was issued 16 months later on 7 February 1992. The application for the federal permit was received by the Office of Management Authority in Washington on 3 April 1991. During June or July 1991, responsibility for federal permit issuance was shifted from Washington, D.C. to Portland, Oregon. As of 7 March 1994 - two years and 11 months later - the Portland office of the Service has not issued the 10(a) permit to Sunland Communities. Sunland Communities, under authority of the state permit and as delineated in the federal HCP, has already deeded 320 acres to the state, at a cost of $168,000, and provided an endowment fund of $45,840.

C. Relative timing of federal permit issuance

The Sunland Communities 10(a) application was received by the Service one year prior to beginning the Church Site HCP. It has now been seven months since the Church Site 10(a) permit was issued. I prepared all documents pursuant to the issuance of these two permits. Documents pursuant to the Church Site 10(a) permit were based on the documents prepared for Sunland Communities. There was little difference between the concepts and language in the two permits.

This paper discusses (1) documents and components of section 10(a) permits; (2) components of section 7 biological opinions; (3) some comparisons between these two processes; and, (4) recommendations to the Service to expedite the issuance of section 10(a) permits.

II. Federal 10(a) permit

A. Habitat Conservation Plan

The Habitat Conservation Plan, or HCP, is the central document pursuant to federal 10(a) permits. The Service's "Draft Conservation Planning Guidelines" (1990a) provide (1) application requirements for the 10(a) permit; (2) mandatory elements of the conservation plan; (3) issuance criteria for the 10(a) permit; and (4) environmental review and documentation. The information is adequate, but not as instructive as the several 10(a) permits that have been issued.

Section 10(a)(1)(B) of the federal Endangered Species Act of 1973, as amended (Act) states, "The Secretary may permit, under such terms and conditions as he shall prescribe - any taking otherwise prohibited by section 9(a)(1)(B) if such taking is *incidental* to, and not the purpose of, an otherwise lawful activity". The section 10(a)(1)(B) permit is not to be confused with the section 10(a)(1)(A) permit, which is issued to scientists working with threatened or endangered species on federally-authorized research projects where take of the species is *intentional*. The 10(a)(1)(B) incidental take permit (herein, "10(a) permit") is available to developers of private projects where threatened or endangered species may be impacted, and when there is no federal involvement. If there is federal involvement, section 7 of the Act (described in section III of this paper) authorizes the incidental take of the threatened or endangered species. See Webster (1987) for a comparison of section 7 and section 10(a).

B. Previously Issued 10(a) Permits

The first 10(a) permit, issued in 1982 in response to the San Bruno Mountain HCP, was designed to protect an endangered butterfly, the Mission Blue, and several species then proposed for endangered status. This and most other 10(a) permits issued have been in response to programmatic HCP's covering large areas and resolving conflicts for several or many private developers. The Coachella Valley Fringe-Toed Lizard HCP and Stephens' Kangaroo Rat HCP are two examples for southern California.

Three 10(a) permits have been issued for tortoises, two in Nevada and the Church Site 10(a) in California. The Clark County short-term programmatic 10(a) permit encompassed 22,000 acres and has resolved several specific development conflicts in the Las Vegas Valley. Other projects within the HCP boundary have been mitigated and compensated using the plan's conservation measures. The other Nevada 10(a) permit, Valley of Fire State Park, was only recently issued (Sherry Barrett, pers. comm., 3 March 1994).

C. Church Site HCP

The Church Site HCP resulted in the world's smallest 10(a) permit: five acres lost, five acres gained. The HCP pursuant to this permit was based on the Sunland Communities HCP, which in turn was based on the Delano State Prison HCP (Rado 1989). Rado's HCP provided a clear example of a Service-approved conservation strategy for a single, relatively small project.

The Church Site HCP had the following components: (1) site description and expected impacts; (2) biological data and species of special concern; (3) measures to mitigate and minimize the take of desert tortoises and impacts to other special-status species; (4) funding for the HCP; (5) alternatives to the proposed project; (6) other measures required by the Service, which for the Church Site, was an "implementing agreement" (see below); (7) references; and, (8) a series of appendices including initial focused surveys and protocols used during implementation of on-site mitigation measures.

Approved mitigation measures for the Church Site included on-site mitigation and off-site compensation. On-site mitigation was very similar to measures delineated in federal biological opinions: (1) a tortoise-awareness program for construction personnel; (2) a Service-approved biologist to monitor construction activities; (3) a tortoise-proof fence installed around the site; (4) removal of tortoises from inside the perimeter fence; (5) veterinary inspections of tortoises to determine if they were healthy or diseased; (6) disposition of tortoises removed from the site; (7) take limits for tortoises, including the number that may be accidentally killed or moved out of harm's way; and, (8) guidelines governing construction personnel and their activities while on-site.

Off-site compensation included acquisition of five acres of Department-designated "crucial habitat", which were also in an area of Bureau-designated "category 1 habitat", in exchange for the five acres to be developed. The Service approved the Preserve Committee to acquire and manage the compensation lands in perpetuity for the conservation of desert tortoises. For that purpose, the Churches gave the following funds to the Preserve Committee: (1) $6,500 ("Acquisition Fund") to purchase the five acres; (2) $650 ("Transferal Fund") for deed transferal fees and closing costs; and (3) $500 ("Enhancement Fund") to "enhance the biological carrying capacity" of the compensation lands, as required by the Department. Additionally, the Department required $1,500 ("Endowment Fund"), which was placed in a special account to generate interest that will be used by the Department to manage the acquired five-acres.

D. Other Documents for the Church Site 10(a) Permit

Documents other than the HCP that were required by the Service included an Implementation Agreement and an Environmental Assessment. The implementing agreement is the signatory document obligating responsible parties to fulfill duties delineated in the HCP. For the Church Site, it (1) incorporated the HCP by reference; (2) stated the term of the permit (three years); and (3) described the obligations of each party. The two Churches, Preserve Committee, Department, and Service were signatory to the document.

An Environmental Assessment (EA) is a National Environmental Policy Act (NEPA) document listing (1) purpose and need for action; (2) proposed action and alternatives; (3) description of the affected environment; (4) environmental consequences; and (5) public involvement. The EA is sent to interested parties to solicit comments on the conservation plan. For the Church Site 10(a), the EA was sent to the Desert Tortoise Council, California Turtle and Tortoise Club, Bureau of Land Management, Joshua Tree National Monument, San Bernardino County Planning Department, Yucca Valley's Mayor, Yucca Valley's Planning Director, local engineers, administrative offices of San Bernardino County libraries, and to the local library in Yucca Valley.

The Service prepared the following documents and notices: (1) *Federal Register* Notice of the Service's intent to issue the permit; (2) Finding Of No Significant Impact (FONSI); and, (3) intra-Service section 7 biological opinion.

The Church Site 10(a) permit was implemented on 6 October 1993, when the site was fenced, surveyed, and cleared of vegetation. It was 19 months after the initial meeting with the Service and California Department of Fish and Game. No tortoises were found on-site, nor were any killed during brushing or subsequent construction activities. The Preserve Committee has purchased five acres within the Desert Tortoise Natural Area, near California City, and is now developing a site monitoring and management plan for the five-acre parcel.

III. Federal Biological Opinion

If a project is authorized, funded, or carried out by a federal agency (i.e., has a federal nexus), section 7 of the Act requires that the agency (action agency) consult with the Service to ensure that the project does not jeopardize the continued existence of the endangered or threatened species. The Service then drafts its biological opinion for the project's effect on the species. This *inter*-agency opinion has the same components has the *intra*-agency opinion mentioned in the previous section.

In California for the desert tortoise, the Bureau is most often the action agency. Mining on lands administered by the Bureau must be permitted; a pipeline crossing Bureau lands requires a right-of-way permit; wool growers must obtain permits from the Bureau to graze sheep on federal lands. In each case, if tortoises may be affected, the Bureau consults with the Service prior to issuing the permit to avoid violating section 9 of the Act. The Bureau's "stipulations" for the project incorporates terms and conditions of the Service's biological opinion to minimize take of tortoises; additional requirements for the permittee are included.

Other federal action agencies and examples of permitting activities resulting in federal nexuses may include (1) U.S. Army Corps of Engineers when it *authorizes* a project under section 404 of the Clean Water Act; (2) U.S. Federal Highway Administration when it *funds* an interstate project; (3) U.S. Department of Education when it *funds* a new school with Section 3 Impact Aid funds; (4) U.S. Federal Housing Administration when it *funds* a project by providing a loan; and, (5) U.S. Federal Energy Regulatory Commission when it *authorizes* a power plant.

If the action agency determines that the project "may effect" the species, and informal consultation fails to resolve the conflict, a formal consultation is required. The action agency provides the Service with available biological information (i.e., Environmental Assessment, Biological Evaluation, or consultant's report), and initiates formal consultation. The Service has 90 days to scope and review the project, and 45 days to draft the biological opinion. Components of a typical opinion for take of desert tortoises will include (1) jeopardy or non-jeopardy opinion for the project's effect on tortoises; (2) if a jeopardy opinion is reached, then reasonable and prudent alternatives are developed; (3) description of the proposed action; (4) effects of the proposed action on tortoises, including species accounts and analysis of impacts; (5) cumulative effects of the project on tortoises within the "action area;" (6) incidental take of tortoises, including the number that may be accidentally killed or removed from the project site; (7) reasonable and prudent measures to minimize incidental take; (8) terms and conditions to implement the reasonable and prudent measures; (9) disposition of dead, injured, or sick tortoises; (10) conservation recommendations; and (11) conclusion, which lists the reasons why formal consultation would be reinitiated.

IV. Effectiveness of section 7 relative to section 10(a)

Section 7(a), "Federal Agency Actions and Consultations", has been in the Act since its inception in 1973. Regulations implementing section 7(a) of the Act were published in the *Federal Register* in June 1986. The regulations establish policies to ensure that section 7 is defined and implemented consistently. Section 10(a) was added to the Act in 1982. Until that time, the Act did not authorize non-federal projects to take federally-designated threatened or endangered species. Its now 12 years later and there are no implementing regulations for section 10(a). The absence of these regulations may be one reason 10(a) is poorly understood and implemented inconsistently.

Proponents of section 7 say that it is an effective tool, that it provides better protection than section 10(a). Section 7 consultations are performed if a project "may effect" a threatened or endangered species, whereas section 10(a) is used only when the species is directly impacted, or "taken". Thus the species need not be directly impacted for a section 7 consultation to be required. Many federal projects have been redesigned so that they no longer have a "may effect" determination, which further expedites project initiation.

Since the listing of the tortoise in 1990, approximately 150 biological opinions have been issued for tortoises by California's Ventura and Carlsbad offices (Kirk Waln, pers. comm., 3 March 1994; Art Davenport, pers. comm., 9 March 1994). In the same time, one 10(a) permit has been issued. These data imply that only one non-federal project has affected tortoises in California since 1990, and that every other project has had a federal nexus.

It would benefit desert tortoises, and facilitate compliance with the Act, if section 10(a) were implemented as efficiently and effectively as is section 7. As described in the following sections, there are many advantages to having a federal nexus and resolving conflicts under section 7 as compared with section 10(a).

A. Section 7 is quicker

In January 1992 a biological opinion was issued on behalf of Southern California Edison for a project that resulted in loss of 8.5 acres of tortoise habitat in Homestead, California. In March 1993 the Service rendered a non-jeopardy opinion on the Rand Mountain-Fremont Valley Management Plan, which covered about 65,000 acres of federal and state lands. Regardless of project size and scope, the Service is obligated to have a biological opinion prepared in 135 days, or about four-and-a-half months. For California's first two 10(a) permits, it took 16 months to permit the five-acre site and more than three years to permit the 160 acre site. The absence of section 10(a) implementing regulations is likely one reason permit issuance takes so long; i.e., a timeline has not been established as policy. The delay and uncertainty of 10(a) permit issuance have undoubtedly resulted in violation of section 9 of the Act and occasional abuse of section 7.

The Service does not have its own legal advisor, or solicitor; it uses the U.S. Department of the Interior's (USDI) solicitor. Therefore, the small-project 10(a) permit is reviewed by a lawyer who also reviews materials for the Bureau of Land Management, Bureau of Mines, Bureau of Reclamation, Bureau of Indian Affairs, Minerals Management Service, National Park Service, U.S. Geological Survey, and the newly created National Biological Survey. The Sunland Communities 10(a) permit was in Portland's solicitor's office, alone, for six months.

Non-jeopardy biological opinions are prepared and reviewed entirely within the field office receiving the request for consultation. There is no review by the regional office, the solicitor's office, nor by the state, all of which have resulted in lengthy delays during the 10(a) process. It took three months for the Portland and Ventura offices to resolve the policy of standard compensation (see section V.D.), and only then after California Congressman Jerry Lewis intervened.

B. Section 7 facilitates project completion

Under section 7, in California, the Service facilitates projects in the following ways: (a) by avoiding a "may effect" determination during informal consultation the project is not delayed by formal consultation; (b) by providing approximately 150 examples of acceptable "reasonable and prudent measures" and "terms and conditions" section 7 is clearly defined and its measures predictable; and, (c) where the Bureau is the action agency, a land manager is provided for the compensation lands, which can be a major problem for the 10(a) process.

Section 7 facilitates project completion more effectively than 10(a). Consider the following directive given in the regulations implementing Section 7: "Reasonable and prudent measures, along with the terms and conditions that implement them, cannot alter the basic design, location, scope, duration, or timing of the action and may involve only minor changes." It would appear that the Service is mandated to implement section 7 expediently and with minimal ability to modify the federally-authorized action.

Issuance of a 10(a) permit depends on the proponent's ability (and creativity) to develop a meaningful conservation plan. Given that so few small-project permits have been issued, it is often unclear what constitutes "meaningful conservation". Without implementation regulations, and with so few examples of Service approved conservation strategies, one feels that the 10(a) process is unclear. Conversely, Section 7 is so often exercised in California that drafting a biological opinion seems a formality. Indeed, depending on the species involved, one non-jeopardy opinion is very much like another. New staff will predictably prepare dozens of non-jeopardy opinions before they are *confronted*, if ever, with a 10(a) permit.

In California, only two of about 150 federal opinions have stated that tortoises would be jeopardized by the project as proposed. The number of jeopardy opinions may increase due to the February 1994 designation of critical habitat on 4,776,700 acres in the Mojave Desert. California's only two jeopardy opinions included the proposed Fort Irwin expansion onto 250,000 acres of high density tortoise habitat, and sheep grazing on 1,260,367 acres of Bureau category 1, 2, and 3 tortoise habitat. If a jeopardy opinion is rendered, the Service is obligated to provide reasonable and prudent *alternatives* to reverse or avoid the opinion. Thus, even if the project would jeopardize tortoises, the Service is required to offer suggestions that would avoid jeopardy and facilitate project completion.

C. Section 7 avoids interagency conflicts

Tom Egan, of the Bureau's Barstow office, said (15 March 1994) that the state is informed each time the Bureau consults with the Service. In the past, the state has rarely given input on federal projects, although, recently, has been more responsive. State permits should be issued for each project that affects tortoises, or the state should formally adopt the federal opinion. However this has not been the case: of the 150 or so biological opinions issued in California for tortoises, California 2081 permits have been issued on only two or three projects (personal observation confirmed by several state and federal agency personnel).

For 10(a) permits there is no choice; the state is signatory to the HCP's implementing agreement. One of the obligations in the agreement is that the Department will uphold its responsibilities delineated in the state permit. Additionally, on the application for the 10(a) permit, the proponent is asked if there are any other permits required for the action, and if so, have those permits been issued. In the case of Sunland Communities, the federal Office of Management Authority, which then issued 10(a) permits, said it would not review documents pursuant to the federal permit until it received a copy of the signed state permit.

Currently the state permit must precede the federal permit, there is no mechanism to process the permits simultaneously. This often results in conflicting conservation measures. This happened with Sunland Communities when local staff of the Service, Department, and Bureau agreed that the compensation lands would be deeded to and managed by the Bureau. However, when the Department's solicitor reviewed the documents, he flatly stated that management by the Bureau was unacceptable. The HCP had to be rewritten to deed the land to the state, *and* endowment funds were required. There were no endowment funds when the Bureau was the intended land manager.

D. Section 7 is less expensive

Although section 7 opinions and section 10(a) permits both typically have a land compensation element, the lack of state involvement ultimately makes section 7 less expensive. In California, most section 7 consultations are between the Service and the Bureau. The Bureau requires land compensation for each of these projects, but does not require endowment funds.

For 10(a) permits, the state has required endowment funds regardless of the land manager. For the Church Site 10(a) permit, the land was deeded to the Preserve Committee, yet the state demanded $300 per acre to manage the lands. For the Sunland Communities 10(a) permit, the state was deeded 320 acres of land at the cost of $168,000, and required an additional $45,840 for management and fencing.

Proponents often develop additional phases of a project with money made on the first phase(s). For federal biological opinions where the Bureau is the action agency, compensation lands are typically deeded to the Bureau within one year after initiation of construction. For 10(a) permits, the proponent has had to provide endowment funds to the state and acquisition funds to the land manager *before* construction can be initiated. This requirement often puts the project developer in a situation where he is unable to develop the site even if the 10(a) permit is issued. Additionally the delay may be very costly. While waiting for federal permit issuance, Sunland Communities has paid three years of property taxes on a site it cannot develop.

Section 7 consultations are performed at no cost to the developer, whereas he will have to hire a consultant to draft the HCP and other documents for a 10(a) permit. Although this cost is only several thousand dollars for a small-project 10(a), every dollar is one more than has to be paid for a biological opinion.

V. Recommendations

In section 7 of the Act, the Service has an efficient, effective method of avoiding or resolving conflicts between developers and tortoises. Section 10(a) was intended to provide the same mechanism for private development. However, section 10(a) is not being used, and development continues to occur on private lands occupied by tortoises. The following recommendations are made to expedite issuance of small-project 10(a) permits.

A. Provide meaningful direction to the private development community

As 10(a) permits are issued for tortoises, the Service should provide developers with those documents to provide examples of appropriate conservation measures and strategies. These strategies should be discussed with developers at Service-scheduled meetings, such as those held monthly in Chino, California.

The Service should publicize standards that have already been set, and make them available to private developers. For example, (1) the Service is not receptive to large cash payments in the guise of conservation, yet the first question asked by most developers is, "Can't we just give 'em $600/acre, and let 'em take care of tortoises?" One has to explain that such mitigation fees are a part of HCP's, not in lieu of them. (2) There is a Service-approved, multiagency-coordinated policy for compensating lost tortoise habitat (see section V.D.). The document would inform the developer, up front, whether he would have to compensate impacts at 1:1 or 3:1, or maybe not at all. (3) On-site mitigation measures are well delineated in many documents, including federal biological opinions. (4) The Service has protocols for performing surveys (1992), complying with the Endangered Species Act (1990b), and handling desert tortoises (Desert Tortoise Council *in prep.*). Such information demystifies the 10(a) process. It also allows the developer to estimate the cost of a conservation plan. Insufficient funding will neither benefit the tortoises on the project site, nor the ones on the lands to be managed.

B. Set a time limit for 10(a) permit review

I perceive that developers are most frustrated by the length of time and uncertainty of 10(a) permit issuance. The Service should have a limited amount of time to review and issue small-project 10(a) permits. The real work of a small-project HCP is consensus building, which unlike the programmatic HCP, typically involves only the Service, state, and project proponent. Depending on the plan, a management organization like the Preserve Committee may also be involved.

It may take several weeks or several months to reach consensus, formulate the plan, draft it, and send it to the field office. The Ventura Field Office typically reviews and edits section 10(a) documents in six to eight weeks. The documents then go to Portland or Sacramento, where they are reviewed by the biological staff and the legal staff. At this point the process becomes arbitrary: issuance of the permit is totally dependent on the person(s) to whom the permit is assigned (see section V.C. for a proposed solution to this problem).

In California, it is recommended that the appropriate *Field Office* of the Service have 45 days for internal review of the small-project HCP and EA. During the same 45 days, the *Sacramento* office of the solicitor would review the implementing agreement, and Portland would review the documents for policy compliance only. The field office would then send the HCP and EA back to the project proponent with required modifications. The proponent would make necessary changes and send it back to the Service. After a brief review by the Service of 15 days, the documents would be published in the *Federal Register* for 30 days. The Service would then have 45 days to draft the Intra-Service biological opinion, Finding of No Significant Impact (if appropriate), and issue the implementing agreement for signature. It will likely take about 30 days for all parties to sign the implementing agreement, and for Portland to issue the actual permit. Thus, the permit could be implementable in about 165 days, only 30 days more than the 135 days the Service currently has to issue a biological opinion.

C. Localize the review process

I perceive two problems for small-project 10(a) permits: (a) field office personnel recommend measures that are not acceptable in Portland, and (b) Portland is so busy that the permits are not issued expeditiously. In California, I believe that both problems would be solved if the field office reviewed the HCP, the USDI's Sacramento solicitor reviewed the implementing agreement, and Portland's role was limited to policy compliance.

Localizing the review process for small-project 10(a) permits may accomplish the following: (1) eliminate inconsistent intra-agency, inter-office decisions; (2) ensure that Service personnel most familiar with local issues are reviewing the 10(a) permit application; and (3) eliminate the inequity between implementation of section 7 and section 10(a).

(1) Eliminate inconsistent intra-agency, inter-office decisions -

For the Church Site permit, field office personnel gave sound advice and reached consensus with personnel from the Churches, Preserve Committee, and Department. The Church Site HCP went through the entire review process, including Portland, with minimal revisions. The Churches were fortunate that their HCP was reviewed by Dennis Mackey in Portland, and that the implementing agreement was reviewed by Lynn Cox in Sacramento. Sunland Communities was not so fortunate.

Sunland Communities' EA was sent back and forth between Ventura and Portland three times before the Portland staffer was satisfied. Most of the comments were editorial. Subsequent changes were made on parts of the EA that were acceptable the first and second times the same Portland staffer reviewed the document. The delay cost Sunland Communities several months. Similar conflicts arose on the issues of tortoise adoption versus using tortoises solely for research; on the different compensation ratios between the two projects; on the decision to modify Sunland Communities' documents *after* public review; on the decision to call the signatory document the "implementing agreement" versus a "memorandum of understanding"; to name but a few.

Whether 10(a) permits continue to be reviewed in the regional office, or the authority is shifted to the field offices, Portland and the field offices must eliminate arbitrary decisions made by their staffs. There must be a consistent review process. Regulations implementing section 10(a) must be drafted as soon as possible.

(2) Ensure that Service personnel most familiar with local issues are reviewing the 10(a) permit application -

Regardless of the location - Ventura or Portland - fallible humans review HCP's and draft FONSI's, and its usually the local people, as opposed to regional personnel, who are most familiar with local species and issues. Mr. Jim Hatter of Sunland Communities was often told by the Portland biologist handling his project, that the permit was on hold until he, the Portland biologist, finished working on a spotted owl issue!

Portland personnel review documents prepared for least Bell's vireos and California gnatcatchers in San Diego County, for blunt-nosed leopard lizards in Kern County, for southern sea otters in Monterey Bay, for marbled murrelets along the Oregon Coast, and for northern spotted owls in Oregon and Washington. In short, Portland reviews everything between Mexico and Canada, and from Idaho to Hawaii. In addition to the diversity, the extensive list of threatened and endangered species results in excessive workloads for Portland personnel. Portland is reviewing regional HCP's covering much of western Riverside, San Bernardino and Kern Counties in California, and Clark County in Nevada. It is understandable that an HCP for a five-acre or a 160-acre site would not get the attention and priority that it would receive in a local field office.

(3) Eliminate the inequity between implementation of section 7 and section 10(a) -

The recommendation to localize the review process is consistent with the Service's much-used section 7 process. Under section 7, biological opinions are issued expeditiously, usually under 135 days, with no input from the regional office. Somehow the 10(a) permit is treated with more gravity, as if tortoises are more susceptible to a bulldozer authorized by section 10(a) than they are to a bulldozer authorized by section 7.

A Service person recently offered me the regulations implementing section 7 of the Act, but said he did not have a copy of the analogous document for section 10. He did not apparently know that implementing regulations do not exist for section 10(a). I perceive that many Service personnel have an ingrained attitude against 10(a) permits, regardless of the size. However, they should not equate small-project HCP's with programmatic plans; the latter are extremely more complicated and problematic. The Service should consider section 10(a) as much its responsibility as section 7, and demonstrate this by issuing the implementing regulations now.

D. Ensure consistency

The *Federal Register* notice of intent to issue the Sunland Communities permit was published on 28 April 1993, two days after the Church Site notice was published. At the end of 30 days, there were no public comments on either permit. The Church Site permit was immediately sent by the Service to be signed by the project proponent, Department, and Preserve Committee. It was then signed by the Regional Director of the Service and promptly issued.

Conversely, at the discretion of someone in Portland, the Sunland Communities permit was modified *after* public review, sent back to the solicitor, sent back through environmental review in Portland *and* Ventura, and, as already indicated, has not yet been issued. The Service must ensure that 10(a) permits are reviewed consistently and issued expeditiously.

Field Supervisors of the Service, State Directors of the Bureau, and heads of state departments of fish and game for Arizona, California, Nevada, and Utah - collectively called the "Desert Tortoise Oversight Management Group" or "MOG" - prepared a document called, "Compensation for the Desert Tortoise" (Desert Tortoise Management Oversight Group 1991). That policy document was supposed to ensure consistency among the six agencies with regards to compensating impacts to tortoises and their habitats. In spite of that document, in 1993 Portland delayed issuance of the Church Site and Sunland Communities 10(a) permits for about three months; it required that Ventura develop a consistent compensation policy for *future* projects before it would issue the permits. The MOG compensation policy should have been an effective way to avoid excessive delays and ensure consistency. However, Portland was apparently not aware of, or not in agreement with, the policy, which was signed by Field Supervisors in Arizona, Nevada, and Utah.

E. Ensure continuity

The Service has a high rate of personnel turnover. People knowledgeable of local issues move to Washington, or elsewhere within the agency. Other senior staffers are given new responsibilities, or assigned to new species. Experienced people are replaced by new people, many of them untrained. Training may take several years, but in the interim, the expertise is lacking. The Service does address this problem by having junior staff attend meetings with experienced senior staff. However, expedient permit issuance presently relies on experienced staff, or more often than not, on the person with the most energy, regardless of his or her experience.

The Service's "Procedures for Endangered Species Act Compliance" (1990b) should be amended to provide specific examples of appropriate 10(a) conservation strategies. The "Procedures" lists 15 pages of reasonable and prudent measures for section 7 consultations involving impacts of off-highway vehicles, right-of-ways, and grazing. There are no such specific examples given for section 10(a) in the document. The Service's "Guidelines" (1990a) should be amended to list suggested and approved conservation measures. Presently, the "Guidelines" offer no specific examples. Each office should have copies of every 10(a) permit that is issued. Less experienced Service personnel should be given these materials to ensure competent replacement of experienced people as they leave.

The Service should ensure continuity, in part, by eliminating personal biases. The Church Site 10(a) permit was issued in a relatively expedient manner solely because of the individuals in Ventura, Sacramento, and Portland who worked on it. Sunland Communities has endured significant delays because of several people in Portland.

Expediency of permit issuance should not rely on personal bias. The Service should employ more biologists to meet the demands of implementing the Act.

VI. Conclusions

The small-project 10(a) permit is, itself, proposed for endangered status. As California develops its 9,000,000-acre West Mojave Coordinated Management Plan, as Nevada formulates its 22,000-acre long-term HCP, and as Utah develops its Washington County HCP, the likelihood of encountering a small-project 10(a) permit in the field is minimal. Even so, there will be that small project just outside the county line, or just outside the HCP boundary, that will require a 10(a) permit. This already happened in Riverside County, California in 1993, where in spite of the Stephen's kangaroo rat programmatic HCP, a small-project 10(a) was issued for the same species in Colton, just outside the HCP boundary.

I am aware of several projects that should have been authorized by section 10(a), but were instead authorized by section 7 when a federal nexus was contrived. Projects are designed to cross federal lands; the Army Corps is brought in to determine "waters" on sandy alluvium; funds are solicited from federal agencies to develop the nexus. The perception is that section 10(a) should be avoided at all costs, even at the expense of section 7. The Service would change this perception, in part, by implementing section 10(a) as efficiently as it does section 7.

Sunland Communities occupies one parcel within a large assessment district of exclusively private lands in western Victorville, California. Tortoises have been found in adjacent areas, on all sides of the site (Tierra Madre Consultants 1992 and personal observation). Parcels east and south of Sunland Communities, within the same district, have been developed; the dirt road south of the site has been widened and paved; a sewer trunk line has been installed immediately east and north of the site. Yet no 10(a) permits have been issued for these developments. Developers within the district chide Mr. Hatter of Sunland Communities on his futile attempt to secure a 10(a) permit, when, as they are quick to point out, tortoises have not stopped *them*.

In 1991 a building inspector with the City of Adelanto, California told me that tortoises were reported in six of the first ten reports submitted to that city's planning department. There have been no 10(a) permits issued for Adelanto, which is largely comprised of private lands. I suspect that tortoises are being killed in Adelanto, I know that 10(a) permits are not being issued. New tract homes and industrial complexes recently constructed in the area are evidence that tortoises have not stopped development.

The Service needs desperately to demonstrate that the section 10(a) permit process is available and viable. Otherwise there will continue to be abuse of section 7, and developers will continue to develop lands and kill tortoises in spite of the Endangered Species Act.

VII. Acknowledgments

I would like to thank the following Service personnel for their helpfulness and/or empathy during the Church Site and Sunland Communities 10(a) permit processes: Ray Bransfield and Judy Hohman of the Ventura office; Dennis Mackey of Portland; and Carol Harlow of the Office of Management Authority in Washington. Lynn Cox of the USDI's Sacramento Solicitor's Office is also commended.

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The Continued Saga of Desert Tortoise Adoptions in Northern Nevada

Darlene Pond

At the last symposium, I told this group that the Northern Nevada Desert Tortoise Adoption Program began in the spring of 1992, when Clark County opened up the whole state of Nevada to tortoise adoption, a project sanctioned by the U.S. Fish and Wildlife Service. The reason for the program was to find homes for Desert Tortoises that were being displaced by land development in Southern Nevada. The Reno Tur-Toise Club volunteered to handle the program in Northern Nevada.

At that time, the Nevada Air Guard brought the tortoises from Las Vegas to Reno during routine missions. In 1992 a total of 147 tortoises was adopted to northern Nevada backyards that had been inspected and made tortoise-safe. We stopped short of our goal of 200 animals because URTD was rampant in the Vegas holding yards, and then the deadly disease broke out in ours. We battled it with everything known. Sometimes we won, sometimes we lost.

Vegas holding facility was opened with more room for the incarcerated animals who seemed less stressed, and, because of this, apparently less susceptible to URTD. At least only health certified reptiles came to us, and they have remained more healthy. Part of the reason may be that the new tortoise chow, a completely balanced food developed by Smithsonian researchers from an iguana chow base, was used to feed them, and our adopters are continuing its use. I understand studies are being done to see if this correct nutrition will help prevent URTD outbreak.

We enlisted the help of the Nevada Department of Transportation to bring the tortoises north when air guard schedules didn't allow. So we now have two transportation sources which is a luxury.

We submitted a small budget to Clark County Commissioners, which they approved, so the burden of providing our own funding for necessary expenses such as printing and postage was lifted.

Because of the failure of a plan to introduce displaced tortoises into already established tortoise habitat, and the unwillingness of Clark County to spend the exorbitant amount predicted to establish a colony of tortoises on the islands of Lake Meade (which, in essence, would have been a tortoise farm surrounded by barbed wire with paid keepers in order to keep it pristine), we literally became the only game in town as only so many animals could be utilized by research and zoos. This put a great deal of responsibility squarely on the Reno Tur-Toise Club. We agreed to adopt out 400 tortoises in the northern part of the state from June 1993 to June 1994.

We still feel some urgency, however, as the Vegas holding facility has over 200 tortoises (many of them hatchlings), as we speak. It is essential we clear out as many as possible this spring so new arrivals can be processed without undue crowding.

While things have improved in a year, everything isn't rosy. There are still problems facing the program, such as an overabundance of very large males, which must be housed separately in the holding facility, a shortage of large females to match them for those who want pairs, and what to do with all the hatchlings who require special care in captivity if they are to beat the 2% survival odds they face in the wild.

The biggest problem we face, however, is where to find enough adopters to take all the tortoises that are coming into the holding facility this year and in the future.

In anticipation of this problem, we spent the winter setting into motion a marketing and advertising plan to find new adopters as we realized early-on the "eager-adopter-well" would quickly dry up and we would need such a tool to succeed in coming years. After 20 years of adoptions, Las Vegas area is super-saturated with captive tortoises. After only two years of adoptions, northern Nevada is not.

Further, we get great press because the program is fairly new. Whenever we have a large shipment of tortoises arriving, we contact the television stations and they send out camera crews to photograph the event. We then appear on the nightly news. We do public service announcements with radio stations and the newspapers print stories and photos. In fact, the San Francisco Chronicle sent a reporter and photographer to Carson City last October to greet our last flight of the year by the Department of Transportation and subsequently did a story with photos of the success of the adoption program. Whenever publicity comes out, we get a surge of interest and inquiries about how to adopt a tortoise. We send them one of our brochures listing the requirements for a tortoise-safe yard, such as making sure they cannot dig out, that the yard is large enough, a burrow is provided, they agree to provide veterinary care, etc.

We did a mail-out to interested persons touting the idea of Desert Tortoises as low maintenance backyard dwellers and emphasizing their ancientness, referring to them as "Jurassic Pets". This was at the time the movie "Jurassic Park" was playing in the area.

With assistance from The Nature Conservancy publicity office, we had photographs taken of a tortoise with a showgirl and these were made into posters that were distributed to advertise the program. We also have a committee working on an exhibit at a popular Reno park with help from the Wilbur May Foundation to present a complete, natural Desert Tortoise habitat with live tortoises and a walk-through for the public, scheduled to open in 1995. We have no doubt this will raise public awareness and make known the need for adopters over the next few years.

Education is, after all, the key to the success of programs like ours. We continue to visit area schools with live animals so the children of Nevada will grow up respecting their state reptile and be willing participants in the effort to save it from going the way of the passenger pigeon. We continually emphasize that the Desert Tortoise is a Keystone species and that many other desert animals depend on its ability to dig nice, safe burrows and that they are essential to healthy desert ecology.

Speaking of education, we have, of necessity, learned a great deal from experience, from reading information published by some of the folks here today and by attending these symposia which have proven very valuable to us and our goals.

We also know that some of you disagree with a program that does not allow the tortoise extinction process to proceed naturally and that we are meddling with nature by making them captive. My answer is that due to mankind's past and present meddling in several negative ways, the Desert Tortoise cannot proceed naturally to extinction any more than in the case of the dodo, or, very nearly, the North American Bison. We feel it's about time for some positive meddling to offset the negative.

At least now there is more awareness about the plight of the Desert Tortoise. We are all trying to do something to prevent their total demise in the wild. We would, of course, all prefer they be left in the wild to live as tortoises are meant to live. Since, in some cases, this cannot be, we remind you of zoo projects to breed exotic animals that are endangered and may someday be released back into stable habitat in the wild under controlled conditions where they'll be safe, and of the very successful Galapagos tortoise breeding program.

While we will continue to work with all of you for safe wild habitat, we do not apologize for the Northern Nevada Desert Tortoise Adoption Program. It is better, we feel, to have them living in backyards all over Nevada with proper nutrition and a good chance at life, and perhaps even a future for the species, than to have them plowed under, euthanized or any number of other deadly alternatives.

Someday you scientists and researchers may need these backyard tortoises to restore portions of the desert. Wouldn't that be wonderful?

There is something about Desert Tortoises, you'll have to agree. Those of you who study them scientifically did not select them as your life's work "just because". You like the little buggers just as much as I do!

Digestive Physiology and Nutritional Ecology of the Desert Tortoise Fed Native Versus Non-native Vegetation: Implications for Tortoise Conservation and Land Management

Harold W. Avery

Abstract: Among the most limiting resources associated with animal populations inhabiting desert ecosystems are water and food availability. Research on the digestive physiology and nutritional ecology of desert tortoises is critical in determining physiological and nutritional constraints associated with survivorship and reproductive output of tortoise populations. Such data are also consequential for developing more effective land management and conservation policies affecting the desert tortoise.

The herbivorous desert tortoise is potentially sensitive to changes in species composition of plant communities. Over the last several decades, major changes have occurred in the species composition and biodiversity of plants within the geographic range of the desert tortoise. In the western Mojave Desert of California, major influxes of Mediterranean and Asian annual plants have occurred. Hypothesized anthropogenic causes for these influxes include off-highway vehicle use, livestock grazing, urbanization, and other impacting land uses.

I determined the digestive performance of desert tortoises fed native versus exotic annual plants, and compared the nutrient contents of native versus exotic annual and herbaceous perennial vegetation known to be consumed by free-living desert tortoises. Energy digestion rates were not different between tortoises fed exotic, native, or a mix of native/exotic forage, but tortoises fed native vegetation assimilated dietary nitrogen at significantly greater rates than tortoises fed exotic or mixed diets. Tortoises fed native vegetation maintained a positive nitrogen balance, whereas tortoises consuming exotic or mixed vegetation were in negative or zero nitrogen balance. Organic matter digestibilities of tortoises were significantly greater in tortoises fed native versus exotic or mix vegetation, indicating that tortoises are physiologically more capable of utilizing native vegetation compared to exotic vegetation.

Tortoises fed a native or native/exotic mixed-plant diet maintained constant body mass, whereas tortoises fed exotic plants lost body mass. Packed cell volumes of blood were not significantly different between tortoises fed native versus exotic vegetation. Comprehensive nutrient assays of native and exotic vegetation suggest that native vegetation is more nutritionally beneficial to desert tortoises than exotic vegetation.

Traditional measurements of range condition utilized by range conservationists are not designed to determine habitat quality for the desert tortoise. For example, estimation of annual plant or perennial grass biomass is not an adequate determinant for deciding the stocking rates of livestock grazing, from the perspective of desert tortoise nutrition. Findings reported here and elsewhere indicate that species composition of plants may be of greater importance in tortoise nutrition than standing biomass. Availability of specific plant species may be a more suitable measure for making decisions on delineating critical tortoise habitat and recommending the turnout and stocking rates of ephemeral livestock grazing.

Critical Habitat for the Desert Tortoise

Sherry Barrett

Abstract: On February 8, 1994, the U.S. Fish and Wildlife Service (FWS) published a final rule designating critical habitat for the Mojave population of the desert tortoise (*Gopherus agassizii*). The designation became effective 30 days after the publication date. The designation encompasses primarily Federal lands in southwestern Utah, northwestern Arizona, southern Nevada, and southern California.

The Endangered Species Act requires that Federal agencies consult with FWS to ensure their activities will not jeopardize the continued existence of a listed species or destroy or adversely modify critical habitat. Thus, designation of critical habitat provides additional protection to habitat necessary for the survival and recovery of the desert tortoise.

In California, FWS designated eight critical habitat units totalling 4,754,000 acres in Imperial, Kern, Los Angeles, Riverside, and San Bernardino counties, of this, 3,327,400 acres are Bureau of Land Management land and 242,200 acres are military land. The remainder includes 132,900 acres of State land and 1,051,500 acres are privately owned.

In Nevada, four units totalling 1,224,400 acres are designated in Clark and Lincoln counties. Of this, 1,085,000 acres are Bureau of Land Management land, 103,600 acres are National Park Service lands, and 35,800 acres are private.

In Utah, two units totalling 129,100 acres are designated in Washington County. These units consist of 89,400 acres of Bureau of Land Management land, 27,600 acres of State land, 1,600 acres of Indian Tribal land, and 10,500 acres of private land.

In Arizona, the FWS designated two units totalling 538,700 acres in Mojave County. These units consist of 288,800 acres of Bureau of Land Management land, 43,600 acres of National Park Service land, 5,700 acres of State land, and 600 acres of private land.

The critical habitat designation was based on recommendations for desert wildlife management areas provided in the "Draft Recovery Plan for the Desert Tortoise, Mojave Population". The service may reevaluate and redesignate critical habitat at any time when new information indicates changes are warranted. Critical habitat units could be decreased in size, increased in size, or eliminated based on changes in certain environmental variables, land status, or tortoise populations.

Surveys for Desert Tortoise Demographic Data: Reflections on the 60-day Spring Plots

Kristin H. Berry

Since 1979, the 60-day spring survey technique has been used on 15 California study plots, as well as on plots in other states, to gather demographic data on desert tortoise populations for assessing condition and trends. While the 60-day technique has limitations, it provided valuable information on population attributes (e.g., distribution by habitat type, densities by size and age class, sex ratios, recruitment, mortality rates, and causes of death). The technique requires field workers to spend 480 hours in surveys for tortoises during the key activity period in spring. The survey must be accomplished over 45 to 60 calendar days. Data were more reliable and productive when sample sizes were large (>100 tortoises enumerated/mi^2) for each survey, but were less so when sample sizes were smaller, particularly when samples of enumerated tortoises fell below 30 individuals.

New approaches designed to increase sample sizes in low density populations are desirable. One option is to increase plot size, which may be done without affecting integrity of the survey technique or increasing field time. To evaluate how survey hours have been used in previous samples, I divided the 480 survey hours into search vs. processing times. Significant differences were apparent between high and low density plots. For example, field workers may spend more than 90% of the 480 survey hours in searching for tortoises on a low density plot compared with 60% on a high density plot of equivalent size. Thus low density plots might be enlarged by $>30\%$ without compromising overall search time and comparability of data with the higher density plots. Advantages and disadvantages of this and other options are discussed.

The 16S rRNA Gene Identifies *Mycoplasma agassizii* Isolated from Ill Desert Tortoises

D. R. Brown and M. B. Brown

Mycoplasma agassizii is a pathogenic agent of upper respiratory tract disease (URTD) in the desert tortoise, *Gopherus agassizii*. The mycoplasma is antigenically distinct from *Mycoplasma testudinis*, the only other characterized mycoplasma isolated from a reptile (*Testudo gracea*). Mycoplasma strains isolated from ill desert tortoises were characterized by polymerase chain amplification (PCR) of the 16S rRNA gene using genus-specific primers. The nucleotide sequence of the variable regions of the gene was determined by automated fluorescent dideoxy analysis without cloning. *M. agassizii* variable sequences were different from those of *M. testudinis*, confirming that the two are distinct species. Presence of a Sau961 restriction endonuclease recognition site (RFLP) in the V2 region of the gene was diagnostic for *M. testudinis*. The 16S rRNA gene was amplified from 33 mycoplasma isolates from the respiratory tract of ill desert tortoises and selected other tortoises using as little as 2 μl of broth culture. None of the isolates gave the distinctive RFLP associated with *M. testudinis*. Preliminary results indicate that PCR also can be used to detect the presence of *M. agassizii* in nasal washes.

The nucleotide sequence of the complete *M. agassizii* 16S rRNA gene is undergoing analysis to identify unique RFLPs. Partial sequence data for the 16S rRNA gene variable regions of mycoplasma isolated from the Florida gopher tortoise (*G. polyphemus*, a species of special concern for conservation) with URTD indicated homology to the nucleotide sequence of *M. agassizii* but not *M. testudinis*. On the basis of these studies, we suggest that the PCR-based 16S rRNA gene analysis is a rapid and sensitive complement to culture and species identification of *M. agassizii*. Further, *M. agassizii*, the causative agent of URTD in the desert tortoise is the same species as that isolated from gopher tortoise populations with URTD.

A Two Year Survey of the Presence of Specific Antibody to (*Mycoplasma agassizii*) in the Serum of Desert Tortoises from Three Geographical Locations

M. B. Brown, I. M. Schumacher, P. A. Klein, K. Nagy,

Serum samples were obtained over a two year period from desert tortoises in Ivanpah (IV), Goffs (GF), and the Desert Tortoise Natural Area (DTNA). The survey was a component of an overall health assessment study in these areas. Samples were obtained in March, May, August, and October of 1992 and 1993. Specific antibody levels were determined in an ELISA using antigen prepared from *Mycoplasma agassizii* strain PS6 and a monoclonal antibody directed against desert tortoise immunoglobulin. A negative and positive control serum were included in each assay. Over the two year period, the negative control serum mean ELISA value was .310 ± .009 SE and the positive control serum mean ELISA value was 2.744 + .045 SE. Antibody levels were not influenced by the sex of the tortoise. Therefore, the effects of both the geographical location and time of collection on serum antibody levels were analyzed without considering sex as a variable. Serum values were expressed as the ELISA value ± standard error and are summarized in the table below.

Month	DTNA (N)	Ivanpah (N)	Goffs (N)
March 1992	.352 ± .108 (18)	.299 ± .033 (20)	.211 ± .034 (24)
May 1992	.454 ± .111 (16)	.385 ± .040 (18)	.226 ± .031 (23)
August 1992	.892 ± .141 (14)	.480 ± .054 (18)	.386 ± .045 (23)
October 1992	.839 ± .141 (13)	.314 ± .046 (16)	.204 ± .025 (23)
March 1993	.483 ± .122 (13)	.325 ± .041 (14)	.208 ± .048 (20)
May 1993	.495 ± .130 (14)	.533 ± .090 (16)	.201 ± .023 (21)
August 1993	.685 ± .153 (13)	.758 ± .087 (15)	.587 ± .051 (17)
October 1993	.395 ± .072 (13)	.357 ± .056 (17)	.278 ± .042 (19)

Significant differences in antibody levels among the three populations were observed by analysis of variance. In 1992, antibody levels were significantly higher in sera of tortoises from the DTNA population than were antibody levels obtained from tortoises from the Goffs population in all months except March. Levels in sera from animals in the DTNA population were also higher than levels obtained from animals in the Ivanpah population in August and October 1992. No other differences were noted in the 1992 samples. In 1993 a disturbing trend was noted. The antibody levels seen in tortoises from both Ivanpah and Goffs began to increase. In March 1993, levels of antibody in sera from animals in the DTNA population were higher than those from the Goffs population. However, in May through October 1993 the serum antibody levels from the DTNA and Ivanpah populations were not significantly different from each other. In both the August and October 1993 samples, no significant differences were observed among the three populations. In order to assess the differences in the 1992 vs. 1993 samples, we used a paired T analysis to compare the change in antibody levels in individual animals for each sample time. This analysis revealed that antibody levels in individual animals in DTNA decreased significantly in August and October of 1993 as compared to the antibody levels in 1992. Conversely, antibody levels increased significantly in the Ivanpah population in May and August 1993 as well as in the Goffs population in August and October 1993. The pattern observed in DTNA is suggestive of a population which has been exposed to an infectious agent, responded immunologically by production of specific antibody, and may now be in the convalescent stage of infection. The decreased levels could be a result of decreased antigenic stimulation (i.e., the mycoplasma has been cleared by the tortoise or is no longer present in high numbers) or immunosuppression. It is not known if these tortoises have recovered from infection, are carriers, or are resistant to subsequent challenge with the infectious agent. The pattern observed in both Ivanpah and Goffs is suggestive of a population which is in the initial stages of an infection. As exposure to the pathogen increases, the number of animals which produce specific antibody as well as the amount of specific antibody present will increase. It is not known how many of these animals will clear the infectious agent, develop disease, or become asymptomatic carriers. It is clear that continued monitoring of these populations could provide valuable information with respect to the spread of URTD in wild tortoise populations as well as the predictive value of serological profiles in this disease.

Important Considerations in the Isolation and Identification of *Mycoplasma agassizii*

M. B. Brown and D. R. Brown

Diagnosis of most bacterial infections usually depends on cultural isolation of the microorganism. However, because of the fastidious nature of mycoplasmas and the relatively long incubation periods required for growth, cultural isolation is often among the most difficult methods (and sometimes least sensitive) of diagnosis. Alternate methods of diagnosis include serology to determine exposure histopathology or lesion analysis, or molecular methods such as polymerase chain reaction (PCR) based tests.

In 10 infected animals, mycoplasmas were isolated from the choana (N=9), nasal passage (N=8), trachea (N=2) and lung (N=1). The preferred site for cultural isolation of *M. agassizii* is nasal washes of live tortoises; choanal or nasal swabs may be obtained at necropsy. Samples obtained at necropsy should be plated directly onto SP4 agar and into SP4 broth. Because of the long incubation time required for growth, bacterial and fungal contamination may be a problem even though the inhibitors are present in the medium. We routinely filter inoculated broth through a 0.45 µm filter prior to incubation. It is imperative that the swab not be left for a prolonged period of time without plating since many mycoplasmas are inhibited by swab materials. Calcium alginate swabs are preferable for use. Nasal washes which are collected in the field or which must be transported to the laboratory should be placed in transport broth (or collected by flushing with the transport broth), frozen at -70° C, and transported on dry ice. Once in the laboratory, isolation protocols are the same as for necropsy samples.

Plates should be incubated at 30° C in 5% CO_2 for 6 weeks. Plates should be read at weekly intervals for growth. Colonies on agar are variable in morphology, with both mulberry and fried egg characteristics. Mulberry colonies are common on primary isolation plates. Primary isolation requires 3-6 weeks of incubation. The colonies are very small, and plates much be screened using a dissecting microscope at 50X magnification or an inverted microscope. Colonies will appear grainy if seen using the inverted microscope. If the colony is easily visible at low magnification or with the naked eye, it is not *M. agassizii*. Special care should be taken to avoid misinterpretation of pseudocolonies as mycoplasma colonies. Use of the Diene's stain will differentiate between true colonies and pseudocolonies. *M. agassizii* should be transferable to SP4 broth and will ferment glucose, producing a pH shift. Any suspicious colonies should be transferred to broth to check for glucose utilization. Broth cultures (primary isolation or subculture) should be examined at regular intervals for a color change indicative of glucose fermentation. If turbidity is noted, then bacterial contamination has occurred. Mycoplasmas are very small and will not cause light scatter so color change is the only way to determine growth. Conclusive identification of *M. agassizii* is based on reaction with specific typing antiserum, species-specific PCR amplification of the culture, or hybridization with species-specific DNA probes. The identification may be done on primary agar plates or broth subcultures.

Construction and Implementation of Revegetative Machinery along the Morongo Valley Pipeline

Gary L. Burchett

In March of 1993, construction of the Morongo Valley pipeline began between Yucca Valley and Hesperia, California. This pipeline is approximately 70 miles long, disturbing approximately 650 acres of prime desert habitat. The major biological concern was to replant and reseed the disturbed habitat, to give it as strong a chance as possible to revegetate, as quickly as possible. Native seed were harvested. Large mature flora were moved offsite during actual pipeline construction and placed in their original locations post-construction. Agri-Cat was contacted about the possibility of constructing a piece of machinery which would: (1) break up the soil which was compacted by heavy equipment construction; (2) spread native desert flora seed in a consistent manner; (3) implant the seed in the soil; (4) deal with possible soil erosion due to rain, and (5) be able to seed in areas with wide-ranging terrain types. Construction of the proposed revegetation implement began in October of 1993. The machinery was delivered onsite in November 1993. Since 15 November, 35 linear miles of the pipeline have been seeded, encompassing 275 acres, and 4125 lbs. of live native seed. The project is slated to continue through March 1994 and resume again October 1994.

Demographics of Long-Lived Organisms: Implications for Conservation and Management

J. D. Congdon, A. E. Dunham, R. C. van Loben Sels

Demographic studies of Blanding's turtles (*Emydoidea blandingii*) and snapping turtles (*Chelydra serpentina*) conducted during the last 20 years have provided demographic data sufficient to examine how life history characteristics may constrain population responses of long-lived organisms. Both turtles exhibit delayed sexual maturity (11 to 20 years) and high adult survival (> 96%). However, annual fecundity is relatively low in Blanding's turtles (4) and high in snapping turtles (4 and 11 females producing eggs, respectively). Nest survival of both species was variable and ranged from 0.0 to 63% annually. Recruitment of juveniles and adults of both species was highly variable and sufficient to replace individuals estimated to have died during the study. Life tables for the populations resulted in a cohort generation time greater than 30 years, and required 72% annual survivorship of juveniles between one year and sexual maturity to maintain stable populations. Population stability was most sensitive to changes in adult or juvenile survival and less sensitive to changes in age at sexual maturity, nest survival or fecundity. The results from the present study indicate that life history traits of long-lived organisms consist of co-evolved traits that result in severe constraints on the ability of populations to respond to chronic disturbances. Successful management and conservation programs for long-lived organisms will be those that recognize that protection of all life stages is necessary. Programs such as headstarting or protection only of nesting sites may be less than adequate to save long-lived organisms such as freshwater and sea turtles, and many tortoises.

Health Studies of Mojave Desert Tortoises, 1993 Annual Report

Vanessa M. Dickinson

Hematological, bacteriological, and parasitic characteristics were sampled for three groups of free-ranging desert tortoises (*Gopherus agassizii*) in the Mojave Desert; one group from Littlefield, Mohave County, Arizona, the second group from Paradise Canyon, Washington County, Utah, and the third group from City Creed, Washington County, Utah.

Tortoises were sampled for health characteristics in three collection periods in 1993. Tortoises were captured and fitted with radio transmitters in 1989 with additional captures in 1993. 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 swabs, and fecal samples.

City Creek and Littlefield tortoise populations exhibited the effects of site, sex, and season on hematology, clinical chemistry, and electrolyte/osmolality levels. Five nonpathogenic bacteria were isolated from tortoise cloacae. One potential pathogen, *Pasteurella testudinis*, was detected in nasal aspirate. *Mycoplasma*-like colonies were isolated from the majority of tortoise nasal aspirate at both sites (88%). The identity of the *Mycoplasma*-like colonies is in question. An enzyme-linked immunosorbent assay (ELISA) for detecting *Mycoplasma agassizii*, the causative agent of Upper Respiratory Tract Disease (URTD), indicated five tortoises which tested positive and two which tested suspect at City Creek (n = 19). Two tortoises tested positive for *M. agassizii*, and two were suspect at Littlefield (n = 26). The single Paradise Canyon tortoise tested positive in all three seasons. All of the tortoise fecal samples had nonpathogenic pinworm ova (n = 4).

Effects of Wildfire on Desert Tortoises and Their Habitats

Todd C. Esque, Timothy Hughes, Lesley A. DeFalco, Brian E. Hatfield and Russell B. Duncan

Winter rains of 1991-1993 resulted in abundant annual plant biomass production. Although this provided a feeding opportunity for tortoises, it also created high fuel loads in some parts of the desert. Fires occurred throughout the warm deserts within the range of the desert tortoises. We report on the effects of five wildfires on desert tortoises and their habitats. We surveyed three fires in the Sonoran Desert Upland of Arizona: two in the Santan Mountains of Pinal County; and one earlier fire (1987) in the Santa Catalina Mountains of Pima County. Two fires were surveyed in the Mojave Desertscrub of Washington County, Utah. Standardized line transects were conducted immediately after fires to determine the effects of fires on desert tortoises and other wildlife. We searched burned areas for tortoises, post-burn tortoise activity, and other wildlife mortality due to fires. Surveys consisted of walking transects spaced according to visibility (10-15 m apart). In Arizona, permanent vegetation monitoring plots (one at each fire) were established in 1990 prior to the fires. In Utah, permanent line-intercept perennial vegetation transects were established subsequent to the fires to determine the immediate effect of the fire and to monitor the recovery of habitats. On the vegetation transects, perennial vegetation transects were established subsequent to the fires to determine the immediate effect of the fire and to monitor the recovery of habitats. On the vegetation transects, perennial cover was measured, and fire damage to perennial plants was ranked using a scale of zero to five (zero = undamaged and five = burned to the ground). We also surveyed the effects of fire suppression tactics (e.g. using pump trucks off of established roads, and fire lines scratched in soil surfaces by hand tools) in Utah.

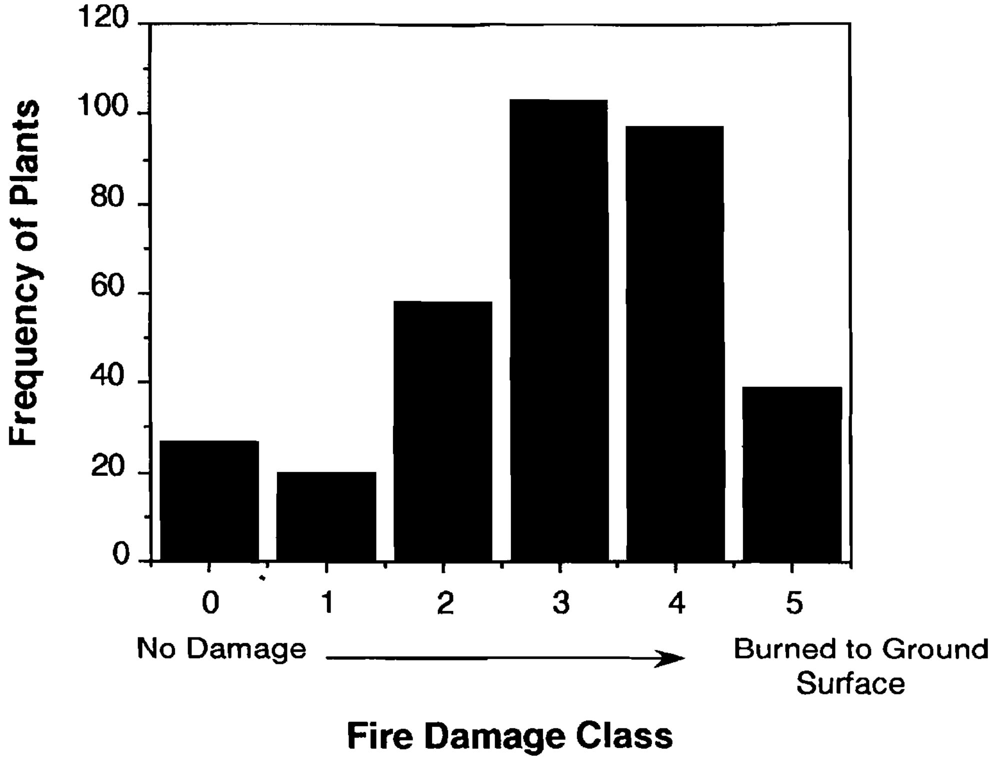

Figure 1. Frequency of individual plants that were damaged in the Mill Creed Fire, Washington County, Utah in 1993

The five fires covered 300 - 4300 acres each. Between 40 and 200 acres were surveyed for wildlife remains on each fire. Small fires were surveyed more completely. Tortoise mortalities numbered between zero and seven on the transects. One live tortoise was seen during each of four surveys, and five live tortoises were seen on one survey. Signs of post-burn activity by tortoises included fresh digging and tracks. Signs of activity indicated that more tortoises survived the fires than were located on surveys. There were long species lists of live wildlife found on burned areas including: birds, javelina, rodents, lagomorphs, lizards and snakes. Other than tortoises, only small animals (< 1 kg) were found dead on the surveys. Paired vegetation transects along fire breaks indicated, in all cases, that there were statistically significant losses of perennial cover. Some fires left unburned patches of vegetation that can serve as refugia for tortoises, other wildlife, and plants. Surveys (100%) of routes where pump trucks traveled off roads, and fire lines were created did not result in the discovery of any destroyed burrows or desert tortoise mortalities in Utah.

The direct effects of fires on tortoises and their habitats can be highly variable depending upon the intensity of fires and whether or not the tortoises are active or dormant. High intensity fires that occur when desert tortoises are active or occupying shallow shelter sites would have more direct impact on tortoises than fires occurring when tortoises are deep in their shelter sites. Losses of adult tortoises may have immediate and long-term impacts on tortoise populations resulting in a loss of recruitment. Indirect effects of fire may include temporary loss of food plants, a shift in forage species, loss of perennial plants that provide thermal cover, and loss of cover from predators. We predict that these indirect effects may influence adult populations of tortoises in the long term, even if there is not a high loss of adult tortoises directly related to the fires. We also predict that juvenile tortoises could have reduced survivorship during their next activity period subsequent to the fire. Indirect impacts such as habitat alterations are not necessarily limited to a particular season in which fires occur. The long-term effects of habitat change due to wildfire depends upon fire patterns and the recovery time of the plant community. Tortoises and plants in refugia may be important to the long-term recovery of desert ecosystems after wildfire. Habitat characteristics coupled with biophysical information about the thermal requirements of desert tortoises relative to body size might help us to understand the long-term effects of fires on desert tortoise populations. Fire suppression tactics are important as means of stopping the spread of desert wildfires that alter desert tortoise habitat. When fire suppression maneuvers are planned, carefully monitored, and mitigated they can prevent losses of individual tortoises and their habitats.

Drought Reduction of Resources Allocation to Reproduction in Female Desert Tortoises (*Gopherus agassizii*)

Brian T. Henen and Kenneth A. Nagy

We measured egg production (using x-ray radiology), energy metabolism (doubly labeled water), and water influx rate (doubly labeled water) in female tortoises near Goffs during two years of low rainfall (1988 and 1989). Remarkably, many females were able to produce eggs, but the average number produced per female was lower than half the number produced by the same population in 1983-1985. There was much variability between individuals in rates of water intake, field metabolic rate and energy allocated to eggs, so there were few statistically significant differences between 1988 and the much drier 1989, and between females that produced eggs and those that did not. During 1989, females tended to have lower rates of energy metabolism and fat storage than in 1988, but energy allocated to reproduction (reproductive effort, RE) was about 11% of total energy available in both years. There is some evidence that protein may be an important, and potentially limiting, resource for breeding females. Producing eggs during drought conditions is consistent with bet-hedging life-history strategy.

Physiological and Morphological Effects of Burn Injury in a Desert Tortoise, *Gopherus agassizii*

Bruce L. Homer, D.V.M., Ph.D., Elliot R. Jacobson, D.V.M., Ph.D.,
Mary M. Christopher, D.V.M., Ph.D., and Mary B. Brown, Ph.D.

An adult male desert tortoise from the Hackberry Mountains in the eastern Mojave Desert, San Bernardino County, California was received for necropsy following burn injury to the sell, limbs, face, and head. The tortoise received a complete necropsy. Blood was collected for hematologic and biochemical profiles and urine was collected for urinalysis. Swab specimens of nasopharynx and colon were collected for bacterial isolation and swab specimens of the choana and nasal cavity were collected for Mycoplasma isolation. Representative sections of all tissues were immersed in formalin and prepared for microscopic evaluation. A leukopenia (1700/μl), associated with a heteropenia (450/μl) and lymphopenia (50/μl), was indicative of overwhelming sepsis. There was indeed severe multifocal transmural necrotizing inflammation of the small and large intestine, associated with inflammation of serosal surfaces and marked granulocytic depletion of the bone marrow. Citrobacter and Pasteurella testudinis, two potential pathogens, were isolated from the colon. The intestinal lesions were attributed to impaired humeral and cell-mediated immunity which is often a complication in the early postburn period. Subcutaneous tissue in one burned leg was infected with bacteria. Burn wound infection is usually caused by endogenous bacteria from the skin or gastrointestinal tract. The most profound serum biochemical changes were marked increases in creatine kinase (239,784 U/L) and aspartate amino transferase (3,065 U/L), the combination of which is usually indicative of skeletal muscle disease. However, a severe skeletal muscle lesion was not detected, suggesting that the enzyme elevations were due to the marked gastrointestinal disease. Low serum protein (2.0 g/dl) and globulin concentrations (1.1 g/dl) were attributed to loss of protein through the gastrointestinal tract and, to a lesser extent, through the kidney. Hypoglobulinemia correlated with impaired humeral immunity. One complication of hypoproteinemia was hypocalcemia (8.1 mg/dl). Urinalysis revealed proteinuria and marked hemoglobinuria. Intravascular hemolysis, a cause of hemoglobinuria, often occurs in animals with burn injury. The pathophysiology of acute burn injury will be discussed.

An Update on Shell Disease Cutaneous Dyskeratosis) in Desert Tortoises, *Gopherus agassizii*

Bruce L. Homer, D.V.M., Ph.D., Elliot R. Jacobson, D.V.M., Ph.D.,
Mary M. Christopher, D.V.M., Ph.D., and Mary B. Brown, Ph.D.

Fourteen desert tortoises were received from different locations in the southwestern United States during a nineteen month period. Seven of these tortoises were submitted due to shell lesions, characterized by excessive flaking, white discoloration and irregular ridge formation of the shell adjacent to seams between scutes, particularly on the plastron. Some scutes, particularly on the carapace, were pitted, chipped, and had excessive concavity. The most severely affected scutes were either discolored white or contained large defects. Tortoises received complete necropsies. Blood was collected from all live tortoises for hematologic and biochemical profiles, *Mycoplasma* serology, and analysis of copper, selenium, vitamin A and vitamin E. At necropsy, urine was collected for urinalysis. Swab specimens of nasopharynx and colon were collected for bacterial isolation and swab specimens of the choana and nasal cavity were collected for *Mycoplasma* isolation. Liver and kidney were collected for analysis of minerals and organic compounds. Representative sections of all tissues were immersed in formalin and prepared for microscopic evaluation. Data from these seven tortoises were compared to data from the remaining seven tortoises that were submitted due to other illnesses, including bacterial pneumonia, hepatic degeneration, burn injury, fungal pneumonia, septicemia, and mycoplasmosis. The most consistent shell lesion was cutaneous dyskeratosis as reported by Jacobson *et al.* Dermal plates and long bones also had a variety of changes including irregularity of the external contour of the dermal bony plate with formation of woven bone, and an increase in cement lines (indicating increased turnover of bone). The most severely affected bones had increased osteoclastic resorption of trabecular bone, widened osteoid seams on bone surfaces, and increased amount of fibrous tissue in interosseous spaces. All tortoises with shell disease had liver lesions characterized by hepatocellular swelling and feathery to discrete cytoplasmic vacuolation. Plasma copper of tortoises with shell lesions had a mean of .225 ± .09 ppm while that of the other tortoises had a mean of .318 ± -.15 ppm. Plasma copper may have been low in both groups. The calcium:phosphorus (C:P) quotient in tortoises with shell lesions averaged 2.7 ± -1.4 versus an average of 5.9 ± -3.31 in the other tortoises. The C:P quotient in composite populations of desert tortoises averages 5.7. Tortoises with the most severe shell lesions had the lowest C:P quotient.

Hibernation Behavior Of Desert Tortoises At Yucca Mountain, Nevada

Audrey L. Hughes, Kurt R. Rautenstrauch, and Danny L. Rakestraw

Abstract. We determined when radiomarked desert tortoises (*Gopherus agassizii*) hibernated at Yucca Mountain, Nevada, during 1991-1993. The mean dates tortoises entered hibernacula were 25 October 1991 (n = 76, SD = 12.3, range = 28 Sep - 7 Dec), 22 October 1992 (n = 83, SD = 13.7, range = 12 August - 21 Nov), and 16 October 1993 (n = 95, SD = 13.4, range = 18 August - 19 November). By 15 November, 97% of all tortoises had entered hibernacula. The mean dates tortoises exited hibernacula were 27 March 1992 (n = 79, SD = 13.7 days, range = 27 Feb - 2 May) and 24 March 1993 (n = 78, SD = 12.3 days, range = 5 March - 25 April). Only one tortoise exited its hibernaculum prior to 1 March. Radiomarked tortoises were checked 2,198 times between December and February, and undisturbed tortoises were seen out of hibernacula only once. Tortoises handled during the hibernation period exited hibernacula earlier than tortoises that were not handled. We conclude that tortoises in this region do not need to be monitored during construction activities from November 15 through March 1.

This work was funded by the U.S. Department of Energy, Yucca Mountain Site Characterization Project, under Contract No. DE- AC08-93NV11265.

Upper Respiratory Disease in the Gopher Tortoise, *Gopherus polyphemus*

Elliott R. Jacobson, Mary B. Brown, Paul A. Klein,
Isabella Schumacher, Dan Brown and Hank Adams

An upper respiratory tract disease (URTD) has been seen in both captive and free-ranging tortoises in Florida. Symptomatic captive tortoises have been seen in: 1) Jacksonville, Duval County; 2) Miami Educational Facility, Dade County; 3) Ft. Lauderdale, Broward County; 4) Moccasin Lake Nature Center, Pinellas County; and 5) Gainesville, Alachua County. Wild symptomatic gopher tortoises have been seen on: 1) Sanibel Island, Lee County; 2) Gasparilla Island, Lee County; 3) Little Gasparilla Island, Charlotte County; 4) Emerald Bay Development, Collier County; and 5) Summer Beach Development, Nassau County.

The best documented example of a symptomatic population of gopher tortoises is that on Sanibel Island, Lee County, Florida. While there is no documentation of the origin of the Sanibel population of gopher tortoises, personal communications and anecdotal reports suggest tortoises were introduced to Sanibel and adjacent barrier islands by Caloosa Indians and Spanish sailors for a source of protein while exploring the gulf. The population on Sanibel Island was augmented in 1978 by the release of 108 tortoises from the annual Edison Festival of Light gopher tortoise race. That was also the last year in which the race was allowed. Illegal dumping of tortoises from around southwest Florida on Sanibel Island probably still occurs because the island is thought of as a wildlife sanctuary.

Studies are ongoing to define the etiology of URTD in the gopher tortoise and to develop a sensitive polymerase chain reaction (PCR) test to detect the presence of the etiologic agent in infected tortoises. Preliminary pathologic investigations indicated that the lesions in the nasal cavities of affected gopher tortoises are similar to those seen in desert tortoises with URTD. *Mycoplasma* has been isolated from the nasal cavity of ill gopher tortoises and has been seen by electron microscopy on the surface of the nasal cavity mucosal epithelium.

Reproduction in Desert Tortoises: Ecological and Evolutionary Perspectives

Alice Karl

Aside from their heuristic value, studies of reproductive ecology in long-lived organisms can offer insights into their population demography and evolutionary processes, while answering crucial questions for conservation and management. From 1990 to 1993, reproduction in 32 female desert tortoises was investigated in an ongoing study of 3 subsets of an eastern Mojave Desert tortoise population. Radiography, radiotelemetry, direct observation, and continual monitoring of body condition were used to determine clutch size and frequency, timing of oviposition, oviposition sites, and hatching success. These variables were used to assess several ecological and evolutionary aspects of tortoise reproduction, including: (1) intrapopulation variability; (2) individual versus population variability; (3) environmental tracking; (4) trade-offs; (5) allometric relationships; and (6) effective fecundity.

Survey of Normal Bacterial Flora in the Upper Respiratory Tract of the Desert Tortoise (*Gopherus agassizii*) in Southern Nevada

Janice M. Klaassen, James K. Klaassen, D. Bradford Hardenbrook

The desert tortoise (*Gopherus agassizii*) was permanently listed as an endangered species in 1990 due to rapidly decreasing populations. Serious respiratory disease, regional drought, and habitat encroachment are thought to have significantly contributed to this decrease. Although a new species of Mycoplasma has now been shown to cause the upper respiratory disease, apparently healthy animals can also harbor the organism. Lack of fundamental information about what constitutes normal bacterial flora in the desert tortoise has hampered descriptions of "healthy" animals.

In this study, respiratory samples, obtained from 243 healthy desert tortoises located in the Las Vegas Valley, were cultured for resident bacterial flora. The majority of the isolates (78%) consisted of various Gram-positive bacilli and cocci, including *Staphylococcus, Streptococcus, Corynebacterium,* and *Rhodococcus* species. Gram-negative bacilli, such as *Pasteurella, Actinobacillus, Pseudomonas,* and *Achromobacter* species were also isolated.

Statistical comparisons were made between demographic groups of desert tortoises and frequencies of bacterial isolates. No significant differences were seen between flora of male and female tortoises. However, Gram-negative bacilli were found more often in younger tortoises and from cultures obtained during the third and fourth quarters of the calendar year. Gram-negative bacilli were also more common in tortoises from the northwest section of the valley where intense land development and construction has occurred. The presence of potentially opportunistic Gram-negative bacilli may indicate animals under increased environmental stress and therefore at greater risk for upper respiratory disease.

Population Estimation in Sonoran Desert Tortoise

Christopher M. Klug

Survey data from three 1 mi^2 desert tortoise permanent study plots were analyzed using program "Jolly". This analysis represents the first time that sufficient data have existed to use an open population model to examine Sonoran desert tortoise demography. Chi-square analysis of capture histories showed that subadults and adults had significantly different ($p < 0.05$) capture probabilities than juveniles and immatures. For adult and subadult tortoises, male and female capture probabilities did not differ. Population estimates varied widely by plot. In those years that it was possible to calculate both Lincoln-Peterson and "Jolly" estimates, the 95% confidence ranges usually overlapped at each site. For tortoises $\leq$ 180 mm MCL (adults and subadults) survival rate estimates were not markedly different among plots. For many variables, confidence intervals were broad. Further plot surveys, already planned, should increase the accuracy and precision of "Jolly" estimates.

Thin-Plate Splines: A Novel Technology for Modeling Desert Tortoise Populations on Landscape and Regional Scales

Anthony J. Krzysik, Kevin C. Seel, Scott A. Tweddale, and Helena Mitasova

Conservation biologists and resource managers are becoming increasingly aware of the desirability and importance of modeling and monitoring metapopulations on landscape and even regional scales. Geographic Information Systems (GIS) and associated spatial analysis tools represent the platforms to conduct such analyses. Desert tortoise populations represent excellent subjects for developing and testing spatial modeling tools on landscape scales. The species is found throughout the Mojave Desert, but local distribution and density patterns are highly patchy, reflecting true metapopulation structure. This patchy structure of tortoise populations on landscape scales is the combined result of habitat suitability, elevation, climate, natural barriers, historical events, and a long list of recent anthropogenic impacts, including the spread of URTD.

Spline techniques develop surface functions that interpolate and smooth discontinuous data points such that the generated surface represents the minimum deviation from the original data. These generated surfaces can represent multidimensional vectors derived from univariate or multivariate operations on any set of environmental parameters. Three dimensional representations can be displayed as one of the database layers in a GIS. Thin-plate smoothing splines with tension are defined, and demonstrated to model the distribution and density patterns of desert tortoises on landscape scales as determined by large scale U.S. Army training exercises.

The Recovery Plan and Population Management of the Critically Endangered *Pseudemydura umbrina*

Gerald Kuchling

The ephemeral clay swamps north of Perth, in the Swan river coastal plain just below the Darling range, nearly disappeared due to agricultural, industrial and urban development. The reason why two small patches of this unique habitat still exist is one of the rarest and most endangered chelonians of the world: the Western Swamp Turtle, *Pseudemydura umbrina*, which represents a monotypic genus and subfamily of side-necked turtles. Its habitats are clay pans and sink holes which are covered with bush-land and which contain water only for 5-6 months of the year, during winter and early spring (May/June to November). The animals are only active in water and aestivate (are dormant) when the swamps are dry. Therefore, in this Mediterranean type of climate, they have to feed, grow and reproduce during the cool time of the year, an uncommon pattern for a reptile. *P. umbrina* is only known to occur in two small Nature Reserves, the Ellen Brook Nature Reserve (EBNR, 65 ha) and the Twin Swamps Nature Reserve (TSNR, 155 ha), which were created in 1962 especially for its protection.

The first Western Swamp Turtle known to science was acquired in 1839 by the Museum of Natural History in Vienna, Austria, with its origin vaguely given as "Nova Hollandia". It was not until 1901 that it was described as a new genus and species, *Pseudemydura umbrina*, by Siebenrock. The second specimen was discovered in 1953 by the Director of the Western Australian Museum, Glauert, at the "West Australian Naturalists' Club Wild Life Show" where a Perth school boy exhibited it as his pet turtle which he had found in a swamp north of Perth.

The biology of *P. umbrina* was part of a Ph.D. study (1967) by Dr. Andrew Burbidge who later continued work with the species and communities in Western Australia. His work demonstrated that numbers of *P. umbrina* at TSSNR have dropped from about 200 in the mid-1960's to about 50 in the early 1970's, to near zero by 1985. Over the same period numbers at EBNR remained fairly static at around 20 to 30 turtles. A captive group of 25 turtles had been established in 1959 and was maintained by Perth Zoo.

Adaptations of the Western Swamp Turtle

The Western Swamp Turtle shows several interesting adaptations to its special life style. Females have annual ovarian cycles, but ovulate and produce eggs only when they experience a feeding bout in early spring. In dry years, when food is limited, they do not reproduce and re-absorb the yolk material which accumulates in the follicles. Mating occurs during winter when water temperatures are cool and animals disperse in the flooded areas. Males are larger than females and mount and overpower any smaller turtle. During spring, when temperatures rise and food concentrates in the last puddles of water, mating ceases and the turtles stay close together and feed.

Females oviposit in spring and dig the nest cavity with the front legs, a unique behavior for chelonians. This enables the small females to bury the eggs deep enough into the ground to cope with the hot, harsh and dry summers. Embryonic development takes about three months, but hatching does not occur until five to six months and may be induced by a sudden drop in temperature. This ensures that hatchlings emerge in autumn when the swamps fill with water.

Research on Reproduction and Captive Breeding

When I arrived in Western Australia in 1987 the situation of the species was critical. The wild population was reduced to 20-30 animals in a single population. Only 17 animals remained in captivity, of which three were adult females, and they had not produced eggs for six years. With a total world population of under 50 individuals and no success in captive breeding, *P. umbrina* was close to extinction.

Working at the Zoology Department of the University of Western Australia I developed a method to investigate ovarian activity, follicular growth, ovulation and egg shelling in the oviducts of turtles and tortoises by ultrasound scanning. This method is non-invasive and does not harm animals, of crucial importance when working with the last handful of an endangered species. I discovered why *P. umbrina* did not reproduce in captivity and then initiated and led a crash project to get them again to breed. This first step was successful and 69 captive offspring from the last five years more than doubled the total world population of the species. Since the middle of 1991, Perth Zoo took over the responsibility for captive breeding.

From the start the captive breeding project was funded by World Wildlife Fund-Australia, the Department of Conservation and Land Management, the Australian National Parks and Wildlife Service, and Perth Zoo.

Population Management and Recovery Planning

From 1988 to 1990 population management focused on increasing the world number; all available females were taken in two separate captive colonies to bolster production of hatchlings. In 1991 all animals, including females, from the last wild population at EBNR were returned to the reserve which was secured by a fox-proof fence. Interference with this population is now minimized, only males are removed for short periods during the mating time to copulate with captive females in order to broaden the genetic basis of captive breeding. Genetic fingerprinting was used to assess the genetic variability of individuals and a mating plan ensures that all adult individuals, in captivity as well as in the wild, reproduce and pass on their genes. By 1993, the captive colony reached a total number of 98 animals and the wild population of over 30 animals.

The initial successes of the captive breeding program generated a recovery program for *P. umbrina*. A recovery team was set up in 1990 to coordinate the following actions: 1) management of the wild population at EBNR; 2) captive breeding; 3) re-introduction at TSNR; 4) education, publicity and sponsorship. The recovery criteria until the year 2002 are: 1) increase the number of adults and sub-adults at EBNR from about 30 to more than 45; 2) create a population at TSNR of at least 40 adult and sub-adult turtles; 3) establish and maintain a captive population of at least 50.

The implementation of the recovery program, of which I am the principal investigator, is coordinated by a recovery team which includes members from all funding organizations mentioned above, plus from the University of Western Australia and Curtin University. The program is also supported by the German Bundesverband für fachgerechten Natur und Artenschutz, the AG Schildkröten of the German Herpetological Society, the British Chelonia Group and several companies in Western Australia.

The critical factors which have to be addressed to improve the situation for *P. umbrina* are: 1) existing reserves seem to offer only marginal habitat for the species; 2) an insufficient period of swamp life in years with average of dry winters; 3) sub-optimal aestivation sites in one of the reserves; 4) fire; 5) pollution problems; 6) the loss of drought refuges outside the reserves; 7) unknown carrying capacities; 8) impacts of adjacent land use on water tables; and 8) concentration of predators and predation by the European Red Fox.

The remedial actions until now include: construction of fox-proof fences around the last wild population at EBNR and around TSNR where re-introduction of captive bred animals will start in 1994; purchase of former swamp turtle habitat and its restoration; further negotiations to purchase additional land; construction of a ground-water bore to supplement water to TSNR during dry winters; investigation of reproduction and recruitment of the last wild population; continued captive breeding; successful rearing of hatchlings; and genetic management.

Predation on Turtles in South-Western Australia and Experiences with Three Years of Protective Fencing of the Last Wild Population of *Pseudemydura umbrina*

Gerald Kuchling

The main predators of freshwater turtles in south-western Australia are the introduced red fox and native ravens which increased due to anthropogenic impacts on the land. Predation is mainly directed towards adult females which move over land to nest and towards eggs. In 1991 the last wild population of *P. umbrina* was enclosed by a fox-proof fence in an area of 29 ha. Apart from the fact that the fence restricted habitat movements of some turtles, the exclusion of a main predator caused some unforeseen management problems. In particular, an increase in breeding ducks and in the hatching success of ducklings causes competition for food in critical times of the year. The competition for food reduces the survival chances of turtle hatchlings.

The Clark County Short-Term Habitat Conservation Plan: Are There Lessons to be Learned from this Failure?

Ronald William Marlow and Karen von Seckendorff Hoff

On July 24, 1991, the U.S. Fish & Wildlife Service (Service) issued a Section 10(a) permit to "take" up to 3,710 tortoises during the development of up to 22,352 acres of habitat in the Las Vegas Valley. This permit, one of less than a dozen issued at that time and the first for the desert tortoise was unique in that it proposed as mitigation to "conserve" 400,000 acres of habitat on public land by enhancing management. Mitigation also included spending $500,000 on specific research and relocation projects, and during the 3 year life of the permit produce a long-term Habitat Conservation Plan (HCP) that would substantially increase the area and level of protection for tortoises and other species of concern. In addition "take" was to be minimized by funding a public information program and requiring survey of construction sites and removal of tortoises prior to any land disturbance. Clark County (County) and several of its cities, the Bureau of Land Management (BLM), the National Park Service (NPS), the Nevada Division of Wildlife (NDOW) and the Service entered into a contractual agreement (Implementation Agreement, IA) that outlined and assigned specific obligations. Among other tasks the Service agreed that it would enforce each and every provision of the IA, the HCP and the permit.

Ray Butler and the California Native Plant Society have called for evaluation of the successes and short-comings of HCP's in order that the cautionary tales thus generated would guide us in the formulation of new and better HCP's. As the expiration date for the County's permit approaches it is necessary to examine compliance with the specific terms of the HCP documents as well as the real conservation accomplishments of this ground-breaking HCP, the IA and the Environmental Assessment (EA). The County has failed to meet any of its "conserved habitat" bench marks while it has continued to "take". The County has failed to produce a multi-species long-term HCP. It has expended only $26,000 on research and has failed to implement a translocation study. BLM and the NPS have failed to produce a preserve management plan that establishes realistic management objectives that would preserve tortoise populations. The Service has failed to enforce the terms of the HCP, EA, IA or the Permit.

The habitat that has been "conserved" is severely impacted by vehicle traffic on highways, roads and utility access corridors. Traffic level has increased substantially during the life of the permit and resulted in a greater negative impact and "take" of tortoises and habitat in the "preserve" than in the Las Vegas Valley where "take" is permitted. The failure to address impacts to tortoise populations within the "preserve" in a systematic fashion has resulted in tortoise populations in the preserve being less viable now than they were before the permit was issued. Despite boasting by all the signatories the Clark County Short-term HCP has failed to meet the Endangered Species Act test (section 10(a)) to "not appreciably reduce the likelihood of the survival and recovery of the species in the wild". The Clark County Short-term Habitat Conservation Plan is a failure because the Service has not met its obligation to enforce the terms of the HCP, EA, IA and the Permit. The County is now requesting an extension of this Permit and an 8,000 acre "take" increase in the amount of habitat.

Several lessons can be learned from the Clark County HCP: 1) mitigating "take" on private lands by supplementing the budgets of public land managers is risky if it is the mismanagement of the public lands that initially caused the species to be listed, 2) complex accounting of "take", funds, conserved habitat and management actions must be audited by objective and independent sources, 3) if the Service does not have the staff time or the inclination to enforce the terms of the 10(a) permits then the permits should not be issued. The integrity of the ESA requires that the Service attend to the implementation of the terms of 10(a) permits with greater rigor than has been the case in Clark County thus far.

Allozyme Differentiations Among Gopher Tortoises (*Gopherus*): Conservation Genetics, and Phylogenetic and Taxonomic Implications

D. J. Morafka, L. G. Aguirre and R. W. Murphy

The genetic diversity among 18 loci within and among the four species of gopher tortoises was investigated during horizontal starch gel electrophoresis. Within species variation ranged from 2-4% by direct count, and from 2-8% by Hardy-Weinberg expectation. Among the loci resolved, 11-22% expressed variation. The northern and southern populations of *G. polyphemis* could not be distinguished. No fixed differences were observed between *G. agassizii* and *G. berlandieri* as reflected in a Nei distance value of 0.008. These species may be little more than allopatric populations of *G. agassizii*. Differentiation among the remaining species was not extensive. *Gopherus polyphemus* was only slightly distinct from *G. flavomarginatus* being separated by a Nei genetic distance value of only 0.006. The two pairs of species were separated by an average genetic distance of 0.200. The evolutionary rates of divergence were observed to be unequal, especially among *G. polyphemus* and *G. flavomarginatus*. The overall genetic similarity suggests a relatively recent age of origin.

Reproductive Characteristics Of Desert Tortoises At Yucca Mountain, Nevada

James M. Mueller, Kamila R. Naifeh, Danny L. Rakestraw,
Kurt R. Rautenstrauch, and Katherine K. Zander

Abstract. We are monitoring the reproductive success of desert tortoises (*Gopherus agassizii*) at Yucca Mountain and Calico Hills, Nevada, to assess impacts of the Yucca Mountain Site Characterization Project on this species. During 1991 and 1992 we developed methods for finding desert tortoise nests. Thirty-one nests were found in 1992 and 1993. Clutch size ranged from 1 to 10 eggs ($\bar{x}=4.9$ eggs, SD=2.0) and individual egg mass ranged from 17.8 to 41.7 g ($\bar{x}=31.5$ g, SD=4.1, n=147). Time to emergence of first hatchling was 79 to 112 days ($\bar{x}=91$ days, SD=8.4, n=27). Eggs in one nest were eaten by a predator. Eighty-seven percent of the eggs not eaten by predators (n=146) produced viable offspring.

This work was funded by the U.S. Department of Energy, Yucca Mountain Site Characterization Project, under Contract No. DE- AC08-93NV11265.

Preliminary Results of an Evaluation of the Effects of Cattle Grazing on the Desert Tortoise

John L. Oldemeyer, Phillip A. Medica, and P. Stephen Corn

In 1993, we initiated a study to determine if tortoise abundance or vegetation characteristics varied with distance from stock watering tanks. We hypothesize that tortoise density or growth rates will increase as distance from water increases because cattle tend to center their activities around water. The effect on tortoises may be indirect and manifested through changes in food and cover. Further, because desert vegetation recovers slowly from disturbance, any patterns that occur should be detectable even if cattle have been removed from the allotment within the past few years. In 1993, tanks were studied at upper Mormon Mesa and in the Piute Valley near the LORAN towers and Ten-mile Well. Only the Mormon Mesa site was being grazed in 1993. Preliminary analyses indicate that the abundance of tortoises and characteristics of vegetation vary considerably without relationship to water.

Role of the National Biological Survey in Desert Tortoise Research

John L. Oldemeyer, National Ecology Research Center

Creation of the National Biological Survey resulted in the placement of all Department of the Interior desert tortoise research biologists into one bureau, whereas they previously had worked for three. Most are in one agency, the National Ecology Research Center, where Bureau of Land Management biologists from Riverside and Palm Springs, California; Las Vegas, Nevada; and St. George, Utah were placed with Fish and Wildlife Service tortoise researchers. Although this type of organizational change removes researchers one step further from land managers, it has advantages: 1) National Ecology Research Center tortoise biologists are not now as constrained from crossing state boundaries as they were when working in the management bureaus; 2) the critical mass of desert expertise has increased, resulting in an organization better capable of addressing a wide variety of issues of tortoise and desert ecology; and 3) range-wide issues may now be examined and integrated more easily. The first step to integration of the BLM and FWS research programs was to begin development of a strategic plan. This plan will identify the mission of the Desert Tortoise Research Project, will identify goals that support the mission, and objectives to achieve each goal. Prior to finalizing the strategic plan, input from the desert tortoise Management Oversight Group will be obtained to assure that informational and organizational needs of management are met.

Selecting An Appropriate Method For Calculating Desert Tortoise Home Range Size And Location

Kurt R. Rautenstrauch and Eric A. Holt

Abstract. We are comparing the movements of potentially affected and unaffected (control) desert tortoises (*Gopherus agassizii*) to evaluate the effects of the U.S. Department of Energy, Yucca Mountain Site Characterization Project, on this species. The methods we choose to summarize and quantify movements must provide meaningful estimates of the locations of home ranges and unbiased indices of their sizes. In addition, the methods must provide these estimates using a reasonable number of locations and must have assumptions that are not violated by the movement patterns of desert tortoises. To select an appropriate method for quantifying movements, we compared the sample size requirements, assumptions, and results of six methods using 64 sets of locations. Each of these data sets contained ≥60 locations of one tortoise during one activity season (i.e., the period starting when a tortoise exited its hibernaculum in the spring and ending when it entered its hibernaculum in the fall). Dates of locations were distributed evenly throughout the activity season.

We concluded that the 100% minimum convex polygon is a valid method for identifying the maximum area used by tortoises at Yucca Mountain during one year if those tortoises were located ≥60 times during an activity season. Only 25% of the 64 data sets met the assumption of this technique that locations are distributed uniformly throughout the home range. Therefore, the minimum convex polygon method should not be used to identify core areas or answer other questions that require removing outer proportions of the locations. The sample size correction factor presented by Jennrich and Turner (1969) overestimated home range size by as much as 200% and should not be used for desert tortoise data.

The bivariate normal ellipse (Jennrich and Turner 1969) and weighted bivariate normal ellipse (Samuel and Garton 1985) calculations should not be used to calculate home range size of desert tortoises because they are based on an assumption that is not met by the movement patterns of desert tortoises we studied. These techniques assume that an animal uses the arithmetic-mean center of its home range the most and the probability of it being found at distances from that center is based on a bivariate normal function. Only 5% of 64 data sets met that assumption. In addition, >80 locations were required to obtain precise estimates of home range size for all of the data sets.

The general pattern of movement of desert tortoises at Yucca Mountain is to use an area centered around a burrow or group of burrows for a time and then move to other, sometimes distant groups of burrows throughout the activity season. It is therefore important to obtain locations throughout the season. Home range calculations that allow multiple centers of activity fit this pattern of movement better than those which calculate only one activity center, such as the minimum convex polygon and bivariate normal ellipse. Three techniques to consider are the cluster method (Kenward 1987), harmonic mean analysis (Dixon and Chapman 1980), and kernel analysis (Worton 1989). The techniques all require a relatively large (>60) number of locations for desert tortoises at Yucca Mountain.

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Correlation of the Presence of Antibodies to *Mycoplasma agassizii* with the Presence of Clinical Signs in 144 Desert Tortoises from Las Vegas Valley

Isabella M. Schumacher, Elliott R. Jacobson,
M. B. Brown, Paul A. Klein and D. Bradford Hardenbrook

In 1990 blood samples were taken by jugular venipuncture from a total of 277 wild, free-ranging desert tortoises (*Gopherus agassizii*) from Las Vegas Valley, Nevada for baseline studies. Surplus plasma from 144 animals was stored frozen until June 1993 when it was tested for antibodies to *Mycoplasma agassizii* using an enzyme-linked immunosorbent assay (ELISA). Chi-square analysis was used to identify the relationship between clinical signs and ELISA results. A P value of 0.05 was considered significant.

Of the 144 tortoises tested 72 (50%) were seropositive and 72 (50%) were seronegative. Clinical signs compatible with upper respiratory tract disease (URTD) were seen in 45 (31.2%) of the tortoises. There was a significant correlation ($P < 0.0001$) of clinical signs with a positive ELISA result. Of 28 tortoises with nasal discharge, alone or in combination with other signs, 26 (92.9%) tested positive for exposure to *M. agassizii* ($P < 0.0001$).

These results show that tortoises which exhibit clinical signs compatible with URTD have also been exposed to *M. agassizii*. The presence of nasal discharge seems to be a good indicator for a possible *M. agassizii* infection. However, it can not be concluded that only animals which show clinical signs have been exposed to this pathogen, since 33 (22.9%) tortoises tested seropositive without showing signs of the disease at the time of blood collection.

Of the 7 (4.9%) tortoises with clinical signs that tested seronegative, only 2 (1.4%) had nasal discharge. The others were seen with wet noses, labored breathing or making wheezing sounds. Different pathogens, like *Pasteurella testudinis*, have been found in tortoises and could be responsible for the clinical signs in *M. agassizii* negative animals. It is also possible that the very low cutoff that was used to define seropositive animals in the ELISA, to avoid false negative results, may still be too high.

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Implementation of Desert Tortoise (*Gopherus agassizii*) Recovery in Nevada

Sidney C. Slone

The Bureau of Land Management administers 3.5 million acres of the approximately 5 million acres of desert tortoise habitat in Nevada. Beginning with the *Desert Tortoise Habitat Management on the Public Lands: A RANGEWIDE PLAN*, the Bureau has attempted to take steps initially to reduce the need for listing the desert tortoise and later to take appropriate actions of eventual recovery. Within Nevada, local, State and Federal processes are operating concurrently, which, once completed, will cumulatively result in benefits to the desert tortoise. The USFWS has designated critical habitat and will shortly complete the *Desert Tortoise Recovery Plan*. Clark County, in cooperation with both incorporated and unincorporated communities, developers, State agencies, and public land user groups, is developing the *Clark County Desert Conservation Plan* with a major emphasis on desert tortoise conservation and recovery. The Bureau is close to completing the *Proposed Final Stateline Reserve Management Plan* and initiating an amendment to the *Caliente Management Framework Plan*, both of which will incorporate many of the recovery actions identified in the Recovery Plan. Ultimately, the Bureau's land use plans will include recovery actions identified in the *Desert Tortoise Recovery Plan* with funding support through Clark County's *Desert Conservation Plan*.

Preliminary Correlation between Coprophagy, Growth and the Bacterial Parasitic Intestinal Biota in Neonatal Desert Tortoises, *Gopherus agassizii*: An Experimental Study

D. E. Soleymani, E. Treviño, D. J. Morafka , M. A. Joyner , and M. Dezfulian

The four treatment groups (A-D) of *Gopherus agassizii* consisting of captive neonates were maintained on a standard diet formulated from calcium enriched alfalfa (19% protein). The four groups differed their exposure to adult tortoise feces in their diets. Group A served as a control, receiving tortoise chow and no adult feces. Group B were offered autoclaved sterile feces from captive adult tortoises as a dietary supplement in their standardized tortoise diet. Group C was provided untreated fresh feces from wild tortoises in their tortoise diet. Group D was provided captive but unsterilized adult tortoise feces in the standard tortoise diet, as group B. Their feces were monitored for bacterial and parasitic loads. Their growth and survivorship were recorded monthly for one year.

A total of 19 microorganisms was isolated from the intestinal contents of four treatment groups (A-D) of *Gopherus agassizii*. The microorganisms included thirteen aerobic bacteria identified as *Escherichia coli*, *Citrobacter freundii*, *Klebsiella oxytoca*, *Klebsiella pneumonia*, *Shigella flexnera 6*, *Entrobacter agglomerans*, *Salmonella enteritidis*, *Staphylococcus aureus*, *Arizona* sp., *Providencia* sp., *Branhamella* sp., *Erysipelothrix* sp., *Proteus* sp., and two parasitic protozoa including *Entamoeba* sp., and oocyst typical of *Isospora* sp., as well as four following parasitic helminths, ascarid ova, oxyurid ova, *Strongyloides* ova, and *Physalopetra* ova. However, in control group A, more organisms were found than in groups B-D. The results of the present study indicate that coprophagy through the first year could be adaptive rather than incidental. Fecal inocula may introduce and stabilize a relatively benign microflora. This complement may also play a critical role in the production of VFA and other essential nutrients for the host.

Spring Foraging Behavior, Movements, and General Activities of Two Adult Female and Immature Desert Tortoises near Kramer Junction, San Bernardino, California

E. Karen Spangenberg

The food preferences and daily movements of two immature and two adult female tortoises were observed and recorded from April 21 to June 25, 1993, at a study site southeast of Kramer Junction, San Bernardino County, California. Individuals of both age classes were observed to compare forage plant preferences and tortoise utilization of activity areas. A total of 23,479 bites were recorded and 35 foraging trails measured and mapped. Thirty-three species of plants were eaten. The top ten species of plants observed to be eaten by each tortoise comprised a range of 93-99% of their diets. There was little overlap of food plants between the four tortoises. Twelve species were consumed by only one animal. Tortoises were active above ground 34 out of 35 days observed. When morning and afternoon activity periods were considered together on a daily basis, they emerged from their burrows or cover sites 77% of the time. If a tortoise left the cover site where it had spent the night, it would go to another cover site 36 % of the time. One immature tortoise made a long-distance movement of more than 7 km. Long-range movements need to be considered in planning desert tortoise preserves.

Controlling Competition for Forage between Desert Tortoise and Domestic Stock

C. Richard Tracy, Peter F. Brussard , and Todd Esque

We have used laboratory and field data to determine the quality and quantity of forage required by desert tortoises. We assembled data from several studies, including some of our own (these studies were conducted throughout the range of the Mojave desert tortoises), to learn that adult desert tortoises have much larger home ranges when tortoises do not have much forage within their habitat. Furthermore, still another synthesis of data from several studies shows that females do not produce as many eggs when forage is sparse. The level at which these detrimental changes in forage availability occur is approximately 3 grams of dry forage per square meter which is very sparse vegetation. We assembled data on forage production throughout the Mojave, and we determined that forage levels below 3 g/m^1 occurs in different frequencies in different parts of the Mojave. However, these low levels of forage occur periodically throughout the Mojave, indicating that desert tortoises naturally endure years in which they do not achieve full reproduction. We calculated the forage consumption by cattle on the Beaver Dam Slope and determined that cattle grazing exacerbates natural periods of inadequate forage for tortoises. From these data and analyses, we have proposed that cattle grazing should be controlled to occur only when it does not cause food-resource competition with desert tortoises. We have drawn up a protocol for cattle grazing that protects desert tortoises from competition with domestic grazers, and provides for grazing by cattle. This protocol would permit cattle grazing at generally reduced levels in the Eastern and Northeastern Mojave where forage production is particularly low normally. It would also restrict grazing in the Western Mojave, but not nearly as greatly.

Patterns of Fire Incidence and Implications for Management of Desert Wildlife Management Areas

C. Richard Tracy

With the help of the personnel from the Bureau of Land Management, we have analyzed the occurrences of fires in the Mojave during the 1980's. Fires have increased in frequency in some areas, and decreased in others. Increases in fire frequency are clearly related to human activity both because increases in fire frequency are not related to natural fires from lightning strikes, and also because fires tend to occur much more frequently around towns and roads. Fire is implicated in changes in vegetation in the Mojave that is generally detrimental to desert tortoises. The patterns of occurrence of fires suggests conservation needs for the proposed Desert Wildlife Management Areas.

Optimal Foraging in Desert Tortoise

C. Richard Tracy and Todd Esque

We have combined models of optimal foraging and optimal digestion into a comprehensive model of optimal resource acquisition. From this model, we learn that the energetic value of different food types for vertebrate herbivores is not constant. Instead, at each time a herbivore switches to new food type, that switch causes a change in the resource base for the endosymbionts which are responsible for digestion of the fiber in the herbivore's diet. This change in the resource base results in (a) a change in the gut endosymbiont community, (b) a transient reduction in efficiency of the gut to digest the new food type, and (c) a reduced energetic value of the food type. Thus, switching food types carries an energetic cost. This cost of switching leads to the prediction that herbivores should avoid switching food types unless the time-integrated cost of switching is less than the time-integrated cost of searching for a new food type. This prediction suggests that, under some circumstances, herbivores will appear to specialize on particular food items, but that different individuals may not "specialize" in the same food type(s). This pattern is exactly that found from an analysis of observations from more than 150,000 instances of biting (and eating) food items by desert tortoises (*Gopherus agassizii*). We conclude that a new form of foraging (avoiding switching among food types taking precedent over a search for food types with the highest energy content) explains the pattern of feeding by desert tortoises. We also conclude that this foraging mode should occur in all vertebrate herbivores when the digestive cost of switching food types is greater than the cost of searching for a new food type.

A Community-Based Tortoise Reserve Design for Rancho Sombreretillo and the Bolson Tortoise, *Gopherus flavomarignata*

Eddie Treviño, David J. Morafka, and Gustavo Aguirre

The tortoise occurs at Rancho Sombreretillo in the state of Chihuahua, (27°24'58" N and 103°58'15" W, Elevation 4148 feet), and situated along the northern edge of its current range that contains several demes of these tortoises as a potential reserve dedicated, in part, to tortoise conservation. Under IUCN sponsorship, a team of U.S. and Mexican investigators have been assessing the genetic and ecological distinctiveness of a population of the endangered Mexican bolson tortoise, *Gopherus flavomarignata*.

Habitat quality at Rancho Sombreretillo had deteriorated since the late 1980's due to increased cattle grazing. Cattle densities had increased, partially as a result of expanded pumping of underground water to local troughs and reservoirs. However, tortoise populations remained robust, with ample evidence of nests, hatchlings, and juvenile age size classes.

In August 1992 carapace samples confirmed that Sombreretillo tortoise yellow pigments are largely confined to the marginals, especially in sub adult to adult individuals. Juvenile carapaces presented more extensively distributed yellow than previously reported.

Starch gel electrophoresis of frozen whole blood identified 18 isozymes (presumptive gene loci) through differential staining and mobility. No differences in allozymes were found between the northern (Sombreretillo) population and the better studied southern population from the Mapimi Reserve in Durango. Not only were fixed differences absent, but allozyme frequencies were identical. Generally, indices of polymorphism/heterozygosity were much lower for the bolson tortoise than for any of its three congeners. The close relationship of this species to the gopher tortoise, *G. polyphemus*, was confirmed, again by the absence of fixed allozyme differences.

The IUCN team concludes that Rancho Sombreretillo is still suitable and appropriate as a bolson tortoise reserve. The options of: 1) purchase, 2) lease, 3) easement, and/or 4) cooperative agreements are reviewed here. The latter is recommended as most effective because it will generate local community support, involve less investment, and because outright land acquisition would be exploited by local poachers if subsequent patrolling proves inadequate.

Conservation Problems of *Geochelone chilensis* in Argentina: Livestock Grazing

Tomás Waller

Geochelone chilensis (sensu lato) dwells throughout semi-xerophitic forests (Chaco) and desert shrublands (Monte). Both combined illegal collection for the pet trade and habitat modification impacts on their populations. Forests and deserts are affected by free ranging livestock, mainly goats, but also bovines and sheep. Low tortoise densities and biased population structures correlates with livestock presence. Domestic animals impact on *Geochelone* in the following ways: spring time ephemerals and summer fruits are more efficiently consumed; bushes are sometimes seriously reduced by foraging and, whatever survives, falls prey to local burning practices, diminishing the overall diversity of perennials which rarely recovers due to the damage to the emerging shoots; fire also kills tortoises, and trampling destroys tortoise burrows and could also affect plant regeneration in compacted soils. The result of this total process is an overall reduction and fragmentation in primary tortoise habitat.

Conservation Problems of *Geochelone chilensis* in Argentina: Trade

Tomás Waller

Since the 1950's, hatchlings and young specimens are being captured to be sold as pets in major cities within this country. In spite of being protected, it has been estimated that around 20,000-50,000 tortoises, coming from two provinces, are consumed annually by the internal market, mainly Buenos Aires. In the past, annual exports accounted for about 5-10% of this figure and were allowed because of the establishment of two hatcheries. As of 1989 CITES MA stopped authorizing these exports, after taking into account the doubtful nature of these breeding centers. In spite of restrictive measures, the permanent existence of a consumer market, led to a continuous illegal internal trade of thousands of specimens throughout Argentina. Different institutions have started to discourage this market by promoting the release of captive and confiscated animals. In the future, this practice could have negative consequences for wild populations (i.e. spread of disease and translocation of species). The local impact of collecting activities, consumption as foodstuff and releasing practices should be assessed and new releases discouraged.

The Ecology and Population Attributes of *Geochelone chilensis* in Argentina: Trade

Tomás Waller and Patricio A. Micucci

Geochelone chilensis dwells throughout semi-xerophitic forests and desert shrublands in the phytogeographical provinces of "Chaco" and "Monte". The distribution area covers approximately 30% of the argentine continental territory. Local studies suggest contiguous distribution with medium to low densities and adult biased populations, associated with primary habitat defined by relief, soil and vegetation structure in direct relation with livestock presence. Differences are observed in the use of the habitat by northern and central populations as compared with those found in the south (i.e., the latter build true burrows instead of shallow pallets, even under basaltic blocks in volcanic areas). The diet analyzed via feces in terms of volume, weight or frequency of items, always reveals a predominance of ephemerals in spring and graminac in summer, though fruits and leaves of different species are commonly found in summertime. The greater activity is found during the local spring with a certain lethargy observed in the middle summer which is more pronounced in winter. Courtship and copulation occur in springtime, the layings--up to 3 per season--take place during the local summer with intervals of one month approximately. The number of eggs per laying--up to 7--seems to be positively correlated with latitude; usually 2-3 eggs in northern populations vs. 4-5 eggs in southern ones. Incubation takes just over one year, apparently due to embryonic overwintering. Morphometric analysis shows differences between sex and among populations: females are greater than males and southern and western populations are bigger in size than northern ones. The species is strongly parasitized by three different species of ticks of *Amblyomma* genus (*Acarii:* Ixodidac) only in the center and north of Argentina. Main predators of adult specimens are big raptors and occasionally foxes and cougars; young and eggs are commonly taken by foxes, skunks, armadillos and Tegu lizards.

The Effects of Annual Precipitation and Raven Predation on the Desert Tortoise: Models Drawn from the New Goffs Life Table

Michael Weinstein

Using the recently revised and updated life table for the Goffs, California desert tortoise population, we modeled the effects of different rainfall regimes and raven predation levels on the ability of a cohort of females to replace itself through reproduction.

Preliminary analyses showed that food availability and/or water availability influenced clutch sizes, number of clutches per year, growth rates, and survival rates of tortoises. We made a series of assumptions and derived quantitative relationships between these effects and annual rainfall amounts. Using actual precipitation amounts for the past 80 years, we modeled the fate of three cohorts of female tortoises hatched in three successive years. The results showed that rainfall conditions during the first 2-3 years of the cohort's existence determine that cohort's ability to replace itself. If a cohort hatches during a period of average or above average rainfall, it can produce more than enough eggs to replace itself. A cohort hatched a year or two earlier or later, however, in a period of poor precipitation, may not be able to replace itself. For example, a cohort of 10,000 female tortoise eggs hatched in 1912 would be predicted to produce 18,985 eggs (or 1.9 female eggs per original female egg in the cohort), leading to a population increase of 2.1%. A cohort hatched a year earlier in 1911 (after one year of low rainfall) would produce 1.3 eggs per original egg, equivalent to a population increase of 0.9%. A cohort hatched in 1910, beginning with two poor rainfall years, would only be predicted to produce 0.96 eggs per original female egg, for a population decline of 0.12%.

Raven predation was modeled by using a conservative estimate for the number of small (< 100 mm carapace length, measured at the mid-line) tortoises taken by a nesting pair of ravens in a year. We then superimposed this additional source of mortality onto the actual mortality rates derived for the life table. Our results showed that a single pair of ravens hunting over a one square mile area of tortoise habitat would seriously impair the ability of those tortoises to replace themselves, thereby impairing the population's ability to maintain its density over time. When applied to the overall life table (using mean values of growth and survival for the period 1977-1990) a cohort of 10,000 initial female eggs would live to produce only 500 female eggs (or 0.05 eggs per initial egg in the cohort). If this continued, the population would decline at a rate of approximately 9% per year. Even for a cohort begun during a period of high rainfall, the number of female eggs would decline from 1.54 eggs per individual as predicted by the model with average levels of mortality, to only 1.19 female eggs for the cohort with a single pair of ravens adding to the mortality rate. This is equivalent to a population increase of 0.57% per year, as opposed to an increase of 1.45% for the same cohort without the raven predation.

The Desert Tortoise Program For The Yucca Mountain Site Characterization Project

Danny L. Rakestraw, Kurt R. Rautenstrauch, and James M. Mueller

The Yucca Mountain Site Characterization Project (YMP) is a study coordinated by the U.S. Department of Energy (DOE) to determine if Yucca Mountain, located about 180 km NW of Las Vegas, Nevada, is a suitable site for long-term, geologic storage of high-level nuclear waste. Since 1982, DOE has taken actions to minimize impacts from this project on desert tortoises (*Gopherus agassizii*) in the area. Following the federal listing of the desert tortoise in 1989, DOE initiated a set of studies and procedures with the common goal of conserving desert tortoises in the Yucca Mountain area. The objectives of the program are to evaluate and mitigate impacts of YMP activities on desert tortoises, develop and test the efficacy of mitigation techniques, and obtain site-specific information on desert tortoise biology needed to achieve these other objectives. Most site characterization activities will be similar to mining activities and will result in two distinctly different types of disturbances. First, there will be many small (< 2 ha each) disturbances such as drill pads, study pits, access roads, and powerlines. Second, there will be a small number (3-5) of large (> 2 ha) disturbances. After reviewing project plans and descriptions of the types of disturbances anticipated, we separated potential impacts of these disturbances into two categories: direct or immediate impacts (e.g., habitat loss or death due to burial or crushing) and indirect or cumulative impacts (e.g., habitat fragmentation, altered forage availability). The Desert Tortoise Program is divided into two suites of interrelated procedures and studies, each of which addresses the different types of impacts anticipated.

IMMEDIATE, DIRECT IMPACTS

Since most immediate, direct impacts are readily identifiable, we evaluate and mitigate them individually for each surface-disturbing activity. Prior to each land-disturbing activity, we conduct surveys to find desert tortoises and their burrows that may be impacted by the activity. To minimize or mitigate potential impacts, we may recommend any of the following actions: worker education (required for all activities), flagging and avoidance of burrows, relocation or redesign of the activity, monitoring of radiomarked tortoises near construction, and displacing tortoises within their home ranges or to areas outside their home ranges.

For small activities, flagging and avoiding burrows and monitoring nearby radiomarked tortoises during construction activities are often adequate measures to minimize impacts on tortoises. Rarely will small activities result in a loss of a large portion of a tortoise's home range. However, in areas where large disturbances will occur, mitigation of impacts often is more difficult. In these areas, we radiomark and monitor tortoises for 1-2 years prior to the beginning of the disturbance to determine movements and habitat use of resident tortoises. We then use this information to determine which tortoises should be moved and to where they should be moved.

In addition to surface disturbances, YMP will cause an increase in vehicular traffic and will cause ground motion during seismic studies and when explosives are used for excavation. We compile sightings of tortoises on roads and, at least once each year, identify mitigation measures necessary to minimize tortoise mortalities along roads. To monitor the impacts on tortoises from ground motion, we monitor the behavior of radiomarked tortoises and the integrity of tortoise burrows near ground- motion-causing activities before and after the activities.

CUMULATIVE, INDIRECT IMPACTS

Cumulative, indirect impacts of YMP on desert tortoises are more difficult to identify and mitigate than direct impacts. To adequately assess these impacts, many parameters must be measured over a long period and these parameters must be compared between potentially affected and unaffected samples. Parameters we are monitoring include movements and habitat use, reproduction, survival, health, diet, and raven populations.

We have developed six studies to evaluate these parameters. The studies evaluating the first five parameters listed above share a common design. The sampling unit for these five studies is the radiomarked tortoise. We radiomarked tortoises during 1989-1991 in areas that represent three levels of potential impacts from YMP. First, we radiomarked tortoises for a "high- impact" sample in areas where large, long-term disturbances were proposed. Second, we radiomarked tortoises for an "area-wide" sample from throughout Yucca Mountain. These tortoises may be affected by the many smaller activities scattered throughout the area. And third, we radiomarked tortoises for a "control" sample in an undisturbed area east of Yucca Mountain. We are monitoring >20 adult tortoises from each sample and are comparing various measurements of each parameter among the three treatments.

Tortoises may react to disturbances by leaving the area, restricting their movements to undisturbed areas, or changing their patterns of activity and habitat use. These behavioral responses may be the most easily identifiable changes caused by YMP activities. Through the Movements and Habitat Use Study, we are measuring changes in home range size, center of activity, percent of time active, number of burrows used, and duration of hibernation. We locate radiomarked tortoises twice each week during the activity period and every other week while they are hibernating. We record location, cover site type, topography, microhabitat, and behavior of each tortoise.

The Reproduction and Survival studies measure parameters controlling the abundance of the Yucca Mountain tortoise population. Reproduction may be suppressed in periods of stress; therefore, we are monitoring the reproductive output of female tortoises (eggs/female/year). We x-ray female tortoises to determine clutch size and track gravid females using thread-trailing devices. When a tortoise loses weight equal to or greater than the expected clutch weight, we follow the thread trail to locate the nest. We excavate most nests to confirm clutch size and to insert temperature data loggers in the nest to monitor incubation temperatures. We monitor nests to assess nest survival and to capture and radiomark a sample of hatchling tortoises. We locate radiomarked hatchlings 2-5 times per week and adult tortoise twice per week to measure survival.

Through the Health Monitoring Study we assess the health of individuals within the three groups of tortoises by measuring annual growth, condition index, blood profiles, and presence of antibodies to *Mycoplasma agassizii*.

Land-disturbing activities caused by YMP may affect the availability of some forage species at Yucca Mountain. We developed the Food Habits Study to evaluate this potential impact, as well as to select forage species to plant during reclamation of disturbed areas. We are determining the diets of tortoises in the three groups by direct observation of radiomarked tortoises and microhistological analysis of scat samples.

The Raven Monitoring Study is the sixth study in our program. Increases in raven populations have been correlated to increases in human activities and structures in the Mojave Desert. It has been speculated that increases in common raven populations have contributed to declines in tortoise populations in some areas. To monitor changes in raven abundance at Yucca Mountain and to identify what structures are used by ravens, we conduct raven surveys at Yucca Mountain and a control area five times every other month. We record the numbers of ravens and raptors seen, and the location, behavior, and structure used (if any) by each bird.

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