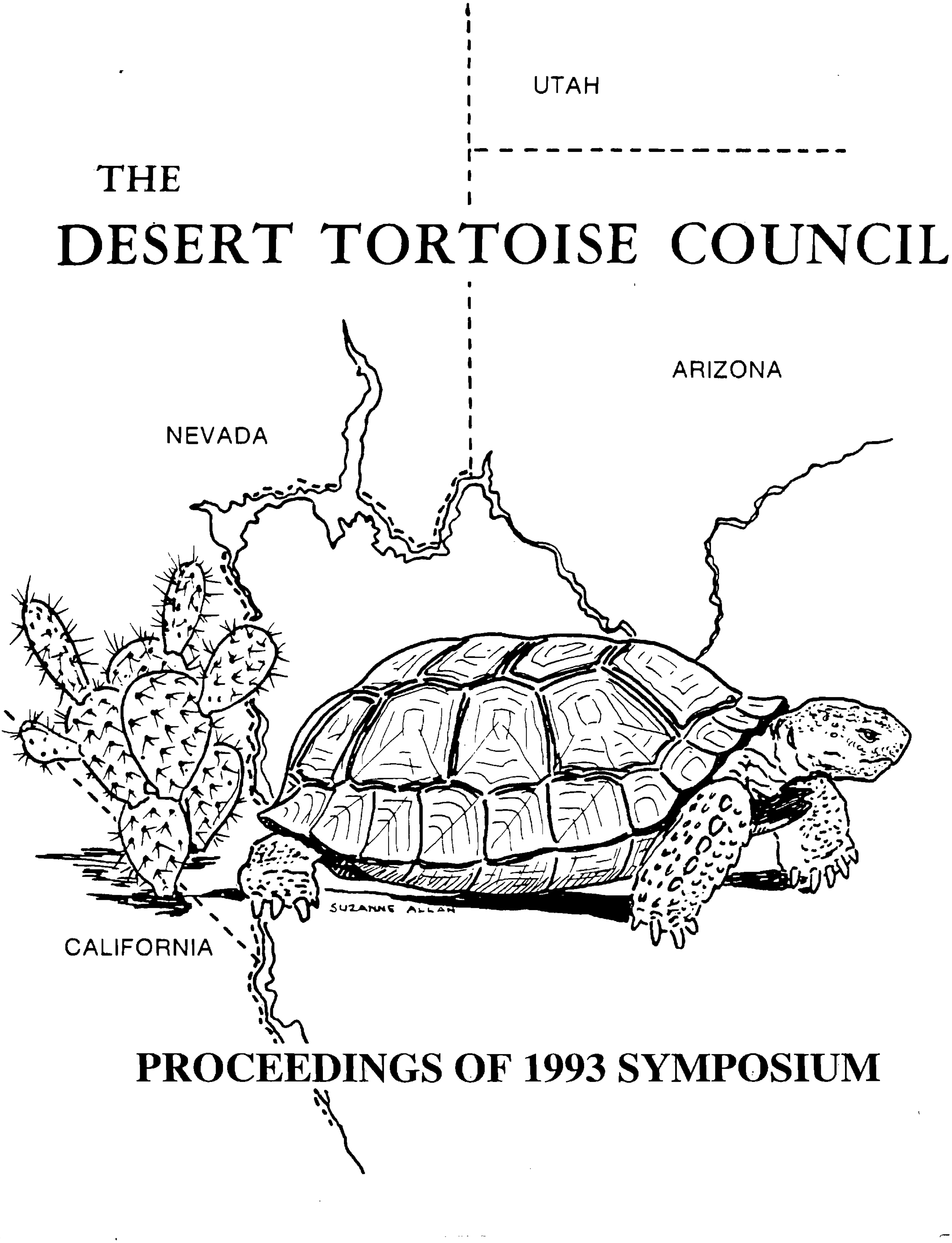
THE DESERT TORTOISE COUNCIL



PROCEEDINGS OF 1993 SYMPOSIUM

DESERT TORTOISE COUNCIL

PROCEEDINGS OF 1993 SYMPOSIUM

A compilation of reports and papers presented at the 18th annual symposium

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THE DESERT TORTOISE COUNCIL

The Desert Tortoise Council is a private, nonprofit organization made up of hundreds of professionals and lay-persons from all walks of life, from across the United States, and on several continents.

The goal of the Desert Tortoise Council is:

> To assure the perpetual survival of viable populations of the desert tortoise within suitable areas of its historic range.

The objectives of the Desert Tortoise Council are:

a. To serve in a professional advisory manner, where appropriate, on matters involving management, conservation, and protection of desert tortoises.

b. To support such measures as will contribute to ensuring the continued survival of desert tortoises and the maintenance of their habitat in a natural state.

c. To stimulate and encourage studies on the ecology, biology, management, and protection of desert tortoises.

d. To serve as a clearinghouse of information among all agencies, organizations, and individuals engaged in work on desert tortoises.

e. To disseminate current information by publishing proceedings and transactions of meetings and other papers as deemed appropriate.

f. To maintain an active public information and conservation education program.

g. To commend outstanding action and dedication by individuals and organizations promoting the objectives of the Council.

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DESERT TORTOISE COUNCIL ANNUAL AWARD FOR 1993

This year's Desert Tortoise Council Annual Award recipient is a very energetic individual who has an outstanding ability to work with a variety of people on very difficult issues. This person devotes full time and then some on tough environmental matters in the California desert both in his private enterprise and through active participation in many professional and community organizations, including the Desert Tortoise Preserve Committee and the California Turtle and Tortoise Club.

A geographer with degrees from U.C. Berkeley, he began his professional career as an environmental protection officer for the Navy and acted as environmental consultant to two California counties. His company now specializes in environmental planning and California Environmental Quality Act compliance projects. Since joining the Council's Board in 1990, he has helped reinvigorate Council activities. Some of his greater accomplishments on complex issues during the last year include:

- Representing several conservation organizations, including the Council, working intensively on the West Mojave Coordinated Management Plan;

- Working very closely with our lawyers to represent the Council's interests with intervention in the California sheep grazers' 1992 appeals of BLM decisions limiting sheep grazing in desert tortoise habitats;

- Actively representing Council interests with groups engaged in litigation to make the U.S. Fish and Wildlife Service determine Critical Habitat for the desert tortoise; and

- When it appeared domestic sheep grazing might be rushed onto West Mojave crucial desert tortoise habitat in the Spring of 1993, tirelessly working with organizations that gained a Temporary Restraining Order and Preliminary Injunction against this Federal activity until Critical Habitat is determined.

By now, many of you have guessed who this year's recipient is. Please join us in congratulating Mr. **Tom Dodson**.

INTERACTIONS OF RANGE CATTLE AND DESERT TORTOISES AT IVANPAH VALLEY, CALIFORNIA: 1993 FIELD OBSERVATIONS

Harold W. Avery and Alexander G. Neibergs

Abstract. Ongoing research at Ivanpah Valley, California involves observing individual radio-transmittered tortoises (*Gopherus agassizii*) by field workers. The primary purpose of the study is to evaluate the foraging rates, determine the important food plants for desert tortoises, and quantify daily time budgets of adult male and female desert tortoises in adjacent grazed and ungrazed areas. During the spring of 1993, additional observations were made on direct and indirect interactions of range cattle and free-living desert tortoises. Observed direct interactions included cattle nudging and rubbing their heads on a desert tortoise foraging near a livestock watering area. Indirect interactions are defined as activities or behaviors which were indirectly influenced by the effects of cattle on tortoise habitat. Indirect interactions observed included destruction of actively used burrows and attempts of tortoises to enter these destroyed burrows, destruction of shrubs associated with actively used burrows, and tortoise consumption of cow dung and soils with presumably high dung and urine content. Implications of direct and indirect interactions of cattle and desert tortoises are discussed within the framework of desert tortoise ecology. Future research on cattle/tortoise interactions must evaluate demographic (e.g., mortality, recruitment), nutritional (foraging time budgets, food competition), behavioral and thermal considerations of desert tortoise ecology.

NUTRITIONAL ECOLOGY OF THE DESERT TORTOISE CONSUMING NATIVE VERSUS EXOTIC DESERT PLANTS

Harold W. Avery

Abstract. Exotic annual and perennial plants have become major components of arid plant communities within certain areas of the desert tortoise (Gopherus agassizii) geographic range. The effects of these exotic plant introductions to tortoise populations have been largely speculative. The objectives of this study were to 1) compare the nutrient content of native and exotic annuals known to be consumed by free-living desert tortoises, and to 2) determine the food preferences of captive tortoises fed exotic and/or native plant species.

Fifteen desert tortoises were used in a diet selectivity trial in outdoor enclosures at The Living Desert, Palm Desert, California. The exotic species filaree (*Erodium cicutarium*) and splitgrass (*Schismus barbatus*) were fed to Group 1 tortoises. The native woody bottlewasher (*Camissonia boothii*) and wishbone bush (*Mirabilis bigelovii*) were fed to Group 2 tortoises. A mix of all four plant species were provided to Group 3 tortoises. Selectivity of forage plants was determined by measuring the consumption rates of each plant species within morning feeding intervals.

There was a significant preference for *Schismus* over *Erodium* in Group 1 tortoises. There was no difference in preference for *Mirabilis* versus *Camissonia* for Group 2 tortoises. Tortoises from Group 3 preferred *Schismus* over all other native and exotic plants when given a choice of all four plants. Nutrient contents for each plant were statistically compared and are discussed. Findings of this food selectivity trial are discussed within the framework of tortoise nutritional ecology and the Nutritional Wisdom Hypothesis.

A COMPARISON OF THE PLANT AND RODENT COMMUNITIES INSIDE TO THOSE OUTSIDE OF THE DESERT TORTOISE NATURAL AREA, KERN COUNTY, CALIFORNIA

Matthew L. Brooks

INTRODUCTION

Livestock grazing and off-highway vehicle (OHV) use are two of the most pervasive forms of human disturbance in the North American deserts. Reduced cover, diversity, and biomass of both annual and perennial desert vegetation can result from livestock grazing (Blydenstein et al. 1957, Pearson 1965, Potter and Krenetsky 1967, Waser and Price 1981, Webb and Stielstra 1979) and OHV use (Davidson and Fox 1974, Vollmer et al. 1976, Webb and Wilshire 1983). Overgrazing can reduce desert plant community diversity (Waser and Price 1981) and facilitate the invasion of weedy, alien, grazing-adapted annual grasses (D'Antonio and Vitousek 1992). Both livestock grazing and OHV use can also hinder seedling establishment by changing soil characteristics (Wilshire and Nakata 1976, Webb and Stielstra 1979).

Human disturbance can also affect first order consumers such as nocturnal desert rodents. Even if the interactions are not direct, decreased plant biomass and seed production due to grazing and OHVs could significantly impact rodent communities. Desert rodent population sizes are correlated positively with yearly variations in primary productivity (Munger et al. 1983, Brown and Zeng 1989) and community species composition varies with plant density, diversity, and cover (Rosenzweig and Winakur 1969, Beatley 1976, Price 1978, Munger et al. 1983). Rodent fitness is augmented by the presence of green vegetation (Bradley and Mauer 1971, Van De Graaff and Balda 1973, French et al. 1974) and rodents rely heavily on seed production for food (French et al. 1974, Price and Jenkins 1986).

The goal of this study was to determine the potential benefits to plant and rodent communities of fenced protection from livestock grazing and OHVs at the Desert Tortoise Natural Area (DTNA). I was particularly interested in determining if fencing, in the absence of any other active land management activities, had any significant effect on the protected biotic communities. Data was collected 11, 12, and 13 years following the completion of fencing; 1990, 1991, and 1992 respectively.

I hypothesized that the following community characteristics differed between the inside and outside of the DTNA: (1) annual plant biomass and diversity, (2) perennial plant cover, density, and diversity, (3) soil seed bank biomass, and (4) nocturnal rodent density and diversity. No specific *a priori* trend directions were indicated since weedy plant species may prefer the more disturbed conditions found outside of the fence while other plant species may favor the protected area inside of the fence. In addition, different rodent species exhibit varied micro habitat affinities which may be associated with either the protected or the unprotected areas. For these reasons two-tailed statistical tests were use in all analyses.

METHODS

The site description and methods are described with more detail in Brooks (1995). Annual plants were harvested in mid-April 1990 through 1992, and above-ground live dry biomass was determined for each species. Perennial plants were censused once in June 1990, using a modified point-quarter technique (Greig-Smith 1964). Soil samples were taken either in January or February 1990 through 1992 and the seeds were separated by flotation (Nelson and Chew 1977). Rodents were trapped on 8 X 8 grids on four to six consecutive nights during March 1990, May 1990, April 1991, November 1991, and February 1992 (6144 total trap nights). All references to significant differences refer to the 95% confidence level.

RESULTS AND DISCUSSION

This study provides data supporting the contention that fenced protection from human disturbance can significantly benefit biotic communities in the western Mojave Desert. Significant trends were detected in annual plant, perennial plant, and rodent community structure.

Annual Plants

Those annual plant species which possessed significantly higher biomass inside of the DTNA were exclusively native, while the two species with significantly higher biomass outside were the alien grasses *Schismus barbatus* (in 1990, 1991, and 1992) and *Bromus madritensis rubens* (in 1992). The combined biomass of the two alien annual grasses mentioned above was significantly higher than the combined biomass of forb species during all three years inside, and only during the third year (1992) outside of the DTNA. The ratio of annual grasses to forbs increased by at least an order of magnitude during each year of the study. A particularly dry 1990 season followed by relatively wet years in 1991 and 1992 is the likely reason for this trend. Alien annual grasses are not well adapted to dry conditions and seem to cycle in relative abundance with peaks following years of above-average rainfall (M. Brooks *unpublished data*).

Alien annual grasses can compete successfully with many native forbs for nitrogen, water, and light (D'Antonio and Vitousek 1992, and references therein), and may alter ecosystem dynamics by changing nutrient cycling and fire regimes (Vitousek 1990, D'Antonio and Vitousek 1992). Although fires have not been as common near the DTNA as they have been elsewhere in the western Mojave Desert (BLM fire records), the potential for burning could increase along with alien annual grass abundance following years of above-average precipitation (Rogers and Vint 1987).

Perennial Plants

The number of shrub species and the overall shrub density were not significantly different between the inside and the outside of the fence. This is not particularly surprising when one considers that Creosote Bush Scrub habitat has been estimated to take from 46 (Webb et al. 1987) to over 100 years (Vasek 1979/1980) to regenerate following disturbance. It is important to note that shrub cover and, to a lesser degree, diversity are higher inside of the DTNA. Even though protection may not influence plant density, the perennial plant community benefits from the exclusion of livestock and OHVs which are known to reduce perennial plant cover (Webb and Stielstra 1979, Davidson and Fox 1974).

Seed Bank and Nocturnal Rodents

Some forms of disturbance can be beneficial to natural communities (Souza 1984), especially if they are intermediate in frequency and intensity (Caswell 1978). Moderate levels of disturbance can minimize competitive exclusion by keeping competitively superior species from dominating a community by limiting their numbers (Nobel and Slayter 1980, Souza 1984). In addition, it has been suggested that grazing may benefit rodent populations by reducing cover (Reynolds 1950, 1958). The present study suggests that the intensity of human disturbance in the vicinity of the DTNA is currently too great and is detrimental to the resident nocturnal rodent community.

Soil seed biomass was consistently lower (significantly in 1991) outside compared to inside of the DTNA. I believe that this is a major reason why the population densities of three rodent species, *Chaetodipus formosus, Dipodomys merriami, and Onychomys torridus,* were found to be significantly higher inside than outside of the fence. In addition, species richness, evenness, and the Shannon-Wiener index were all significantly higher inside the DTNA as well. Even though *Dipodomys merriami* has been shown to prefer more open habitats with lower cover (Reynolds 1950,1958), the population density of this species at the DTNA was higher where plant cover was greatest, inside of the fence. Presumably, other aspects of habitat quality, such as seed abundance, outweighed the preference of *Dipodomys merriami* for areas of low cover and resulted in a higher population density in the protected area.

CONCLUSIONS

Since little pre-fencing data is available I cannot attribute any of the differences observed to recovery *per se*. Continued degradation of the area outside of the fence may have also contributed to the detected trends. I can definitively say, however, that without protection the communities studied would have been negatively affected, and that fenced protection can significantly benefit Creosote Bush Scrub habitat. This paper is based upon the results published in Brooks (1995) and other unpublished data. Additional studies are in progress to determine how bird and lizard populations are affected by fencing at the DTNA. In addition, I am studying the potential micro habitat differences between the inside and the outside of the DTNA which may account for the differing distributions in alien annual grasses and forbs between the two areas.

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FORAGING AND DIET SELECTION IN DESERT TORTOISES: ANNUAL UPDATE ON RESEARCH IN THE NORTHEAST MOJAVE DESERT OF ARIZONA AND UTAH

Todd C. Esque, Lesley A. DeFalco, and C. Richard Tracy

Knowledge of foraging ecology of desert tortoises (*Gopherus agassizii*) provides insight about how tortoises meet their nutritional needs in relation to environmental heterogeneity. Foraging and diet selection were studied at the City Creek Site, Utah and the Littlefield Site, Arizona in the northeast Mojave Desert. The City Creek Site, near St. George, Utah has a rugged and patchy landscape characterized by Navajo sandstone outcrops and valleys filled by aeolian sands. The Littlefield Site is relatively flat and homogeneous, with deeply cut arroyos on the south margin of the site. Soils there consist of ancient alluvium and are predominantly sandy loams with a calcium carbonate hardpan. Both sites receive most of their rain from October to March, but sporadic and localized tropical summer rains occur here. Over the last five years we have addressed foraging and diet selection of desert tortoises by sampling annual vegetation and by observing tortoises while they foraged.

Availability of annual plant species and use by tortoises of annual plants were estimated at both the City Creek Site and the Littlefield Site. We estimated annual plant biomass with one meter-squared quadrats placed within subhabitat types for the fifth consecutive year in 1993. Vegetation was sampled in 1 m^2 randomly located quadrats that were stratified in number by subhabitat types across each study plot. Availability estimates were weighted to account for unequal sampling within subhabitats. In addition to sampling annual plant availability, we observed a total of fifty adult male and female desert tortoises at the two sites. Diets were determined by recording the number of bites of individual plants eaten by tortoises during feeding bouts. We estimated plant species use by counting the number of bites per species in 1 m^2 feeding patches along tortoise foraging paths. Food availability was based on counts of annual plants in randomly placed quadrats and was compared with observations of tortoises foraging to test the hypothesis that tortoises selected diet species at random with respect to plant availability.

Diet selection was analyzed using the alpha preference method. This method uses individual animals as the sample unit and provides a mean alpha preference value for each plant species that tortoises eat. The index range is from zero to one. Plants with low values were avoided and plant species with higher values were preferred. Plants that were not different from the mean alpha value were eaten at random. We included all plant species that had >1% of the bites or occurred in >1% of the vegetation transects to eliminate rare plant species. Alpha values were compared using Hotelling's T^2 test. Multiple t-tests were used to compare all possible combinations of plant species and determine significance between selection of individual species. Bonferonni's inequality was used to correct the critical value of multiple t-tests. Data were analyzed at each site among years and within years. The among years analysis of diet selection was designed to test selection of the plants that were common to the diets of tortoises in all years.

During the five years of study, the diversity of winter annual plants was greater at the City Creek Site, where 65 species were identified, in contrast to only 36 species at the Littlefield Site. Biomass production in the northeast Mojave is tremendously variable. We gathered data during years that represent the entire range of food plant availability in the northeast Mojave Desert and *Erodium cicutarium*), and the perennials did not produce leaves. In contrast, production exceeded 40 g/m^2 at the Littlefield Site in 1992. The Littlefield Site always had greater biomass production than at the City Creek Site (Figure 1).

Bite count studies showed that exotic annual species comprised two out of three of the most commonly eaten species at each site. Based on the number of bites, the top three species at the City Creek Site were *Bromus spp.*, *Stephanomeria exigua*, and *Erodium cicutarium*. At the Littlefield Site the top three species were *Schismus barbatus*, *Erodium cicutarium* and *Plantago spp. E. cicutarium* is an exotic plant that is herbaceous, while *S. barbatus* and *Bromus spp.* are exotic annual grasses.

There was a positive correlation between the number of plant species available and the number of species in desert tortoise diets (Figure 2). This relationship indicates that tortoises will make use of the diversity of plants when they are available. In some cases tortoises used more species than we were able to find in random quadrats. For example in 1991, at the City Creek Site, we found 43 plant species available on random vegetation quadrats, but the tortoises were observed to eat 61 species. Diversity of plants in the diet can be enigmatic: greater plant species availability results in a greater number of species in the diet. However, even though many species are consumed, diets are dominated by only three to four species in any given year when the proportion of plant species in diets were analyzed.

Diet selection was significant in all years at the City Creek and the Littlefield sites (Table 1). After determining the general trend of diet selection, we compared selection among individual plant species. At the City Creek Site, *Erodium cicutarium* was always preferred in significant comparisons, but *Bromus rubens* was preferred once and avoided once. The only native annual that was significantly preferred in among years comparisons, at City Creek, was *Cryptantha micrantha*. At the Littlefield Site *Erodium cicutarium* was always preferred when it occurred in comparisons (similarly to the City Creek Site). One exotic annual grass (*Schismus barbatus*) was preferred over another (*Bromus rubens*). The native annual forb was preferred over *Bromus rubens* in 1992, but avoided when compared to *Erodium cicutarium* in 1990. In 1991 there were no significant pair-wise comparisons at the Littlefield Site.

Patchiness of food resources in time and space can have an effect on the diet and diet selection of tortoises. As management strategies for recovery of tortoises are developed it may be important to manage for annual species diversity as well as perennial shrub cover. Multiple year studies should be considered, because the variability of weather in the Mojave Desert affects forage availability and diet. Single year studies or studies of short duration may provide erroneous conclusions about diet and selection. Intensity of sampling can also affect the results of bite count studies. There was a positive relationship between the number of bites observed for individual tortoises and the number of species observed in their diets. Therefore, small sample sizes of observations could lead to under representation of the number of plant species in the diets of tortoises. Rare plants in the diet also add to variability of the diet of tortoises. Clearly, diet and diet selection are dynamic among sites and years in the Mojave Desert. Diets depend on the year in which research is conducted, the intensity of sampling, and probably some aspects of physiological ecology that have not yet been elucidated.

Author's Note: For a thorough analyses of these and more recent data see: Esque, T.C. 1994. Diet and diet selection of the desert tortoise (*Gopherus agassizii*) in the northeast Mojave Desert. Master's Thesis. Colorado State University. 243 pages.

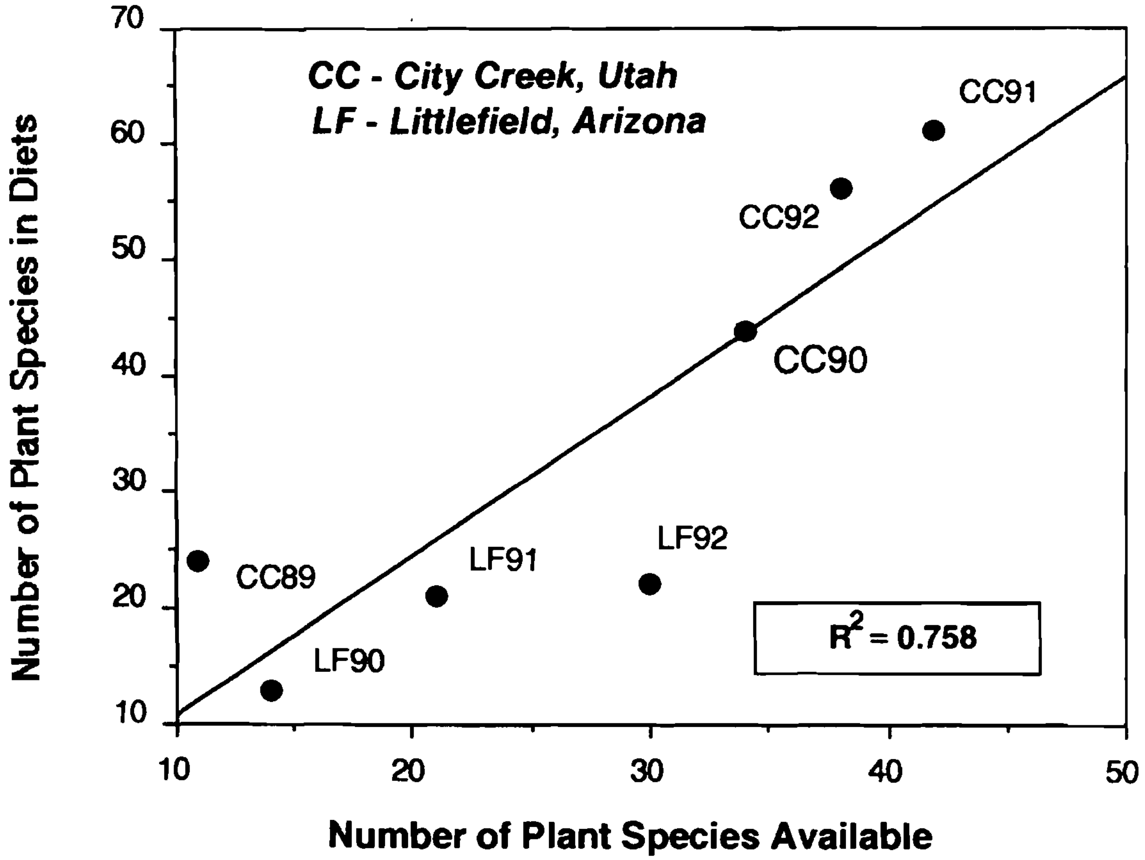

Figure 1. Relationship between the number of plant species present in desert tortoise habitats and the number of plant species in tortoise diets at the City Creek Site and the Littlefield Site in 1989 to 1992.

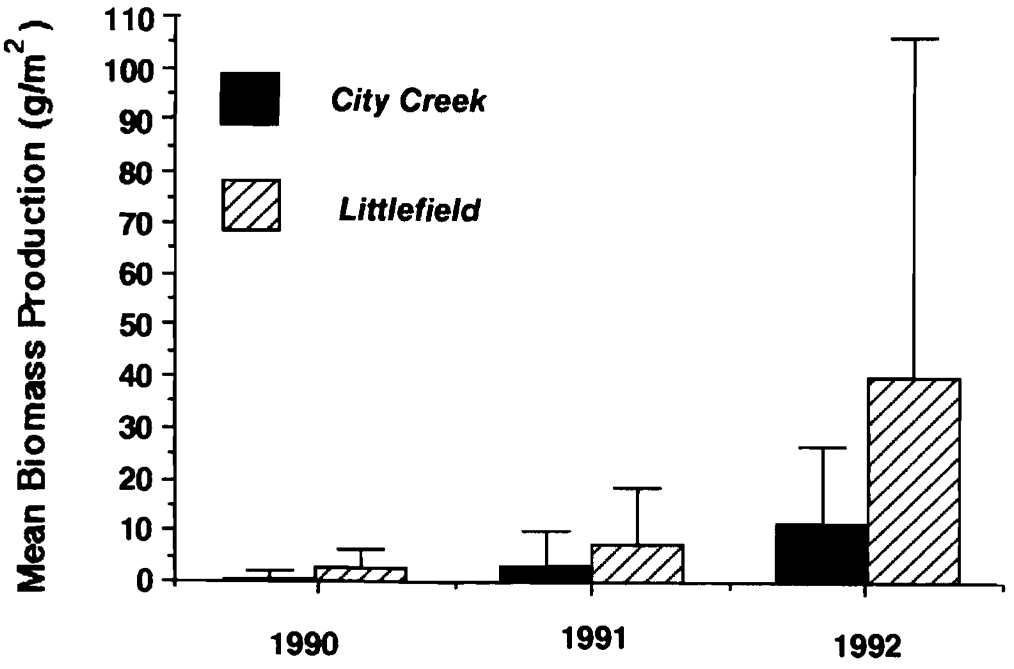

Figure 2. Among site (within years) and among years (within site) comparisons of mean aboveground dry biomass production estimates (error bars are one standard deviation from the mean) of spring annual vegetation at the City Creek and Littlefield Sties in 1990 to 1992.

Table 1. Diet selection for plant species that occurred in greater than one percent of bites and vegetation transects in all years* at the City Creek Site, Utah and the Littlefield Site, Arizona.

Site	Year	F-statistic	Degrees of Freedom	P-value	Number of Animals
CITY CREEK	90	3.6	4, 4	0.0290	8
	91	8.1	4, 9	0.0050	13
	92	7.2	4,13	0.0030	17
LITTLEFIELD	90	24.5	3, 4	0.0050	7
	91	11.6	3, 5	0.0110	8
	92	27.7	3, 10	< 0.0001	13

* species differed among sites:

The City Creek Site: *Schismus barbatus, Erodium cicutarium, Cryptantha spp., Cryptantha micrantha, and Bromus rubens.*

The Littlefield Site: *Plantago patagonica, Bromus rubens, Schismus barbatus, Erodium cicutarium.*

FORAGING ECOLOGY OF THE DESERT TORTOISE (*Gopherus agassizii*) IN THE WESTERN MOJAVE DESERT, CALIFORNIA

W. Bryan Jennings

Abstract. Food preferences and foraging behavior of the desert tortoise (*Gopherus agassizii*) were studied during the spring of 1992 at the Desert Tortoise Research Natural Area, western Mojave Desert, California. Feeding observations were initiated on 24 March and were continued on almost a daily basis until 21 June, during which time a total of 35,401 bites were recorded from 16 adult tortoises (8 males and 8 females). Comparisons between availability of ephemeral plants and tortoise diet revealed that tortoises were highly selective feeders throughout the spring activity period ($X^2 P=0.0001$), feeding almost exclusively upon succulent, native plants. Seasonal variation in tortoise diet was apparent as tortoises switched food preferences several times to keep pace with the seasonal shifts in the emergence of different ephemeral plant species. Although tortoises were observed foraging throughout the spring, activity was highest from late April to late May and virtually ceased by the third week of June.

NUTRITIONAL CONSTRAINTS ASSOCIATED WITH DESERT PLANTS IN THE EASTERN MOJAVE

O. T. Oftedal, P. S. Barboza, D. E. Ullrey, M. E. Allen, J. C. Keene, and D. L. Freitas

Abstract. The growth, reproduction, morbidity and mortality of desert tortoises may be influenced by nutritional constraints. We conducted a survey of the nutritional composition of 196 samples of desert plants collected a four sites in southern Nevada (Coyote Springs Valley; south of the Desert Tortoise Conservation Center; western Mormon Mesa; Piute Valley). Either the entire above-ground plant of selected vegetative and/or reproductive parts were obtained from 58 plant species, including important food species such as grasses (*Bromus* spp. *Erioneuron* spp., *Hilaria* spp., *Oryzopsis* ssp., *Schismus* ssp.), legumes (*Astragalus* ssp., *Lupinuc* ssp.), borages (*Amsinckia* ssp., *Cyptantha* ssp., *Petocarya* ssp.), cacti (*Opuntia* ssp.), plantain (*Plantago* ssp.), desert mallow (*Sphaeralcea* ssp.), and filaree (*Erodium* ssp.). Samples were assayed for water, fiber fractions (NDF, ADF and acid lignin), crude protein (= total organic nitrogen X 6.25), fat, ash, acid-insoluble ash, calcium (Ca), phosphorus (P), sodium (Na), potassium (K), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), and selenium (Se). Based on these results and observations of captive tortoises, we suggest that the following nutritional constraints may affect the desert tortoise in the eastern Mojave:

Water. After the spring flush, the water content of plants other than cacti drops rapidly. The need to maintain water and electrolyte balance could preclude consumption of many species of "dry" plants, especially if they are high in K.

Protein. Mature grasses, cacti and some other plants contain 10% or less crude protein (dry matter basis), a level that may limit growth in young tortoises.

Fiber. Fiber increases with maturity in grasses and some other plants. High dietary fiber may reduce energy digestibility, and require higher food intake to meet energy demands.

Ca and P. Many desert plants contain high Ca and low P, indicating that P, rather than Ca, may be limiting for tortoises. The reproductive parts (flowers, fruits) of desert plants are usually higher in P and lower in Ca than are vegetative parts (leaves, stems).

Na. Desert grasses, cacti and many other plants are extremely low in Na, suggesting that Na appetite may influence tortoise feeding.

K. The high K levels in many desert plants could limit consumption by tortoises, especially if water and protein intakes are restricted.

Cu. Mature grasses, cacti and some other plants contain Cu levels that could produce deficiency in domestic herbivores, but Cu concentrations appeared to vary among collection sites.

Se. There was no evidence of toxic Se levels, even among known selenium-accumulating plants (e.g., *Astragalus* ssp.).

FORAGING ECOLOGY OF SONORAN DESERT TORTOISES, 1992 ANNUAL REPORT

John R. Snider

***Abstract*.** Sonoran desert tortoises (*Gopherus agassizii*) were observed feeding at Little Shipp Wash and the Harcuvar Mountains, Arizona from March 1992 through November 1992. Nine tortoises were observed at Little Shipp and 11 at the Harcuvar Mountains.

Tortoises at Little Shipp Wash fed on 14 plant species during 73.3 hours of observations. A total of 2351 bites were recorded. Grasses comprised 51.6% of the bites; forbs, 29.3%, and cacti, 19.1%. Tortoises at the Harcuvar Mountains fed on four plant species. Seventy-three bites were recorded during 81.9 hours of observations. Grasses comprised 35.6% of the bites; forbs, 64.4%

Of the 4396 minutes of activity recorded at Little Shipp Wash, tortoises spent 4.5% of the time feeding, 6.1% walking, 24.3% basking, and 65% inactive. Of the 4914 minutes of activity recorded at the Harcuvar Mountains, tortoises spent 0.2% of the time feeding, 2.2% walking, 12.1% basking, and 85.5% inactive. The only significant difference in tortoise activity between the two sites was that the Harcuvar Mountain tortoises remained inactive longer.

PRELIMINARY STUDY OF DESERT TORTOISE (*Xerobates agassizii*) DIET IN THE NORTHEASTERN SONORAN DESERT

Thomas R. Van Devender, Howard E. Lawler, and Elizabeth Wirt

Abstract. Individual fecal pellets were analyzed for dietary information from four sites in saguaro-paloverde desert scrub in Pima County, Arizona. The matrix of most pellets were grass stems and blades or mallow twigs and epidermis. A total of 63 taxa including trees and shrubs (9.5%); a woody vine (*Janusia gracilis*), a prickly pear (*Opuntia phaeacantha*), and a spike moss (*Selaginella arizonica*) (all 1.6%), grasses (22.2%), and dicot herbs (42.9%), mostly annuals (34.9%, with 29.9% spring obligates), were identified from seeds, achenes, fruits, florets, and leaves. Microscopic analyses of epidermal fragments in 15 combined samples provided quantitative estimates of 30 taxa including five not recognized as fragments. Grasses and mallows were the most common plants consumed. Important grasses included the perennials *Aristida ternipes, Enneapogon desvauxii, Erioneuron pulchellum,* and *Hilaria belangeria* and the annuals *Bouteloua aristidoides* and *B. barbata*. Important mallows included *Abutilon* sp., *Herissantia crispa, Hibiscus* sp., *Sphaeralcea amigua*, and *S. laxa*. *Janusia gracilis* was present, mostly at low levels in 73.3% of the samples. *Opuntia phaeacantha* fruits and the herbs *Allionia incarnata, Boerhaavia intermedia, Euphorbia capitellata, Evolvulus alsinoides, Kallstroemia* sp., and *Pectis cylindrica* were eaten in August and September. Spring annuals were only important in May-June, three to nine weeks after hot temperatures ended the winter-spring season and the plants died. Dried spring annuals were eaten sporadically from July to November. *Bromus rubens* and *Erodium cicutarium* were the only introduced species.

Sapium biloculare (MEXICAN JUMPING BEAN) AS A POSSIBLE CAUSE OF MORTALITY FOR *Gopherus agassizii* (DESERT TORTOISE) IN THE MARICOPA MOUNTAINS, MARICOPA CO, ARIZONA.

Elizabeth B. Wirt

Sapium biloculare (Euphorbiaceae), a toxic Sonoran Desert shrub was investigated as a possible cause of widespread mortality for desert tortoises (*Gopherus agassizii*) in the Maricopa Mountains, Maricopa Co., Arizona. The Maricopa Mountains desert tortoise permanent study plot (PSP) has the highest number of recorded desert tortoise remains collected from Arizona (N = 131). Gut samples were removed from four Maricopa desert tortoise remains which had intestinal material still present in the body cavity and *Sapium* plant parts were identified from two out of four of the remains. Tortoise scats from live animals at the Maricopas do not have *Sapium* present (N=30)(Wirt in prep).

Desert tortoises in the Maricopas were eating fallen leaf litter from trees and shrubs during recent drought years when most of the high mortality took place. The Maricopa PSP has a high density of *Sapium* shrubs. Both fresh and old plant material collected from leaf litter at the base of *Sapium* shrubs were used in bioassays.

Extracts of *Sapium* fruits, stems, flowers, leaves, and extracts made from material found in dead tortoise gut cavities were analyzed for the presence and bioactivity of phorbol esters. Phorbol esters are toxic compounds known to promote tumors in animal models of carcinogenesis. (Boutwell, 1974).

Phorbol dibutyrate (PDBu) displacement from rat brain membranes was used to measure the relative total levels of phorbol esters present in the *Sapium* plant parts and tortoise gut contents (Beutler et al, 1989). All plant parts were found to contain substantial amounts of PDBu displacing activity (Table 1). Two gut samples which contained *Sapium* plant parts were also found to contain significant levels of bioactivity.

The plant extracts are directly comparable with each other. The fresh material is 5 to 10 times more potent than the old material. Apparently the phorbol esters in *Sapium* are not greatly diminished by age.

The gut material from the remains and the control scats are also shown in Table 1. The animal extracts are composed of various grasses and forbs that would normally fill a tortoise gut, plus in some cases, an unknown amount of *Sapium*. Samples from tortoise remains #63 and #104 are quite bioactive and comparable to the pure forms of *Sapium* plant parts. Gut samples from #63 and #104 had identifiable *Sapium* parts in them. Samples from tortoise remains #107 and #89 did not have *Sapium* parts identified from them and showed correspondingly weaker activity. The PDBu displacement assay is specific to phorbol esters indicating that the gut samples were loaded with various concentrations of *Sapium* or other PDBu active Euphorbias. Whether these levels of toxicity contributed to the mortality of these tortoises cannot be determined.

The control samples were clearly not bioactive. The Maricopa control scat was collected from live animals where *Sapium* is present, but during a non drought season when *Sapium* is not expected in the diet and was not observed in the scat. The Ragged Top Mt control scat was from live animals in a location where *Sapium* is not found.

Table 1. Relative displacement of [3H]-PDBu Binding from Rat Brain Membranes of Extracts of *Sapium biloculare* Plant Parts, Tortoise Gut Contents, and Scat Samples. Several concentration points (1, 10, 100 ug/ml for controls) were run in duplicate, for each sample.

Sample	Approximate IC50 PDBu (ug/ml)
PLANT	
fresh fruit	<<1.0
fresh stems	<<1.0
fresh flowers	1.0
fresh leaves	1.0
old fruits	<1.0
old sticks	5.0
old flowers	1.0
old leaves	5.0
ANIMAL	
tortoise remains #63	8.0
tortoise remains #104	9.0
tortoise remains #107	80.0
tortoise remains #89	>100.0
Control scat Maricopa PSP	>>100.0
Control scat Ragged Top Mt	>>100.0

Eating *Sapium* may have accelerated inevitable death in some individuals but probably did not kill the majority of Maricopa tortoises. Tortoises are herbivores adapted to tolerate plant toxins. Tortoises commonly eat other Euphorbia family members such as spurges, and *Janusia gracilis* (Malpighiaceae), both native plant groups known to have toxins. However, phorbol esters have a massive purgative effect on humans and other mammals, which used to be used in pharmacy in the form of *Croton* oil (Hecker 1968). Eating *Sapium* may cause a drought stressed tortoise to further dehydrate and exceed the lethal level of 400 mosM plasma osmolality (Peterson 1993). Tortoises in the Maricopas were severely drought stressed during the high mortality years and probably had very high concentrations of body fluid solutes. *Sapium* may have killed only the animals that were nearing their lethal limits. *Sapium* may not greatly affect hydrated tortoises.

The distribution of tortoises and *Sapium* in the Maricopas is patchy. Many desert tortoise remains were found in areas of the Maricopa Mountains where *Sapium* was not present. This suggests that *Sapium* was not a factor in the death of those animals.

The results of this study are inconclusive. *Sapium* was found to contain high levels of bioactive phorbol esters. Desert tortoises eat *Sapium* and may or may not survive, however, it is unknown what effect *Sapium* actually has on the desert tortoise. Desert tortoise mortality in the Maricopas was high in areas where *Sapium* was not present. *Sapium* does not completely explain the high mortality of desert tortoises in the Maricopa Mountains, but may have been a contributor.

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WINTER SHELTERSITE USE IN A SONORAN DESERT TORTOISE POPULATION

Scott J. Bailey, Cecil R. Schwalbe, and Charles H. Lowe

Abstract. We quantified several aspects of hibernacula use by desert tortoises (*Gopherus agassizii*) in the San Pedro River Valley, Pinal County, Arizona. Tortoises hibernated primarily on steep southerly slopes. Hibernacula included burrows in silt, silt with loose gravel, diatomite and/or diatomaceous marl, and beneath an ash layer, often in conjunction with live vegetation, dead and downed vegetation, and packrat (*Neotoma albigula*) nests. Male tortoises used longer hibernacula than females ($p < 0.02$). Female maximum hibernacula temperatures were consistently higher than male maximum hibernacula temperatures, but the difference was not significant ($0.05 < p < 0.10$). Female minimum hibernacula temperatures were significantly lower than males ($p < 0.001$) and female hibernacula temperatures fluctuated over a significantly wider temperature range than males ($p < 0.01$). Hibernacula used by males provided greater thermal buffering than those used by females. Duration of hibernation was positively correlated with shelter length. No individual used the same hibernaculum during both winters of the study.

THE GOFFS POPULATION MODEL REVISITED: NEW DATA AND NEW MODELS

Kristin Berry, Michael Weinstein, Fred Turner, David Randall, and Gary White

Abstract. In 1987 F. B. Turner, K. H. Berry, D. Randall and G. White published a report on a life table for a population of desert tortoises (*Gopherus agassizii*) near Goffs, California. Based on data collected between 1977 and 1986, attributes of the population included: a 1:1 sex ratio, estimated age of first reproduction at 12 to 20 years, annual survival rates of 0.76 to 0.97 after year 1, age-specific fecundity of 3.7 to 5.0 eggs, an R_O of 1.8, and a mean length of generation at 32 years. The model predicted an annual rate of increase of only about 2%. Several weak areas in the model were identified, including estimates of growth rates (slow and fast growers) and frequency of large adult females (est. at 7.2%).

A new life table was prepared in 1993 using new data gathered in 1990. New growth and survivorship models were prepared. Growth was examined for males and females by using 1467 pairs of records. Growth essentially ceases for females at 230 mm in carapace length (CL) and for males at 290 mm CL. The main determinants of growth rate were size and sex of tortoises and general availability of food and water. Most variation in growth between individuals disappeared when data were examined by year. For example, there was more variation in growth rates between 1983-85 and 1986-90 than between sexes or between juvenile and immature tortoises. There was not evidence to support the assumption that variation in growth was caused by fast or slow growing tortoises. Large females composed only 1.1%. Variation in survivorship was substantially greater than for the 1987 model. For example, between 1985-86, the survival rate of 1-year old tortoises was 26.2% (low). The 1993 life table revealed a population which was declining at a rate of 2.9% per year.

BURROW USE BY DESERT TORTOISES (*Gopherus agassizii*): SOCIAL FACTORS

Susan J. Bulova

A knowledge of burrow use patterns by desert tortoises, *Gopherus agassizii*, is important in designing effective management programs for this threatened species. Tortoises use underground burrows as thermal refugia from daily and seasonal temperature fluctuations (Burge, 1977; McGinnis and Voigt, 1971), and burrows are often the site of social interactions among individuals including courtship and aggression (Bulova, 1994; Burge, 1977). Thus, patterns of cohabitation may be influenced by desert tortoise social structure.

I observed movement patterns among burrows by free-ranging desert tortoises in a 7.5 km^2 area outside the perimeter of the Desert Tortoise Conservation Center (DTCC) near Las Vegas, Clark Co., Nevada (Bulova, 1994; Zimmerman et al., 1994). Twenty-eight adult tortoises (15 males, 13 females; body mass >1600 g) were individually marked with small blue tags and fitted with radio transmitters. Transmitters were glued to the front of the carapace and covered with silicone sealant.

From June through October, 1992, I located tortoises six out of every seven days within the study site using a scanner/receiver (Telonics TS-1/TR2). Shelters found occupied by radio-tagged tortoises were marked with flagging tape and categorized as a pallet (a shallow depression scratched into the soil), a burrow dug in the soil, or a den (burrow formed as a cavity under consolidated gravels); (Burge, 1978; Woodbury and Hardy, 1948). Non-tagged tortoises sharing a shelter with a located radio-tagged tortoise were noted and were marked with a blue tag.

Analysis of covariance (ANCOVA) was used to compare monthly movement patterns between sexes during the months of June through October. Sex differences in burrow sharing were compared using a Mann-Whitney U test.

Most of the shelters used by tortoises over five months were soil burrows (141) as opposed to dens (24) or pallets (44). For hibernation, tortoises used soil burrows and dens but no pallets. Activity for the season ended at the beginning of November; however, by October, tortoises were observed using burrows in which they eventually hibernated. For example, a large den, which was used for hibernation by at least two marked tortoises, was used several times in October by as many as four marked male and female tortoises.

Seventy-three percent of burrows (soil burrow and dens collectively) and 96% of pallets were occupied by only one tortoise. Few burrows were observed being used by more than one individual, either by co-occupancy or non-simultaneous use. However, one burrow was used over the course of the season by seven different tortoises either alone or in groups as large as four.

Patterns of movement among burrows and of burrow sharing corresponded to the reproductive cycle (Rostal et al. 1994) and movement to hibernacula. Tortoises used an average of 9.1 different shelters (range: 3 to 18) over the course of the study period; however, monthly averages of numbers of shelters used differed between males and females. During the latter part of the nesting season (June), females used significantly more burrows than males used (mean number of burrows used: females: 5.8, males: 2.7; $F_{1,8} = 9.39$, $p = 0.016$). The pattern reversed with the onset of the mating season (late July), at which time males used significantly more burrows than did females (mean number of burrows used: August: males 5.3, females 3.8, $F_{1,9} = 12.55$, p =

0.006; September: males 5.1, females 4.5, $F_{1,14} = 4.88$, $p = 0.044$). In October, tortoises began occupying burrows that were eventually used for hibernation, and the mean number of burrows used by males and females (3.0 for both sexes) was not significantly different ($p > 0.05$).

Patterns of co-occupancy differed between males and females and changed over the course of the study. Males co-occupied burrows with other males during every month of the study, but females did not share with other females until August. Male-female cohabitation was first observed with the onset of the mating season in late July (four observations of male-female cohabitation) and peaked in August (nine observations) and September (15 observations). Of tortoises that shared shelters (21 of the 28 tagged), males tortoises shared burrows with significantly more females than females shared with other females ($U = 16$, $Z = -2.826$, $p = 0.0047$). Males ($n = 11$) shared with a mean of 1.7 females (range = 0-5), and females ($n = 10$) shared with a mean of 0.5 other females (range = 0-2). Males and females shared with similar numbers of other males (male mean = 2.6 other males, female mean = 2.5 males; $p > 0.05$).

In summary, tortoises used several different shelters during the active season. Tortoises were usually found alone in shelters, but most tortoises cohabited with at least one other tortoise of the same or opposite sex at some time during the active season. Patterns of movement among burrows and of burrow sharing correspond to their reproductive cycle and movement to hibernacula.

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SOCIAL INTERACTIONS OF DESERT TORTOISES AT TWO SITES IN THE NORTHEAST MOJAVE DESERT

L. A. DeFalco and T. C. Esque

Abstract. Detailed behavioral observations were made on 50 free-ranging, radio-telemetered desert tortoises (*Gopherus agassizii)* at two sites in the northeast Mojave Desert over 4 years. Five hundred and eighty behavioral observations were recorded comprising 1557 hours during the spring activity season. The number and type of interactions that occurred at the two sites are compared between sites. The range of encounters included no interaction, chases, copulations, and agonistic encounters resulting in death of individuals. Variability of the rate of encounters by individuals among sites has potential importance for management issues such as reserve size and transmission of epizootics.

DEMOGRAPHICS OF THREE DESERT TORTOISE POPULATIONS IN THE SONORAN DESERT

Scott D. Hart

Abstract. Three one-square mile plots (Little Shipp Wash, Granite Hills, and Eagletail Mountains) in the Sonoran Desert, Arizona, were surveyed during the summers of three consecutive years (1990-1992) by the Arizona Game and Fish Department (AGFD). Methodology for the surveys, plot locations, and plot descriptions are outlined in Woodman et al. (1993). Little Shipp Wash and Granite Hills were surveyed for approximately 60 field days each year. Eagletail Mountains was surveyed for 60 days in 1990, and approximately 35 days in 1991 and 1992. It was originally surveyed by the Bureau of Land Management (BLM) in 1987, as a 60-day plot. That data has not been used in this paper, in order to make the data from the three plots more comparable.

The purpose of this paper is to provide information on some of the demographic characteristics of the three plots, including; number of tortoises found, population estimates, sex ratios, and size class structures. Included is a comparison of mean adult maximum carapace length (MCL) among these three plots and four others surveyed in 1991.

The general survey technique was to search the entire square mile for tortoises and tortoise sign during the first part of the survey, then concentrate on areas with sign. The main objective was to find and mark as many tortoises as possible, collecting demographic and behavioral data.

Little Shipp Wash had the greatest number of tortoises found each year (Table 1). The number found remained fairly consistent, ranging from 82 to 90, with the greatest year to year change being a 10% rise from 1991 to 1992. A total of 134 tortoiseswere marked in three years. Little Shipp Wash also has the greatest amount of tortoise habitat on the plot; tortoises have been captured in about 60% of the 100 grid cells.

Table 1. Number of desert tortoises found (1990, 1991, 1992, and cumulative) at three study plots in the Sonoran Desert, Arizona.

	1990	1991	1992	Total
Little Shipp Wash	84	82	90	134
Granite Hills	47	70	75	114
Eagletail Mountains	32	32	28	46

Granite Hills has had the second most tortoises found each year. From 1990 to 1991 there was a 25% increase (from 47 to 70) in the number found. The increase may in part be attributed to fieldworker inexperience in 1990. In 1992 there was a rise of less than 10%, to 75 tortoises. There have been 114 tortoises marked in three years. Tortoises have been found in about 40% of the 102 grid cells on the plot. This plot is unique among the three, with tortoises being found not only on heavily bouldered slopes, but also on the bajada and on slopes with few boulders.

The fewest number of tortoises have been found at Eagletail Mountains each year. The number found has remained stable, ranging from 28 to 32. Thirty-two tortoises were found in each of 1990 and 1991, despite the search time dropping from 60 days in 1990 to 35 days in 1991. Twenty-eight tortoises were found in 1992, again with the shortened search period. A total of 46 tortoises have been marked since 1990. The search effort was reduced in 1991 due to the relatively small amount of tortoise habitat contained within plot boundaries; tortoises have been found in about 25% of the 100 grid cells. This has proven to be an efficient search effort at Eagletail Mountains.

Population estimates for the plots were calculated using the Lincoln-Peterson Method (Pollock et al. 1990), a mark and recapture technique. In 1990, the first half of the field days were used as the mark period, and the second half as the recapture period. In 1991 and 1992, the previous year was considered the mark phase, and the current year as the recapture. Estimates were calculated for total populations, and for the subadult plus adult populations ($\geq$180 mm MCL). This eliminated the smaller size classes, which are recaptured much less from year to year, and lead to larger variances.

For subadults plus adults, the point estimate has tended to decrease each year, as has the 95% confidence interval (Table 2). This indicates there has been less difference between the capture and recapture periods with each progressive estimate. The only exception has been at Little Shipp Wash from 1991 to 1992, when there was a 35% increase in the estimate. Although the variance for that estimate was also higher than in 1991, the percentage of the point estimate that the variance represented was lower.

Table 2. Desert tortoise <subadult plus adult> population estimates (with 95% confidence interval) for 1990, 1991, and 1992, at three study plots in the Sonoran Desert, Arizona.

	1990	1991	1992
Little Shipp Wash	85 ± 14.5	79 ± 4.0	107 ± 9.7
Granite Hills	68 ± 44.1	63 ± 13.2	60 ± 4.1
Eagletail Mountains	31 ± 5.0	30 ± 1.6	29 ± 2.2

For the total population, the trend has been somewhat different; point estimates have increased each year (Table 3). The 95% confidence intervals decreased from 1990 to 1991, but increased in 1992. The difference in estimates from that for tortoises ≥180 mm MCL must be attributed to the low recapture rate of the smaller tortoises.

Sex ratios have been calculated for each plot each year (Table 4). Along with the ratio for all tortoises ≥180 mm MCL, the ratios have been calculated for adults (≥208 mm MCL) without subadults. This reduces the potential for including tortoises whose sex has been misidentified, which can happen with tortoises whose gender identifying characteristics have not fully developed. All ratios have favored females, except the adults ratio at the Granite Hills in 1990, when the male to female ratio was 1.08:1. Only two ratios have been significantly different from a 1:1 ratio; Little Shipp Wash (0.59:1 for adults) and Eagletail Mountains (0.42:1 for both ratios), both in 1990. The ratios have varied considerably within each plot from year to year. This could be due in part to differential activity patterns between the genders, with one sex being relatively more active than the other in different years because of vegetative or other conditions.

Table 3. Desert tortoise <total> population estimates (with 95% confidence interval) for 1990, 1991, and 1992, at three study plots in the Sonoran Desert, Arizona.

	1990	1991	1992
Little Shipp Wash	101 ± 15.0	120 ± 9.0	126 ± 10.5
Granite Hills	75 ± 31.2	108 ± 17.3	124 ±61.3
Eagletail Mountains	36 ± 7.6	41 ± 3.4	41 ± 4.6

Table 4. Sex ratios (numbers in parentheses) of desert tortoises in 1990, 1991, 1992, and cumulative, at three study plots in the Sonoran Desert, Arizona. * denotes significant at P<.05.

	1990	1991	1992	Total
Little Shipp Wash				
Adults + subadults:	0.62:1 (26:42)	0.82:1 (30:37)	0.81:1 (34:42)	0.67:1 (42:63)
Adults:	0.59:1 (24:41)*	0.78:1 (29:36)	0.94:1 (32:34)	0.67:1 (37:55)
Granite Hills				
Adults + subadults:	0.94:1 (16:17)	0.63:1 (19:30)	0.96:1 (22:23)	0.76:1 (28:37)
Adults:	1.08:1 (14:13)	0.60:1 (15:25)	0.84:1 (16:19)	0.68:1 (21:31)
Eagletail Mountains				
Adults + subadults:	0.42:1 (8:21)*	0.53:1 (9:17)	0.83:1 (10:12)	0.52:1 (12:23)
Adults:	0.42:1 (8:21)*	0.53:1 (9:17)	0.83:1 (10:12)	0.52:1 (12:23)

The male to female sex ratio of all tortoises that were caught over the three year period is generally lower than the ratio for any particular year, although there is one exception to this at each plot. None of these ratios are significantly different from 1:1 size class structures (Turner and Berry 1984) among the three plots have varied considerably. The structures between years at any plot have been fairly stable, so only the 1992 data are presented. The three-year cumulative size class structure of the three plots are similar to their 1992 structure, but with a higher percent of smaller tortoises. These are not presented here.

The size class structure at Granite Hills had the most equal distribution among size classes of the three plots (Table 5). Nearly equal numbers of tortoises were found in the adult 2, adult 1, and immature 2 size classes (21.3 to 24.0%). The next largest class was subadult (13.3%), which covers a relatively narrow size range, and represents a size when tortoises are normally growing relatively rapidly. There were fewer still of immature 1 tortoises (10.4%), and relatively few juveniles (4.0% in each of juvenile 2 and juvenile 1). The structure at this plot has changed the most over the past three years; there was a large increase in the immature 2 class in 1992.

Table 5. Number of desert tortoises found in the different size classes at the Granite Hills study plot, Arizona; 1992.

SIZE CLASS	Sex unknown	Males	Females	Total	Percent
Juvenile 1 (<60 mm)	3			3	4.0
Juvenile 2 (60-99 mm)	3			3	4.0
Immature 1 (100-139 mm)	8			8	10.7
Immature 2 (140-179 mm)	16			16	21.3
Subadult (180-207 mm)		6	4	10	13.3
Adult 1 (208-239 mm)		9	8	17	22.7
Adult 2 (≥240 mm)		7	11	18	24.0
TOTALS	30	22	23	75	100

At Eagletail Mountains the size class structure was dominated by adult 2 tortoises (74.1%), with 7.4% of the tortoises in the adult 1 class (Table 6). The only other classes represented were the juvenile 2 (14.8%) and juvenile 1 (3.7%). There were no tortoises found between 100 and 208 mm MCL, although a few tortoises were found in that range in 1990 and 1991.

Table 6. Number of desert tortoises found in the different size classes at the Eagletail Mountains study plot, Arizona; 1992.

SIZE-CLASS	Sex unknown	Males	Females	Total	Percent
Juvenile 1 (<60 mm)	1			1	3.7
Juvenile 2 (60-99 mm)	4			4	14.8
Immature 1 (100-139 mm)	0			0	0
Immature 2 (140-179 mm)	0			0	0
Subadult (180-207 mm)		0	0	0	0
Adult 1 (208-239 mm)		0	2	2	7.4
Adult 2 (≥240 mm)		10	10	20	74.1
TOTALS	5	10	12	27	100

At Little Shipp Wash the size class structure was also dominated, to a lesser extent, by adult 2 tortoises (67.0%; Table 7). Adult 1 tortoises (8.0%) and subadults (11.4%) made up a majority of the remaining tortoises. There were tortoises found in each of the remaining classes; immature 2 (1.1%), immature 1 (4.6%), juvenile 2 (4.6%), and juvenile 1 (3.4%). This is very similar to both 1991 and 1990.

The low percent of smaller tortoises found at the plots is not too surprising, given the difficulty of finding those tortoises. Therefore, the size class structures at Granite Hills and Little Shipp Wash suggest these are populations where there is ample recruitment into the reproduction pool. The same may not be said of the Eagletail Mountains structure, because of the big gap in the immature through subadult range. However, this is a relatively small population, where it would not take as many recruits in order to maintain its current population level. Additionally, there was a relatively large number of juvenile 2 tortoises found in 1992.

Table 7. Number of desert tortoises found in the different size classes at the Little Shipp Wash study plot, Arizona; 1992.

SIZE-CLASS	Sex unknown	Males	Females	Total	Percent
Juvenile 1 (<60 mm)	3			3	3.4
Juvenile 2 (60-99 mm)	4			4	4.6
Immature 1 (100-139 mm)	4			4	4.6
Immature 2 (140-179 mm)	1			1	1.1
Subadult (180-207 mm)		2	8	10	11.4
Adult 1 (208-239 mm)		2	5	7	8.0
Adult 2 (≥240 mm)		30	29	59	67.0
TOTALS	12	34	42	88	100.0

In cooperation with AGFD, the BLM in Arizona funded similar population surveys at four plots in Arizona in 1991 (San Pedro Wash, Silverbell Mountains, Hualapai Foothills, and Wickenburg Mountain) (Hart et al. 1992). Mean MCL of mature tortoises (≥180 mm MCL) was tested for differences among all BLM and AGFD plots that year. First, mean MCL of males was tested against mean MCL of females (Table 8). Mean MCL of males was larger than that of females at all plots except San Pedro Wash, but the difference was significant only at Eagletail Mountains.

Because of the significant difference between male and females at the Eagletail Mountains, mean MCL among plots was tested separately for males (Table 9) and females (Table 10). The results of the analysis were the same for males and females, and the plots fell into two groups. One group consisted of the Granite Hills, San Pedro Wash, and the Silverbell Mountains. Mean MCL did not differ significantly among any of these. The other four plots made up the second group, among which there were no significant differences. However, all plots of the first group were significantly smaller than all plots of the second group. It so happens that all of the plots with larger tortoises lie northwest of a line drawn approximately from Phoenix to Gila Bend. All plots with smaller tortoises lie southeast of that line.

Table 8. Male vs. female mean MCL for desert tortoises at seven Sonoran Desert study plots, Arizona; fall, 1991. * denotes P <0.05

	Males N (Mean mm MCL)	Females N (Mean mm MCL)	t-value
Eagletail Mountains	9 (276.8)	16 (256.4)	2.764*
Granite Hills	19 (228.9)	30 (224.8)	0.715
Hualapai Foothills	19 (267.4)	13 (256.4)	1.107
Little Shipp Wash	31 (266.4)	36 (256.1)	1.622
San Pedro Wash	16 (232.6)	18 (235.6)	-0.424
Silverbell Mountains	20 (241.6)	39 (233.5)	1.489
Wickenburg Mountain	10 (273.1)	5 (258.6)	1.526

Table 9. One-way ANOVA ($F_{6,150}$=10.847; $P < 0.001$) of mean MCL among desert tortoise males at seven Sonoran Desert study plots, Arizona; fall, 1991. Fisher PLSD values for pair-wise test are given; * denotes $P < 0.05$.

	N	Granite Hills	San Pedro Wash	Silverbell Mtns	Eagletail Mtns	Hualapai Foothills	Little Shipp Wash
Granite Hills^1	19						
San Pedro Wash	16	16.326					
Silverbell Mtns^1	20	15.414	16.138				
Eagletail Mtns^2	9	19.470*	20.048*	19.313*			
Hualapai Foothills^1	19	15.611*	16.326*	15.414*	19.470		
Little Shipp Wash^1	31	14.019*	14.811*	13.800*	18.218	14.019	
Wickenburg Mtn^2	10	18.798*	19.396*	18.635*	22.107	18.798	17.498

No significant difference among plots with same number (1 or 2); $P < 0.05$ between 1 and 2.

Table 10. One-way ANOVA ($F_{6,150}$=10.847; $P < 0.001$) of mean MCL among desert tortoise females at seven Sonoran Desert study plots, Arizona; fall, 1991. Fisher PLSD values for pair-wise test are given; * denotes $P < 0.05$.

	N	Granite Hills	San Pedro Wash	Silverbell Mtns	Eagletail Mtns	Hualapai Foothills	Little Shipp Wash
Granite Hills^1	30						
San Pedro Wash	18	11.992					
Silverbell Mtns^1	39	9.768	1.461				
Eagletail Mtns^2	16	12.451*	13.820*	11.941*			
Hualapai Foothills^2	13	13.396*	14.640*	12.881*	15.019		
Little Shipp Wash^2	36	9.943*	11.611*	9.296*	12.085	13.015	
Wickenburg Mtn^2	5	19.429*	20.333*	19.106*	20.607	21.166	19.196

No significant difference among plots with same number (1 or 2); $P < 0.05$ between 1 and 2.

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A SUMMARY OF SONORAN DESERT TORTOISE POPULATION MONITORING IN ARIZONA

J. M. Howland and A. P. Woodman

Abstract. The Bureau of Land Management began establishment of long-term desert tortoise (*Gopherus agassizii*) population monitoring plots in the Sonoran Desert in the late 1980s, with first coverages of plots in six different Arizona mountain ranges (the Arrastra [Poachie], Eagletail, Harcuvar, Harquahala, Maricopa, and New Water mountains). In 1990, with funding from Section 6 of the Endangered Species Act, the Arizona Game and Fish Department resurveyed tortoise populations on four areas that had been previously surveyed: Little Shipp Wash, the Granite Hills, the Eagletail Mountains, and the Maricopa Mountains (only the latter two having been initiated under a standard plot monitoring protocol). These were the first repeat surveys for estimation of population trends within the Sonoran Desert population of the desert tortoise. Another 9 to 10 plots have been established in the past three years. We must now begin planning for a long-term rotation schedule, for repeated surveys on plots already established, in order to meet the goals of population monitoring.

A 25-YEAR STUDY OF THREE-TOED BOX TURTLE POPULATION DYNAMICS

Ross Kiester

Abstract. This study in central Missouri, conducted with Charles and Elizabeth Schwartz, shows that the population remained steady for many years, but has now begun to decline. The core study area has remained the same except for succession, but the surrounding area has become much more developed and this development may be the primary factor in the decline. These results point out that while some individual turtles may have small home ranges, the area required to maintain a population may be quite large due to patterns of movement by other individuals in the population. Further, this study shows that the numbers of the two sexes fluctuate randomly with respect to each other and this result is applied to the problem of the evolution of sex-determining mechanisms in turtles.

STATUS AND EXPLOITATION OF THE PANCAKE TORTOISE (*Malacocherus tornieri*) IN TANZANIA

Michael W. Klemens

The pancake tortoise, (*Malacocherus tornieri*), is an unusual, crevice-dwelling species endemic to the kopjes and rocky hillsides scattered through the Somalia-Masaai floristic region of southern Kenya and northern and central Tanzania. The species' flattened shape and lizard-like behavior distinguish it from all other tortoises, heightening its appeal for hobbyists and, more recently, pet owners, in markets as distant as the United States, Japan, and until 1988, Europe. Since Kenya prohibited exports of the species in 1981, international trade has originated exclusively from Tanzania, with exports from that country increasing substantially through the late 1980s. The species' low reproductive capacity and restricted, disjunct distribution prompted concern that excessive exploitation may be adversely affecting wild populations. A field assessment of the conservation status was identified as a high priority in the IUCN/SSC Tortoise and Freshwater Turtle Action Plan and by the CITES Animals Committee.

In February-March 1992, pancake tortoise abundance data were collected by Ayubu Ajalale of the Tanzanian Wildlife Society in the Kondoa and Mwanza Districts, followed by a field assessment in May-June 1992 by Don Moll (Southwestern Missouri State University) and Michael Klemens (American Museum of Natural History) in the Arusha and Dodoma Regions, including Arusha and Tarangire National Parks and the Ngorongoro Crater Conservation Area. In February 1993, Klemens returned to Tanzania to collect additional ecological data and measurements, and to gather samples of blood, nasal mucous and feces to assess the health and genetic variability of pancake tortoises at two widely separated sites (Tarangire National Park and Ruaha National Park).

Pancake tortoises are very specialized in their micro-habitat requirements, particularly as regards crevice type and internal crevice configuration. A seemingly extensive habitat therefore, may contain only a small number of crevices that are sufficiently deep and narrow to afford tortoises adequate protection against predators and desiccation. Eroded kopjes with little soil or plant growth are not favored; the ideal conditions appear to be small rocky outcrops scattered in grass savanna dotted with woodland, essentially Masaai steppe habitat of *Acacia*-baobab parkland and *Brachystegia*-wooded hills.

Collection and trade of pancake tortoises is reported to be concentrated in the area between Arusha and Dodoma. Major centers of collection and trans-shipment include Dodoma, Kondoa, and Magugu. Areas lying within easy access of the Arusha-Dodoma Road showed evidence of over-collection and serious population declines. In collected areas, only a few tortoises were usually found despite an abundance of suitable crevices and sample forage. Many of the populations were so depleted that it may take decades for them to recover; other sites may have been so heavily collected that the tortoises are locally extinct. Collectors interviewed quite readily admitted that pancake tortoises are increasingly hard to find because they have removed so many of them.

Sites that had not been exploited by collectors were characterized by a significantly higher number of tortoises encountered per units of search time, a greater proportion of multiple tortoise occupancies per crevice, and usually a greater proportion of adult tortoises, in comparison to exploited sites. For example, sites in the heavily patrolled central areas of Tarangire National Park contained robust populations and the remains of predated pancake tortoises were found. The presence of predated tortoise may indicate that these populations are sufficiently robust to serve as occasional food source for carnivores and/or that the number of tortoise predators is higher in protected areas.

Commercial collecting of pancake tortoises is conducted through a well-organized, multi-tier system that is effective in securing large numbers of tortoises for the export trade. Interviews with villagers, collectors, and personal observations, indicate that despite a purported export ban, some collecting is continuing for this trade. Wildlife dealers/exporter(s) were reported to travel along the Arusha-Dodoma Road, stopping at villages to purchase tortoises. These tortoises had been gathered by local people, primarily young, unmarried males, and sold the a village middleman for TSh 20 (US$0.05) a piece, who in turn sold tortoises to the dealers for TSh 150 (US$0.38). On the periphery of Tarangire National Park (located near Magugu, a major tortoise collection center), two sites showed evidence that jacks had been employed to lift up rocks to facilitate collection of pancake tortoises and the microsympatric plated lizards *Gerrhosaurus* sp.

Although time and other constraints did not permit investigation of populations over the species' entire range, sufficient data were gathered to conclude that commercial collection has had a severe impact upon pancake tortoise populations in areas visited. At these sites, pancake tortoises have been collected at non-sustainable levels. This conclusion is based upon field observations; the levels of offtake reported by collectors and wildlife exporters; and the delayed maturity, low reproductive output, and low recruitment rates characteristic of the Testudinidae. Due to the pancake tortoise's low reproductive potential and the disjunction of most habitats from possible source populations, natural recovery or re-colonization of depleted populations is unlikely.

The exploitation of the pancake tortoise in Tanzania is a classic example of a resource that has been grossly undervalued to the detriment of the species and the people of Tanzania. Although some financial benefits accrue locally through the various steps of the trade, these are quite low. The bulk of the profits of this trade accrue once the tortoises have been exported from Tanzania. A very limited and strictly controlled harvest, coupled with a substantial export tariff, might provide the incentive and capital to manage and conserve this resource, while encouraging captive breeding efforts. However, enactment of substantial export tariffs may have detrimental side-effects, such as creating an incentive for individuals to engage in illicit trade. Whatever management regimes are enacted, increased investment is needed in enforcing controls on collection and export.

STATISTICAL VALIDITY AND DESERT TORTOISE DENSITY ESTIMATES: THE PROBLEMS OF 100% SAMPLING AND STATISTICAL POWER

Anthony J. Krzysik

Abstract. The two most common and potentially serious statistically relevant concerns encountered in desert tortoise (*Gopherus agassizii*) surveys are the routine acceptance of the validity of 100% surveys, and the estimation of tortoise densities by experimental designs possessing low statistical power.

Complete or 100% surveys are almost always more inaccurate than correctly conceived sampling designs. There are two categories of survey errors: sampling and nonsampling. Sampling errors represent sampling variability, the reflection of variance in the sampling frame, and are addressed by statistical theory. Sampling errors decrease with increasing sample sizes. Nonsampling errors are beyond the control of statistics and represent sampling biases, or a wide variety of systematic, confounding, execution, or procedural errors. These errors increase with increasing sample sizes. In most surveys, nonsampling errors predominate, and represent the most important contributions to overall survey error. When dealing with conservation biology issues and endangered populations, the routine unquestioned acceptance of the results from 100% surveys is a potentially dangerous practice.

A comparable problem is the drawing of unjustified interpretations, conclusions, and resource management decisions from experiments possessing low statistical power. Low statistical power is related to making a Type II error, the failure to reject a false null hypothesis. Tortoise experimental studies or surveys possessing low statistical power may give the false interpretation that tortoises are not affected by a given "experimental treatment" or environmental impact, when in reality they are affected.

METHODS FOR MONITORING SONORAN POPULATIONS OF THE DESERT TORTOISE

Roy C. Murray and Cecil R. Schwalbe

Abstract. Most desert tortoise (*Gopherus agassizii*) population studies have been based on a 60-day, one-square-mile study plot design that was developed in the Mojave Desert, where tortoise habitat occurs contiguously over hundreds of square miles. The rocky foothills and low mountain slopes inhabited by tortoises in the Sonoran Desert of Arizona are more disjunct and difficult to survey; it is difficult to find a square-mile of continuous tortoise habitat there. A smaller plot size is suggested for Sonoran Desert tortoise habitats.

Forty-nine tortoises were captured, marked, and released on a one square-kilometer study plot surveyed in the Mazatzal Mountains, Tonto National Forest, Arizona, for 56 person-days (40 calendar-days) during summer of 1992. Assumptions and biases of several population estimators were investigated, especially with regard to plot size, duration, and sampling. Population sizes were estimated using appropriate models for this plot as well as three plots that have been surveyed for three years by the Arizona Game and Fish Department and the Bureau of Land Management. Results of this study provide methods for increasing the efficiency, reliability, and repeatability for long-term monitoring of desert tortoise populations in Arizona.

ROLE OF MALE-MALE INTERACTION AND FEMALE CHOICE IN THE MATING SYSTEM OF THE DESERT TORTOISE

Hope A. Niblick, David Rostal, and Thomas Classen

Abstract. Three types of behavioral experiments were performed on captive desert tortoise (*Gopherus agassizii*) at the Desert Tortoise Conservation Center (DTCC) in Las Vegas, Nevada to determine the role of male-male interactions and female choice in the mating system of this species. We conducted 64 male-male aggression trials. Results demonstrate that dominance is affected by size (p=0.0002), past encounters (p=0.0093), and residency (p=0.0096). Thirty-two female choice experiments resulted in no significant preference for large or dominant males by females but some preference for large males was suggested. Eight trials were performed in which two males and one female were allowed to interact freely. Dominant males courted and mounted females significantly more frequently than subordinate males (p=0.0059 and 0.0233, respectively). From these results, we conclude that while size is most important to the establishment of dominance relations and in female choice, where there is not a great difference in the size of males, dominance based on residency and previous interactions may determine courtship and mating opportunities.

The mating system of the desert tortoise is not well characterized. Emlen and Oring (1977) define mating systems as the pattern of actual mating frequency within a population, including the number of simultaneous mates, the type(s) of pair bonding, and behaviors which control access to the opposite sex. The few studies of wild populations make some suggestion as to the social behavior and mating system of the desert tortoise, but these are not definitive (Berry, 1986; Burge, 1977). Understanding the importance of male-male aggression and the role of female choice is necessary for understanding the social structure and mating system of a species, which is in turn necessary for proper management of the species.

THE DESERT TORTOISE: ADAPTED XEROPHILE OR TENUOUS RELIC

Charles C. Peterson

Abstract. The desert tortoise (*Gopherus agassizii*) traditionally has been regarded as "well-adapted" to its environment. In this context results from a two-year field study of the physiological ecology of two Mojave Desert tortoise populations are presented.

During a drought, tortoises lost body mass, body water content declined, and solute concentrations of blood plasma increased to very high levels. Tortoises expended more energy than they took in by feeding. Only when tortoises were able to drink rain water were body masses, water contents, and fluid concentrations restored; tortoises then foraged on dry plants and probably made an energy profit. Hence, water balance, osmoregulation, and energetics were all highly dependent on rainfall. Despite low rates of water loss and energy metabolism, and their ability to tolerate imbalances, some tortoises did not survive the drought.

These results do not seem suggestive of an "adapted" desert species; desert tortoises may be tenuous relics of a less rigorous climate.

SEASONAL REPRODUCTIVE CYCLE OF THE DESERT TORTOISE (*Gopherus agassizii*) IN THE EASTERN MOJAVE DESERT

David C. Rostal, Valentine A. Lance, Janice S. Grumbles, and Allison C. Alberts

***Abstract*.** The seasonal reproductive cycle of male and female desert tortoises (*Gopherus agassizii*) were studied under semi-natural conditions. The tortoises were maintained in outdoor pens and supplemented with food and water. Heparinized blood samples were collected monthly using jugular puncture. Ovarian follicular growth and egg development were monitored using ultrasonography. Male chin glands were measured monthly and secretions collected. Mating was observed during the fall (following nesting) and the spring (prior to nesting). Vitellogensis occurred during the fall prior to winter brumation. Nesting was observed from May to July with females producing one to two clutches. Clutches ranged from 2 to 7 eggs. Both males and females displayed seasonal testosterone cycles.

NON-LETHAL SEXING TECHNIQUES FOR HATCHLING AND IMMATURE DESERT TORTOISES (*Gopherus agassizii*)

David C. Rostal, Janice S. Grumbles, Valentine A. Lance, and James R. Spotila

Abstract. The development of non-lethal techniques for sexing hatchling and immature desert tortoises (*Gopherus agassizii*) is critical to population and ecological studies. Two methods for sexing desert tortoises were evaluated with respect to accuracy, efficiency, and suitability to field application. Laparoscopy was found to be 100% accurate and could be used on hatchlings as small as 28 grams total body mass. Plasma testosterone was 96% accurate for immature tortoises ranging from 120 to 200 mm straight carapace length and 480 to 2000 grams total body mass. Plasma testosterone is the most suitable methodology for field studies in that only a small blood sample is required for sexing purposes; however, it is applicable only to larger immatures. Laparoscopy is 100% accurate, but it may require holding the animal for an extended period of time.

BEHAVIORAL INVENTORY OF THE DESERT TORTOISE: DEVELOPMENT OF AN ETHOGRAM

Douglas E. Ruby and Hope A. Niblick

Abstract. A behavioral inventory of the desert tortoise (*Gopherus agassizii*) was compiled from observations on confined tortoises in experimental pens and free-ranging tortoises within semi-natural enclosures. We describe 80 actions. Much of a tortoise's active time outside burrows is spent in feeding behavior. Display sequences have both visual and olfactory components. Aggressive and courtship sequences have similar beginnings which proceed differently as animals respond to each other. Aggressive behavior involves much head bobbing, sniffing, biting, and ramming. A pushing match enables tortoises to assess body weight and determine dominance. Courtship behaviors may involve trailing, circling of the female by the male, and biting and sniffing sequences before mounting. There is no rejection display by females of courting males. Comparisons between *Gopherus* species and related tortoise groups suggest a very conservative evolution of behaviors within the *Gopherus* group. Details are reported in Ruby and Niblick (1994).

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EFFECTS OF INCUBATION CONDITIONS ON SEX DETERMINATION, HATCHING SUCCESS, AND GROWTH OF HATCHLING DESERT TORTOISES (*Gopherus agassizii*)

James R. Spotila, L. C. Zimmerman, Christopher A. Binkley, David C. Rostal,
Albert List jr., Janice Grumbles, Eva C. Beyer, Kelly M. Phillips, and Stanley J. Kemp

Abstract. Incubation temperature has a direct effect on sex determination of the desert tortoise (*Gopherus agassizii*). Low temperatures (26.0 to 30.6°C) produce males and high temperatures (32.8 to 35.3°C) produce females. Pivotal temperature is approximately 31.8°C. Macroscopic and microscopic anatomy of the gonads is similar to that of other turtles. Hatching success and survival is very good between 28.1 and 32.8°C in dry sand (-4300 kPa). Incubation at 35.3°C is lethal for 72% of the eggs and produces weak hatchlings that die within 45 days. Moist sand (-280 kPa) is lethal for desert tortoise eggs. Hatchling size was dependent upon egg size and incubation condition. Hatchlings from eggs incubated at 28.1 and 30.6°C (ANOCVA, Tukey-Kramer ad hoc test, $p = 0.05$). Hatching mass had not effect on growth rate of hatchlings. Thus, large eggs produced large hatchlings that were larger than their siblings at 120 days of age. Hatchlings from eggs incubated at 30.6°C grew significantly more than other hatchlings while hatchlings incubated at 28.1°C grew like those incubated at 32.8 C° but more than those incubated at 35.3°C, which lost mass. Incubation condition did not affect temperature selected in a substrate thermal gradient when tested within one week ($\bar{X} = 29.2$°C) or 40 days of hatching ($\bar{X} = 26.6$°C).

Because of temperature dependent sex determination and the effect of incubation conditions on hatching success and later growth, management strategies for the desert tortoise must be very conservative. To insure normal sex rations of desert tortoises natural vegetation communities and native soil composition and structure must be preserved or restored. Long term recovery and survival of desert tortoises can only be assured when we have information on pivotal temperatures and nesting ecology for its various populations.

COMPARISONS OF SIZE CLASS STRUCTURES, GROWTH RATES, AND RECRUITMENT OF SONORAN AND MOJAVE DESERT TORTOISES

A. P. Woodman and J. M. Howland

***Abstract*.** Compilation and analysis of data from study sites in the Sonoran Desert is now beginning to allow comparison of Sonoran population characteristics with those of the more extensively known Mojave population of the desert tortoise (*Gopherus agassizii*). We present information on size class structure growth rates and recruitment for all Sonoran plots from which data could be obtained. The potential effects of differences in several environmental factors (including preferred habitat and quantity and seasonability of rainfall) on these characteristics are evaluated.

It appears that average growth rates are somewhat higher for the Sonoran Desert, perhaps due to increased food availability over two seasons. Body size structure of Sonoran populations may appear top heavy because more tortoises reach larger size classes at younger ages. It is also possible that tortoises may reach maturity more rapidly in the Sonoran Desert for the same reason.

Mycoplasma agassizii CAUSES UPPER RESPIRATORY TRACT DISEASE IN THE DESERT TORTOISE, A THREATENED SPECIES

Mary B. Brown, Isabella M. Schumacher, Paul A. Klein, Terrie Correll,
and Elliott R. Jacobson

Abstract. The desert tortoise (*Gopherus agassizii*) is listed by the United States government as a threatened species. A major contributing factor in the decline of this animal has been the presence of an upper respiratory tract disease (URTD). Animals have a chronic long-term disease which eventually leads to severe occlusion of the nares with viscous exudate and destruction of the respiratory epithelium. Electron microscopy of infected tissues demonstrated the presence of a mycoplasma-like organism attached to the respiratory surfaces. The mycoplasma was isolated and designed as a new species, proposed name *Mycoplasma agassizii*. The current study was designed to fulfill Koch's postulate and determine if *M. agassizii* was the etiologic agent of URTD. Clinically healthy animals with known antibody status were infected intranasal with pooled exudate (N=8) from ill donor animals, *M. agassizii* along (N=9) or in combination with *Pasteurella testudinis* (N=8), *P. testudinis* alone (N=9), or sterile broth (N=12). The pooled exudate was culture-positive for *M. agassizii*. Tortoises which received exudate or *M. agassizii* alone or in conjunction with *P. testudinis* were significantly more likely to develop clinical disease ($\underline{P}<0.0004$) than animals which received *P. testudinis* alone or the broth controls. Tortoises demonstrated a strong immune response to *M. agassizii* and seroconversion was seen in all groups with clinical disease. *M. agassizii* was isolated from the upper respiratory tract of clinically ill animals up to six months post-infection. Based on the results of these transmission studies, we conclude that *M. agassizii* is an etiologic agent of URTD in the desert tortoise.

LABORATORY HEALTH PROFILES OF FREE-RANGING DESERT TORTOISES IN CALIFORNIA: EVALUATION OF PHYSIOLOGIC AND PATHOLOGIC ALTERATIONS

M. M. Christopher, K. A. Nagy, I. R. Wallis, B. T. Henen,
C. C. Peterson, J. K. Klaassen, and K. H. Berry

Survival of the desert tortoise (*Gopherus agassizii*) is dependent upon its ability to adapt to drought, habitat loss, and competition for forage, and upon our ability to detect and eradicate disease. It was the purpose of this study to interpret laboratory data from healthy, free-ranging desert tortoises in order to establish reference ranges under a variety of environmental and physiological conditions, and to develop laboratory guidelines for the identification of stressed and diseased tortoises.

Blood and tissue samples were obtained at seasonal intervals between October 1990 and October 1991, as part of an ongoing study organized by Dr. Kristin Berry and sponsored by the Bureau of Land Management. Tortoises were from three sites in the California Mojave desert: Desert Tortoise Natural Area (DTNA), Goffs and Ivanpah. Laboratory tests included a complete blood count, plasma biochemical profile, bacterial cultures of nasal swabs for *Pasteurella* and *Mycoplasma* spp., and serology for *M. agassizii*. In addition, physical examinations were done to document external disease symptoms or disorders.

Reference ranges were constructed as the mean ± 2 SD for tortoises at a particular site and season, and significant differences were identified based on sex, site and season. Data showed normal distribution and outliers were deleted if values exceeded ± 3 SD. Males had significantly higher values for packed cell volume, hemoglobin concentration, and plasma aspartate transaminase (AST) activity. Females had greater plasma concentrations of cholesterol, calcium, and phosphorus, which varied seasonally in conjunction with reproductive activity. Increased plasma glucose, decreased osmolality, and decreased urea nitrogen concentrations were suggestive of improved nutritional status and hydration in the spring of 1991, in conjunction with substantial rainfall.

Severe drought in previous years (1989-1990) likely contributed to debilitation of DTNA tortoises, as evidenced by lower total protein and albumin concentrations and a higher prevalence of mycoplasmosis (as determined by serology) than tortoises at other sites. Tortoises positive for *M. agassizii* tended to have lower plasma glucose and protein concentrations, and mild elevations in plasma AST activity. Two tortoises from DTNA that died had marked azotemia, hypoproteinemia, and clinical debilitation. One DTNA tortoise died of peritonitis, which was thought to be associated with traumatic cystocentesis. There was poor correlation of mycoplasma serology with mycoplasma cultures.

Severe drought in previous years (1989-1990) likely contributed to marked post-hibernational urea nitrogen values and high tortoise mortality at Ivanpah in 1990-91. Drought may also have increased the susceptibility of Ivanpah tortoises to infections, as they frequently had oculo-nasal discharges, and several had marked leukocytosis, with increased heterophils, basophils and/or lymphocytes. High heterophil counts in Ivanpah tortoises were associated with heavy growth of *P. testudinis* in nasal cultures. Tortoises at Goffs showed the greatest physiological variation in laboratory values, particularly urea nitrogen, and were the healthiest population, as determined by laboratory tests, physical exams, and serology. Two tortoises at Goffs were chronically anemic.

In summary, reference ranges were useful when seasonal, site, and sex differences were taken into account. Ill tortoises were best identified by a combination of laboratory tests, physical findings, microbiological cultures, and serology. Abnormal test findings in tortoises serologically positive for *M. agassizii* were neither specific nor marked, but rather suggested nutritional deficit and debilitation, particularly in tortoises at the DTNA. Previous drought conditions at DTNA and Ivanpah substantially affected laboratory test results and likely contributed to disease susceptibility and mortality.

EVALUATION OF BONE MARROW FROM DESERT TORTOISES (*Gopherus agassizii*)

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Betty J. Hall and Wayne A. Weis

(**Editor's note**: The following abstract is from a full length manuscript submitted for publication to the American Journal of Veterinary Research.)

Abstract. Bone marrow was sampled from several locations of 3 healthy and 13 ill desert tortoises (*Gopherus agassizii*). Marrow histology was performed on all tortoises, marrow cytology was performed on 15 tortoises, and complete blood counts were evaluated on 9 tortoises. In histologic sections, hematopoietic cells were most abundant in the pelvis, proximal humerus and femur of sick tortoises; however, thickened portions of the cranial to craniolateral and caudal to caudolateral margins of the carapace and plastron were adequate for evaluating bone marrow. Heterophils were the most common leukocytes found in the marrow and when hyperplastic, heterophils tended to form a mantle around blood sinuses. It was difficult to differentiate among monocytes, lymphocytes, thrombocytes, and blast cells in histologic sections, and eosinophils could not be differentiated from heterophils. Basophils only occurred in very occasional small clusters of 3 to 12 cells in histologic sections. Lymphoid follicles sometimes occurred in the pelvis and long bones. As in histologic preparations, heterophils were the most common leukocytes found on cytology.

Marrow cells were evaluated for reactivity to the following cytochemical stains: periodic acid-Schiff (PAS), Giemsa, naphthyl butyrate esterase (NBE), chloroacetate esterase (CAE), Sudan black B, alpha-naphthyl acetate esterase (ANAE), leukocyte alkaline phosphatase (LAP), acid phosphatase (ACP), and benzidine peroxidase (BP). Heterophils had very slightly PAS-positive cytoplasm, scattered LAP-positive cytoplasmic pinpoint red precipitate, a NBE-positive large perinuclear red focus, CAE-positive minute red/brown cytoplasmic granules, and a large perinuclear red focus with pinpoint red cytoplasmic precipitate when stained for ANAE. Heterophils had pink rod-shaped granules in Giemsa-stained preparations. Eosinophils were easily identified by the presence of brown BP-positive granules and large pink round granules in Giemsa-stained preparations. Basophils were uncommon, and were distinguished by small metachromatic cytoplasmic granules in Giemsa-stained sections. The number of basophils in the marrow appeared to be much less than would account for the number in the peripheral blood. Monocytes and azurophils had an ACP-positive perinuclear red focus and occasional red cytoplasmic granules.

Staining with Sudan black B differentiated erythrocytic precursors from lymphocytes. Erythrocytes were uniformly sudanophilic, even in early progenitor cells. Thrombocytes very occasionally had PAS-positive cytoplasm. Overall, there was a paucity of thrombocytes in the bone marrow. Lymphocytes did not stain positively by any of the cytochemical stains and were extremely difficult to differentiate from thrombocytes.

Differential percentages of hematopoietic cells in cytologic and histologic specimens of bone marrow, and peripheral blood were compared. Heterophil percentages were similar by all

methods. Acidoblasts were not detected in the peripheral blood of sick or healthy tortoises. Although basophils were numerous in peripheral blood of most tortoises, these cells occurred in low numbers in the marrow of all animals. The combined percentages of monocytes and lymphocytes in the peripheral blood correlated with numbers of mononuclear cells in the bone marrow (25% in the peripheral blood versus 22% in the marrow), but did not correlate with numbers of mononuclear cells in the cytologies, which were much lower. Eosinophils could not be detected in histologic specimens but percentages were similar in cytologies and CBC's. Erythrocyte progenitors were not detected in the peripheral blood smears of tortoises in this study, but percentages in cytologic and histologic specimens of the marrow were similar. Although thrombocyte numbers were within normal limits in peripheral blood smears of all examined tortoises, thrombocytes were in very low numbers in cytologic specimens, and could not be reliably identified in histologic specimens. Azurophilic monocytes and blast cells of undetermined lineage were not observed in peripheral blood smears of examined tortoises, and were included in the mononuclear cell count in histologic specimens. They occurred in very low numbers in cytologic specimens.

We concluded that there were distinct cytochemical markers for heterophils, eosinophils, basophils, monocytes, azurophilic monocytes, and erythrocyte progenitors. For evaluation of bone marrow cellular constituents, histology was best for determining total numbers of cells, distribution of cells in the marrow cavity, and overall stage of maturity, but poor for individual differentiation of mononuclear and granulocytic leukocytes. Cytology was excellent for evaluating cellular morphology and differentiation among cell types.

VARIATIONS IN UPPER RESPIRATORY TRACT DISEASE AT THE DESERT TORTOISE CONSERVATION CENTER, LAS VEGAS, NEVADA: OCCURRENCE, HEMATOLOGIC AND BIOCHEMICAL

Janice S. Grumbles, Linda C. Zimmerman, David C. Rostal,
Robert H. George, and Michael O'Connor

Abstract. Upper Respiratory Tract Disease (URTD) symptoms were observed one or more times in 56 desert tortoises (*Gopherus agassizii*) (12 females, 17 males, and 27 undetermined sex) of 172 tortoises from 4-ha pens and once from one male tortoises out of 70 tortoises from a 7.7 km^2 area adjacent to the Desert Tortoise Conservation Center during April to October, 1992. Symptoms ranged from mild (serous nasal discharge) to debilitating (purulent nasal discharge and muscle wasting). Fewer females exhibited signs of disease than males or tortoises of undetermined sex. The smallest size class of tortoises had the lowest incidence of symptoms with the adult size class having the greatest incidence. Symptoms were seen throughout the season with the greatest occurrence in October and the lowest in July. Symptomatic tortoises were found in pens both with and without supplemental food and water and the lowest incidence occurred in the field site. The frequency of bleeding contributed to the development of symptoms. Some tortoises chronically exhibited symptoms of disease, while others were sporadically symptomatic. Hematologic and biochemical parameters were similar between symptomatic and asymptomatic tortoises and the results from symptomatic animals were often more similar to the filed site animals than the DTCC asymptomatic animals. While there are seasonal variations in a number of parameters, none of the parameters are predictive of symptom occurrence. It will ultimately be necessary to do serologic testing to determine whether an animal has URTD.

TRANSMISSION STUDIES WITH UPPER RESPIRATORY TRACT DISEASE OF THE DESERT TORTOISE: SETTING UP THE EXPERIMENTAL CHALLENGE GROUPS

Elliott R. Jacobson, Terrie Correll, Virginia Skinner, Jean Voshall, Mary B. Brown,
Paul A. Kline, Isabella Schumacher, and Bobby R. Collins

Abstract. *Mycoplasma agassizii* sp. nov. and *Pasteurella testudinis* have been incriminated as possible etiologic agents of an upper respiratory tract disease (URTD) of the desert tortoise (*Gopherus agassizii*). In order to fulfill Koch's postulates and establish a casual relationship between these organisms and URTD, a transmission study was designed utilizing 60 desert tortoises originating from the Desert Tortoise Conservation Center, Las Vegas, Nevada. Pens for tortoises were constructed at The Living Desert, Palm Desert, California, at a site remote from the display collection. The actual cost for constructing the pens and maintaining the tortoises exceeded anticipated costs. The timing of completion of pens and acquisition of tortoises also entailed a considerable amount of extra work not initially envisioned. Preparation of the pen site began in September 1990 and pens were completed in the spring of 1991. Following the arrival of 60 clinically healthy desert tortoises in May/June 1991, tortoises were acclimated for 10 months prior to initiation of the challenge study. During this acclimation period, 3 tortoises died and 7 tortoises were excluded from the study because of clinical signs of illness. A number of tortoises had to be force-fed for several weeks because of poor appetite. Nevertheless, the transmission study commenced in April and ended in October 1992 with successful fulfillment of Koch's postulates.

HEMATOLOGICAL AND BIOCHEMICAL INDICATORS OF STRESS IN FREE-RANGING DESERT TORTOISES AND CAPTIVE TORTOISES EXPOSED TO A HYDRIC STRESS GRADIENT

Michael P. O'Connor, Janice Grumbles, Robert H. George,
Linda C. Zimmerman, and James R. Spotila

Abstract. Hematologic and plasma biochemical parameters were monitored on free-ranging desert tortoises (*Gopherus agassizii*) near Las Vegas, Nevada and on a population of captive tortoises maintained in 4-ha pens with natural physiography and vegetation and subjected to varying levels of water stress. No reliably predictive indicators of water stress - or other stress - were found. Increased plasma electrolyte concentrations and white blood cell counts (compared to free-ranging and water-supplemented, captive animals) occurred in the captive animal without water supplementation and is likely due to altered water balance. The electrolyte and white blood cell changes were not predictive, however, and thus fail as good stress predictors.

Several biochemical assays suggested specific stresses with which some of the tortoises had to contend. Elevated creatine phosphokinase activity in some males in spring suggests trauma, perhaps due to fights with other male tortoises. Elevated serum glutamate oxalocetate transaminase activity, again primarily in males in the spring, are consistent with and suggestive of hepatocellular injury. A plausible mechanism for such injuries is hepatotoxins ingested with forage. Deceases in glucose and uric acid as the activity season progress, suggested decrease in energy intact and changes in energy balance. Lower plasma protein concentrations and lower hematocrits in smaller tortoises suggest that growth places demands on the energy, carbon, and/or nitrogen balances of young, rapidly growing tortoises.

Mycoplasma agassizii - SPECIFIC ANTIBODIES IN DESERT TORTOISES FROM DESERT TORTOISE NATURAL AREA, GOFFS, AND IVANPAH

Isabella Schumacher, Mary B. Brown, Elliott R. Jacobson, Kristin Berry,
Brian Henen, Kenneth Nagy, Ian Wallis, and Paul A. Klein

Abstract. A recent transmission study showed that *Mycoplasma agassizii* causes upper respiratory tract disease (URTD) in the desert tortoise (*Gopherus agassizii*). A serologic test (Enzyme-Linked Immunosorbent Assay [ELISA]) was used to detect antibodies to *Mycoplasma agassizii* in 60 desert tortoises from three different study sites in California (Desert Tortoise Natural Area [DTNA] [n=19], Goffs [n=21], and Ivanpah [n=20]). Antibody levels were determined for plasma samples from March, May, July/August, and October 1992 for each tortoise.

There were no major seasonal difference in specific antibody levels in most of the tortoises from the three sits. However, the number of antibody-positive tortoises varied for each site. The highest percentage of positives was found in DTNA (47%, 9 of 19). Ten percent (2 of 20) of the tortoises from Ivanpah were positive. No positives (0 of 21) were detected in the Goffs group. Of the tortoises that tested positive, only two females from Ivanpah showed minimal signs of URTD (nares occluded) at one time in 1992.

HEALTH, PHYSIOLOGY AND MORTALITY IN DESERT TORTOISES IN CALIFORNIA FROM 1989 TO 1991

I. R. Wallis, K. A. Nagy, B. S. Wilson, B. T. Henen, C. C. Peterson,
C. Meienberger, and I. A. Girard

***Abstract*.** Adult, radio-telemetered desert tortoises (*Gopherus agassizii*) near Goffs, near Ivanpah, and at Desert Tortoise Natural Area (DTNA) were captured periodically between 1989 and 1991 for evaluation of clinical health profiles, external symptoms of respiratory disease (URTD), body condition, and water and energy balance. Differences in these parameters between sexes were minor and infrequent. However, large differences between seasons and study sites occurred, in concert with seasonal and regional differences in rainfall. Drought was associated with increased hematocrit and blood and urine osmotic concentrations, among other changes. Summer rain at Goffs in 1989 allowed tortoises to return their body composition to more normal values, but tortoises at Ivanpah and DTNA had no rain, and their condition worsened. Rainfall in 1990 and 1991 was higher, but still below average, and tortoise mortality was high. No reliable predictor or mortality was found among the measured health profile, body condition, or physiological parameters.

MORTALITY RATES AND HEALTH OF SONORAN DESERT TORTOISES

A.P. Woodman and J. M. Howland

Abstract. Unusually high rates of mortality have been observed at two Sonoran desert tortoise (*Gopherus agassizii*) population monitoring plots. The population in the Maricopa Mountains underwent a severe decline in the late 1980s and early 1990s. The population at the Bonanza plot has apparently decreased by nearly 50% in the past several years. Mortality rates in the Arrastra Mountains, the Hualapai Foothills, and the San Pedro Valley plots may be slightly higher than normal. Symptoms of shell disease, apparently the same as those observed on the Chuckwalla Bench and other sites within the Mojave population, have been observed at the Tortilla Mountains, Bonanza and Little Shipp Wash. Tortoises throughout the Arizona range have tested positive for *Mycoplasma agassizii* and minor symptoms of upper respiratory tract disease (URTD) have been noted in a few instances. Are we beginning to see the kind of widespread and severe declines in Arizona that have impacted the Mojave population over the past decade?

THERMOREGULATION BY DESERT TORTOISES IN THE EASTERN MOJAVE DESERT: SEASONAL PATTERNS OF OPERATIVE AND BODY TEMPERATURES, AND MICROHABITAT UTILIZATION

L. C. Zimmerman, M. P. O'Connor, S. Bulova, J. R. Spotila, S. Kemp, and G. Salice

Abstract. We monitored meteorological variables, daily and seasonal patterns of body temperatures, corresponding operative temperatures and microhabitat utilization by desert tortoises (*Gopherus agassizii*) during the 1991 and 1992 activity seasons of tortoises in the eastern Mojave Desert. We studied tortoises in enclosures of natural habitat at the Desert Tortoise Conservation Center (DTCC) near Las Vegas, Nevada and a population of free-ranging tortoises in a field site adjacent to the DTCC. Air, ground, and operative temperatures coincided with daily and monthly pattern of incident solar radiation. Variation in body temperature was primarily a consequence of microhabitat selection, principally use of burrows. During July-October, in the morning, body temperatures of tortoises in burrows were cooler than those individuals on the surface. During midday, tortoises remained in burrows where body temperatures were cooler than extreme surface operative temperatures. While tortoises remained in burrows during much of the day, tortoises typically did not sleep in burrows at night. Microhabitat utilization was dictated by avoidance of extreme temperatures during midday, and microhabitat selection corresponded to maintenance of energy and water balances.

DESERT TORTOISE ABUNDANCE AND QUANTITATIVE MEASURES OF HUMAN USE IN THE RAND MOUNTAINS, FREMONT VALLEY, AND SPANGLER HILLS

Kristin Berry, Michael Weinstein, Gilbert Goodlett,
Glenn Goodlett, and Peter Woodman

Abstract. Changes in distribution and abundance of desert tortoise (*Gopherus agassizii*) populations were compared for two sample periods, 1977-78 and 1990, using sign counts from strip transects. The 1977-78 and 1990 samples were situated at 100 sites (100 transects) and 150 sites (450 transects, 3 per site), respectively, in an area of 425 mi^2 in the western Mojave Desert. The transect data were sorted into four areas: Desert Tortoise Research Natural Area (DTNA), Fremont Valley, Rand Mountains, and Spangler Hills. In 1977-78, tortoise populations ranged from densities of 20 to 50/mi^2 in the Spangler Hills to $\geq$250 mi^2 in the other three areas. By 1990, sign counts had not changed significantly in the Spangler Hills. However, in the other three areas, sign counts had declined (estimated tortoise densities = 30 to 60/mi^2), and the changes were statistically significant (ANOVA, $p = 0.05$). Population densities of tortoises were significantly higher at the DTNA than at Spangler Hills, Rand Mountains, and in California City (ANOVA, $p \leq 0.05$).

The histories of human-related uses were evaluated at each of the four sites. The Spangler Hills (public lands) has had few restrictions and has been used as an "open" off-road vehicle (ORV) use area with virtually no restrictions on vehicle use since the early 1970s. The Spangler Hills also has mining and sheep grazing. The Rand Mountains/Fremont Valley also had few restrictions between 1973 and 1980. The area has a checkered history of ORV use and was "open" between 1973 and 1980; after 1980, vehicle use was restricted to "existing" routes, ways, and trails. California City, which is adjacent to the DTNA and Rand Mountains/Fremont Valley, is predominantly private lands with no controls on vehicle or grazing. In contrast, the DTNA has been closed to recreation vehicle use since 1973, to sheep grazing since about 1978, and to mining since 1980. The Spangler Hills and most of California City are not considered important tortoise habitat by the Bureau of Land Management (classified as Category 3), whereas all or most of the DTNA and Rand Mountains/Fremont Valley are considered essential for the continued viability of the species (classified as Category 1).

During the 1990 sampling period, data were also recorded on signs of human uses on each transect: paved roads, dirt roads, trails, tracks, garbage, shooting targets, shooting areas, mining, campsites, livestock-sheep, livestock-cattle, wild horse or burro scats, dogs, fence lines, posts, utility lines or towers, old buildings, and partially or totally denuded areas. The most frequently encountered evidence of human use was garbage (found on 149/150 transect sites), followed by vehicle tracks (142/150 transect sites), vehicle trails (132/150 transect sites) and sheep scat (116/150 transect sites). dirt roads, shooting targets, and evidence of mining were also common. The DTNA had significantly fewer vehicle trails, tracks and sheep scats than the other three areas. In the year prior to the transect surveys, the Rand Mountains and Fremont Valley were closed to recreational vehicle use on an emergency basis. In spite of the emergency closure, the Rand Mountains and Fremont Valley had very high numbers of "recent" vehicle tracks. The counts of

vehicle trails were not significantly different between the Spangler Hills and Rand Mountains/Fremont Valley. California City had significantly higher counts of garbage than the other three areas.

TORTOISE BEHAVIOR: HIGHWAYS, FENCES, AND PRESERVE DESIGN

William I. Boarman, Marc Sazaki, Gilbert C. Goodlett, Glen O. Goodlett,
Tracy Okamoto, and W. Bryan Jennings

Abstract. Highway traffic has been, and continues to be, an important cause of mortality for the desert tortoise (*Gopherus agassizii*). A multi-agency effort is underway to determine the effectiveness of a tortoise-proof fence and storm-drain culverts at reducing mortality, helping the local population to recover, and reducing population fragmentation. The study is being conducted near Kramer Junction, San Bernardino Co., California. In spring 1992, radio-tagged tortoises were followed to determine home range sizes and to document encounters with the barrier fence. Also, the edges of two highways were searched for remains of road-killed tortoises and other animals.

By 15 June 1992, 70 tortoises were marked in the study area, which is east of Kramer Junction along Highway 58, and 50 animals were equipped with radio transmitters. Sufficient data to determine activity areas were obtained from 41 animals. Very cursory analyses suggest that the average use areas for adult males was 41 (+/- 10.9) ha, adult females was 27 (+/- 3.6) ha, and immatures was 7 (+/- 4.3) ha. Determination of spring home range sizes was prohibited because eight out of 43 (19%) animals with five or more observations exhibited linear movements in excess of 0.8 km, which appeared to be outside of their normal home ranges or seasonal use areas. All of these individuals were either immatures or subadults. Such apparently long-range movements must be considered in addition to standard activity areas when considering space requirements for tortoise preserves and special management areas. In addition, three animals were found at the fence, two of which moved along the fence for some distance.

We found 13 tortoises that appeared to have been killed in the previous five months along a 15-mile unfenced section of Highway 395, south of Kramer Junction. Sixteen carcasses representing 12 other vertebrate species were also found. Surveys conducted along the fenced section of Highway 58 were unreliable because of heavy construction activity.

STATUS OF THE BUREAU OF LAND MANAGEMENT'S RAVEN MANAGEMENT AND EXPERIMENTAL REMOVAL PROGRAM

William I. Boarman

Abstract. Common Ravens (*Corvus corax*) have recently become common predators in the deserts of California due to the expanding presence of human activities. In 1990, the desert tortoise (*Gopherus agassizii*) was listed as a threatened species in the Mojave Desert; one probable cause for tortoise population declines is predation by ravens on juvenile tortoises. Three lines of evidence support the hypothesis that raven predation is an important source of mortality in tortoise populations: (1) people have observed ravens attacking or eating juvenile tortoises; (2) deposits of tortoise shells have been found at raven nests and perches; and (3) shells with signs of predation by ravens have been found throughout the desert, but not necessarily associated with nests and perches. In additions, in recent years there has been a statistically significant reduction in the representation of juvenile tortoises, of the size ravens are known to prey on, in size-class distribution of several tortoise populations.

The Bureau of Land Management (BLM) is developing a plan to reduce the impact of raven predation on tortoise populations. The plan includes research, habitat alteration, lethal control, and monitoring actions. In the interim, the BLM has implemented an experimental program to remove all ravens foraging within the Desert Tortoise Natural Area and specific problem ravens in other parts of the desert. The program was designed under the direction of the BLM's Raven Technical Review Team, but met with last-minute objections from the Humane Society of the United States, which had previously approved the program. To effect some removal of ravens in 1993, the BLM modified the interim program to only remove birds closely associated with tortoise shells showing evidence of raven predation.

HOME RANGE AND MOVEMENTS OF SONORAN DESERT TORTOISES

Steve Boland and Scott D. Hart

Abstract. Home ranges were calculated and movements within and among years were analyzed for individual tortoises at three sites in the Sonoran Desert of Arizona. Because observations of specific tortoises were made sporadically during population monitoring studies, they may not accurately portray the complete home ranges of the study animals. Instances of long range movements were noted over short periods of time (sometimes over 1000 meters in a few days), as well as extreme site fidelity over long periods of time (up to six years). Patterns of movement may be limited or influenced by habitat characteristics as illustrated by differences in movement patterns along sites differing in habitat structure.

SURVEYING TORTOISES AT JOSHUA TREE NATIONAL MONUMENT: RESULTS OF TWO SEASONS' WORK ON KILOMETER SQUARE PLOTS

Jerry Freilich and Bob Moon

Abstract. Joshua Tree National Monument needs to locate tortoises and assess their population trends over time. Because of budget restrictions, we were forced to devise cost-effective, non-standard methods for collecting data. In spring 1991, two permanent study plots (one 1.6 km^2, the other 1 km^2) were searched for tortoises. In 1992 and 1993, the 1.6-km^2 site was searched again and two additional 1-km^2 sites were added. We used teams of staff and volunteers working a few hours on each site one day each week in April and May only. We concentrate here on the site studied in three consecutive years (including a half-season's data for 1993). At that site we found and marked 47 tortoises in Year 1, 77 by the end of Year 2, and 92 by the middle of Year 3. We discuss here mark/recapture results from this plot and implications of our methodology.

INTRODUCTION

Joshua Tree National Monument (JTNM) comprises an area of more than 200,000 ha containing some of the most pristine desert in southern California. In 1988, a study based on triangular transects estimated that 8 to 29 desert tortoises (*Gopherus agassizii*) per km^2 might be found in 21% of the monument's area (Karl 1988). Few areas in the Monument are completely without tortoises (Freilich, personal observation).

Unable to use standard methods due to budgetary and logistical realities, we adopted a survey method within our means and started censusing several areas where tortoises were known to occur in relatively large numbers. An earlier study by Barrow (1978) had shown tortoises present at a mile-square site in the Pinto Basin along the Black Eagle Road. Using the BLM 60-day census method (Berry 1984) Barrow marked 51 tortoises and wrote that their numbers were declining based on his analysis of their population age structure (Barrow 1978). We decided to resurvey this site in 1991, 1992, and 1993, but being unable to cover the whole square mile, we examined only the 1.6 km^2 area north of the road. We also established five other 1-km^2 sites from 1991 to 1993, but this paper will focus attention on the "Barrow Site" because it is representative and has been most studied.

This study is important for two reasons. First, it is a rare opportunity to assess tortoise numbers using data from the same site in multiple successive years. Because these data are cumulative, we can judge the importance of such temporal variables as weather and vegetation on perceived tortoise numbers. Second, the intensity of effort (720 staff hours spent on 26 days in 3 different years on a single 1.6-km^2 plot) gives us a view of tortoise activity patterns, movements, and phenology quite different from that seen by the one or two observers doing a 1-mi^2 survey in the standard 60-day survey.

METHODS

Study Site

The Barrow site is located in the Pinto Basin, in the eastern part of JTNM (UTM Zone 11, 37-45-500N, 6-17-500E). The site is bordered to the south by an unpaved road that receives little traffic. Firearms, off-road driving, roadside camping, and disturbing native vegetation are all prohibited. The area has been undisturbed since JTNM was established in 1936. The site is relatively level desert dominated by *Larrea tridentata, Ambrosia dumosa, Krameria parvifolia*, and *Opuntia ramosissima*. Slope is less than 2% and elevation is from 630 to 660 m.

Sampling Procedure

Standard 60-day surveys are expensive. Having no tortoise project money available, we adopted a method that relies heavily on volunteers from the community. Lacking staff to sample square miles, we decided to use kilometer squares, an area less than half (39%) the size of a square mile.

Our method used at least two staff employees working with from 1 to 12 volunteers, walking north-south compass lines looking for tortoises. All searchers walked abreast approximately 10-m apart. Distance walked and observer-hours were recorded. Each week, transect lines were resumed at the spot where they left off the previous week. Because group size differed from week to week (dependent on available observers), time to cover the entire plot was variable, but each site was completely surveyed at least four times each season.

Tortoises were located, measured, sexed, photographed, weighed, and individually marked with both shell notches and plastic number tags attached with epoxy. Global positioning receivers determined the location of each tortoise to ± 5-m using differential post-processing. Dead tortoises were measured if the shell was complete enough to do so. The date of first discovery was painted on the bottom of each dead tortoise and the shell left in place.

To the greatest degree possible, our line of observers kept moving after location of a tortoise. Typically two people were left behind to process the tortoise while the other observers moved forward. If numerous tortoises were found, however, the line was unavoidably delayed because someone had to watch each tortoise until the processing team arrived.

Surveys were conducted from 0600 to 1400 hrs except on very hot days when work stopped at noon. During hotter weather in May, work began at or close to dawn. Each plot was examined a single morning each week in April and May. Spring mornings were chosen as the period of greatest above-ground tortoise activity based on previous observation of radio-transmittered tortoises.

The Schnabel (1938) estimate was used to calculate relative density of tortoises. This method is a simple variant of the Lincoln/Petersen method but uses more data, from multiple occasions, to improve the accuracy of its estimate (Begon 1979). Program CAPTURE was also employed to model mark/recapture parameters, make relative density estimates, and compare with the Schnabel estimates (White et al. 1982).

RESULTS

Numbers Caught and Effort Expended

Surveys were conducted on a total of 26 days; nine in 1991, ten in 1992, and seven in the partial 1993 season. In all, 720 staff-hours were used over the period (o(x,¯)= 7.1 people per day, ±3.74 SD, range 3 to 14 people) (Figure 1). Each tortoise capture required o(x,¯)= 3.3 hours of searching. As expected, numbers of captures rose together with cumulative hours of effort expended, but note that new animals continued to be found at a gradual but still increasing rate at the end of the period (Figure 1).

Because effort was different on each occasion, varying with the numbers of observers, we performed a regression to examine the relation between observer effort on each given day and the number of tortoises found that day. Intuitively, the number of tortoises found should increase with increasing numbers of observers. This relationship was observed considering all days ($p = 0.002$, $r^2 = 0.34$), but this was partly due to the presence of a single day when 14 tortoises were found by a large class of student volunteers (120 staff hours expended) (Figure 2). If this point is excluded as an outlier (circle on Figure 2), the resulting regression is not significant and the r^2 value drops to 0.18, indicating that the regression explained only a small part of the variance.

Tortoises were most frequently captured between 0800 and 1200 hrs with a peak of captures occurring between 0930 and 1100 hrs (all times converted to Pacific Daylight Saving Time) (Figure 3). Although most tortoises were found sheltering under bushes or in burrows, no obvious correlation between ambient temperatures was noted. Time of day of capture seemed to be independent of temperature and time of sunrise. Efforts to capture more tortoises when they were actively moving about (as opposed to sheltering) by starting at or before dawn were not successful (Figure 3).

A total of 92 tortoises were captured over the period; 47 new animals in 1991, 30 in 1992, and 15 in 1993 (Table 1). Juveniles accounted for only 13% of the tagged animals in 1991, 30% of new tags in 1992, and 53% of the eight new tags in 1993 (Table 1). Of the 92 animals tagged, 32 were never recaptured, 27 were recaptured a single time, 9 recaptured twice, 9 recaptured thrice, 10 recaptured four times, 2 recaptured five times, and 3 recaptured six times. This pattern suggests that many of the tortoises remained in the area, perhaps leaving and returning several times over the course of this study. Five animals found in 1991 were not seen again until 1993.

No mortality of tagged individuals was observed, although one tortoise was found dead, apparently a victim of predation, six months after the period described here. Twelve dead tortoises were found in the site, of which four were juveniles. All four dead juveniles were found in 1992. No new dead tortoises were found in 1993.

Density Estimates

Because mark/recapture methods make an assumption that all animals are equally capturable, juvenile animals (<140 mm maximum carapace length [MCL]) were excluded because they're so hard to capture. Therefore, these estimates must be considered very low because 23 marked, and an unknown number of unmarked juveniles are ignored. Because the site is 1-km wide by 1.6-km long, we report the numbers estimated for the whole plot and then convert to numbers of adult tortoises per km^2 (Table 2).

Figure 1

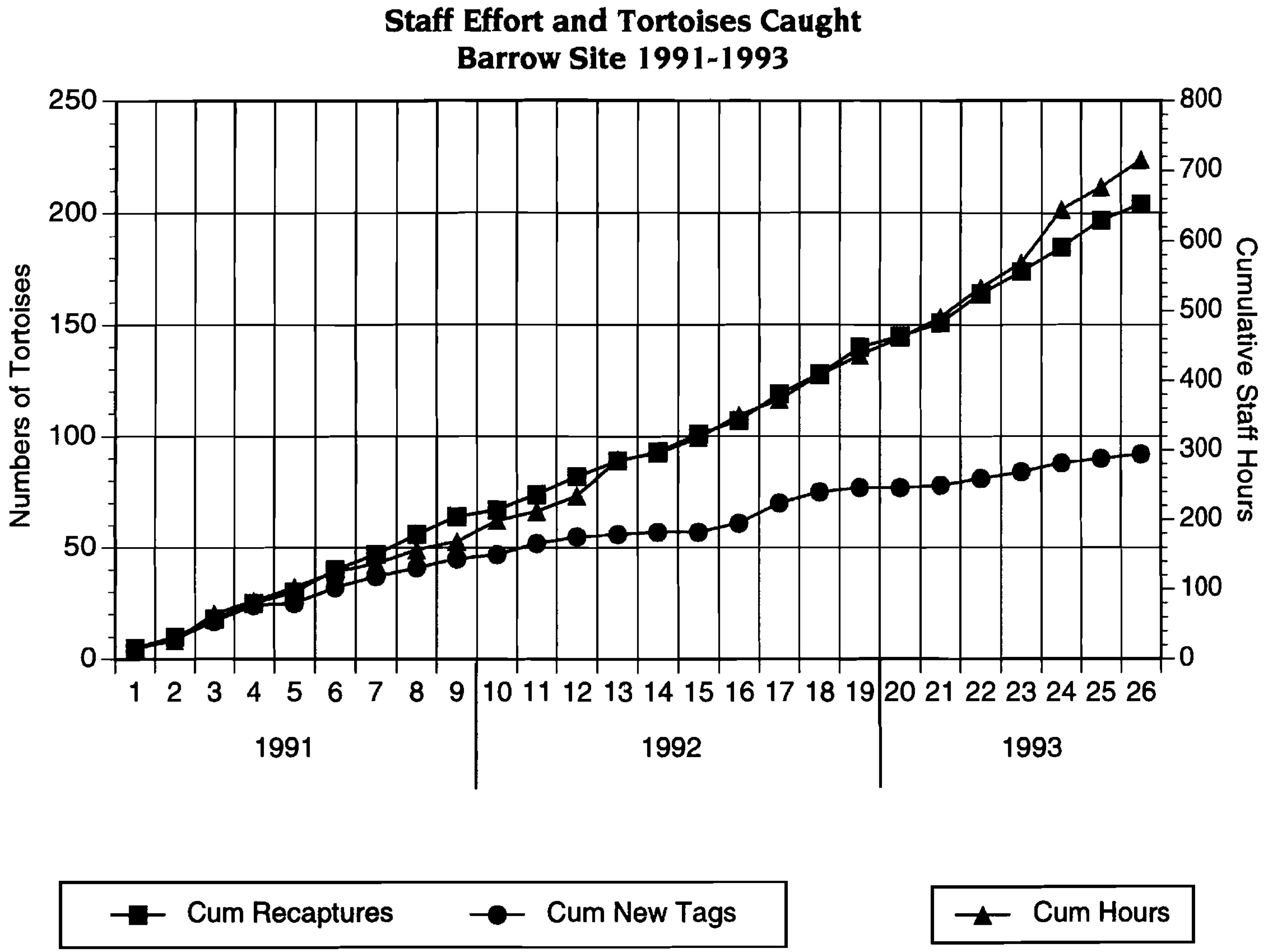
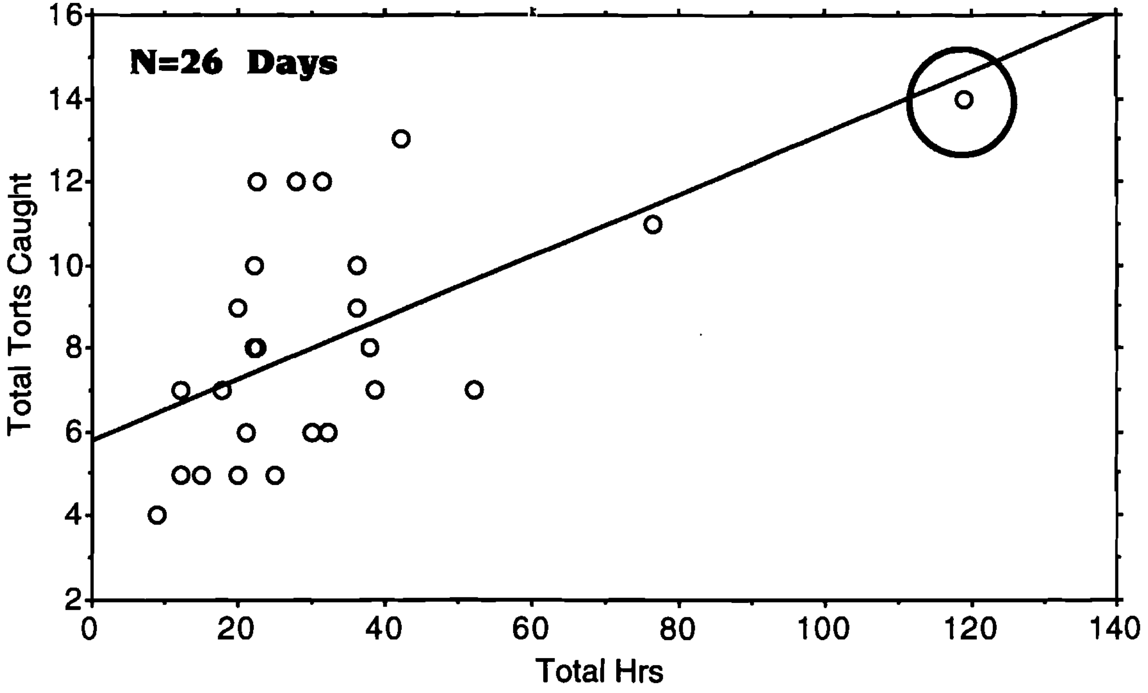

Staff Effort and Tortoises Caught
Barrow Site 1991-1993
Numbers of Tortoises
0
50
100
150
200
250
Cumulative Staff Hours
0
100
200
300
400
500
600
700
800
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
1991
1992
1993
Cum Recaptures
Cum New Tags
Cum Hours

Figure 2



Total Effort Each Day vs Tortoises Caught

Regression Significant at p=0.002, $R^2 = 0.347$

Figure 3

Frequency Distribution of Times of Capture
Barrow Site 1991-1993

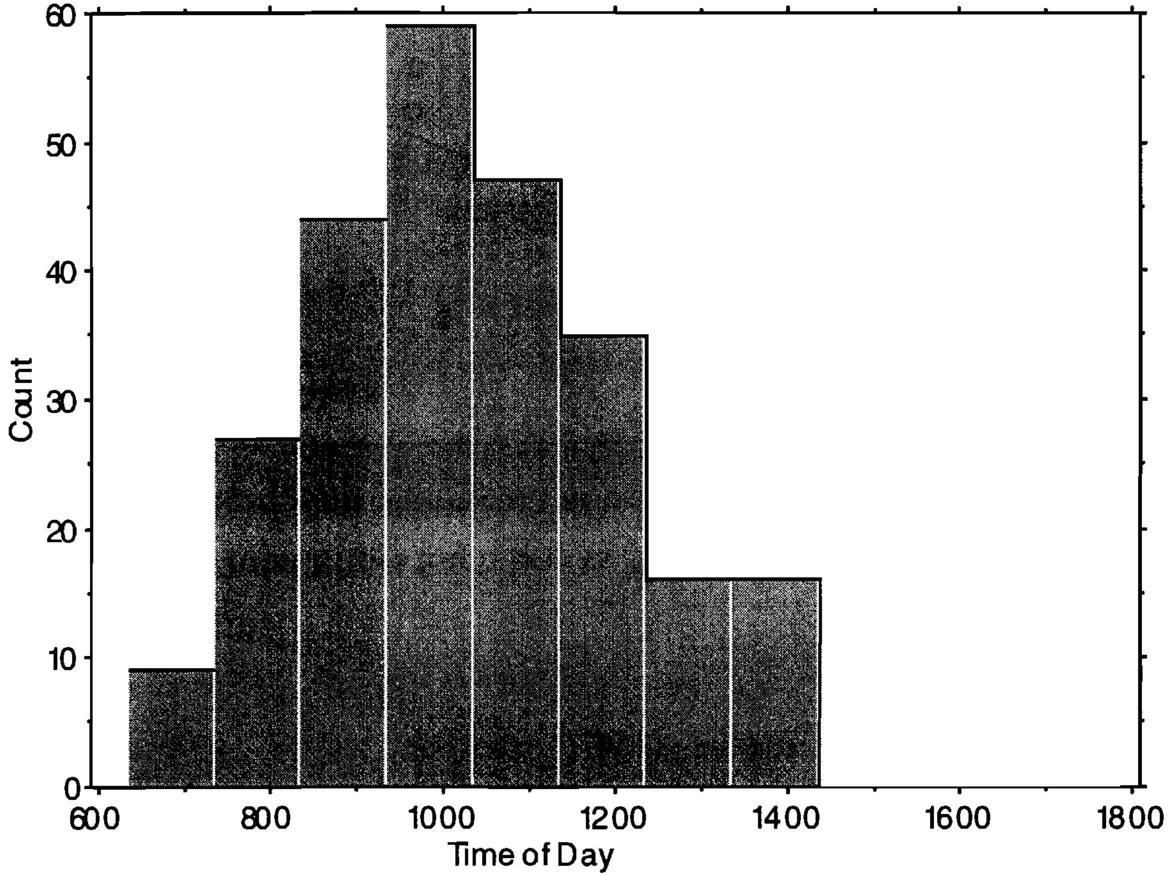


Table 1

RECAPTURE SUMMARIES

Barrow Site 1991-1993 †

	Total New Tags	New Tags Juveniles	Cumulative # Tagged	% of Cum. Total Juveniles	Number and % of Cum. Total Recaptured*	Number and % of Recaptured Juveniles
1991	47	6(13%)	47	13%	16 (34%)	1 (2%)
1992	30	9(30%)	77	19%	37(48%)	5(6%)
1993†	15	8(53%)	92	25%	36 (39%)	2 (2%)

† Based on one half season's data

* Multiple captures of the same tortoise count as one

Schnabel estimates using individual years' data indicated presence of 50, 63 and 44 (1991-1993 respectively) adult tortoises per km^2 (o(x,¯)=52). If all the data are considered together (as though the separate dates were all in a single season), the overall estimate is 48 animals (Table 2). Unfortunately, the Schnabel method does not produce a reliable confidence interval for the estimate.

Program CAPTURE gave estimates of 45, 51, and 47 for the three years in chronological order (o(x,¯)= 48). If all the data are considered as though collected in a single season, CAPTURE's estimate is 50 animals per km^2 (Table 2). Note that confidence intervals are given for CAPTURE estimates for the whole plot (but we did not attempt to resize the intervals to adjust for the single km^2 plot size) (Table 2). The confidence interval for the three-year estimate of the whole plot is very small (75 ± 3.16 SE) because all n=26 occasions are considered (Figure 4). We used CAPTURE's model $M_{(0)}$ for these calculations, the case that makes the fewest deviations from the fundamental assumptions of mark/recapture studies. However it is also true that model $M_{(0)}$ is biologically unrealistic and that other models would give better results (Otis et al. 1978; Murray 1993).

DISCUSSION

The "Joshua Tree method" outlined here produces a different view of tortoises than that of the 60-day census. Because many observers are afield at the same time, the day's results are more analogous to an instantaneous scan sample (Altmann 1974) than the series of isolated points made by one or two observers. Because the large group allows more captures to be made in a shorter time, such phenomena as effort per day (Figure 2) and time of capture (Figure 3) contain more information and have more meaning than they would if recorded on a 60-day census.

The relationship of effort to number of tortoises caught has important ramifications for survey methodology. Our results show that number of observers was only weakly or not at all correlated with number of tortoises caught (Figure 2), suggesting that particular days were better for tortoise captures than others. If this is so, a method that samples many different days (perhaps for short time periods) will have a much better chance of finding tortoises than another method where a long time is spent each day despite few captures made. If it could be shown that particular days are, in fact, better for tortoises than others, an ideal sampling plan would target those days for field work. More work should be directed towards discovery if this true.

Another goal of efficient sampling is to use those times mostly likely to yield tortoises. Our peak of captures between 0830 and 1130 hrs suggest that these times are optimum for field-work. We did not test the possibility that another window of opportunity exists late in the day as temperatures cool, but additional work should be directed to that question.

The years of this study were all good for tortoises, with good rainfall and abundant annual growth. In particular, 1991 was notable because it was the first wet year following a severe drought from 1985 to 1990. Improved conditions probably account for the low observed mortality. Although the remains of 12 dead tortoises were found in the site, none of our marked animals died during the seasons we report here. Eight of the 12 remains were found in 1991 and had therefore died before the study began, representing an unknown number of previous years' mortality. Except for four juveniles found dead in 1992, there was no other evidence of mortality. No additional adult tortoises were found dead in 1992 or 1993 and no animals were found with runny

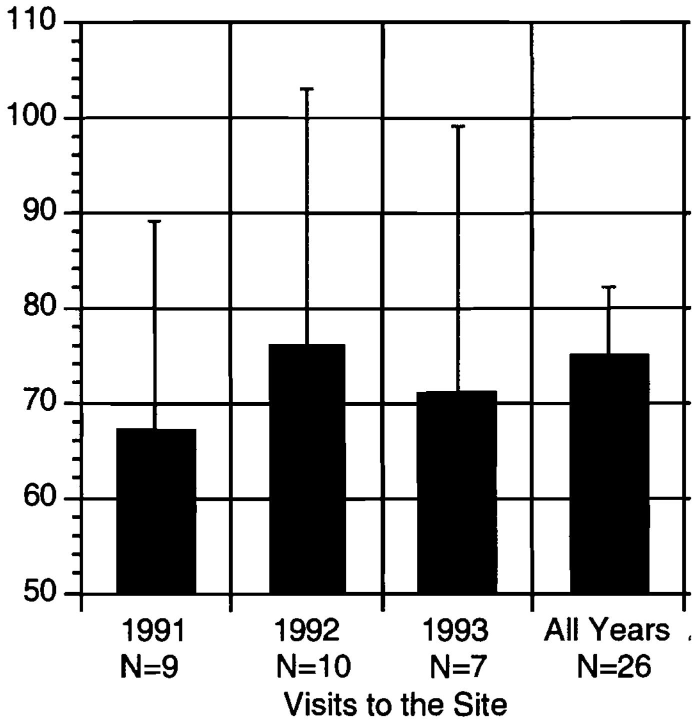
Table 2

Summary Statistics by Schnabel and Program Capture
Barrow Site 1991-1993

	SCHNABEL	Estimated # Per Km2	CAPTURE	Estimated # Per Km2
1991 Juveniles Excluded	75	50	67±10.7 SE	45
1992 Juveniles Excluded	94	63	76±13.4 SE	51
1993 Juveniles Excluded †	66	44	71±13.8 SE	47
All Years Juveniles Excluded	72	48	75±3.16 SE*	50

† Based on one half-season's data

Figure 4



Population Estimates and 95% Confidence Intervals from Program Capture noses, inflamed eyes, breathing problems, or other symptoms of Upper Respiratory Tract Disease (URTD).

Each year, an increasing percentage of the total new tags were juveniles (Table 1), a pattern consistent with the likelihood that juveniles, although difficult to find, were present throughout the study. Of the dozen dead tortoises found, 33% were juveniles. All of the dead juveniles were found in 1992, three of these being very small, most likely 1991 hatchlings. There was no other evidence of high juvenile mortality, and no additional dead juveniles were found in 1993.

Discovery of new animals slowed, but did not cease in the third year of this study, suggesting that either immigration was occurring, or that some animals had remained unseen despite their long-time presence in the site (Figure 1). A goal of future studies should be determination of the inflection point where new captures diverge from the trend of recaptures. This point, reached at Day 10 in our study (Figure 1), might be a point at which studies could be considered sufficient to make population estimates. Although this pattern requires much greater testing with alternate statistical treatments and sampling designs, it is clear that the population estimates we obtained after a single season (50 per km^2 by Schnabel, 45 by CAPTURE), were very close to those estimates obtained for all three years (48 per km^2 by Schnabel, 50 by CAPTURE). In fact, all three years' data taken independently support the validity of our method, in that estimates year-by-year according to program CAPTURE were all very close and certainly within the 95% confidence interval of the estimates (Figure 4).

Observed fluctuations in estimated population size seen in Table 2 are mostly attributable to the specific performance parameters of the estimators used. The Schnabel estimator, for example, is particularly sensitive to numbers of captures made, followed by a period with only small numbers of recaptures. In such cases, the Schnabel estimate is greatly inflated. It is our belief that this is why the 1992 Schnabel estimate was 94, much higher than any other estimate. CAPTURE and other methods (e.g., Jolly-Seber, Fisher-Ford) (Begon 1979) are more robust to stochastic uncertainties in schedules of recaptures.

CONCLUSIONS

Certainly future study should address determination of the minimum size plot, shortest period of sampling, least use of human effort, and most repeatable method — all compatible with the goal of producing the most accurate tortoise population estimate with the narrowest confidence interval.

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THE IMPORTANCE OF WASHES AND WASHLETS TO DESERT TORTOISES (*Gopherus agassizii*) IN THE WESTERN MOJAVE DESERT

W. Bryan Jennings

Abstract. Desert tortoise (*Gopherus agassizii*) habitat in the western Mojave Desert can be divided into several different sub-habitats or strata defined by topographical and edaphic characteristics which, in turn, influence the local distribution of plants. Because tortoises are dependent upon vegetation for food, water, and shelter, understanding how tortoises utilize these sub-habitats is important from a management perspective. During the spring of 1991 and 1992, foraging behavior and habitat utilization of desert tortoises were studied at the Desert Tortoise Natural Area in the western Mojave Desert. The purpose of this paper is to present data on habitat utilization; data for foraging behavior will be presented elsewhere.

Throughout spring of 1992, tortoises non-randomly utilized habitat strata ($X^2P=0.0001$). Although wash strata cover only 10% of the study site, tortoises spent a considerable amount of time traveling along washes. Tortoises appeared to utilize washes primarily for locating preferred plant species, many of which are restricted to wash margins. Also, tortoises utilized the same washes to revisit burrows; thus, wash systems may possibly serve as navigational aids. Moreover, 70% (26 of 37) of tortoise burrows were located within 5 m of a wash.

These results suggest that off road vehicles (ORV) may negatively impact tortoise populations in at least two ways. First, ORV users with a propensity for driving in washes may disturb relatively rare species of plants that are restricted to washes. Second, if tortoises are utilizing washes for navigational purposes, then "pseudowashes" created by ORV users may disorient tortoises attempting to locate preferred foods or burrows.

LAND-USE PRACTICES: DO THEY AFFECT DIFFERENT-SIZED DESERT TORTOISES IN SIMILAR WAYS?

K. Bruce Jones

Abstract. Numerous studies have attempted to quantify the effects of various land-use practices (e.g., grazing) on the desert tortoise (*Xerobates agassizii*). Unfortunately, many of these studies have yielded results mostly for larger, mature tortoises. However, recent data have been collected on mortality in small tortoises (e.g., on the Desert Tortoise Natural Area); these data suggest high juvenile mortality rates. Recent experiences of the U.S. Fish and Wildlife Service with a Federally-listed reptile, the Concho water snake, *Nerodia harteri harteri*, suggest that impacts associated with land-use practices may have little or no effect on adult survivorship, but a tremendous negative effect on hatchling and immature survivorship; certain populations of this snake may have been lost solely due to cessation of recruitment that results from habitat alteration. Greater impact on small reptiles may result from physiological and behavioral limitations associated with small size. In this paper, I will discuss findings on this snake and suggest how they might relate to the desert tortoise.

INTRODUCTION

There has been much recent concern generated over the status of the desert tortoise throughout much of its range (Berry 1984). Such concern results from data obtained during a number of both short and long-term studies (Berry 1986a). Many of these studies suggest that various land-use practices have reduced the quality of tortoise habitat throughout a significant portion of this turtle's range. They conclude that such land uses have a number of direct (e.g., destruction of burrows and individual tortoises associated with off-road vehicle (ORV) races) and indirect (e.g., increase predation on tortoises as a function of an increase in artificial structures, such as power lines and fence posts, that increase the effectiveness of avian predators) negative effects on tortoises.

Despite the large number of studies on tortoises, few have attempted to determine if there are any significant ecological differences between different-sized tortoises (e.g., requirements of young vs. those of adults). Furthermore, fewer data are available on ecological requirements of young tortoises that might explain if and how young turtles might be more vulnerable to certain types of land uses than larger-sized tortoises. Berry (1978) and Schamberger and Turner (1986) have suggested that young tortoises may have different requirements than adult tortoises. Berry (1978) indicated that because of their smaller home ranges, young tortoises may be more susceptible to impacts associated with certain land uses (e.g., grazing). In addition, new data suggest that predation on young tortoises might be increasing in certain regions, such as the western Mojave Desert (Berry, 1987). To fully understand the cause and effect of predation on young tortoises, the ecological and behavioral characteristics of these turtles must be better understood.

The U.S. Fish and Wildlife Service (Service) recently listed the Concho water snake (*Nerodia harteri paucimaculata*), a snake that is restricted to shallow riffle habitats on the Concho and

Colorado rivers of west-central Texas. During this process, the Service was challenged with determining how this snake was associated with riffles.

DISCUSSION

The Concho Water Snake

The Concho water snake is a subspecies that has had its range substantial reduced since the 1930's (approximately 25 % of its range has been lost, Scott and Fitzgerald 1985). Several herpetologists believed that the loss of the snake's range was a direct result of increases in the number of water impoundments on the Concho and Colorado rivers. After impoundment, riffle habitats either become inundated (above dams) or silted in and lost (reduced flow and siltation below dams). However, data suggest that snake populations persisted in some areas for up to 15 years after certain impoundment projects were implemented. This period represented the approximate life-span of an individual snake. Apparently, dam-induced habitat alterations were significant enough to stop recruitment of young, but not severe enough to cause significant mortality in adults. Either adults stopped producing young or young snakes were not surviving. Reduced survivorship of young snakes seems to be the most plausible explanation, although I will also discuss the former.

Pough (1977) found that adult garter snakes (many aquatic forms of garter snakes, Thamnophis sp., are ecologically similar to water snakes) could maintain activity 4 to 8 times longer than young garter snakes. He related difference in endurance among different sized snakes to differences in anaerobic and aerobic energy production. Adult garter snakes have lactic acid concentrations of 1.5 times that of young snakes, and they also have more efficient pulmonary ventilation, and a 3-fold increase in total blood oxygen capacity (BOC). Overall, adult snakes have a more efficient means of providing oxygen to muscles during high demand, and they are also capable of sustaining activity longer than young snakes because of a greater ability to obtain energy from anaerobic sources. Pough (1977) suggested that reduced metabolic capabilities may limit young snakes to certain microhabitats and behaviors. When examining the microhabitats and behaviors used by young versus adult Concho water snakes, Pough's hypothesis seems relevant. The Concho water snake is piscivorous (Scott and Fitzgerald 1985). Young Concho water snakes are restricted entirely to shallow riffles (Scott and Fitzgerald 1985) where they feed on fishes that commonly move into these shallow riffles at night. Young snakes appear to employ a bottom-crawling feeding strategy (Drummond 1983), moving slowly between rocks in shallows were small fish can be ambushed or trapped. Bottom-crawling behavior would seem to require far less energy than actively chasing fish in open water. Conversely, based on Pough's (1977) findings, adult Concho water snakes should possess the ability to actively forage on fish either in shallow riffles or pools. When a dam is placed on a stream, shallow riffles are inundated above the dam and silted-in below the dam. Adult snakes have the metabolic ability to continue to successfully feed in deep, silt -bound pools that result from the dam. Hatchling and juvenile snakes do not have the metabolic capacity to actively chase fish in deep, silt-bound pools. Important forage fish of the Concho water snake are abundant in these pools, but small snakes are not capable of capturing these prey in deep pools. Hence, young snakes do not survive.

That other water snakes were surviving and reproducing after dams were built was somewhat puzzling. However, hatchlings of all other water snakes on the Concho and Colorado river are between 2 to 3 times larger (biomass) than hatchlings of the Concho water snake. Larger size may allow hatchlings of other water snakes to feed on fish in deeper water, and they may also feed on other types of prey (e.g., earthworms and anurans). The loss of Concho water snakes after the construction of a dam seems to be entirely related to mortality of hatchling snakes. Because adult snakes are able to obtain fish in deep pools, it is unlikely that female snakes stop producing young.

These findings on differences in energy available to different-sized snakes seem highly relevant to the desert tortoise. Similar to the Concho water snakes, small tortoises should possess physiological characteristics that restrict them to certain feeding strategies, movement and activity patterns, and microhabitats. Like young Concho water snakes, small tortoises should be more vulnerable to alteration of their habitats.

Characteristics of Young Desert Tortoises

Information on young desert tortoises is extremely limited, usually to casual observations made during studies of tortoise populations. However, these data suggest that young tortoises have (1) small home ranges (Coombs 1977; Berry 1978), (2) activity periods restricted to times when succulent forage is available, usually in the spring (Berry 1975; Berry 1978), and (3) high predation rates (Berry 1978; Berry 1987). Studies on the metabolism of tortoises are even more limited. Naegle (1976) determined thermal preferences and oxygen consumption in different sized tortoises. He found that young tortoises had higher metabolic rates and preferred body temperatures than adults. Higher metabolic rates in young are common in a number of animals (Payne and Burke 1964; Naegle 1976). Tortoises and other herbivorous reptiles have a lower blood oxygen capacity than other predatory reptiles such as monitor lizards (Pough 1977). Herbivorous reptiles also have a reduced ability to accumulate oxygen debt and maintain activity, simultaneously (Pough 1977). Although Payne and Burke (1964) found that young eastern box turtles (*Terrepine carolina*) had greater blood oxygen capacity per unit mass than adults, he attributed this to higher metabolic demands of smaller tortoises. Although there are no data demonstrating differences in anaerobic and aerobic metabolism in small versus large tortoises, Pough's (1977) findings on snakes suggest that young turtles might be less efficient in delivering blood oxygen to muscles and may have a reduced capacity of maintaining activity during oxygen debt. Lower metabolic efficiencies may explain why young tortoises have relatively small home ranges and reduced activity periods. However, similar to Concho water snakes, lower metabolic efficiency may make young tortoises significantly more vulnerable to impacts associated with land uses.

Land-uses and Their Effects on the Desert Tortoise

In general, the desert tortoise is remarkably well adapted for life in the desert. Some of these adaptations, which have been described mostly for adult tortoises, include the ability to (1) consistently locate and relocate resources such as burrow complexes and patches of wildflowers and other food (Burge 1977; Berry 1986b), (2) move over large distances (up to 7.4 km) (Hohman and Ohmart 1980; Berry 1986. (3) expand their home ranges during favorable years (e.g., high annual production) (Sheppard 1982), (4) modify their activity given different environmental conditions (e.g., remain mostly inactive in burrows during dry years)(Nagy and Medica 1986), (5) consistently produce at least one clutch of eggs even during dry years, possibly due to storage of fat from the previous year (Luckenbach 1982) or because of an ability to switch their diet to cacti (Turner et. al. 1986)(but Berry (1978) suggests that females may not produce eggs every year), (6) tolerate high concentrations of urine in the blood (Nagy and Medica 1986), (7) construct water catchments to accumulate surface water for drinking (Nagy and Medica 1986), (8) actively mine and consume mineral deposits and distinguish between calcium rich and calcium poor soils (Marlow and Tollestrup 1982), and (9) protect eggs at nest sites from potential predators (e.g., Gila monsters, *Heloderma suspectum*)(Barrett and Humphrey 1986). Despite all of these and other adaptations, the desert tortoise appears to be declining throughout a significant portion of its range.

Studies of the desert tortoise have alluded to how certain land-use practices might be detrimentally affecting the desert tortoise. These include large scale deterioration of habitat due to intensive livestock grazing for the past 100 or more years (Woodbury and Hardy 1948; Hardy 1972; Coombs 1977; Berry 1978; Sheppard 1982), and more recent loss of habitat due to urban development and ORVs (Bury 1977). Additionally, other studies have suggested direct physical impacts to individual tortoises from human activities, such as road fatalities (Leach and Fisk 1969). Few of these studies discuss how these impacts might affect different-sized tortoises. The earlier discussion on the Concho water snake points out how acute the differences can be among different-sized animals. The tortoise is a long-lived animal that should, based on knowledge of other tortoises, have a relatively low reproductive capacity and mortality rate. Overall, it appears that, for many populations, reproductive capacity is currently too low and mortality too high to maintain stability. As Berry (1978) suggested, any factors that significantly reduce reproductive capacity or increase mortality could have a severe effect on the population. So how significant is chronic, long-term reduction of reproductive capacity and hatchling and juvenile survival. Medica et. al. (1975) found that tortoise growth was correlated with winter precipitation, presumably a function of production of annual forage. Berry (1978) suggested that tortoises may not produce clutches during dry years due to lack of food. Furthermore, other studies of reptiles have demonstrated decreases in clutch sizes in years with low precipitation, again most likely a function of food production (Worthington 1982; Seigel and Fitch 1985). Although Turner et. al. (1986) demonstrated a consistent production of clutches in dry, wet, and normal years, they did show that tortoises were less likely to produce a second clutch during dry periods, especially during dry summers. The tortoise would, therefore, appear to be capable of adjusting its reproductive effort to environmental conditions such as precipitation. However, how capable are these animals in responding to 30 or more years of drought? Berry (1978) stated that "livestock grazing during late winter and spring often reduces the abundance of tortoise food to a point where drought conditions are simulated." Woodbury and Hardy (1948) stated that "sheep herds sweep the carpet clean," leaving only a few days for tortoises to feed. And perhaps most importantly, Nagy and Medica (1986) found that tortoises must feed on dried vegetation and it is extremely important for tortoises to achieve a positive energy balance in any given year. Therefore, both annuals and perennials may play an important role. However, in most areas, few annuals make it to the dried stage; most are eaten by livestock when they are green (Woodbury and Hardy 1948; Hardy 1972; and Berry 1978). Coombs (1977) noted the importance of perennial plants in the tortoise's diet, perhaps an important source of energy during summer months. Unfortunately, Coombs (1977) also noted a decline in perennial grasses and shrubs within the range of the desert tortoise in Utah. This phenomenon is probably widespread throughout the range of the desert tortoise. Even if adults can survive by reducing activity, and females produce clutches even during dry years (as suggested for at least some sites in California by Turner et. al. 1986), what are the chances that any hatchlings will be recruited into a given population. Based on what was learned about the Concho water snake, very little. Although recruitment of young tortoises into a given population prior to grazing was probably low, recruitment since the advent of livestock grazing is probably several orders lower.

Although small tortoises have higher metabolic rates and preferred body temperatures (Naegle 1976), they probably have between 4 to 8 times less endurance than adult turtles (similar to the Concho water snake). Larger tortoises seem to have the ability to find isolated patches of food. Food patchiness is probably quite common within grazed desert ecosystems. For an adult tortoise, finding such patches may be common; however, for a hatchling tortoise, it may be very difficult. First, they do not have the energy reserves to move over large distances. Second, those individuals who attempt to find food may become metabolically stressed to the point where the likelihood of disorientation and/or predation is increased. Essentially, hatchling and young tortoises have two choices: remain in a burrow and wait for a "good" year or attempt to find food and likely die due to predation or metabolic stress. In fact, feeding activity in young tortoises may be stimulated by precipitation, temperature, and humidity. But even in "good" years, livestock may severely reduce annual vegetation to the point where a drought is simulated. In either wet or dry years, young tortoises are likely to die in their burrows or during movement to locate food. Even the ability to consistently locate and move between a burrow and a food patch may not be advantageous in certain areas. The high degree of predation on tortoises by ravens in the western Mojave Desert (Berry 1987) may not only be a function of artificial structures such as fence posts and power lines, but also a function of the ability of ravens to learn where and when young turtles migrate in attempts to locate food patches and burrows. Although adults may not fall victim to ravens, perhaps due to their size, predation on adult tortoises by large predators, such as golden eagles, may be a function of the predator "learning" migrational patterns of these turtles.

Historically during "good" years, annual vegetation probably covered the landscape. During these "boom" periods, a hatchling tortoise could find food at or near its birthplace. In addition, there was probably an abundance of dried vegetation during late spring and summer. These are the conditions under which the desert tortoise evolved. There is no question that they are capable of persisting through continuous periods of erratic precipitation and climatic patterns. However, I do not believe tortoises are capable of handling a grazing-simulated drought on the order of 30 to 50 years. And whereas some adults apparently survive long-term, grazing-simulated droughts, it is doubtful that any significant recruitment of young turtles occurs under such conditions.

CONCLUSIONS

Management Options

Unfortunately, it is more difficult to sample young tortoises than adults because of their more restricted activity periods and smaller home range. However, given the Service's experience with the Concho water snake, knowledge of reptile metabolism, and what we currently know about the impact of grazing and other land uses on tortoise habitat, we can no longer afford to blame the lack of hatchling and young tortoises on sampling methods. Although some prior sampling efforts may have underestimated young turtles within populations, it is my opinion, that recruitment of young tortoises into populations has been drastically reduced over the past 100 years. This combined with increased adult mortality and fewer overall clutches will almost certainly cause local extinctions of desert tortoise populations over the next 30-50 years. To avoid these extinctions, the conservation community must take on an active role in both population and applied management research. Dodd (1986) pointed out that an aggressive approach to both research and applied management is needed to conserve the desert tortoise. Efforts must be made to increase recruitment of young into populations, which should include increased reproductive effort by females and increased success of nests and survivorship of young turtles. Additionally, mortality of subadult and adult tortoises must also be reduced. These goals can only be achieved through aggressive on-the-ground habitat management. These goals will have to be achieved through both short-term and long-term strategies, depending on the situation on a given site. For example, where habitat deterioration has become acute, it may be necessary to provide an immediate boost to reproductive effort. This might include fencing of a 100 m radius around known tortoise nesting sites (twice the size of the home range reported by Coombs [1977]). In addition, it may be necessary to attempt to seed these exclosures with native annual grasses and forbs, especially in wet years, since long-term grazing often decreases an area's natural seed base. This strategy might provide a short-term increase in hatchling and juvenile survivorship, while at the same time buying more time to implement a more comprehensive long-term strategy such as reestablishment of perennial shrubs and grasses. Restriction of ORV's and other land uses that cause unnatural movements of tortoises away from their principle habitat (Gibbons 1986) should be encouraged, and law enforcement capabilities should be increased in areas with high gunshot incidences (e.g., western Mojave Desert). Although these measures will provide some immediate benefits, the only viable long-term strategy that should be taken for the desert tortoise is to restore the desert ecosystems upon which the tortoise depends. This may not be an easy task. Much of the desert tortoise's habitat resides on lands managed for multiple use. As the population of the Southwest has swelled over the past two decades, so have the number and intensity of public uses. Furthermore, degraded desert habitats often take a long time to restore, primarily due to low precipitation and easily-compacted soils (Webb and Wilshire 1980).

This species is a true indicator of the health of two major North American deserts. We must restore and maintain the health of these systems if the desert tortoise is to survive. In our efforts to manage these ecosystems, we must recognize the important differences in the ecology of different sized tortoises, and be able to apply our knowledge of these differences to on-the-ground management.

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CONSERVATION LESSONS FROM GLOBAL PATTERNS OF TURTLE DIVERSITY

Ross Kiester

Abstract**.** World-wide maps of turtle and tortoise species richness were constructed from the data of John Iverson. Almost 20,000 locality points for all non-marine turtle species were used. The patterns of species richness can be used to determine priorities for action in turtle and tortoise conservation. The priorities derived from this approach are compared to other global biodiversity prioritization schemes. Areas of suspiciously low diversity likely due to lack of knowledge are also identified and recommendations offered for a global turtle research agenda.

HEALTH AND CONDITION INDEX OF RELOCATED TORTOISES: FEASIBILITY OF RELOCATING TORTOISES AS A SUCCESSFUL MITIGATION TOOL

Edward B. Mullen and Patrick Ross

***Abstract*.** Seventy-two desert tortoises, *Gopherus agassizii*, were removed from a section (1 square mile) of habitat in Cantil, California, on the western edge of the Mojave Desert in 1989. Tortoises were relocated to a diagonally adjacent section of fenced habitat in the Desert Tortoise Natural Area (DTNA). A study was designed to assess the effects of relocation on tortoise health and survival. Supplemental irrigation was added to half of the study site to assess whether the additional water would positively affect the survival and health of both the relocated tortoises and the population of tortoises originally inhabiting the study site (residents). Relocated and resident tortoises were studied for 3 years after the relocation. The condition indices of all surviving tortoises increased each year of the project. There was a consistent decrease in the condition index from spring to fall in all years. There was no significant difference between male and female tortoises nor between relocated and resident tortoises. Tortoises receiving supplemental irrigation had higher condition indices than tortoises without irrigation.

INTRODUCTION

This paper summarizes some of the activities and results of a 3-year project that was designed to assess the effects of relocation on the survival, behavior, health, growth, and movement of both relocated and resident populations of desert tortoises *(Xerobates* [=*Gopherus] agassizii*), with and without habitat enhancement through irrigation. The study was designed to contribute information on such issues as the feasibility of relocating desert tortoises as a mitigation tool and the possibility of considering relocation as a viable component of Habitat Conservation Plans for the species.

The health of relocated and unrelocated tortoises was recorded in monthly visits when tortoises in the study area were weighed, measured, and inspected for external symptoms of Upper Respiratory Tract Disease (URTD). This paper presents an assessment of the health of tortoises with the use of a "condition index" developed from measurements of tortoise weight and length. The weight of a tortoise is correlated to its length. If the weight is standardized to its length it could be used as a measurement of its health. Changes or large differences between cohorts regarding this weight-length ratio (or condition index) could be an indication of sickness, heavy stress, or a lack of food.

Project History

American Honda Motor Company, Inc. (Honda) proposed construction of a vehicle testing facility on six sections of land in Cantil, California, eastern Kern County, on the western edge of the Mojave Desert (Figure 1). The primary feature of the testing facility was an oval track that traversed all six sections. Honda purchased the six sections of land in 1987-88. Five of the six sections had been used for irrigated agriculture, reportedly for approximately 40 years, and at the

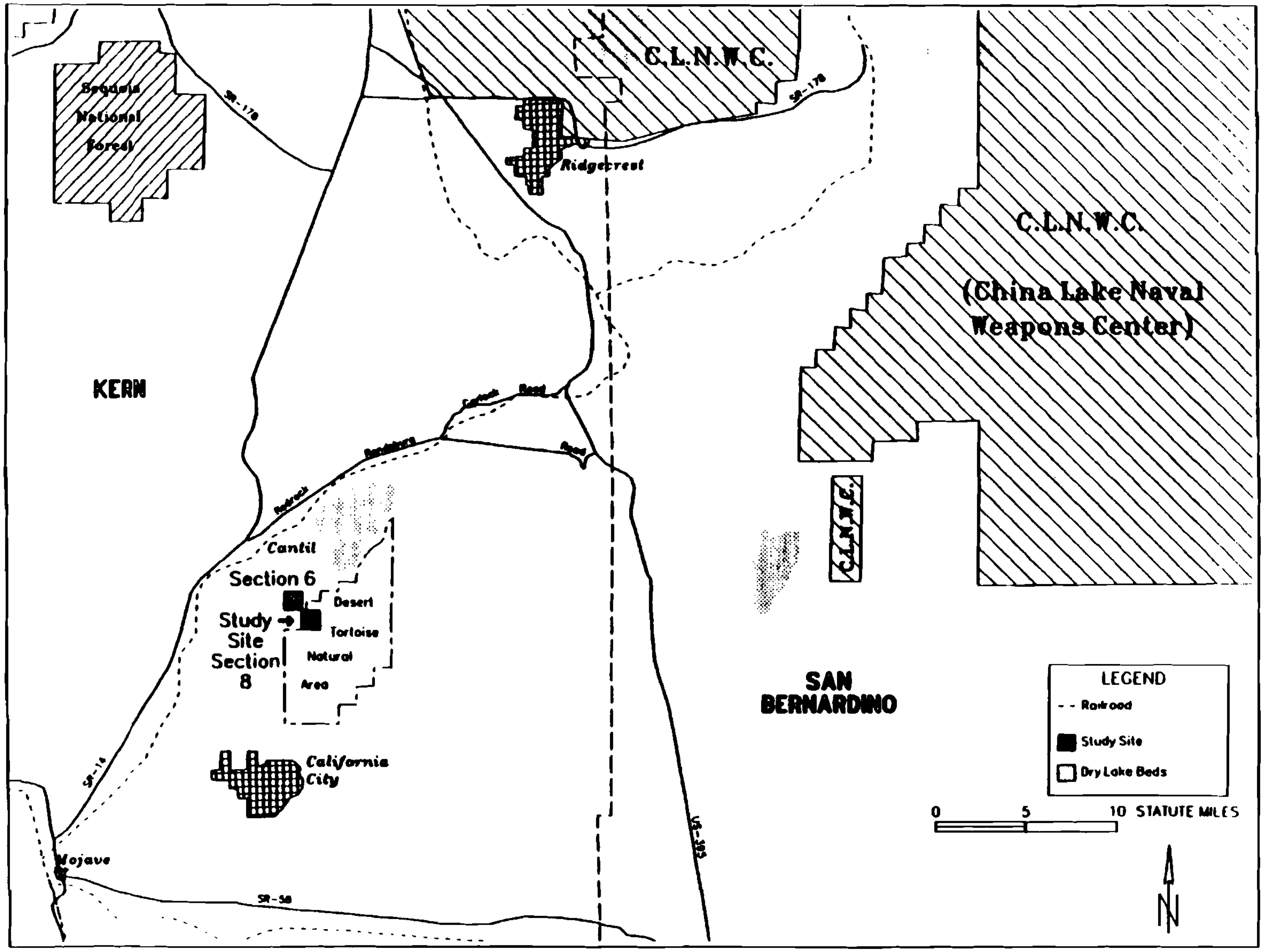

Figure 1

STUDY SITE MAP

time of Honda's acquisition, no longer offered viable desert tortoise habitat. The sixth section (Section 6), however, had remained undeveloped, and was inhabited by desert tortoises.

On May 31, 1989, the California Department of Fish and Game (CDFG) and Honda executed an "Agreement for Habitat Mitigation/Acquisition and Wildlife Mitigation" relating to the desert tortoise. Under this agreement, Honda was given permission to remove desert tortoises from Section 6 in two phases under prescribed conditions and protocols.

Under Phase 1 (carried out between June 1 and August 3, 1989), Honda enclosed the strip of Section 6 with tortoise-proof fencing where the test track would be constructed. Nineteen tortoises were removed from this construction zone during the summer of 1989 and held in specially designed tortoise pens until the following spring. Pens were monitored and supplemented with food and water. Two of the 19 tortoises were found to be symptomatic for URTD and were donated, under the direction of CDFG, to an URTD study; another tortoise died of a chronic kidney malfunction; and a fourth died of unknown causes. This left a total of 15 tortoises that were relocated to pens during Phase 1.

On August 4, 1989, the U. S. Fish and Wildlife Service (USFWS) announced an emergency listing for the desert tortoise to give it protected status under the federal Endangered Species Act. (Presently, the tortoise is both federally- and state-listed as endangered.) The remaining tortoise relocations of Phase 2 and the 3-year research project was authorized by the USFWS permit #PRT 746049. The project's design was advised by a Desert Tortoise Advisory Committee consisting of tortoise experts from federal and state agencies and the academic field. The committee included Dr. Kristin Berry (BLM), Dr. Ken Nagy (UCLA), Dr. Elliot Jacobson (University of Florida), and Dr. Frank Vasek (Emeritus Professor, UC Riverside).

During the spring of 1990, an additional 57 tortoises were relocated from Section 6 (Phase 2). Accompanied with the original (Phase 1) 15 tortoises, all of the tortoises were relocated to Section 8 of Township 31S, Range 38E. Section 8 is part of the DTNA, and is under the jurisdiction of the Bureau of Land Management (BLM). In total, 72 tortoises were relocated from Section 6 to Section 8. This population of tortoises consisted of 23 males, 41 females, and 8 immature tortoises that were too small to determine sex (less than 180mm mid-carapace length).

The northwest corner of Section 8 abuts the southeast corner of Section 6. Section 8 is 1 square mile in area and was divided into four test plots (Figure 2). Each test plot was approximately one-quarter square mile. Each of the four test plots of Section 8 was separately double-fenced to prevent tortoises from moving off site or having direct contact with tortoises outside of their plot. The 1-inch-mesh chicken wire fence was buried 6 inches underground and extended 1.5 feet above ground. In addition, the DTNA had an existing hog wire fence to restrict grazing animals from the study site.

The principal topographic feature of the study site is a gentle slope descending from the southeast to the northwest. The only exception to this broad plain is an area of greater relief to the northeast. This corner area had to be eliminated from the study site because it was not possible to continue the boundary fences through the steep, rocky terrain. This required the fencing to cut diagonally through the northeast plot (Plot 3), excluding approximately 30 percent of the plot from the study site.

An irrigation system was installed to supplement natural precipitation on the western half (plots 1 and 4) of Section 8. The irrigation sprinklers watered a circle approximately 100 feet in radius, and delivered approximately 4 inches of precipitation per winter.

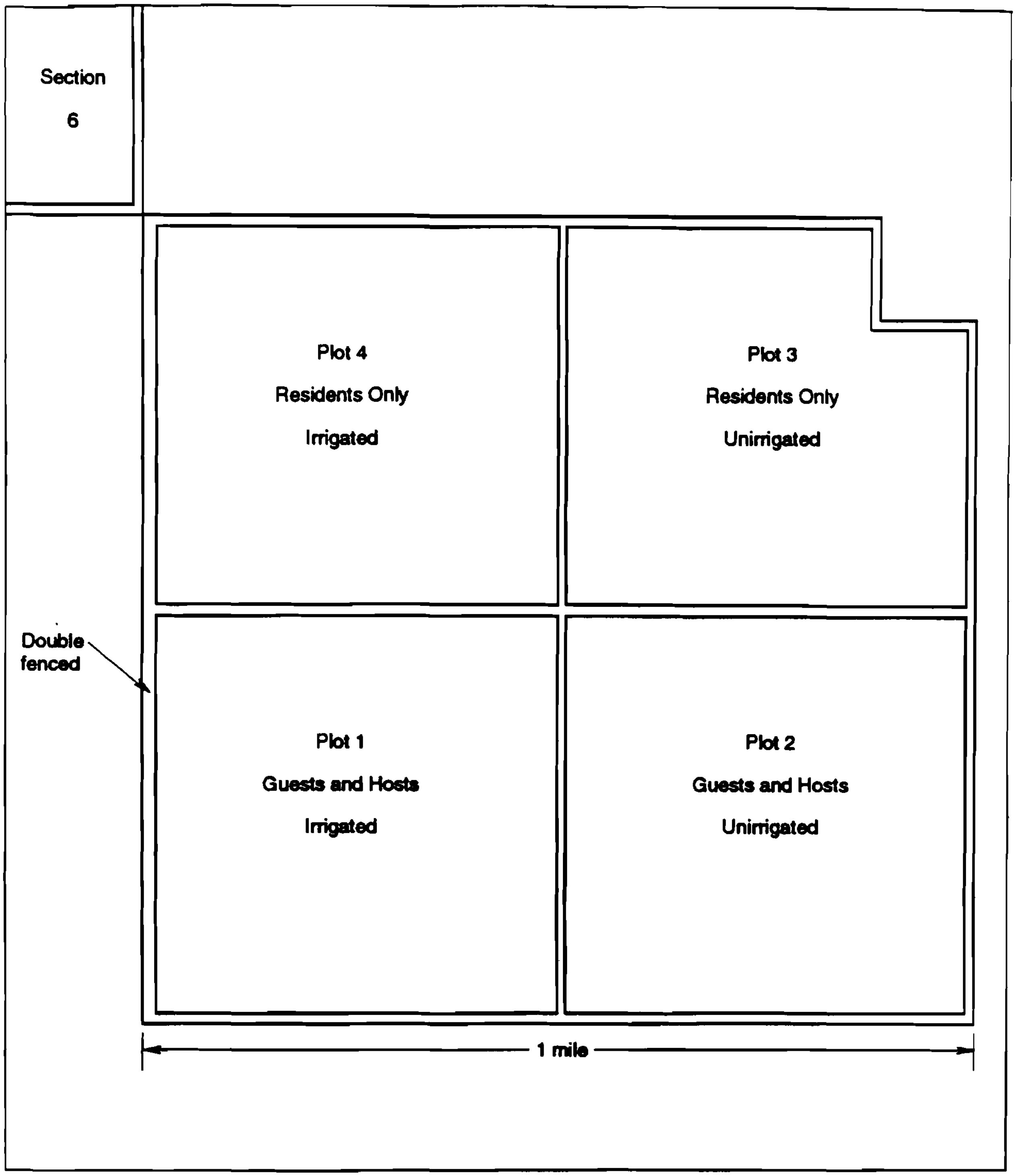

Figure 2

STUDY PLOT DESIGN
SECTION 8 - DESERT TORTOISE NATURAL AREA

Telemeters were attached to the adult tortoises relocated from Section 6 and a majority of the resident tortoises from Section 8. There was a high level of mortality during the first year of the project. To increase the sample size of the different cohorts and replace tortoises that had died the first year, additional tortoises were found on the study site, telemetered, and subsequently added to the resident and host populations during the 1991 field season. Survivorship values and analyses include these additional tortoises when appropriate.

Experimental Treatment Groups

Tortoises were grouped into one of six treatment groups or cohorts. Cohort grouping was dependent on (A) status, whether a tortoise was resident, guest, or a host, and (B) by the presence or absence of irrigation.

The cohorts consisted of the following populations:

Cohort 1: "Residents" alone on an irrigated plot;
Cohort 2: "Residents" alone on an unirrigated plot;
Cohort 3: "Host" tortoises (resident tortoises) sharing an irrigated plot with relocated tortoises;
Cohort 4: "Host" tortoises (resident tortoises) sharing an unirrigated plot with relocated tortoises;
Cohort 5 "Guest" tortoises relocated into an irrigated plot; and
Cohort 6: "Guest" tortoises relocated into an unirrigated plot.

The goal of this paper is to contribute information on the following:

(1) differences between relocated and unrelocated tortoises with respect to condition index;
(2) the effect of habitat enhancement through irrigation upon the condition index of both relocated and unrelocated populations of tortoises;
(3) yearly changes in condition index as related to both relocation and the presence of irrigation; and
(4) differences in the condition index of male and female tortoises.

METHODS

Tortoise Revisit Procedure

During most full calendar months of tortoise activity (April through October), as many tortoises as possible were located (or revisited) using radiotelemetry. During most revisits, each tortoise had its length measured (in millimeters along the mid-line of the carapace [MCL]), was weighed (in grams), and was inspected for external symptoms of URTD. This monthly sampling produced a history of each tortoise's condition index.

Condition Index

The body weight of a desert tortoise is correlated with its length, which in turn is correlated with its age. This makes it difficult to assess the effect of any factor upon the weight of tortoises that already differ in length. In order to make meaningful comparisons of tortoises based on weight, differences in length must be incorporated into the analysis. Figure 3 shows the relationship between tortoise's mid-carapace length and weight for all of the revisits conducted during the course of the study. A log-log regression analysis of the data set determined that weight was

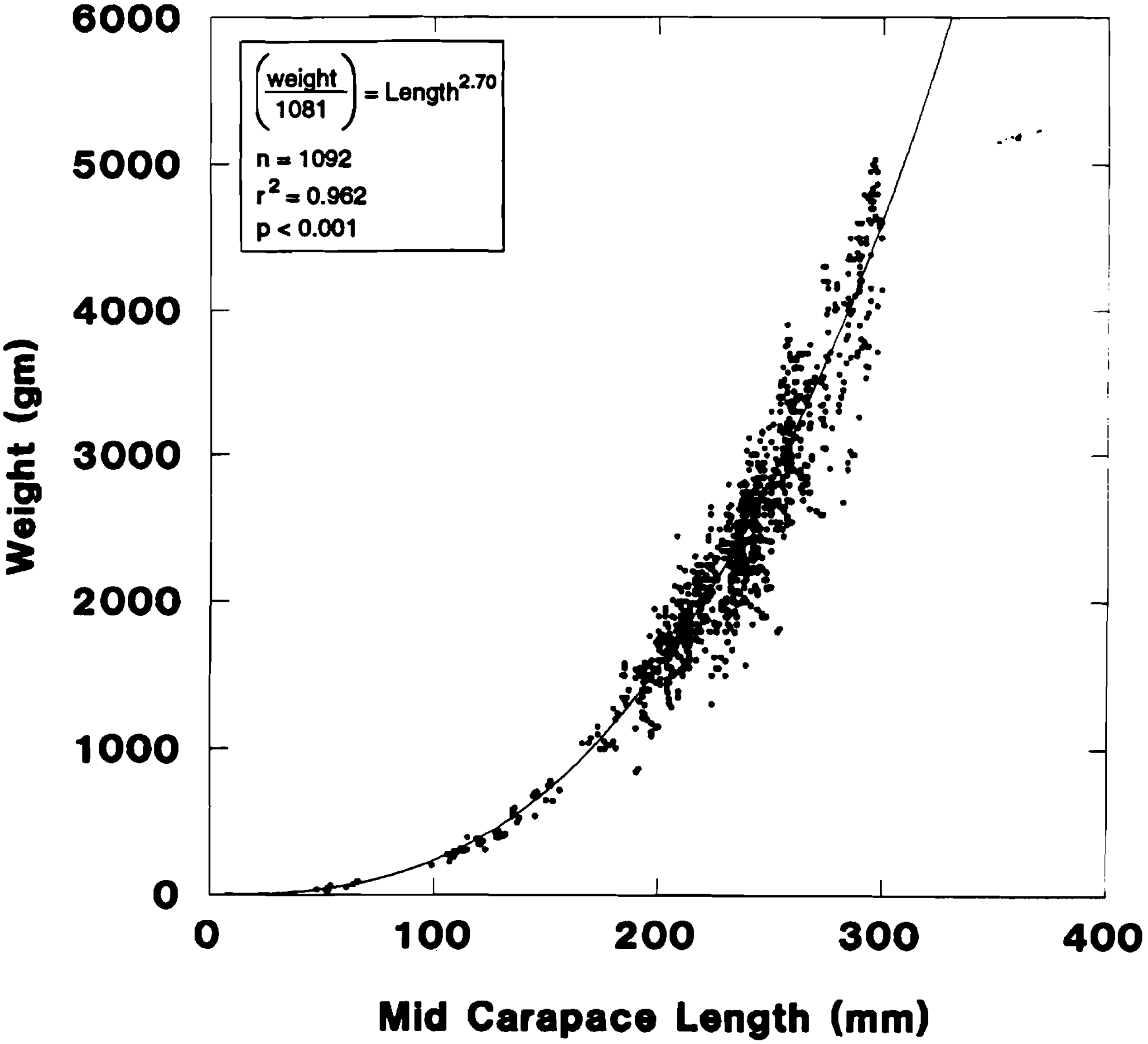

Figure 3. The mid-carapace length (mm) regressed against the weight (grams) of all tortoises for every revisit (1092) during the three-year study.

approximately equal to length (MCL) raised to the 2.7 power. This relationship was incorporated into all subsequent analyses to give an index of weight independent of length. This index, hereafter referred to as the condition index, was calculated by dividing weight by length to the 2.7 power.

$$\text{Condition Index} = \frac{W/1000}{[L]^{2.7}}$$

The condition index of a desert tortoise fluctuates greatly, depending on hydration, nutritional status, and other factors. Typically, a tortoise in this study population should possess a condition index close to 1.0. Differences in condition index can often be linked to differences in the overall tortoise health. Extremely low condition indices are associated with tortoises in bad health, possibly due to starvation or dehydration. The condition index also shows some differences unrelated to health, due to sexual differences in body shape.

Condition indices were derived for each tortoise for every revisit in which both length and weight were recorded (1,022 total). For the purposes of analysis, a mean condition index was calculated for each tortoise for each season in every year (625 total). The seasons were defined as follows: spring (March, April, May), summer (June, July, August), and fall (September, October). Use of seasonal mean indices for each tortoise reduced the problems of pseudoreplication associated with some tortoises being sampled more often than others during a particular period of the year. Comparisons were made between different populations of tortoises based on year, season, sex, status, and the presence of irrigation. This analysis did not include condition indices from tortoises sampled in the spring of 1993. Because of the small number of immature tortoises in the data set (43 out of 625), they were not included in the analysis.

During the process of relocation, guest tortoises also had their length and weight recorded to assess the initial condition indices of the relocated population. A similar set of measurements were taken from the unrelocated tortoises during the initial phase of the project in which telemeters were being attached.

Statistical Methods

The initial condition index using the first measurements of weight and length of relocated and unrelocated tortoises were compared using a t-test.

A five-way analysis of variance was conducted on all of the measured condition indices for all three years. This analysis was used to ascertain the effects of tortoise status, the presence of irrigation, sex, season, and year on tortoise condition.

There are weaknesses present within this analysis. Measurements made on the same tortoise in different seasons and years are not independent. This analysis used those measurements as independent replicates to determine those factors that could affect condition index. This type of pseudoreplication can overstate these effects by artificially increasing the sample size and the overall power of the test. In addition to the problem of pseudoreplication, this analysis was conducted on a mixture of tortoises that survived and tortoises that died during the course of the study. It is probable that many of those tortoises with a low condition index died. An increase in the mean condition indices that were derived for analysis could reflect an overall increase in tortoise health or just the death of tortoises with low condition indices.

One way to address these problems is through a repeated measures analysis of variance. This type of test treats each tortoise as a single replicate with several measurements being conducted on each tortoise. However, this analytical technique requires that each tortoise must have at least one measurement for each combination of season and year. This requirement is only met by a few of the tortoises in this study, far too few to conduct a meaningful analysis (n=14). To increase the sample size, a mean condition index was calculated for each tortoise for each year, forgoing seasonal comparisons. A repeated measures analysis of variance on this data set required only that each tortoise be measured at least once per year. Although the data set was still small (n=47), it allowed a repeated measures 4-way analysis of variance to be conducted. This analysis evaluated the effect of year, status, and the presence of irrigation on condition index, independent of differences in survivorship. The smaller sample size in this analysis did not permit a simultaneous analysis for the effect of sex. Each year, the condition indices of those tortoises that survived were compared to those that did not survive to the next year using a t-test.

Using the results of the antibody test for previous exposure to *Mycoplasma* obtained in the spring of 1993, the condition indices of those positive testing tortoises were compared to those testing negative for exposure using a t-test. The condition index was derived from the length and weight measurements taken at the same time that the samples were taken for the antibody test.

RESULTS

Initial Values

The condition indices for all tortoises in 1990 immediately prior to relocation were measured to compare the initial state of health of the relocated (guest) population in comparison to the unrelocated population. Figure 4 shows the difference in condition indices of the two groups of tortoises. Unrelocated tortoises (Residents and Hosts) show a significantly higher condition index than the guest tortoises before relocation took place.

All Tortoises

Significantly different condition indices were observed among years, seasons, and irrigation conditions. There was no significant difference among tortoises of different statuses and different sexes. The results pertaining to each specified factor will be discussed separately below.

Yearly Effects

The analysis of variance indicated that the condition indices were significantly different among the 3 years of the project. Figure 5 shows the mean condition index of tortoises for each year. The results indicate a steady increase in condition index from 1990 to 1992. Post-hoc pairwise comparisons of the yearly means (Tukey's method) indicated that each year was significantly different from each of the other years.

Seasonal Effects

The analysis of variance indicated that the condition indices were significantly different among the three seasons sampled. Figure 6 shows the mean condition index of tortoises for each season. Separate charts are given for each year. The results indicate a consistent decrease in condition index from spring to fall in all years. Post-hoc pairwise comparisons of the seasonal

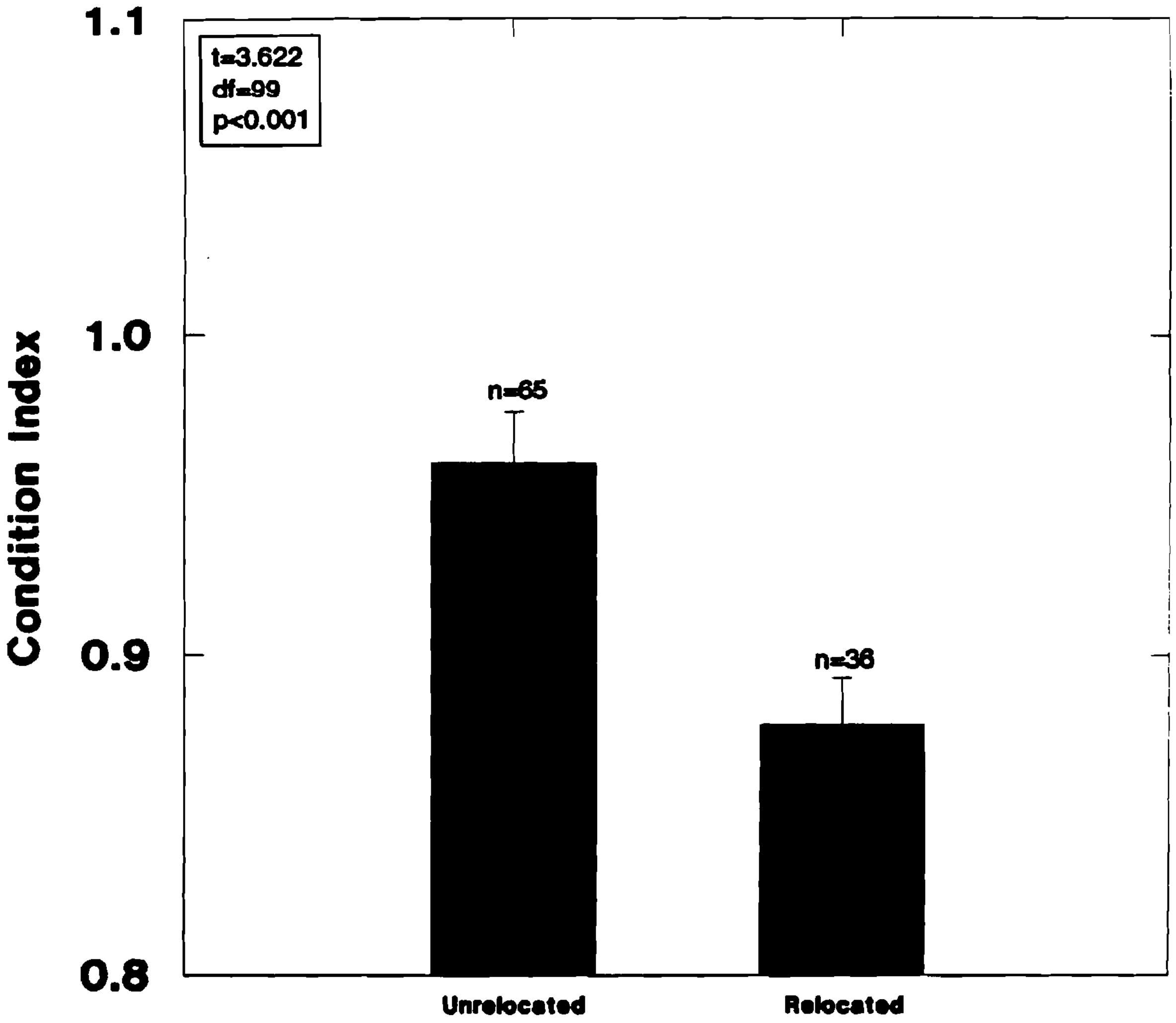

Figure 4. The first condition index of tortoises (derived from the first weighing and measuring prior to relocation) is displayed for both relocated (guests) and unrelocated (hosts and residents). The number of tortoises used to derive the mean condition index is displayed above each bar.

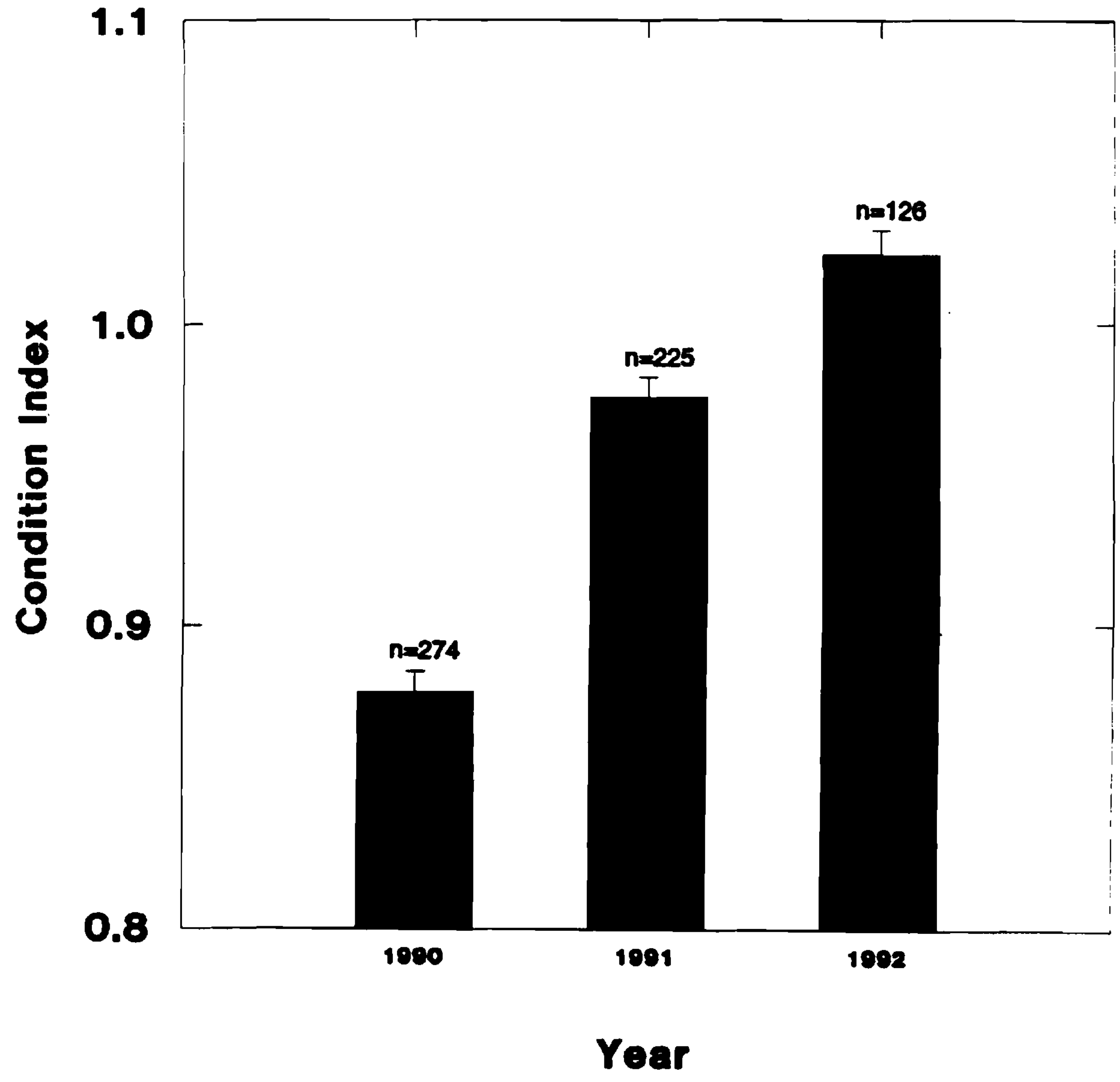

Figure 5. THE MEAN CONDITION INDEX OF TORTOISES IS DISPLAYED FOR EACH YEAR OF THE PROJECT. All of the condition indices recorded for a tortoise in a single season were averaged to produce a single value. These seasonal means were the basis for this analysis. n = the number of seasonal means.

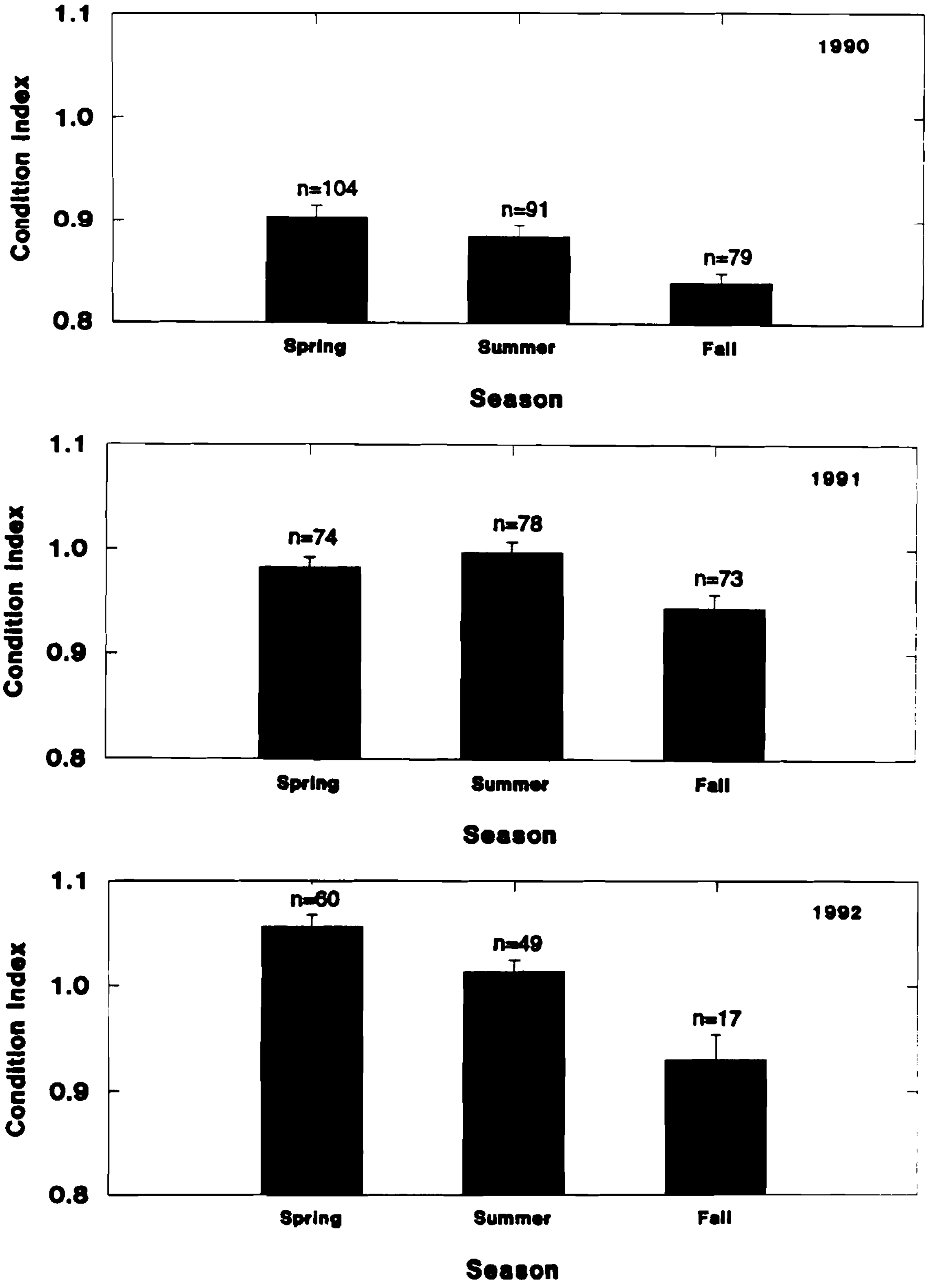

Figure 6. THE MEAN CONDITION INDEX OF TORTOISES DURING EACH SEASON IS DISPLAYED FOR EACH YEAR OF THE PROJECT. All of the condition indices recorded for a tortoise in a single season were averaged to produce a single value. These seasonal means were the basis for this analysis. n = the number of seasonal means.

means (Tukey's method) indicated that each season was significantly different from each of the other two seasons.

The analysis of variance also indicated the presence of significant differences in condition index due to an interaction between season and year. This result indicates that the seasonal trends in condition index were significantly different among years. Examination of the means presented in Figure 6 indicates that although the trend was always in the same direction, the magnitude of the seasonal decline in condition index was greatest in 1990 and 1992.

Sex Effects

The analysis of variance indicated that the condition indices were not significantly different between the two sexes. Figure 7 shows the mean condition index of tortoises for each sex in each year. The analysis of variance results indicate that the relationship between of sex upon condition index had significant yearly differences. Figure 7 shows the males have a higher condition index in 1990 and 1991, while females have a higher condition index in 1992.

Effects of Irrigation

The condition indices of tortoises with irrigation were significantly different from tortoises without irrigation. Figure 8 shows the mean condition index of tortoises in the presence or absence of irrigation. Separate charts are presented for each year. The results indicate that tortoises with irrigation possess a significantly higher condition index than tortoises without irrigation.

The analysis of variance also indicated the presence of significant differences in condition index due to an interaction between the presence of irrigation and year. This result indicates that the differences in condition index due to the presence of irrigation were significantly different among years. Examination of the means presented in Figure 8 indicates that only in 1990 (the driest year of the study) does the presence of irrigation positively affect condition index. Both populations have condition indices less than 0.9, indicating sub-optimal conditions. The effect of irrigation in the other two years is negligible and both samples have condition indices close to 1.0.

Effects of Relocation

The analysis of variance indicated that the condition indices were not significantly different among the three statuses. Figure 9 shows the mean condition index of tortoises for each status. Separate charts are presented for each year.

No interactions involving tortoise status were found to be significant in the analysis of variance. This indicates that the effect of relocation upon condition index was not altered by any other factor. However, it is apparent that in 1990 there were strong differences between guests tortoises and the two groups of tortoises that were not relocated (residents and hosts). This difference was not seen in the two subsequent years, 1991 and 1992.

Survival-Based Differences in Condition Index

The condition index of surviving and dead tortoises for each year is presented in Figure 10. Surviving tortoises had significantly higher condition indices in 1990 and 1991. In 1992 there was no significant difference between the condition indices of surviving tortoises and those that were presumed to have died prior to the 1993 season.

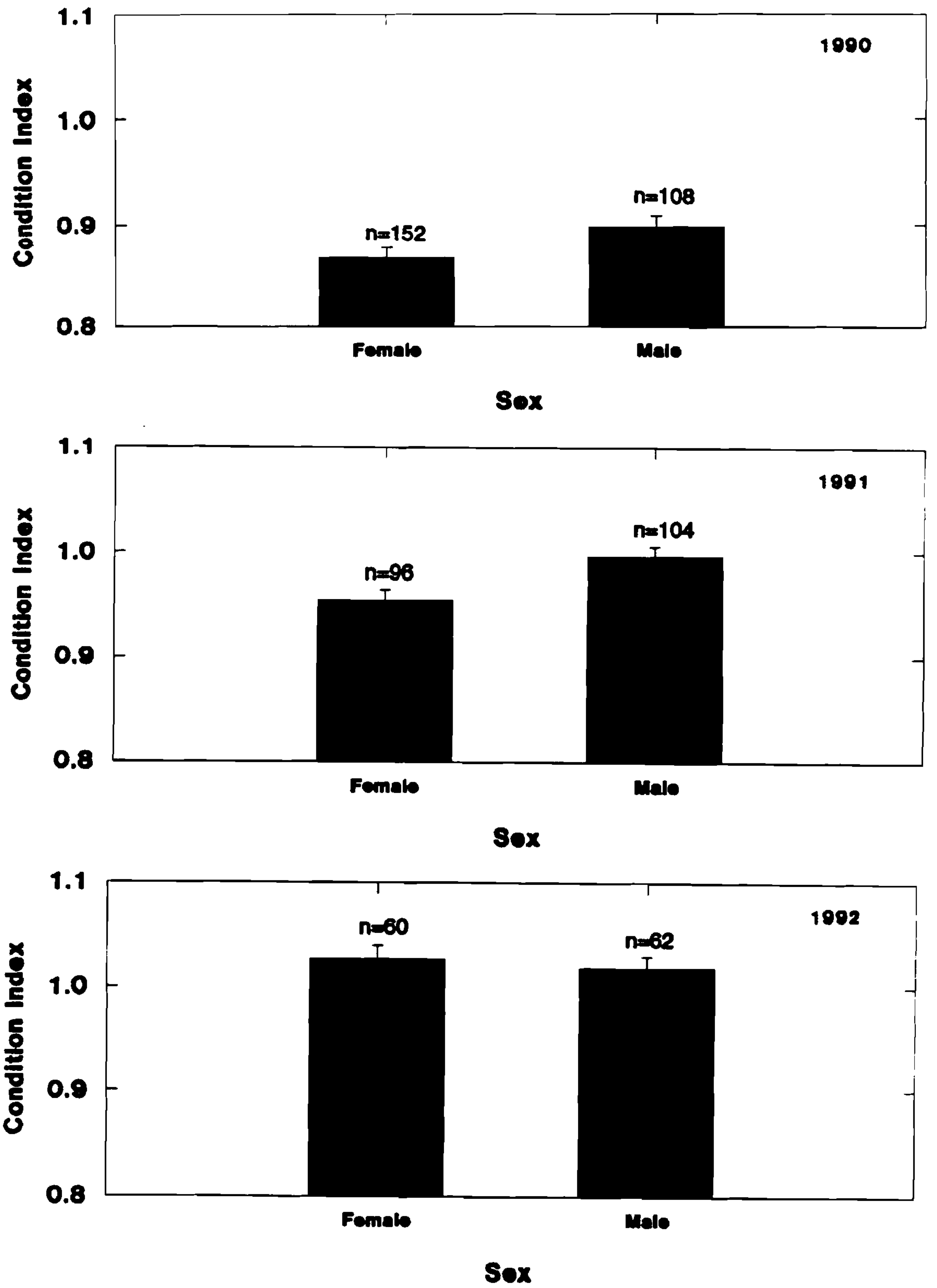

Figure 7. THE MEAN CONDITION INDEX OF FEMALE AND MALE TORTOISES IS DISPLAYED FOR EACH YEAR OF THE PROJECT. All of the condition indices recorded for a tortoise in a single season were averaged to produce a single value. These seasonal means were the basis for this analysis. n = the number of seasonal means.

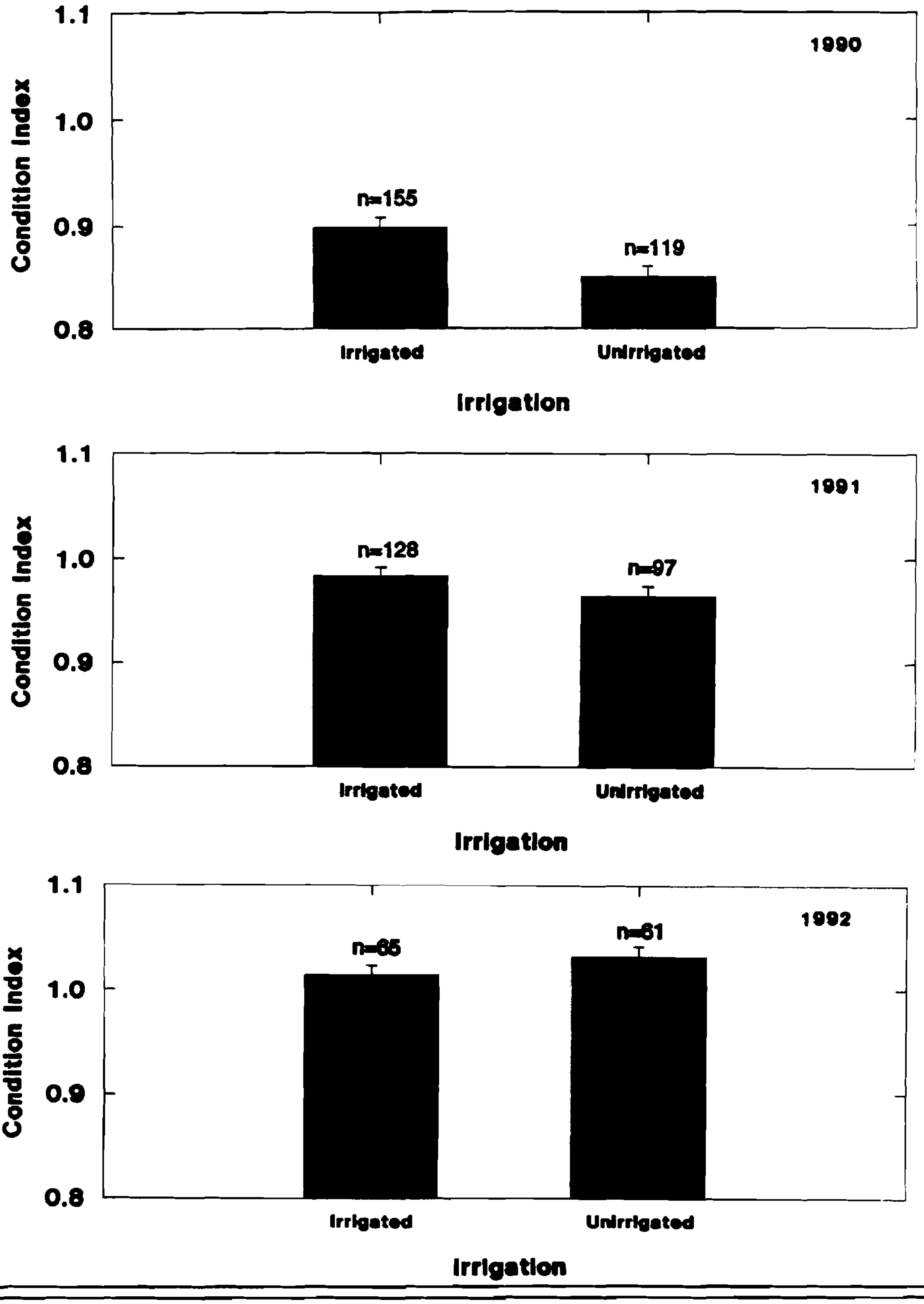

Figure 8. THE MEAN CONDITION INDEX OF TORTOISES IN THE PRESENCE AND ABSENCE OF IRRIGATION IS DISPLAYED FOR EACH YEAR OF THE PROJECT. All of the condition indices recorded for a tortoise in a single season were averaged to produce a single value. These seasonal means were the basis for this analysis. n = the number of seasonal means.

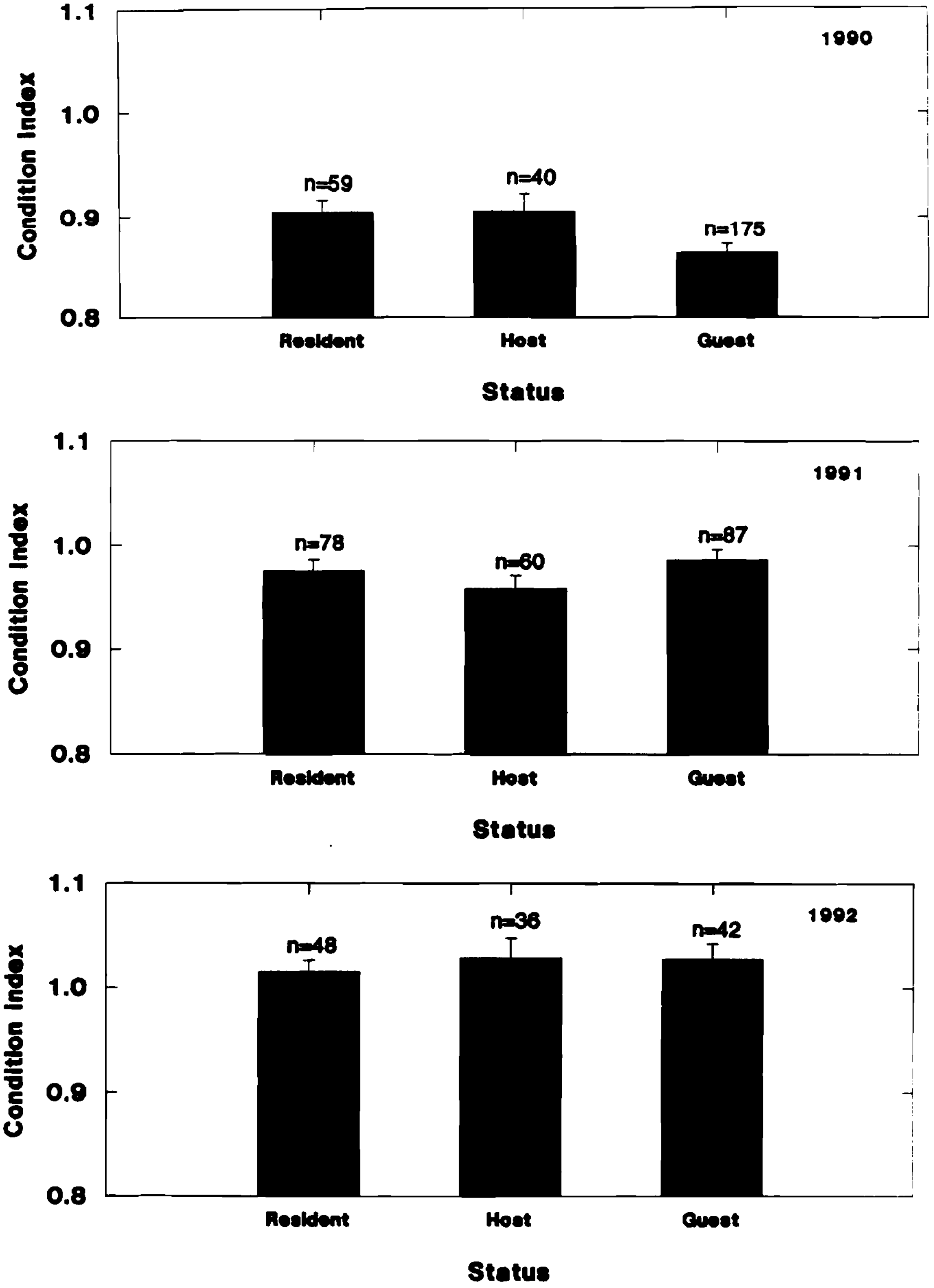

Figure 9. THE MEAN CONDITION INDEX OF RESIDENT, HOST AND GUEST TORTOISES IS DISPLAYED FOR EACH YEAR OF THE PROJECT. All of the condition indices recorded for a tortoise in a single season were averaged to produce a single value. These seasonal means were the basis for this analysis. n = the number of seasonal means.

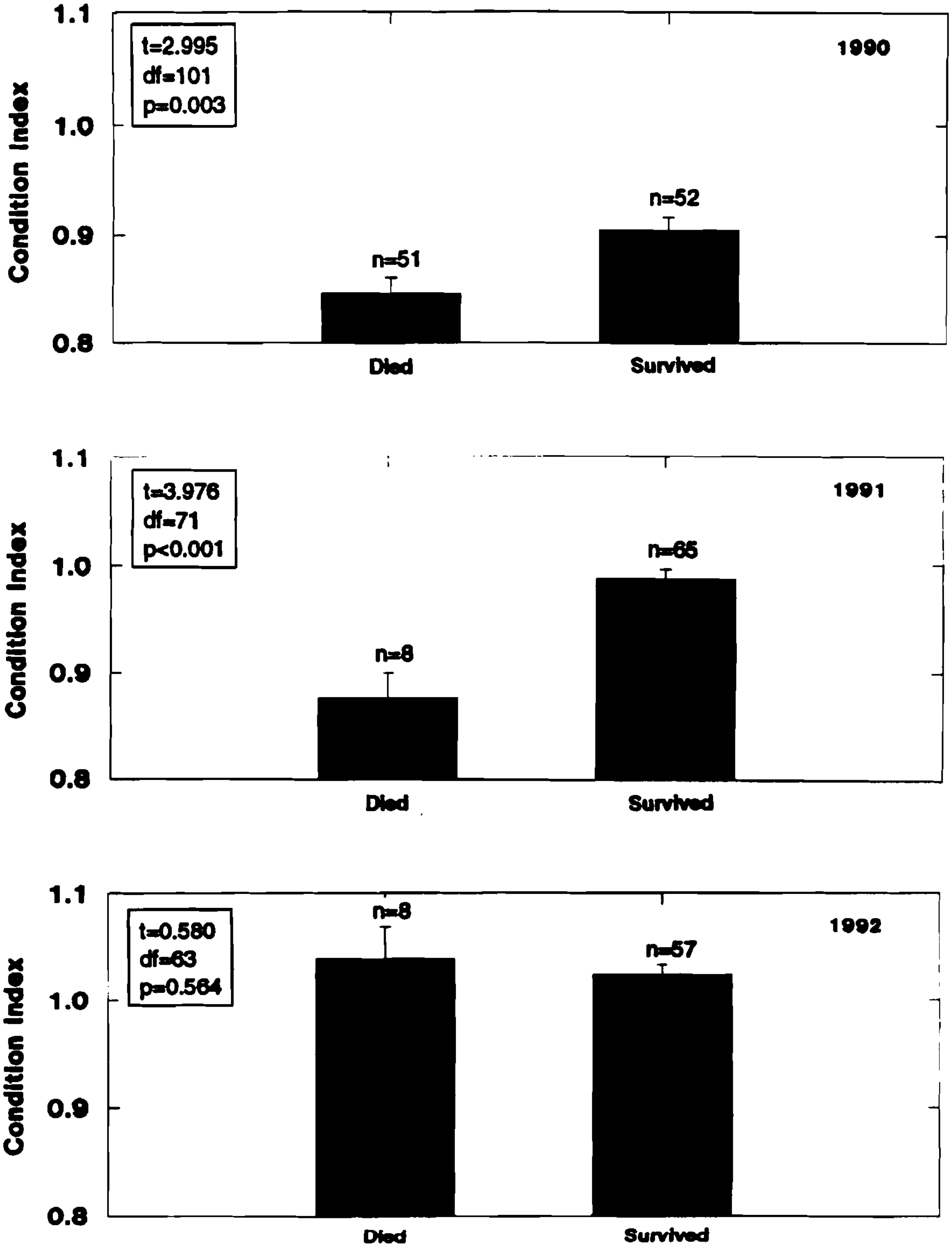

Figure 10. THE MEAN CONDITION INDEX FOR BOTH SURVIVING TORTOISES AND THOSE THAT DID NOT SURVIVE INTO THE FOLLOWING SEASON IS DISPLAYED FOR EACH YEAR OF THE PROJECT. All of the condition indices recorded for a tortoise in a single season were averaged to produce a single value. These seasonal means were the basis for this analysis. n = the number of seasonal means.

DISCUSSION

Initial Values

The condition indices of all tortoises were low during the first year of the project and increased to higher, or healthier, levels in the second and third years. Guest tortoises, prior to relocation, had condition indices that were already significantly lower than those of both resident and host tortoises. In subsequent years, condition indices between cohorts were not found to be significantly different.

The initial low condition index of the relocated population has important implications for the interpretation of the lowered survival of relocated tortoises in this study. The initial low mean condition index of this population indicates that the population as a whole was in very poor health. It is possible that the high mortality seen in the relocated tortoises was not due to relocation, but may have been the result of their initial poor health. If relocation does lead to physiological stress for tortoises, such effects would have further intensified the adverse effects of this population's already weakened condition.

Surviving and Dead Tortoises

Yearly Effects

The mean yearly condition indices of tortoises increased continuously from 1990-1992. Each year of the project was progressively wetter. As the amount of rainfall increased, so too did the amount of vegetation available for food increase. It would be expected that this increase in vegetation could cause the condition index of all tortoises to increase. Another factor contributing to the low condition indices in the first year is that 1990 was the year in which most of the tortoises were first handled, marked, and fitted with radio telemeters. This extra handling would have increased stress levels and could have decreased the yearly mean condition index.

Tortoise mortality could also have led to yearly changes in condition index. Many of the tortoises that did not survive to 1991 were in poor health and had lower condition indices. If these tortoises were not present in subsequent years, the mean condition index should increase. However, analyses that were limited to only surviving tortoises also showed an overall increase in mean condition index over time. This indicates that as tortoises in poor condition were dying, tortoises in good condition were improving.

Seasonal Effects

Within each year of the project, the condition indices of tortoises decreased from spring to fall, which coincided with the decrease of fresh vegetation and available water. Comparing this decrease among the 3 years, the magnitude of the decrease differed, with 1990 and 1992 having the most dramatic decrease. These were the driest (1990) and wettest (1993) years of the project. The lowest seasonal mean condition index observed during the entire project occurred in the fall of 1990. Both 1991 and 1992 show condition index values in the fall that are similar to those observed in the spring of 1990.

Sex Effects

Generally, male tortoises had higher condition indices than females. However, this result was not strong and was not reflected in all tortoise populations at all times. The difference could be the result of small morphological and physiological differences causing males to be intrinsically heavier bodied than females or alternatively, females might be more dramatically affected by the water stress.

Effects of Irrigation

Tortoises in the presence of irrigation possessed a higher condition index than tortoises without irrigation in 1990, the driest of the three years. During years with higher levels of rainfall (1991 and 1992), irrigation does not have any appreciable effect on the tortoise's condition index for all cohorts. Irrigation during the winter preceding a dry year increased the amount of succulent vegetation available to tortoises. This extra food and water resulted in an increase of the mean condition indices that persisted through each of the three subsequent seasons.

Effects of Relocation

Condition indices of relocated tortoises were not statistically different from those of the host and resident tortoises, although Figure 9 shows that guests in 1990 had a much lower condition index than residents and hosts. The condition indices of guests in 1991 and 1992 were similar to those of the other two statuses. In 1990, the guest population presumably experienced high levels of stress due to the initial effects of relocation. It would be expected that the condition indices would be low for guests in this year due to tortoises: (1) exerting extra energy attempting to get back to their home ranges; (2) searching for food in unfamiliar habitat; and (3) experiencing extra competition having been placed in other tortoise's territories. In addition, guests experienced more stress than hosts and residents due to the additional handling required in the movement of tortoises from Section 6 to Section 8.

Surviving Tortoises

It was expected that dying tortoises and tortoises in poor health would possess low condition indices. Significant differences found in the analysis of all tortoises could have been due to differences in the number of sick and dying tortoises in the groups tested. However, removing these tortoises from the analysis did not change the overall results dramatically, indicating that the results were also true for just the surviving tortoises. Condition indices for surviving tortoises showed the same trends as the analysis using all tortoises, but the overall mean condition indices were higher and the differences between years were reduced. This was due mainly to an overall increase of condition indices in 1990 for surviving tortoises.

CONCLUSIONS

Condition indices could be used as a tool to help determine the feasibility of successfully relocating tortoises by identifying populations in poor health that might be more susceptible to the stresses of relocation. Populations with low condition indices would be poor candidates for any relocation effort. Relocations could be postponed during the driest years, which are associated with low food levels and lower condition indices. Condition indices also change during the course of the year due to seasonal changes in food availability and tortoise behavior. It may be advisable to attempt relocation in late spring after tortoises have had a chance to fully exploit the spring vegetation and increase their weight. It may also be advisable to avoid conducting relocations in the fall when condition indices have dropped to a yearly low. If relocation is unavoidable, enhancing the new site with irrigation could increase the condition index of tortoises and possibly increase tortoise survival. During dry years, relocation into irrigated plots should occur during the early spring so that tortoises can fully take advantage of the succulent annual vegetation.

HOME RANGE SIZE AND MOVEMENTS OF DESERT TORTOISES, *Gopherus agassizii*, IN THE EASTERN MOJAVE DESERT

Michael P. O'Connor, Linda C. Zimmerman, Douglas E. Ruby,
Susan Bulova, and James R. Spotila

Abstract. We constructed minimum convex polygon (MCP) home ranges for free-ranging desert tortoises (*Gopherus agassizii*) from a natural population adjacent to the Desert Tortoise Conservation Center, near Las Vegas, Nevada. Home range estimates were not significantly different from those estimated for other desert tortoise populations in the Mojave and Sonoran deserts. Male tortoises had significantly larger and more variable home ranges in a combined statistical analysis of this study with those of Burge (1977) and Barrett (1990).

Jack-knife analysis of the MCP areas suggested substantial autocorrelation of tortoise sightings despite a mean interval between recaptures of 3.2 days, violating an assumption of nearly all home range estimation techniques and predisposing to underestimation of the true home range area. Increasing the interval between recaptures would severely limit the number of points that could be obtained on an individual tortoise in a single activity season. We also created "by eye" minimum polygons to compare with MCP's for the same tortoises. This comparison suggests that MCP's for desert tortoises include, as substantial fractions of their total area (12 to 56%, mean = 35%), area with no evidence that tortoises use them.

Movements between resightings vary with the sex of the animal (male > female) and interval since last resighting. The distances of movements was approximately exponentially distributed, with short movements more common than longer movements, predisposing home range estimates for desert tortoises to be autocorrelated.

We urge the consideration of home range as an indictor of movement scales and patterns with less emphasis on the biological meaning of area as a resource or characteristic of the animal.

NORTHERN NEVADA TORTOISE ADOPTION PROGRAM-- A BAPTSMAL BY FIRE

Darlene Pond

The Reno Tur-Toise Club was organized in October 1991, when it became apparent that something needed to be done to prevent the euthanization of an estimated 3,700 desert tortoises, (*Gopherus agassizii*),which were being displaced due to land development in the Las Vegas area of southern Nevada. We felt it was unconscionable for anyone to even entertain the thought of euthanizing a member of a threatened species under the Endangered Species Act.

Our proposal to Clark County, Nevada, was that if they opened up the entire state of Nevada to adoption of these excess tortoises, our group would be the northern Nevada adoption agency for the program, thus alleviating the need for the unpopular possibility of euthanization. The public, upon hearing of the possible euthanization plan, had already raised a hue and cry, which we took up. Clark County Commissioners, to their credit, listened to the public, forbade the euthanizations and speedily approved our adoption plan. By December 1992, the entire state of Nevada was opened up for legal adoption of desert tortoises.

Several other options were to be utilized in combination with the adoption program. These included moving some wild tortoises to habitat on islands in Lake Mead, which entailed studies to see if this was feasible; and the placing of tortoises in zoos, museums, and for specific research purposes, mostly to determine the cause and cure for the Upper Respiratory Tract Disease (URTD) that had been decimating wild tortoise populations throughout their ranges. A great deal of money was appropriated for the programs to save the desert tortoises. Most of it was earmarked for research and the purchase of established wild tortoise habitat. However, the most immediate option was the adoption program because it did not cost much and it did not require lengthy studies nor time-consuming preparations because Tortoise Group had been doing it on a limited basis for 19 years in the Las Vegas area. Reno Tur-Toise Club quickly patterned its program after that of Tortoise Group and plunged into the fray. In fact, at last year's Desert Tortoise Symposium, we arranged with U.S. Fish and Wildlife Service (USFWS), which gave us our adoption program permit, to transport the first 16 adoptees (all of them juveniles) back to Reno with us when we left the symposium. We placed the animals in a cool room where they were checked periodically throughout the rest of their hibernation because we were worried about the difference in climate between southern and northern Nevada; that perhaps the animals would not have put on enough weight to sustain them through the longer hibernation period in the Reno area. There were no problems with this, and there were no signs of URTD.

There was a sense of urgency because we were soon notified that Tortoise Group, which was holding all tortoises displaced until a special holding facility could be built, already had more tortoises available in late April. On May 12, the Nevada Air Guard, stationed in Reno, airlifted 38 tortoises of all sizes to Reno after completing a training mission in southern Nevada. We called it Operation Desert Tortoise, and the event received a lot of press attention from Reno's four television stations, several radio stations and newspapers. In fact, when we announced that the animals would be up for adoption, the club and the media were deluged with requests: 1500 of them in one week! Most were from Nevada, some from California, Ohio, Utah, Arizona, and even

New York City! We had no idea we would get such a flood of potential adopters and were kept busy for a month sending out adoption packets.

Tortoise Group, which was very experienced while we were new, warned us that only about 10% of the people requesting would actually follow through because of the stringent regulations for adoption: the first being that Nevada tortoises, under federal law, can be adopted only by Nevada residents. Adopted desert tortoises must be kept outdoors in a large, fenced, dig-proof area, and an appropriate place must be provided for them to come indoors and hibernate in the winter, as it is too cold in Reno for them to hibernate outdoors in burrows.

In the interest of the animals, we would not adopt to wet, cold areas like Lake Tahoe nor would we adopt to families with small children or large dogs. These restrictions proved, in the light of recent research findings, to be very valid, as it is now thought by some that URTD is brought on or augmented by stress. Inspection of yards of potential adopters gave us the chance to meet the people who would be caring for the tortoises and to chat for about an hour with them. We could easily tell who would make good adopters and would wouldn't. One man told us it was like trying to adopt a human baby. But we had to find people willing to make a lifelong commitment instead of looking upon the tortoises as a flash-in-the-pan novelty item. We have had great success abiding by these strict rules which were set down originally by Tortoise Group. Several people have informed us they have made provisions in their wills for the extended care of their tortoises after they are deceased.

We were, however, unprepared for the large number of people who already had desert tortoises in northern Nevada, either by bringing them with them when they moved from Las Vegas and southern California, by finding stray ones crossing a highway, someone gave them one, etc. When the ban on captive tortoises outside urban Las Vegas was lifted, we even discovered people who were breeding and raising desert tortoises in Reno: one couple has done so for 30 years!

To facilitate the adoption process, we trained volunteers in other areas of northern Nevada such as Hawthorne, Elko, Carson City, Minden, Wells and Winnemucca, to handle adoptions there. Tortoise Group and Reno Tur-Toise Club split the state and this made it easier on everyone.

In July, the Nevada Air Guard airlifted another 68 tortoises who actually had a pretty high powered pilot. They hitched a ride with General Molini as he was returning from a ceremony at Nellis Air Force Base. We talked him into stopping at Las Vegas airport and bringing the tortoises to Reno. They were picked up in a 34-foot air-conditioned motor home. This time, we had yards ready and waiting. In comfort, we checked every box and designated who wanted what and put the adopter's name right on the tortoise box. The people were called and came to pick them up. It worked extremely well. Those tortoises not adopted immediately were placed in holding yards until they could be.

To date, we have adopted out 147 tortoises. There would have been over 200, but we cut the season short because of an outbreak of URTD in the last adoptees from Las Vegas. We refused to accept any more until spring, when the holding facility in Las Vegas would be completed and in full swing and, hopefully, URTD would no longer be a problem. This was, indeed, the case and the holding-facility tortoises are healthy as they have more space and don't seem as stressed.

Even though we feared for their lives, we did not dare bring more diseased animals to Reno as all our holding yards had broken out in epidemic proportions. We exhausted our new club's funds quickly and had to ask for donations for medical supplies. Thankfully, we have a good group of people intensely interested in the health and welfare of desert tortoises and we gathered enough funds to be certain every animal was treated with a series of Baytril shots and Vibramycin by mouth. We had 30 to 40 tortoises down with the disease at one time and became very proficient at giving shots and keeping records of treated tortoises.

Every tortoise adopted out is accompanied by a set of care sheets for feeding and shelter as well as a health warning. Because numerous tortoises were adopted out seemingly well but later developed URTD, we quickly copied all the information we could get on URTD treatments and mailed them to area veterinarians. Many tortoises were saved; we had some deaths, but not nearly as many as expected.

Because northern Nevada is not an area saturated by captive desert tortoises, as is southern Nevada, interest in the adoption program is very high. A number of people have come forward and offered assistance in the form of helping build pens in holding yards, caring for sick tortoises, babysitting for vacationing owners, and calling first-time adopters to eliminate problems.

We are prepared to place 400 animals in 1993, and feel this program is very worthwhile and inexpensive. It helps alleviate the stalemate between developers and environmentalists in the Las Vegas area; it provides the animals with good, safe home; and provides the public with the chance to get to know, first hand, how valuable their state reptile is.

While we were at our wits' end at times last year, (for instance, the URTD outbreak was very discouraging to everyone), we had some very bright moments as well: such as providing the first pets they had ever had to several youngsters who are allergic to cats and dogs. We participated in Earth Day education alongside the Reno office of the USFWS, passing out information, displaying tortoises and answering questions. We also gave programs to groups of teachers at a wildlife park in Reno. Because, after all, education is the key to saving the desert tortoise or any other threatened or endangered animal. We feel our first year, though hectic, was very successful. We learned a lot about tortoises and certainly learned a lot about URTD.

Our most satisfying moment, though, was when one of our first adoptees produced six viable eggs; every one of which hatched for a nervous new adopter under the careful telephone guidance of the couple who had been hatching them for 30 years. We later saw the baby pictures because the anxious pseudo-father had meticulously videotaped the entire sequence of events over several days. That was in September. All hatchlings are healthy and happy and have adoptive home waiting for them.

TERRAIN USE AND MOVEMENT OF RELOCATED DESERT TORTOISES: FEASIBILITY OF RELOCATING TORTOISES AS A SUCCESSFUL MITIGATION TOOL

Patrick Ross

Abstract. Seventy-two desert tortoises (*Gopherus agassizii*) were removed from a section (1-square mile) of habitat in Cantil, California, on the western edge of the Mojave Desert in 1989. Tortoises were relocated to a diagonally adjacent section of fenced habitat in the Desert Tortoise Natural Area. The relocated tortoises and a similar population of coexisting, unrelocated tortoises (residents) were monitored over the next three years to assess the effects of relocation on tortoise behavior, health, and survival. The locations of tortoises recorded during monthly visits were used to assess the effect of relocation on terrain use and movement. In general, all tortoises were found in areas near the fenced perimeter more often than would be expected by chance. In addition, relocated tortoises were found in areas of the study plot near the site of their original capture more often than would be expected by chance. Year-to-year and sexual difference in these results were also studied.

BEHAVIORAL RESPONSES AND TIME ALLOCATION DIFFERENCES IN TORTOISES EXPOSED TO ENVIRONMENTAL STRESS IN SEMI-NATURAL ENCLOSURES

D. E. Ruby, L. C. Zimmerman, S. J. Bulova, C. Salice, M. P. O'Connor, and J. R. Spotila

Abstract. We tested the effect of environmental stress on desert tortoises (Gopherus agassizii) in semi-natural enclosures. Populations of adult and immature desert tortoises were established at relatively high densities in 10-acre pens at the Desert Tortoise Conservation Center near Las Vegas, Nevada. Pairs of pens received different levels of food (sod and alfalfa patches) and water supplementation. We postulated that the relatively high densities of tortoises and the different levels of resources created different levels of environmental stress on the populations. The behavior was systematically observed during June-July 1991 and April-September 1992 for differences due to treatment. Behavioral observations were collected during 30-minute focal periods and periodic scan censuses of pens.

Deprived animals, particularly males, moved farther than animals with supplemental diets. Movement varies significantly among months. There were no differences in feeding rates among treatments, although monthly effects were important. Interactions among animals were highest in May and September and were more frequent in deprived pens. The length of activity period was shorter in deprived pens for all months. Within treatments, supplemented females were more visible and were seen for longer periods of time during a morning activity period. Home ranges were not significantly s\different between treatments but showed significant sex effects. Males have larger home ranges than females who have larger home ranges than unsexed animals (Ruby et al. 1994).

LITERATURE CITED

Ruby, D.E., L.C. Zimmerman, S.J. Bulova, C.J. Salice, S.J. Kemp, and J.R. Spotila. 1994. Behavioral responses and time allocation differences in desert tortoises exposed to environmental stress in semi-natural enclosures. Herp. Monog. 8: 27-44.

BEHAVIORAL RESPONSES TO BARRIERS BY DESERT TORTOISES: IMPLICATIONS FOR WILDLIFE MANAGEMENT

D. E. Ruby, J. R. Spotila, S. K. Martin, and S. Kemp

***Abstract*.** We conducted tests on the behavioral responses of captive desert tortoise (*Gopherus agassizii*) to barriers and highway obstacles. Desert tortoises are slow moving but persistent wanderers in their natural habitat. Consequently, they move substantial distances when they meet a barrier that they cannot go around. Tortoises responded differently top solid and non-solid barriers when placed in small pens of various materials. Our tests indicated that a screen mesh with small enough openings to exclude a tortoise's head was the preferred barrier material. When tortoises were tested for 2-hour periods or after an overnight stay in the barrier pen, rates of responses with barriers declined with time but did not discourage tortoise exploration to locate the end of the barrier.

In a choice situation, we found no preference for tortoises to follow wither solid or mesh barrier fences. Tortoises quickly walk past openings in a barrier which are too small to enter but easily escape from a barrier pen within 30 minutes when openings of an appropriate size are available. We found that tortoises willingly entered culverts under large highways and retreated from concrete highway barriers (Ruby et al. 1994).

LITERATURE CITED

Ruby, D.E., J.R. Spotila, S.K. Martin, and S.J. Kemp. 1994. Behavioral responses to barriers by desert tortoises: implications for wildlife management. Herp.Monog. 8: 144-160.

NEVADA STATUS REPORT: DESERT TORTOISE MANAGEMENT ON PUBLIC LANDS

Sid Slone and Phil Medica

Desert Tortoise Management

The Bureau of Land Management (BLM) issued grazing decisions in 1992 deferring livestock grazing in Category I, II, and III desert tortoise habitat between the period of March 1 through June 14 of each year. However, this decision was deferred until 1993 in eight allotments.

This is the second year of implementation of Clark County's Short-term Habitat Conservation Plan. Road designations were made in Piute Valley restricting off highway vehicle (OHV) use to designated roads and trails. Road designations will be made for Eldorado Valley and Cottonwood Cover during the next six months.

The BLM Las Vegas District is in process of developing a new Resource Management Plan for the entire Stateline Resource Area. Protective measures for the desert tortoise is a big issue.

Permanent Study Plot Data

Between 1990 and 1992 five permanent study plots were resampled (Sheep Mountain, Christmas Tree Pass, Gold Butte, Trout Canyon, and Coyote Springs). The adult population on two of these five study plots have remained relatively stable or increased slightly (Sheep Mountain and Coyote Springs), while densities on two other plots have declined slightly (Christmas Tree Pass and Trout Canyon), although on the fifth plot (Gold Butte) there has been a dramatic decline in adult numbers to one-third of the 1986 total.

Preliminary signs of upper respiratory tract disease (URTD) have been observed in three of the five plots resampled between 1990 and 1992 (Christmas Tree Pass, Gold Butte, and Coyote Springs) although the number of animals that exhibited signs was low. None of the animals were tested for *Pasteurella* sp. or *Mycoplasma* sp.

Osteoporosis has been documented in all the study plots sampled between 1990 and 1992. A number of tortoises exhibit concave scutes; this condition has been observed in young as well as old tortoises. The percentages of tortoises exhibiting sunken scute conditions are as follows: Sheep Mountain, 33%; Christmas Tree Pass, 12%, Gold Butte, 50%; Trout Canyon, 22%, and Coyote Springs, 26%.

Shell disease is generally observed on the plastron as a gray-white and sometimes orange color and rough flaky appearance. This can easily be determined from slides that have been taken over the years. The percentages of tortoises exhibiting shell disease are as follows: Sheep Mountain, 18%; Christmas Tree Pass, 15%, Gold Butte, 16%; Trout Canyon, 44 to 52%, and Coyote Springs, 7%.

USE AREAS AND SHELTERSITE CHARACTERISTICS OF SONORAN DESERT TORTOISES: 1992 PROGRESS REPORT

Suzanne Trachy and Vanessa M. Dickinson

(**Editor's note**: This report was originally published in June 1993 by the Arizona Game and Fish Department in cooperation with the U.S. Bureau of Land Management, Arizona State Office, 3707 N. 7th St., Phoenix, Arizona 85014)

***Abstract*.** Desert tortoises from two sites in the Sonoran desert were located to determine habitat use areas and evaluate sheltersite characteristics. A total of ten tortoises from Little Shipp Wash, Yavapai County, Arizona were located between September 1990 and October 1992. Little Shipp Wash tortoises were located an average of 19.5 times. A total of 21 tortoises were located in the Harcuvar Mountains, La Paz County, Arizona between September 1990 and November 1992. Harcuvar Mountain tortoises were located an average of 16.7 times.

Use areas in hectares were determined by the use of the minimum convex polygon method and compared between sites by sex. New sheltersites occupied by tortoises in 1992 were plotted on U. S. Geological Survey topographic maps, flagged for marking, and measured for size comparisons between sites.

Use areas for both sexes combined averaged 7.8 ha at the Harcuvar Mountains (n=13) and 22.7 ha at Little Shipp Wash (n=10). Mean use areas for males (n=9) and females (n=4) were 9.2 and 4.7 ha, respectively, at the Harcuvar Mountains. Mean use areas at Little Shipp Wash were 21.7 ha for males (n=4) and 23.3 ha for females (n=6). Significant differences between sites occurred in use areas with males ($P<0.02$) and both sexes combined ($P<0.02$). Use areas for females were similar between sites.

Most sheltersite characteristics were similar between Little Shipp Wash (n=34) and the Harcuvar Mountains (n=42); significant differences in all seasons combined occurred in slope ($P<0.0001$), elevation ($P<0.02$), interior height ($P<0.04$), and height of shelter cover material ($P<0.02$). Seasonally, most significant differences between sites occurred during late summer/fall and included ground temperature ($P<0.007$), sheltersite temperature ($P<0.04$), opening height ($P<0.01$), and interior height ($P<0.008$).

INTRODUCTION

Decreasing desert tortoise (*Gopherus agassizii*) populations in the Mojave (Mohave) desert led to the listing of the Mojave population as "threatened" by the federal government under the Endangered Species Act in April 1990 (U.S. Fish and Wildlife Service 1990). Its threatened status has since mandated several studies of the species' ecology, behavior, health, and management. The Sonoran population has been protected from collection in Arizona since January 1988 and is a candidate species for inclusion on the State of Arizona's list of Threatened Native Wildlife in Arizona (Arizona Game and Fish Department 1988). The desert tortoise has been the focus of many past observations, reports, and research due to public and individual interest (Woodbury and Hardy 1948, Bury 1982, Barrett and Johnson 1990, Johnson et al. 1990).

Background

Studies of individual home ranges of the desert tortoise remain largely restricted to those completed in the Mojave desert, an area with distinct topographical, habitat, and climatic differences from the Sonoran desert (Barrett and Johnson 1990). Home range studies of tortoises in the Sonoran desert are few (Barrett and Johnson 1990). Barrett (1990) and Schwartzmann (1983) used the minimum convex polygon method to determine average home ranges for tortoises sampled in the Picacho Mountains and an outlying area of the Picachos, the Granite Hills, respectively. Goldsmith and Shaw (1990) and Shields et al. (1990) depicted the minimum polygon area of each tortoises' movements and measured the greatest linear distance across the polygon.

Desert tortoise shelter needs and characteristics have been observed and reported for the Sonoran desert (Vaughan 1984, Barrett 1990, Shields et al. 1990, Dickinson and Snider 1992); however, the majority of study efforts were centered in the Mojave desert where habitats, climate, soil, and topography differ from the Sonoran desert (Barrett and Johnson 1990).

Definitions

This study employed the term "use area" to describe the locations and enclosed polygons of sampled tortoises over a two-year period. Location data presented in this report were not described as "home range," as location points were too few to be judged an adequate basis with which to assume any home range pattern, particularly for such a long-lived species as the desert tortoise (Barrett and Johnson 1990). The term "home range," defined as "that area traversed by an animal in its normal activities of feeding, reproduction, and other facets of its daily life" (Barbour et al. 1969), was not an appropriate term for the purpose of this report; it was intended that this report provide a preliminary evaluation of a five-year home range analysis.

The term "sheltersite" indicated a type of cover associated with rocky outcroppings and granular, coarse soil generally found in Sonoran desert tortoise habitat. The sheltersite canopy was often a boulder or rock formation which provided some sort of opening for cover. The term "sheltersite" described a cover-type for Sonoran desert tortoises; the terms "burrow" and "den" provided a more appropriate description of tortoise cover type evident in the Mojave desert (Burge 1978).

Objectives

This report provides preliminary data on Sonoran desert tortoise use areas and sheltersite characteristics, and is considered to be a progress report for an ongoing five-year study on home ranges and sheltersite characteristics of Sonoran desert tortoises. These data augment existing desert tortoise home range and sheltersite data for the Sonoran desert and provide comparative data for the species as a whole. The objectives of this report were to: (1) evaluate Sonoran desert tortoise habitat use areas and sheltersite characteristics, and (2) determine similarity of sheltersites and use areas between two Sonoran desert sites.

METHODS

Study sites

The Sonoran desert, located south and east of the Colorado River in Arizona and extending south into the states of Sonora and Sinaloa, Mexico, is characterized by a matrix of flat or gentle plains and rocky outcroppings and mountainous "island" areas (Turner and Brown 1982). Primary vegetation types include lowland Sonoran desertscrub, Arizona upland (palo verde-mixed cacti) desertscrub, oak/thorn forest, pinyon pine/juniper chaparral, and sub-alpine forests (McGinnies 1981, Johnson et al. 1990). In Arizona, the Sonoran population of the desert tortoise is found typically in the Arizona upland and lowland Sonoran desertscrub (Luckenbach 1982, Johnson et al. 1990).

United States Fish and Wildlife Service (USFWS), United States Bureau of Land Management (BLM), and Arizona Game and Fish Department (AGFD) personnel selected two sites in 1990 based on the knowledge of suitable wild tortoise populations and characteristic Sonoran desert vegetation (Figure 1). Both study sites are adjacent to existing BLM permanent study plots. Little Shipp Wash is located approximately 9.6 km southeast of Bagdad, Arizona, and is characterized by lowland desertscrub and upland saguaro/palo verde vegetation types. Predominant plant species include little-leaf palo verde (*Cercidium microphyllum*), saguaro (*Carnegia gigantea*), ocotillo (*Fouquieria splendens*), honey 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). Elevations range from 788-975 m. The Little Shipp Wash site is managed by the State of Arizona for multiple uses including cattle grazing, hunting, and outdoor recreation.

The Harcuvar Mountain site, located 24.1 km northwest of Aguila, Arizona, is also in the lower and upper Sonoran desertscrub vegetation, but generally lower in elevation than Little Shipp Wash (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*). The occurrence of prickly pear cactus is rare (Dickinson and Snider 1992). The Harcuvar Mountains are managed by the BLM for multiple uses including cattle grazing, hunting, and outdoor recreation.

Sample collection

Initial capture of tortoises sampled for this study began in the fall of 1990 with the joint effort of BLM, USFWS, and AGFD personnel and contractors. The majority of tortoises were radio-tagged by spring 1991. A sample size of approximately 10-15 adult (> 208 maximum carapace length [MCL]) tortoises at each site were identified by filing or "notching" their marginal scutes at locations representing a separate three-digit number based on the state of Arizona notching/identification protocol (Berry 1988). Model 125 (Telonics, Mesa, AZ) transmitters were placed on each tortoise with 5-minute gel epoxy (Tru-bond, Chicago, IL). Masking tape was placed on each scute suture prior to gluing to protect growth areas. The epoxy, transmitter, and antenna were painted with brown latex paint for the purpose of camouflage.

Locations for the determination of use areas of all tortoises commenced in September 1990 and were completed in November 1992. Sheltersite descriptions and measurements were collected in both 1991 and 1992. This study analyzes data collected in 1992; integration of annual study data will occur in a final report. Sheltersite analyses for 1991 can be found in Dickinson and Snider (1992). Tortoises were located approximately one time per month during winter estivation (November-February) and a minimum of two times per month during the active period (March-October).

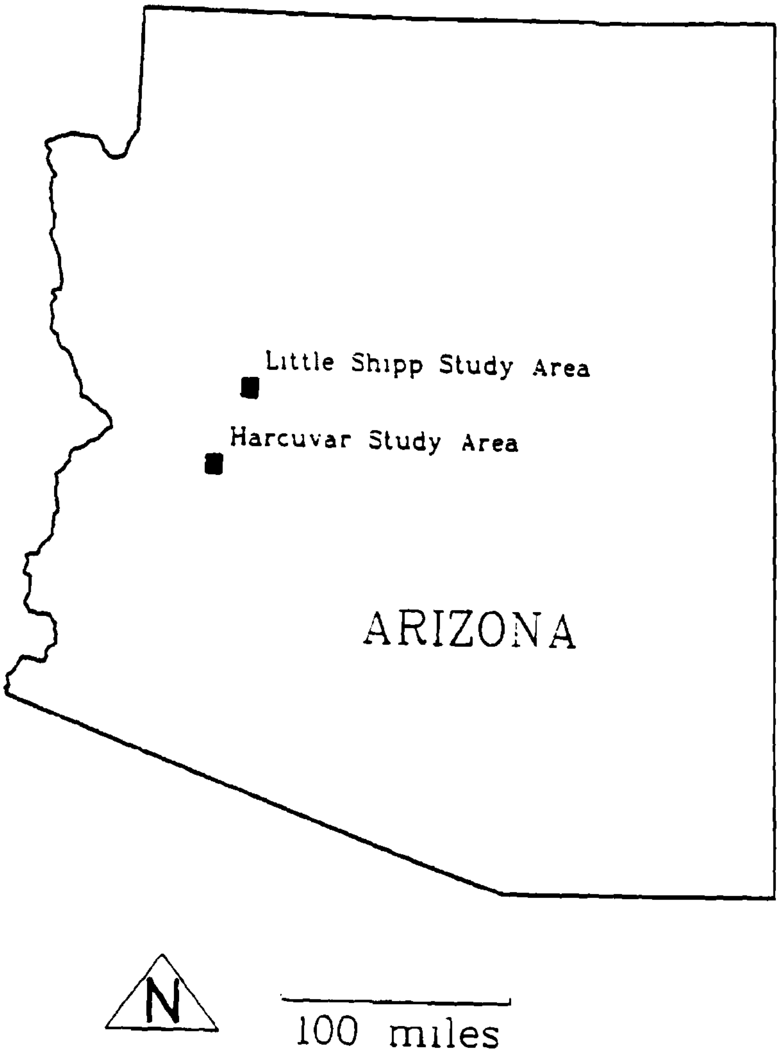

FIGURE 1. Location of Little Shipp Wash and Harcuvar Mountains, Arizona.

Locations of radio-tagged tortoises were plotted on an enlarged copy of a 7.5" U.S. Geological Survey (USGS) topographic map. The location data point and topographic map were labeled with the tortoise identification number and date of location. All new sheltersites were flagged with pink flagging to eliminate repetitive data collection. For analysis, it was assumed that all sheltersites were flagged and thereby measured only once. Any decayed or worn flagging was replaced. Data collected for each sheltersite included the tortoise identification number, the observer, date, site, ground temperature in centigrade directly outside and in the interior of the sheltersite, sheltersite exterior height and length, interior width, height, and length, apron (if any) width and length, cover material height, cover material composition, and, if any, cover vegetation width, height, and percent of sheltersite coverage.

Occasionally, during feeding observations or locating radio-tagged tortoises, the field crew would find non-radioed tortoises. The area where the tortoise was found was marked with flagging. The tortoise was brought back to camp, weighed, measured, and radio-tagged. The tortoise was returned to its marked area of capture, and was included in all aspects of the study.

Locations of each tortoise for use area analysis were plotted on full-size 7.5" USGS topographic maps for digitizing and generating Universal Transverse Mercator (UTM) Grid System locations. Each digitized location point correlated to the tortoise identification number, site, date of location, sex, and season for comparative and analytical purposes. This progress report analyzed two years (1991, 1992) of location data to determine use areas and one year (1992) of characteristics of active sheltersites. Use areas were calculated and graphically displayed using the minimum convex polygon method (Jennrich and Turner 1969) and Program Home Range (Ackerman et al. 1991). Use of this method, while potentially biased (Jennrich and Turner 1969), remains the most widely used method for home range analyses due to its ease of description and presentation and its capability to summarize baseline data. Use of the minimum convex polygon method also facilitated comparison with the Sonoran desert tortoise home range studies by Barrett (1990) and Schwartzmann (1983) and similar studies occurring in the Mojave desert (Coombs 1977, Hohman and Ohmart 1980, Esque et al. 1991).

Statistical analyses

Use areas for sampled tortoises were evaluated using the minimum convex polygon method (Jennrich and Turner 1969, Ackerman et al. 1990). Areas in hectares were summarized by calculation of means ($\bar{x}$) and standard deviations (SD). All data sets were tested for normality with multivariate analysis of variance (MANOVA) probability plots (SPSS Inc., Norusis 1985). Means between sites by sex and both sexes combined were analyzed with parametric tests (T-TEST, SPSS Inc.; Norusis 1983). Significance was judged at $P<0.05$.

Most sheltersite data were summarized by calculation of means ($\bar{x}$) and standard deviations (SD). Data such as sheltersite aspects, sheltersite material composition, and classification of shelter cover plant species were summarized as percentages. The remaining data points were tested for normality with MANOVA probability plots. Most sheltersite variables (91%) were normally distributed and were analyzed with parametric tests (T-TEST, SPSS Inc.; Norusis 1983). Variables that were not normally distributed (5%) were analyzed with non-parametric tests (NPAR TESTS M-W, SPSS Inc.; Norusis 1983). Variables without complete data sets (4%) were not statistically analyzed. Significance was judged at $P<0.05$.

Sheltersite data was divided into three seasons. Data was analyzed between sites by seasons and all seasons combined. Seasonal divisions were based on tortoise activity and climate patterns. The winter season included all data recorded in January, February, March, November, and December of 1992. The spring/early summer season included data recorded in April, May, and June. The late summer/fall season included data recorded in July, August, September, and October.

RESULTS

A total of ten tortoises were located at Little Shipp Wash from September 27, 1990 to October 22, 1992 (Table 1). Tortoises were located an average of 19.5 times over that period, with a range of five (tortoise 502) to 33 (tortoise 309) locations. Observers first found tortoise 502 on June 30, 1992; it was the latest addition to the sample size at Little Shipp Wash. One tortoise death occurred over this period (tortoise 308). Due to the number of locations, tortoise 308 was still included in the use area analysis.

A total of 21 tortoises were located and sampled in the Harcuvar Mountains between September 27, 1990 and November 27, 1992 (Table 1). Tortoises were located an average of 16.7 times, with a range of four (tortoise 222) to 27 (tortoise 203) locations. Tortoise 222 was found on March 26, 1992; it was the latest addition to the Harcuvar Mountains sample. Several tortoises were not analyzed for use areas in the Harcuvar Mountains due to their deaths or lost signals during the study (Table 1).

Use areas

Use area polygons enclosed all, or 100%, of each tortoise's locations. Graphic displays of use areas for all tortoises sampled are in Appendix I. Use area means were analyzed between sites by sex and both sexes combined. Use areas were significantly different between sites by males ($P<0.02$, n=13) and both sexes combined ($P<0.02$, n=23). Use areas of females between sites were similar.

Use areas varied by sex between sites. Average female use areas ($\bar{x} = 23.3 \pm 20.2$ ha, n=6) were larger than male use areas ($\bar{x} = 21.7 \pm 7.1$ ha, n=4) at Little Shipp Wash. At the Harcuvar Mountains, female use areas ($\bar{x} = 4.7 \pm 2.1$ ha, n=4) were smaller than males ($\bar{x} = 9.2 \pm 7.7$ ha, n=9).

Sheltersite characteristics

Of 34 sheltersites located at Little Shipp Wash in 1992, most (23.5%) faced southeast (Figure 2). Southeast-facing sheltersites were most common in winter, spring, and early summer (n=19). In late summer and fall, northeast-facing and northwest-facing sheltersites predominated (26.7% and 20.0% respectively, n=15). No sheltersites faced east throughout the year. Elevations of sheltersites located at Little Shipp Wash ranged from 774 to 988 m, with an average of 876 ± 57 m (n=34) (Table 3). Sheltersites were found at higher elevations in winter than any other season. Slopes ranged from 0° to 40°, with the average slope being 17.8° ± 7.9° (n=31).

At the Harcuvar Mountains, 42 sheltersites were located in 1992. Northwest-facing sites predominated (35.7%), particularly in spring, summer, and fall (Figure 3). No northwest-facing sheltersites were found in winter. East-facing sites ranked second (23.8%) for all seasons combined. Elevations of sheltersites located at the Harcuvar Mountains ranged from 732 to 939m

TABLE 1. Status of all desert tortoises sampled at two sites in the Sonoran desert, 1990-1992.

Site	Tortoise No.	Sex[1]	Date Radioed	Status[2]
Little Shipp Wash, AZ (n=10)	301	F	9-27-90	PA, UA[3]
	302	M	9-27-90	PA, UA
	303	M	9-27-90	PA, UA
	308	F	9-27-90	D (8-8-91), UA
	309	F	10-25-90	PA, UA
	310	M	10-29-90	PA, UA
	499	F	10-18-90	PA, UA
	500	M	4-23-91	PA, UA
	501	F	9-24-91	PA, UA
	502	F	6-30-92	PA, UA
Harcuvar Mountains, AZ (n=21)	201	F	9-25-90	D (4-25-91), NA[4]
	202	M	9-25-90	PA, UA
	203	M	9-25-90	PA, UA
	204	M	9-25-90	PA, UA
	205	M	9-25-90	LS (4-30-92), UA
	207	M	9-26-90	D (4-25-91), NA
	208	F	10-15-90	PA, UA
	209	F	10-15-90	D (7-10-91), NA
	210	M	10-21-90	D (6-24-92), UA
	211	F	10-21-90	PA, UA
	212	M	10-23-90	LS (11-7-90), NA
	213	M	10-23-90	D (6-28-91), NA
	214	M	10-23-90	D (6-28-91), NA
	215	M	10-24-90	D (4-22-92), UA
	216	M	10-24-90	D (7-4-91), NA
	217	M	11-9-90	D (6-28-91), NA
	218	M	7-4-91	PA, UA
	219	F	9-18-91	PA, UA
	220	M	9-26-91	PA, UA
	221	F	9-26-91	PA, UA
	222	M	3-26-92	PA, UA

[1] M = Male
F = Female

[2] PA = Presently active (as of November 1992)
LS = Lost signal (date last seen)
D = Found dead (date found)

[3] UA = Analyzed for use area

[4] NA = Not analyzed for use area

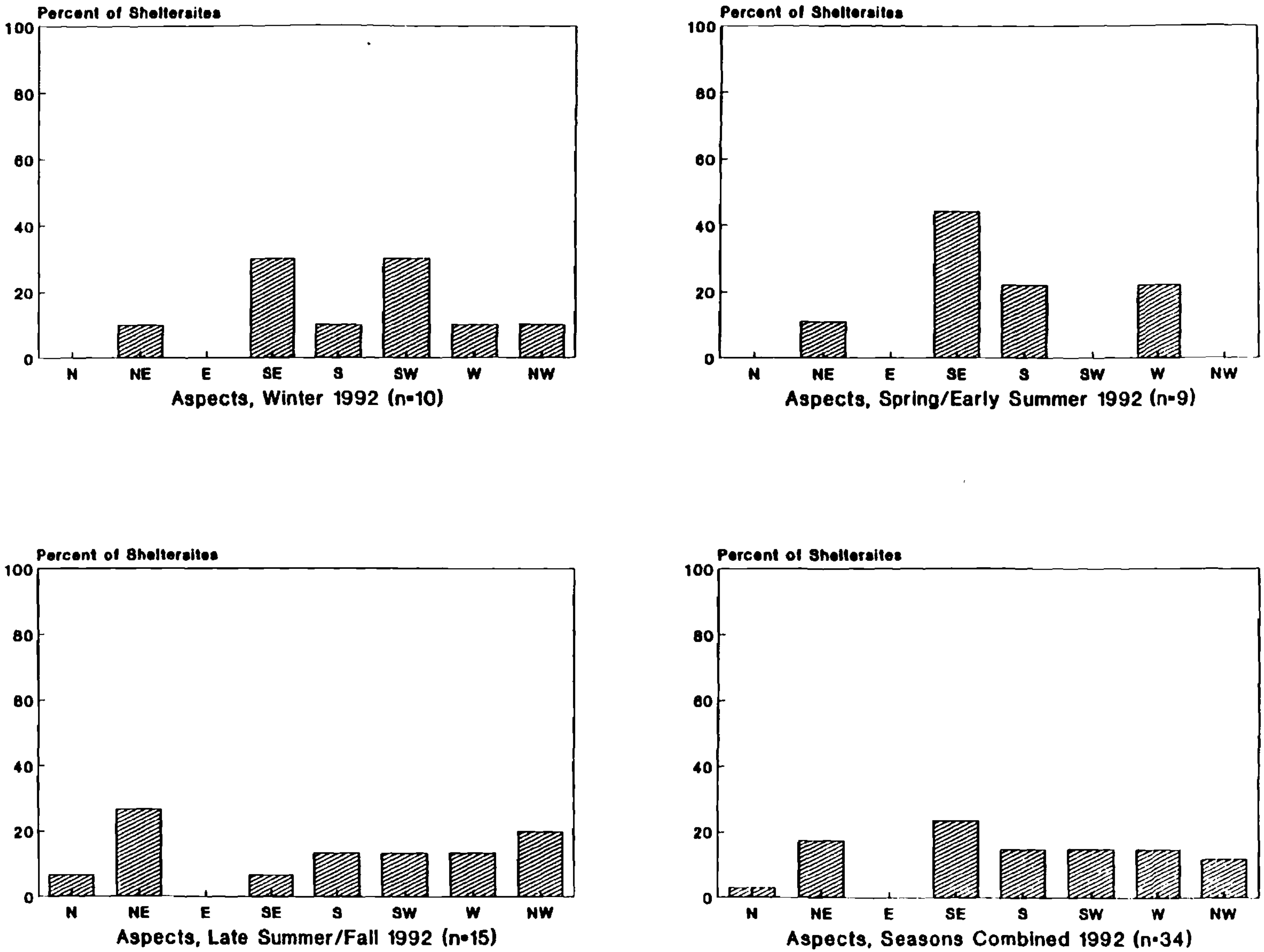

FIGURE 2. Aspects of desert tortoise sheltersites at Little Shipp Wash, Arizona, January-November 1992.

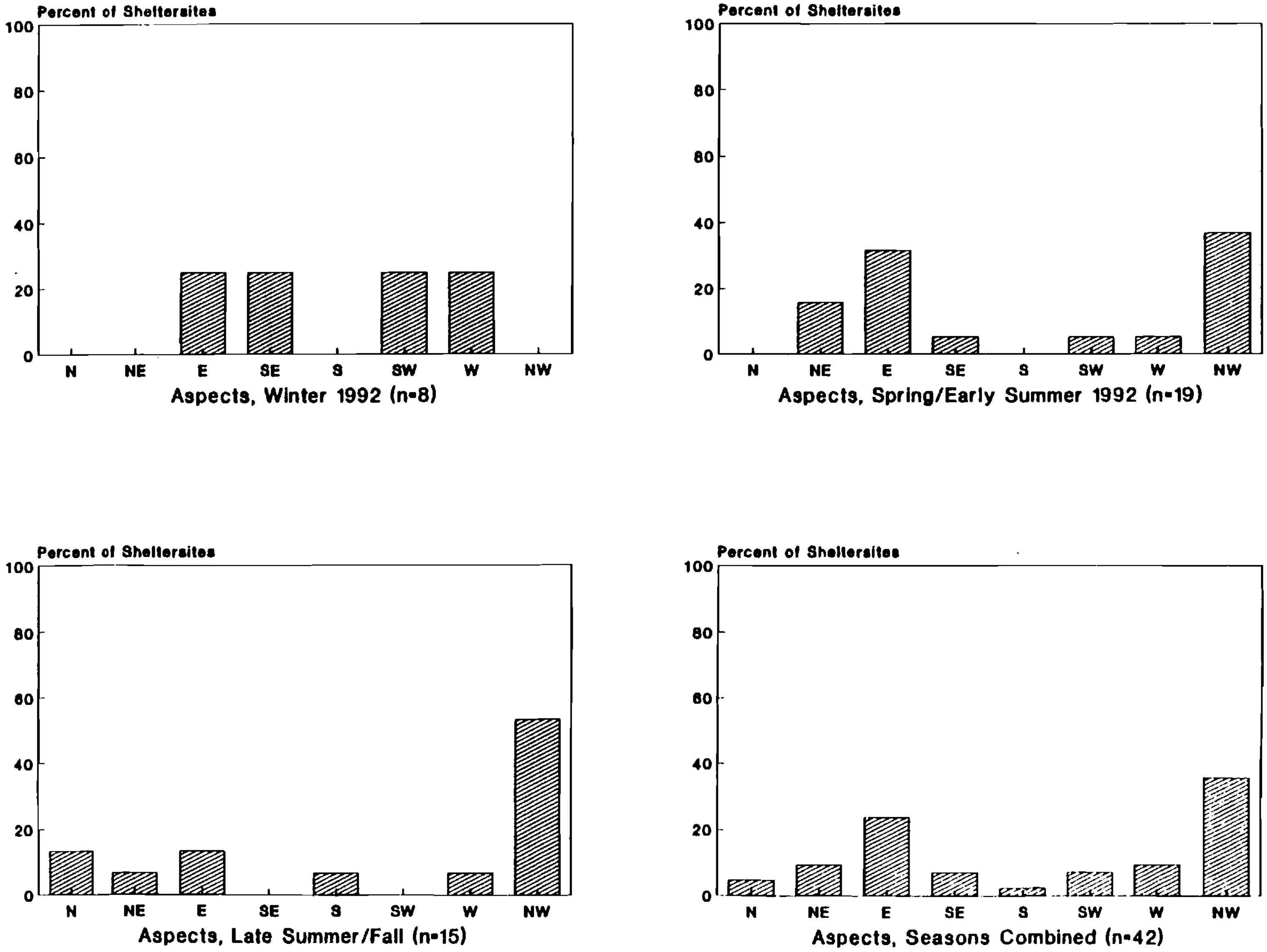

FIGURE 3. Aspects of desert tortoise sheltersites at Harcuvar Mountains, Arizona, January-November 1992.

with a mean of 846 ± 45 m (n=42). Seasonal elevations were highest during winter. Slopes of sheltersites ranged from 5° to 45° with an average of 25.0 ± 8.4° (n=42).

Significant differences between populations in elevation occurred during the late summer/fall season (*P*<0.04) and in all seasons combined (*P*<0.02). Significant differences were also evident in sheltersite slopes between sites during winter (*P*<0.02), spring/early summer (*P*<0.001), and in all seasons combined (*P*<0.0001) (Table 3).

Annual averages indicated that Little Shipp Wash ground temperatures outside sheltersites were 0.8°C higher than temperatures taken inside each sheltersite (Table 3). At the Harcuvar Mountains, annual averages for ground temperatures and sheltersite temperatures were equivalent (Table 3). Significant differences between sites occurred in late summer/fall for both ground temperature (*P*<0.007) and sheltersite temperature (*P*<0.04).

The majority of sheltersites were composed of granitic rock (Figure 4). At Little Shipp Wash, 85.3% of all sheltersites (n=34) were termed "rocky" and "granular" as the primary composition of sheltersite ground material. At the Harcuvar Mountains, 83.3% were composed of rocky and granular substrates (n=42).

No sheltersite at Little Shipp Wash was greater than 100 cm wide at its opening. The width for sheltersite openings ranged from 22 to 90 cm (n=33). At the Harcuvar Mountains, two sheltersites had an opening width of greater than 100 cm, with a total annual range of 15 to 131 cm (n=41). Opening width was similar between sites.

Opening height for sheltersites at Little Shipp Wash ranged from 12 to 90 cm with a total annual average of 27.4 ± 16.1 cm (n=32). At the Harcuvar Mountains, opening height ranged from 13 to 42 cm with an annual mean height of 21.5 ± 7.4 cm (n=41) (Table 3). Mean opening heights were similar between populations for all seasons combined; however, there was a significant difference between sites in the fall (*P*<0.01).

The average sheltersite interior height at Little Shipp Wash (all seasons combined) was 22.6 ± 14.1 cm (n=32); for the Harcuvar Mountains, the mean was 16.9 ± 6.5 cm (n=42). Analysis of interior height showed a significant difference of means between sites during fall (*P*<0.008) and all seasons combined (*P*<0.04), with sheltersites at Little Shipp Wash showing a higher season and annual average than sheltersites at the Harcuvar Mountains.

Five sheltersites found at Little Shipp Wash in 1992 had an interior length of greater than 100 cm. The longest interior length was 260 cm. Mean interior length for all of 1992 averaged 69.0 ± 46.7 cm (n=31). Four sheltersites at the Harcuvar Mountains had an interior length of greater that 100 cm, the longest being 130 cm. Mean interior length for sheltersites in 1992 was 58.2 ± 31.3 cm (n=41) (Table 3). Sheltersite interior lengths were similar between sites in all seasons and in seasons combined. Significant differences were discernible between sites for height of sheltersite cover material in late summer/fall (*P*<0.03) and in all seasons combined (*P*<0.02)(Table 3).

Plant species, if any, covering the sheltersites were identified and measured for width, height, and the percent of sheltersite coverage (Tables 3 and 4). At Little Shipp Wash, the plant species most common over sheltersites was little-leaf palo verde (31.3%, n=16). Flat-topped buckwheat was the most common sheltersite cover vegetation (30%, n=10) at the Harcuvar Mountains. The average height and percent of cover vegetation were similar between sites in all seasons combined.

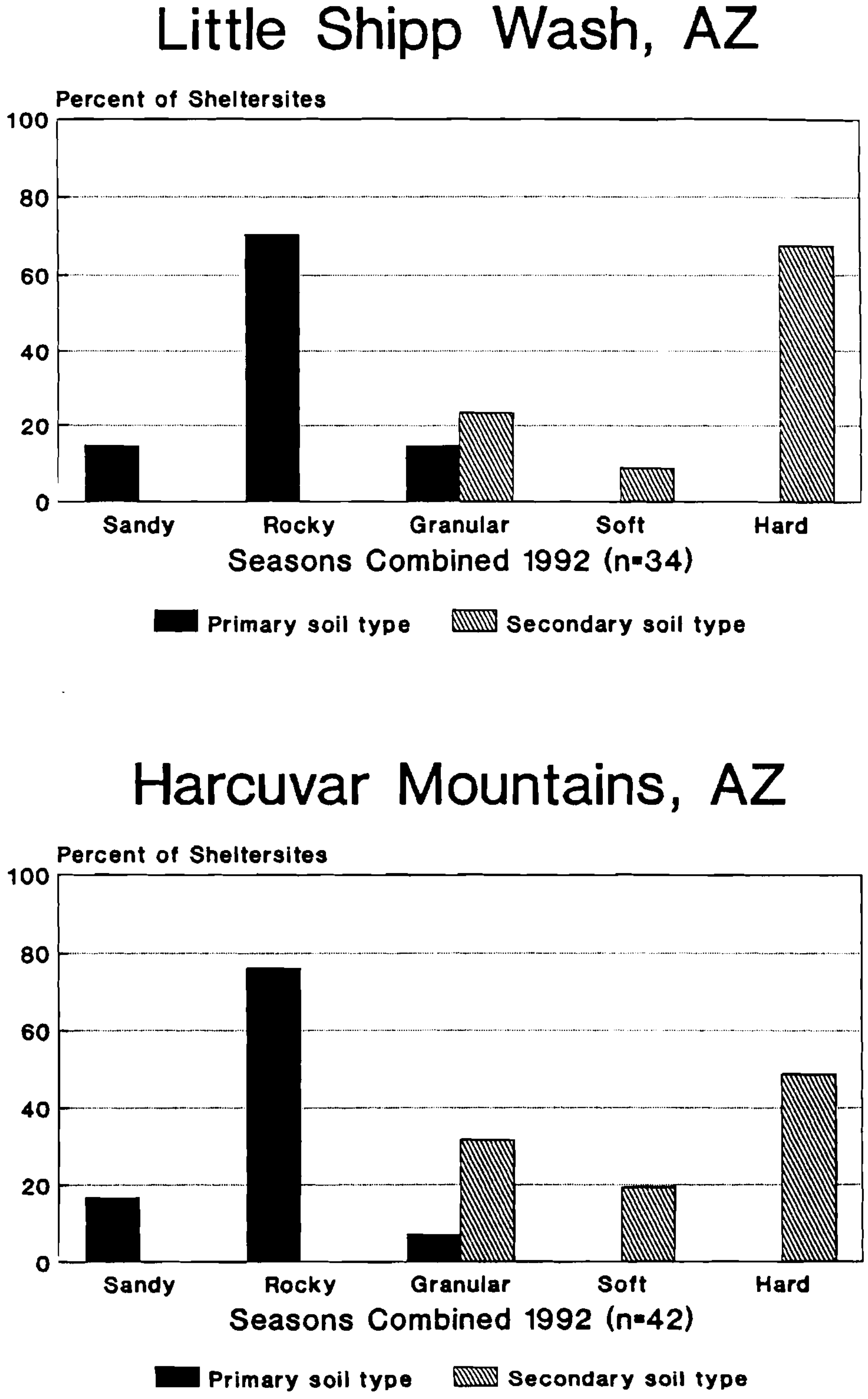

FIGURE 4. Primary and secondary soil-type composition of desert tortoise sheltersites at two sites in the Sonoran desert, Arizona, January-November 1992.

TABLE 3. Desert tortoise sheltersite profiles from two sites in the Sonoran desert, Arizona, January-November 1992. np denotes non-parametric analysis.

SITE: LITTLE SHIPP WASH, ARIZONA

$\bar{x}$ ± SD (n)	Winter[1]	Spring/Early Summer[2]	Late Summer/Fall[3]	Seasons Combined
Slope (°)	20.3 ± 4.9 (10)*	13.1 ± 7.0 (8)*	18.8 ± 9.3 (13)	17.8 ± 7.9 (31)*
Elevation (m)	888 ± 58 (10)	850 ± 69 (9)	885 ± 45 (15)*	876 ± 57 (34)*
Ground Temp (°C)	17.2 ± 2.6 (9)	24.8 ± 5.6 (9)	31.8 ± 5.9 (15)*	25.9 ± 7.9 (33)
Sheltersite Temp (°C)	15.0 ± 1.6 (7)	25.1 ± 5.7 (8)	29.8 ± 4.2 (15)*	25.1 ± 7.3 (30)
Opening Width (cm)	52.7 ± 23.8 (9)	37.7 ± 13.9 (9)	44.9 ± 13.3 (15)	45.0 ± 17.3 (33)
Opening Height (cm)	21.1 ± 7.3 (9)	22.9 ± 7.6 (8)	33.5 ± 20.8 (15)*	27.4 ± 16.1 (32)
Interior Width (cm)	35.8 ± 15.5 (8)	34.6 ± 18.7 (9)	36.1 ± 14.0 (15)	35.6 ± 15.3 (32)
Interior Height (cm)	15.3 ± 4.4 (8)	19.0 ± 6.0 (9)	28.7 ± 18.2 (15)*	22.6 ± 14.1 (32)*
Interior Length (cm)	66.6 ± 38.1 (7)	47.8 ± 12.7 (9)	82.8 ± 58.8 (15)	69.0 ± 46.7 (31)
Apron Width (cm)	66.3 ± 29.4 (4)	49.8 ± 16.0 (6)	58.0 (1)	56.5 ± 21.3 (11)
Apron Length (cm)	90.5 ± 68.0 (4)	47.8 ± 17.8 (6)* (np)	34.0 (1)	62.1 ± 45.5 (11)
Shelter Cover Sub. (cm)	66.1 ± 56.5 (9)	62.6 ± 40.3 (9)	80.4 ± 35.6 (15)*	71.6 ± 42.8 (33)*
Veg. Height (cm)	113.7 ± 44.8 (6)	166.3 ± 74.1 (4)	160.8 ± 91.0 (5)	143.4 ± 67.0 (15)
Veg. Width (cm)	147.2 ± 52.8 (6)	196.5 ± 97.0 (4)	165.4 ± 75.0 (5)	166.4 ± 71.0 (15)
Veg. % Cover	33.6 ± 35.4 (7)	58.8 ± 37.5 (4)	47.5 ± 28.7 (4)	44.0 ± 33.7 (15)

SITE: HARCUVAR MOUNTAINS, ARIZONA

$\bar{x}$ ± SD (n)	Winter	Spring/Early Summer	Late Summer/Fall	Seasons Combined
Slope (°)	26.8 ± 5.9 (8)*	25.0 ± 7.2 (19)*	23.9 ± 10.9 (15)	25.0 ± 8.4 (42)*
Elevation (m)	861 ± 47 (8)	843 ± 45 (19)	841 ± 47 (15)*	846 ± 45 (42)*
Ground Temp (°C)	16.6 ± 3.0 (8)	25.0 ± 4.4 (19)	26.1 ± 4.5 (15)*	23.8 ± 5.5 (42)
Sheltersite Temp (°C)	15.6 ± 2.3 (7)	25.0 ± 3.9 (16)	26.5 ± 4.3 (15)*	23.8 ± 5.5 (38)
Opening Width (cm)	38.6 ± 14.5 (8)	51.2 ± 26.8 (18)	49.1 ± 28.3 (15)	48.0 ± 25.4 (41)
Opening Height (cm)	22.3 ± 7.6 (8)	24.1 ± 8.5 (18)	18.0 ± 4.2 (15)*	21.5 ± 7.4 (41)
Interior Width (cm)	31.5 ± 10.4 (8)	40.7 ± 22.0 (19)	39.8 ± 29.5 (15)	38.6 ± 23.3 (42)
Interior Height (cm)	16.3 ± 5.2 (8)	19.4 ± 8.1 (19)	14.1 ± 2.9 (15)*	16.9 ± 6.5 (42)*
Interior Length (cm)	43.1 ± 7.5 (7)	59.7 ± 32.6 (19)	63.3 ± 35.5 (15)	58.2 ± 31.3 (41)
Apron Width (cm)	33.5 ± 6.4 (2)	36.3 ± 11.0 (3)	57.0 ± 24.1 (8)	48.6 ± 22.0 (13)
Apron Length (cm)	20.5 ± 6.4 (2)	13.7 ± 3.2 (3)* (np)	46.4 ± 20.1 (8)	34.8 ± 21.8 (13)
Shelter Cover Sub. (cm)	38.1 ± 15.3 (8)	57.2 ± 25.6 (18)	46.6 ± 34.2 (12)*	49.8 ± 27.4 (38)*
Veg. Height (cm)	101.0 ± 85.8 (3)	(0)	271.8 ± 276.0 (6)	214.9 ± 238.2 (9)
Veg. Width (cm)	130.0 ± 81.9 (3)	(0)	339.5 ± 469.4 (6)	269.7 ± 387.8 (9)
Veg. % Cover	62.0 ± 31.1 (5)	10.0 (1)	58.4 ± 40.2 (5)	55.6 ± 35.6 (11)

[1] January - March and November 1992

[2] April - June 1992

[3] July - October 1992

* Significantly different means between sites

TABLE 3. (continued) Desert tortoise sheltersite profiles from two sites in the Sonoran desert, Arizona, January-November 1992.

SITE: ALL SITES COMBINED

$\bar{x}$ ± SD (n)	Winter[1]	Spring/Early Summer[2]	Late Summer/Fall[3]	Seasons Combined
Slope (°)	23.2 ± 6.2 (18)	21.5 ± 8.9 (27)	21.5 ± 10.4 (28)	21.9 ± 8.9 (73)
Elevation (m)	876 ± 54 (18)	846 ± 53 (28)	863 ± 50 (30)	860 ± 53 (76)
Ground Temp (°C)	16.9 ± 2.7 (17)	24.9 ± 4.7 (28)	28.9 ± 5.9 (30)	24.7 ± 6.7 (75)
Sheltersite Temp (°C)	15.3 ± 1.9 (14)	25.0 ± 4.5 (24)	28.2 ± 4.5 (30)	24.4 ± 6.3 (68)
Opening Width (cm)	46.0 ± 20.7 (17)	46.7 ± 23.9 (27)	47.0 ± 21.8 (30)	46.7 ± 22.0 (74)
Opening Height (cm)	21.6 ± 7.2 (17)	23.7 ± 8.1 (26)	25.8 ± 16.7 (30)	24.1 ± 12.2 (73)
Interior Width (cm)	33.6 ± 13.0 (16)	38.7 ± 20.8 (28)	38.0 ± 22.8 (30)	37.3 ± 20.1 (74)
Interior Height (cm)	15.8 ± 4.7 (16)	19.3 ± 7.3 (28)	21.4 ± 14.8 (30)	19.4 ± 10.8 (74)
Interior Length (cm)	54.9 ± 29.1 (14)	55.9 ± 28.1 (28)	73.0 ± 48.8 (30)	62.8 ± 38.8 (72)
Apron Width (cm)	55.3 ± 28.5 (6)	45.3 ± 15.4 (9)	57.1 ± 22.6 (9)	52.3 ± 21.6 (24)
Apron Length (cm)	67.2 ± 63.9 (6)	36.4 ± 22.2 (9)	45.0 ± 19.2 (9)	47.3 ± 36.6 (24)
Shelter Cover Sub. (cm)	52.9 ± 43.6 (17)	59.0 ± 30.6 (27)	65.4 ± 38.4 (27)	60.0 ± 36.8 (71)
Veg. Height (cm)	109.4 ± 56.0 (9)	166.3 ± 74.1 (4)	221.4 ± 211.6 (11)	170.2 ± 154.8 (24)
Veg. Width (cm)	141.4 ± 59.1 (9)	196.5 ± 97.0 (4)	260.4 ± 347.4 (11)	205.1 ± 240.8 (24)
Veg. % Cover	45.4 ± 35.4 912)	49.0 ± 39.1 (5)	53.6 ± 33.9 (9)	48.9 ±34.3 (26)

[1] January - March and November 1992

[2] April - June 1992

[3] July - October 1992

TABLE 4. Cover plant species of desert tortoise sheltersites at two sites in the Sonoran desert, Arizona, January-November 1992.

Plant Species	Little Shipp Wash, AZ (n=16) % of Total Recorded	Harcuvar Mountains, AZ (n=10) % of Total Recorded
Cercidium microphyllum	31.3	20.0
Eriogonum fasciculatum	6.3	30.0
Hilaria rigida	--	20.0
Prosopis juliflora	18.8	10.0
Acacia sp.	6.3	--
Opuntia engelmannii	12.5	--
Gutierrezia sp.	12.5	--
Larrea tridentata	6.3	--
Encelia farinosa	--	10.0
Fouquieria splendens	--	10.0
Yucca sp.	6.3	--

DISCUSSION

Use areas

The number of locations over a two-year period were too few to provide an estimate of home range for a species which can survive up to 75 years and beyond in the wild (Barrett and Johnson 1990). As a preliminary phase of an ongoing five-year study, it was reasonable to utilize the minimum convex polygon method to describe these use areas. Both the minimum area polygon and minimum convex polygon methods have been used in the determination of use areas and home ranges; however, the minimum convex polygon method remains the most visually comprehensible and shows "reasonably good statistical stability" (Jennrich and Turner 1969). Minimum convex polygon values exhibit a tendency to increase in size as more capture points are included until an asymptote is reached (Jennrich and Turner 1969, Vaughan 1984). Jennrich and Turner (1969) allow for this bias by the use of an index for the comparison with other observations or populations. They defend the use of the minimum convex polygon over the minimum area polygon, as the area polygon becomes too complex to display and is not as statistically stable as the convex polygon. In effect, Jennrich and Turner (1969) recommend the use of the minimum convex polygon method due to these factors, its graphical simplicity, and "historical prominence." Additionally, its widespread use facilitates comparisons with those home range studies completed for Sonoran desert tortoises (Schwartzmann 1983, Vaughan 1984, Barrett 1990).

Additionally, use of Program Home Range (Ackerman et al. 1990) allows for a variety of calculations with the minimum convex polygon method. This report utilized all, or 100%, of the tortoise's locations, including all "outliers" or extreme locations which could alter home range estimates by including large areas of potentially unused habitat in the resulting calculated area. While outliers can represent a variety of movements (transitional movements to new or seasonal territories, searches for mates and food), they also influence calculations of minimum convex polygon areas (Ackerman et al. 1990).

In comparison with other Sonoran desert tortoise home range studies, Barrett (1990) reports that tortoise home ranges in the Picacho Mountains averaged 19.1 ± 4.6 ha, with a range of 3-53 ha (n=14). Schwartzmann (1983) reported home ranges of 20.0 ± 8 ha (males) and 13 ± 4 ha (females) for a sample size of 11. Mean use areas for males, females, and both sexes combined were greater at Little Shipp Wash and less at the Harcuvar Mountains than both of the Sonoran desert studies mentioned above.

It is recommended that the final report include the analysis of the core areas used by each tortoise. Core areas include 50% of the most centered locations for each tortoise. Evaluation of core areas is useful as it describes "central areas of consistent or intense use" (Kaufmann 1962) and represents that area used repeatedly over a prolonged segment of an animal's lifetime activity patterns. Outliers or remote points and small sample sizes do not influence the analysis of core areas (Ackerman et al. 1990). Additionally, the inclusion of vegetation transects for the determination of plant availability and feeding selection for each site will be initiated. This procedure will provide an additional parameter with which to determine and compare annual and seasonal home range movements.

Sheltersite characteristics

The majority of sheltersite characteristics proved to be similar between sites with most significant differences occurring between sites during the late summer/fall season. These differences could be a result of environmental influences on tortoise activity. Little Shipp Wash contains prickly pear, which germinated during and after the fall monsoon season. Tortoises at Little Shipp Wash were observed feeding on prickly pear fruit, a food item not occurring in the Harcuvar Mountains. This activity could alter sheltersite use or selection. Elevations for tortoises in Arizona range from 158 to 1615 m (Barrett and Johnson 1990). Tortoises in this study were located between 732 and 939 m; while there was a significant difference between sites, tortoises remained within the elevation range reported by Barrett and Johnson (1990).

In 1991, 89% of sheltersites at Little Shipp Wash (n=9) and 93% of sheltersites at the Harcuvar Mountains (n=28) were located in granitic rock dens (Dickinson and Snider 1992). In 1992, tortoises at both sites utilized naturally occurring granitic outcroppings (97%, n=76) rather than pallets (3%, n=76). Warmer southeast and southwest slopes were preferred during the cool winter months; northeast, northwest, and east-facing slopes were preferred in summer and fall. This is most consistent with Wirt (1988), who reported that north-facing sheltersites were favored in summer by tortoises in the Maricopa Mountains. Interior length of sheltersites for both 1991 and 1992 were longest during the summer season for both Little Shipp Wash and Harcuvar Mountains (Dickinson and Snider 1992). This is consistent with tortoises in the Picacho Mountains, which used deeper dens in summer than in winter (Barrett 1990).

Barrett (1990) reported the importance of washes to desert tortoises in the Picacho Mountains for the construction or modification of caliche dens and sandy soils for the excavation of nests. No observations of den construction and use or nesting in washes occurred at Little Shipp Wash or in the Harcuvar Mountains in 1992. In the warmer months of summer, two tortoises from Little Shipp Wash (301, 309) were located at or near washes. It is possible given the season, that the tortoises were selecting a cooler microclimate.

For additional analysis, it is recommended that aspects of the total surface area of each site be evaluated with the Geographic Information System (GIS) and correlated to the aspects of active sheltersites to determine if selection of sheltersites occurs. It is also recommended that sheltersite temperatures be analyzed based on the time of day taken.

CONCLUSIONS

This report provided preliminary baseline use area and sheltersite data for an ongoing five-year home range and sheltersite study of Sonoran desert tortoises. A total of ten tortoises were located an average of 19.5 times at Little Shipp Wash, Yavapai County, Arizona between September 1990 and October 1992. A total of 21 tortoises were located an average of 16.7 times in the Harcuvar Mountains, La Paz County, Arizona between September 1990 and November 1992. New sheltersites occupied by tortoises in 1992 were marked and measured.

This report determined use areas of Sonoran desert tortoises by the minimum convex polygon method. Analysis showed a significant difference occurred between sites in use areas of males and both sexes combined; female use areas were similar between sites. Annual and seasonal movements of these populations will be evaluated for the five-year final report.

The majority of sheltersite characteristics were similar between sites. Significant differences in all seasons combined occurred in slope, elevation, interior height, and height of shelter cover material. Seasonally, most significant differences between sites occurred in the late summer/fall and were evident in elevation, ground temperature, sheltersite temperature, sheltersite opening width, opening height, interior height, and height of shelter cover material.

Vegetation transects will be initiated in 1993 to determine perennial and annual vegetation availability for each site. This procedure will provide an additional parameter with which to determine and compare annual and seasonal home range patterns.

Data will continue to be collected for ongoing sheltersite studies to show length of estivation, sheltersite size and aspect preferences, and seasonal slope and elevation changes. Additionally, aspects of the total surface area of each site will be evaluated through GIS analysis and correlated to the aspects of active sheltersites to determine if selection of sheltersites occurs. It is also recommended that sheltersite temperatures be analyzed based on the time of day taken. It is intended that the final report will consolidate all sheltersite data and provide an integrated evaluation of sheltersite use by Sonoran desert tortoises.

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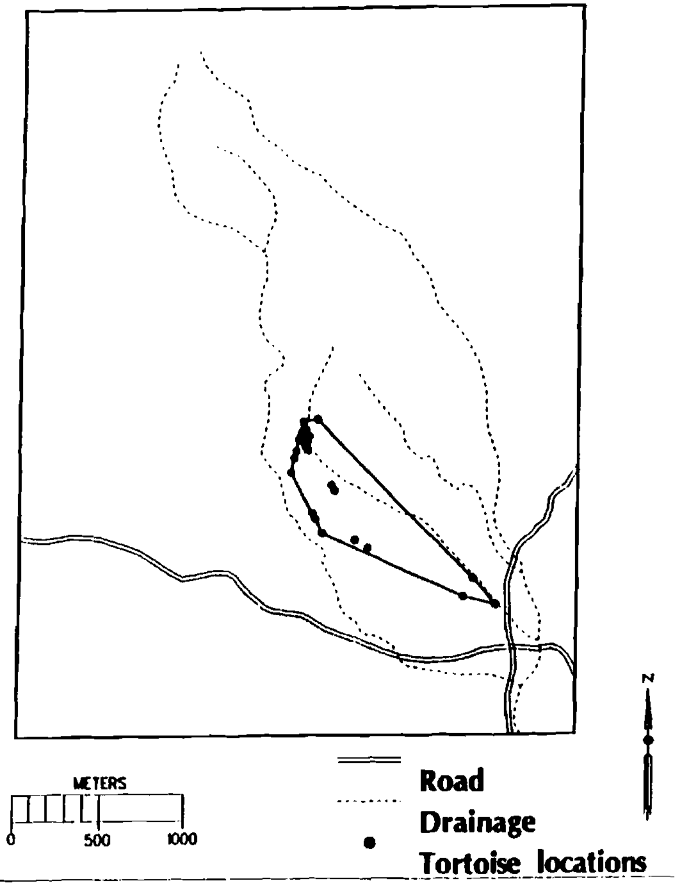
APPENDIX I

Use Area of Tortoise 301
Little Shipp Wash, Arizona
1990 - 1992



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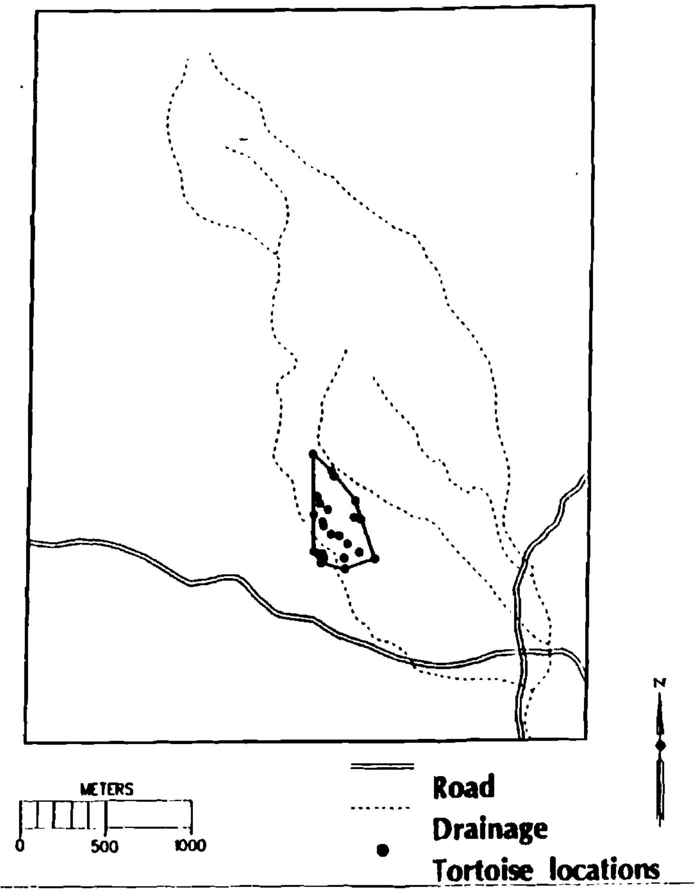
1990 - 1992



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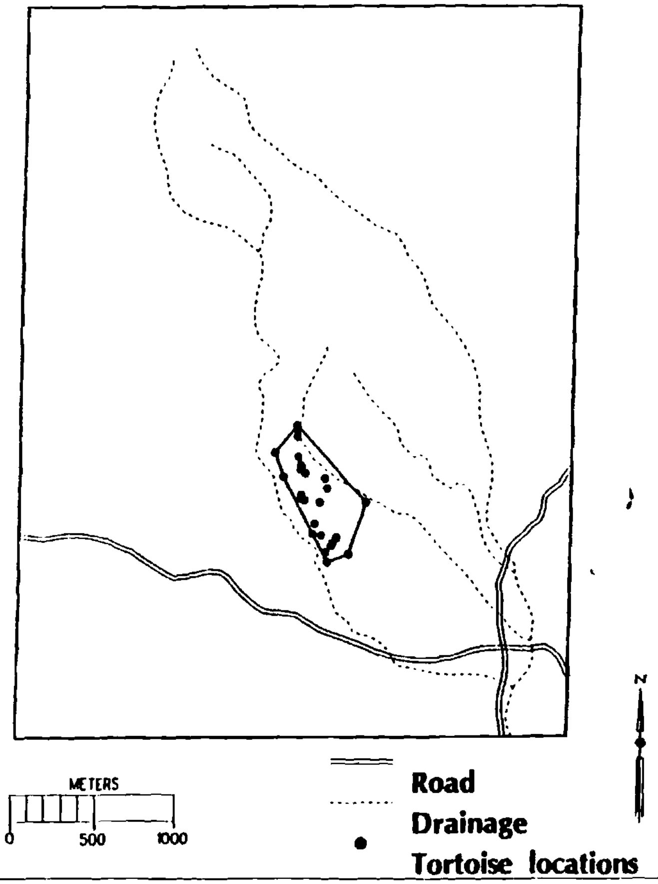

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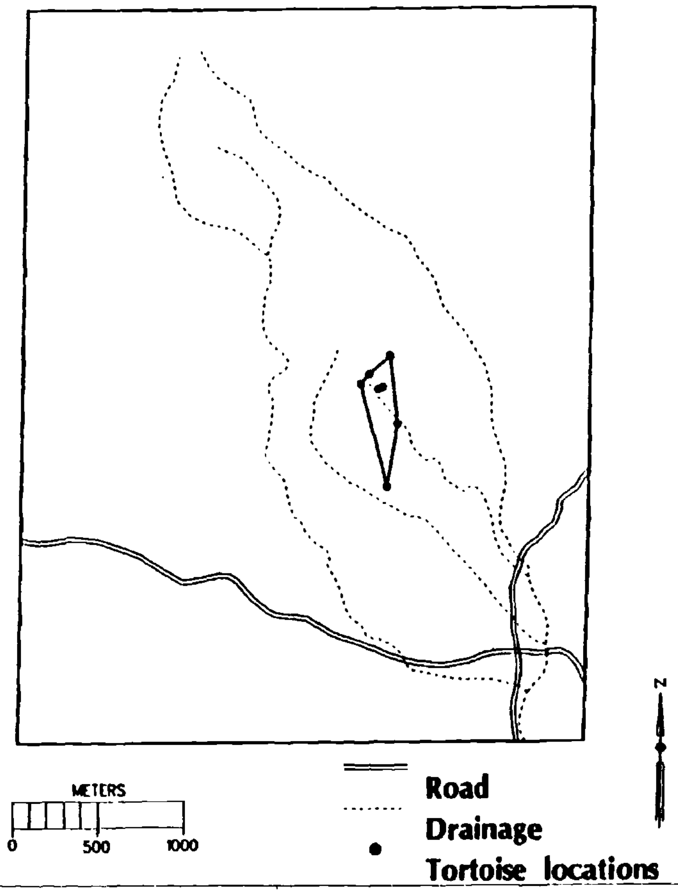

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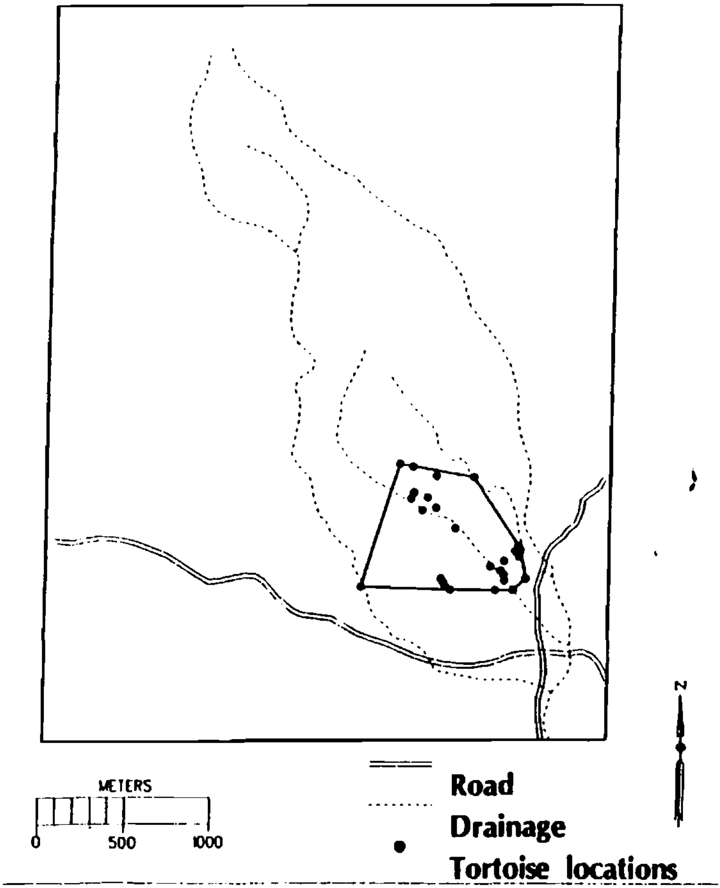

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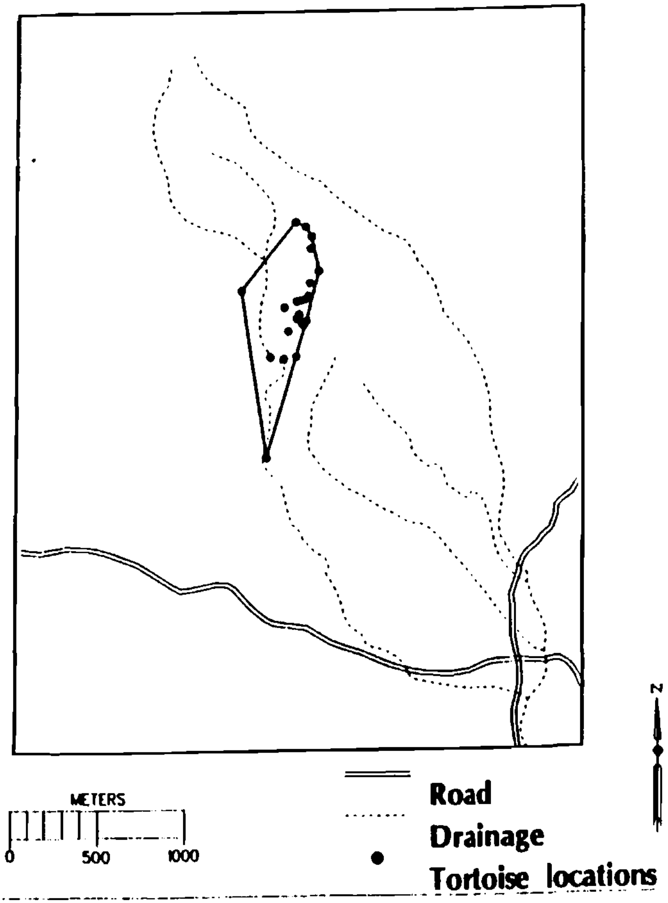

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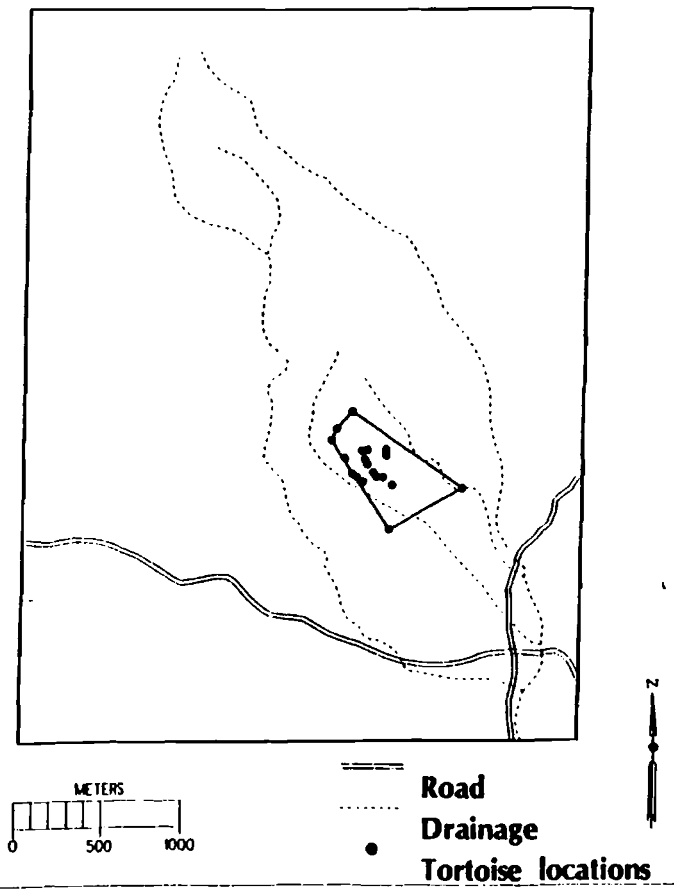

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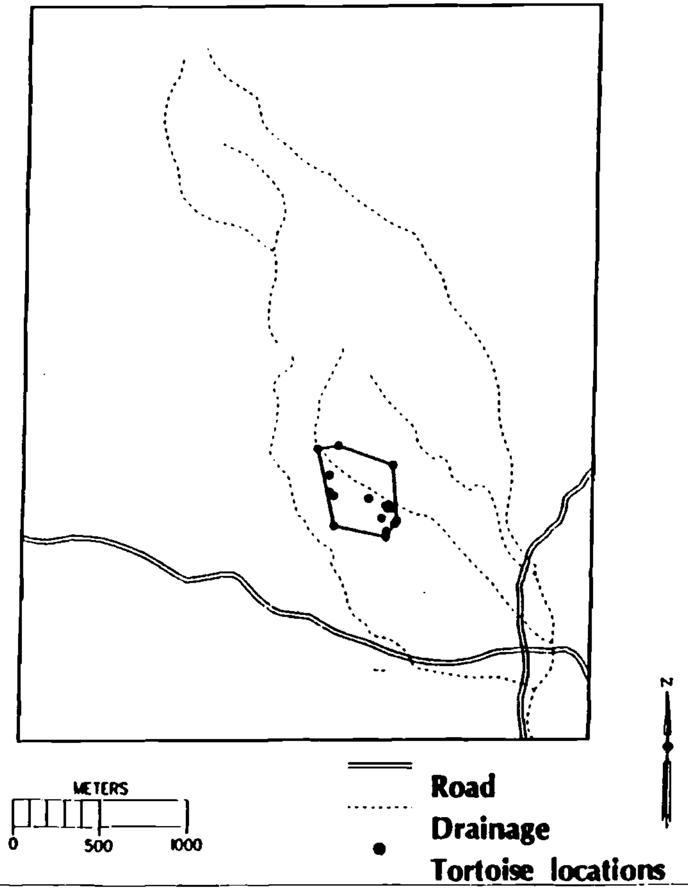

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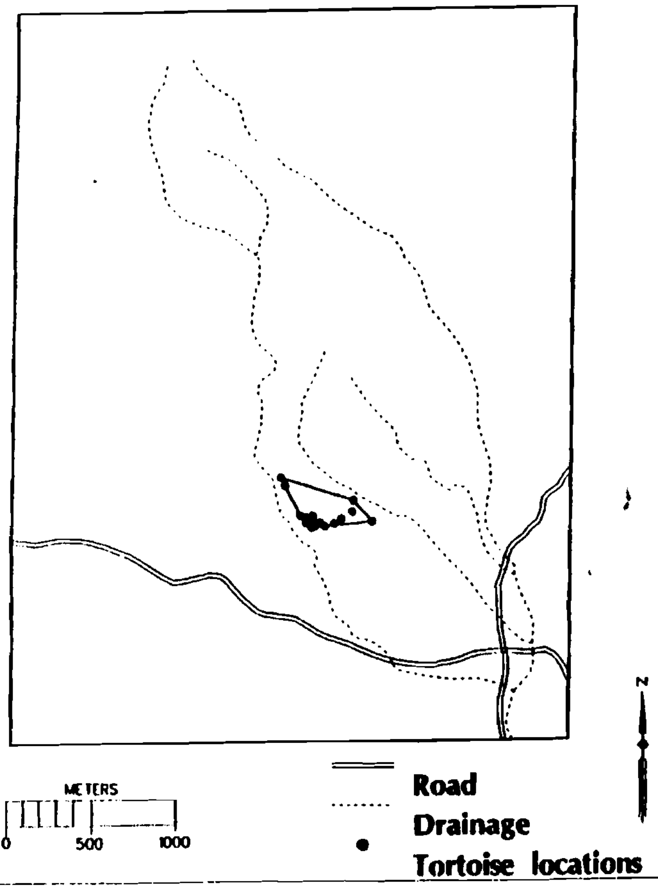

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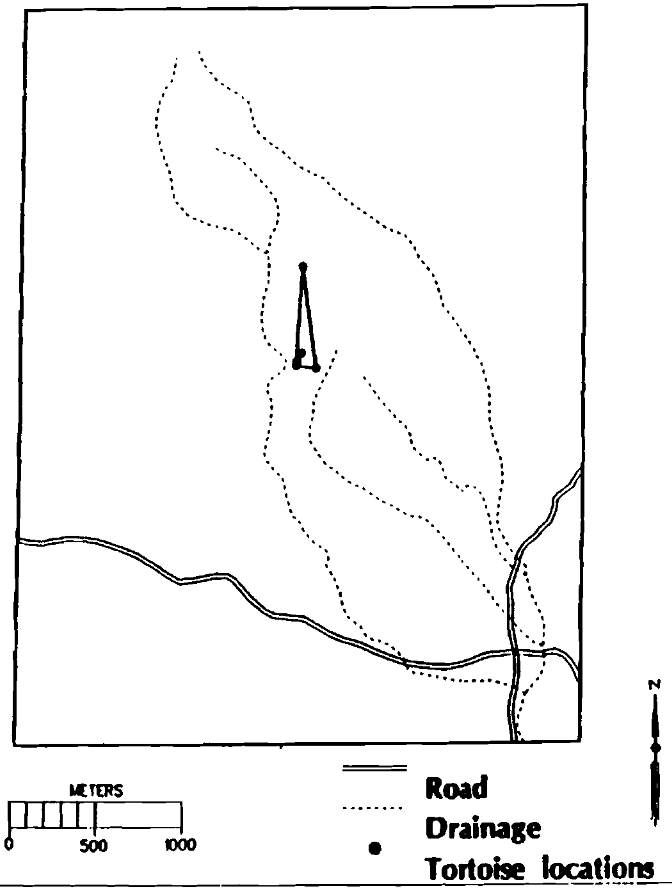

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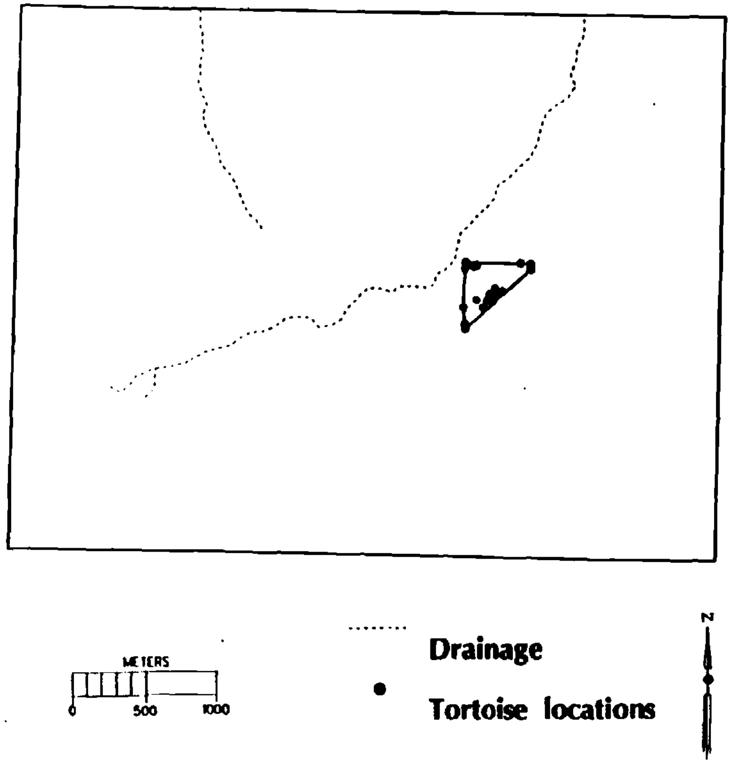
1990 - 1992



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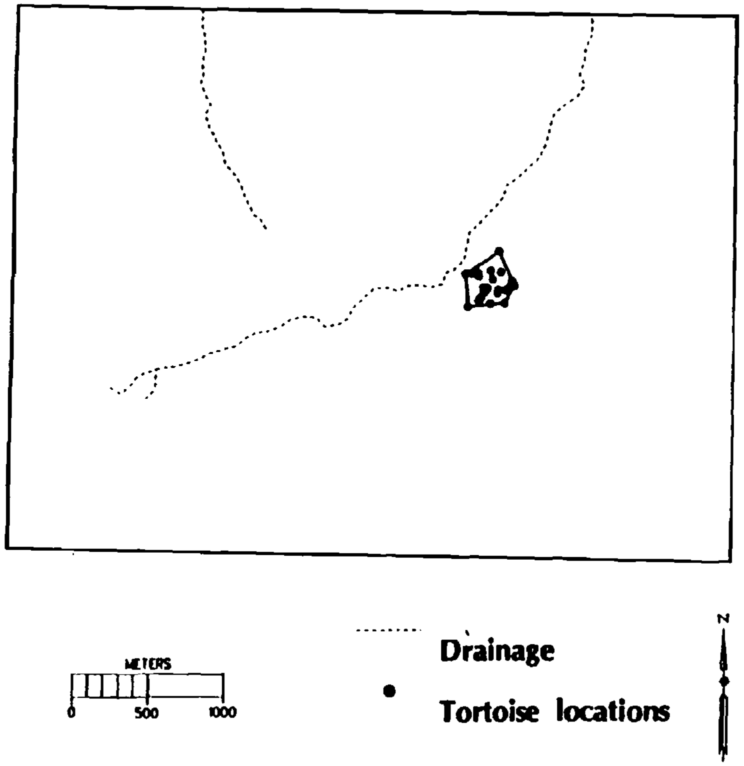

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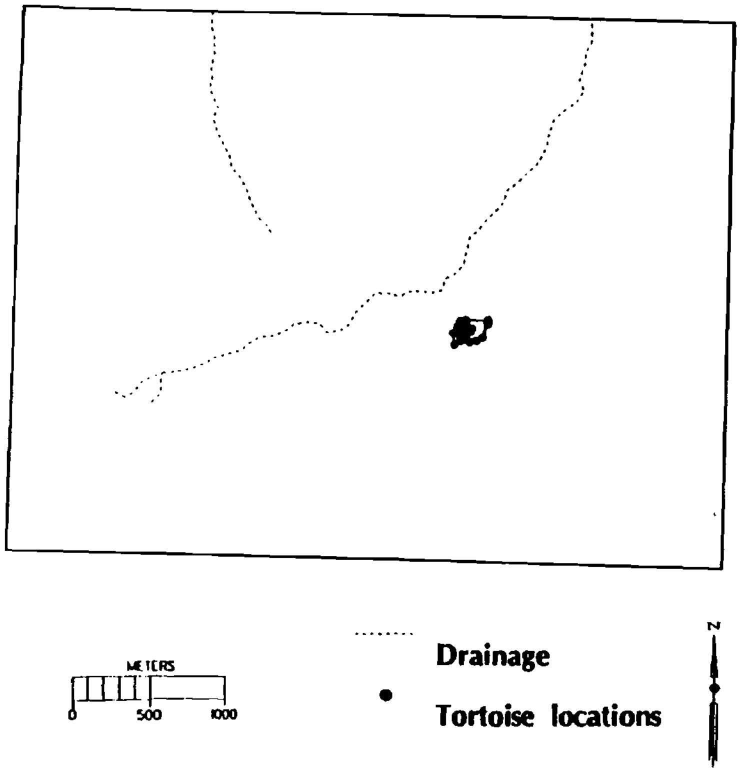

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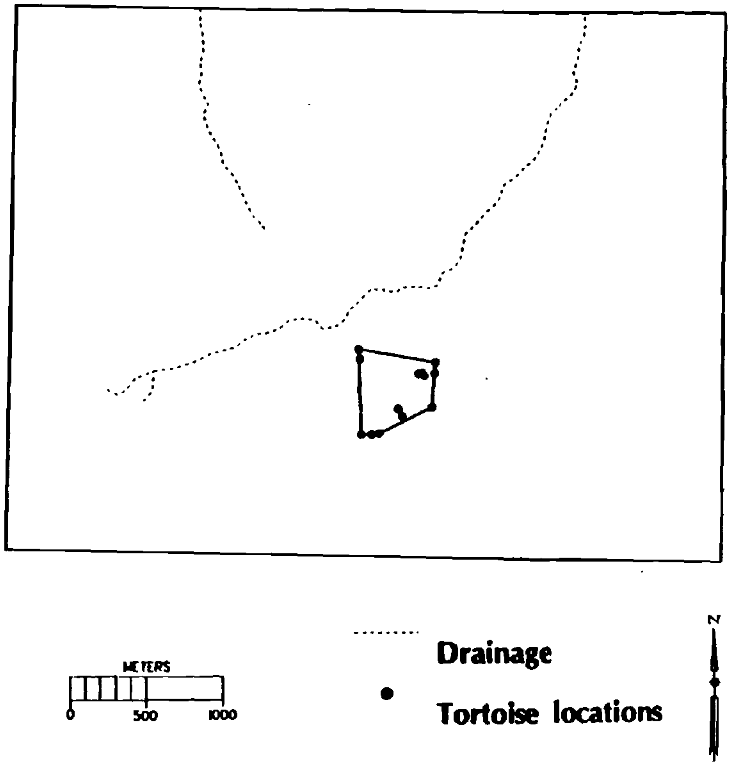

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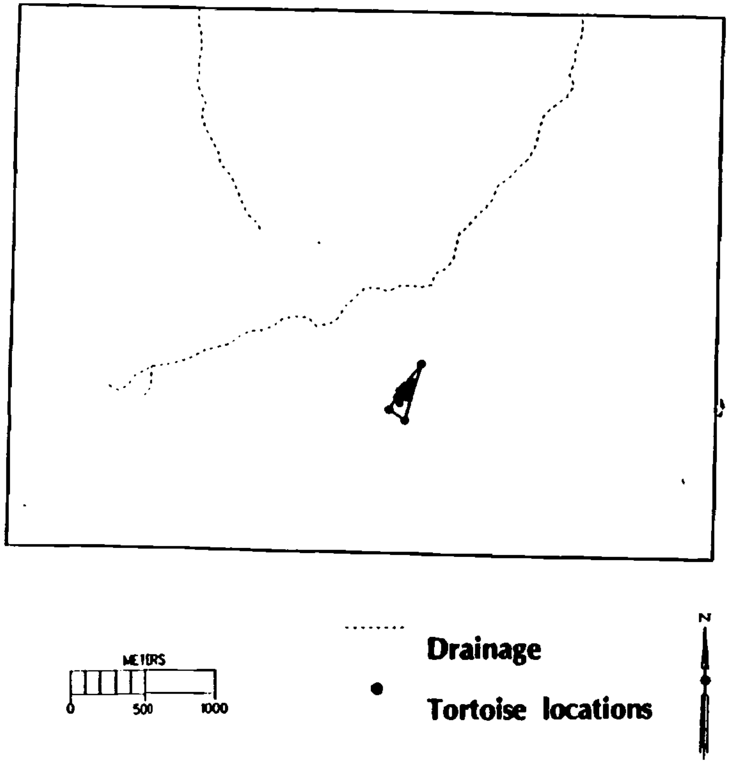

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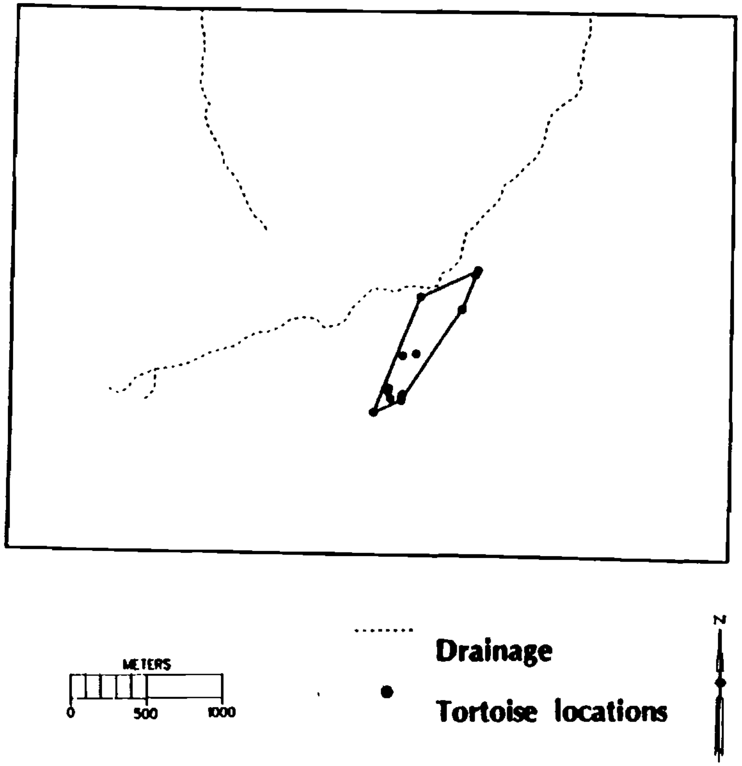

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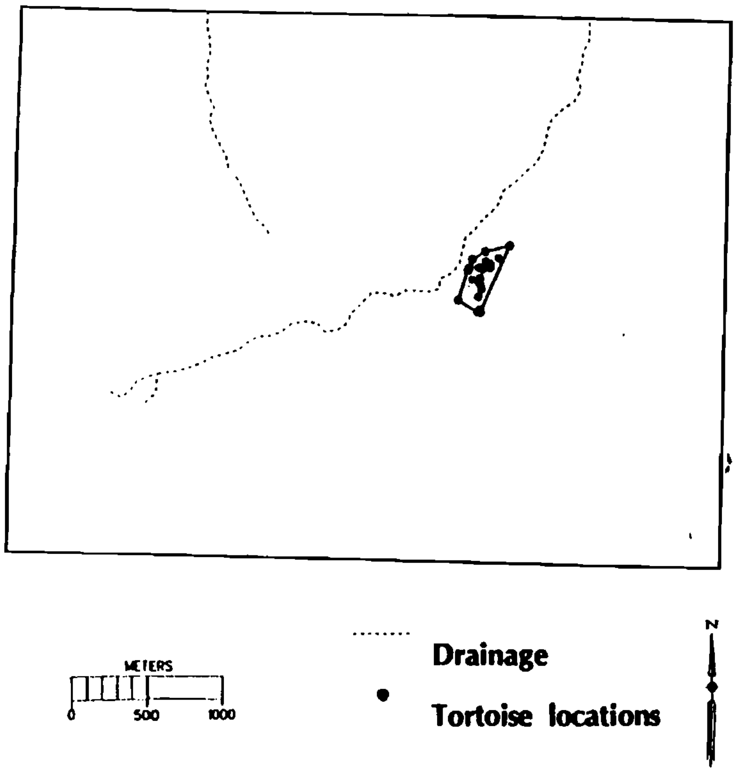

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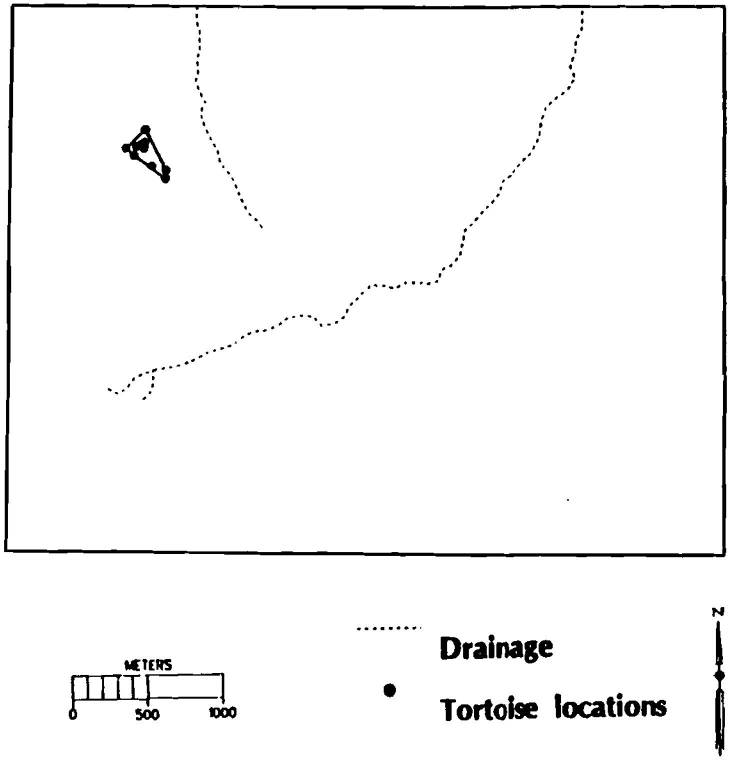
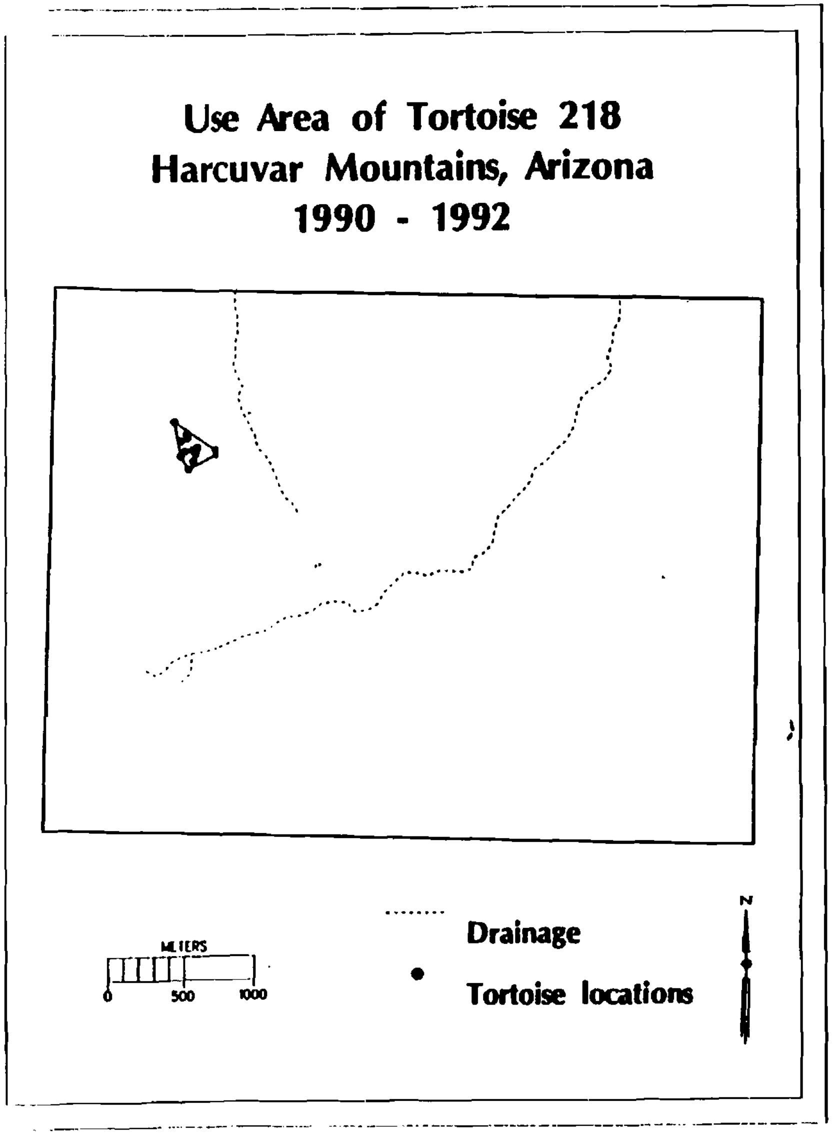
1990 - 1992





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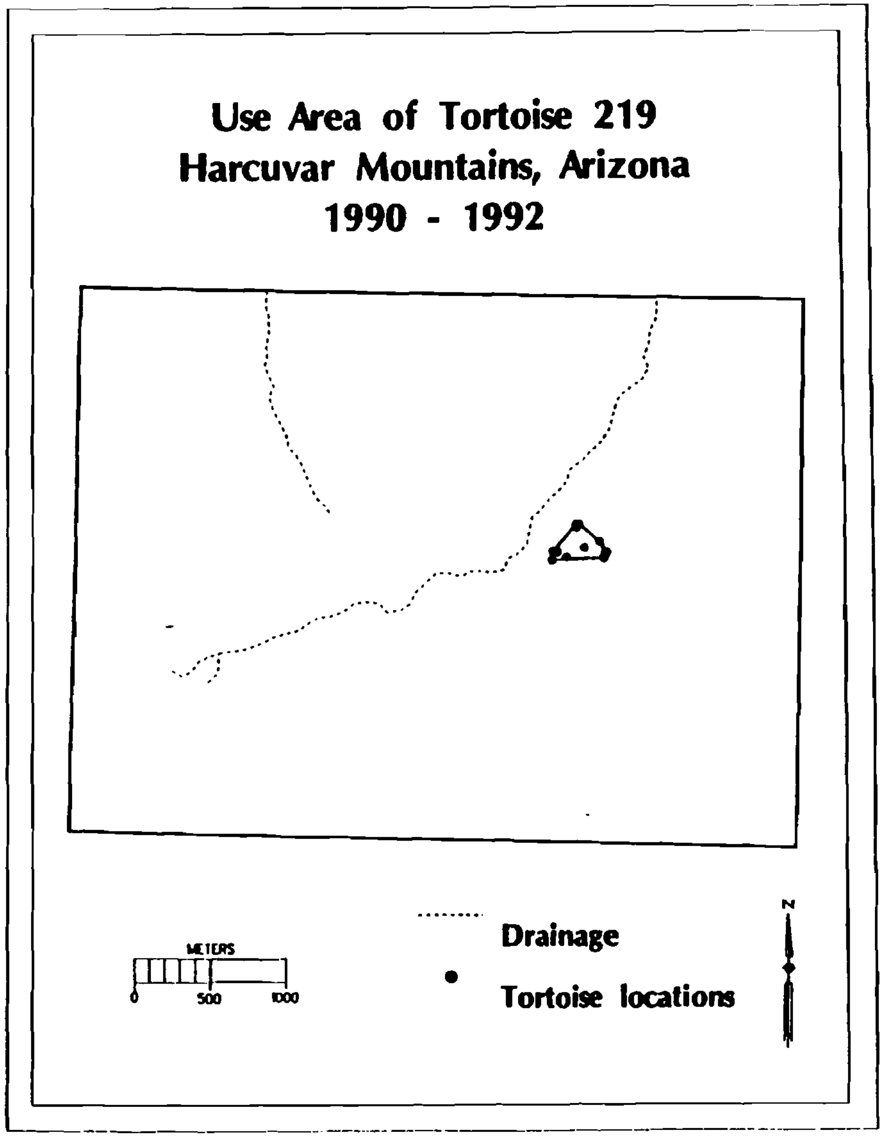

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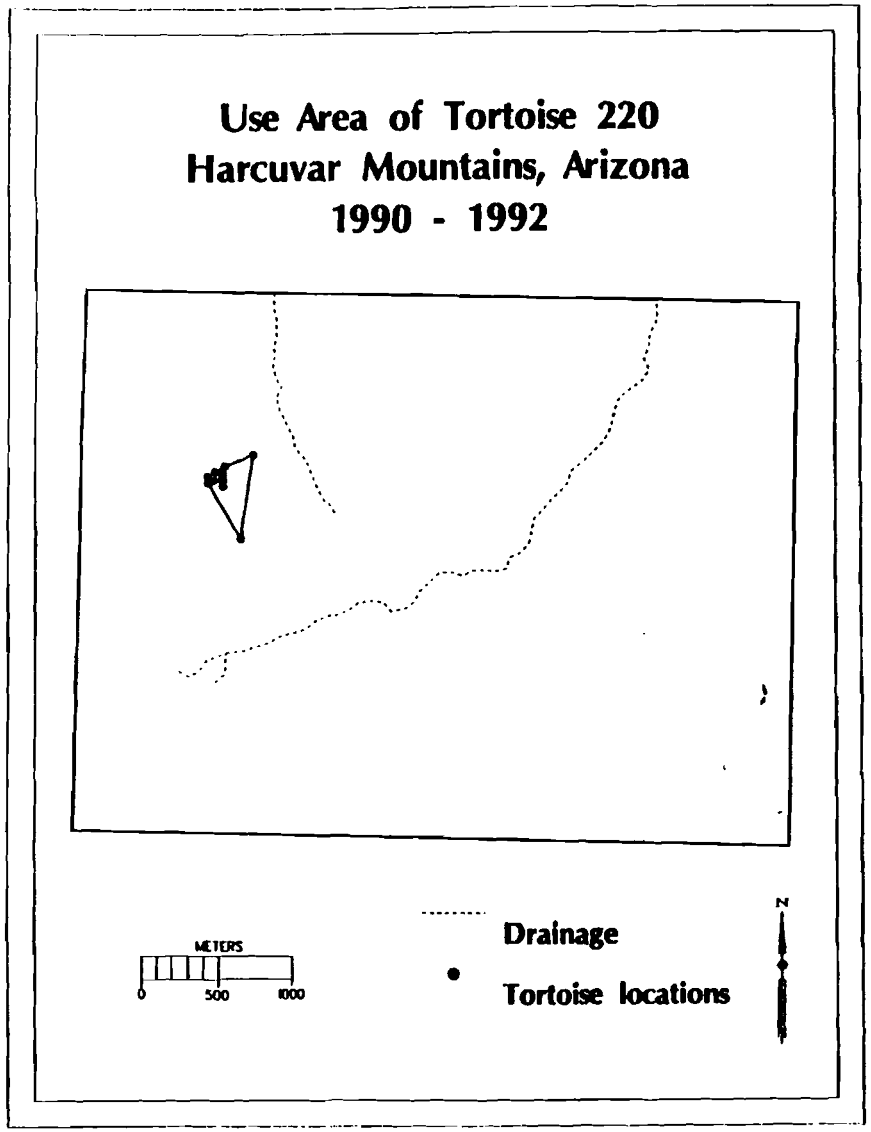

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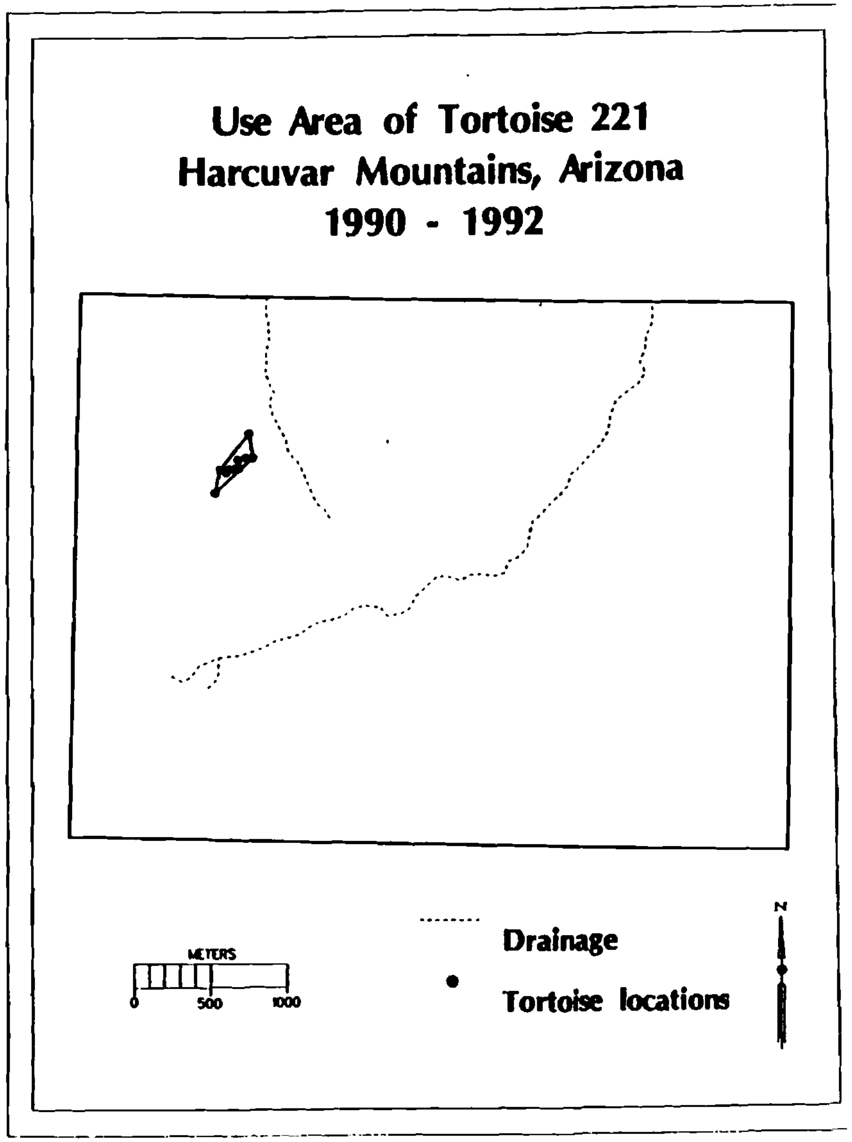

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1990 - 1992

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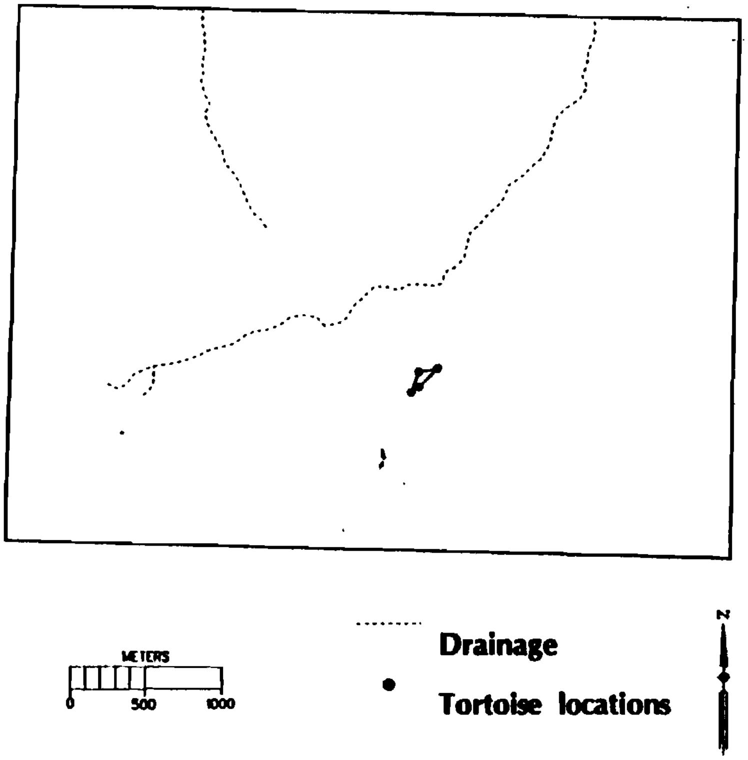

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