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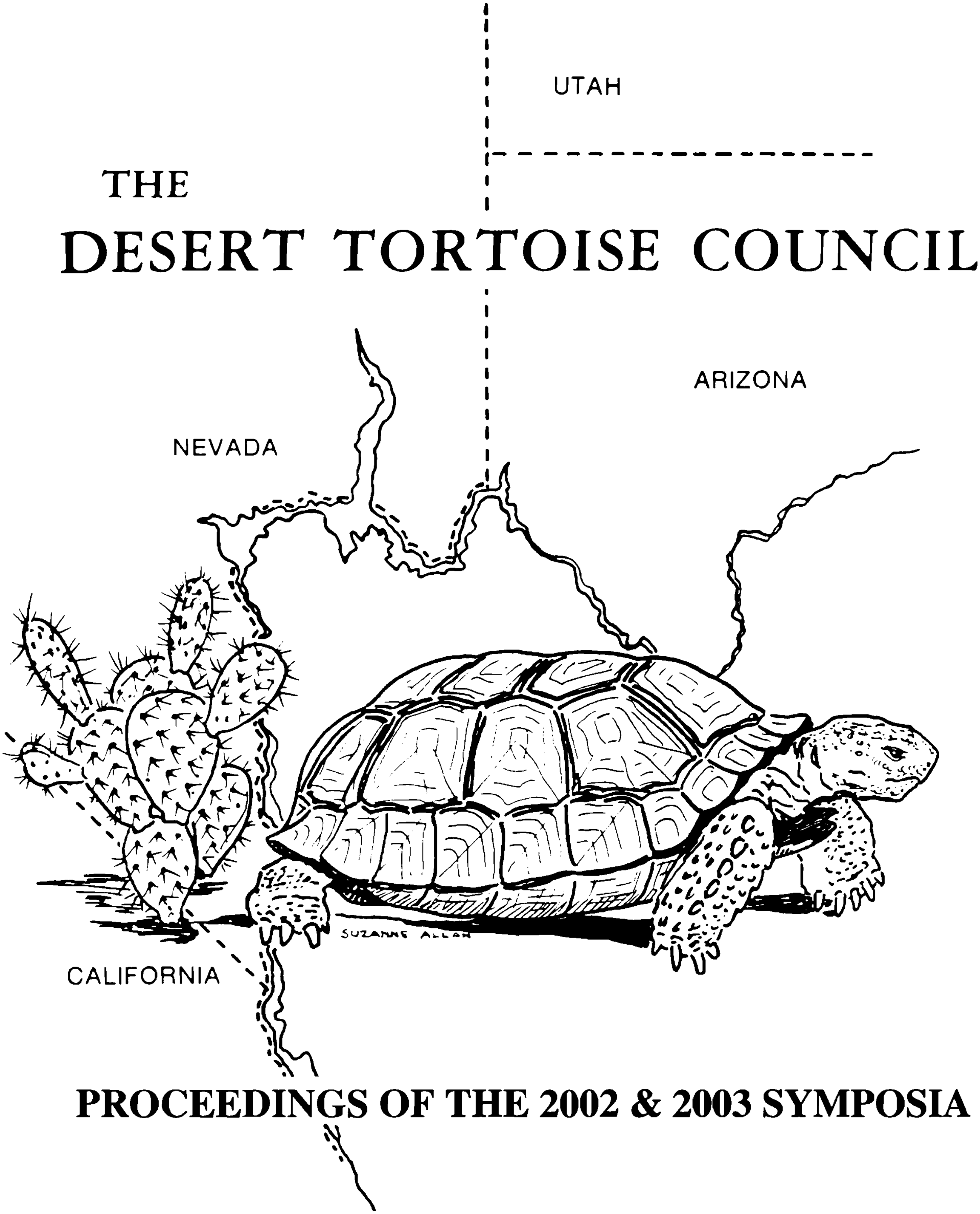

PROCEEDINGS OF THE 2002 & 2003 SYMPOSIA

DESERT TORTOISE COUNCIL

Proceedings of the 2002 and 2003 Symposia

A compilation of reports and papers from the twenty-seventh and twenty-eighth annual symposia of the Desert Tortoise Council, March 22 to 25, 2002, in Palm Springs, California and February 21 to 23, 2003, in Las Vegas, Nevada

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ABSTRACTS AND PAPERS FROM THE 27TH ANNUAL SMPOSIUM

ABSTRACTS AND PAPERS FROM THE 28TH ANNUAL SYMPOSIUM

ABSTRACTS AND PAPERS FROM THE

27TH ANNUAL SMPOSIUM

PALM SPRINGS, CALIFORNIA, MARCH 22 to 25, 2002

DISTANCE SAMPLING AT TWO SONORAN DESERT TORTOISE POPULATIONS, 2001

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We used distance sampling to survey for desert tortoises at two sites in Arizona's Sonoran Desert during summer 2001. The surveys occurred at dramatically different scales: on a 450.8-ha parcel of Saguaro National Park (SAGU) and across the approximately 77,000-ha Ironwood Forest National Monument (IFNM). At SAGU we surveyed a grid of 34, 1-km transects systematically laid across the parcel. We surveyed each transect twice for a total of 68 km; transects were typically located on upland slopes of steep topography. We encountered 45 tortoises ≥150 mm MCL. Software program DISTANCE estimated density at 0.41 tortoises/ha (%CV=24.27). Component percentages of density variance consisted of 55.2% for encounter rate, 40.5% for g_0, and 4.3% for detection probability. At IFNM we surveyed 109, 1-km transects (108.25 km) randomly located across the landscape, but stratified according to BLM's tortoise habitat categorization. Sixty percent of transects occurred in combined categories 1 and 2, 30% in category 3, and 10% in uncategorized habitat. Many transects occurred in valleys and creosote bush flats, even in categories 1 and 2, due to the resolution of the habitat mapping. We encountered 39 tortoises ≥150 mm MCL. Stratification based on BLM categories did not improve results; unstratified analysis estimated density at 0.23 tortoises/ha (%CV=29.73). Component percentages of density variance were 63.2% for encounter rate, 23.3% for g_0, and 13.5% for detection probability. Our results suggest that distance sampling can be effective at estimating tortoise density in the Sonoran Desert at both small and large scales, especially if effort is stratified based on topography.

LIFE HISTORY AND DEMOGRAPHIC ANALYSIS OF THE DESERT TORTOISE AT FORT IRWIN AND REFERENCE SITES: STUDY DESIGN AND EARLY FINDINGS

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Tortoise populations are thought to fluctuate as a result of spatial and temporal variations in environmental factors, such as rainfall and forage availability. However the ability to accurately predict how environmental variations affect demographic parameters of tortoise populations is currently lacking, because accurate data on birth rates, recruitment rates, death rates, and growth rates in response to environmental variations are not known for the desert tortoise. Conservation and management efforts have been encumbered as a result of the inability to connect environmental variation to demographic rates of tortoises. Demographic

studies are underway at and near the National Training Center Fort Irwin (NTC), and Ivanpah Valley, Mojave National Preserve, California, and physiological studies are being initiated, to elucidate the relationships between environmental fluctuations and tortoise demography. We report on the preliminary demographic findings from two study sites, at Ivanpah Valley, and the Fort Irwin Reference Site (FIRS), near the southern border just outside the NTC boundary. At Ivanpah Valley, where reproduction has been monitored since1997, rainfall varies three- to four-fold along an about10 km gradient, ranging from 850 to 1,150 m elevation. At lower elevation sites where annual rainfall is lower, mean clutch size of female tortoises is 3.77 eggs clutch^{-1}, whereas at higher elevation sites, mean clutch size is 4.87 eggs clutch^{-1}. Mean clutch frequency at the lower elevation sites is 1.30, compared to 1.54 at the higher elevation sites. Adult female survivorship during 1997 to 2000 has been 77.8% at the lower elevation sites, compared to 100% survivorship at the higher elevation sites. At the FIRS Site, our first year of data collection in 2000 indicated relatively low fecundity rates of 3.18 eggs clutch^{-1}, and a mean clutch frequency of 0.92. Adult female survivorship rate at FIRS was 90.5% from May 2000 to November 2001. In a separate symposium paper, nesting success is reported for each site by Bryan Franks. We plan to continue the study of demography at these two sites, and establish new study sites this spring in NTC expansion areas and surrounding reference areas, to further our understanding of the viability of tortoise populations in this important area of the Mojave Desert.

HEALTH ASSESSMENTS OF CAPTIVE AND WILD DESERT TORTOISES AT 16 SITES IN THE MOJAVE AND COLORADO DESERTS, CALIFORNIA

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Between 1998 and 2001 we conducted in-depth health assessments of captive desert tortoises (*Gopherus agassizii*) at two desert towns and of wild desert tortoises at 14 field sites in the Mojave and Colorado Deserts of California. Health assessments included collecting data on detailed clinical signs of health and disease, e.g., recording signs of upper respiratory tract disease (URTD), shell disease, and trauma; and taking blood and lymph samples and nasal lavages for laboratory analysis. The field health assessments were followed by analysis of tissue samples using enzyme-linked immunoassay (ELISA) and polymerase chain reaction (PCR) tests and cultures for *Mycoplasma* at the University of Florida. Some populations were tested for herpesvirus using the new ELISA test developed by Dr. Origgi and others.

Using a combination of laboratory tests, 61.8% of captive tortoises from Ridgecrest and Inyokern (N = 34) and 60% of captive tortoises from Joshua Tree, Twentynine Palms, and

Palm Springs (N = 30) tested positive for *Mycoplasma agassizii* or *M. "mysteriosa."* Most tortoises with positive clinical tests also showed multiple, moderate to severe clinical signs of URTD. The group of captive tortoises from Joshua Tree, Twentynine Palms, and Palm Springs were also tested for herpesvirus and 32.1% had positive tests. In general, captive tortoises kept isolated from other captive tortoises and with a history of only one owner tested negative for mycoplasmosis and herpesvirus.

Between 1997 and 1999, 145 samples were collected from 143 wild desert tortoises at six plots (Tiefort, Alvord 6, Langford, Eastgate 1, Eastgate 2, Goldstone) within Ft. Irwin in the central Mojave Desert for URTD tests. Only the Goldstone plots produced positive samples (2 of 9 tortoises). Between 2000 and 2001, 121 samples were taken from 119 wild tortoises at nine study plots from the western Mojave, central Mojave, northeastern Mojave, eastern Mojave, and northern Colorado Deserts. Sites and sample sizes were Fremont Valley (N = 9), Ft. Irwin-Control (N = 20), Ft. Irwin-Tiefort (N = 17), Marine Corps Air Ground Combat Center (MCAGCC)-Sandhill (N = 25), Ord-Rodman (N = 12), Superior-Cronese (N = 6), Ivanpah Valley (N = 16), Goffs (N = 6), and Ward Valley (N = 10). Samples were not necessarily available for all the tortoises for all the different URTD tests. None of the 119 tortoises sampled tested positive for *Mycoplasma agassizii* or *M. "mysteriosa."* However, of 66 tortoises tested for herpesvirus, six (9%) were positive: three at MCAGCC-Sandhill, two at Ord-Rodman, and one at Ivanpah Valley. The sites where animals tested positive for herpes were sites with higher sample sizes (N > 12). Twenty G_0 tortoises from the line-distance sampling projects at MCAGCC-Sandhill, Ord-Rodman, and Superior-Cronese were tested for herpesvirus; of the 20, four (20%) tested positive.

Overall, the percentages of captive tortoises with positive tests for one or more infectious diseases were considerably higher than percentages observed in the samples from most wild populations, a pattern reported previously by April Johnson et al. at this meeting and others in the literature. We recommend continued and more intensive sampling of desert tortoises for clinical signs of all diseases. We think all tortoises in research and monitoring programs should be tested using the available ELISA and PCR tests and cultures, and records should be kept and analyzed on patterns of clinical signs of disease.

ACKNOWLEDGMENTS

Financial support was provided by the U. S. Geological Survey, National Training Center at Ft. Irwin, and Marine Air Ground Task Force Training Command at Twentynine Palms. Thanks are due to Rhys Evans, Peter Woodman, Paul Frank, Rachel Woodard, and Taylor Edwards for field and clinical support.

LONG-TERM VEGETATION DYNAMICS IN THE SOUTHWESTERN U.S.: EMPIRICAL NEEDS FOR PREDICTING FUTURE VEGETATION CHANGE

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Deterministic and statistically-based biogeographic models, coupled with Atmospheric General Circulation Models, are being used to predict large-scale vegetation responses to climate change. One deterministic model relates site water balance to the distribution of physiognomic types or biomes by way of the difference between potential and actual transpiration over an annual cycle; the direct effects of CO_2 are simulated through changes in stomatal conductance. This particular deterministic model predicts greater summer moisture and eventual conversion of much of our southwestern desert scrub into grassland. By contrast, statistical biogeographic models envision plant distributions as stochastic, spatial realizations of response surfaces, decision trees, and bioclimatic envelopes; statistical functions that describe the way in which each species' expected distribution and abundance depend on the combined effects of several environmental variables. Both the deterministic and statistical biogeographic models yield impressive maps contrasting modern with potential vegetation under doubled-CO_2 climatic scenarios, assuming equilibrium conditions. When forced by climatic conditions under double modern CO_2, one statistical model predicts expansion of Joshua tree all the way to west Texas.

What these biogeographic models don't yield is a dynamic view of the slow and complex ecological processes involved in getting from Map A to Map B, a progression that will surely take more than a millennium to complete. These processes include migration, succession, biotic interactions, and hydrological and biogeochemical processes that vary with the life histories of the organisms, the initial conditions, and intrinsic rates of change. For most organisms and ecosystems, there are currently few empirical data to support dynamic biogeographic models that can predict transitional stages between Map A and Map B for any point in time and space. These are the kinds of predictions that might prove most useful for anticipating consequences of climate change for ecosystem and resource management on decadal to century scales. I will present a few examples of how historical, large-scale analyses of migration and demography can serve empirical needs for anticipating ongoing and future vegetation change in the western U.S.

Natural migrations provide model systems for understanding biotic responses to global change and invasions of nonnative species. Here, I'll draw from the fossil record of plant migration (e.g., creosote bush, Utah juniper, pinyon, ponderosa pine) of western North America to highlight the influence of environmental heterogeneity in dictating patterns of establishment and spread, and of climatic variability in pacing migration. I have purposefully selected ongoing natural migrations that are now being modulated by contemporary land use. Current theory of biotic invasions emphasizes population processes of dispersal, establishment, and expansion, where environmental heterogeneity is typically treated as a binary classification of favorable and unfavorable sites, and climatic variation as stochastic variation about a mean. Favorable sites, however, may range from places that can be occupied only with continual immigration to those where populations can persist independently despite environmental variability. In heterogeneous landscapes, the most favorable sites may occur far from the advancing front, and migration can thus follow unexpected pathways. Climate variability may set the tempo, with unfavorable climate imposing a prolonged colonization phase, and periods of rapid population spread reflecting episodes of favorable climate rather than attainment of population "critical mass." To some extent, the record of nonnative species invasions mimics the fossil record. Most introductions of nonnative species appear to fail multiple times before they eventually succeed. Both multiple failures and eventual successes are generally attributed to some combination of demographic and environmental stochasticity. A key distinction between past and contemporary invasions is the increasing probabilities of long-distance dispersal associated with our modern road and transportation system.

The second part of my presentation will focus on regional synchrony of disturbance and demographic phenomena. Many biotic and abiotic factors exhibit synchrony over large geographic areas. Understanding regional synchrony is essential to evaluate theory about what regulates local and regional populations, and for predicting thresholds and other nonlinear processes associated with vegetation change. For example, broadscale plant mortality during catastrophic drought and other disturbances (fire, insect, and pathogen outbreaks) resets demographic clocks and opens niches for new recruitment across the region. Succession of the dead can involve individuals of the same species, other local species that increase at least temporarily, or extralocal species concurrently undergoing migration. Studies of synchrony require extensive regional networks of long-term data, multi-year for birds and mammals to multi-century for conifers. Tree-ring data can be used to examine regional synchrony, not only in tree growth, but also in vegetation disturbance and demography. Synchrony is embodied best in the ability to cross-date a Douglas fir from southern Arizona with a ponderosa pine from northern New Mexico. Tree growth, fire occurrence, insect outbreaks, and demography are entrained across the southwestern U.S. by cool season (frontal) precipitation, which varies little in space but greatly in time, usually in lockstep with large-scale indices of climate such as SOI, PNA, PDO, and CTI. The cause of regional synchrony is evident not in comparing time series from one site to another, but in correlating spatially-aggregated histories of disturbance or demography to independent, dendroclimatic reconstructions. Understanding the scales and causes of regional synchrony, as well as knowing the disturbance and demographic histories of regional vegetation, are essential for forecasting future vegetation change. I will use disturbance and demographic histories of dominant trees in the southwestern U.S. to illustrate the effects of inter-annual and decadal-scale climate variability on vegetation.

In the final analysis, I will present evidence that the growing season has lengthened in recent decades. The coincidence of a longer growing season with a warm Pacific and wetter Southwest has yielded unusual warm, wet springs ideal for tree growth at upper treelines, a surge in woody plant recruitment at all elevations, and the spread of winter-flowering, nonnative grasses such as red brome. Because precipitation will always vary both year to year and decadally, predictions of future plant migration and population dynamics should now encompass the consequences of a longer growing season during both wet and dry episodes.

DESERT TORTOISE NEST SITE SELECTION AND EMBRYOGENESIS IN A CHANGING ENVIRONMENT

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Chelonian embryogenesis and sex determination is strongly affected by soil temperature and humidity, putting this group at risk to changes in temperature and precipitation associated with global warming. During 1998 to 1999, we investigated nesting behavior and the influence of nest site characteristics on embryology for the desert tortoise (*Gopherus agassizii*) in the Mojave Desert of southern California. Most females chose nest sites near resting burrows (88.1%), altering their choices in favor of subterranean and thermally insulated locations as the season progressed. Nests laid deep underground had lower mean temperatures, smaller daily temperature fluctuations, and spent fewer hours above the laboratory-identified threshold for female sex determination. In addition, date of oviposition and year both affected incubation time. Low ambient temperature and high nest humidity during 1999 also may have caused the increased neonate mass for similar-sized eggs during that year. These data indicate that both female nest site selection and ambient weather conditions significantly alter nest microclimate and desert tortoise embryology, and could reduce individual fitness and skew population sex ratios. These interactions likely will be complicated by global climate change, with uncertain outcome.

SEARCH DOGS MAY PROVE A VITAL TOOL IN THE MONITORING AND RECOVERY OF THE DESERT TORTOISE

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Desert tortoises and their sign (e.g., scat, burrows, bone fragments) can be notoriously difficult to locate, especially for young age classes. Low numbers, cryptic coloration, and dense vegetation can lead to detection difficulties, and in experimental trials, have caused human observers to display variable search aptitudes. We propose that professionally trained search dogs may be a more effective method for locating tortoises and their sign. The scent discrimination ability of dogs is well documented from their use in law-enforcement and search and rescue missions. Moreover, dogs have been known to improve search efforts in wildlife research, successfully locating wildlife sign (e.g., bird nests and carcasses, ringed seal lairs, urine marks, scats) and wildlife (e.g., brown tree snakes, box turtles). During a recent trial, dogs trained to detect species-specific fecal samples, recovered nine times more kit fox scat in dense vegetation than human observers. The use of detection dogs may

greatly enhance current techniques used for tortoise population surveys and provide unambiguous presence or absence data at proposed construction sites. Furthermore, scent-following dogs may significantly increase detection probability of small tortoises, yielding new information on little studied early life stages.

ARIZONA GAME AND FISH DEPARTMENT'S SPONSOR-A-TORTOISE PROGRAM

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The need to find or create new funding sources is important for all biological research projects. Public outreach and education are also increasingly important to maintain support of ecological research and generate awareness of its results and implications. The Arizona Game and Fish Department's Desert Tortoise Project implemented the SPONSOR-A-TORTOISE program to provide supplemental income to purchase radio telemetry equipment, X-radiography film, and other miscellaneous field supplies for ongoing research of the Sonoran desert tortoise (*Gopherus agassizii*). This program provides the opportunity for interested individuals or organizations to support conservation and research efforts for desert tortoises through tax-deductible donations. Contributors learn about the desert tortoise project in particular, and hopefully a little about ecological research in general, through annual project reports. Contributors of $100 or more also receive a closer glimpse of their sponsored tortoise's annual activities through individual tortoise summaries. The Sponsor-a-Tortoise program has reached people across the country and is becoming increasingly important in maintaining operational funding for current research.

PACIFIC CLIMATE INFLUENCES ON THE SOUTHWEST: FROM DAYS TO DECADES

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The effect of ENSO (El Nino/Southern California Oscillation) and the PDO (Pacific Decadal Oscillation) on climate variability in the Southwest is discussed. These climate modes are felt by Southwest desert ecosystems through their linkage to surface climate measures such as the frequency and intensity of precipitation, streamflow levels, and the frequency of temperature extremes. Because these modes develop over several month or several year time scales, there is enough lead time to provide useful seasonal predictive skill.

On the Road to Cooperation: Protecting the Desert Tortoise During a Federal Highway Project in Joshua Tree National Park

Pedro Mazier Chavarria

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The rehabilitation of roads and the conservation of the desert tortoise (*Gopherus agassizii*) are issues of ongoing concern within Joshua Tree National Park (JTNP). JTNP's Project 173, improvements of Route 12, reflects the park's ongoing commitment to maintain safe roads and adequately serve the growth of current as well as future visitation levels. The park is also committed to mitigate potential take of desert tortoise through habitat restoration and active monitoring programs. The park surveys habitats affected by construction for threatened and endangered species. Through mutual cooperation of the Denver Service Center, Federal Highway Administration, and biologists at JTNP, appropriate mitigation measures were implemented to enable better egress opportunities for wildlife and minimize the impact to the surrounding habitat.

Feasible Demography Analyses: Consequences of Additional Adult and Juvenile Mortality on a Stable Population of Desert Tortoises

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In populations of long-lived organisms, the negative impact to populations caused by increased mortality of adults is greater than similar levels of impact on eggs or juveniles. A cohort model for a stable population of desert tortoises was generated using data on clutch size (4.9 eggs), reproductive frequency (1.5 clutches per year), and adult survivorship of 0.985 from the upper Ivanpah Valley study population. Age at maturity was estimated at 15 and 20 years and average nest survivorship at 0.30. This, combined with an average juvenile survivorship (ages 1-14) of 0.75 resulted in a stable population. If adult survival rate was reduced by 1% and 2% the population would be halved in just less than 100 years and 50 years, respectively. A similar reduction in juvenile survivorship would have about half the negative impact on the population. Two components of risk associated with paved roads (traffic volumes and vehicle speeds) have the potential to have substantial impact on populations. Mortality associated with roads may be higher in adults because they represent a larger portion of the population, they move more frequently, and move greater distances than do young juveniles. However, mortality of juveniles may be higher than their representation in the population because they are smaller and thus more difficult for drivers to see. In areas with high tortoise densities that border paved roads with high traffic volumes and speeds, fencing represents an important tool for reducing additional mortality of desert tortoises and other terrestrial turtles.

CONSERVATION THROUGH COOPERATION: DESERT TORTOISE PRESERVE COMMITTEE ACHIEVEMENTS AND PLANS FOR 2001-2002

Michael J. Connor

Desert Tortoise Preserve Committee, 4067 Mission Inn Ave., Riverside, CA 92501

The mission of the Desert Tortoise Preserve Committee is to promote the welfare of the desert tortoise, *Gopherus agassizii*, in its native wild state in the southwestern United States through establishing preserves, developing and implementing management programs for preserve lands, and providing information, education, and research on critical ecosystems. These goals can only be achieved through close cooperation with the many federal, state, and local government agencies, business interests, desert users, and other conservation organizations that operate in desert tortoise habitat.

During 2001, cooperative efforts yielded significant progress in habitat acquisition and management, education, and research. Agreements with the City of Palmdale and the California Department of Fish and Game enabled the Committee to close escrow on 32 ha of prime habitat within the historic boundaries of the Desert Tortoise Natural Area (DTNA). In culmination of a three-year effort, the Committee completed clearing title from a 12 ha parcel of DTNA habitat and sold this to the Bureau of Land Management to allow the Bureau to complete a land exchange with the Indian Wells Valley Water District. In conjunction with the California Energy Commission, California Department of Fish and Game, and various businesses involved with the High Desert Power project, acquisitions were made in the Committee's Buffer Zone immediately southeast of the DTNA, and in critical habitat east of the DTNA. Acquisitions in these areas are essential to create both defensible boundaries and to reduce the degree of isolation of the DTNA from critical habitat to the east. Habitat acquisitions are also occurring on the Chuckwalla Bench ACEC and adjacent critical habitat courtesy of similar cooperative agreements.

The Committee's research and education programs saw similar advances in 2001. Mojave Desert Discovery Center kiosks are now installed in Bakersfield at the California Living Museum, Joshua Tree National Park, and the California Welcome Center in Barstow. In August 2001, the Committee released a report on two years of survey data for the Mojave ground squirrel, a State-listed species which is endemic to the western Mojave Desert. The surveys and report were funded by a CEC agreement with the Committee, contributions from the Committee, and donations of time from Dr. Phil Leitner, the Principal Investigator. Working with the BLM, the Committee obtained a challenge grant from the National Fish and Wildlife Foundation to provide matching funds for the DTNA naturalist program, interpretive services, a head-starting project, and for tortoise surveys on the DTNA's permanent study plots. Through DTPC's collaboration with California Department of Fish and Game, BLM, U. S. Geological Survey, and contract biologists, this funding has allowed all four square miles of permanent study plots at the DTNA to be surveyed in a single season. Given the tortoises' lengthy generation time, the demographic data these surveys will produce will be invaluable in evaluating the species current status and the likely effectiveness of recovery efforts.

BONE GROWTH PATTERNS AS INDICATORS OF THE EVOLUTION AND ECOLOGY OF DESERT TORTOISE (*GOPHERUS AGASSIZII*) POPULATIONS

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The purpose of my study is to determine whether bone, specifically bone from dead animals, could be used to indicate differences in growth strategies and evolution among wild desert tortoise populations. Growth variation, due to ecological constraints (like diet and climate) and disease, should be visible in the skeletons of both wild and captive desert tortoises. Ecological constraints are known to influence bone growth strategies, and thus life history strategies, in a wide variety of amphibians and reptiles, however few such studies have been done on tortoises. *Gopherus agassizii* represents a perfect species to investigate, as they are long-lived tortoises, living in a habitat where their survival is extremely dependent on resource availability and quality, which is directly or indirectly influenced by climate (mainly rainfall) and human intervention (e.g., off road vehicle use, grazing, and urban expansion). Chronic disease is also a problem in certain populations and because the skeleton can be viewed as a summary of an animal's growth history, I will compare the bone microstructure of diseased and healthy animals to assess whether disease has an impact on growth in general. This will be the first study to attempt to answer questions about tortoise biology across a broad geographic scope and time range, incorporating many populations of wild and captive animals, and has the added advantage of not having to harm, kill, or disturb living animals of this threatened species.

RECENT PROJECTIONS OF CLIMATE CHANGE FOR THE DESERT SOUTHWEST, 1900-2100

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Recent historical global climate simulations by the Parallel Climate Model (PCM), made as part of the Department of Energy's Accelerated Climate Prediction Initiative, are part of a new generation of coupled ocean-atmosphere climate-change projections that have been shown to reflect historical climate and ocean changes with reassuring fidelity. Historical-period and future climate-changes for the desert southwest projected by PCM will be presented. Projections of changes in extreme temperatures, frequency of large and small precipitation events, monsoons, and soil moisture will be discussed and, where possible, will be related to projected changes in Pacific climate variations like El Nino and Pacific decadal climate regimes.

PHYLOGEOGRAPHIC PATTERNS IN MOJAVE AND SONORAN POPULATIONS OF THE DESERT TORTOISE

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Mitochondrial DNA (mtDNA) analysis has played an important role in our understanding of the evolutionary relationships among North American gopher tortoises. In the desert tortoise (*Gopherus agassizii*), restriction fragment surveys of mtDNA have been used to examine intraspecific phylogeny, genetic variability, and population structure. However, the slow rate of mtDNA evolution within Testudinae limits the amount of variability detectable with this method. To complement our current knowledge of desert tortoise population genetics, we used DNA sequencing which provides higher resolution and allows us to examine variation among populations on a finer geographic scale. We sampled 30 individuals in four populations in the western Mojave Desert and 42 individuals from seven populations in the Sonoran Desert. We obtained ~1000 base pairs of sequence from the ND3 region of the mtDNA molecule. Populations sampled from within each of these desert regions are within a 150-km radius of each other. Mojave and Sonoran populations show a fixed difference of ~3.5%, however, little variability is detected within each desert region. In our analysis, we compare variability between Mojave and Sonoran populations and examine the phylogeography for each site to assess the occurrence of localized events such as founder effects and rates of movement among populations.

HOME RANGE AND MOVEMENTS OF DESERT TORTOISES (*GOPHERUS AGASSIZII*) IN THE CALIFORNIA MOJAVE DESERT IN RESPONSE TO RAINFALL AND VEGETATION PARAMETERS

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Between May and November 2000, I monitored 58 adult tortoises weekly for movement and activity at four sites in the Mojave Desert. Of the 58 tortoises, 44 were female and 14 were male. The four sites studied were all predominately creosote-scrub communities but each differed in rainfall and amount of vegetational cover. The sites range from Ivanpah Valley in the Eastern Mojave Desert to Helendale in the Western Mojave Desert. Ivanpah Valley received the largest amount of rainfall and had more cover when compared to the other three sites. Also, Ivanpah Valley differed in rainfall and vegetational cover within the valley itself.

I tracked tortoises using radio telemetry with transmitter attachments that did not inhibit movement of animals. From these data, I calculated home range size and timing of movements with respect to rainfall events. Home ranges were calculated using the minimum convex polygon method within ArcView GIS. From preliminary data analysis it appeared that home range sizes differed both among the four sites studied as well as within the Ivanpah Valley site. Also, home range size differed considerably between sexes with males having a much larger home range than female tortoises. Both minor and major amounts of precipitation in rainfall events had a considerable effect on tortoise activity. The results of this study provide insight into how precipitation patterns and plant productivity affect the movements and activity of tortoises.

NESTING SUCCESS OF DESERT TORTOISES (*GOPHERUS AGASSIZII*) AT IVANPAH VALLEY AND FORT IRWIN REFERENCE SITE, CALIFORNIA, DURING THE YEAR 2000

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Between May and July 2000, twenty-four adult female desert tortoises were monitored for egg laying, seven from the Fort Irwin Reference Site, California (FIRS) and 17 from Ivanpah Valley, California. FIRS is located just outside the southeastern edge of the National Training Center at Fort Irwin. Ivanpah Valley is located within the Mojave National Preserve. Ten nests were found, six from Ivanpah Valley and four from FIRS. All 10 nests were laid inside burrows that were dug under creosote bushes. The average clutch size for nests found at FIRS was 3.5 eggs while the average clutch size for nests in Ivanpah Valley was 5.7 eggs. Nine of 10 nests were destroyed either by predation or flooding. Seven of the 10 were confirmed as predated. A coyote was assumed to be the predator for one of the nests while kit foxes were suspected as predators in the other six predated nests. In Ivanpah Valley, flooding was assumed to be the reason for mortality in two of the nests. One nest was monitored for 85 days and hatching did not occur. It was assumed that these eggs died due to collapse of the burrow and heavy rainfall in late August. Therefore, there was 100% mortality for the nests found and a predation rate of 70%. These results for hatching success, nest mortality, and predation rate show that head starting of desert tortoise nests and hatchlings in predator proof enclosures may be a valuable tool in recovering desert tortoise populations.

CHARACTERISTICS OF WINTER HIBERNACULA USED BY RECENTLY RELEASED NEONATE AND JUVENILE DESERT TORTOISES AT FORT IRWIN

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Behavior of young tortoises released from semi-natural hatcheries could be affected by the age of the tortoise or by the length of time spent within the hatchery before release. Juvenile (6-8 years old) and neonate (< 2 months old) desert tortoises (12 per group) were fitted with radiotransmitters and released from the hatchery at the Fort Irwin Study Site (National Training Center, Fort Irwin, CA) in October 1999, and their movements were tracked until all stopped moving (presumably hibernating) and no activity was observed, 34 days later. Juvenile and neonate tortoises exhibited differences in dispersal behaviors; neonates selected a hibernation burrow more quickly. To test whether age classes differed in burrow selectivity, we measured characteristics of hibernation burrows and neighboring burrows (in February, after the animals had vacated the burrows). Juvenile tortoises used larger burrows than neonates, but within age class there was no correlation between tortoise size and burrow size. The burrows of neonates were not oriented in any particular direction, whereas juvenile burrow orientation did differ significantly from a uniform distribution, with a mean direction of 149° (SSE). The selectivity of juveniles compared to neonates may have resulted in more movement by the juveniles (longer time to select a hibernation burrow and more sites occupied per individual before hibernation). This increased movement could result in higher exposure to predation risk, though there was no mortality in either group in this study.

DESERT TORTOISE RESEARCH AT THE UNIVERSITY OF REDLANDS IN THE CONTEXT OF THE FORT IRWIN PROPOSED EXPANSION

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The Redlands Institute (RI) for Environmental Design, Management, and Policy, which is housed within the Center for Environmental Studies at the University of Redlands, is beginning a three-year project to study certain aspects of desert tortoise ecology and management in the Mojave Desert. Studies will be centered within the context of, but not limited to, the Ft. Irwin National Training Center (NTC) and its proposed expansion study area. The RI research team will attempt to optimize methods and technologies for the collection, compilation, analysis, management, synthesis, and visualization of desert tortoise-

related data by blending environmental science and information science. Our research agenda can be described in the context of an integrated research framework intended to (1) evaluate the effects of spatial and temporal threats on the long-term sustainability of the desert tortoise; (2) assist the NTC in establishing baseline desert tortoise information needs within the expansion study area; and, (3) provide a context for which to compare pre- and post-expansion conditions given baseline information and the existence of spatial and temporal threats. To address these issues we will employ a variety of traditional methods and advanced technologies including GIS, remote sensing, visualization software, knowledge management, environmental modeling and simulation software, and decision support tools. In addition, we have and will continue to develop ties with interested desert tortoise biologists and managers, universities, and other interested parties. Specific aspects of our developing research agenda will be discussed.

CLIMATE VARIATION AND GEOMORPHIC PROCESSES SINCE 1900 IN THE CENTRAL MOJAVE DESERT

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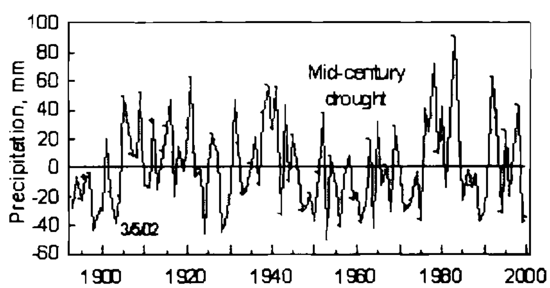
The climate of the Mojave Desert region is perceived as static and unchanging. In the 20th century, however, precipitation has varied from drought (1893–1904 and 1942–77) to relatively wet (1905–1941 and 1978–98). This research, a component of the USGS Recoverability and Vulnerability of Desert Ecosystems Project, addresses climate variability in the Mojave Desert and its effect on the physical landscape: the substrate of the desert ecosystem. Three components of landscape change amenable to geologic study are the frequency of surface runoff, sediment yield, and channel alluviation in large washes. Generally, sediment yield and runoff frequency increase during wet climate episodes and decrease during dry episodes while channels aggrade (dry) or degrade (wet). The question is whether historic-age climate variation was sufficient to alter these components of the landscape.

The answer to this question is important for understanding landscape recovery from human and natural disturbances, because the frequency of sediment movement by water is one of the principal processes of geomorphic change. Aridity aside, evidence supporting the effectiveness of water in sculpting the desert landscape is seen in the numerous washes and countless rills and gullies. The rate at which the desert landscape recovers from disturbance, therefore, is directly related to the frequency of surface runoff and sediment movement. Moreover, the frequency of runoff directly influences the



Average annual deviation of high intensity (> 90th percentile) daily precipitation in the Mojave Desert region, 1893-2000 Maximum of 52 stations reporting.

availability of surface water and shallow subsurface water. Regional estimates of runoff frequency help model the availability of surface water, replenishment of shallow aquifers, erosion, sediment yield, and surface stability.

Two types of alluvial deposits provide stratigraphic evidence of historic-age landscape change in the central Mojave Desert. These are ponded alluvial deposits that accumulated upstream of artificial barriers and alluvium in large washes that form floodplains and terraces. Ponded deposits accumulate where railbeds cross piedmonts and the mouths of small drainage basins. In the first case, the deposits record the frequency of surface runoff in the alluvial washes of the piedmont; these are large drainage basins measured in km^2. In the second case, they record sediment yield and the frequency of hillslope runoff from small basins measured in thousands of m^2. Alluvium in large washes of the region accumulates episodically on floodplains or floodplain-like surfaces. Establishing the chronology of deposition and erosion of these floodplains may document a temporal and perhaps causal link to historic-age climate variation.

High intensity, geomorphically significant precipitation has varied episodically during the 20th century. High intensity precipitation was relatively frequent from the early 1900s to 1940s and again from the late 1970s to 1998, whereas precipitation frequency was low in the intervening period of the early 1940s to mid-1970s. Dry years occurred during the two wet intervals, but they were typically less frequent and of shorter duration than during the dry period. Likewise, wet years occurred during the dry period, however, these were of short duration and regional precipitation was suppressed.

This variation in precipitation was coincident with changes in the desert landscape (Hereford and Webb 2001). During the wet periods, relatively frequent high-intensity precipitation increased the occurrence of hillslope runoff. This increased sediment accumulation in about 70% of the ponded sites during the early to mid-1900s and again in the late 1900s. During the dry period, the frequency of runoff-producing precipitation was reduced for several decades. This in turn decreased the frequency of overland flow, as suggested by the stratigraphy of the ponded sites. Precipitation variability evidently affected the alluvial washes as well, because a long-term change of intense precipitation alters the likelihood of large floods. Large floods were probably more frequent during the wet periods, resulting in channel incision with little sediment storage. These recent changes in precipitation were evidently large enough to alter hillslope runoff and channel processes. The desert landscape and climate, despite the overall aridity, cannot be viewed as static. The landscape is dynamic, changing detectably in only a few decades. As elsewhere in the Southwest (Swetnam and Betancourt 1998), the mid-century drought and subsequent wet interval probably affected the ecology of the desert.

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POTENTIAL IMPACTS OF CAPTIVE PET TORTOISES ON WILD POPULATIONS

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The collection and importation of exotic chelonians for the pet trade, along with the maintenance of local native species has been accompanied by numerous reports in the literature of a variety of infectious and noninfectious disease problems in these animals. Imported exotics often arrive in poor health and thus allow certain latent infections to become active. Even locally collected chelonians when brought into captivity may break with certain infectious diseases because of stresses imposed upon these animals in a captive situation. Poor nutrition or an abrupt change from natural to commercially available foods may predispose these animals to emergence of infectious agents. Added upon this situation is cross-contamination when different species are brought together in a common holding pen, whether at an exporter, importer, or ultimate owner of these animals. Pathogens in animals from different parts of the globe can intermix between their hosts and the potential for a disastrous infectious disease outbreak increases.

Chelonian recovery stations or conservation centers have developed in recent times as responses to dramatic declines of native turtle stocks, the huge number of displaced animals, unwanted pets, and confiscations. Centers have developed for tortoises and freshwater turtles in southern Europe, Africa, northwestern Madagascar, India, and western North America. Often these centers, with meager funds, have impressive educational programs. Unfortunately, shortcuts are often the rule for captive management and repatriation elements of such conservation programs. Many centers lack special veterinary and herpetological expertise, and they can ill afford the expense of securing such support. In such situations, health screens and genetic assessments are often lacking, and rigid quarantine facilities are inadequate or absent. Repatriation protocols are generally developed without wildlife and veterinary science expert review. When a recovery center includes relocation, repatriation, or translocation exercises among its programs, the motives for advocating these strategies must be carefully examined through peer review before the release and recommended pre- and post-release biological and management criteria are followed. It is imperative that projects are carefully monitored so that accurate results, either positive or negative, can be published.

It is clear from the literature that several pathogens have surfaced as the most significant infectious agents in chelonians, including tortoises. Mycoplasmosis, herpesvirus infection, iridovirus infection, and intranuclear coccidiosis are the most significant infectious diseases identified in these animals. With time, as more dead animals are examined in detail the list will probably grow.

Large numbers of desert tortoises are kept as pets throughout their range in the southwestern US. Many are kept in outdoor enclosures in areas where native populations exist. Desert tortoise owners also may be the owners of exotic tortoises which potentially harbor foreign pathogens. Mycoplasmosis and herpesvirus infections have been documented in captive tortoises and while information on the importance and presence of mycoplasmosis in wild populations has been building since its first description in 1991, we are just realizing the potential significance of herpesvirus in wild populations. While it is easy to focus on these two disease problems/pathogens of tortoises we must never lose sight that other pathogens may surface as more and more tortoises are kept as pets and become intensively managed. The public has been drawn to the importance of nonnative emerging infectious diseases such as West Nile Virus infections in birds and humans in the eastern United States and the potential for something similar happening when a pathogen from captive tortoises, particularly nonnative species, spreading into wild populations exists. Chiefly by education, this must be brought to the attention of those owners of these animals. The release of captive tortoises needs to be tightly controlled to keep this risk at a minimum.

CLINICAL IMPLICATIONS OF THE ANATOMY AND ARCHITECTURE OF THE NASAL CAVITY OF TORTOISES

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The nasal cavity of chelonians occupies a large space cranial to the eyes and brain. This is a particularly prominent structure in tortoises. Cranially, the nasal cavity is continuous with the external nares. A heavily collagenous septum separates the cavity into both left and right portions. Caudally the nasal passageways are continuous with the internal nares (choanae). The nasal cavity varies in structure from cranial to rostral and at a histological level differs ventrally and dorsally. Ventrally, the mucosa consists of both mucous and ciliated cells while dorsally it is primarily olfactory. There is a very rapid transition from one type of epithelium to the other. The olfactory lobes of the brain send projections to the dorsal aspect of the cavity and only a small distance separates the brain from the nasal cavity.

In studying mycoplasmosis and herpesvirus infection in tortoises, the nasal cavity is the main site of involvement in the former and one of several sites of involvement in the later. In mycoplasmosis, the causative agent appears to first become established in a ventral recess that is continuous with the nasal passageway. Subsequently it spreads dorsally. In diagnosing both mycoplasmosis and herpesvirus infection, collections of samples (flushes) from the nasal cavity are routinely done to attempt isolation of these pathogens or identification of gene sequences using polymerase chain reaction. However, collecting good representative samples of the cavity is often more difficult than first anticipated. Saline or a culture media is often flushed into and out of each nares or may be completely flushed through the nares and fluid escaping from the oral cavity of the animal collected as a "free catch." When the nasal cavity is examined, both by dissection and through specialized imaging such as the reconstruction of a three-dimensional CAT scan, the complexity of the cavity and the inherent difficulties of acquiring a representative sample from the entire cavity can be appreciated. Placing the tortoise in dorsal recumbency (carapace down) and the head tilted down, may allow the fluid used in the flush to have a better opportunity to come in contact with more dorsal regions of the cavity. Because the cavity may become occluded in chronically ill animals, trephining both sides of the cavity and inserting catheters for subsequent flushing should be considered.

HEALTH ASSESSMENT OF NEONATE TORTOISES: PROBLEMS WITH THE TOO SMALL

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Health assessment of both extremely large and extremely small vertebrates is problematic. With those extremely large animals, difficulties with health assessment center on access to the animal itself. Health assessment by its very nature requires direct contact with the animal. In many situations, this may necessitate some form of manual or chemical restraint, something that is impractical to use with certain mega vertebrates such as large cetaceans. Small vertebrates, both those that are small as adults or small as neonates, the access issue may center around size related diagnostic limitations with the animal in hand.

As a group, chelonians are difficult animals to evaluate clinically. Many species are capable of withdrawing into the margins of their shell when threatened, becoming "bony boxes." Clinicians experienced in evaluating chelonians have devised methods for coaxing them out of their shells. For medium to small-sized chelonians, one method is to push in or gently touch the hind limbs, which often results in head extensions. Slow, deliberate movements will reduce fearful responses and retraction into the shell. Many tortoises will extend their forelimbs and head if tilted slightly downward, perhaps in an effort to avoid falling. Above all, examination of a frightened chelonian requires a good deal of patience.

The chelonian family Testudinidae consists of members ranging in adult size from 90 g to some over 300 kg. Even for the largest tortoises, the small size of their neonates makes collection of certain samples and the use of certain diagnostic tools difficult or impossible. Neonate desert tortoises range in weight from about 25 to 35 g vs. adult weight ranges of 800 g or larger. The most common diagnostic tools used in evaluating chelonians include morphologic measurements, blood sampling for determining hematology, blood chemistry and serology, imaging for determining the status of internal structure, and samples from the nasal cavity, oral cavity, and lower gastrointestinal tract. Biopsies may be needed from either external or internal structures. Regarding neonates, while morphologic measurements such as carapace length in the midline, carapace width, and weight are easy to collect and may provide information relevant to health status, collecting biologic samples such as blood may be challenging, while others such as nasal washes may be very difficult to obtain.

As an investigator selectively works with a life stage of an animal, techniques and procedures will develop and will subsequently be modified and refined to meet the restrictions imposed by the size of the animal being studied. While the resourcefulness and experience of the investigator may allow them to transcend some of the size related restrictions, certain diagnostic tools available for assessing health of adults may never be adaptable for neonates.

2002 Health Surveys of Sonoran Desert Tortoises

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In 2000 we initiated health surveys of tortoises in Sonoran Desert populations. We collected samples for herpes and mycoplasma ELISA testing, plasma biochemistries, bile acids, and PCVs. In 2001 we continued the same sampling protocol, increasing the numbers of samples from Florence Military Reservation (FMR) and the Ragged Top Mountains (RT). We included two new sites, Saguaro National Park (SAG) and Rocking K (RK) Ranch, in the Rincon Mountains. Full CBCs were performed on samples from RT to determine the cause for a recent high mortality rate in the population.

A total of 39 tortoises were sampled in 2001: FMR 5, RT 9, RK 19, and SAG 6. Twenty-three tortoises were seropositive for mycoplasma: FMR 0, RT 2, RK 16, and SAG 5. Many of the tortoises from RK showed clinical signs of URTD. Herpes ELISA results were performed on samples from RT and SAG with two American-strain positives from SAG and six American-strain positives and three European-strain positives at RK (2 of the 3 European-strain positive tortoises were also American-strain positive). Chemistries are still being evaluated and will be reported at the end of the study.

Results of CBCs from RT show moderate leukopenia (low white blood cell count) and a high number of eosinophils. Leukopenia is indicative of a physiologic stress or immunosuppressive process occurring. The significance of the high percentage of eosinophils is not fully understood at this time. Further monitoring of cell counts from this site will occur in 2002.

PREVALENCE OF URTD IN CAPTIVE DESERT TORTOISES ON AND ADJACENT TO FORT IRWIN: POTENTIAL IMPACTS TO WILD POPULATIONS

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Captive desert tortoises on the grounds of Ft. Irwin and representative tortoises kept by private individuals in surrounding towns, were sampled over the summers of 2000 and 2001 for exposure to a tortoise herpesvirus and *Mycoplasma agassizii*, two pathogens known or suspected to cause signs of URTD in desert and other species of tortoises. In 2000, 162 tortoises were tested by enzyme linked immunosorbent assay (ELISA) for exposure to *Mycoplasma agassizii*, and 111 of these same tortoises were also tested by ELISA for exposure to herpesvirus. Results demonstrated 80% were positive, 6.4% suspect, and 13.6% negative for exposure to *M. agassizii*. 26% were positive for exposure to herpesvirus, and the remaining 74% were negative. Of the 29 tortoises testing positive for herpesvirus, 24 were positive for exposure to both *M. agassizii* and herpesvirus.

In 2001, 47 tortoises were sampled for exposure to *M. agassizii*. Of these, 21 samples were from tortoises not previously sampled, of which 18 were positive on ELISA, and three were negative. The remaining 26 samples were collected from tortoises that tested positive in 2000 and had clinical signs of disease (nasal discharge, conjunctivitis, palpebral edema), and who according to owners were still showing signs. All 26 were still positive on ELISA with an average rise in the ratio of 9.00.

Due to the high prevalence of captive tortoises exposed to *M. agassizii* and herpevirus, tortoises may pose a serious threat of pathogen introduction to surrounding naive wild populations. One of the 162 tortoises tested in 2000 is potentially back in the wild having dug itself out of the owner's yard. Education of tortoise owners is an essential aspect to helping decrease the risk of captive tortoises spreading disease to wild tortoise populations on Ft. Irwin.

REVISED TECHNIQUES FOR ESTIMATING DESERT TORTOISE ABUNDANCE IN THE FORT IRWIN NATIONAL TRAINING CENTER EXPANSION AREA IN 2001 AND THE RESULTS OF THOSE SURVEYS

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In an ongoing effort to examine impacts to desert tortoises that could occur from the expansion of Fort Irwin's National Training Center (NTC), the U.S. Department of the Army

(Army) directed studies in 2001 to examine tortoise density. Studies were concentrated in the western expansion area (Superior Valley area) where the most intensive military training is anticipated, with limited sampling in the southern portion of the expansion area, in the area (9-0 Area). Six 1.0 km^2 mark-recapture plots and one 1.44 km^2 mark –recapture plot were completed in spring, 2001, and 568 belt transects were completed the following summer. Of the 258 km^2 in the western proposed expansion area, we sampled 115 km^2 by either transects or mark-recapture plots. While this was 44% of the kilometers in the western area, the concentration of transects resulted in a sampling of 61% of the square kilometers in the main-use area.

Techniques of both data collection and analysis were modified from earlier studies to improve the accuracy of the results in estimating tortoise density. For mark-recapture plots, these included: (1) choosing a 1.0 km^2 plot area, based on a comparison of different plot sizes attempted during the previous studies on the NTC and their attendant difficulties with edge effects and effective coverage; and (2) using a sampling crew of eight people to complete the mark and recapture sampling in approximately four days, thereby ensuring the closed population assumption for the statistical analysis, as well as minimizing sampling difficulties associated with tortoise movement. For belt transects, the 2.4 km transect length and triangular shape of the 2001 transects were identical to earlier transects, but improvements for statistical accuracy included: (1) increasing the sampling rate from the typical rate of 0.39 transects per square kilometer (1 transect per square mile), to 4.0 transects per kilometer (10.4 transects per mile); (2) analyzing only the size group that was actually sampled, the adult cohort (i.e., tortoises >179 mm in carapace length), rather than all sizes of tortoise; (3) truncating transect width by sign type and individually for each observer; (4) using sign types that provided the highest correlation coefficients to known tortoise density; and (5) conducting calibration transects on mark-recapture plots conducted the same year as the transects.

Tortoise densities were low throughout the western expansion area and those portions of the 9-0 area sampled. Nowhere did adult tortoise densities exceed 18 tortoises/km^2 (47 tortoises/mi^2) and broad areas were calculated to have one or fewer tortoises per square kilometer. For the entire western expansion area, the number of adult tortoises was estimated to be < 700 animals.

It is likely that the drought cycle of the past 13 years has resulted in substantial mortality and concomitantly depressed reproduction and recruitment. Adult annualized mortality rates (AM) on mark-recapture plots with enough live tortoises to be meaningful were 11.8 to 13.8% for the previous two-year period and 9.6 to 10.8% for the previous four-year period. One plot with low adult densities had a disproportionately high absolute number of carcasses and a 42.0% AM for the previous two years. However, it is likely that tortoise densities have never been high in the western expansion area, due to factors associated with the relatively high elevation there. By contrast, the 9-0 area is higher quality habitat and probably hosted substantially more tortoises before the severe recent drought.

CAN WE IDENTIFY THE SEX OF IMMATURE TORTOISES BY FECAL STEROID ASSAYS?

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It is important that we know the sex ratio of neonate and immature tortoise populations when studying the ecology of the species. As recognizable secondary sex characters are not evident until tortoises are sexually mature, often in excess of ten years, a simple and reliable method to identify the sex of immature tortoises is needed. Laparoscopy in the hands of an expert has proven to be 100% reliable, but the equipment is very expensive and it does require that a small incision be made in the body wall of the neonate tortoise. Measuring circulating testosterone is also reliable in some species, but again it requires that a jugular puncture be made to draw the blood sample. Both of these methods are stressful to the young tortoises, and in wild populations under severe environmental stress the added insult of such procedures could prove detrimental to the health of the individual. Our laboratory has considerable experience studying reproductive cycles in birds and mammals, and pregnancy in a variety of mammals by measuring metabolites of steroid hormones in fecal samples. We are currently testing this method using fecal samples from desert tortoises and gopher tortoises. The preliminary results are unclear, but additional tests will be performed. We have looked at testosterone and estradiol in fecal extracts of both species and will present our initial results. Data from animals of known sex will be presented.

DISTRIBUTION, BIOLOGY, AND STATUS OF THE RADIATED TORTOISE, *GEOCHELONE RADIATA*, IN SOUTHWESTERN MADAGASCAR

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Madagascar is one of 25 global "biological hotspots" and a "megadiversity" country. The radiated tortoise or sokatra (*Geochelone radiata)* is one of four tortoises endemic to Madagascar. The IUCN Red List classifies it as "Vulnerable." The primary threats to the tortoise's survival are collection for human consumption and the pet trade, and habitat loss. There are several published studies on the biology of captive radiated tortoises, but only a few reports on field research of radiated tortoises. The project was designed to examine these parameters in the field over a two-year period; specifically during the tortoises' active season (rainy season - November to April). To determine the status and distribution of radiated tortoises, sampling was conducted across the species' entire range. Seven transect sites (Cap Sainte Marie, Lavanono, Ankirikirika, Nisoa-Ambony, Lavavolo, Vohombe, and Lake Tsimanampetsotsa) were sampled during the 1998/99 and 2000 field seasons. Cap Sainte Marie (CSM), a special nature reserve in the extreme southern portion of the Province of Tulear, was chosen as the principal study site and the location of the reproductive study.

Tortoises range from south of Tulear to CSM. East of CSM tortoise populations become severely fragmented. Line transect sampling was conducted across the species range to estimate tortoise density. Density estimates ranged from 27.5 to 5,744 tortoises/km^2. The estimated mean population size of radiated tortoises in the core of the range is between 12 and 54 million. At my study site at CSM there were between 1,905 and 2,105 tortoises (actual marked individuals 1,438) based on Lincoln-Peterson mark-recapture. Based on mtDNA extracted from blood samples gathered across the range, tortoise populations do not appear to exhibit phylogeographic structure.

This study also examined reproductive behavior and egg production in a natural radiated tortoise population by observing and recording tortoise interactions, and radiographing marked females at regular intervals over two nesting seasons. Individual females at Cap Sainte Marie were polyoestrous, producing from 1 to 3 clutches per season (mean = 1.7±1.1, n=12). The eggs were generally spherical with a brittle calcareous shell and had a mean mass of 39.0 ±5.8 g (range 28.0-55.0 g, n=56), a mean length of 4.2±0.2 cm (range 3.5-4.7 cm, n=58), and a mean width of 3.8±0.2 cm (range 3.4-4.3 cm, n=58). The incubation period was about 303 to 309 days. Hatchling success was high and consistent between years; 65.6% of eggs (9 nests, 32 eggs) hatched in 1999, and 66.7% of eggs (3 nests, 9 eggs) hatched in 2000.

A series of general and specific Cap Sainte Marie recommendations are given for radiated tortoise conservation in Madagascar based on this study. One of the most encouraging things about radiated tortoise conservation is that their numbers are quite high, which means now is the time to act before populations start to dwindle and these unique tortoises enter a state of crisis.

TRENDS IN DESERT TORTOISE RESEARCH: DTC PROCEEDINGS 1976-2001

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For the last 25 years a representative portion of desert tortoise (*Gopherus agassizii*) research has been reflected in Desert Tortoise Council symposia. Some individuals and agencies have been active in the Symposia for the full 25 years, while others have come and gone. Regardless of the players, the symposium has evolved over the years to incorporate new disciplines and experts as science and our understanding of desert tortoise biology has grown. With 25 years of consistent and repeated study by dedicated, world-class scientists, analysis of the symposia proceedings can provide insight into topical, temporal, and spatial trends in desert tortoise research. The author, affiliation, agency, paper title, and abstract were compared across the 25-year history of the symposia (1976-2001). Specifically, the abstracts were analyzed to identify research trends in relation to major environmental regulations (i.e., listing of the desert tortoise), research discoveries (i.e., discovery of URTD in wild populations), and agency affiliation. In addition, where possible, we have investigated spatial relationships and trends in agency and individual research, as well as

changes through time. The results of our analyses are presented textually and graphically and will be made available on-line at a later date.

DESERT TORTOISE CONSERVATION AT THE NTC AND FORT IRWIN, CALIFORNIA

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Despite more than 20 years of intense brigade level training at Fort Irwin, desert tortoises continue to be observed throughout many areas of the nearly 262,000 ha military reservation. Numerous surveys have revealed several distinct sub-populations of desert tortoises on the installation, the largest of which occur along the post's southern border and in the foothills of the Tiefort Mountains, in areas not regularly used by tactical vehicles.

Fort Irwin has implemented a series of programs that contribute to desert tortoise conservation. These programs center on extensive education and public outreach programs, maintenance of off-limits areas, and scientific research. A 1995 USFWS Biological Opinion identifies terms and conditions which the Army must follow to be in compliance with the Endangered Species Act. In addition, a Programmatic Management Plan for the tortoise has been developed to guide management of the tortoise sub-populations on the NTC.

Fort Irwin is a leader in desert tortoise research. This research, funded by Fort Irwin and conducted by world-renowned scientists, has greatly increased our knowledge of desert tortoise life history and demography, physiology, reproductive ecology, social behavior, and the effects of disease and toxic contaminants on tortoise populations. Research conducted at the Fort Irwin Study Site has provided much of what we know on the neonate and juvenile stages of desert tortoises. Ongoing projects include a long-term life history and demography study, a study to determine the viability of using head-starting programs as a recovery aid, and distance sampling of the Superior-Cronese and Fremont-Kramer critical habitat units.

IMPLEMENTATION OF THE LINE DISTANCE SAMPLING METHOD THROUGHOUT THE MOJAVE DESERT IN 2001

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During the spring of 2001, rangewide line distance sampling was initiated within every Desert Wildlife Management Area (DWMA) and several military installations and national parks. A total of nearly 3,000 km were walked and 572 live tortoises were observed, 219 of which were from the Virgin River Recovery Unit alone. From this first year sampling data, the encounter rate for each DWMA or critical habitat area could be determined. Based upon the 2001 encounter rates we will upscale our sampling to include additional kilometers in 2002. Encounter rates varied from lows of 0.05 in Shadow Valley, California (in the northern portion of Ivanpah DWMA), 0.06 in Beaver Dam Slope, and 0.10 in the Northeast Mojave DWMA, to highs of 0.70 in the Virgin River Recovery Unit (VRRU), Red Cliffs Desert Reserve and 0.32 in parts of the Chuckwalla DWMA on Chocolate Mountain Gunnery Range. The overall mean encounter rate combining all the DWMAs sampled (excluding VRRU) was 0.13 rangewide. Preliminary results indicate that larger sample sizes of live desert tortoises need to be documented, therefore sample size (kilometers sampled) needs to be increased. By coupling transects together and increasing the length of each transect from 1.6 km to 2.0 km, we will be able to increase the number of kilometers sampled in 2002 without any appreciable increase in cost. Thus, nearly 5,500 km of transects are planned to be sampled in 2002, again sampling all DWMA's and critical habitat areas rangewide. The above sampling effort would not have been possible without the dedicated cooperation of contractors and volunteers, support of the Desert Managers Group and the Mojave Desert Ecosystem Program, and funding provided by the Bureau of Land Management, National Park Service, Department of Defense, U.S. Fish and Wildlife Service, Arizona Game and Fish Department, Utah Division of Wildlife Resources, and the Habitat Conservation Plans of Clark County, Nevada and Washington County, Utah.

UTAH DIVISION OF WILDLIFE RESOURCES DESERT TORTOISE FOSTER CARE PROGRAM

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The Utah Desert Tortoise Foster Care Program was established to prevent illegal adoption of tortoises and the potential spread of disease of released captive tortoises. The general public of Utah is eligible to participate in the Desert Tortoise Foster Care Program with the exception of those individuals who live in Washington, Kane, and Garfield Counties. This is to prevent the possible release of captive tortoises into the Red Cliffs Desert Reserve.

Most tortoises in the Utah Desert Tortoise Foster Care Program were found in areas associated with high populations centers such as Salt Lake, Utah, and Davis Counties. The Salt Lake City office of the Utah Division of Wildlife Resources receives about six tortoises a year that need to be placed in the foster care program. Currently there are 89 active state permits (Certificate of Registration) for desert tortoises, eight were issued for education or research purposes and 81 were issued to individuals participating in the program.

Finding foster care homes for tortoises in Utah is a challenge. Interested individuals are given an information packet containing the needed forms, care information, and facility requirements. The facility must be approved before an applicant can receive a tortoise. The commitments to provide an appropriate facility and care for the life of the tortoise are the factors that keep most people from entering the Utah Desert Tortoise Foster Care Program.

Time and funding have been limiting factors in the promotion of the Desert Tortoise Foster Care Program. Additional effort is needed to find people willing to care for captive tortoises. Possible solutions include education and Desert Tortoise Foster Care Program information on the Utah Division of Wildlife website, and promotion of the program through herpetological societies in Utah.

DESERT TORTOISE NEONATES: WEAKEST LINK IN DEMOGRAPHIC RECRUITMENT, MOST RESPONSIVE AGE-CLASS FOR MITIGATION, OR BOTH?

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For many decades neonatal and juvenile desert tortoises have been overlooked in both life history and conservation literature. They were rarely encountered in the field, active at times of year when few field surveys were conducted, and utilized burrows which lacked the easily recognized diagnostic characteristics of adult tortoise burrows. Furthermore, young reptiles have been traditionally viewed as simply miniatures of adults, simply growing in an isometric trajectory leading to reproductive adulthood. It has also been assumed that, taken individually, they were relatively unimportant to demographic recruitment.

None of these generalized assumptions are completely true, and most are false. Here we focus on neonatal tortoises in particular. Among their most distinguishing characteristics are the following: (1) Even in an isometric ontogeny, body surface area only squares as a function of linear growth while volume cubes. As a result, neonatal tortoises have advantages in behavioral thermoregulation in the cool fall and winter seasons. (2) For the same reasons, they have lower water reserves and lower resistance to dehydration, and they have much greater vulnerability to predation. (3) They function as "post-natal lecithotrophs," capable of vigorous (> 1 km) dispersion and overwinter hibernation without eating. Nonetheless, residual yolk may only provide energy and rehydration for movement and for some further morphogenesis of organs, not calcium for skeletal growth. (4) Conspecific coprophagy may play an important role inoculating the hindgut with cellulose digesting anaerobic mutualists. (5) Neonates utilize abandoned rodent burrows as their primary hibernacula, deferring construction of their burrows until soils are softened by winter rains in the spring or later. (6) Spring foraging may follow a complex sequence of selectivity to satisfy the needs of rehydration, protein, and calcium for growth, and the PEP (Potassium Excretion Potential) ratio to avoid intoxication. (7) Since the early 1980s demographic evidence has been accruing to indicate that egg nest success rates typically reach or exceed 50%, neonatal year survivorship >50%, and estimates of survivorship from year one to sexual maturity range up to 89%, depending upon assumptions and evidence.

These assets and vulnerabilities of neonatal and juveniles are reviewed in the context of natural recruitment, and with regard to conservation interventions. They include the possible role of hatchery-nurseries installed "in situ" at sites supporting distressed populations.

PROPOSED PHYSIOLOGICAL STUDIES ON DESERT TORTOISES AT FORT IRWIN, CALIFORNIA

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Desert tortoises are ectothermic herbivores that face a series of challenges in their environment including both the rigors of their xeric and often thermally inhospitable habitat, anthropogenic effects (habitat destruction and disturbance), and a range of diseases. As part of the management planning for desert tortoises, three independent population viability analyses have been done. Those analyses are unanimous in noting that one of the fundamental problems with the analyses, and hence with the management plans, is the lack of data allowing one to match temporal and spatial variation in habitat characteristics to variation in demographic rates of tortoises. The studies aim to create such linkages by proposing that habitat characteristics strongly affect the activity, thermal, hydric, and energy and resource budgets of tortoises and that those budgets play a significant role in determining the demographic rates of tortoises. We choose to focus initially on how environmental characteristics and disease (seroreactivity to *Mycoplasma*) affect the activity, hydric, and energetic budgets of tortoises in several sites. We will examine the relationships between those budgets and the vital rates (growth, reproduction, and survivorship) of the tortoises. The study will be conducted and the vital rates measured in conjunction with a tortoise demography study ongoing at Ft. Irwin, California. In addition to the factors cited above, we will attempt to address the effect of the Army's training activities on both the tortoises' physiological states and vital rates by selecting sites that experience varying intensities of training activities (including no activity). This information may be used by the study's sponsor (Ft. Irwin, DOD) to guide tortoise management efforts.

CAN JUVENILE TORTOISES OBTAIN HIGH PEP FORAGE THROUGHOUT THE SPRING?

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A broad array of annual plants germinates in response to winter rains in the Mojave Desert, providing juvenile tortoises the opportunity to be selective in feeding during the spring. In an El Niño year (1998) we observed that tortoises were very selective in both the species and parts of plants eaten, and by this means were able to ingest a high quality diet. Diet quality was measured as the relative amounts of water, nitrogen, and potassium in the diet, and was expressed as the Potassium Excretion Potential (PEP) index. Based on these results, we predict that juvenile tortoises will self-select a high PEP diet whenever they have the opportunity.

To test this prediction, and to determine if the ability to self-select a high PEP diet is dependent on the time of season, we conducted a study of foraging juveniles in 2001. Fifteen juvenile tortoises in a naturally vegetated pen at the Fort Irwin Study Site (FISS, National Training Center, California) were observed over three-week periods (I: April 8-14, II: April 30-May 6, III: May 19-24). All plants that foraging tortoise encountered within one body width to each side (except the abundant alien grass *Schismus*) were recorded. All effective bites of plants were recorded according to species and part. More than 33,000 bites were observed, including about 700 bites of non-food items (soil, gravel, bark, scats).

The major food plants (>1% of bites in a period) were as follows: Period I, evening primrose (*Camissonia claviformis*, 43%), desert dandelion (*Malacothrix glabrata*, 40%), filaree (*Erodium cicutarium*, 10%), and split grass (*Schismus barbatus*, 1.5%); Period II, filaree (66%), evening primrose (9.9%), desert dandelion (8.4%), cryptanth (*Cryptantha angustifolia*, 3.6%), split grass (3.3%), woolly plantain (*Plantago ovata*, 2.4%), and desert pincushion (*Chaenactis fremontii, 2.2%*); Period III, filaree (80.5%), cryptanth (8.7%), split grass (8.1%), and big galleta (*Pleuraphis rigida*, 1.4%).

The primary plant part eaten in all periods was leaves (92% of bites in I, 47% in II, 74% in III), but fruit (filaree, primrose, and dandelion) became very important in period II, accounting for 37% of all bites. The change in diet from a preponderance of native annuals (I) to a preponderance of introduced filaree (III) appeared to reflect changes in phenology: both primrose and dandelion matured and senesced over the course of this study, but filaree retained some green leaves and unripe fruit until the end of III.

Although we have yet to complete all nutritional analyses for this study, we estimated the nutrient composition of the ingested diet using nutritional data on these plant species and parts from the same site in 1998. The estimated PEP index dropped from >20 in I, to about 13 in II, and about 10 in III. The very high PEP index in early April (I) was attributable to the high PEP values of the two major parts eaten, evening primrose leaves (42% of bites), and desert dandelion leaves (36% of bites). By early May, these parts were becoming scarce and by late May were no longer available, and tortoises had switched to other parts that were mostly lower in PEP.

A high PEP diet provides surplus protein and water beyond the needs for potassium excretion, and thus may be very important for growth of shell, muscle, and other protein-containing organs. Growth is believed to be important for juvenile survival for at least two reasons: (1) An increase in shell size and strength may deter predation by ravens; and (2) Muscle and internal organs represent nutrient reservoirs, which may need to be drawn upon during prolonged food shortage, as during drought. Our study indicates that juvenile tortoises were very successful in acquiring high PEP foods in mid-spring (April), but less so in late spring (May). Given that annual plants in early phenological stages in February and

March appear to have similar or higher PEP values than in April (Oftedal 2002), we predict that the entire early to mid spring period is characterized by high PEP intakes in years of good rainfall.

This study provides an additional explanation why it may be important for juvenile tortoises to become active early in the spring. Juvenile tortoises at FISS are often observed above ground during warmer and sunny days as early as January and early February, although the extent of foraging on rosettes and early emergent parts of winter annuals has not been determined. There would appear to be selective pressures favoring early foraging on high PEP parts, so long as basking behavior allows acquisition of body temperatures favorable to digestive and renal processing of plant nutrients.

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SEROLOGICAL AND MOLECULAR EVIDENCES OF HERPESVIRUS EXPOSURE IN DESERT TORTOISES FROM THE MOJAVE DESERT OF CALIFORNIA

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Herpesvirus has been associated with a disease in several species of tortoises characterized by stomatitis-rhinitis. Although most of the tortoise herpesvirus literature involves Mediterranean tortoises (*Testudo greca* and *T. hermannii*), the occurrence of herpesvirus infection has been reported in three captive desert tortoises (*Gopherus agassizii*). Herpesvirus infection was identified upon post-mortem evaluation of these animals.

Because of a lack of epidemiological data about the prevalence of tortoise herpesvirus in captive and free ranging desert tortoises, we tested a total of 415 plasma samples collected from captive and free ranging desert tortoises from in and around Fort Irwin (Barstow, CA). The serological test used was an enzyme linked immunosorbent assay (ELISA) recently validated for Mediterranean tortoises. One hundred and ten samples (26.5%) were positive for exposure to tortoise herpesvirus. The serological test was complemented by a polymerase chain reaction (PCR) recently developed, that confirmed the presence of herpesviral DNA in two of six tissue samples obtained from wild desert tortoises. The sequencing of the amplified fragments is currently ongoing.

Several of the desert tortoises ELISA positive for herpesvirus exposure were known to be also positive for mycoplasma exposure. While *Mycoplasma agassizii* has been shown to be a serious pathogen for desert tortoises, the role of tortoise herpesvirus is still not clear. However, the results presented indicate that herpesvirus may operate as an important pathogen in wild populations of desert tortoises.

ETHICAL CONCERNS IN BIOLOGICAL CONSERVATION

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The various fields of environmental science are more abundantly endowed with technological expertise than with a broad ethical and philosophical base to guide application of this technology. Many "judgement calls" must be made, often without the benefit of procedural guidelines, and under strong political pressure from development interests to compromise the basic natural resource. Compounding this problem is a general failure of many university resource management curricula to require (or even offer) courses in the rapidly emerging fields of environmental ethics or philosophy, thereby producing (in effect) missiles without guidance systems. Evidence of this syndrome is universal, and related potential resource degradation is enormous.

Human impacts on biodiversity which essentially began with the era of industrialization and accompanying exploitation of natural resources, and more recently exacerbated by population explosion, have burgeoned since World War II to a point of critical concern throughout the world. Although much of this impact has resulted from activities designed to serve the needs of humankind (timber harvest, agriculture, hydroelectric dams, urban expansion, etc.), society has now reached a point where it must ask how much additional habitat destruction and species loss can be permitted before human standards of living and quality of life decline to unacceptable levels. As the only species known to possess a conscience, humans must now explore their ethical obligations to preserve ecosystem integrity. The lecture discusses these increasingly vital and pertinent issues, based upon the speaker's personal observations during the second half of the twentieth century and augmented by the views of renowned conservationist Aldo Leopold.

A Combined Research and Education Project with Hatchling Desert Tortoises

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ABSTRACT

The Desert Tortoise Project combined research and community-based education in a collaborative program sponsored by Arizona State University West. The basis of the project was a study of the effect of diet on the growth rate of desert tortoises. Hatchling tortoises were assigned to one of two diet groups: the standard zoo salad diet or a pelleted diet. Body mass and linear dimensions were measured regularly during the growing season for five years. Tortoises fed the pelleted diet grew significantly faster than those fed salad. Two educational programs were linked to the study. Working with teenage volunteers at the Zoo, a group of ASU West undergraduates developed, tested, revised, and implemented a presentation format for zoo visitors that dramatically increased the amount of information conveyed about the biology of desert tortoises and the diet study. A second group of undergraduates worked with middle school students who weighed and measured the tortoises in the study and used the data as the basis for class activities in mathematics, writing, and art.

Some species of turtles may be well suited for head-starting programs because juveniles grow slowly in nature and suffer size-dependent mortality, but in captivity they can grow rapidly to a size that frees them from some predators (Germano et al. 2002). The U.S. National Zoo (Smithsonian Institution) has developed a pelleted diet for desert tortoises that produced rapid growth with little or no deformation of the carapace in a research setting. In that study small, wild-caught tortoises from the Mojave Desert were caged individually indoors, fed daily, and kept warm during the winter. These tortoises, which were probably between one and five years old when they entered the study, grew to adult size in 2.5 to 4.5 years (Olav T. Oftedal and Mary E. Allen, unpublished data).

Few conservation programs have the time or facilities to duplicate the intensive husbandry methods that can be used in small-scale research programs, but head-starting could be useful in some cases if results can be achieved with less intensive methods. In addition, public engagement can be a valuable element of the increasing involvement of zoos with conservation and management programs. The Desert Tortoise Project carried out by Arizona State University West combined several forms of education and community participation with a test of the effect of diet on the growth rate of hatchling desert tortoises in a zoo setting.

DIET AND GROWTH

Materials and Methods

We obtained newly hatched desert tortoises from hobbyists in Phoenix and Tucson, in the fall of 1995 and 1996. To the best of our knowledge, all hatchlings were from Sonoran tortoise parents. All were less than two months old when they entered the study. The animals were kept at The Phoenix Zoo and cared for by Zoo staff. During the first winter of the study the hatchlings were housed in groups in plastic wading pools in a warm room (25-30° C) on a 12L:12D photoperiod. Heat lamps allowed the tortoises to regulate their body temperatures during the light period, and fluorescent bulbs (Iguana Light 5.0 UVB, Zoo Med Laboratories, Inc., San Luis Obispo, CA 93401) in ceiling fixtures provided ultraviolet light. The tortoises were fed ad libidum three days a week. During this period the tortoises in the pelleted diet group were trained to eat pellets. Initially we sprinkled ground pellets on the salad, then mixed salad with moistened pellets and gradually increased the proportion of pellets. By March the tortoises in the pellet group were eating moistened pellets without salad.

The experimental design was initially based on two variables: diet (pellets or salad) and winter conditions (hibernation or active); this 2x2 design yielded four combinations of variables (cells). The characteristics of the pelleted and salad diets are shown in Table 1.

All of the tortoises in the 1995 cohort were moved to outdoor pens (about 3x6 m) in the Suzan L. Biehler Tortoise Conservation Center in March 1996. Water was available at all times and food was provided ad libidum three days per week. The two diet groups had to be kept separate, so the groups of tortoises were switched among pens to minimize the effect of pen-to-pen variation. Tortoises were weighed on an electronic balance and measured with calipers (straight-line carapace and plastron length and maximum carapace width and height) regularly from November 1995 through September 2000, when the experiment was terminated because of competing demands for space.

During the second winter the tortoises in the active group were maintained under the same conditions as the first winter and the tortoises in the hibernation group were placed individually in boxes in a darkened room at about 10° C for nine weeks. Although the tortoises in the active group were fed during the winter, they were not significantly larger than those in the hibernation group the following spring. Because the care required to keep tortoises active during the winter was incompatible with the goal of developing time-effective husbandry methods, we left all of the tortoises in outdoor pens year-round from the third year onward. Food was provided three times a week during the winter.

No symptoms of disease were seen in the 1995 cohort of tortoises during the first two years of the study, but the addition of a second cohort of hatchlings in 1996 apparently introduced *Mycoplasma* to the colony. The 1996 cohort was removed from the study and the results presented here are based on the 1995 cohort. By the summer of 1997 all of the tortoises in the 1995 cohort showed intermittent symptoms of upper respiratory tract disease, and ELISA analysis by the University of Florida (BEECS Immunological Analysis Laboratory) of blood samples from 18 tortoises confirmed the presence of antibodies to *Mycoplasma* in 12.

RESULTS

Sixteen tortoises completed the study, and tortoises in the pelleted diet group grew faster than those in the salad group (Figure 1). A statistically significant difference in body mass appeared during the first year, and by the end of the study after five years, the average mass

Table 1. Composition of the diets. The Phoenix Zoo salad diet includes produce (10-20% by volume, bell pepper, carrot, celery, cucumber, green beans, zucchini) and greens (chard, kale, mustard greens, spinach, turnip greens). Zeigler Brothers Medium Fiber Tortoise Diet (no. 5365021800) includes alfalfa, cane molasses, corn, isolated soy, oat hulls, soy oil, soybean meal, wheat, ascorbic acid, avian vitamins and minerals, calcium phosphate, DL methionine, L lysine, limestone, iodized salt. Protein, lipid, and fiber values for the Zeigler diet were taken from company literature, the other values were determined by the Arizona Veterinary Diagnostic Lab.

	Composition (% dry mass)					
Diet	Protein	Lipid	Fiber	Calcium	Phosphorus	Ca:P Ratio
Salad Diet (weighted	23.3-24.2	3.2-3.3	10.5-10.6	1.04-1.10	0.48-0.50	2.2:1-2.4:1
Zeigler Brothers Pelleted Diet	21.2	5.6	14.4	1	0.18	5.6:1

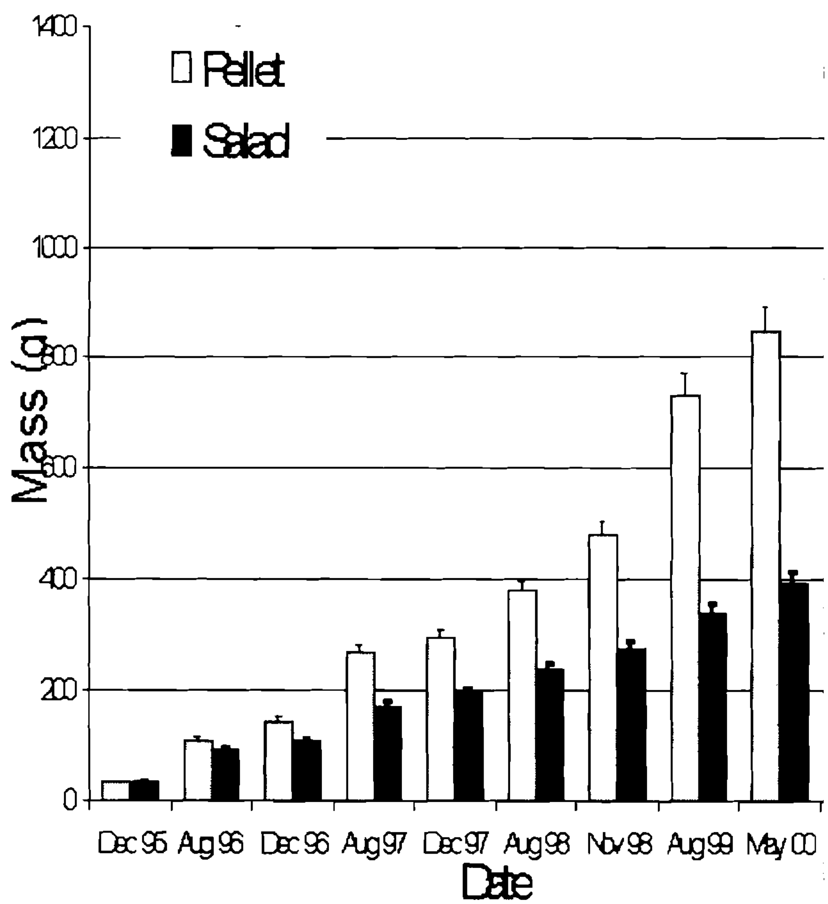

Figure 1. Comparison of body mass over time of the 1995 cohort of desert tortoises on pelleted and salad diets. Values shown are mean ± 1 SE.

Table 2. Final body mass (g) and carapace dimensions (mm) of desert tortoises (mean ± SE).

Diet	Body Mass	Carapace Length	Carapace Width	Carapace Height
Salad	415.7 ± 77.2	133.5 ± 6.8	100.2 ± 5.4	57.2 ± 3.2
Pellet	1260.7 ± 145.4	191.4 ± 8.2	138.7 ± 5.0	80.0 ± 4.9

of tortoises on the pelleted diet was three times that of tortoises in the salad group (Table 2, $F_{1,6} = 24.53$, $p = 0.003$). Elimination of one of the initial variables (winter conditions) and death of some individuals during the study created an imbalance in cell size that was corrected; by omitting one sibling group that lost both representatives of a diet and (2) by using the mean value for cells with more than one surviving individual from a sibling group. The four sibling groups did not differ in body mass at the end of the study (grand mean ± SE = 873.0 ± 171.8 g, $F_{3,4} = 0.16$, $p > 0.9$). The tortoises in this study showed little or no deformation of the carapace.

EDUCATION AND COMMUNITY INVOLVEMENT

Classroom Components

Structured participation by middle school classes (6th, 7th, and 8th grades) and high school juniors engaged students in a hands-on scientific activity that teachers could use as a basis for lesson plans in a variety of subjects. Undergraduate students from Arizona State University West assisted in this portion of the project. Initially the undergraduates conducted a wide-ranging review of the literature on desert tortoises, including basic biology and natural history, information about conservation and diseases, and the role of tortoises in the indigenous cultures of the American Southwest. From this information they developed material to support lesson plans focusing on different themes. Next we met with the participating teachers and provided information for the topics they chose. Because we were unable to find a book about the natural history and behavior of desert tortoises that was suitable for middle school students, we wrote one: Pygal, A Sonoran Desert Tortoise (Pough 1998).

We worked with each group of students for three weeks. The first week was spent in the classroom where we reviewed the background information that the students had received from their teacher and described the goals of our study. We asked the students to design an experiment to test the effect of diet on growth, accounting for possible differences among sibling groups. This was an effective method of engaging the students, and because our experimental design was highly intuitive every class proposed that design. The students readily understood the importance of including sibling group as a variable when we asked them if they had friends who were tall or short and if the brothers and sisters of those friends were also tall or short.

In the second week we met the students at The Phoenix Zoo where they weighed and measured the tortoises in the study. In addition, we gave them the monthly measurements for the tortoises back to the beginning of the study so they had a complete data set. We also developed three activities, done outdoors, to illustrate aspects of the biology of desert tortoises:

- Anatomy and fossil record: We used a mounted turtle skeleton to show the structure of the shell and the relation of the limbs and vertebral column to the shell. We found that a substantial proportion of the students believed that a turtle can crawl out of its shell. Fossil tortoises provided a basis for discussing the history of tortoises in North America and the contraction of the historic geographic range of desert tortoises.
- Size-dependent predation: We used candy, walnuts, and coconuts to illustrate the differential vulnerability of hatchling, juvenile, and adult tortoises. Students began with a cohort of 100 hatchling tortoises (represented by M&Ms) and drew cards from a deck to represent predation. A student who drew a raven card, for example, was allowed to eat an M&M. After five rounds (representing the first five years of the hatchling's life) we replaced the remaining M&Ms with walnuts representing juvenile tortoises. In this round a raven card did not allow a student to eat a walnut, but students who drew fox or coyote cards did get a walnut. After 10 rounds we replaced the remaining walnuts with coconuts (adult tortoises), and only a student who drew a mountain lion card could have a coconut.
- Consequences of small body size: We emphasized the vulnerability of hatchling tortoises to predators by having each student locate the nearest plant that had leaves close enough to the ground for a hatchling tortoise to eat. The student then crawled toward the plant at hatchling tortoise speed. Other students watched for birds, and if a bird flew overhead while a student was crawling the student was "out" (i.e., had been eaten by a predator).

In the interval between the trip to the Zoo and our third meeting with a class, the students used the measurements of tortoises and the other material we had provided in ways selected by the teachers. Younger students wrote and illustrated essays and poems incorporating information about the biology and conservation of desert tortoises, whereas older students used the measurements for graphic and mathematical analyses of the effect of diet on growth. Some of their analyses were quite sophisticated. For example, one class calculated a condition index for the tortoises by dividing body mass by carapace length, and another class worked with an instructor from a nearby community college to apply basic statistics to the data.

Zoo Visitors

An educational activity for visitors to the Zoo was added to the project in the second year. Its origin was serendipitous, on weekends the tortoises in the winter active group were put outdoors in wading pools to bask for an hour or two under the supervision of teenage volunteers (Zoo Teens). The tortoises attracted zoo visitors, and we took the opportunity to expand the educational component of the project by providing information in a structured format to the visitors who stopped to look at the tortoises.

Working with the Zoo Teens, we identified seven items of information about desert tortoises and the diet study that they wanted to convey to visitors, and helped them develop a script to explain these topics. To elicit the information however, visitors had to question the Zoo Teens. Next a group of Arizona State University West undergraduates surveyed visitors as they left the tortoises, asking "What did you learn about desert tortoises?" and "What didn't you learn that you would like to have learned?"

By measuring the time that visitors spent with the tortoises, we found that our window of opportunity for conveying information was short: adults without children spent an average of slightly less than one minute looking at the tortoises, adults with one child spent about two minutes, and groups that included two or more children remained for about three and a half minutes. Nonetheless, 57% of the visitors surveyed as they left volunteered one or more of the seven target items as something they had learned. Unfortunately, 43% of the visitors cited one or more targeted items as something they would like to have learned but did not.

The Zoo Teens decided that a graphic display would help them to convey the target information more effectively, and we developed a poster that was placed on an easel near the tortoises. We also found that, although the Zoo Teens answered questions readily and accurately, they were not comfortable initiating conversations with visitors, and many people left the tortoises without interacting with the Teens. Consequently we added two small teaser signs to stimulate questions from the visitors: "Would you believe that these tortoises are all the same age?" and "Why are they such different sizes?" After the addition of the poster and teaser signs, 94% of the visitors identified one or more of the targeted items as something they had learned, and none mentioned a targeted item as something they had not learned. The average number of visitors per hour increased from 177 when only the tortoises were present to 230 after the addition of the poster and signs.

Community Outreach

We created an annual newsletter that combined essays, poems, and mathematical analyses by the students with information about the progress of the research project. The newsletter was distributed to students in all of the classes we worked with and to the donors of the tortoises in the study. Donors were invited to come to the Zoo to see their tortoises, and several of them did so. In addition, the Tortoise Conservation Center was included in the Zoo's annual open houses and in resource sessions for teachers. Faculty and undergraduates from Arizona State University West explained the project and the biology of desert tortoises. The project was the subject of a newspaper article, two magazine articles, and a segment in the *ASU Research Reports* television show and received an award from *Chart Your Course*, a partnership of major businesses and school districts in Phoenix.

DISCUSSION

The study of diet and growth confirmed the rapid growth and normal carapace development previously described for tortoises fed a pelleted diet, and added two elements. We used captive-bred hatchling tortoises of known age, and we used husbandry methods that minimized the time and effort required to care for the animals. This study shows that captive rearing of hatchling tortoises can produce rapid growth of normal-appearing tortoises with a feasible investment of space and staff time.

The educational components expanded the influence of the study into the community without increasing demands on staff of The Phoenix Zoo by using university faculty and undergraduate students to develop and implement programs that incorporated participation by area schools and by teenage volunteers at the Zoo. The participating teachers were unanimous in saying that the hands-on, real-world experience showed students that what they learn in school can be applied to their lives and career choices, and students echoed that opinion in comments and letters to us. One 8th grade student turned to us, wide-eyed, during our final meeting with her class and exclaimed "Why, I could make a living doing this!"

ACKNOWLEDGMENTS

This project relied on support and participation of many members of the community: The Phoenix Zoo (Bruce Bohmke, Michael Demlong, Kevin Wright, Roger Cogan, Tawny Carlson, Tony Ford, Mike Seidman, Bryan Starrett, and Tara Spankler); The Peoria Unified School District (Terry Mainwaring, Tad Int-Hout, Dorothy Tolliver, and Cindy Croisetiere), Bourgade Catholic High School (Patricia Whalen), and Arizona State University faculty and students (Ellen Smith, Nicola Grimmond [visiting professor], Tracy Diaz, Amy Hokkala, Suzanne Faha, Andy Klunk, Erica Sugiyama, Carey Clifton, Donald Chobanian, and Karen Dryden). We are grateful to Sandy Cate (Arizona Game and Fish Department), Craig Ivanyi (Arizona-Sonora Desert Museum), and several tortoise enthusiasts for providing hatchling tortoises.

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THE TORTOISE AND THE HARE: THE VARIED PACES OF DESERT CLIMATES

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This talk will cover the main general aspects of the climates of the Southwest where desert tortoises are found.

1. Time-averaged or "static" characteristics. These include things such as the spatial distribution of annual precipitation, the seasonal cycle of precipitation and its variations in space (including altitude), and the principal "precipitation seasons" (primarily winter and the summer monsoon). Paradoxically, in this driest of all climates, water is a major element of change. The way in which water arrives and causes things to happen plays a strong role in the resulting biology that we observe. Essentially, not much happens (or appears to) for very great lengths of time, interspersed with short periods where a lot happens. Much of life revolves around preparing for and responding to these short episodes, at least as regards moisture. For temperature, a different set of issues is at work, including long periods of life-threatening extremes, large day-night differences, and occasional frosts or cold extremes. Humidity is generally very low, but gets very high when the monsoon invades. The progression of the monsoon will be presented.

2. Temporal variations. Climate is constantly varying on all time scales. There is no true "normal" climate, except in an approximate sense. The factors which produce the "static" climate mentioned above are generally different for different seasons, and there is no particular reason why the variations through time for one season should be the same as for other seasons. Mean conditions can vary from year to year, decade to decade, century to century, and so on. Similarly, the likelihood of "events" can vary over the same time scales. Examples of "events" are heavy downpours, extended wet spells, playa flooding, tropical storms, and so forth. The relation between event occurrence and average climate conditions is not always clear. The variations in climate can express themselves as slow changes, or as regimes separated by fast transitions. Usually these variations reflect influences from other more distant parts of the climate system.

3. Spatial connections. Local climates cannot be properly understood from purely local perspectives. The climate at a spot (any spot on earth) is the local expression of an integrated system involving connections across a range of scales from a few meters to the size of the earth. All these scales matter. Among the climate connections we know about for this area, the behavior of the faraway tropical Pacific Ocean is known to have influences on the winter precipitation of this area, both positive and negative.

4. Monitoring and data. How do we know what we know about desert climates? There are particular and peculiar difficulties in making long term measurements, including access and inhospitability issues, the extreme spottiness of precipitation, degree of sampling in space (mountains versus valleys, especially), accurately capturing rare but significant events, various presumptions about what we expect to find via measurement, and methods of distilling and disseminating findings gleaned from these observations.

5. Change. As time permits, some thoughts on change and stasis in desert climates, and on climate in general, will be offered.

Web Pages

http://www.wrcc.dri.edu - Background climates for particular stations

http://www.wrcc.dri.edu/climsum.html - Precipitation maps

http://www.wrcc.dri.edu/precip.html- Excessive precipitation rates,
return values for engineering

http://www.wrcc.dri.edu/pcpnfreq.html - ENSO connections

http://www.wrcc.dri.edu/enso/soipcpn.html

http://www.wrcc.dri.edu/enso/maps.html - Hourly historical data from around the Nevada Test Site, low to high desert

http://www.cemp.dri.edu/index.html - Recent climate behavior from airports

http://www.wrcc.dri.edu/recent_climate.html - Divisional climate data, highly interactive, 1895 thru latest month

http://www.wrcc.dri.edu/divisional.html - A potpourri of climate monitoring information, relevant to the West

http://www.wrcc.dri.edu/monitor/wdccmon.html - Abstracts from a recent workshop relevant to this area, including climate

http://www.wmrs.edu/SW-GreatBasin/abstracts.htm

HABITAT USE BY DESERT TORTOISES AT THE FLORENCE MILITARY RESERVATION, PINAL COUNTY, ARIZONA

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The Florence Military Reservation (FMR) is a 10,421-ha site in Pinal County, Arizona, located about 80 km southeast of Phoenix. The Arizona Army National Guard uses FMR as a military training site, utilizing 14, 15x1000-m training areas (firing boxes) for ground support and artillery exercises. FMR contains gently sloping to nearly flat alluvial slopes in the north and more rugged terrain with deeply incised washes to the south. Along the banks of the washes, cavities are eroded into the calcium carbonate (caliche) soils. In 2000, a three-year radio telemetry study was undertaken to determine habitat use and movement patterns of desert tortoises at FMR, relative to land use for military purposes. Up to 14 tortoises have been monitored to date at FMR. Sonoran desert tortoises typically live on steep desert mountain slopes in rocky burrows. At FMR, tortoises confine most activity to the incised washes and caliche caves. When not in washes, tortoises primarily use pallets under bursage clumps and woodrat middens as cover. Tortoises found in the vicinity of boulder-strewn hillsides do use burrows within the boulder piles, in addition to caliche caves. Tortoise movements within the training areas are primarily constrained to a minimal area along the washes. Mean home range size for all tortoises was 15.5 ha. Mean home range for males (20.9 ha) was twice as large as for females (10.1 ha). Monitoring efforts will continue through 2002.

PROFESSIONAL ETHICS WITHIN PUBLIC SERVICE: THE NEW INCOMPATIBILITY

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Public Employees for Environmental Responsibility (PEER) is a service organization for state and federal employees who are struggling with natural resource-related issues. PEER assists public employees in removing or resolving obstructions to environmental protection, especially when those obstructions are lodged within the employee's own agency.

PEER has worked on desert tortoise issues but, unlike the Desert Tortoise Council, we are not focused on a particular species or a habitat or an ecosystem. Our target ecosystem is the inner workings of public agencies: their culture, operations, and ethics.

To be healthy, an agency "ecosystem" needs to be penetrated by light, that is, to be transparent. It should be ventilated by new information, accommodating the wafting flow of both good and bad news into its management and out to affected publics. It should also foster diversity and be tolerant of a healthy range of opinion within its professional staff. In short, PEER's mission is to help employees restore or maintain a healthy agency ecosystem.

The New Challenge

Without harping on the changes occasioned by the Administration of George W. Bush, especially in the Interior Department, it should be noted that the transition is only now just beginning. The events of September 11, the slow pace of nominations and the clumsy handling of early issues have all slowed the pace of new policy formulation and key personnel changes.

In the Bureau of Land Management (BLM), for example, the removal from line positions of moderates such as Idaho Director Martha Hahn and California Desert Conservation Area Manager Tim Salt bode ill for the coming years. Notwithstanding the significance of the Bush transition, the underlying dynamic of growing political pressure on natural resource management is truly non-partisan, occurring at all levels of government, federal, state, and local, and across the spectrum of disciplines.

Three factors drive this dynamic:

1. The environmental conflicts themselves are becoming both more common and acute.
Recent NASA satellite photos show the extent that urban sprawl now dominates the American landscape. Those of you working in wildlife management know that human and wildlife contacts are becoming more frequent and are often the greatest threat to some species' survival. As a consequence of the inexorable human pressure on the natural world,

your job as a natural resource manager is itself more under the gun, so to speak, that ever before. Looking ahead, the conflict between man and nature will only become more acute.

2. The battles are fought on administrative (rather than policy) turf
Few politicians propose the outright repeal of the environmental statutes; instead pro-development politicians advocate a different emphasis, interpretation, or attitude in enforcing these laws (i.e., everyone, including developers, now claims to be an environmentalist). Consequently, the public portrayal of the conflict is not black and white but swathed in shades of gray.

The locus of controversy is the rigor of a resource statute's implementation — the very area inhabited by resource managers. The result is a pressure to undermine laws on the books; which, in turn, leads to a dysfunctional agency.

A prime example is the federal Endangered Species Act. Following the Republican takeover of Congress in 1995, then Interior Secretary Bruce Babbitt ordered the U.S. Fish & Wildlife Service (USFWS) to slow down or avoid implementing the law to save the ESA from political backlash. Key listing decisions by Interior then became more the product of litigation from environmental groups whose most powerful weapon is the scientific data gathered by USFWS scientists who are forbidden from using this data in making honest management decisions.

3. The public's scientific ignorance limits political support for agency policies
To the layperson, the issues that dominate modern resource management often seem hopelessly technical and arcane. Some have referred to this as "the snail darter syndrome" for the little fish which held up (but, significantly, did not block) a massive and, in retrospect unwise, dam. Mobilizing public support for agency policies rooted in protection of uncharismatic creatures, like insects, or complex natural phenomena can prove especially daunting.

The principal considerations that should govern resource decisions are scientific. Since biologists are not political scientists (or spin doctors), they often make poor public advocates. As a result, the technical expertise often remains locked inside agency cubicles and is not made part of the public debate. Meanwhile, in the absence of a persuasive scientific case, the advocate with the best slogan carries the day.

The Endangered Agency Scientist

Caught in the middle of this tug of war are the agency scientists, land managers, and law enforcement officers. The archetypal setting for political pressure that we see at PEER involves a multi-million dollar project hinging on the evaluation of a single field biologist. The field biologist, in essence, holds the future of the project in their hands. In this way, even field specialists can be found at the apex of intense political pressure. In a growing number of cases, that staff member cannot count on support from their chain-of-command in making a professional assessment.

Thus, agency professionals are increasingly at career risk simply for doing their jobs. Three examples from the U.S. Forest Service illustrate:

* The agency's leading goshawk scientist in Arizona had an up and coming career until his research on the amount of undisturbed land area required for a successful mating pair of the birds was used by local environmental groups as evidence in a lawsuit against proposed timber cuts. To defeat the suit, the Forest Service set about not only discrediting its science but its scientist. The researcher was forced to move to Alaska to save his job. Through no action of his own, except what he had been doing for years, this scientist went from "Golden Boy" to "Public Enemy Number One" in a twinkling solely because his work had become institutionally inconvenient;

* Similarly, a botanist on a North Carolina national forest ended her career by discovering rare plants in an area slated for a timber sale. After she refused to renounce her find, she was confined to doing all future plant surveys in the dead of winter until she finally quit in disgust; and

* Forest Service special agents who uncovered massive commercial timber theft in Oregon and California all lost their positions in a curious reorganization. Today, the Forest Service has no single unit dedicated to investigating timber theft on our national forest system. The agency explains that such a unit, of any size, is not cost-effective and deprives the agency of maximum flexibility in its use of investigative staff. Not surprisingly, the agency has stopped bringing multi-million dollar timber theft cases for prosecution.

None of these people considered themselves "whistleblowers." They were simply doing their jobs and got caught sideways in agency politics.

The Limits of Law

For employees caught in the undertow of these politics, the legal tools available are sometimes unreliable. By way of brief overview, the three principal areas of law involved in these cases are:

.The First Amendment

Precisely because public employees work for government, the First Amendment protects them on the job in a way their private sector counterparts are not protected. The First Amendment is not without limits and those limits are murkily defined. In a public agency context, employee speech is protected so long as it does not impair the efficient functioning of the public agency. See e.g., United States v. National Treasury Employees Union, 513 U.S. 454 (1995); Pickering v. Board of Ed. Of Township High Sch. Dist. 205, 391 U.S. 563 (1968; Sanjour v. EPA 56 F. 3d 85 (1995).

First Amendment cases generally provide only injunctive relief not monetary damages and thus have restricted utility. To vindicate First Amendment rights the employee must file formal litigation (literally "make a federal case out of it"), a step that usually requires legal counsel and can entail considerable time and expense. For employees undergoing daily, low level harassment due to the circumstances of their jobs rather than speaking out, First Amendment litigation may not be at all a practical avenue.

Whistleblower Laws

There are two basic types of whistleblower statutes: those protecting civil servants and those rooted in a particular statute, such as the Clean Air Act or the Clean Water Act. Civil service statutes generally limit employees to an administrative forum with circumscribed remedies. California is a notable exception: state employees may bring civil actions for monetary damages under legislation PEER drafted that became effective January 1, 2000. Consequently, California has one of the strongest state employee's whistleblower laws in the nation. See Cal. Gov. Code §§ 8547, *et. seq.*

Civil service statutes also require that the employee report some form of misconduct and limit protection only to retaliation caused by management knowledge of that disclosure. Most civil service whistleblower laws do not protect employees for —

Merely doing their jobs;

Expressing reasonable scientific conclusions; or

Adhering to professional ethical standards.

By contrast, statute-based federal whistleblower laws broadly protect employee disclosures that further the enforcement or the administration of that particular law. See, e.g., the Clean Water Act provisions at 33 U.S.C. § 1367. Seven major federal environmental laws have similar provisions; all are enforced by the U.S. Department of Labor. While these statutes are broad there are drawbacks:

Patchwork Protections. Protected speech is limited only to those disclosures furthering the particular statute. Thus, a disclosure relating to the Endangered Species Act (which lacks a whistleblower provision) would be outside the scope of the Clean Water or Clean Air laws.

Very Short Statute of Limitations. Claims must be made within a very short period, ranging from 15 days to six months, depending on the statute, following the act of discrimination or retaliation from which the employee seeks relief.

State Employees May No Longer Be Protected. Due to a string of U.S. Supreme Court cases during the past two years, an expanded doctrine of state sovereignty rooted in the Eleventh Amendment may preclude state employees from citing state agencies under federal law. PEER is litigating the lead case in this area on behalf of Rhode Island's top state hazardous waste scientist. That case is now pending before the federal First Circuit.

The Appearance of Impropriety

This final area is the least defined and most slippery of the lot. In many cases, resource agency employees are counseled that they cannot be involved in environmental issues or organizations in their off duty time because it would create the appearance of a conflict.

As the employee has no financial interest in these matters, in a strict sense there can be no "conflict of interest." Instead, the agency contends that the employee who is an off duty activist is guilty of the appearance of impropriety or partiality. At the federal level, the statutory bulwark of this prohibition can be found in 18 U.S.C. § 205 which bars a federal employee from acting as "an agent or attorney" against the United States in any "case or controversy."

In February of 2000, the limits of this statute were decided in the case of Jeffrey van Ee, an EPA electrical engineer based in Las Vegas who, on his own time, became an advocate for the desert tortoise. Many of you probably know his story. After ten plus years of litigation, the U.S. Court of Appeals for the District of Columbia ruled that van Ee had a constitutional right to advocate, belong to advocacy groups, serve as a spokesperson, and on boards of organizations concerning matters of public interest.

The Court, however, declined to strike down 18 U.S.C. § 205 as unconstitutional and only struck down EPA's interpretation of the statute as overly broad. Thus, there remains more of this legal swamp to drain.

Delivering the Message Without the Messenger

As a practical matter, few agency scientists want to invest the time, emotion, and often the sizeable expense of being a legal test case. At PEER, we constantly remind public employees that if they must fight their agency try to pick a terrain other than their own personnel jackets.

Moreover, even employees who win personnel litigation against their agency often cannot truly be restored to the same career path, professional standing, or peace of mind, before the matter arose. The very employees conscientious enough to take career risks over ethical issues are precisely the people who need to stay in public service.

PEER is not trying to create martyrs; we are trying to solve the environmental conflicts facing conscientious civil servants. To fill this role, PEER has developed a number of techniques designed to deliver the message to the agency while masking the identity of the messenger:

> **Anonymous Activism**. Under this technique, PEER, a professional society, employee union, or environmental organization serves as a vehicle for employee disclosures. With painstakingly careful planning and by using tools of collective disclosure, such as all-employee surveys or anonymously authored white papers, the identity of the true source can be protected;

Pen Pal Privileges. PEER allows employees to use our organizational stationery to communicate with their own agency. Thus, many of our Freedom of Information Act (FOIA) requests are actually drafted by the employee who is the custodian of a critical document but are signed by a PEER staff attorney. Through this technique, employees can file comments under the National Environmental Policy Act (NEPA) or under a counterpart state act. Any form of administrative interaction that a citizen can have with a public agency, a public employee can have as well; and

Litigation. While PEER does provide legal representation in the form of legal defense for whistleblowing or other protected speech, our preferred approach is to play legal offense, if you will, rather than employee defense. Since public employees are discouraged (and often legally prohibited) from suing their own agency for environmental malfeasance, PEER files citizen suits or other environmental enforcement actions in their place with the public servants as the unnamed but nonetheless quite real parties in interest.

In our experience, if the public agency is forced to confront the substance of an issue, without the ability to divert the debate or change topics, half the battle is won because in the clear light of day with focused public attention on the issue, most public agencies will do the right thing, only so long as the spotlight is squarely on them.

CONCLUSION

PEER is premised on the belief that, despite appearances to the contrary, public employees retain the full rights of citizenship. As such, public employees have the right, as well as the ethical duty, to be activists in the public interest. The role of PEER is to provide employees with ways to safely exercise their free speech rights by using their freedom of association, and to defend them when those rights are threatened. The acronym PEER connotes public servants as equals not relegated to a neutered, second class status.

DRY MATTER, ENERGY, AND NITROGEN DIGESTIBILITY IN NATURAL FOODS EATEN BY DESERT TORTOISES, *GOPHERUS AGASSIZII*

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The composition of the diets of desert tortoises has changed in the last fifty years as exotic plants have invaded and flourished in the Mojave Desert. It is possible that these exotic plants do not provide adequate nutrition for tortoises, which might compromise the health and survivorship of this species. We measured the apparent digestibility of dry matter, energy, fiber, and nitrogen in captive juvenile tortoises eating four different diets: *Achnatherum hymenoides* (a native grass), *Schismus barbatus* (an exotic grass), *Malacothrix glabrata* (a native forb), and *Erodium cicutarium* (an exotic forb). We offered known

amounts of dry grass for ~130 consecutive days, and forbs for ~90 consecutive days. Feces and uneaten food (orts) were analyzed for dry matter, energy, fiber, and nitrogen content. Apparent digestibility was calculated as:

100 x [(nutrient ingested – nutrient excreted)/nutrient ingested]

and nutrient availability in the foods eaten was calculated as: mg or kJ retained/ g dry food ingested. Bioavailability of dry matter, energy, and nitrogen was greater in forbs than in grass, and fiber content was variable between diets. Thus, nutritional quality of foods available to tortoises varied, but the differences were among food types (i.e., grass vs. forbs) instead of among geographic origin (native vs. exotic).

DESERT TORTOISE RESEARCH AT FORT IRWIN, CALIFORNIA: OVERVIEW AND IMPORTANCE OF RESEARCH IN TORTOISE RECOVERY

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The desert tortoise continues to either decline in numbers or remain at low numbers in the Mojave Desert. To foster the recovery of the tortoise, much more information is needed about its biology. Current and proposed research at Fort Irwin has the potential to answer many of these questions and will be critical to the recovery of the tortoise. Some of the critical questions include the following: How many desert tortoises are there? Are there sources and sinks for tortoise populations in different parts of the desert? What is the effect of climate and rainfall on tortoise population dynamics? What is the demography of the desert tortoise? Does it change in different places? What is the life history of the tortoise? How do the life history characteristics of the tortoise affect its demography? What is the role of disease in the demography of tortoise populations? Can tortoise populations be "jump started" to escape the predators in the desert such as ravens and kit foxes? Can tortoises be relocated to reestablish populations? In that context, are there important genetic differences between tortoises in different parts of the Mojave Desert? The research program at Fort Irwin can help answer many of these questions while helping the Army to minimize the effect of training on tortoise populations. Studies on hatchling biology, disease, demography and life history, and biophysical ecology and physiology will provide critical data to answer the above questions and to help recover the tortoise. This talk will discuss the important questions above and the role of these Army-funded studies in answering them.

DESERT TORTOISE REPRODUCTION AT TWO SITES IN THE SONORAN DESERT

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In 2001, we studied the reproductive effort for female desert tortoises at two sites in the Sonoran Desert. We monitored female tortoises from May to October by using ultrasound and x-radiography. At Sugarloaf, 60% (9 of 15) of mature (midline carapace length ≥220 mm) females developed eggs. None of three individuals <220 mm (187-199 mm) produced eggs. Mean clutch size was 5.3 eggs (range, 4-9). At Saguaro National Park, we monitored 14 female tortoises. Of these, 71% developed egg clutches. Mean clutch size was 6.9 eggs (range, 1-9). At both sites, ovarian follicles were observed in early May, and all clutches were deposited by August 9. We monitored two nests throughout the incubation period. One failed to hatch; the other produced seven neonates. All neonates were small (mean mass = 12.4 g, average MCL = 36.7 mm), and most failed to survive.

DESERT TORTOISE ECOLOGICAL RESEARCH AT SAGUARO NATIONAL PARK, ARIZONA

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Saguaro National Park has become a focal point for research on the Sonoran Desert population of the desert tortoise, and several collaborative studies are underway that build on previous survey efforts and research on fire effects. To assess the impact of urban development on tortoises we are using radiotelemetry to determine home-range sizes and tortoise movement patterns before and after development adjacent to the park. We are using distance sampling to determine changes in abundance over time, and genetic techniques to assess the effects of habitat fragmentation. We are also studying reproductive ecology and aspects of hatchling ecology such as timing of hatchling emergence, size distribution of

neonates, and after-emergence movement patterns. Finally, we are assessing the significance of positive tests for *Mycoplasma* in this near-urban park tortoise population. Continued research by scientists in this multi-agency partnership is planned to increase our knowledge of how urban development and other environmental factors affect long-term survival of individual tortoises and tortoise populations.

CLIMATIC FLUCTUATIONS AND DESERT VEGETATION RESPONSE IN THE SOUTHWESTERN UNITED STATES

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The twin concepts of preservation and restoration typically require either an assumption of an unchanging undisturbed ecosystem or that changes induced by climate or human land-use practices are predictable. Long-term monitoring ("vital signs") is being instituted for many desert parcels managed by federal and state governments with the intent of detecting change and responding with alteration in management practices. Other common concerns in the Southwest are the "degradation" of desert grasslands by establishment of woody shrubs and trees (Wilson et al. 2001); the downslope movement of junipers onto rangelands (Rogers 1982); the reported loss of riparian ecosystems (Webb et al. 2001a); and whether anthropogenically-driven directional change is occurring in desert ecosystems (Turner et al. 2003).

Directional changes in species composition of Southwestern rangelands have been documented throughout the 20th century. Change has occurred irrespective of land-use practices (Turner 1990, Webb 1996). In all cases, woody vegetation with C3 photosynthetic pathways has expanded, sometimes at the expense of C4 grasses (Wilson et al. 2001, Turner et al. 2003), but in other cases into previously unoccupied habitat (Webb 1996). Turner et al. (2003) have found large increases in biomass depicted in repeat photography of the Sonoran Desert, particularly between the 1960s and 1990s. The conversion of rangeland to woody C3 species has continued despite overall reduction in livestock grazing intensity in the latter part of the 20th century. Despite real concerns about removal of wetlands, riparian vegetation has dramatically increased, not decreased, in most riverine habitats of the Southwest, particularly after 1960 (Webb et al. 2001a, Turner et al. 2003). Biomass in common Mojave Desert ecosystems (particularly ones dominated by *Larrea tridentata*) has increased by a factor of two to four on the Nevada Test Site (Webb et al. 2001b). The expansion of C3 species appears to cross ecological types in the Southwest and northern Mexico and may result from the three interrelated effects of: (1) increased winter precipitation that occurred particularly after 1975 (Wilson et al. 2001, Turner et al. 2003); (2) increased winter temperatures, particularly minima (Webb 1996); and (3) increased atmospheric CO_2 (Bazzaz 1990). Irrespective of the reason, considerable amounts of carbon have been stored in C3 plants in the region.

No attempts have been made to estimate the amount of carbon sequestered in plant biomass over the region using anything remotely approaching an ecosystem-based technique. Several methods can be used to quantify density, cover, and (or) biomass increases, but usually these methods are applied to a few small, permanent plots (Beatley 1980, Goldberg and Turner 1984, Webb et al. 2001b). Permanent plots can be used to quantitatively document long-term vegetation changes, but their number, size, and local conditions at the plots may reduce their regional representation. Systems of regional plots, which typically are designed to monitor single-species changes, are one way to scale plot data to larger land areas (Pierson and Turner 1998).

Several large-scale methods have been used to assess the magnitude of long-term ecosystem changes in the Southwest. Satellite instruments are the most common tools for global and regional assessments of change from 1974 to the present (Kepner et al. 2000), but this technique can only detect very broad habitat change. Aerial photography is commonly used to assess changes in vegetation cover and is available over most of the Southwest from 1935 to the present, but like satellite-based imagery, aerial photogrammetry is limited to assessment of broad changes. In contrast to aerial images, repeat photography can be used to assess changes in plant size, density, and species dating back more than a century, and historical photography is widespread in the region. Large numbers of repeat photographs, and particularly time series photography at specific locations, are required to offset the lack of spatial coverage in each image.

The Desert Laboratory Repeat Photography Collection, combined with related efforts in the region (Figure 1), provides an ideal technique for assessing carbon sequestration in arid and semiarid ecosystems. At present, the aggregate collection contains 5,795 views in most of the region's ecosystems (Table 1), excluding higher-elevation forests. The motivation for building this collection, which was done over a 40-year period by USGS and Mexican-government scientists, was to document long-term landscape changes in the desert regions, including changes in plant biomass. We have documented that the amount of carbon sequestered in arid and semiarid ecosystems has increased in the 20^{th} century in most of the ecosystems in the southwestern United States, particularly since 1960. This biomass increase has occurred despite development and land-use pressures on ecosystems such as grazing and water developments. Increases in winter precipitation and temperatures, as well as increases in atmospheric carbon dioxide, are the probable reasons why biomass has increased in nearly all the vegetation alliances of the region.

The predicted shift to a warmer and drier future climate is based on an analogy to conditions between about 1942 and 1975 in the southwestern United States (Figure 2)(Schmidt and Webb 2001). Because our photographs closely span this period, we have some basis for speculation on how the predicted climate shift may affect carbon sequestration. Increased winter temperatures might increase winter growth and even benefit C3 seedling

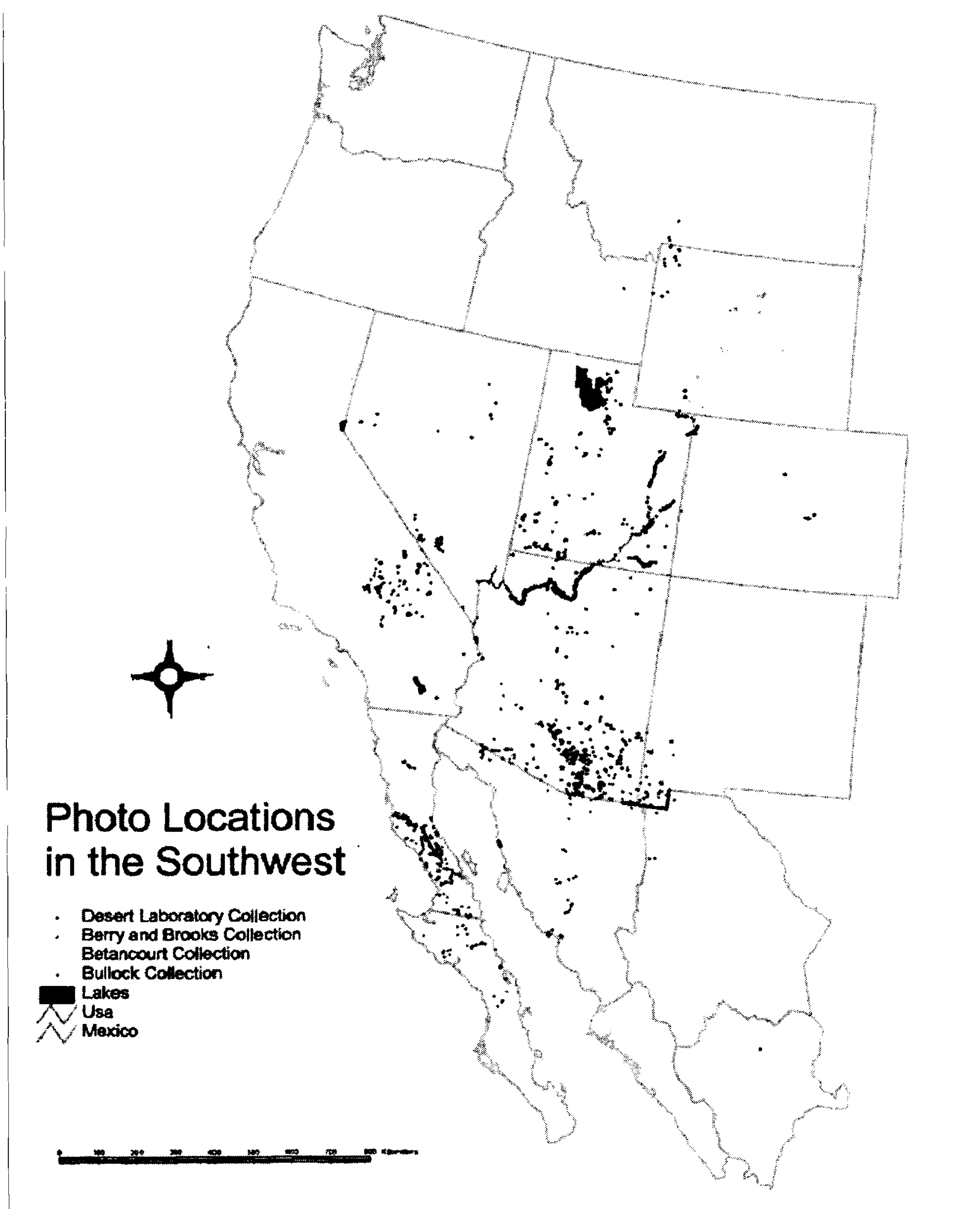

Figure 1. Locations of repeat photography camera stations in the southwestern United States and northern Mexico.

Table 1. Listing of repeat photography by region in the southwestern United States.	
Description	Number of Photos
Total Desert Lab Collection	5236
Collaborator Photos	559
Major rivers in region	2096
Mojave Desert	400
Great Basin Desert	311
Sonoran Desert	1615
Colorado Plateau	157
Chihuahuan Desert	137
Baja California	401

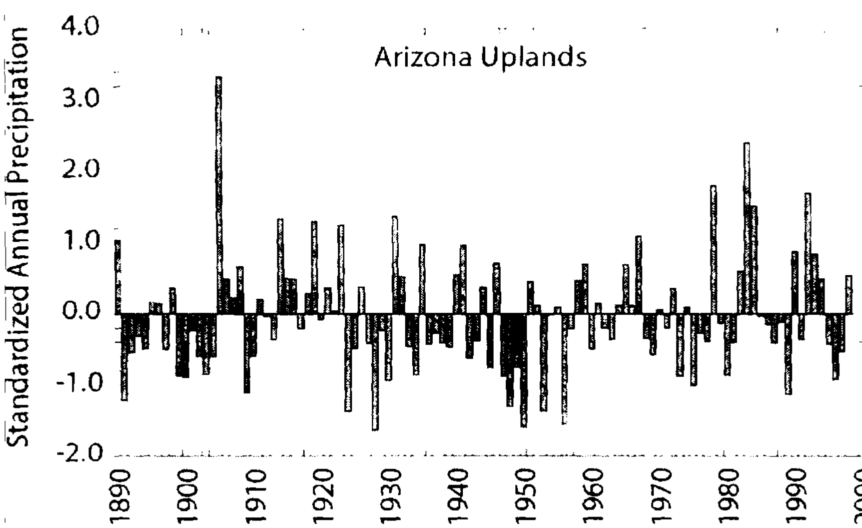

Figure 2. Long-term precipitation changes in the upper Sonoran Desert (from Turner et al. 2003).

establishment. However, pressures on surface-water and ground-water systems will largely drive overall changes in riparian ecosystems, and lack of winter floods and decreased winter precipitation will likely minimize recruitment along natural watercourses and across the desert in general. The recent increases in C3 plants, particularly in desert grasslands, may slow. Drought pruning will probably increase, but carbon storage in the ecosystem may not change much because decreases in soil moisture may decrease the rate of litter decomposition. If severe droughts occur, populations of certain species, particularly members of the Chenopodiaceae, may be deleteriously affected, which could change the nature of some vegetation alliances in the region.

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THE EVOLUTION AND DESIGN OF THE ARS-VIVANT WILDLIFE PROTECTOR SYSTEM FOR USE IN RAISING NEONATE DESERT TORTOISES

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ABSTRACT

This paper traces the design process and the development of the Ars-Vivant Wildlife Protector System. This "natural setting" modular-mobile system is presently used as nursery modules to raise desert tortoises (*Gopherus agassizii*). The paper presents how scientific methodology, mathematics, and scientific data can be used to create a design that is both functional and aesthetically beautiful.

A rare and wonderful opportunity is served to any architect/structural designer the moment he is asked to make creative use of his knowledge and the skills of his profession to assist in the revival of any threatened species of wildlife. An opportunity of this nature served as a catalyst for a personal evolution within a profession that is, at its very best, barely neutral with respect to the preservation of our environment. When the species to be protected happens to be that eternally noble desert wanderer and survivor, *Gopherus agassizii*, the opportunity is all the more delicious; delicious because in the thirty years that I have lived within desert tortoise habitat, personal sightings of this animal have dwindled to nearly zero.

The golden opportunity was presented one day in 1996, when Dr. David Morafka asked if I might be interested in creating a design for an experimental nursery for the purpose of raising desert tortoises at the Ft. Irwin Study Site experimental station in the southern California desert.

INITIAL DESIGN

A successful design was required to have characteristic features that resolved certain specific problems intrinsic to the large, permanent nurseries in use at Ft. Irwin (Morafka et al. 1997). The two nurseries at the Base are known as FISS-I and FISS-II (Ft. Irwin Study Site). Each is a permanent square enclosure of 3,600 m^2. FISS-I is constructed mostly of wood and chicken wire. FISS-II is made of galvanized steel posts and chain link fencing.

Resolution of the problems inherent in FISS-I and FISS-II was the initial catalyst in the development of the modular system for the protection of wildlife, which is now known as the Ars-Vivant Wildlife Protector System. The evolution of the design spans 1996 to 2003, and continues today (U. S. Patent 6,532,701 on March 18, 2003).

The prototype design for the experimental nursery became known as FISS-III. It was erected at the Tortoise Experiment Station at Ft. Irwin, in mid-Spring 1997.

FISS-I and FISS-II adequately protected hatchling desert tortoises from major predators; ravens, coyotes, and foxes. Because the structures are considered permanent, they presented researchers with several potential problems:

- Soil and flora depletion, resulting from overuse of the facilities at a single location; and
- Juvenile tortoises, if held in the cages for extended periods before release into the natural environment demonstrated a tendency to return "home." They would gather at the perimeters and be easily taken by predators.

To resolve these and other short-comings, Dr. Morafka and I developed the following design criteria for FISS III:

Environmental and Species Considerations

- Minimum impact on the environment;
- Preservation of the natural environment for the species: e.g., sunlight, vegetation; and
- Maximum predator resistance.

Facilities Considerations I

- About 280 m^2 of contained and protected natural environment; headspace to accommodate a 1.8 m-tall person;
- Components should be modular, lightweight, reusable, and with minimum numbers;
- Able to survive desert conditions (extremes in temperature, wind, etc.);
- Must be moveable and relocatable;
- Can be installed by two persons using commonly available tools; and
- Structural components must have a 20-year minimum life and covering parts must have 5-year minimum life.

After FISS III was installed, the following criterium was added to the list:

Facilities Consideration II

- Must be expandable and contractible.

In initial design considerations, my first step was to establish criteria for the perimeter boundary shape of the nursery.

Fundamental Geometric Considerations

Because both modularity and minimum weight were of fundamental importance for the initial design, it was necessary to develop a nursery that would enclose the greatest amount of ground surface area with the (theoretically) least amount of material. It is a geometric fact that, on a planar surface, a circle encloses the greatest possible area with the minimum amount of perimeter length. At the opposite end of the scale, and within the family of regular polygons, an equilateral triangle is known to enclose the least interior surface area with the greatest amount of perimeter length. Therefore, each member of the family of regular polygons falls between these polar limits (Table 1).

As can be seen from Table 1, the 90-degreeness of the square has an inherent inefficiency when compared to a circle and other polygons. This is because the basic geometry of the square requires 13% more perimeter length than a circle to enclose an identical interior area. From this brief discussion it can be understood that if one wishes to modularly enclose a certain area efficiently, the use of a polygon that closely approximates a circular ground plan would be the most efficient way to accomplish the task. Minimum materials would be required and the faceted polygon enclosure could be assembled, disassembled and reassembled.

Table 1. Certain selected polygons: percentage of increased perimeter length required to enclose equal interior areas (Williams 1979).

Polygon	% increase of perimeter length to enclose unit area
Circle	0%
Dodecagon (12-edges)	1.0%
Decagon (10-edges)	1.2%
Octagon (8-edges)	2.7%
Hexagon (6-edges)	5.0%
Pentagon (5-edges)	8.0%
Square (4-edges)	13.0%
Triangle (3-edges)	29.0%

For the specific case of FISS III, I decided on a decagon perimeter boundary with 6 m long structural panels. This configuration offered great economy, having only 1.2% more perimeter length than a circular system to enclose the required 270 m^2 of interior space. While it would have been possible to use a dodecagon to accomplish the same result, I chose a decagon in order to have fewer components to manipulate in the field.

FISS III was installed at Ft. Irwin in May 1997. This nursery module enclosed about 270 m^2, and consisted of:

- 10 each, about 2 x 6 m structural panels with attached chain link fencing. All metal was galvanized;
- Center post with tension cables and screw anchors set outside the perimeter boundary of the enclosure;
- Hardware cloth set 50 to 67 cm in the ground and 33 to 50 cm above ground and attached along the entire perimeter; and
- A flexible net cover attached to the top. The cover was made of commercial fishing net woven into a square pattern with 5 cm a side. A sun resistant coating was impregnated into the fabric. The cover allowed 88 to 90% of natural sunlight to penetrate the interior space while protecting the interior space from air-borne predators.

FISS-III encloses about 270 m^2 with about 0.6 m^2 of material in actual contact with the surface of the earth.

IMPROVED DESIGN

Within a few months of installation of FISS III, Dr. Morafka asked if it would be possible to retain the best elements of FISS-III and redesign the system to include the additional feature that it be expandable and contractible. He believed that the system would have more value if the space could be doubled, tripled, or quadrupled, simply by using additional identical components. By making two modifications in the original design, I was able to achieve the desired results:

- For geometric reasons, two additional panels were added to the perimeter of the basic enclosure;
- The length of each structural panel was reduced by 1 m, such that the dimensions of each panel were approximately 2 x 4.5 m.

The first modification allowed enclosed spaces to be expanded and contracted. The second modification made the panels easier to transport, both on the highways and by hand in the field. The change from decagon to dodecagon perimeter geometry was fundamental for maximizing the expansion-contraction capabilities of the Ars-Vivant System.

The key for a design to have the ability to expand and contract spaces of this nature lies in the geometric requirements for covering a floor with identical regular polygons. It is interesting that only three possibilities exist to accomplish this: the square, the beehive hexagon, and the triangle.

By combining the economical features of observed clusters of soap bubbles with the hexagon geometry found in bee hives it was possible to derive a design for an expandable and contractible modular system that allows each module to retain the economy of the circle. The key to being able to use the separate geometries of the hexagon and the dodecagon to achieve great economy lies with the "hidden" hexagon that lives within every dodecagon. The same type of integration of geometries holds when hexagons and dodecagons are transformed into three dimensions. We then begin to have a three-dimensional geometry that has inherently more practical use for our needs.

In June 2002 we installed about 1,400 m^2 of enclosed natural habitat nurseries with two *1-Module* nurseries and one *3-Cluster Module* nursery (Figures 1 and 2) at Edwards Air Force Base, California. We also installed five, 11 m^2 modular-mobile quarantine enclosures. The nurseries are one part of a joint effort between the United States Army, the United States Air Force, and California State University at Dominguez Hills.

CONCLUSION

Improvements in the Ars-Vivant Wildlife Protector System continue. For example, at Edwards Air Force Base, we had difficulty installing the tension cables. We have made a design change that should eliminate the problem.

The most time consuming and environmentally destructive aspect of all field installations of the Ars-Vivant System is the installation of the underground predator barriers of hardware

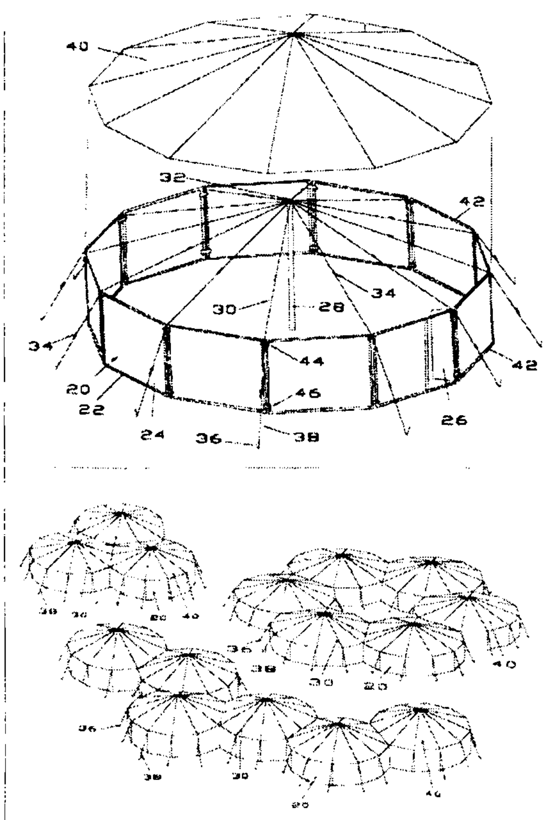

Figure 1. Partially exploded view of the basic module of the Ars-Vivant Wildlife Protector System. Examples of the many clustering possibilities using the Ars-Vivant System.

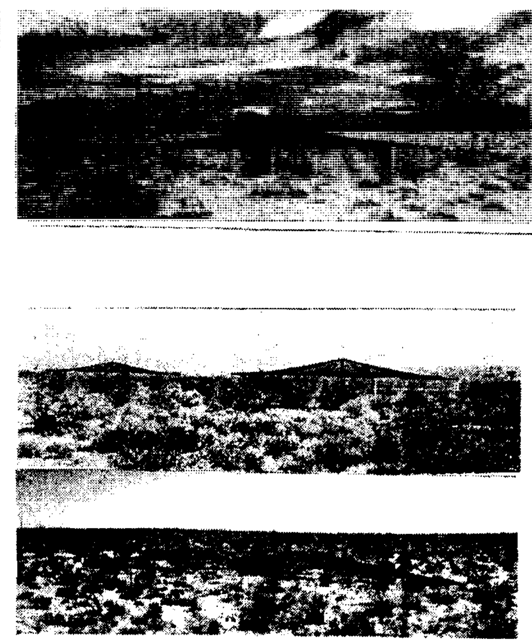

Figure 2. Top: photo of FISS-III installed at Ft. Irwin, California. Middle: the two 1-Modules installed at Edwards Air Force Base. Below: the 3-Cluster Module installed at Edwards Air Force Base.

cloth. The installation difficulty is matched by the difficulty of removal of the hardware cloth when a module is removed. While I believe that a mechanical underground system is the most reliable method now, it remains an unsolved and troublesome issue.

I believe that we have optimized the system in response to both the initial and subsequent design criteria specified by Dr. Morafka. The geometry and the materials have, thus far, functioned superbly.

ACKNOWLEDGEMENTS

I gratefully thank Dr. David Morafka for the unique opportunity to be involved in an effort of this nature. The National Training Center at Ft. Irwin, California supports the research program at the Fort Irwin Study Site. The U. S. Army, the U. S. Air Force, and California State University at Dominguez Hills support the research program at the Juvenile Hatchery at Edwards Tortoise Study Site (JHETSS) at Edwards Air Force Base.

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ABSTRACTS AND PAPERS FROM THE

28TH ANNUAL SYMPOSIUM

LAS VEGAS, NEVADA, FEBRUARY 21 to 23, 2003

COMMUNITY INVOLVEMENT THROUGH ENVIRONMENTAL EDUCATION

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The Bureau of Land Management, Friends of Red Rock, Red Rock Interpretative Association, volunteers, and college interns have developed an education program to coincide with the Mojave Max Emergence contest. A Mojave Max educational program and training guide was developed. Volunteers were trained, and they presented the information in classrooms of Clark County. The educational module teaches creative methods, including dressing up a student like a tortoise. Teachers volunteering for the project were eligible for college credit. The project was reviewed and evaluated by the participants. More than 4,800 students from 37 schools were reached through this project. This project was funded by Friends of Red Rock. The Mojave Max Emergence Contest enabled this education program to get off the ground. Successful partnerships were developed, educational goals were initiated, and the framework for a Mojave Desert classroom education program was established.

COMPARISON OF SONORAN AND MOJAVE TORTOISES: SHOULD THE SONORAN TORTOISE BE LISTED?

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ABSTRACT

Most research and management attention on desert tortoises is focused on the Mojave population due to its precarious status, but the Mojave population only accounts for about one third of the species' range. In this paper, I evaluate how tortoise populations are doing in the Sonoran portion of their range. Few data exist from Mexico (although recent reports indicate that some disease-related declines may be occurring in at least some populations; M. Vaughn, pers. comm., 2002), so I will concentrate on the Sonoran desert tortoise in Arizona and compare its status with that of the Mojave population.

The "Mojave" population, as recognized under the Endangered Species Act (ESA), occurs north and west of the Colorado River, and the "Sonoran" population is south and east of the

Colorado (U.S. Fish and Wildlife Service [USFWS] 1990). The Mojave population was historically characterized by a more or less continuous distribution, while the Sonoran population typically occurs in disjunct, desert mountain foothills (Bury et al. 1994, Gpermano et al. 1994). This distribution pattern is explained primarily by habitat differences (Germano et al. 1994). Genetic differences underlie these patterns (Lamb and McLuckie 2002), and the two populations also vary in other aspects of their natural and life histories (Luckenbach 1982, Germano 1993, Averill-Murray 2002).

In 1991 (the year after the Mojave tortoise was listed as threatened), the U.S. Fish and Wildlife Service determined that listing the Sonoran population was not warranted based on several factors (USFWS 1991): their disjunct populations likely inhibit spread of infectious disease; no evidence of pandemic disease existed; their habitat is less susceptible to disturbance; and an apparent lack of threats in Mexico. These factors were summarized by a 1990 status report, which also included early population monitoring results (Barrett and Johnson 1990).

All the attention on the tortoise before the listing decisions, caused several state and federal agencies in Arizona to form the Arizona Interagency Desert Tortoise Team (AIDTT) to conduct and coordinate research and management efforts for the species in the state. The AIDTT was formalized under a Memorandum of Understanding in 1995. A management plan for the Sonoran tortoise was completed in 1996 (AIDTT 1996). An updated status report, completed in 2000, indicated that the Sonoran population was still stable, even though some threats were identified (AIDTT 2000). This status report summarized an increasing body of research from the last 10 years and included monitoring results from several populations across the state.

SONORAN POPULATION MONITORING

Sixteen populations currently make up the core of Arizona's monitoring program. Most plots exhibit relatively flat trends (for "adult" tortoises), except the Maricopa Mountains in the late 1980s (Fig. 1, Averill-Murray et al. 2002). In 2000, even the Maricopas showed signs of rebounding (Fig. 1). However, four other plots from different parts of the range showed apparent steep declines after the 2001 to 2002 surveys (Fig. 2): the Tortilla Mountains in the east-central part of the tortoise's Arizona distribution, San Pedro in the southeast, and East Bajada (Black Mountains) and Hualapai Foothills in the northwest.

These trend data must be taken somewhat with a grain of salt. Abundance estimates before 2000 were based on multiple years; only since 2000 have independent plot coverages been conducted within an annual survey to derive a valid estimate for that year. For example, the

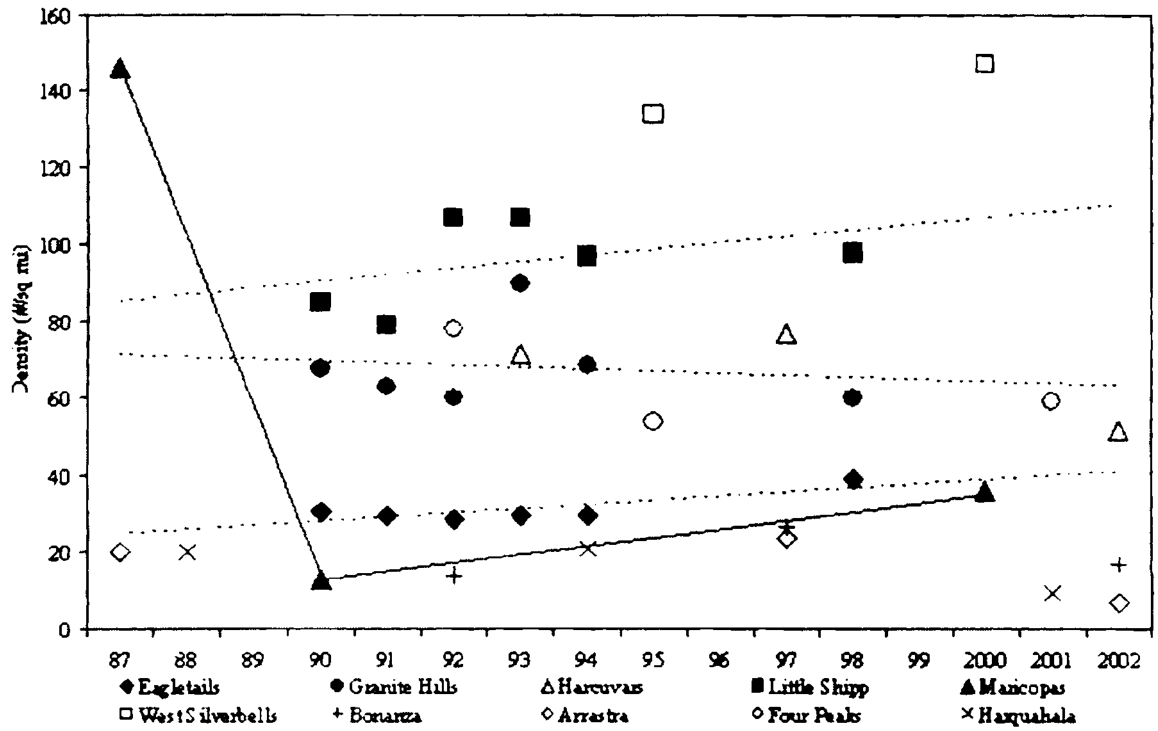

Figure 1. Desert tortoise density estimates from long-term monitoring plots in the Sonoran Desert, Arizona. Confidence limits and some trend lines are not included to reduce clutter.

Lincoln-Peterson estimator applied to the Hualapai Foothills plot using the 1996 survey as the "mark" period and the 2001 survey as the "recapture" period produced an estimate of 69 adult tortoises (95% CI=41-97), whereas the estimate using separate independent plot coverages during the 2001 survey was 16 (95% CI=14-18, as shown in Fig. 2)(Woodman et al. 2002). Therefore, we need a few more years of monitoring to get a better feel for recent trends in tortoise numbers at each site.

Mortality estimates provide another means to give us a sense of tortoise status at each of these plots. Figure 3 shows the proportion of carcasses relative to all live tortoises plus carcasses during selected annual plot surveys. Note that initial plot surveys often have elevated carcass numbers (accumulated mortality before carcass removal; for example, Arrastra Mountains and Bonanza Wash). The Maricopas show a decline in relative carcass numbers in 2000, corresponding with the apparent, but slight, population increase.

The four plots showing steep declines in 2001 to 2002 (Fig. 2) have mixed results when looking at relative carcass numbers. Mortality increased dramatically at the East Bajada.

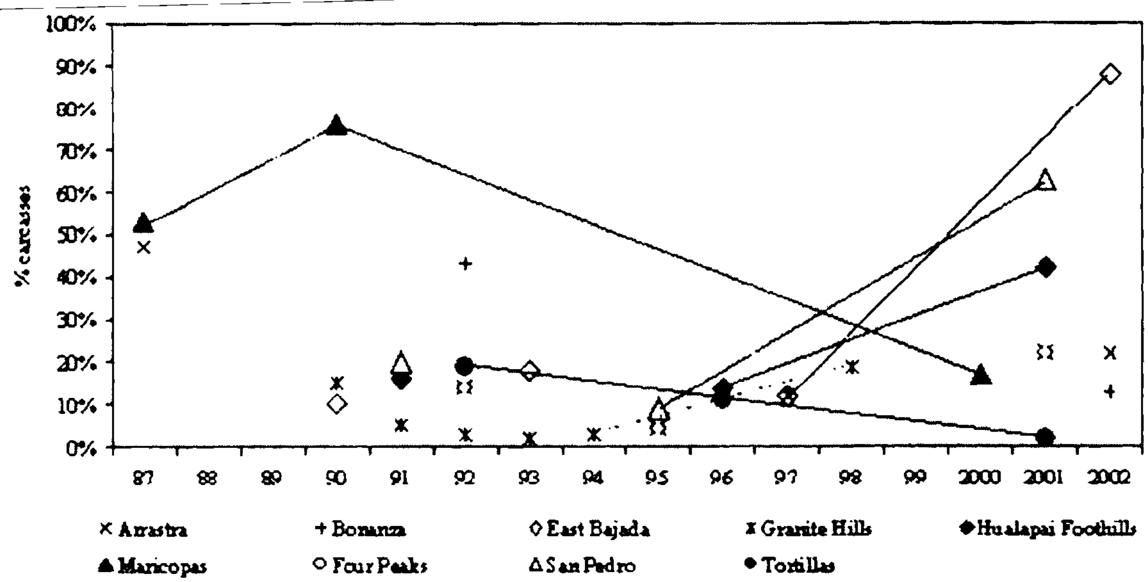

Figure 2. Desert tortoise density estimates from long-term monitoring plots showing recent apparent declines in the Sonoran Desert, Arizona.

Disease may have played a role in this decline, as signs were noted during the previous (1997) survey (Woodman et al. 1998). Note also that, genetically, the East Bajada population aligns with other Mojave Desert populations of tortoises (Lamb and McLuckie 2002). The San Pedro population also experienced a sharp increase in mortality, but from an unknown cause; few disease signs have ever been noted in this population (Hart et al. 1992, Woodman et al. 1996).

The apparent decline of the Hualapai Foothills population is also a mystery. No significant disease signs have been observed at this site (Hart et al. 1992, Woodman et al. 1997). Prior surveys found eight and six carcasses in 1991 and 1996, respectively, compared to 11 in 2001 (Woodman et al. 2002). Live tortoises decreased even more sharply than carcasses increased, however: 36 in 1991, 36 in 1996, and 15 in 2001. Increasing development and human presence may be resulting in poaching, but, just as likely, fewer tortoises may have been detectable during this particularly dry year. The extremely precise Lincoln-Petersen estimate noted above from 2001 may be due to a lack of captures (and recaptures) of individual tortoises that remained in deep shelter sites throughout the survey. Similarly, fewer tortoises were found on the Tortilla Mountains plot in 2001, probably as a result of environmental conditions; relatively few carcasses have been found on this plot every year (Fig. 3, Woodman et al. 2002). Granite Hills and Four Peaks plots had somewhat elevated mortality. Both had

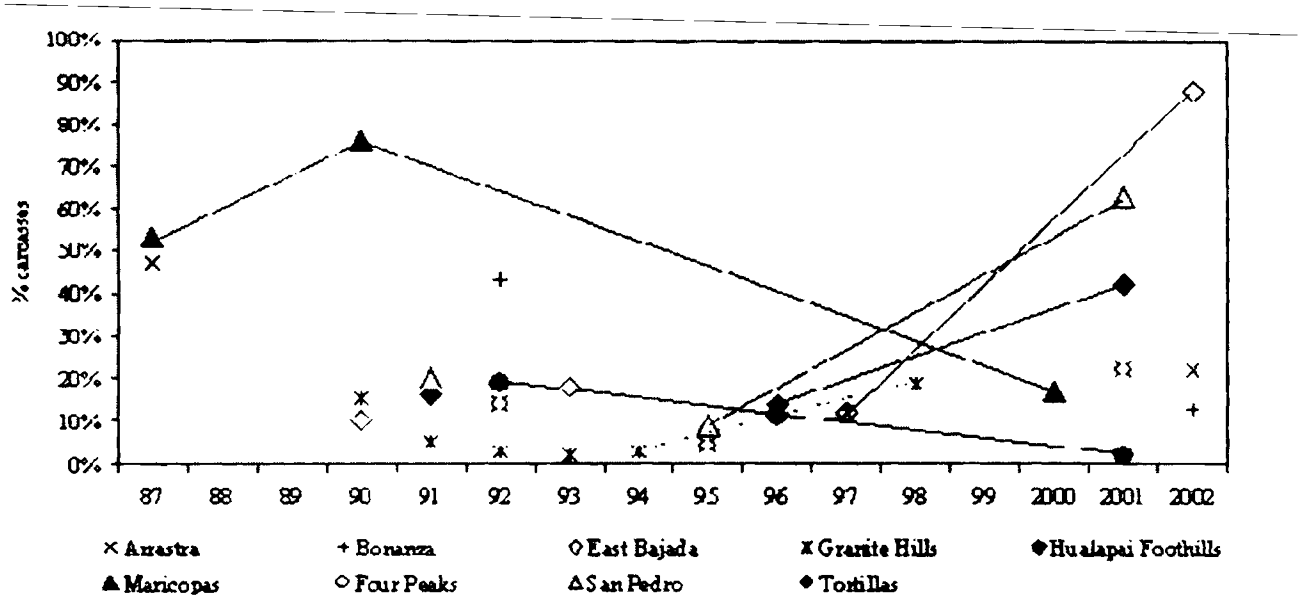

Figure 3. Relative desert tortoise carcass numbers (y=[carcasses/{carcasses+live tortoises}]*100) on selected long-term monitoring plots in the Sonoran Desert, Arizona. Plots with consistent relative carcass numbers ≤20% are not shown.

elevated mountain lion predation combined with accumulated mortality over four or more years (Woodman et al. 1999, 2002).

LISTING FACTORS FOR MOJAVE AND SONORAN TORTOISES

Given the population data described above and current tortoise research and management information relative to the Sonoran population, this section compares the five factors for listing a species under the ESA for the Mojave and Sonoran populations. The five factors are: (1) present or threatened destruction, modification, or curtailment of the species' habitat or range; (2) over utilization for commercial, recreational, scientific, or educational purposes; (3) disease and predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or manmade factors. Table 1 lists the factors that contributed to the listing of the Mojave population as threatened, and the following discussion compares these factors for the Sonoran population.

Impacts due to urbanization, unrestricted vehicle use, large surface disturbances, and grazing are relatively limited or localized for Sonoran tortoises due to their steep, rocky habitat

Table 1. Factors contributing to the listing of the Mojave desert tortoise as threatened (USFWS 1990).	
General Threat	Specific Threat
Habitat loss/destruction	Urbanization Unrestricted vehicle use Large surface disturbances Roads Grazing Fire
Over utilization	Collection Vandalism
Predation/disease	Ravens Feral dogs Upper respiratory tract disease Shell disease Toxicants
Adequacy of regulations	Collection prohibited, but continuing Few state habitat regulations (except CA) Limited federal regulations
Other factors	Drought Fragmentation due to population declines

(Howland and Rorabaugh 2002). Direct impacts from roads are similar to the Mojave Desert, or perhaps slightly less extensive in the Sonoran Desert due to the habitat. Fire is of concern in the Sonoran Desert due to increasing invasions of non-native plants, especially annual and perennial grasses (Esque et al. 2002). In addition to direct mortality during burns, changes in the availability of food plants and changes in the thermal environment may have detrimental effects on tortoise populations. Roads contribute to the establishment and spread of invasive plants, and habitat effects of grazing may also play a role.

Collection and vandalism appear to be fairly limited, primarily due to the difficulty in finding tortoises in their structurally complex habitat. Opportunistic collection and killing of tortoises certainly does occur on occasion, however.

Complex Sonoran tortoise habitat also makes it difficult for aerial predators like ravens to have an effect on tortoises; however, predation by feral dogs has been observed at some sites, including the East Bajada population that crashed (Averill-Murray et al. 2002). Most (8) sites in the Sonoran Desert at which tortoises have recently (2000-02) been tested for *Mycoplasma* antibodies have returned all negative results (Arizona Game and Fish Department, unpubl. data; tortoise samples in 2002 include n=2 for East Bajada and n=4 for San Pedro). However, we have found seropositive tortoises at the two sites surveyed closest to urban areas: 11% at Ragged Top, at the Ironwood Forest National Monument northwest of Tucson, and 84% at Saguaro National Park and the Rocking K Ranch east of Tucson. Note, though, that only a partial decline has occurred at Ragged Top, and no decline has occurred at Saguaro National Park; it is unclear at this point whether URTD affects Sonoran tortoises as severely as Mojave tortoises.

Shell disease (cutaneous dyskeratosis) has been recorded from virtually every tortoise population studied in Arizona (Averill-Murray and Klug 2000, Dickinson et al. 2002). However, the pattern of these observations does not provide a smoking gun for local declines. Only four plots (29%) out of 14 with at least two years of relevant data have shown increasing incidence of shell disease in the most recent surveys compared to prior surveys. Only one of these corresponds to an observed decline (Hualapai Foothills, but few carcasses exist to support the correlation); however, few observations during the last survey of the East Bajada population could be made due to the high mortality at that site.

Existing regulations are similar for the desert tortoise in Arizona and the Mojave portion of its range. The AIDTT management plan has provided some federal management guidance. The Bureau of Land Management also requires compensation for projects occurring in tortoise habitat in the Sonoran Desert, as well as the Mojave. The Arizona Game and Fish Department and several federal agencies, working through the AIDTT, are also in the process of developing a State Conservation Agreement (see below).

Effects of drought on tortoise populations will likely be fairly similar between the populations, although the greater precipitation the Sonoran Desert typically receives during the summer provides more drinking and foraging opportunities for Sonoran tortoises during all but the most severe drought conditions (Oftedal 2002, Van Devender et al. 2002). Mojave populations have been fragmented as declines in some areas leave others more isolated. Recent genetic studies provide evidence of historic genetic interchange between local Sonoran populations (Edwards et al. 2002), but Sonoran populations are increasingly being cut off from each other by urban and agricultural development, roads, canals, and other impacts. These types of fragmentation reduce chances for tortoises to move from one population into habitat that has suffered a decline, and they reduce general genetic interchange.

To summarize the threats to Sonoran tortoises, there are only a few at a scale large enough to likely affect tortoise populations. Exotic plants with associated fire risks are a relatively large-scale threat that could result in incremental effects to tortoise populations. Other than direct mortality associated with roads, fragmentation represents a longer-term threat to population viability and reestablishment at sites with local declines. While widespread, the implications of shell disease are unknown. More isolated threats include urbanization and surface disturbances. OHV effects are probably relatively minor, other than through rapidly increasing human populations bringing OHV recreationists into contact with tortoises more often. Feral dogs have had small effects on local populations. Releases of pet tortoises to populations near urban areas have as of yet undetermined effects through transmission of disease or genetic contamination.

PROSPECTS FOR THE SONORAN POPULATION

While the data at hand do not support listing at this time, one may ask what agencies are doing in Arizona to continue to ensure that the Sonoran tortoise does not need ESA protection. Even though the AIDTT developed a management plan for Sonoran tortoises, it has suffered from spotty implementation and a lack of specific goals and commitments for tortoise conservation. Therefore, the next step we are taking is the development of a State Conservation Agreement that will provide a coordinated commitment to implement actions to achieve common management goals and objectives.

By making a proactive commitment now, we will reduce the potential to list the Sonoran tortoise under the ESA and save significant financial costs associated with recovering a long-lived species after it has already reached the threshold of endangerment. For example, expenditures to date on the Mojave population exceed $100 million (U.S. General Accounting Office 2002). Finally, most desert tortoise management needs occur on federal lands, making a conservation agreement an appropriate, cooperative tool for ensuring the maintenance of viable populations into the future.

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DESERT TORTOISE MANAGEMENT IN ARIZONA

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The listed Mojave population of the desert tortoise occurs in Arizona only in the extreme northwest corner of the State north of the Colorado River, a relatively small area within the Northeast Mojave Recovery Unit. The Arizona Game and Fish Department (AGFD) continues to work closely with the Bureau of Land Management (BLM) and the U.S. Fish and Wildlife Service to monitor the population status of tortoises within this region through both plot monitoring and distance sampling. Habitat management is covered primarily by BLM's Arizona Strip Resource Management Plan, which was prepared, in part, to implement the Mojave population's recovery plan. Additional management actions are needed to address threats related to highway mortality and disease.

In the Sonoran Desert, AGFD and many cooperators continue to monitor population trends and conduct research on the ecology of this population to provide information to better manage the Sonoran tortoise and preclude the need to list under the Endangered Species Act. This research also provides comparative data that may contribute to recovery and management actions for the Mojave population. Members of the Arizona Interagency Desert Tortoise

Team are beginning development of a State Conservation Agreement to further ensure the conservation of the Sonoran population.

ACCOMPLISHMENTS OF THE DESERT TORTOISE COUNCIL IN 2002

Tracy Bailey

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The Desert Tortoise Council (DTC) was formed in 1976 to promote conservation of the desert tortoise in the southwestern United States and Mexico. The single overriding goal of the Desert Tortoise Council is to ensure the survival of viable populations of the desert tortoise throughout its range (Stewart and Berry 1995). During 2002, the DTC continued to strive towards its goal by organizing the annual symposium and workshops, sending letters of comment regarding environmental issues to government agencies, maintaining the web site, and contributing funds for a special volume of Chelonian Conservation and Biology on the genus *Gopherus*. In 2002, the Council had 650 members with 12 officers representing the states of California, Nevada, and Arizona. Representation from the state of Utah is still desired. The Council's accomplishments are outlined below.

In March, the Council held its 27th Annual Symposium. The best and brightest managers and researchers came to Palm Springs to participate in this important conference. Forty papers were presented, including such topics as health assessment of tortoises, tortoise conservation, climate, and ethics. There were 164 registrants, including 50 from government agencies, 32 from universities, 25 from consulting firms, and 22 from other organized groups.

The 11th Annual Desert Tortoise Handling, Monitoring and Surveying Workshop was held in Ridgecrest, California. The DTC coordinates these workshops because we believe that well-trained, knowledgeable biologists and monitors for projects play essential roles in the conservation of tortoises and their habitats. One hundred students attended this year, bringing the total 11-year enrollment to more than 700.

A portion of DTC funds were spent on travel for the Desert Tortoise Health and Disease Workshop, for at least two presenters to give materials at the Symposium, as well as to make copies of the workbook. The DTC will also provide funds to publish and distribute the findings. The final report will contain: What we know, what we suspect, what we don't know and what we need to know. Two moderators led the workshop: Dr. Carol Meteyer from U.S. Geological Survey's National Wildlife Health Center Office in Madison, Wisconsin and Dr. Jerry Simecka from the Department of Molecular Biology and Immunology, University of North Texas Health Science Center. Also present were 15 scientists and biologists and 18 other participants.

The DTC was represented at 12 meetings of the West Mojave and the Northern and Eastern Colorado Desert (NECO) Plans. The DTC sent 11 comment letters to the Bureau of Land Management, National Training Center, Federal Energy Regulatory Commission, Mojave National Preserve, National Park Service, and California City. The DTC sent scoping comments to the Mojave National Preserve and National Park Service regarding their Livestock Management Plan and Fire Management Plan. Other scoping comments were sent regarding the West Mojave Plan and Environmental Impact Statement, Automotive Test Course Project at California City, and Fort Irwin Expansion. The DTC along with nine other groups, including the Desert Tortoise Preserve Committee, Center for Biological Diversity, Desert Protective Council, Sierra Club, and Public Employees for Environmental Responsibility, sent a letter of protest to the Bureau of Land Management over the NECO Plan. The DTC also sent a Notice of Intent over the hunting issue in the Mojave National Preserve. The Council, with Dr. Michael Connor's help, will continue commenting on environmental issues and continue supporting education and awareness.

The DTC provided funds for the latest volume of the Chelonian Conservation and Biology Journal. The volume honors more than 25 years of DTC Symposia. The journal contains 27 peer-reviewed papers, and most, though not all of the papers, were presented in whole or in part at DTC Symposia.

During 2002, the Council's website received 850,000 hits. There was an increase in activity before the Handling Workshop and the Symposium. On our website, you can find electronic versions of our newsletters, symposium abstracts, information, and in HTML format, the paper Answering Questions About Desert Tortoises by Kristin Berry and Tim Duck.

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THE TORTOISE AND THE GILA MONSTER: COMMON PLACE; COMMON DESTINY?

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The desert tortoise shares much of its geographic distribution with its rival, the Gila monster. Gila monsters have been observed feeding on tortoise eggs and tortoises have been observed to vigorously defend their shelters and nests from marauding Gila monsters. However, these two ancient desert denizens share more than just habitat. Both are long-lived members of very old genera, dating back at least 23 million years. Both have evolved a frugal energy use strategy as a means to cope with the predictable food shortages that occur in their desert habitats. Both species exhibit impressive combat behaviors and both rely heavily on shelters to provide suitable microenvironments, refuge from predators, and access to favorable thermoregulatory sites, foraging areas, and potential mates. In contrast to the desert tortoise, the Gila monster remains an elusive and poorly understood icon of the American Southwest. While the Gila monster is not federally listed, populations of *Heloderma suspectum cinctum* throughout the Mojave Desert are listed by individual states as "endangered," "imperiled," or "extremely imperiled." Most desert habitats support Gila monster population densities far below those of the desert tortoise, yet resource managers still do not have sufficient information on the distribution, population characteristics, or habitat needs of Gila monsters to make informed management decisions. Gila monsters were once very common around St. George, Utah, but the explosive growth of Washington County has eliminated much of the lizard's historic habitat in that state. Ironically, a promising new drug for treating adult onset diabetes (which afflicts 17 million Americans) has recently been discovered from Gila monster venom samples originating in Utah. Washington County's Habitat Conservation Plan, prepared in response to federal listing of the desert tortoise, offers the best chance for survival of remaining Utah Gila monster populations. The desert tortoise, therefore, may act as an

umbrella species for *Heloderma suspectum*, and thereby protect vital habitat for Gila monsters. This will happen only if biologists and resource managers take a more proactive approach to understanding the distribution, habitat needs, and ecology of the Gila monster. Otherwise, we could see the difficult history of the desert tortoise in the Mojave Desert repeated by America's largest, and only, venomous lizard.

DECLINING TRENDS IN DESERT TORTOISE POPULATIONS AT LONG-TERM STUDY PLOTS IN CALIFORNIA BETWEEN 1979 AND 2002: MULTIPLE ISSUES

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Between 1971 and 1980, 27 study plots were established in the Mojave and Colorado (western Sonoran) deserts in California to conduct research on demographic attributes of desert tortoise populations. Fifteen of these plots were ultimately selected for long-term monitoring of status and trends in populations and their habitats. The plots were in habitat types typical of valleys and alluvial fans on public lands throughout the Mojave and Colorado Deserts. The plots had tortoise populations with densities ranging from <25 tortoises/km^2 (low) to >75 tortoises/km^2 (high) when they were initially established. The 15 plots have been surveyed periodically in spring at intervals ranging from one to 10 years using mark-recapture techniques. Since the Desert Tortoise (Mojave Population) Recovery Plan (U.S. Fish and Wildlife Service 1994) was prepared in 1992 to 1993, 12 of the 15 plots have been resurveyed, and recent data sets are available. Plots are in five of the desert tortoise "recovery units:" Western Mojave, Northeastern Mojave, Eastern Mojave, Northern Colorado, and Eastern Colorado.

Since the plots were first established, tortoise populations have experienced declines both in numbers of tortoises registered during the censuses and in densities of live tortoises at most sites (Berry and Medica 1995, Brown et al. 1999, Berry et al. 2002). Declines of >50% and up to 96% have occurred regardless of whether initial tortoise densities were low (<25 tortoises/km^2), moderate (25-75 tortoises/km^2), or high (>75 tortoises/km^2). Populations at each study plot have somewhat different characteristics. For example, two populations were increasing in densities during the 1980s (Ward Valley, Chemehuevi Valley) but experienced significant declines that began in the late 1980s. The "gold standard" population at Goffs remained stable between 1977 and 1994, but declined catastrophically between 1994 and 2000. Declines in numbers and densities of live tortoises have been confirmed by corresponding increases in shell-skeletal remains, including remains of marked tortoises (except at one site, Kramer, where poaching has been documented).

In the ~25 to 30 years since the plots were first established, causes of mortality have varied by region, year(s) or groups of years, degree of protection of the site from anthropogenic disturbances, remoteness from human activities, and lack of access (e.g., see Berry 1986). At many sites, multiple factors contribute to deaths of tortoises and habitat deterioration (e.g., grazing, roads, invasion and proliferation of alien plants, vandalism, off-highway vehicle use, raven predation, domestic dogs). For example, in an evaluation of shell-skeletal remains collected from the Chemehuevi plot in 1999, a substantial number of tortoises appeared to have been killed or severely injured by vehicles. Likewise, the Goffs plot also had shell-skeletal remains of road-killed or vehicle-injured tortoises.

Diseases appear to be playing increasingly important roles in mortality, especially since the mid-1980s. Shell diseases, present at low levels in many populations when the plots were first established, increased during the 1980s and 1990s (Jacobson et al. 1994, Christopher et al. 2003). Shell diseases appear to be associated with high mortality rates at several sites, particularly in the northeastern and eastern Mojave and Colorado Deserts (e.g., Jacobson et al. 1994, Berry 1997). Necropsies provide important information on causes of ill health and death (Homer et al. 1998). Necropsies of tortoises with shell disease from the Goffs and Chemehuevi Valley plots have confirmed the presence of shell diseases, thyroid degeneration and dysplasia, possible toxic changes, degeneration and atrophy of pancreas, liver, testes, atrophy, or degeneration of skeletal muscle, and elevated levels of one or more elements (Homer and Berry, unpublished data). Upper respiratory tract disease (URTD) has been documented at Mojave plots but not, at this time, on Colorado Desert plots. URTD undoubtedly has contributed to population declines within the Desert Tortoise Research Natural Area (Berry 1997, Brown et al. 1999) and other sites in the western Mojave Desert.

The effects of diseases on tortoises are likely exacerbated by altered habitats and changes in available food items. For example, in desert tortoise critical habitat in the western Mojave Desert, alien annual plants now compose >60% of the annual biomass (Brooks 1998), and aliens effectively invade tortoise habitats and compete with native annuals for nutrients (Brooks 1999, 2000). In this region, tortoises prefer native to non-native plants (Jennings 1993). Protection has a beneficial effect on tortoise populations and habitat. At the Desert Tortoise Research Natural Area, tortoise numbers and densities are higher in the protected area inside the fence compared with the unprotected area outside the fence. Surveys conducted in 2002 indicated that densities of tortoises inside the fence were about three times higher than outside the fence.

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HEALTH ASSESSMENTS OF CAPTIVE AND WILD DESERT TORTOISES AT 26 SITES IN THE MOJAVE AND COLORADO DESERTS, CALIFORNIA, IN 2002

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Between 1998 and 2002 we conducted in-depth health assessments of captive desert tortoises (*Gopherus agassizii*) at two desert towns and of wild desert tortoises at 26 field sites in the Mojave and Colorado Deserts of California. Health assessments included collecting data on detailed clinical signs of health and disease, e.g., recording signs of upper respiratory tract

disease (URTD), shell disease, and trauma; and taking blood or lymph samples and nasal lavages for laboratory analysis. The field health assessments were followed by analysis of tissue samples using enzyme-linked immunoassay (ELISA) and polymerase chain reaction (PCR) tests and cultures for *Mycoplasma* at the University of Florida. Some populations were tested for the herpesvirus using the new ELISA test developed by Dr. Origgi and others; this test has not yet been validated. In 2002, field sampling was markedly enhanced by using two teams of field biologists. The first team located the tortoises and the second team, with expertise in drawing blood and collecting the nasal lavages, followed and took samples.

In 2002, samples were collected from 225 wild desert tortoises at 19 plots from the western Mojave, central Mojave, northeastern Mojave, eastern Mojave, and northern and eastern Colorado Deserts. Sites and sample sizes were Desert Tortoise Research Natural Area, Sites 3 and 4 (n=3, 22), Fremont-Kramer (n=9), Ft. Irwin-Control (n=20), Ft. Irwin-Tiefort (n=19), FISS (n=3), Marine Corps Air Ground Combat Center (MCAGCC)-Sandhill (n=24), MCAGCC-Lavic (n=10), MCAGCC-Bullion (n=7), Ord-Rodman (n=14), Superior Cronese (n=9), Ivanpah Valley-Site 14 and G_0 (n=11, 16), Fenner Valley (n=6), Chemehuevi (n =12), Lucerne Valley (n=7), Shadow Valley (n=3), and Ward Valley (n=6). As in previous surveys, samples were not necessarily available for all the tortoises for all the different tests and not all of the laboratory samples have been analyzed. Six tortoises tested positive for *Mycoplasma agassizii* and/or *M.cheloniae*, prop. nov. sp. out of 198 tortoises with ELISA tests and 178 with cultures. Of the 149 tortoises with herpes test results now available, 48% tested positive for herpesvirus. One hundred twenty-six tortoises were from nine sites in the line-distance sampling projects at Fremont-Kramer, MCAGCC-Sandhill, MCAGCC-Lavic, Ord-Rodman, Superior-Cronese, Ivanpah Valley, Fenner Valley, Chemehuevi, and Chocolate Mountains Aerial Gunnery Range. Some of the tortoises were G_0 tortoises and some were captured opportunistically nearby. None tested positive for *Mycoplasma*. However, of 101 tortoises with herpesvirus ELISA tests, 51% tested positive, a higher percentage than in 2001.

The 2002 results can be compared with two older data sets: (1) 141 samples taken from 131 desert tortoises between 1997 and 1999 at seven plots on the Ft. Irwin National Training in the central Mojave Desert; and (2) 121 samples from 119 wild tortoises at nine study plots from the western Mojave, central Mojave, northeastern Mojave, eastern Mojave, and northern Colorado. Samples were not necessarily available for all the tortoises for all the different URTD tests or for the herpesvirus tests. For the first data set, only one plot at Goldstone produced positive samples (2 of 5 tortoises tested for both ELISA and cultures). For the second data set, none of the 119 tortoises tested positive for *Mycoplasma agassizii* and/or *M. cheloniae*, prop. nov. sp. However, of 66 tortoises tested for herpesvirus, six (9%) were positive: three at MCAGCC-Sandhill, two at Ord-Rodman, and one at Ivanpah Valley. The sites where animals tested positive for herpesvirus were sites with higher sample sizes (n >

12). Twenty G_0 tortoises from the line-distance sampling projects at MCAGCC-Sandhill, Ord-Rodman, and Superior-Cronese were tested for herpesvirus; of the 20, four (20%) tested positive.

The wild desert tortoises we have sampled have lower percentages of positive URTD tests than the captive tortoises sampled at Ridgecrest and Inyokern (n=34) and Joshua Tree/Twentynine Palms/Palm Springs (n =30). Using a combination of laboratory tests, 61.8% of captive tortoises from Ridgecrest and Inyokern and 60% of captive tortoises from Joshua Tree, Twentynine Palms, and Palm Springs (n=30) tested positive for *Mycoplasma agassizii* and/or *M. cheloniae* prop. nov. sp. The group of captive tortoises from the Joshua Tree, Twentynine Palms, and Palm Springs areas also tested for herpesvirus and 32.1% had positive tests. Of the tortoises that tested positive for antibody to herpesvirus, 44.4% had concomitant positive tests for mycoplasma. Our findings on captive tortoises are similar to those reported by Johnson et al. (2001) and others in the literature.

We recommend continued and more intensive sampling of desert tortoises for clinical signs of all significant diseases. We reiterate previous recommendations that all tortoises in research and monitoring programs should be tested using the available ELISA and PCR tests and cultures, and records should be kept and analyzed on patterns of clinical signs of disease. We recommend education programs for owners of captive tortoises about infectious diseases, development of protocols for quarantining individuals and segregating different chelonian species, and development of action plans to prevent escape or deliberate releases of captive tortoises to the wild.

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REFERENCE CITED

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MOVEMENT PATTERNS OF TRANSLOCATED DESERT TORTOISES

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Translocation is often advocated as a conservation strategy for wildlife, including desert tortoises. The effectiveness of translocating tortoises likely depends on a host of factors including the physical availability of habitat and potential issues related to social structure. We examined how Sonoran desert tortoises responded to short-distance translocations from an area scheduled for development near Saguaro National Park, Tucson, Arizona. We assessed the effects of three translocated distances for nine tortoises. Movements of tortoises translocated 800 m, the maximum distance tested, differed from controls in all aspects measured, including increases in total distance moved, net displacement, area traversed, and fractal dimension of each path. Tortoises returned to their home ranges within a few days of being translocated, regardless of the distance. Translocations $\leq$ 800 m are not likely to be effective for tortoises on lands being developed, and more research is needed to understand homing ability in desert tortoises and the implications of this behavior for translocations.

THE ECOLOGY OF A SUBSIDIZED PREDATOR IN THE MOJAVE DESERT: COMMON RAVEN

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Subsidized predators are species whose populations survive and often thrive on resources (e.g., food, water, safety) provided by humans. Common ravens (*Corvus corax*) are an excellent example of a subsidized predator. Their populations have grown precipitously in recent years because of the proliferation of human activities in the desert. In a multi-year study at Edwards Air Force Base, California, significantly more ravens were found at landfills and sewage ponds than at other human-dominated and natural areas. Radio-tagged ravens moved among anthropogenic resource sites, sometimes over 100 km apart. Some ravens moved into undisturbed desert habitat. Raven abundance at a landfill decreased after garbage

containment practices were changed, but the reduction was not apparent at other sites. Nestling and fledgling survivorship was higher in nests located near anthropogenic resources and predation risk was greater near those sites and close to occupied raven nests. Ravens prey on many native animals including juvenile desert tortoises. It is not known if raven predation is high enough to prevent tortoise recovery rangewide, but it is likely high enough in some areas to hamper success of recovery efforts. Aggressive efforts to reduce availability of garbage at landfills may help to reduce the raven populations regionally.

CURRENT STATUS AND MANAGEMENT OF ALIEN PLANTS AND FIRE IN DESERT TORTOISE HABITAT

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Alien plants and fire have been recognized recently as significant land management problems in desert tortoise habitat. Annual species dominate the alien flora, although only *Bromus rubens*, *Schismus* spp., and *Erodium cicutarium* are currently widespread and abundant. These species can compete with native plants, and *B. rubens* in particular has contributed to significant increases in fire frequency since the 1970s. Native desert plants are often poorly adapted to fire, and recurrent fire has converted native shrubland to alien annual grassland in some areas. Changes in plant communities caused by alien plants and recurrent fire may negatively affect native animals such as the desert tortoise by altering habitat structure and the species composition of their food plants.

Increased levels of surface disturbing activities, rainfall, and atmospheric nitrogen and carbon dioxide may increase dominance of alien plants and frequency of fire in the future. Land managers should focus on early detection and eradication of new alien species, especially those that pose significant fire threats, and law enforcement to minimize the frequency of ignitions by humans. Additional information on the ecology and effects of invasive plants and fire in the Mojave and Colorado deserts are needed to develop effective management plans.

EFFECTS OF FENCED HABITAT PROTECTION ON ANNUAL AND PERENNIAL PLANTS IN THE WESTERN MOJAVE DESERT

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Two major forms of anthropogenic disturbance, livestock grazing (mostly by sheep) and off-highway vehicle (OHV) use, have been prevalent in the western Mojave Desert since the late 1800s and 1960s respectively. These disturbances have been cited as reducing plant cover, biomass, and species diversity, and promoting plant invasions, but the effects of subsequent removal of these disturbances on Mojave Desert plant communities are mostly unknown. In 1973, the 10,100 ha Desert Tortoise Research Natural Area (DTNA) was closed to OHVs, and in 1976 it was closed to livestock grazing. Effective habitat protection from these disturbances began in 1980 with the completion of a 1m-tall fence around the perimeter.

Fenced habitat protection has two effects on plant communities: it allows recovery from past disturbances and provides protection from additional future disturbances that adjacent unprotected areas continue to be subject to. Habitat protection can also be coupled with active restoration, although this is not the case at the DTNA where disturbance exclusion is the only management treatment inside the fence. The DTNA provides an opportunity to test the hypothesis that fenced habitat protection from human disturbances can have positive effects on plant community structure in the western Mojave Desert.

Above-ground live biomass and species richness of annual plants were measured during April 1990, 1991, and 1992. More species of annual plants had higher biomass inside than outside the DTNA during each year. Biomass of goldfields (*Lasthenia californica*) and comb-bur (*Pectocarya* spp.) were significantly higher inside in 1990, small-flowered poppy (*Eschscholzia minutiflora*) and goldfields were higher inside in 1991, and fiddleneck (*Amsinckia tessellata*), Mojave suncup (*Camissonia campestris*), and lacy phacelia (*Phacelia tanacetifolia*) were higher inside in 1992. The only species with higher biomass outside was the alien Mediterranean grass (*Schismus* spp.) during each of the three years. Annual plants were also sampled during 1994 and 1995. Biomass of red brome (*Bromus madritensis* ssp. *rubens*), Mediterranean grass, and total alien annual biomass were significantly higher in unprotected areas during at least one of two years. In no cases were alien species significantly more abundant inside the DTNA.

Density and cover of perennial shrubs were measured in June 1990, and cover, height, volume, and diversity were measured in June 1995. Total density of perennial shrubs was generally unaffected by protection, whereas total cover and diversity (Shannon-Wiener index) were 33 to 50% higher in the protected area. Cover of burrobush (*Ambrosia dumosa*), California buckwheat (*Eriogonum fasciculatum*), boxthorn (*Lycium andersonii*), and Fremont dalea (*Dalea fremontii*) were all significantly higher in protected areas. Because cover was higher inside the DTNA, and density was generally unaffected by protection, the average size of individual shrubs was higher inside the DTNA. Height diversity, cover diversity, and volume diversity of perennial shrubs were not significantly affected by protection.

Seedbank biomass in the top two centimeters of soil was measured in April 1990, 1991, and 1992. Biomass was higher inside than outside the DTNA during each year, but high intersample variance limited significant differences to 1992.

These data support the hypothesis that fenced habitat protection can have positive effects on plant community structure in the western Mojave Desert after only 10 to 15 years of protection. These benefits should be considered when evaluating the wide range of effects of habitat protection for threatened or endangered species such as the desert tortoise (*Gopherus agassizii*), the Mojave ground squirrel (*Spermophilus mohavensis*), or the many listed plants species that inhabit this region.

RECENT FIRE HISTORY IN THE MOJAVE DESERT, 1980-2001

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Mojave Desert shrublands are generally considered fire-proof, and fire is thought to be historically infrequent in this region. However, fire records maintained by land management agencies since 1980 indicate that fires have not been uncommon during the past few decades. This has sparked concern about the potential negative effects of fire on native plant communities, and on threatened or endangered species such as the desert tortoise (*Gopherus agassizii*). In this poster we summarize fire trends between 1980 and 2001 in the Mojave Desert. We specifically compare fire cause (lightning vs. human), size, and seasonal distribution among Recovery Units for the desert tortoise (Mojave population), vegetation types, and rainfall years. This information will provide a basis for evaluating the predominance of fire within various parts of the Mojave Desert, specifically in relation to sub-populations of the desert tortoise.

POTENTIAL EFFECTS OF ATMOSPHERIC NITROGEN DEPOSITION ON THE DOMINANCE OF ALIEN ANNUAL PLANTS IN THE MOJAVE DESERT

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Deserts are one of the least invaded ecosystems by plants, possibly due to naturally low levels of soil nitrogen. Increased levels of soil nitrogen caused by atmospheric nitrogen deposition may increase the dominance of invasive alien plants and decrease the diversity of plant communities in desert regions, as it has in other ecosystems. Deserts should be particularly susceptible to even small increases in soil nitrogen levels because the ratio of increased nitrogen to plant biomass is higher compared to most other ecosystems.

The hypothesis that increased soil nitrogen will lead to increased dominance by alien plants and decreased plant species diversity was tested in field experiments using nitrogen additions at three sites in the in the Mojave Desert of western North America. Responses of alien and native annual plants to soil nitrogen additions were measured in terms of density, biomass, and species richness. Effects of nitrogen additions were evaluated during two years of contrasting rainfall and annual plant productivity. The rate of nitrogen addition was similar to published rates of atmospheric nitrogen deposition in urban areas adjacent to the Mojave Desert (3.2g $N/m^2/yr$). The dominant alien species included the grasses *Bromus madritensis* ssp. *rubens* and *Schismus arabicus* and *barbatus*, and the forb *Erodium cicutarium*.

Soil nitrogen addition increased the density and biomass of alien annual plants during both years, but decreased density, biomass, and species richness of native species only during the year of highest annual plant productivity. The negative response of natives may have been due to increased competitive stress for soil water and other nutrients caused by the increased productivity of aliens.

The effects of nitrogen additions were significant at both ends of a natural nutrient gradient, beneath creosote bush (*Larrea tridentata*) canopies and in the interspaces between them, although responses varied among individual alien species. The positive effects of nitrogen addition were highest in the beneath-canopy for *Bromus rubens* and in interspaces for *Schismus* spp. and *Erodium cicutarium*.

The results indicated that increased levels of soil nitrogen from atmospheric nitrogen deposition or from other sources could increase the dominance of alien annual plants and possibly promote the invasion of new species in desert regions. Increased dominance by alien annuals may decrease the diversity of native annual plants, and increased biomass of alien annual grasses may also increase the frequency of fire.

Although nitrogen deposition cannot be controlled by local land managers, they need to understand its potential effects on plant communities and ecosystem properties, in particular how these effects may interact with land use activities that can be managed at the local scale. These interactions are currently unknown, and hinder the ability of managers to make appropriate land use decisions related to nitrogen deposition in desert ecosystems. The effects of nitrogen deposition on invasive alien plants should be considered when deciding where to locate new conservation areas, and in evaluating the full scope of ecological effects of new projects that would increase nitrogen deposition rates.

FIRE HAZARD MAPPING AT THE MOJAVE NATIONAL PRESERVE

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Region-wide characterization of vegetation and fuels can be useful for fire managers at both strategical planning levels (e.g., defining locations to place permanent fire-suppression resources) and at operational and tactical levels (e.g., knowing where areas of potentially high fire hazard exists during an actual wildfire). Relatively fine-resolution vegetation maps for regions in the Mojave Desert have recently been developed, which can now be combined with other spatial data to define areas of high wildfire hazards. In this poster we describe this process for a fire hazard map we developed for the Mojave National Preserve.

We first classified vegetation cover types into high, medium, and low categories for fire spread rate and fire line intensity. This classification was further refined into six categories using BEHAVE, a fire behavior modeling program, to develop slope-adjusted fire spread rates and intensities based upon standard fuel models. These slope-adjusted categories were then applied across the Mojave National Preserve using a vegetation map and DEM-derived slope map. We also developed an annual lightning strike density map based on lighting data collected by the Bureau of Land Management from 1989 to 1995. A composite fire hazard map for the Preserve was created by combining fire spread rate, fire line intensity, and lightning strike density layers. This process provides a starting point, which can be further refined, for future region-wide analyses of fire hazards in the Mojave Desert.

CAN REMOVAL OF ALIEN ANNUAL GRASSES SIGNIFICANTLY BENEFIT NATIVE ANNUAL PLANTS?

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Alien annual grasses in the genera *Bromus* (*B. rubens*, *B. tectorum*, and *B. trinii*) and *Schismus* (*S. arabicus* and *S. barbatus*) are widespread and abundant in the Mojave Desert, and negative correlations between the abundance and diversity of these aliens and native annual plants suggest that competition may occur between them. It is assumed that this competitive effect reduces density and biomass, and therefore reproductive success and diversity, of native plant species. General land management plans for large administrative units, and specific restoration plans for individual sites, typically include stipulations for reducing dominance of alien plants for the purpose of benefitting native plants. However, the hypothesis that thinning of alien annual plants will significantly increase density, biomass, and diversity of native annual plants in the Mojave Desert have not been substantiated experimentally, and is only supported by correlative data. This poster presents an experimental test of this hypothesis involving the thinning of the two dominant alien annual grass taxa in the Mojave Desert, *Bromus* and *Schismus*.

Alien annual grass seedlings were thinned from 25 replicate 20x25cm treatment plots, in beneath-shrub (north side of *Larrea tridentata* canopy) and interspace (>1m from the nearest shrub canopy) microhabitats, at three sites in the central, south-central, and southwestern Mojave Desert, during two years of contrasting plant productivity (1996 and 1997). All alien annual grass seedlings were removed first at the end of January, then a second time about two weeks later at the beginning of February, during each year. Effects of *Bromus* and *Schismus* thinning were evaluated separately in the microhabitat where each was most abundant, in the beneath-shrub microhabitat for *Bromus* and in the interspace for *Schismus*.

Thinning of *Bromus* and *Schismus* significantly increased density, biomass, and species richness of native annuals at all three sites, but only during a year of high annual plant productivity and species richness. Effects of thinning were strongest for the native *Amsinckia tessellata* and for a group of relatively uncommon native annuals. Thinning also significantly increased the density and biomass of the alien forb, *Erodium cicutarium*, highlighting the need to evaluate the entire alien plant flora before instituting control efforts for individual alien species. If the target alien annual plant may be replaced by an even less desirable species, then control efforts should be avoided.

These results indicate that removal of alien annual grasses can increase density, biomass, and species richness of native annual plants, but that this type of control method may only be effective during years of high annual plant productivity. This study is limited at temporal and spatial scales to two years of native plant response in small experimental plots. The longer-term effects of thinning at larger spatial scales, and the effects of thinning using more cost-effective methods such as grass-specific herbicides, remain unknown. Native plant responses to control methods for invasive alien forbs and perennial grasses are also needed. These types of studies are the next steps in providing land managers with the information they need to reliably predict the effects of efforts to manage alien annual plants in the Mojave Desert.

FIRE TEMPERATURES AND THEIR EFFECTS ON ANNUAL PLANTS IN CREOSOTEBUSH SCRUB

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Very little is known about the behavior and effects of fire in the Mojave Desert, because fire was historically uncommon. However, fire has become more frequent since the 1970s with increased dominance of the invasive annual grasses *Bromus rubens* and *Schismus* spp. In this poster, we describe patterns of peak fire temperature and their effects on annual plants in creosote bush scrub vegetation of the Mojave Desert. Temperatures were monitored among microhabitats and distances from the soil surface, and between spring and summer. Microhabitats ranged from high amounts of fuel beneath creosote bush (*Larrea tridentata*) canopies, to intermediate amounts at the canopy dripline, to low amounts in the interspaces between them. Distances from the soil surface were within the vertical range where most annual plant seeds occur (-2, 0, 5, 10cm). We also compared temperature patterns with post-fire changes in soil properties and annual plant biomass and species richness to infer potential mechanisms by which fires affect annual plants.

TORTOISE MYCOPLASMAS AND URTD

Adapted from: APPLICATION OF DIAGNOSTIC TESTS FOR MYCOPLASMAL INFECTIONS OF DESERT AND GOPHER TORTOISES WITH MANAGEMENT RECOMMENDATIONS,
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URTD refers to one or more clinical signs of illness seen in tortoises, including nasal discharge, palpebral edema, conjunctivitis, and ocular discharge. It is likely that multiple infectious agents may cause similar clinical presentations. To date, Koch's postulates have been fulfilled only for *Mycoplasma agassizii*, and thus it is the only rigorously confirmed etiologic agent of URTD in desert and gopher tortoises (Brown et al. 1994, 1999b). Preliminary studies indicate that other pathogens, including other species of *Mycoplasma*, also may cause overlapping signs (McLaughlin 1997). *M. cheloniae* has been isolated from clinically ill, wild desert tortoises and has caused URTD in a limited experimental infection pilot study. An iridovirus was reported in a gopher tortoise with URTD (Westhouse et al. 1996). A wild desert tortoise with signs of respiratory disease was found to have a fungal pneumonia (Homer et al. 1998). In Europe, Mediterranean tortoises (*Testudo hermanni* and *T. graeca)* with clinical signs of URTD have been associated with a herpesvirus by electron microscopy and serology (Muller et al. 1990), and cases of herpesvirus infection have been reported in captive desert tortoises (Harper et al. 1982, Pettan-Brewer et al. 1996). However, to date experimental transmission studies resulting in clinical signs compatible with URTD have been performed for a herpesvirus in a limited number of Greek tortoises. The herpesvirus ELISA has been used with sera from desert tortoises, but experimental infection studies and correlation of ELISA test results with histopathology and lesion development need to be done to further validate the assay.

The current evidence supports horizontal transmission of *Mycoplasma* in desert and gopher tortoises, most likely through direct contact of tortoises. Mycoplasmas lack a cell wall and are susceptible to desiccation; therefore, they do not normally persist in the natural environment for any appreciable length of time. A critical concern is contaminated fomites such as field equipment that might contribute to the spread of the organism, especially when mucous and organic contamination is present and proper disinfection techniques are not used. Fomite transmission does occur for other mycoplasmal infections, particularly in food and fiber animals (McMartin et al. 1987). A limited experimental study suggests that environment transmission does not occur in gopher tortoises (McLaughlin 1997). Seropositive, clinically ill tortoises were housed in outdoor enclosures, these tortoises were removed, and seronegative gopher tortoises were immediately placed in the enclosures (McLaughlin 1997). None of these tortoises seroconverted or developed URTD. Vertical transmission of mycoplasma is known to occur in poultry, but the rate of transmission is low (Lin and Kleven 1982, Yoder 1984). In a study of a very limited number of infected gopher tortoises, no egg transmission was documented (McLaughlin 1997). Because the sample size was so small, egg transmission cannot be ruled out. Further, maternal antibody is present in the egg and persists in hatchlings, potentially confounding serologic tests (Schumacher et al. 1999).

Under experimental conditions, the onset of clinical signs in desert and gopher tortoises occurs as early as two weeks after infection. However, seroconversion lags behind clinical signs, with reliable detection by eight weeks after infection. Affected desert and gopher tortoises are assumed to be capable of transmitting *Mycoplasma* through direct contact during the time between onset of signs and seroconversion, because we have found large numbers of *Mycoplasma* in the upper respiratory tract and nasal secretions of experimentally inoculated gopher tortoises during this time.

Clinical signs of URTD such as nasal discharge and conjunctivitis may reflect nonspecific host responses to infection (inflammation, mobilization of phagocytes) as well as specific responses (immune-mediated complement activation, formation of immune complexes), although these have not been investigated. Signs may intensify and then abate in cycles, reflecting the progression of URTD. Based upon our transmission studies, our findings suggest that infection and expression of URTD occurs in the following steps: (1) initial colonization with *Mycoplasma*; (2) host response which reduces the population of *Mycoplasma* and simultaneously causes acute illness and signs of disease; and (3) progression to chronic disease with intermittent expression of clinical signs and shedding of *Mycoplasma*. The presence of a specific antibody to *M. agassizii* was associated with clinical signs of URTD in wild desert tortoises (Schumacher et al. 1993). In a desert tortoise population with natural infection, some initial fluctuation in antibody levels were observed, but once an animal had a strong seroconversion, the antibody levels persisted for years (Brown et al. 1999a). These findings are typical of many mycoplasmal respiratory infections in other hosts.

Upon re-exposure to *Mycoplasma*, previously infected gopher tortoises may develop clinical signs of URTD more rapidly than naive animals. Under experimental conditions, the clinical signs were more severe, higher numbers of *Mycoplasma* were recovered from nasal flushes, and the antibody response was more rapid than after first exposure (McLaughlin 1997). Thus upon re-exposure to the pathogen, previously infected tortoises may actually experience exacerbated signs of illness rather than immune protection. This is consistent with the immunopathology associated with most mycoplasmal infections, where the host immune response is a key component in determining disease severity. While this evidence is limited to gopher tortoises, we expect a similar response in other tortoises infected with *Mycoplasma*. It is not clear if naturally infected tortoises develop a protective immune response. Our limited data in experimentally infected tortoises suggests this most likely does not occur. However, there are populations with seropositive animals and no overt disease. Seronegative animals in these populations do often seroconvert, suggesting that *Mycoplasma* are still present in the population but the extent of carriers is unknown. At this point, there is insufficient data to determine if a protective immune response exists in tortoises.

Most hosts do not typically clear mycoplasmal infections, and numbers of mycoplasmas may be substantially lowered during chronic phases of infection in the absence of clinical signs. It is possible that this may occur in the tortoise as well. An additional consideration is the particular strain of mycoplasma present in the individual or population. Strains of most mycoplasmal species vary in virulence. We have limited evidence in the gopher tortoise that suggests strains of *M. agassizii* differ in the minimum dose required to colonize and cause disease. Knowledge of the virulence potential of different strains will be important for risk assessment for future management decisions and also for evaluating the role of the microbe in disease transmission.

Mycoplasma agassizii can cause severe changes in the mucosal epithelium of the upper respiratory tract of desert and gopher tortoises (Jacobson et al. 1991, Homer et al. 1998, McLaughlin et al. 2000). These lesions disrupt the normal epithelial arrangement of the tissues and more than likely compromise their function. We have seen a reduction in appetite and other changes in behavior in experimentally challenged tortoises (McLaughlin 1997). Experimentally infected desert and gopher tortoises often remained in their burrows for extended periods of time once clinical signs of illness developed. Further, irregular basking and burrowing behaviors have been noted in a limited number of animals in the wild (J. Berish and K. Berry, pers. comm.). The full impact of URTD on behavior and the implications of altered behavior on disease transmission and individual health and survival remains to be determined.

Mycoplasmosis is a complex, possibly multifactorial disease, associated with declines of desert tortoises in the southwest United States. Over the last 10 years much critical information has been gained (Table 1). Koch's postulates have been fulfilled for *M. agassizii*, validated diagnostic tests are now available for *M. agassizii*, the lesions associated with URTD have been described, and seroprevalence studies have been conducted for a number of wild and captive populations. However, there are significant gaps in our knowledge of the host response, other potential infectious agents, interaction among infectious agents, noninfectious influences on morbidity and mortality, and population dynamics that need to be addressed in future research studies. Some of the major questions regarding URTD that need to be addressed in future studies are summarized in Table 2. Any summary of current knowledge should be considered dynamic and will need to be updated and revised as additional data from stringent scientific studies are reported in peer-reviewed literature.

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Table 1. Summary of major conclusions and current knowledge of URTD.

It is certain that:

- ☐ *Mycoplasma agassizii* (strains PS6 and 723) is a cause of URTD.
- ☐ The pathology of mycoplasmosis involves hyperplastic and dysplastic lesions in the upper respiratory tract.
- ☐ Clinical signs of URTD vary in onset, duration, and severity.
- ☐ Mycoplasmosis is chronic and may be clinically silent (subclinical) in adult tortoises.
- ☐ Infection with *Mycoplasma agassizii* elicits specific antibody responses that can be detected by ELISA.
- ☐ The current ELISA cannot detect exposure of all tortoises to mycoplasmas other than *M. agassizii*, although some cross-reactions do occur.
- ☐ The antibody responses to *Mycoplasma agassizii* are reliably detectable by ELISA beginning eight weeks after experimental infection.
- ☐ Under experimental conditions, gopher tortoises become ill quicker after repeated exposure to *Mycoplasma agassizii*.
- ☐ Colonization of the upper respiratory tract with *Mycoplasma agassizii* may be detected by culture and PCR, but assay sensitivity is not as high as the ELISA.
- ☐ Mycoplasmosis is a horizontally transmissible disease.

It is probable:

- ☐ Pathogenic and nonpathogenic tortoise mycoplasmas exist.
- ☐ There is variation among strains of *Mycoplasma agassizii* in their ability to cause URTD.
- ☐ Other species of *Mycoplasma* (such as *M. cheloniae*) also can cause URTD.
- ☐ Specific antibodies against *Mycoplasma agassizii* do not confer protective immunity.
- ☐ *Mycoplasma* can be transmitted by some forms of indirect contact.

We suspect the following:

- ☐ In gopher tortoises, if vertical egg transmission of *Mycoplasma* occurs, it does so at a relatively low rate.
- ☐ Mycoplasmosis can affect the survival and reproduction of individual tortoises.
- ☐ Mycoplasmosis is a multifactorial disease, interacting in some circumstances with other stressors to affect tortoise population dynamics and viability.
- ☐ Mycoplasmosis directly affects desert and gopher tortoise population dynamics and viability.

It is unlikely that:

- ☐ *Mycoplasma* can persist in burrows of infected tortoises.

Table 2. Suggested future directions for URTD research.
Immunobiology of tortoises: ☐ Develop reagents to detect and measure critical changes in immune function and immune activation. ☐ Establish a database for normal immune function in healthy tortoises. ☐ Evaluate the impact of infectious, toxicological, and environmental impacts on immune function.
Infectious agents: ☐ Conduct experimental infection studies to confirm pathogenic potential of other mycoplasmal species. ☐ Sequence the genome of *M. agassizii*, comparison with other mycoplasmal agents, identification of putative virulence factors, and potential diagnostic antigens. ☐ Determine interaction between mycoplasmosis and other infectious agents, particularly herpesvirus. ☐ Determine etiology of dyskeratosis and if concurrent infection with mycoplasmas is involved in the pathogenesis.
Diagnostic tests: ☐ Conduct experimental infection studies and natural infection studies to validate the herpesvirus ELISA in desert tortoises. ☐ Determine the cross reactivity of different mycoplasmal species in the current ELISA and refine existing assay if needed to detect newly identified species.
Population Dynamics: ☐ Identify critical sites for continued long-term monitoring. ☐ Determine the true impact of URTD on population demographics (for example: reproduction, survival rates, age class effects). ☐ Determine the population characteristics (i.e., disease threshold, population size, etc.) required to initiate and sustain disease in a population.

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CONCEPTS AND IMPORTANCE OF DISINFECTION

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Little is known about infectious diseases present within wild populations or the long-term impact of these diseases. This creates a major dilemma for scientists, wildlife biologists, conservationists, and public policy makers when trying to manage and ensure the survival of wildlife species. This is even more critical when the animal concerned is a keystone species such as the desert tortoise, which is critical to the health of its ecosystem and the survival of many additional species. As we seek to evaluate and monitor populations and individuals, we have come to realize that we may also present a risk in facilitation or potentiation of spread of disease in the very animals we hope to preserve. For the desert tortoise, the most widely studied disease is respiratory mycoplasmosis. However, this is only one infectious agent and other agents, particularly viruses, are even more likely to be spread unintentionally if appropriate disinfection measures are not used. It is also important to note that many of the newly recognized diseases affecting humans are caused by zoonotic agents with wildlife reservoirs or have resulted from large-scale ecological changes that may increase human exposure to insect vectors as well as to animal and environmental sources of disease. Thus, failure to use appropriate field disinfection techniques might also represent a risk to humans.

This talk will highlight some of the common concepts of disinfection. Disinfection refers to the inactivation of most pathogens (but not necessarily bacterial endospores) on inanimate objects. Factors which influence successful disinfection include number of microbes present, type of microbes, length of exposure to the chemical agent, concentration of the chemical, amount of organic matter present, type of material to be disinfected, and temperature. An antiseptic is used on or in a living tissue to inhibit or destroy microbes. Although an agent may be used as both a disinfectant and antiseptic there may be differences in formulation or concentrations, so care should be taken not to use disinfectants on living tissue unless a use for antisepsis is provided by the manufacturer.

A critical concern is contaminated fomites such as field equipment that might contribute to the spread of the organism, especially when mucous and organic contamination is present and proper disinfection techniques are not used. A fomite is an inanimate object that may be contaminated with infectious agents and serve in their transmission, for example field calipers, trapping, or holding containers. Mycoplasmas lack a cell wall and are susceptible to desiccation; therefore, they do not normally persist in the natural environment for any appreciable length of time. However, other bacteria and many viruses, including herpes viruses, are extremely hardy and survive well in the environment. It is important to remember that disinfection is not just for mycoplasmas, but also for viruses, bacteria, fungi, and parasites. It is imperative that the disinfectant has the broadest spectrum of activity.

A number of compounds are available for disinfection. However, most have a limited spectrum of activity and many are poor against nonenveloped viruses. The agents with the broadest overall spectrum of activity are chlorine or bleach. Classes of disinfectants with poor to no activity against certain viruses include phenols (Cresl-400, Environ, Laro, Amphyl, Lysol), chlorhexidines (Vikron S), alcohol, and quarternary ammonia compounds (Roccal, Germex, HiLethol, Sanofec, Zephiran). These are NOT effective against certain viruses and should not be used. Most hand sanitizers are alcohol based and therefore are not effective against viruses.

By far, the best overall choice of disinfectant is bleach. In fact, for maximum effectiveness in cleaning blood spills with potential infectious agents like HIV, the CDC recommends a 1:10 dilution of 5.25% bleach, resulting in 5,000 ppm available Cl as the disinfectant of choice. For most microbes, 100 to 200 ppm is effective. For field use, a 1:30 dilution of bleach should give 1,667 ppm and be sufficient. There are a few caveats that need to be noted about bleach. First, not all bleaches are 5.25% sodium hypochlorite, so check the label. Also, a high organic load under field conditions can cause inactivation of bleach solutions. Therefore, instruments and containers should have dirt and organic material rinsed off and then sprayed with bleach solution for maximum effectiveness. Light inactivates bleach so it should be stored in opaque containers or covered. In addition, even opening of stock bleach bottles with normal use over a 30-day period can decrease the activity by 50%. Be sure to make fresh working solutions frequently (once a week or every 10 days). Finally, bleach can be corrosive to equipment. Despite this, it is still the most effective disinfectant. If alternate disinfectants are used, one must remember that a low organic load and a minimum contact time of 30 minutes are required. Although oxidizing agents (Novalsan) and aldehydes (Wavicide) have good activity against viruses, both require longer contact times (10 min to 10 hrs) than bleach. Wavicide is more effective if organic matter debris is present and could be used for example, to soak drill bits, BUT contact time required for effective disinfection can be as long as 10 hours! Novalsan requires less contact time but is not effective when organic debris is present.

In summary, strict disinfection protocols should be followed to prevent spread of known and potentially unknown agents. Bleach is the most effective disinfectant, with a broad spectrum of activity. It is also highly cost effective. However, organic loads should be minimized, field solutions should be made frequently and stored in opaque containers, and the active concentration of bleach solution used for disinfection should be 1,667 ppm (1:30 dilution of 5.25% sodium hypochlorite).

More detailed information can be found at University of Nebraska Cooperative Extension website, http://www.ianr.unl.edu/pubs/animaldisease/g1410.htm or in *Block. 2001. Disinfection, Sterilization and Preservation. Lippincott Williams & Wilkins, Philadelphia. 139pp.*

NSF PROJECT ON "URTD AND THE ENVIRONMENTALLY-THREATENED GOPHER TORTOISE"

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In a unique interdisciplinary program (http://grants.nih.gov/grants/guide/rfa-files/RFA-TW-01-004.html), the National Institutes of Health, the National Science Foundation, and the U.S. Geological Survey combined to sponsor a program initiative "Ecology of Infection Diseases" to elucidate the underlying mechanisms that govern the relationships between anthropogenic environmental changes and the transmission dynamics of infectious diseases. Investigators at the University of Florida, the University of South Florida, and Florida Fish and Wildlife Conservation Commission were awarded a five-year grant under this program. The project is described below.

Infectious diseases are an ever-present risk to wildlife, particularly during situations in which animals are removed from their natural habitat for captive breeding programs or during conditions of stress such as release into new habitats, translocation, ecosystem perturbation, and encroachment on their habitats by urbanization. This is even more important when the species concerned is a keystone species such as the gopher tortoise that is critical to ecosystem health, maintenance of biological diversity of upland habitats, and survival of more than 360 vertebrate and invertebrate species. Further, in a long-lived species that does not attain reproductive maturity for 10 to 20 years, a single catastrophic event such as a disease epidemic can result in devastating population losses from which the population may have difficulty in recovering.

Upper respiratory tract disease (URTD) is among the best, if not the best, characterized infectious disease in reptiles. The primary etiologic agent of URTD in both gopher and desert tortoises is *Mycoplasma agassizii* (Brown et al. 1994, Brown et al. 1999b). Serological and molecular diagnostic tests have been developed for the infectious agent, and these diagnostic tests have been applied to both wild and captive populations (Schumacher et al. 1993, Brown et al. 1995, Jacobson et al. 1995, Berry 1997, Schumacher et al. 1997, Brown et al. 1999a, Diemer Berish et al. 2000). Finally, the presence of a specific antibody has been correlated with the presence of clinical signs and histopathological lesions (Jacobson et al. 1995, McLaughlin 1997, Schumacher et al. 1997, Homer et al. 1998, McLaughlin et al. 2000). The next logical step, which is the focus of this project, will be to study the influence of URTD on wild tortoise populations. Our long-term goal is to understand the relationship between URTD and tortoise population dynamics and health, with special emphasis on the impact of anthropogenic effects such as relocation practices and habitat alteration on disease transmission. Our study will address the following hypotheses:

(1) Both natural and anthropogenic-induced population characteristics play a critical role in disease transmission and prevalence;

(2) Habitat factors such as quality, size, and fragmentation influence disease transmission;

(3) URTD has a negative impact on tortoise demographic characteristics, and therefore on the viability of tortoise populations;

(4) Mycoplasma strains vary in virulence, and the strain of mycoplasma present in a given population will influence the severity and transmission of URTD;

(5) URTD remains clinically undetectable until a certain threshold (as quantified by seroprevalence) of infected individuals is reached. Beyond that critical threshold, disease spread is more rapid and host population declines may occur.

This research project represents a unique, multidisciplinary approach to understanding the relationship between URTD and the ecology and basic biology of the gopher tortoise. The research includes studies at the population, individual, physiological, cellular, and molecular levels. Causal and predictive models will be developed for the transmission of URTD within wild tortoise populations. The information gained will benefit the long-term survival of the gopher tortoise in its natural habitat by providing new data on the effect of URTD on threatened tortoise populations. URTD represents an intriguing model to study establishment, transmission, maintenance, and consequences of chronic infection within a population. Understanding the dynamics of disease spread in natural wildlife populations may provide valuable new insights into host:parasite: population interactions in this era of emerging infectious diseases.

Similar research funding opportunities for investigating the multi-factorial causes of morbidity and mortality in the desert tortoise exist. There are several keys to obtaining significant funding from sources such as the National Science Foundation and National Institutes of Health. First, interdisciplinary teams of scientists representing broad disciplines must be established. Secondly, the projects must be hypothesis driven and represent strong science with cutting edge technologies. Third, because the factors influencing morbidity and mortality are undoubtedly multi-factorial, individuals with a strong training in theoretical modeling should be part of the team. Fourth, publication track record is a major evaluation tool for NSF

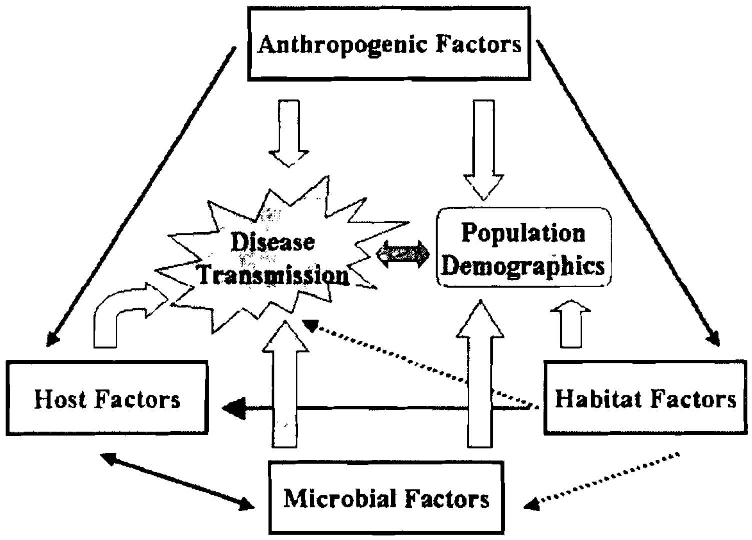

Figure 1. Conceptual representation of the influence of anthropogenic, host, microbial, and habitat factors on disease transmission and population demographics. Major effects on the response variables (disease transmission and population demographics) are depicted by large, shaded arrows. Interaction among forcing variables (anthropogenic, host, habitat, and microbial factors) are depicted by small arrows; stippled arrows indicate indirect influences while solid arrows indicate direct influences.

and NIH reviewers. Therefore, it is imperative that team members publish their studies in the strongest peer-reviewed journals available. Data that is not accessible through standard search engines will likely be lost to the scientific community at large. Finally, the NIH and NSF web sites provide a wealth of information as to specific programs that are available. Successful applications are those that present their research questions and projects within the framework of interest of the specific funding agency or program.

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CLARK COUNTY HIGHWAY FENCING PROGRESS

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The Clark County Desert Conservation Program (DCP) is committed to fencing along roadways to reduce tortoise mortality from vehicle impacts. The DCP has identified fencing priorities and expenditures of up to one million dollars for fencing in each biennial funding cycle since its inception. The fencing program is collaborative and well developed. It is overseen by a public, multi-agency working group established by Clark County's DCP Implementation and Monitoring Committee. The priorities of the fencing program include the desert tortoise ACECs in Clark County and other fencing to support desert tortoise recovery. To date, about 377 km of tortoise fencing have been installed in Clark County. An additional 451 km of required fencing have been identified along major roads. The fencing program has incorporated the results of research addressing the impacts of major roads on desert tortoise habitat in southern Nevada, but has yet to address small roads and fragmentation of habitat. The effectiveness of the fencing program will be evaluated through Clark County's DCP Adaptive Management Program.

DESERT TORTOISE COLLECTION, HUSBANDRY, AND DISPOSITION IN NEVADA

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Desert tortoises have been collected from the wild and held as pets in southern Nevada for decades. The listing of the Mojave population of the desert tortoise in 1989 resulted in concerns by wildlife managers and the public regarding the disposition of unknown status desert tortoise and the distinction between wild tortoises protected by the Endangered Species Act (Act) and pre-Act tortoises lawfully held before listing. In 1995, a habitat conservation plan (HCP) for Clark County, Nevada was approved by the U.S. Fish and Wildlife Service (USFWS). The HCP and associated incidental take permit issued by the USFWS included programs and funding to collect all tortoises in developed areas, at the interface between desert and development, tortoises that occur on private lands to be developed, and unwanted captives. The objectives of these programs were to minimize the potential release of captive tortoises into wild populations and the consequential spread of disease, and the interstate transportation of captive tortoises. The protocols involved in collecting, processing, housing, and translocating tortoises will be presented.

DESERT TORTOISE PRESERVE COMMITTEE: MAJOR ACCOMPLISHMENTS IN 2002 AND PLANS FOR 2003

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The Desert Tortoise Preserve Committee (DTPC) was founded in 1974 to promote the welfare of the desert tortoise in its native wild state by developing and managing preserves, and through research and education. The year 2002 saw major advances in each of these areas. The Committee acquired more than 800 ha of land in and around the Desert Tortoise Natural Area as part of its program to protect and expand the boundaries of the only dedicated tortoise preserve in California. The Committee also took title to 32 ha of prime tortoise habitat in the Chuckwalla Bench. Management Plans were developed for the Committee's land holdings at the Natural Area and at the Pilot Knob grazing allotment. A conservation strategy was drafted to protect the desert tortoise and the rare Harwood's Milkvetch on the DTPC's new landholdings at the Chuckwalla Bench.

In cooperation with the Bureau of Land Management's Ridgecrest Field Office, the U.S. Geological Survey, and the California Department of Fish and Game, the Committee used grant funding from the National Fish and Wildlife Foundation to make possible tortoise demographic and health surveys of four square miles of permanent study plots at the Natural Area in spring 2002: the first time all four square miles have been covered in a single season since the late 1970s. In addition, successful surveys for Mojave ground squirrel were conducted on three sites on the Pilot Knob grazing allotment.

The Committee's educational endeavors were equally outstanding. The Committee staffed a naturalist at the DTNA for the fourteenth year in a row, with a record 37% of visitors seeing a wild desert tortoise during the spring 2002 season. Committee volunteers and staff gave 29 educational presentations. The DTPC's interactive educational kiosks, Mojave Desert Discovery Centers, continued to educate the public at Bakersfield and Barstow (and soon in Yucca Valley). The Committee's website attracted more than 660,000 hits, a 42% increase over 2001.

The Committee's plans for 2003 include significant habitat acquisitions and enhancements in and around the Desert Tortoise Natural Area; on the ground management actions and tortoise surveys at the Natural Area's Honda study site in preparation for head starting and other tortoise recovery initiatives; and additional biosurveys and land acquisitions at the Chuckwalla Bench.

Analysis of Gene Flow Among Sonoran Desert Tortoise Populations Using Molecular Techniques and Radiotelemetry

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We used molecular techniques and radiotelemetry to examine movement patterns of desert tortoises, *Gopherus agassizii*, in southern Arizona. We collected blood samples from 170 individuals in nine mountain ranges surrounding Tucson. We analyzed mitochondrial DNA sequences and developed six novel microsatellite markers useful for conservation genetic studies of this species. Two microsatellite loci exhibited only marginal variability (2-3 alleles), but four were highly variable (8-27 alleles). Five of these markers successfully cross-amplified in Mojave Desert samples and may be applicable to studies of other congeners. Genetic differentiation among Sonoran populations was low, indicating that gene flow occurred historically among populations. Gene flow estimates among populations suggest that tortoises exchanged individuals historically at a rate greater than one migrant per generation. We found a positive correlation between genetic and geographic distance of population pairs, a pattern characteristic of isolation by distance. During the study, we observed a radiotelemetered tortoise make an inter-population movement (>32km) and documented the anthropogenic barriers it encountered. Desert tortoises are capable of and sometimes motivated to disperse great distances and these movements result in the exchange of genetic material among adjacent populations. Because many historic dispersal routes are no longer available to desert tortoises as a result of anthropogenic landscape change, informed management strategies need to be in place to facilitate the long-term persistence of Sonoran desert tortoise populations.

A Regional Study of Hibernation of Desert Tortoises: Hibernation Temperatures, Timing, and Site Characteristics

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Desert tortoises retreat to underground cover sites called hibernacula during winter months in the colder parts of their range. We studied hibernation behavior and the timing of hibernation of radio-telemetered tortoises at four sites distributed in three states: Nevada, Arizona, and Utah. These sites differ in elevation, physiognomy, and vegetation. Bird Springs Valley, NV (BSV), Lake Mead, NV (LM), Littlefield, AZ (LF), and City Creek, UT (CC) create a "transect" covering a distance of 240 km of northeastern Mojave desert habitat. We discuss data from four sites for two years and two of those sites for four years.

For the two-year period we monitored animals at four study sites, there were significant differences in the onset date among sites. This was largely driven by the LM site, at which tortoises entered hibernation later than the BSV and CC sites. The onset date at LM was not significantly different than at the LF site. There was no effect of year (averaged across all sites) on onset date. The duration of hibernation differed among sites as well, with a general gradient (days in hibernation LM=106, LF=132, BSV=137, CC=151) of increasing hibernation time with decreasing site temperature. There were no differences in duration between years. The termination date was earlier at LM (59) than at the three other sites. Tortoises at the other three sites stopped hibernating within an eight-day period on average (BSV=80, CC=83, LF=75), indicating that the duration of hibernation at most of the sites was dictated by the entry date in the fall rather than the timing of spring emergence.

For the four-year period from 1995 to 1998, there was no overall difference between CC and LF for the average date that tortoises entered hibernation (Julian date for CC=298, LF=305). There were differences in the date of onset of hibernation among years. The average date of onset in the fall of 1995 was eleven days later than the average date of onset in the fall of 1996. However, the onset dates for all other years were statistically indistinguishable from one another. Tortoises at the CC and LF sites also spent the same number of days on average in hibernation (CC 147.75 days vs. LF 139.29 days), although the duration of hibernation varied among years. This can be attributed to a twenty-day difference in duration between the winter of 1997/1998 and the winter of 1998/1999 (152 vs. 132 days respectively). All other years were statistically indistinguishable from one another. The termination date in the spring did not differ on average between the two sites (average termination Julian date for

CC=81.178, LF=80). There were significant differences in the termination date among years. The termination of hibernation (averaged for both sites) was earlier in the spring of 1997 (75.8), and in the spring of 1999 (73.4), than in the spring of 1996 (87) or 1998 (86).

Tortoises exhibited differences in the timing of the onset, duration, and termination of hibernation, which were generally consistent with the overall climate of the site. Thus, in cooler sites hibernation was initiated earlier, and lasted longer than at warmer sites. Although this appeared to be an environmentally driven phenomenon, there was great variation within sites in the timing of hibernation. For example, at one of our sites in 1997 the initiation date of hibernation varied by 72 days from the day the first animal entered hibernation to that of the last. The other three sites during the same year varied by 21, 31, and 34 days in their initiation dates. The range for all sites and all years was typically 30 days. This suggests that while tortoises responded generally to seasonal cues with respect to the timing of initiating hibernation, there were no acute climatic events that caused all tortoises to enter hibernation within a short time period at any site. We evaluated several models using exogenous cues to predict the timing of hibernation, and they were all refuted. Individual preferences relative to the timing of hibernation swamped all predictions that were based on climatic variables measured at the sites each year.

Managers charged with determining "safe" time periods for surface-disturbing activities should note that the initiation and conclusion of hibernation are gradual processes and vary greatly within locations. The months of December and January had the fewest number of active tortoises, all other months had some level of surface activity.

DESERT TORTOISE CONSERVATION AND MANAGEMENT AT THE MARINE CORPS AIR GROUND COMBAT CENTER, TWENTYNINE PALMS, CALIFORNIA

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The Marine Corps Air Ground Combat Center is located near Twentynine Palms, California, in the south-central Mojave Desert. Its mission is to provide realistic, live-fire military training. The “Combined Arms Exercise” integrates aircraft, artillery, and ground forces into a large-scale “task force” that prepares Marines for warfare around the world. The Marine Corps (USMC) has supported resource management and training land sustainability for decades. Since the listing of the desert tortoise (*Gopherus agassizii*), research on USMC lands has significantly contributed to the available knowledge and protection of this species. Though not a Critical Habitat Unit (CHU), the USMC tested different Line Distance Sampling methodologies and funded off-base surveys in adjacent critical habitat. Our G_0 animals are used for two other CHUs. Gardner looked at ecology of tortoises in mountainous habitats. Bjurlin investigated reproduction and early life-stage survival of hatchlings (these studies were presented at previous Symposia). Disease monitoring is continuing. A programmatic Endangered Species Act Section 7 consultation and an Integrated Natural Resources Management Plan were completed; both of these interagency-coordinated documents guide our resource management. Education is a constant and multi-faceted project: newspaper articles are frequently published, signs are installed, and 50,000 Marines attend comprehensive Natural and Cultural Resources briefings annually.

SPRING, FALL, OR WINTER? SUCCESS OF DESERT TORTOISE TRANSLOCATION AS AFFECTED BY SEASON OF RELEASE

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Translocation gives numerous desert tortoises in Clark County, Nevada a second chance at living full lives in the wild. Urban expansion is displacing tortoises at an alarming rate. Before our experiments in translocation, tortoises collected from the wild were kept in pens at the Desert Tortoise Conservation Center (DTCC) in Las Vegas with no plans for them to become functioning members of recovering wild populations. Numerous variables may affect the success of translocation. In this experiment we investigated the effects of season of release on mortality, movements, and body mass of desert tortoises.

We attached radio transmitters to selected tortoises from the DTCC and translocated these tortoises to the Large Scale Translocation Study (LSTS) site near Jean, Nevada in spring 1998, fall 1998, and winter 1999. In spring 1998, 14 females, 16 males, and 10 juveniles were released. In fall 1998, 16 females, 14 males, and 10 juveniles were released. In winter 1999, 9 females, 21 males, and 10 juveniles were released. Tortoises were located at least once each week during their active season and less frequently during hibernation. Body mass of tortoises was measured once each month.

The maximum distance moved from burrows of release within one year were calculated for adults and juveniles. The sex by season of release interaction was significant for adults. Females released in the winter moved farther than did all other sex by season groups (P=0.0088). This significant interaction was strongly influenced by a single female's movement (8,767 m or 3,700 m farther than others). No significant differences were found and power to detect differences was extremely low when this individual was dropped from the analysis. Generally, tortoises moved 2,000 m (range=330-8,700 m) maximum straight-line distance from their burrows of release regardless of season of release. Maximum distance moved from burrow of release was also calculated for juveniles after one year. There were no significant differences between juveniles released in the different seasons, yet power was low due to small sample sizes. The maximum distance moved from hibernacula was calculated for adults and juveniles tracked through mid-July 1999. For adults, season of release was a significant variable (P=0.0003). Adults released in spring moved the least from their hibernacula, followed by those released in fall, and those released in winter moved the farthest. Season of release was also significant for juveniles (P=0.0105) with the mean distance moved by the winter group (1,464 m) farther than the mean distance moved by the spring group (146 m).

Changes in body mass were calculated for adults only, as juveniles had too few data points for statistical comparisons. Five months after release, changes in body mass of animals released in spring and winter differed from those released in the fall (P=0.0001). Tortoises released in fall lost a small amount of body mass (-4%) during this time, while body mass was gained by spring (+10%) and winter (+7%) groups.

Mortality after one year differed for adults (P=0.0280). None of the adults released in spring (0/28), 22% (6/27) released in fall, and 21% (6/28) released in winter were found dead. Mortality rates for juveniles did not differ (P = 0.1844), but sample sizes were very small. There were 22% (2/9) of juveniles released in spring, 42% (3/7) of juveniles released in fall, and none (0/6) from the winter group found dead.

Managers should be prepared for tortoises to move away from a release area regardless of the season of release. Tortoises released in spring and winter gained body mass, while those released in fall lost a small amount in their first five months after release. It may be advantageous to release animals in spring or late winter, so that they will have the opportunity to gain body mass through intake of food and water in the several months following their release. None of the adults released in the spring of 1999 died during their first year. The spring of 1998 had plentiful rainfall, which resulted in an abundance of annuals. Adult tortoises released at the LSTS in spring 1997, during a drought, had 23% mortality rate their first year. This was no different from mortality rates of resident and translocated tortoises at a nearby site (Bird Spring Valley), that same spring. Releasing animals in the spring, especially one with plentiful rainfall may provide the most advantages to animals following their release. Considerations such as costs (money, likelihood of contracting disease, etc.) of maintaining tortoises in captivity before translocation may also affect decisions and should be considered in concert with expected mortality rates, behaviors, and changes in health status following translocation.

MOJAVE MAX: THE MAKING OF A LOCAL ICON

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In 1991, the Clark County Desert Conservation Program (DCP) established a Public Information and Education (PIE) program to provide information about the terms of the Section 10(a) permit and to educate the public about conservation in the Mojave Desert. The program is administered by Clark County in coordination with a public advisory committee. Traditional advertising methods including billboards, hotlines, specialty products, brochures, and public service announcements have been used to send conservation messages to school children, desert recreation groups, and the general public. The PIE program developed a tortoise cartoon character called Mojave Max to illustrate materials and speak for the program in 1995. Mojave Max is also a live tortoise at the Bureau of Land Management's (BLM) Red Rock National Conservation Area visitor's center.

Currently, the Mojave Max Emergence Contest is the single largest focal event sponsored by the PIE program. The contest is a broad collaboration of the Clark County School District, natural resource agencies, and local celebrities. The internet-based contest asks students to guess when the real Mojave Max will emerge from his burrow each spring. The contest is announced through a media campaign and is supported by curriculum materials and classroom visits by Mojave Max and friends. The contest provides an opportunity for teachers to use current events to illustrate features of the local environment and to direct students to internet resources for independent investigation. Mojave Max is now a locally recognized environmental icon. Like the famous groundhog, Punxsutawney Phil, seeing his shadow in the eastern United States, we intend that Mojave Max's emergence will be a celebrated harbinger of spring in the desert southwest. Future PIE efforts will assess program efforts and build on its successes to develop effective instruments for conservation education.

ZERO TAKE STRATEGIES FOR CONSTRUCTION PROJECTS IN HIGH DENSITY TORTOISE HABITAT

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Resource agencies have required biological monitoring on construction projects to mitigate the potential adverse effects of development activities since the desert tortoise was listed as a threatened species 13 years ago. Few changes in monitoring techniques have occurred in that time. On the recent High Desert Power Project, a 51 km gas pipeline was constructed from June to August between Kramer Junction and Adelanto, California. About 50 individual tortoises were observed in hundreds of encounters during the project and tortoises were active every day during construction activities. None were injured or killed. It is thought that innovative techniques utilized on the project contributed to achieving zero take. Some of these strategies included the following: extensive pre-construction surveys to identify sensitive resources and effective dissemination and utilization of these data, fencing the construction right-of-way in high density tortoise habitat, building enclosures around active tortoise burrows adjacent to construction areas, use of burrow transmitters to remotely monitor tortoise activity, monitoring of tortoises as well as construction activities, minimizing burrow excavations and tortoise relocations, and establishing a management structure that encouraged staffing flexibility and innovative thinking.

THE DESERT TORTOISE DENSITY EXPERIMENT: DOES CARRYING CAPACITY EXIST FOR A SPECIES LIVING IN A STOCHASTIC DESERT ENVIRONMENT?

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From 2000 through 2002, Clark County Nevada Multiple Species Habitat Conservation Plan (MSHCP) funded research to determine if tortoise health, behavior, reproductive output, and mortality changed with increasing tortoise density. The results of this study will be used by the U.S. Fish and Wildlife Service to determine whether additional tortoises may be placed at the large scale translocation site. Research was conducted at the Desert Tortoise Conservation Center (DTCC) located in the central Mojave Desert, south of Las Vegas, Nevada. Tortoises were placed in nine pens (about 4 ha each) at densities ranging from 337 to 3,204 tortoise/km^2. Tortoises were monitored monthly during the spring and summer for condition index (the ratio of body mass relative to body volume), signs of upper respiratory tract disease (URTD) and shell lesions, behavior, reproductive output of female tortoises, and mortality. Condition index was not significantly different with respect to the density of tortoises. Only tortoises that tested negative for URTD and showed no overt signs of disease were placed into the pens in 2000. By 2002, there were tortoises with signs of URTD in every pen, but the percentage of tortoises found to have signs of URTD or shell disease were not correlated to the density of tortoises in the pens. There were no significant differences in behaviors in relation to the density of the experimental plots in 2000 and 2001. However, in 2002, all tortoises spent more time below ground than in previous years, and tortoises in higher density pens spent significantly less time eating than tortoises in lower density pens. In 2001, there was no significant difference in the sizes of the first or second clutch in relation to tortoise density. The total average annual egg production of tortoises in high-density pens was significantly greater than that in lower density pens. Mortality did not vary significantly in relation to tortoise density, but the lowest density pen was the only pen that did not have any deaths. While there were very few statistically significant results, trends in the data suggest that if tortoise responses follow the same trajectory, differences between low and high density populations will begin to emerge. Because the desert tortoise is a long-lived species, the effects of population densities maintained above carrying capacity may not be measurable after only three years.

REPRODUCTION OF THE DESERT TORTOISE (*GOPHERUS AGASSIZII*) IN CLARK COUNTY, NEVADA

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Reproductive output of female desert tortoises was examined at three sites in the central Mojave Desert; Bird Spring Valley (BSV) from 1997 through 2002, Piute Valley (PV) from 1998 through 2002, and Cottonwood Cove (CWC) in 2001 and 2002. We used x-ray photography to determine clutch size, clutch frequency, egg width, and total annual fecundity. We compared these reproductive parameters with winter annual plant production and winter precipitation to look for significant relationships that would allow us to predict reproductive output in future years. Tortoises at BSV produced more eggs per clutch than tortoises at PV; however, tortoises at PV had a higher frequency of clutches than tortoises at BSV. While these two populations employed different reproductive strategies, the outcome was that tortoises at both sites had similar annual egg production for all years. Large body size of tortoises at BSV may be responsible for the larger eggs that were found in this population compared with PV. Reproductive output of tortoises at CWC was unable to be accurately determined because of the difficulty of extracting tortoises from their caliche caves at this site.

Reproductive parameters were poorly correlated with annual plant above-ground biomass (with the exception of the number of eggs produced per gravid female at PV). Winter precipitation was significantly related to clutch frequency, percentage of egg-layers, and mean annual fecundity and thus was a better predictor of reproductive parameters.

DESERT TORTOISE PROTECTION AND MANAGEMENT AT EDWARDS AIR FORCE BASE, CALIFORNIA

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Since the desert tortoise (*Gopherus agassizii*) was first listed as a threatened species, the Air Force has implemented the terms and conditions of biological opinions, such as presurveys and monitoring construction projects. Several projects have been undertaken to protect and recover this species. A desert tortoise adoption program was developed to track captive animals. Edwards AFB is participating in a head starting program with Fort Irwin. An awareness program has been implemented to educate base personnel about the desert tortoise. The entire base boundary has been fenced to prevent trespassing. Desert tortoise fences have been placed along some roads where desert tortoises are commonly encountered. Desert tortoise fencing has also been placed in strategic locations within the Precision Impact Range Area (PIRA). Pitfall hazards have been closed by various methods. Revegetation of disturbed areas has been accomplished on over 200 ha. The desert tortoise awareness program has been very successful and utilizes a video, decals, cards, brochures, and other printed materials. It is necessary to continue the education of base personnel. The boundary fence has completely eliminated unauthorized sheep grazing and nearly all illegal trash dumping. Although reduced, off road vehicle riders are cutting the fence and continuing to trespass onto the base, mostly along the western boundary. Desert tortoise fencing was accomplished only along one side of paved roads. This has resulted in desert tortoises spending more time in the road. Future projects will be developed to remedy this situation. Desert tortoise fencing in the PIRA is intended to prevent animals from entering high impact areas. A total of 133 pitfall hazards have been closed. Further monitoring will be required to determine the success of some projects like pitfall closures and revegetation.

RECOVERY OF THE DESERT TORTOISE IN THE CALIFORNIA DESERT CONSERVATION AREA

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The Bureau of Land Management, California Desert District has recently completed three of five scheduled regional plan amendments for the California Desert Conservation Area. The plan amendments establish a suite of management actions to be followed in conserving and recovering desert tortoise on public lands under the administration of the BLM. Public lands within the planning area will be managed in accordance with applicable laws, regulations, and policies that comprise the overall desert tortoise recovery strategy.

The discussion will address the basics of the regional plan amendments and their relationship to other planning efforts, the establishment of the Desert Wildlife Management Areas (DWMAs) and their locations, the management actions to be applied within the DWMAs, implementation goals and objectives, and assumptions about resource needs to be allocated to plan implementation.

DESERT TORTOISE MANAGEMENT ISSUES: QUADSTATE COUNTY GOVERNMENT COALITION

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QuadState is a formal JPA of six counties in the Mojave. We were not and are not anti-tortoise. We advocate reasonableness in implementing tortoise programs.

Our primary concerns:

- The agencies should attack the primary causes of tortoise decline, which appear to be disease and predation;
- Maintaining economic viability of land uses in the region;
- Establishing a reasonable recovery plan;

- The lack of reflecting the institutional framework in critical habitat and land management;
- Establishing population baselines and assuring regular monitoring;
- Establish efficacy monitoring;
- Focus must become outputs, not inputs;
- The Clark County HCP model and take authorization are inappropriate elsewhere and lack fairness.

The GAO audit fell short of reflecting all expenditures to date, lacking State and private mitigation expenditures and business losses. We support its findings of a lack of efficacy monitoring.

We support partnerships and dialogue to solve issues, but to date have been rebuffed, with protests denied by the Bureau of Land Management in each State's new plans. Cooperating agency status should mean something; local elected officials are a key element in decision-making and implementation processes.

Agency emphasis seems directed to implementing a Recovery Plan that we believe flawed and dated. We counsel review of that plan and its efficacy. Decisions are not abstract; they cost real money to implement, they affect real people and their livelihoods, and they result in lost funding to local governments to carry out their functions that are often in support of Federal agencies.

A MODEST PROPOSAL: HALTING DESERT TORTOISE DECLINES BY FOCUSING ALL RECOVERY EFFORTS ON DISEASE CONTROL AND RAVEN REMOVAL

David P. Hubbard, Esq.

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In 1988, desert tortoises in the Desert Tortoise Natural Area (DTNA), Kern County, California, suffered a severe outbreak of Upper Respiratory Tract Disease (URTD), causing a large number of adult tortoises to die. As a result, the U.S. Fish and Wildlife Service (USFWS) issued an emergency rule in 1989, listing the tortoise as a threatened species. Since that time, the federal government has spent more than $100 million on efforts to recover the desert tortoise. Ironically, however, very little of this money has been spent on disease detection and control. Instead, most recovery resources have been directed toward closing large areas of the California desert to human use, presumably to provide untrammeled habitat for the tortoise.

Unfortunately, this approach has failed. The relevant data indicate that tortoise populations continue to decline precipitously, and that the species is spiraling toward extinction. With no comprehensive, on-the-ground effort to control URTD, infected tortoises continue to transmit the disease to naive populations. Not surprisingly, URTD has assumed epidemic proportions, and is now killing adult (i.e., sexually mature) tortoises in California, Arizona, Nevada, and Utah, often in areas with pristine habitat (e.g., Goffs, Kern DTNA). Nevertheless, USFWS and the Bureau of Land Management remain inert on the issue and persist in land use and conservation policies that not only neglect the disease problem but may perpetuate it as well.

To make matters worse, raven predation of juvenile tortoises has increased significantly over the last decade, depleting the number of tortoises that can be recruited to replace the adults afflicted with URTD. This dual pressure, URTD in adults and raven predation of juveniles, has had a devastating effect on tortoise reproduction. If aggressive action to arrest URTD and control raven predation is not taken immediately, all other recovery efforts will be meaningless. The tortoise will not meet, much less sustain, the recovery lamda of 1.0 mandated by the Desert Tortoise Recovery Plan (1994).

To halt the tortoise's slide toward extinction, disease control, and raven management must become the overwhelming priorities of the recovery effort. This means that land use and conservation plans for the California Desert must be radically reoriented if the tortoise is to survive. Historically, these plans have sought to restrict human activities in the desert as a means of providing additional habitat for the tortoise. But it is now time to accept the fact that enough habitat for the tortoise has been cordoned off, and that URTD and raven predation, not humans or habitat loss, are the forces driving the tortoise to extinction. Therefore, land use and conservation plans should: (1) focus on disease and raven control, and (2) retreat from the long-standing, failed policy of shutting people out of the desert.

SPATIAL AND TEMPORAL SEARCHING OF DESERT TORTOISE INFORMATION

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The Mojave desert tortoise was first studied in detail by Woodbury and Hardy (1948), however, the majority of the existing data and related information was collected within the past 30 years, representing a large cumulative investment by agencies, institutions, and individuals. These data exist today in a wide variety of forms and media, and much of this information is not generally accessible, limiting the consensus building among scientists, policy makers, and managers. To date, there has been no systematic inventory, consistent descriptive cataloging, or comparative assessment of these data, outside of traditional annotated bibliographies. The Redlands Institute is undertaking such an effort, and is developing an integrated and innovative environment for tracking and searching a wide variety of information sources, called SPINE. Using the Redlands Institute's "Cross-Media Database (XMDB)™" as a platform, the SPINE system consists of desert tortoise related data and resources, a search platform, and an interface to access and search for information. Such data and information can include: scientific investigations, tabular and statistical databases, photographs, GIS data, multi-media, websites, people, organizations, events, and other types. Common search techniques such as simple keyword or full-text searching are included, and in addition, other methods such as spatial and temporal searching and topical hierarchies are being incorporated. More sophisticated search and discovery techniques, such as collaborative filtering or importance ranking are also being developed. This paper will focus on basic keyword and topic search techniques in addition to the more advanced spatial and temporal search functionality.

HERPESVIRUS INFECTION IN A CAPTIVE DESERT TORTOISE (*GOPHERUS AGASSIZII*)

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Herpesvirus infections have been reported in a variety of tortoises including Greek (*Testudo graeca*) and Hermann's (*Testudo hermanni*) tortoises in Europe, Chilean tortoises imported into the United States from South America and several species of tortoises imported into Japan for the pet trade (Jacobson et al. 1985, Drury et al. 1998, Muro et al. 1998, Une et al. 1999, Origgi et al. 2001). Herpesvirus infections also have been reported in captive desert tortoises (*Gopherus agassizii*)(Harper et al. 1982, Pettan Brewer et al. 1996). Until now, the virus infecting desert tortoises has not been isolated or sequenced. Thus, comparisons have not been made between herpesvirus infecting desert tortoises and isolates from Greek and Hermann's tortoises. Recently, a desert tortoise owned by the San Diego Turtle and Tortoise Society was submitted to a consulting veterinarian for clinical evaluation. The tortoise had emerged at an unusual time from hibernation and exhibited anorexia and lethargy. Upon clinical examination, necrotizing lesions were observed in the oral cavity, with the tongue extensively affected. Biopsies were obtained and submitted to the College of Veterinary Medicine, University of Florida for light microscopic evaluation, viral isolation attempts, and gene amplification. Light microscopy revealed epithelial cell necrosis and proliferation. Many epithelial cells contained intranuclear inclusions consistent with those seen in herpesvirus infections. Using a set of consensus primers used to detect herpesvirus in multiple species of animals (Van Devanter et al. 1996), a 215 bp segment of the polymerase gene was amplified. A set of primers designed specifically for the ribonucleotide reductase (RR) gene of herpesvirus found in a Hermann's tortoise was also used successfully to amplify a 386 bp segment. Subsequent sequencing of both products were compared to existing known sequences of genes and found to be most closely related to other tortoise herpesviruses. Comparisons made with isolates from Hermann's tortoises indicated a 72% homology with the RR gene. Viral isolation attempts are in progress. Isolation of the herpesvirus in desert tortoises will be important in interpreting current ELISA testing. Once the virus is isolated, it will be purified and used as the antigen in the test. Transmission studies are necessary to demonstrate a causal relationship between this virus and disease in desert tortoises.

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Desert Tortoise Conservation and Management at Marine Corps Logistics Base, Barstow, California

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Marine Corps Logistics Base (MCLB), Barstow is one of two logistics bases operated by the U.S. Marine Corps. It is located in western San Bernardino County, California less than 10 km east of the City of Barstow. MCLB is located next to the Mojave River. The MCLB includes three operational units occupying approximately 2,486 ha: Nebo Main Base, Yermo

Annex, and the Rifle Range (RR). The RR is home to the desert tortoise (*Gopherus agassizii*), with about 220 ha designated as critical habitat. After our 1993 and 1997 Biological Opinions issued by USFWS, we have instituted an education program of briefing all RR users, newly assigned base personnel, contractors, and visitors to the area. Tortoise fencing has been installed along the perimeter fencing adjoining NEBO and the RR to protect them from equipment operations at the test pond and during construction of the landfill cap activities; tortoise fencing is also attached to the perimeter fencing surrounding the capped landfills, protecting them from contamination. We are currently processing an Environmental Assessment and Biological Assessment for the proposed installation of perimeter fencing of the RR. About 11,000 m of four-strand barbed wire (not lower than 30 cm) on three sides of the range and the north side with a chain link. The needed fencing will help deter off road vehicle activities on the RR and also help eliminate illegal dumping. Recently, a 1.1 m gas pipeline was installed through the RR, with very stringent rules on plant protection, Revegetation, and tortoise control, which was strictly enforced and adhered to.

The MCLB's vision for environmental stewardship, the *Strategic Plan,* states: "attain full and sustained environmental compliance and protection of our natural, cultural, and historical resources and achieve the mission of the United States Marine Corps, train, fight, and win." As the west Mojave Desert is increasingly used for commercial, industrial, and urban development, preservation of the extensive existing natural resources will continue to be a high priority.

CALIFORNIA DEPARTMENT OF FISH AND GAME AND THE DESERT TORTOISE, OUR STATE REPTILE

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Since 1939 state laws have been in place to protect the desert tortoise. In August of 1989, the tortoise was officially listed as federally threatened. The Department's mandate for protecting the tortoise is the California Endangered Species Act (CESA). Section 2081 of the Fish and Game code allows take with a permit for scientific, educational, management, or incidental take to an otherwise lawful activity provided the take is minimized and fully mitigated. In addition to the Take Permit, a Memorandum of Understanding (MOU) for Handling Tortoises is needed and we must review the qualification of each person who applies for the MOU. The

Department also issues Scientific Collecting Permits for research and studies on desert tortoise and permits for Possession of Captive Tortoises.

The Department, through the CESA permitting process, and by other means, has acquired more than 12,000 ha of desert lands within recovery units. Along with the land, the Department has also collected enhancement and endowment fees for management of the lands. Fencing has been installed in some of the areas to exclude cattle grazing and off highway vehicle use.

The Department has also been an integral member of the West Mojave Plan, and has participated in the Northeastern Mojave, the Northeastern Colorado, and other planning efforts that effect desert tortoise habitat. We are also active participants in the Desert Tortoise Management Oversight Group and the Desert Managers Group.

This past year the Department also funded long-term study plot surveys including blood work and necropsies for health and disease information. We co-hosted the Desert Tortoise Disease workshop. Enforcement activities resulted in the seizure of about fifty illegally possessed tortoises, with charges being filed against the perpetrators. We are also currently working with the California Tortoise and Turtle Club to improve permitting for captive tortoises.

DESERT MANAGERS GROUP TORTOISE RECOVERY ACTIONS, WITH EMPHASIS ON THE EFFECTIVENESS EVALUATION

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The Desert Managers Group (DMG), at the June 12 to 13 meeting, decided to increase emphasis on implementation of cooperative recovery actions for desert tortoise, and to become more assertive as a group in promoting recovery actions. The overall strategy was presented to, and accepted by, the Management Oversight Group. The strategy has four components: (1) evaluate management actions, (2) continue desert tortoise population monitoring, (3) finish land use plans, and (4) increase focus on causes of mortality. One of the four emphasis areas in the strategy was effectiveness evaluation. Step one in evaluation of actions taken was to compile actions taken by member agencies toward recovery of the desert tortoise since listing. That step was completed in coordination with the Management Oversight Group Technical Advisory Committee and University of Redlands. In its December meeting in Needles, California, the Desert Managers Group chartered a working group to work on the second step toward evaluation. The first meeting of that group occurred on March 6, 2003 in Riverside. Once the second step is completed, the DMG plans to sponsor design of long-term (15 years or longer) adaptive management or monitoring studies to be implemented in areas where management action is being taken or has been taken. The intent is for all studies to be peer reviewed and allow for stakeholder participation.

THE RED CLIFFS DESERT RESERVE IN UTAH: ACCOMPLISHMENTS AND THOUGHTS

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The Red Cliffs Desert Reserve in Utah has made significant strides in establishing a 25,000 ha Desert Wildlife Management Area that meets the goals of the tortoise recovery plan while also gaining the support of local communities. The foremost reason for this success has been the establishment of an effective partnership between Washington County, Bureau of Land Management, U. S. Fish and Wildlife Service, Utah Department of Natural Resources, School Trust Lands, and seven participating cities. This partnership has emphasized on the ground results achieved via an open public process that stresses accountability and reduced bureaucracy. Notable partnership achievements include: more than 3,100 ha of land trades and purchases, an education outreach program, improved reserve design, systematic monitoring of tortoises, 69 km of fencing, ordinances, an extensive Public Use Plan and user map, trail-heads to control recreational access, and Congressional support. A tortoise recovery review meeting, specific to the reserve, was held in December of 2002 to ascertain accomplishments and appropriate next steps. Human impact monitoring and a new education center will be underway in 2003.

PLANT COMMUNITY STRUCTURE ASSOCIATED WITH LIVESTOCK WATERING SITES IN THE CENTRAL MOJAVE DESERT

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Domestic livestock have grazed the Mojave Desert for more than 150 years. Recently, land management agencies have reduced grazing and focused efforts on restoring degraded rangelands. Assessments of plant community changes caused by grazing are lacking in this region, but are required when defining restoration objectives. We quantified plant community structure along a grazing disturbance gradient associated with livestock watering sites in a recently closed grazing allotment. Annual and perennial plants were sampled in interspace and beneath-shrub microhabitats at 0, 50, 200, and 800 m from the edge of 10 watering sites during two years of contrasting rainfall (1998 annuals, 2000 annuals and perennials). Annual plant trends were significant only during 1998 when rainfall was high. Annual plant cover decreased 36% between 0 and 50 m from watering sites, primarily due to declining cover of the aliens *Erodium cicutarium* and *Schismus* spp. However, cover of another less abundant alien, *Bromus madritensis* ssp. *rubens*, increased with distance from watering sites, indicating that not all alien annuals were more abundant closer to the sites. In contrast, native annual plant cover increased 156% between 0 and 200 m. Within interspaces, total annual plant richness (0.02 m^2 > scale) increased 68% between 0 and 50 m, and 33% between 50 and 200 m, due to increasing numbers of native species. Beneath-shrub annual richness increased 33% between 0 and 800 m. Perennial cover declined 50%, and perennial richness declined 30, 37, and 48% (at 100, 300, and 600 m^2 scales) between 0 and 50 m from watering sites. Structural diversity of perennial plants was unchanged along the gradient, although perennials in the <0.5 m^2 cover class were less common near watering sites. Our findings suggest that grazing impacts on plant community structure are greatest within 50 to 200 m from watering sites in the central Mojave Desert.

BASELINE MONITORING IN THE UPPER VIRGIN RIVER RECOVERY UNIT

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The Upper Virgin River Recovery Unit, managed as the Red Cliffs Desert Reserve, is considered a highly threatened population due to its proximity to urban growth and small size. The Reserve includes 15,640 ha of Mojave desert tortoise habitat and its goal is to maintain a stable or increasing tortoise population in perpetuity. The Reserve is located in southwest Utah, Washington County, within the Upper Virgin River Valley. The Reserve represents the northeastern extent of the desert tortoise's geographic distribution.

Accurate regional desert tortoise density estimates are a critical component of the Washington County HCP. The monitoring objective for the Reserve is to: (1) obtain precise and accurate baseline abundance and density estimates, and (2) assess long-term density and abundance trends over a 20-year period. The pooled density of adult tortoises in Zone 3, the core of the Reserve, was 0.32 tortoises per hectare (95% CI: 0.29-0.36; CV: 5.85%) while the pooled density across the Reserve was estimated at 0.29 tortoises per hectare (95% CI: 0.26-0.33; CV: 5.87%).

Several demographic parameters including growth rates and health assessments, were observed as a byproduct of monitoring. In all years, growth rate of recaptured tortoises was significantly correlated with original capture carapace length with annual growth declining as carapace length increased. In 2001, the annual growth rate was significantly below the 95% confidence interval of 1998, 1999, and 2000 monitoring years.

Although URTD symptoms have been previously observed within the Reserve, a general increase in the percent of tortoises processed during monitoring has been observed since 1997. In the last three years precipitation in the St. George area has been well below the 50-year mean as well as the 95% confidence interval. If physiological stress exacerbates the signs of the disease, clinical symptoms would be expressed during these stressful or drought periods. Although health observations not only suggest the presence of URTD but a possible increase in tortoises with the disease, biological samples (e.g., blood, exudates, biopsy specimens) are required to confirm the pattern and magnitude of URTD occurrence within the Reserve.

REPRODUCTION IN A DESERT TORTOISE (*GOPHERUS AGASSIZII*) POPULATION ON THE BEAVER DAM SLOPE, WASHINGTON COUNTY, UTAH

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Life history information including clutch size, clutch frequency, annual fecundity, egg dimensions, and hatchling success were collected in 1989 from the Beaver Dam Slope desert tortoise population, in southwestern Utah. The mean clutch size for both first and second clutches was 5.2 ± 0.50 eggs (n=16). Mean clutch size of the first and second clutches did not significantly differ. Mean clutch frequency was 1.33 ± 0.14 clutches per reproductive female (n=12). Carapace length was significantly correlated with mean clutch size and clutch frequency. Annual fecundity of tortoises ranged from 3 to 18 eggs. Mean annual fecundity was 7.0 ± 1.16 eggs and was significantly correlated with carapace length (n=12). Carapace length was significantly correlated with egg width but not egg length. Reproductive tortoises had a smaller home range than non-reproducing tortoises; however, this difference was not significant. Compared with other Mojave desert tortoise reproductive studies, the Beaver Dam Slope population had a lower clutch frequency and percentage of reproducing females. In the past decade, the Beaver Dam Slope has experienced population declines due primarily to disease and habitat degradation and alteration.

EVOLUTION OF LINE DISTANCE SAMPLING TO MONITOR DESERT TORTOISES IN THE MOJAVE DESERT

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The United States Fish and Wildlife Service approved the Desert Tortoise Recovery Plan in June 1994. The plan recommended development of a methodology to determine desert tortoise population status and trends rangewide. A series of technical meetings ensued beginning in the winter of 1995 in Reno, Nevada, and in 1996 at Laughlin, Nevada, and finally with a workshop in Las Vegas in the fall of 1998 using model styrofoam tortoises to evaluate

the sampling technique. In June 1999, the Desert Tortoise Management Oversight Group agreed to use the line distance sampling technique as the method of choice to monitor desert tortoise populations rangewide. Beginning in the spring of 2001, line distance sampling was implemented throughout the geographic range of the Mojave Population of the desert tortoise. Sampling in 2001 provided encounter rates for each of the Desert Wildlife Management Areas but not enough captures to obtain adequate sample sizes for each area. To compensate for this, the number of transect kilometers was increased rangewide from the 2,901 km sampled in 2001 to 4,117 km in 2002. Also, the transect footprint was modified from a single 400 m square (1.6 km) transect, to two square transects each 500 m on a side (each 2 km) in the shape of a bow tie, totaling 4.0 km. In 2001, the mean observed rangewide encounter rate was 0.145 tortoises/km, and the encounter rate in 2002 was 0.092 tortoises/km. This reduction in activity of live tortoises observed above ground or observable within their burrows was documented with the focal animals. In 2001, the overall mean activity recorded for g_0 was 84% rangewide and 64% in 2002. This reduction in activity and encounter rate was likely drought induced. The resulting numbers of live adult tortoises ($\geq$ 180mm) MCL were about equal in 2001 and 2002 although over 1,200 more kilometers were surveyed in 2002.

POTENTIAL ASSETS AND LIABILITIES INHERENT TO DESERT TORTOISE HATCHERY NURSERIES

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In North America, nursery hatcheries have been established for two tortoise species, *Gopherus agassizii* and *Gopherus flavomarginatus*. A hatchery-nursery was established in Mexico in 1983 for *G. flavomarginatus*. A second hatchery-nursery, the Ft. Irwin Study Site (FISS), was established in 1990 at Ft. Irwin National Training Center, Ft. Irwin, California for *G. agassizii*, and is still in use. However, certain concerns are associated with their activities, making the hatchery-nurseries a topic of controversy.

There are many benefits associated with hatchery nurseries. They provide hatchlings a semi-natural environment with suppressed predation and suppressed contact with diseased adults. It allows for dispersion of neonatal and juvenile desert tortoises into high quality habitats that have suffered prior extirpation. Such programs also provide the settings for long term studies using high numbers of tortoises. Using tortoises of known ages from the same confined area reduces the effects of confounding variables, and allows for studies therein to resolve many unknown issues, such as the causes of morbidity and mortality in the surrounding depleted populations, the identification of genetic variation in populations, and the effect of assortive mating.

On the other hand, liabilities may be associated with hatchery nurseries. These liabilities need to be identified and plans made in advance to minimize the negative effects. Predation may be subsidized by releasing a large number of neonates and juveniles at once, or by providing artificial feeding or water to the site. If artificial feeding is not conducted, tortoises may be nutritionally restricted to available food within the enclosure. Inappropriate genetic stock may lead to outbreeding depression. Data collection might be artificially skewed with these semi-wild populations of tortoises from what might naturally be found. High density of animals may lead to altered behavior or increased rates of transmission of disease agents and parasites. Exhaustion of a site and loss of carrying capacity may also occur due to the high density of animals over many years and the increased amount of foot traffic of those managing the site. The site may also be vulnerable to vandalism of equipment and animals.

Certain environmental and demographic conditions do justify construction of a desert tortoise hatchery nursery. There should be a consistent and unambiguous long term trend in declining numbers or a confirmed failure of recruitment. There should be a failure to diagnose causes of morbidity and mortality or the absence of effective alternative mitigation to reverse known causes. Local densities or total numbers should be so low so as to preclude the likelihood of natural recovery, but still sufficient for recruiting local females and eggs for the hatcheries. The hatchery should be close to good habitat with an adequate carrying capacity, and protected to reduce the risk of predation, vandalism and poaching. There needs to be a long term commitment of funding sources and management authorities to ensure that the long term goals of research are met.

In conclusion, although offering many assets to research of the biology of the young desert tortoises, hatchery nurseries have many liabilities that make them such a topic of controversy. As experimental hatchery nurseries are studied, these risks can be identified and addressed in the development of protocols for present and future hatchery nurseries.

STATUS OF THE BUREAU OF LAND MANAGEMENT'S DESERT TORTOISE RECOVERY PROGRAM IN NEVADA

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In 1998, the Bureau of Land Management (BLM) Las Vegas Field Office Resource Management Plan (RMP) was approved and implementation begun, incorporating management recommendations set forth in the Desert Tortoise Recovery Plan (US Fish and Wildlife Service 1994). The Recovery Plan established four Areas of Critical Environmental Concern (ACECs), affording protection to designated critical tortoise habitat within the Nevada Recovery Units. Management direction for ACECs reduces or eliminates certain resource uses and activities identified in the Recovery Plan as incompatible with desert tortoise recovery. Since implementation of the RMP, BLM has focused its efforts on six primary objectives to protect the desert tortoise and improve its habitat within ACECs: (1) closing grazing allotments, (2) designating approved routes, (3) restoring disturbed areas, (4) restricting off highway vehicle events, (5) closing areas to mineral entry, and (6) retaining areas in federal ownership. Through careful planning and cooperation between its federal and state partners, Clark County, environmental and recreational user groups, and other interested stakeholders, BLM has made significant progress in meeting these objectives. Additionally, funding opportunities provided through the Clark County Multiple Species Habitat Conservation Plan have enabled BLM to further tortoise recovery by increasing law enforcement, implementing population monitoring studies, fencing highways, funding research, and developing conservation management plans. In an era of changing national priorities and shrinking federal budgets, maintaining ongoing efforts and implementing new initiatives will continue to be increasingly challenging for BLM. Creative funding mechanisms and close, collaborative working relationships will define BLM's future success in desert tortoise conservation.

SOLAR ABSORPTANCE OF THE CARAPACE APPEARS TO HAVE LITTLE INFLUENCE ON THE THERMAL BIOLOGY OF DESERT TORTOISES

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There is great variation in the carapace color of individual tortoises, permitting animals to range from very light to very dark coloration. Coloration should influence the amount of the incident solar energy that is absorbed (absorptance) by the animal, which should, in turn, influence the thermal energy balance, and therefore the behavior of the animal. To understand the relative importance of this energy exchange mechanism, we manipulated absorptance to solar radiation of desert tortoises by painting the carapace with very reflective or very absorptive paints (only non-toxic tempura paints were used). This caused the animals to have absorptances to solar radiation that were both greater than and less than that naturally occurring. Animals were placed in outdoor enclosures that provided full exposure to the sun, and a burrow, which could be used as a shelter from sun exposure. We compared the amount of activity time, the times of day that animals were active, rates of heating, and body temperatures of treatment tortoises with light and dark paints to unpainted tortoises. Surprisingly neither light nor dark tortoises differed in the amount of time in which they were active relative to naturally colored tortoises. Neither did they heat or cool at different rates. In addition, all tortoises, regardless of their colors, experienced similar body temperatures. These results appear to be counterintuitive when considering only heat transfer between the animal and its environment. However, the explanation for this surprising result may be found in regulation of heat transfer within the animal. We suggest that the carapace may function as a regulatable insulator for heat transfer within the tortoise thus regulating warming due to incident solar radiation. We observed tortoises behaving in a manner consistent with this hypothesis. Tortoises with higher absorptances frequently covered their carapace with soil, which may act to shield the carapace from excessive solar radiation. These results suggest that tortoises likely have physiological and behavioral mechanisms to regulate heat exchange with the environment so as to keep body temperatures within tolerable limits. Coloration of the tortoise carapace may play a lesser role in the thermal ecology of this species than previously thought.

ARE DESERT TORTOISES NUTRITIONALLY CONSTRAINED BY A SHORTAGE OF HIGH PEP PLANTS, AND IF SO, WHAT DO WE DO?

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In the absence of late spring or summer rains that permit drinking, desert tortoises must obtain sufficient water and nitrogen in food plants to excrete ingested potassium. They do this by selecting food plants having positive PEP (Potassium Excretion Potential) values. The amount of protein nitrogen available to support growth, reproduction, and disease resistance will depend on the PEP value of the overall diet. I suggest that access to and ingestion of high PEP plants may be essential to short- and long-term nitrogen balance, overall health in the face of infectious disease, and female reproductive output. If so, a shortage of high PEP plants may underlie the precipitous population crashes evident in recent decades in much of the Mojave Desert.

Is there botanical evidence in support of this plant shortage hypothesis?

- Plants that are high in PEP typically contain high levels of tissue water, high concentrations of leaf protein, and modest levels of potassium, all of which typify plants of high photosynthetic rate that are intolerant of low soil moisture (Oftedal 2002). Thus high PEP plants appear to be restricted in time and space to very moist conditions, and thus achieve abundance in numbers and biomass only in years of high winter rainfall and relatively cool springs, such as the 1991 to 1992 and 1997 to 1998 El Niño Southern Oscillations.
- In 1992 tortoises at the Desert Tortoise Research Natural Area (DTNA) were found to target high PEP plants (such as *Lotus humistratus* and *Astragalus didymocarpus*) that were both uncommon and highly patchy in distribution (Jennings 1993). Yet this was after the major tortoise population crash at DTNA, suggesting that a larger tortoise population would have been hard pressed to obtain a high PEP diet.
- Tortoises in Ivanpah Valley that foraged within exclosures that kept out range cattle selected high PEP plants (such as *Malacothrix glabrata*) that were largely unavailable in adjacent areas where cattle grazed, causing a significant shift in tortoise diet (Avery 1998). The calculated effect was that dietary PEP was reduced to one half outside the exclosures, compared to within.
- At Fort Irwin, although a high PEP evening primrose (*Camissonia claviformis*) was moderately abundant in both 1998 and 2001, juvenile tortoises could only rely on them in early spring when conditions remained moist (Oftedal et al. 2002). As the season

progressed, these plants withered (and were damaged by tortoise and caterpillar foraging), leading tortoises to forage on lower PEP plants, with a reduction in overall dietary PEP.

- In years of lower rainfall, fewer plant species germinated and grew on the Beaver Dam Slope (AZ) and at City Creek (UT), leading tortoises to forage predominantly on lower PEP plants such as the invasive exotic annuals *Bromus rubens*, *Schismus barbatus*, and *Erodium cicutarium* (Esque 1994). These plant species adapt to low soil moisture by reducing tissue water or nitrogen, and increasing tissue potassium, such that their PEP values are particularly low under such conditions.

Desert tortoises apparently derive from southern arid regions in which summer rainfall is important. I speculate that they were able to colonize the Mojave and Colorado Deserts (winter rainfall deserts) only because they could regularly find a sufficient abundance of high PEP plants. If so, any factor that reduces the temporal or spatial abundance of high PEP plants in these areas could have calamitous effects. In particular the abundance, biomass, reproductive success, and size of the seed bank of high PEP plants may have been reduced by:

- plant removal by grazing livestock (see third bullet above);
- changes in soil moisture associated with disturbance of the soil surface (by livestock, ORVs, construction activities, tank maneuvers, etc.);
- competition for soil moisture and nutrients by ubiquitous invading species such as *Bromus rubens*, *Schismus barbatus*, and *Erodium cicutarium;* and
- changes in the amount and distribution of rainfall due to climate change associated with global warming.

Unfortunately, it is difficult to evaluate the plant shortage hypothesis due to lack of data on historic trends in the abundance of annual plant species (other than the known massive increases in abundance and biomass of invasive species). I suggest two research strategies that may be fruitful: (1) Studies of stable isotope levels in tortoise carcass and shell materials that might indicate diet shifts by tortoises over time (including changes in the importance of high PEP legumes to tortoise diets); and (2) Manipulation of the abundance of high PEP plants (both via revegetation and removal experiments) to determine the impact on tortoise diets. If the current seed bank of high PEP plants is in fact depleted, habitat protection may be a necessary but insufficient measure for the restoration of tortoise diets to a high nutritional plane.

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DOES NUTRITIONAL ECOLOGY UNDERLIE THE GREATER SUSCEPTIBILITY OF MOJAVE TORTOISES THAN SONORAN TORTOISES TO POPULATION CRASHES?

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It is apparent that tortoises as a group are particularly susceptible to dietary nutrient imbalance due to their inability to excrete potassium, a ubiquitous plant constituent, either via salt gland secretions or via concentration of urine. In most circumstances, tortoises require periodic access to drinking water, access to high moisture foods, or access to protein-rich foods to eliminate the potassium loads associated with feeding.

In most if not all of the Mojave Desert, summer rainfall events are rare and localized and thus cannot be depended on as a source of water. In the absence of drinking water, the ability of tortoises to utilize dietary protein for anything other than potassium excretion via urate production will depend on the relative proportions of potassium, water, and protein (nitrogen) in the food. This relationship may be approximated by the Potassium Excretion Potential or PEP index. In moderately dry years, when high PEP plants are not available, tortoises may feed but remain in negative nitrogen balance, gradually losing body lean mass and condition, as demonstrated by Nagy and Medica (1986), Peterson (1996), and Henen (1994, 1997).

In good rainfall years, Mojave tortoises may be able to locate patchy or dispersed plants of high PEP, as demonstrated by Jennings (1993) and Oftedal et al. (in press; unpublished data from 2001). Diets of high PEP plants will allow positive nitrogen balance, and provide protein for growth and reproduction. However, Avery's data (1998) indicate that cattle grazing may selectively remove high PEP plants, such as desert dandelion (Oftedal et al. 2002). Unfortunately, we have no good data to indicate the extent to which the abundance of high PEP plants has been affected by such factors as livestock grazing, soil compaction, invasive exotic species, air pollution, fire, climate change, or other human-impacted variables. The higher water needs of many high PEP plants may make them particularly susceptible to anything that reduces soil moisture retention. I believe it is likely that many high PEP plants that were essential components of diets that once allowed recovery of tortoise body condition in wet years are now greatly reduced, not only in terms of above-ground biomass, but also in terms of the available seed bank. This may be especially true of species with large seeds (such as legumes) that are not easily dispersed back into areas of former abundance.

If this is true, Mojave tortoises may be fighting a losing battle with environmental nitrogen, being unable to accumulate enough in body protein to consistently offset losses in dry years. A series of dry years, or a change in local flora due to invasive plants, or increased nitrogen losses associated with infection may be enough to initiate a health crisis that has been building over a long time period. Poor nitrogen status may also increase tortoise susceptibility to disease, as it does in other species. Both juvenile growth and egg production require substantial amounts of protein nitrogen. Thus long-term changes in nutritional ecology may ultimately cause population crises in terms of morbidity and mortality even though the proximal causes may vary from place to place.

This hypothesized scenario predicts that access to drinking water would reduce the dependence on high PEP plants, because tortoises that can drink can dispose of potassium without needing to utilize dietary or stored protein. Several studies also suggest that drinking of water frees tortoises to consume large amounts of dry or senescent material that can be used to generate body fat. Preliminary analysis of summer foraging observations at Ragged Top, Arizona, in the Sonoran Desert are consistent with the idea that tortoises that drink may be less selective in feeding (Oftedal, Averill-Murray, and Christopher, unpub. data). Thus it appears that tortoises in the Sonoran Desert where summer rainfall is regular would not have the same dependence on high PEP plants as do Mojave tortoises. Given the trend for summer rainfall to decline in the Sonoran desert from southeast to northwest, the only area in which a loss of high PEP plants might be critical is the Colorado subdivision of the Sonoran Desert.

This hypothesized scenario is consistent with historical patterns of population crashes north and west of the Colorado River. If true, it suggests that tortoise health may be closely linked to changes in plant communities, and that simple management solutions, such as restrictions on grazing in low-rainfall years, may not address the underlying problem. Should attempts be made to experimentally alter the abundance of high PEP plants, or to look at the relation between disease prevalence and abundance of high PEP plants? These and other potential management and research actions warrant careful consideration.

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VALIDATION OF THE ELISA TEST FOR HERPESVIRUS EXPOSURE DETECTION IN DESERT TORTOISES: OPTIONS AND LIMITATIONS

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An Enzyme Linked Immunosobent Assay (ELISA) was applied to the serological diagnosis of tortoise herpesvirus exposure in Greek and Hermann's tortoises (*Testudo graeca* and *Testudo hemanni*). Subsequently, it was validated through a transmission study in Greek tortoises. The ELISA was statistically as reliable as serum neutralization test (SN), which is traditionally considered to be the gold standard test for serological diagnosis of viral infection. Recently, the ELISA test was used to determine exposure of desert tortoises (*Gopherus agassizii*) to tortoise herpesvirus. Despite preliminary data that suggested a positive correlation between the ELISA test results and those obtained by polymerase chain reaction (PCR) specific for tortoise herpesvirus sequences, the ELISA test still needs to be validated for use in desert tortoises. Ideally, a transmission study in desert tortoises would be the best approach for validation. The principal obstacle to this possible approach is the lack of a herpesvirus isolate from a desert tortoise. Until a desert tortoise isolate is available for use as an antigen in the test, another approach could entail the use of Western blots in parallel with the ELISA test. While Western blots are known to have a lower sensitivity than ELISA tests, they have a higher specificity. This diagnostic protocol is commonly used in human medicine to confirm that a positive ELISA is truly positive. The use of PCR on plasma samples could be a further confirmatory test. However its use would be limited to those infected tortoises that are also viremic.

NEW TECHNOLOGIES TO ASSESS VEGETATION CHANGES AND TO REVEGETATE DISTURBANCES IN THE MOJAVE DESERT

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Research funded by the U.S. Department of Defense (DOD), U.S. Department of Energy (DOE), and the U.S. Environmental Protection Agency as part of the Strategic Environmental Research and Development Program evaluated novel techniques for collecting and processing high-resolution images in the Mojave Desert. New image-processing software makes it possible to accurately measure areas for total plant canopy cover and locations of up to four dominant shrub species in minutes compared to hours or days of fieldwork. Analysis shows that data from images are highly correlated with data from field sampling. Canopy cover and individual shrub parameters such as width, length, circumference, and shape factors can be readily measured yielding size distribution histograms and other statistical data on plant community structure. These techniques have been evaluated at Fort Irwin, California and the Nevada Test Site, Nevada. Results were compared among the new and conventional image processing techniques, including 1-meter pixel IKONOS satellite images. These techniques facilitate the development of georectified color-coded contour maps of shrub cover for use with Geographic Information System software and have been used at Fort Irwin to develop a cover map of the entire 2,850 square km facility. They are valuable tools to accurately assess vegetation change and identify areas that require mitigation. The DOD has recognized the need to use lands on a sustainable basis so they are implementing measures to not only document disturbances but to investigate ways to mitigate the impact of their activities. Over 35% of all reclamation projects fail in arid environments because of harsh site conditions. Our research has focused on techniques to revegetate various levels of disturbance at Fort Irwin with an emphasis on low-cost techniques such as seeding. A series of field test plots have been implemented over the past four years and techniques have been developed to effectively restore these disturbances. Temperature and moisture are key factors that influence germination and establishment and these factors can be used to optimize seeding success. Treatment of seed to remove germination inhibitors can speed germination and increase seeding success. Mulches are effective at enhancing germination and retaining soil moisture as well as controlling erosion. User manuals that describe how to implement these technologies have been developed and are available upon request. The work was supported by the Strategic Environmental Research and Development Program.

TWO YEARS AFTER THE CDCA LAWSUIT SETTLEMENT: INTERIOR ROLLS-BACK CONSERVATION AND FORCES NEW LITIGATION

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In 1976, Congress designated a 10 million ha swath of the Sonoran, Mojave, and Great Basin Deserts stretching from the Mexican border north to Death Valley and the eastern Sierra Nevada Mountains as the California Desert Conservation Area (CDCA). The CDCA includes some of the most scenic and biologically important areas in Imperial, San Diego, Los Angeles, Riverside, San Bernardino, Kern, Inyo, and Mono Counties. This Virginia-sized expanse was entrusted to Bureau of Land Management (BLM) to be forever protected for wildlife, open-space, sustainable use, and human enjoyment.

BLM's 4.4 million ha share of the CDCA contains 1.4 million ha of habitat designated critical to the survival and recovery of the threatened desert tortoise (*Gopherus agassizii*).[1] The CDCA also harbors 23 other federally protected threatened or endangered species including Peninsular Ranges bighorn sheep, Inyo California towhee, desert pupfish, Coachella Valley

[1]U.S. Fish & Wildlife Service, final rule (59-5820), *Federal Register*, 2/8/94.

fringe-toed lizard, and rare plants such as Cushenberry oxytheca, Amargosa niterwort, and Peirson's milkvetch.

These 24 species and the entire ecological health of the CDCA are jeopardized by new BLM plans which favor the historic status quo of mining, livestock grazing, road building, utility projects, and off-roading. Imperiled species, such as the desert tortoise, are declining as regional planning efforts dominated by anti-environmental politics short-change wildlife by not implementing recovery plans.

In late 2000 and early 2001, The Center for Biological Diversity (CBD), Public Employees for Environmental Responsibility (PEER), the Sierra Club, and five off-road groups settled a landmark lawsuit with BLM over its failure to follow the Endangered Species Act. In the settlement BLM agreed to: prohibit mining expansions or new mines on all designated or occupied listed species habitat within the CDCA; reduce or prohibit livestock on 0.8 million ha; prohibit ORVs on 220,000 ha of sensitive habitat areas, including 19,880 ha of the Algodones Sand Dunes; route designation on 352,000 ha of the West Mojave; complete desert-wide route designation by 2004; and other conservation and recovery measures.[2] The CDCA settlement had BLM implementing on-the-ground recovery actions but it did not require everything needed to recover species and now its balanced management is abandoned as BLM rolls-back protections across millions of hectares.

Aided by U.S. Fish and Wildlife Service (USFWS) non-jeopardy biological opinions, BLM has now finalized its Northern and Eastern Colorado Desert Plan (NECO), Northern and Eastern Mojave Desert Plan (NEMO), Coachella Valley Plan, Western Colorado Desert Routes of Travel Plan (WECO), and Algodones (Imperial) Dunes Plan, but all these plans fall far short of species and habitat recovery needs. Species recovery plans are not implemented, despite a finding by GAO that the tortoise plan is based on sound science. With the Ft. Irwin expansion lurking, proposals for tank training on China Lake Naval Air Weapons Station, and an aggressive anti-environmental administration, the abandonment of the minimum species recovery shield provided by the CDCA settlement represents a dangerous roll-back in wildlife protection. The settlement remains in place within the West Mojave (WEMO) planning area until plan completion. The roll-back of conservation through these BLM plans forced new litigation against Interior, especially USFWS.

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[2]Center for Biological Diversity, Legal Settlement Protects 24 Endangered Species on 11 Million Acres, *www.biologicaldiversity.org/swcbd/goldenstate/cdca/settlement.html*

The abandoned CDCA settlement offered management toward species recovery, but long-term results will come from new litigation, better cumulative effects planning and consultations, and more scrutiny.

DESERT TORTOISE CONSERVATION AND MANAGEMENT AT NAVAL AIR WEAPONS STATION, CHINA LAKE, CALIFORNIA

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The Naval Air Weapons Station (NAWS) at China Lake is located in the northwestern corner of the Mojave Desert. The Navy at China Lake manages greater than 444,000 ha of land. NAWS lands cover portions of three floristic provinces: California, Great Basin, and Mojave Desert. Since the desert tortoise (*Gopherus agassizii*) was listed as a threatened species, the Navy has implemented an innovative planning and management program to protect and conserve this species.

Tortoise population densities were established for China Lake through extensive field surveys conducted by Kiva Biological Consulting (1991) throughout desert tortoise habitat located on-Station. Based on these surveys, a land use management and habitat management plan was designed to accommodate the Navy's ongoing and evolving military mission operations throughout the Station, and provide an effective conservation and protection strategy for desert tortoise habitat.

In 1992, the Station formally consulted with U.S. Fish and Wildlife Service (USFWS) for the implementation of a programmatic Desert Tortoise Habitat Management Plan (HMP). China Lake's HMP accommodates the Station's ongoing military mission and provides guidelines for new project's review and approval within the designated Habitat Management Areas (HMA), standard mitigation measures, and the designation of about 80,600 ha of the South Range as a management area for the desert tortoise. A non-jeopardy opinion was issued for the NAWS HMP by USFWS in 1992. The Biological Opinion (BO) formalized the Station's avoidance and minimization process, defined a review and approval process for Navy projects occurring in tortoise habitat throughout the Station, provided incidental take limits, defined annual reporting requirements, and identified other reasonable and prudent measures.

The Station has managed ongoing military operations and desert tortoise management in accordance with the BO. The HMP has been fully incorporated into the Station's Integrated Natural Resources Management Plan (INRMP). The INRMP was reviewed and approved by both the Service and the California Department of Fish and Game in September, 1999. NAWS China Lake has augmented the HMP through other actions beneficial to the desert tortoise, including the removal of sheep grazing from the HMA and through fencing of Station land adjacent to other public lands.

DESERT TORTOISE PROTECTION, MANAGEMENT, AND EDUCATION ON THE NATIONAL TRAINING CENTER AND FORT IRWIN, CALIFORNIA

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The desert tortoise (*Gopherus agassizii*) was listed as threatened under an Emergency listing in 1989. The Environmental Division, within the Directorate of Public Works at Fort Irwin, has implemented an aggressive program to educate the soldiers training at the NTC and the civilian workforce employed there. Every soldier training at the NTC is required to attend at least two briefings on environmental issues, including the desert tortoise issues. The Environmental Division also participated in at least six public outreach events, where tortoise awareness programs are provided to at least 10,000 civilians annually. In 1993, in a proactive effort to protect tortoise habitat, the post biologist solicited the aid of an Engineering Company to erect a fence to protect the southern boundary of the NTC from military activities, until such time the U.S. Fish and Wildlife Service could designate critical habitat. In 1990, with funds from the Army and Southern California Edison Company, we initiated a study on desert tortoise neonates under the direction of Dr. David Morafka (California State University, Dominguez Hills). Before our initiating these studies at the Fort Irwin Study Site (FISS), very little was known about this stage in the life cycle of the desert tortoise. This program has grown into a Head Start Program, which could be used in the future to reestablish tortoise into areas from which they have been extirpated. The NTC has been proactive in the area of desert tortoise disease research, having funded several studies on URTD, herpesvirus, and the effects of heavy metals on the tortoise population.

Habitat Use By Desert Tortoises At The Florence Military Reservation, Pinal County, Arizona

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The Florence Military Reservation (FMR) is a 10,421-ha site in Pinal County, Arizona, located approximately 80 km southeast of Phoenix. The Arizona Army National Guard uses FMR as a military training site, utilizing 14, 500 x 1000-m training areas (firing boxes) for ground support and artillery exercises. FMR contains gently sloping to nearly flat alluvial slopes in the north, and more rugged terrain with deeply incised washes to the south. Along the banks of the washes, cavities are eroded into the calcium carbonate (caliche) soils. In 2000, we initiated a four-year radio telemetry study to determine habitat use and movement patterns of desert tortoises at FMR, relative to military use.

We tracked up to 17 tortoises through 2002: 7 males, 7 females, and 3 juveniles. We estimated home range sizes up to 53.7 ha. Mean home range ($\pm$ 1 SD) for males (20.9 $\pm$ 19.56 ha) was twice the size as the mean home range for females (10.1 $\pm$ 8.69 ha). Home range size was variable within each sex, ranging from 6.32 to 69.16 ha in males and 2.8 to 25.8 ha in females. The length of time a tortoise has been monitored is not related to home range size. We determined habitat selection by use of compositional analysis. Tortoises used three habitat types, defined as vegetation associations: triangle leaf bursage-mixed cacti-mixed scrub association; creosote bush–triangle leaf bursage association; and a xeroriprarian scrub complex. Tortoises showed selection towards the xeroriparian scrub complex, which is typically associated with incised washes.

Tortoises used four types of shelter sites: caliche caves, soil burrows, woodrat middens, and pallets under clumps of vegetation. Caliche caves were the most utilized shelter type and are also associated with deeply incised washes. Tortoise restricted their movements within firing boxes primarily to washes, but we also observed them in bursage–mixed cacti association. The bursage-mixed cacti association typically occurs along flat benches between washes. Tortoises found in this association were either active or resting in pallets under clumps of bursage.

We determined nest-site selection by use of X-radiography. In May 2002 we located females and brought them to a central point to be X-rayed. We radiographed females using a HF-80 (MinXray) portable X-ray machine powered by a gasoline generator. We felt eggs by palpitation, but used radiographs to confirm presence of shelled eggs and to determine clutch size. We located nest sites by observing female movement patterns. Female desert tortoises typically lay eggs in the loose soil of a burrow. They may remain in the burrow before and after oviposition. Field workers also looked for nests in the burrow entrance using hand trowels.

Four of the 7 monitored females produced eggs, and mean clutch size ($\pm$ 1SD) was 5.0 $\pm$ 0.82. We suspect that 3 of the 4 tortoises nested in caliche caves. Although we found no nests in the shelter entrance by observers, females stayed at the shelter sites several weeks pre-and post- oviposition. The nest site for the fourth female was uncertain, as she was very mobile, moving from shelter site to shelter site during the time of oviposition.

The observed use of xeroriparian and bursage dominated habitats is important relative to National Guard training activities because of a preponderance of both habitat types within all firing boxes. We are currently in the process of mapping all caliche caves in the study area. If tortoises are indeed tied to the presence of caliche caves, this could be a useful tool in future firebox placement.

DISEASE INCIDENCE ON SONORAN DESERT LONG TERM MONITORING PLOTS

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Through 2002, 16 monitoring plots within the Sonoran desert tortoise population in Arizona had been surveyed at least twice, in addition to a new plot added in 2002. Populations have generally remained stable through 1999 with the exception of a decline at the Maricopa Mountains plot in the late 1980's (Arizona Interagency Desert Tortoise Team [AIDTT], 2000). Since 2000, there have been apparent declines documented on the East Bajada (Black Mountains), San Pedro, and Hualapai Foothills plots (Averill-Murray *this volume*). Current monitoring plot protocol (Averill-Murray 2000) states that all tortoises should be visually inspected for clinical signs of upper respiratory tract disease (URTD) and cutaneous dyskeratosis (CD). We reviewed each plot's history to see if incidence of disease sign was correlated with population declines.

METHODS

During each plot survey, field workers examined all captured tortoises for clinical signs of URTD (serous discharge bubbling or flowing from the nares or swollen eyes, eyelids, and conjunctiva [Brown et al. 2002]) and CD (gray-white dry, roughened, and flaky scutes [Jacobson et al. 1994; Dickinson et al. 2002]). We reviewed the 2000 update on Sonoran desert tortoise populations (AIDTT 2000) and recent plot reports (Woodman et al. 1999, 2000, 2001, 2002, 2003) to determine the relative numbers of tortoises showing signs of URTD and CD for each sampling period. We then compared numbers of tortoises with clinical disease signs to current and historic population estimates and numbers of carcasses found during each sampling period.

In 2002 researchers drew blood from tortoises on six different monitoring plots by jugular venipuncture. The University of Florida conducted enzyme linked immunosorbant assays (ELISA) to test for *Mycoplasma* (causative agent of URTD) and herpesvirus antibodies.

RESULTS

Clinical signs for URTD have typically been relatively low (<10%) to non-existent on most plots. There are a few exceptions: Arrastra Mountains (29% in 2002), Bonanza Wash (23% in 2002), East Bajada (18% in 1990 and 33% in 2002), Harquahala Mountains (12% in 2001), and San Pedro Wash (11% in 2001). Field workers conducted CD exams on multiple surveys of 14 plots. Incidence of CD ranged from 0 to 65% and increased on four (29%) of the plots (Figure 1). There was no strong correlation between URTD and documented declines, but the number of tortoises with CD has increased dramatically on three plots (Table 1).

Field workers drew blood from 41 tortoises on six different long-term monitoring plots. No tortoises tested positive for URTD antibodies (Table 2). Twenty tortoises on four plots tested positive for herpes antibodies; 14 tortoises tested positive for both American and European isolates, and six tested positive for the European isolate only.

DISCUSSION

Several tortoise population declines have occurred on long-term monitoring plots (Maricopa Mountains, San Pedro Wash, and East Bajada) and are backed up by large numbers of carcasses that accumulated between sampling periods. Other apparent declines can be attributed to several factors, including differences in data analysis (Averill-Murray *this volume*) and the difficulty of finding tortoises in the Sonoran Desert, especially during sub-optimal weather conditions (Van Devender 2002, Averill-Murray *this volume*).

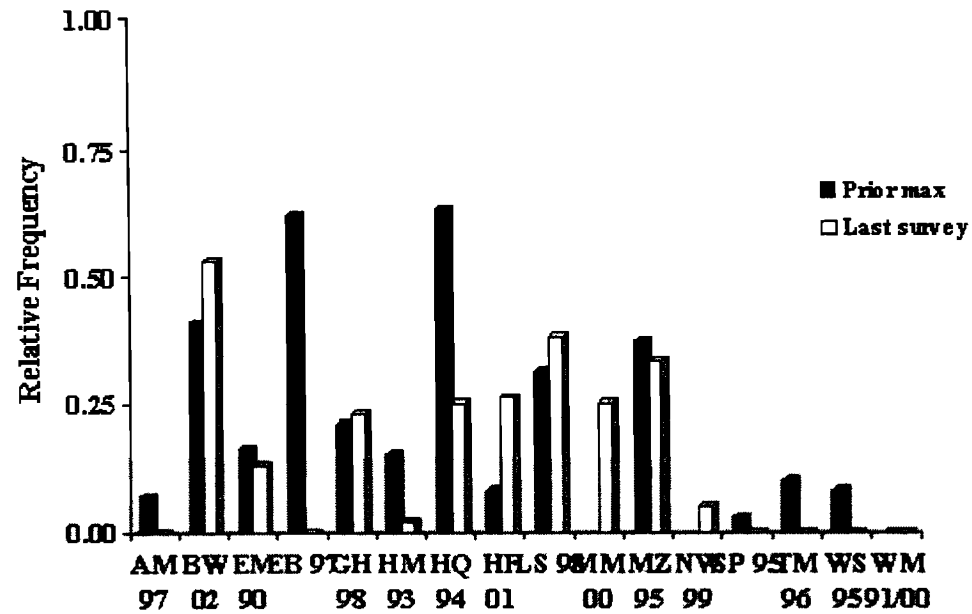

Figure 1. Relative frequency of desert tortoises on monitoring plots in Arizona with cutaneous dyskeratosis. For plots where CD has been documented on two or more consecutive sampling periods, the values for the prior max and latest survey period are given. Plot abbreviations are as follows: AM, Arrastra Mountains; BW, Bonanza Wash; EM, Eagletail Mountains; EB, East Bajada; GH, Granite Hills; HM, Harcuvar Mountains; HQ, Harquahla Mountains; HF, Hualapai Foothills; LS, Little Ship; MM, Maricopa Mountains; MZ, Mazatzal Mountains; NW; New Water Mountains; SP, San Pedro; TM, Tortilla Mountains; WS, West Silverbells; and WM, Wickenburg Mountains.

Field workers documented a high incidence of CD on the East Bajada Plot, but no other alarming disease frequencies were noted. Cutaneous dyskeratosis was present on over half the tortoises at two other plots (Bonanza Wash and Harquahala Mountains), but the population estimates have only declined slightly, with confidence intervals overlapping between sampling periods (Table 1). Care must be used when placing blame on one factor, such as CD, as the cause of a decline. We still do not understand the nature or cause of CD, nor its actual effects on the long-term health of tortoises (Dickinson et al. 2002).

Table 1. Comparison of population estimates (PE) with 95% confidence limits number of carcasses (CARC) relative frequency of desert tortoises showing clinical signs of upper respiratory tract disease (URTD) and relative frequency of tortoises with cutaneous dyskeratosis (CD) between years on selected Sonoran Desert, Arizona, long-term monitoring plots.

Plot	CD	Year	PE	CARC	URTD
Bonanza Wash	0.41	1992	------	13	0.06
	0.38	1997	27(16-38)	2	0.08
	0.53	2002	17(8-26)	2	0.23
East Bajada	------	1990	------	5	0.18
	------	1993	67(51-83)	10	0.04
	0.62	1997	61(50-72)	6	0.04
	0.65	2002	9(8-10)	67	0.33
Harquahala Mountains	0.29	1988	------	4	0.00
	0.63	1994	15(13-17)	0	0.00
	0.50	2001	10(6-14)	3	0.12
Hualapai Foothills	0.09	1991	------	8	0.00
	0.13	1996	37(34-40)	6	0.00
	0.26	2001	16(14-18)	11	0.00
San Pedro Wash	------	1991	------	11	0.05
	0.03	1995	125(103-147)	9	0.06
	0.00	2001	39(22-50)	46	0.11

Upper Respiratory Tract Disease does not seem prevalent outside urban areas. Results from blood samples taken in conjunction with those described in this paper show few to no tortoises testing positive for *Mycoplasma* antibodies at isolated sites, while a high percentage of tortoises at Saguaro National Park (SNP) did test positive (Table 2). Only a few of the SNP tortoises showed clinical signs, and there have been few mortalities within the group of *Mycoplasma*-positive tortoises. To date, no tortoises occurring on monitoring plots have tested positive. The frequency of tortoises testing positive for herpesvirus antibodies is much higher. The significance of these results is not clearly understood, as the herpesvirus ELISA has only been validated on European *Testudo* and has yet to be validated for any *Gopherus* species (Brown et al. 2002).

Table 2. *Mycoplasma* ELISA results from Sonoran Desert tortoise research sites, Arizona. All sites are relatively isolated from major urban areas except for Saguaro National Park.

Site	*n*	0	-
Florence Military Reservation, Pinal County	13	0	13
Various Monitoring Plots[1]	41	0	41
Ragged Top Mountain, Pima County	18	2	16
Saguaro National Park, Pima County	25	21	4
Sugarloaf Mountain, Maricopa County	26	0	26

[1] Monitoring plots sampled include Bonanza Wash, Buck Mountain, East Bajada, Harcuvar Mountains, San Pedro Wash, and West Silverbell Mountains.

Sonoran desert tortoises live in disjunct populations along rocky slopes associated with desert mountain ranges (Van Devender 2002), so disease issues may be less of a problem on a range-wide scale in the Sonoran Desert (Howland and Rorabaugh 2002). Disease may be a secondary factor in tortoise declines, as other factors including natural population fluctuations, drought, and fragmented migration routes may influence or exacerbate disease issues within populations. To address desert tortoise population ecology and disease issues, monitoring plot protocols will continue to undergo revision as needed to better capture population information needs. Periodic blood sampling will continue, in addition to setting up a necropsy protocol for dead or dying tortoises found on research sites.

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THE HISTORY OF UPPER RESPIRATORY TRACT DISEASE IN THE EASTERN MOJAVE DESERT TORTOISE: OBSERVATIONS FROM THE DESERT TORTOISE CONSERVATION CENTER, LAS VEGAS, NEVADA

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Upper Respiratory Tract Disease (URTD) in the desert tortoise (*Gopherus agassizii*) continues to be a major factor affecting health and survival in wild populations. *Mycoplasma agassizii* is one causative agent of URTD. Other pathogens as well as other strains of *Mycoplasma* may also cause URTD or similar symptoms. The objective of this talk is to provide some history on what we have learned at the Desert Tortoise Conservation Center (DTCC) and put this into perspective. URTD was first identified in desert tortoises in the Mojave Desert in the late 1980s. Since its identification, it has been detected in a variety of other tortoise species including the gopher tortoise (*Gopherus polyphemus*) from the southeastern United States. The desert tortoise was listed as a threatened species under the Endangered Species Act by USFWS due to declines in populations throughout the Mojave Desert. Studies funded in 1991 to provide basic information on the biology of desert tortoise were confounded by outbreaks of URTD in animals maintained under semi-natural conditions at the DTCC. These animals were healthy appearing animals which had been collected off development sites throughout the Las Vegas Valley. All animals underwent a 30-day visual quarantine for signs of URTD. At the time, there were no tests available to determine if an animal had been exposed to *Mycoplasma* or carried the organism in its upper respiratory tract. We have now learned that this organism is probably transmitted via direct contact, is highly contagious, and has an apparent acute phase followed by a chronic phase. Reproduction was observed to drop off in sick animals during the acute phase. However, there appears to be a potential for recovery following the acute phase if the animal is relatively healthy when it is exposed. There also appears to be a low probability that the organism is transmitted vertically from mother to egg. Current methods for testing for the organisms include an ELISA that detects antibodies to the organism; and a Culture/PCR technique that allows for the detection of *Mycoplasma* DNA in nasal flushes. It should be noted that animals collected during the early period of these studies, but not incorporated in study groups, were left alone in pens without the stress of interacting with other individuals, and were rarely observed to break with signs of URTD. As well, offspring produced from mothers during the acute phase of URTD in 1992 to 1993 have been raised for 10 years with no signs of URTD. Several hypotheses have been presented as to how URTD was spread in the desert tortoise including the release of sick captive animals back into wild populations. This is possible and probably now continues to be a factor. However, this is also confounded by the fact that the gopher tortoise in the southeastern USA has been shown to also harbor

Mycoplasma spp., which is associated with URTD outbreaks in many wild populations in Florida. It is important to note that gopher tortoises have not been kept as pets but were a food source up until recent times, and in some areas continue to be. Other factors related to increased development may be involved, and must be investigated.

TEMPERATURE-DEPENDENT SEX DETERMINATION IN NORTH AMERICAN TORTOISES, *GOPHERUS AGASSIZII* AND *GOPHERUS POLYPHEMUS*

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Two of the four North American tortoise species (*Gopherus agassizii* and *Gopherus polyphemus*) show temperature-dependent sex determination (TSD). Both species have extensive latitudinal ranges varying in xeric habitat structure. *Gopherus agassizii* occurs in the Sonoran and Mojave Deserts, from Southwestern Utah to Alamos, Mexico, while *G. polyphemus* occurs in the southeastern U.S., from southern Florida to southern South Carolina and west to Louisiana. *Gopherus agassizii* displays the highest pivotal temperatures (31.3° C) for a turtle species while *G. polyphemus* displays a pivotal temperature similar to other turtle species in its range (29.3° C). Temperature dataloggers were set in latitudinal arrays throughout both species U.S. ranges to measure ground temperatures in suitable nest site areas, including one site which extended beyond the northern-most range for both species. All other sites had tortoises present or exhibited suitable vegetation characteristics. Variation in ground temperature of nest site choices by females was compared to laboratory based pivotal temperatures for both species. Timing of nesting and nest site locations by females in different regions provided temperature conditions near laboratory pivotal temperatures during the critical period of incubation. Relationships between timing of nesting, nest site choice, and northern range extent for these species will be discussed.

DETERMINING THE CARRYING CAPACITY OF DESERT TORTOISES

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Translocation is being studied as a method of handling desert tortoises that have been displaced by urban development in Las Vegas, Nevada. Beginning in 1990, displaced animals were housed at a holding facility, the Desert Tortoise Conservation Center (DTCC), until a release site and protocols could be established. Between April 1997 and November 1999, 2,000 desert tortoises were released at the Large-Scale Translocation Study (LSTS) site. This was the maximum number allowed under the U.S. Fish & Wildlife Service Endangered Species permit and the LSTS was considered to be "full" at a somewhat arbitrary density of 29 animals/km^2 for animals greater than 180-mm midline carapace (MCL). To investigate the feasibility of releasing more tortoises at the LSTS, the Clark County Nevada Multi-Species Habitat Conservation Plan (MSHCP) funded this study to establish a maximum density below which desert tortoises showed no adverse effects. The parameters studied were mortality, behavior, body condition, disease symptoms, and reproductive output. In April 2000, animals greater than 180 mm MCL were stocked at densities ranging from 150 animals/km^2 to 1,500 animals/km^2 into a set of nine pens at the DTCC. To reflect more realistic conditions, additional animals smaller than 180 mm MCL were added to each pen. Beginning in 2000, animals were weighed monthly and the pens were monitored daily for aboveground activity from May through October. In 2001, monthly weighing continued and a sample of females were monitored for egg production. There were no significant differences among pens in mean annual plant biomass in 2000 (a year of below average rainfall) and in 2001 (a year of adequate rainfall). In the first year of release, there was a greater incidence of fighting in the three highest density pens than in the three lowest density pens for all months except the release month (April). Animals in the three highest density pens were also more likely to share burrows (up to seven in one burrow) than animals in the three lowest density pens. There were no trends evident in body condition index (CI) among pens in 2000 or in 2001. There was no trend between density and presence of upper respiratory tract disease symptoms in 2000 or in 2001. Reproduction also did not vary among the densities. While not significant, there was a positive trend in mortality among densities. It also appears that, at least through the first two years, extremely large and extremely small desert tortoises are most "at risk" for dying regardless of density. Although this is intended to be a long-term study,

the first two years of data indicate that at least the three highest densities, densities more than 850 animals/km^2 (tortoises greater than 180 mm MCL), are likely to be detrimental to survival.

AN HISTORICAL OVERVIEW OF THE CLARK COUNTY DESERT CONSERVATION PLAN: KEY ISSUES AND HOW THEY WERE RESOLVED

Paul Selzer

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In August of 1989, the Desert Tortoise was listed as a threatened species under the terms of the federal Endangered Species Act (ESA). The immediate effect of the listing was to make land disturbance activities in southern Nevada, especially grading, construction, and cattle grazing, potentially liable under the ESA. Builders, developers, OHV users, and others were suddenly in danger of becoming subject to criminal and civil penalties by pursuing their normally legal activities. In response to the listing, the state of Nevada, the city of Las Vegas, and the Southern Nevada Homebuilders Association sued the Department of Interior to challenge the listing. Initial proceedings in the lawsuit were unsuccessful and led many to believe that a new strategy to deal with the likely disastrous economic impacts of the listing had to be undertaken. The alternative chosen by Clark County and the incorporated cities within its boundaries was to initiate and develop a habitat conservation plan which would benefit both the species and the local economy. Within months of the emergency listing, the County initiated the process to develop the Desert Conservation Plan for the Desert Tortoise.

The Clark County Desert Conservation Plan was approved and a Section 10(a) Incidental Take Permit was issued in 1992. Since then, Clark County and the stakeholders in its public process have continued to develop and implement the terms of the Plan to benefit the desert tortoise, to improve the status of its habitat, and to retain the permit, which allows development to continue without fear of violating the ESA. The purpose of the presentation is to describe the process utilized to resolve specific issues with the hope that other communities that are facing similar conflicts between preservation of natural resources and economic development might be able to use the same or similar methods for resolving their conflicts.

Among the issues that were addressed in the formulation of the DCP and which will be described in the presentation are: (1) Why did such disparate groups agree to participate in the process? (2) How were the lawsuits resolved? (3) What was to be the disposition of tortoises displaced by development? (4) What about urban and suburban populations located within the path of development, grazing, roads, OHV activities, and other interests of the rural communities; funding issues; resolution of political resistance; URTD; (5) Where should conservation activities be focused; and (6) How to deal with public information and education, fencing of linear features, and other issues.

IMMUNITY AND THE DESERT TORTOISE: THE UNKNOWN FACTOR IN SURVIVAL?

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ABSTRACT

The immune system is a critical determinant in the survival of many different species of animals, and therefore is likely vital to the survival of desert tortoises. Immune responses are required in the protection and recovery from infectious and other diseases. For some infectious agents like mycoplasmas, the host immune response can contribute to damaging the host. However, little information is available about the immune system in desert tortoises and its interactions with known agents of disease. This paper will present an overview of immunity and what is known about immune responses in the desert tortoise. As mycoplasma are implicated in the current losses in desert tortoise populations, the contrasting roles of the immune system in similar diseases found in another animal species will be described. Lastly, the potential effects of seasonal variation, nutrition, gender and genetic background on immunity and susceptibility to disease in desert tortoises will be discussed. There is a critical need to determine the relationship between immune responses and the survival of the desert tortoise. This understanding may provide additional markers of stress and disease, eventually leading to improved knowledge-based approaches to management or treatment of desert tortoise populations.

OVERVIEW OF THE IMMUNE SYSTEM

Immunity is a critical factor for survival. The immune system protects the host from infection, cancer, and other diseases. It does this by removing and inactivating potentially damaging agents and promoting resistance to re-exposure to infectious and other agents. Immune responses help in the disease recovery. Not only is this done through the elimination of disease causing agents, immune responses also localize agents to the initial site of infection, preventing spread to other sites of the body, which, if allowed, can subsequently cause more severe disease and lead to death. There are multiple immune mechanisms responsible for ultimately removing the infecting agent or irritant. Each of these mechanisms has unique capabilities to handle a variety of insults and provides an overlapping system to protect the host. Lastly, the immune system helps begin the repair of tissue damage once the infectious agent or irritant is removed. Thus, the major function of the immune system is the protection and recovery from diseases, and any impairment of immunity will impact survival. For information beyond what is discussed below, there is an excellent review of the immune system in reptiles (Brown 2002).

The initial responders to infection: The phagocytes. One of the initial cell types that respond to a potential pathogen is the phagocyte. These cells have the ability to recognize foreign particles and infectious agents, and subsequently eat and digest them (Figure 1). The phagocyte internalizes the agent in a small membrane sac (vacuole) within its cytoplasm, known as a phagosome. The phagosome subsequently fuses with another membrane sac (lysosome), which contains digestive enzymes and other factors, and this eventually destroys the agent. The phagocytes are also the major cell types that contribute to the cascade of events in inflammation.

There are two main populations of phagocytes in the tortoise, heterophils and macrophages (Alleman et al. 1992). Macrophages are phagocytes that reside in tissues. Resident macrophages often make the initial contact with an infectious agent and subsequently release factors to recruit additional phagocytes. Based on what is known about mammalian neutrophils, which are similar to heterophils, the initial phagocyte recruited to the site of an infection should be the heterophil. Neutrophils in mammals are very potent cells and can often eliminate most irritants, and heterophils in tortoises may have similar activity. If neutrophils/heterophils are unable to clear the irritant or infection, then additional macrophages are recruited to the site to help in localizing or eliminating the agent. Overall, the phagocytes are critical in the initial responses against infections. For example, humans with deficiencies in phagocytes are plagued with chronic infections due to bacterial agents. Furthermore, macrophages, in concert with other cell types, initiate the development of adaptive immunity, another potent arm of the immune system. Thus, the phagocytes are part of the initial line of defense against infections and contribute to the subsequent development of immunity.

Adaptive immunity is specific and remembers. Adaptive immunity is elicited in response to a foreign agent. In contrast to the phagocytes that can immediately recognize a large number of foreign agents and attempt to eliminate them, adaptive immune responses take time to be generated and are specific for the agent. The role of adaptive immunity is to focus a large number of powerful mechanisms on a specific agent to eliminate and prevent disease.

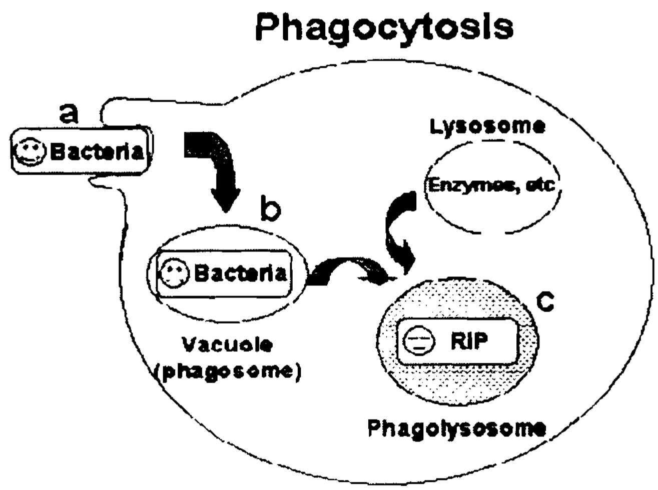

Figure 1. Phagocytosis. a) Phagocytes (heterophils/neutrophils and macrophages) recognize foreign particles or bacteria. The phagocyte forms membrane projections or fingers out to surround and engulf the target. b) Once engulfed the bacteria is within a membrane vesicle called a vacuole of phagosome. c) The phagosome fuses with lysosomes to form a new vesicle called a phagolysome. Lysosomal contents in the phagolysome digest and kill the bacteria.

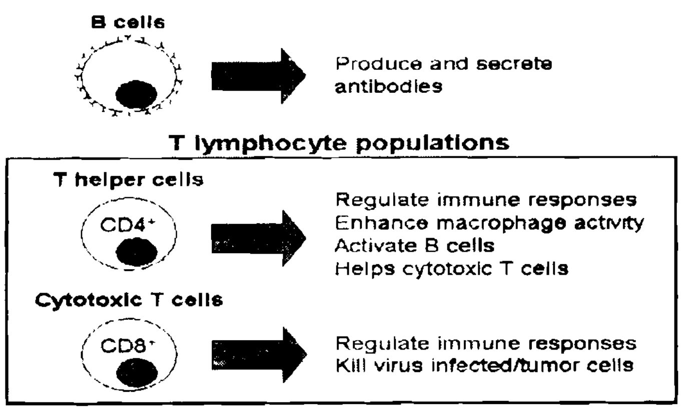

Figure 2. Lymphocyte populations. Lymphocytes consists of two major populations the B cells and T cells. B cells are derived from the bone marrow while the thymus is the site of T cell development and maturation. T cells can be divided into two major populations, the T helper cell and cytotoxic T cells. Each lymphocyte population has their unique functions. See text for further discussion.

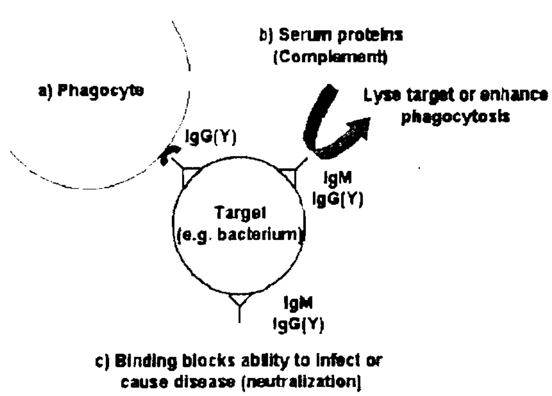

Figure 3. Function of antibody classes. IgY of the desert tortoise appears to have similar functions as IgG in mammals. a) Phagocytes are able to recognize IgG(Y) bound to a target, facilitating the uptake and destruction of the target. b) A series of serum proteins, known as complement, interacts with antibody, IgM or IgG(Y), and either lyses the target or coats it with complement proteins that enhance phagocytosis. c) The binding of antibody can result in neutralization of a bacteria, virus or toxin by interfering with the normal function of these targets.

Once an adaptive immune response is generated, the host will respond more quickly and more vigorously to re-exposure to the same agent. Thus, a major characteristic of adaptive immunity is its specificity for the eliciting agent and the ability to respond faster upon subsequent exposures (memory).

The major cell type responsible for the development of adaptive immunity is the lymphocyte. There are two major lymphocyte populations, B cells and T cells (Figure 2). B cells are derived from the bone marrow while T cells are derived from the thymus. B cells are responsible for production of antibody. T cells have multiple functions, including determining the type of immune responses elicited, killing infected cells, and stimulating macrophages to enhance their ability to destroy infectious agents (macrophage activation).

T cells consist of two major populations: T helper cells and cytotoxic T cells. T helper cells can stimulate macrophage activation and help generate cytotoxic T cells. T helper cells also contribute to B cell activation and generation of antibody responses. Cytotoxic T cells are able to kill virus-infected cells and tumor cells. Importantly, both T helper cells and cytotoxic T cells can play significant roles in regulating immune responses. In mammals, T helper cells are identified by their expression of a cell surface protein known as CD4, while cytotoxic T cells express CD8. Currently, there are no reagents available to identify these cell populations in desert tortoises or other reptiles. Development of these reagents is critical in being able to evaluate immune capability because impairment of these cell populations can have devastating impact on the survival of the host. As an example, HIV infects $CD4^+$ T helper cells and eventually kills these cells. The loss of T helper cells increases the susceptibility of HIV infected patients to a number of agents that normally are readily controlled. Thus, changes in T cell populations in response to environmental and nutritional stresses may have a significant impact on multiple components of adaptive immunity and ultimately the survival of the host.

Antibody responses are protective and used for serologic testing. Antibody responses recognize and target infectious agents for destruction. There are multiple classes of antibodies, each employing different methods of destruction. In tortoises, there are two known classes of antibodies, IgM and IgY (Andreas and Ambrosius 1989). IgM is typically the first antibody class produced in response to a foreign agent, whereas IgY, similar to IgG in mammals (Warr et al. 1995), is produced later. IgM binding to a foreign agent can inactivate an agent through interference with the agent's ability to infect or cause damage (Figure 3). IgM can also interact with other proteins (complement) in the blood to help destroy the agent. IgY has activities similar to IgM, but in addition, the binding of IgY to bacteria or other agents enhances the ability of phagocytes to recognize and destroy them (Sekizawa et al. 1984, Warr et al. 1995).

Antibody responses are used for serologic diagnosis of infections. This is because they are specific for the infecting agent and are elicited only in response to significant exposure to the infectious agent. One complication for serologic testing in desert tortoise hatchlings is that antibodies from the mother are transferred to the babies. These maternal antibodies can be detected one year later in desert tortoises (Schumacher et al. 1999), providing some protection against infection. Thus, if the mother has a bacterial infection and generates an antibodies response, the hatchling will likely have antibody specific for this bacterial species in its blood even though the hatchling was uninfected. Thus, serologic diagnosis in tortoises within the first year of life should be interpreted with caution.

IMMUNITY AND MYCOPLASMA DISEASE

Mycoplasma diseases are persistent infections. Mycoplasma diseases are a health problem in the desert tortoise and are implicated in population crashes in some regions in the west (Brown et al. 1994). Mycoplasma diseases are also significant problems in humans and other animals, including cattle, laboratory rodents, pigs, alligators, poultry, etc. (Simecka et al. 1992). In humans, *Mycoplasma pneumoniae* respiratory disease, also referred to as "walking pneumonia," is a major cause of pneumonia in humans (Foy et al. 1979, Foy 1993, Krause and Taylor-Robinson 1993). Similarly, mycoplasma respiratory diseases are a tremendous problem in agriculture, as they can significantly affect the health of livestock (Howard et al. 1987, Brown et al. 1990, Allen et al. 1991, Simecka et al. 1992, Fox and Gay 1993, Adegboye et al. 1996, Wilson et al. 1997, Kusiluka et al. 2000). Thus, mycoplasma respiratory diseases have a wide-ranging impact on the economy, health, and wildlife.

Mycoplasmas are important pathogens of the respiratory tract, and the pathologies of mycoplasma respiratory diseases are remarkably similar, indicating that the processes that lead to disease are analogous. Respiratory infections by mycoplasma, including *Mycoplasma agassizi* in the tortoise, are characterized by an intimate association between the mycoplasma and respiratory epithelium (Simecka et al. 1992, Krause and Taylor-Robinson, 1993, Brown et al. 1994). During the evolution of mycoplasmas, there was a reduction in the numbers of genes, resulting in the loss of the cell wall and a number of metabolic pathways. The intimate interactions between the host and the mycoplasma are necessary due to the organism's complex nutritional requirements to compensate for the lack of key metabolic pathways. The colonization of the epithelium results in damage to the respiratory epithelial cells and leads to the development of inflammatory disease (Stadtlander et al. 1991). Interestingly, colonization of respiratory epithelium alone does not necessarily lead to disease. Mycoplasma infections often remain subclinical (no symptoms) until some other factor, such as stress, environmental conditions, or other infectious agents, triggers progression to clinical disease.

Importantly, clinical disease is characterized by the development of strong immune-mediated inflammatory responses at the site of infection.

Adaptive immunity plays both beneficial and detrimental roles in mycoplasma disease. The mechanisms of immunity and their impact in mycoplasma disease are still unclear. Probably the best-studied model of mycoplasma disease and immunity is *Mycoplasma pulmonis* disease in laboratory rodents. A series of studies demonstrates that macrophages play a key role in controlling mycoplasma numbers soon after infection (Jones and Hirsch 1971, Jones et al. 1972, Jones and Hang 1977, Jones et al. 1977, Howard and Taylor 1979, Davis et al. 1980, Parker et al. 1987, Davis et al. 1992, Hickman-Davis et al. 1997, Cartner et al. 1998, Hickman-Davis et al. 1998, Hickman-Davis et al. 1999). Any impairment of macrophage function results in more severe disease due to increased numbers of mycoplasma in respiratory tissues (Davis et al. 1992, Hickman-Davis et al. 1997). Adaptive immunity is also critical in determining the outcome of mycoplasma diseases. Hodge and Simecka (2002) demonstrated that the generation of adaptive immunity along the respiratory tract can provide some resistance against mycoplasma infection and disease. However, they also demonstrated that immune responses contribute to disease severity, as immunodeficient mice (lacking both B and T cells) develop much less severe respiratory disease than immunocompetent mice (Cartner et al. 1998). On the other hand, immunodeficient mice die of mycoplasma dissemination to other tissues, which can be prevented with anti-mycoplasma antibodies in the circulation. Thus, immune responses have both beneficial and detrimental effects in mycoplasma infections.

T cell populations most likely play contrasting roles in mycoplasma diseases (Jones and Simecka 2003, Simecka 2003). T helper cells contribute to development of mycoplasma disease, as depletion of $CD4^+$ T cells in *M. pulmonis* infected mice results in less severe disease (Jones et al. 2002). In contrast, mycoplasma disease was substantially more severe in mice where $CD8^+$ T cells were depleted. The differences in disease severity were not linked to changes in numbers of mycoplasma. This indicates that $CD8^+$ T cells dampen disease while $CD4^+$ T helper cells increase lesion severity through the regulation of immune responses. Ongoing work from our laboratory also suggests that subpopulations of T helper cells may also differ in their role in controlling mycoplasma infection and disease severity. Thus, T cell populations will likely play a complex role in the development and resistance to mycoplasma respiratory disease, and factors that impact T cell function, such as stress, nutrition, environmental conditions and infectious agents, can play a significant role in this process. Please refer to our recent review articles (Jones and Simecka 2003, Simecka 2003) for a more complete discussion of immunity and mycoplasma disease.

FACTORS THAT MAY IMPACT IMMUNITY AND DISEASE IN THE DESERT TORTOISE

Little is known about the factors that impact immunity and disease in the desert tortoise. Based on studies in other reptiles, there is likely seasonal variation in the capacity of the immune system to respond to infections. Furthermore, nutritional status will probably play a significant role and contribute to some degree on the seasonal variation. Epidemiologic and experimental studies in humans and animals have identified gender as another factor that influences resistance to disease. Similarly, the genetic makeup of an individual can influence the response to infection and determine outcome. Each of these factors alone or in combination will likely influence the immune capacity of the desert tortoise and, because of this, impact the susceptibility to infection, disease severity, and transmission within a population. In this section, I will briefly discuss each of these factors and identify areas that need to be considered in future studies on the desert tortoise, immune function, and survival.

Seasonal variation in immune function. There is seasonal variation in lymphoid tissues and lymphocyte responses in turtles and lizards. In turtles, the size of splenic lymphoid tissue (the major lymphoid tissue in reptiles) and the thymus (site of T cell development) decreases during the winter, but these tissues are repopulated with cells (e.g., lymphocytes) by spring (Hussein et al. 1978). Concurrently, the ability of turtle lymphocytes to respond to various stimuli also fluctuates by season with some stimuli mounting the best responses in the spring (McKinney and Bentley 1985, Munoz and De la Fuente 2001). However, other immunologic parameters examined in turtles are optimal during the summer, decreasing in the autumn (Munoz and De la Fuente 2001). Although not directly demonstrated, desert tortoises are likely to have similar seasonal variability in immune capabilities. In support of this hypothesis, seasonal variation in a variety of biochemical and hematological parameters were identified in blood samples from desert tortoises (Christopher et al. 1999). Little is known about more subtle seasonal changes in immune function, such as the activity of different T cell populations, which could have a significant impact on the health of the desert tortoise or any reptile. Thus, the capacity for the desert tortoise to develop an immune response is likely to fluctuate between the seasons of a year, but it is unknown how these seasonal effects on immune function impact resistance to or development of disease.

Malnutrition promotes disease susceptibility. Probably the most critical factor to be considered is the nutritional status of desert tortoise populations. The survival of the desert tortoise certainly is linked to the availability of water and food, and this becomes of increasing concern during times of drought and in areas of habitat destruction. In humans and other animal species, there is a clear link between malnutrition status, impaired immune functions and susceptibility to infection (reviewed in [Bhaskaram 2002, Amati et al. 2003, Felblinger 2003, Keusch 2003]). Ongoing studies on the nutritional status of desert tortoises ([Oftedal et al. 2002], see these proceedings) should provide a foundation for future studies to investigate the impact of diet on the susceptibility to and transmission of infectious agents. Ideally, studies are needed to obtain data to begin modeling the transmission of infectious diseases in a population as a function of nutritional and immune status. This should allow the development of novel and focused approaches to managing desert tortoise populations, including assessing interventions during population crashes resulting from or accelerated by infectious disease.

Gender is a factor. Gender is also a factor that may contribute to disease outcome. Research shows that male mice develop more severe mycoplasma respiratory disease than females and this is linked to the ability of macrophages to readily kill the infectious organisms (Yancey et al. 2001). This is not unique to mycoplasma infections as females (humans or animals) are more resistant to several other infectious agents (Cherry et al. 1975, Foy et al. 1979, Huber et al. 1982, Mock and Nacy 1988, Yamamoto et al. 1990, Ashman et al. 1991, Yamamoto et al. 1991, Chen et al. 1992, Foy 1993, Callahan and Wolinsky 1996, Gordon and Rosenthal 1999, Loeb et al. 1999, Offner et al. 1999). In mammals, it is also well established that females generate higher adaptive immune responses to a foreign agent than males (Wyle and Kent 1977, Krzych et al. 1981, Ahmed and Talal 1990, Schuurs and Verheul 1990, Wang et al. 1993). Although studies have yet to fully examine the association of immune capability in the desert tortoise, gender differences were described in desert tortoises in hematological and biochemical values (Christopher et al. 1999), supporting the idea that gender matters in disease resistance. However, further studies are needed and warranted, as there are indications that desert tortoise population crashes are associated with the early loss of males (See papers this proceedings).

Are you a good gene or a bad gene? An unappreciated factor that will impact immunity and resistance to disease is the genetic background of the different populations of desert tortoises. There is substantial evidence that genetic differences between hosts influence disease susceptibility. For example, our laboratories demonstrated that there are strains of laboratory animals that resist infection and development of mycoplasma disease while other strains are more susceptible (Davis and Cassell 1982, Davis et al. 1982, Davis et al. 1985, McIntosh et al. 1992, Cartner et al. 1995, Cartner et al. 1996, Cartner et al. 1998). This was shown to be a complex genetic trait, as resistance is not linked to a single set of genes (Cartner et al. 1996). These differences are associated with genetic variations in the ability of the immune system to appropriately respond and control infections (Davis et al. 1982, Davis et al. 1985, Parker et al. 1987, Simecka et al. 1991, Cartner et al. 1995, Hickman-Davis et al. 1997). Populations of desert tortoises or even individual animals may be more susceptible to disease while others are relatively resistant. Thus, potential genetic differences in desert tortoise populations should be considered in monitoring the spread and impact of disease, and it may ultimately be important to maintain sufficient heterogeneity within a population to allow its long-term survival.

PERSPECTIVE AND CONCLUSION

The immune system is a critical determinant in the survival of many different species of animals, and therefore is likely vital to the survival of desert tortoises. Immune responses are generated because of a well-regulated interplay between phagocyte and lymphocyte populations. These interactions ultimately will determine the level of protection and the ability to recover from infectious and other diseases. For some infectious agents like mycoplasmas, the host immune response not only helps control infection, but may also contribute to damaging the host. Although not discussed, lesions due to herpesvirus are prevented by good immune responses, but as the virus has the ability to hide (become latent) in the host, the lesions reappear whenever the immune system becomes compromised due to nutritional and other stresses. Thus, the ability of the desert tortoise to generate immune responses is likely a critical factor in its survival.

Unfortunately, little information is available about the immune system in the desert tortoise and its interactions with known agents of disease. There is a need to develop reagents and approaches to monitor immune function in tortoises. Reagents are needed to identify the different T cell populations that influence the ability of the desert tortoise to respond to infectious or other agents. A complicating factor is that there are limitations on the types and numbers of samples that can be obtained from desert tortoises, and therefore, unique approaches need to be developed to evaluate immune status using these limited samples. There is a need to develop such approaches to assess the impact of environmental and nutritional stresses on immunity and ultimately the survival of the desert tortoise. This understanding may provide additional markers of stress and disease, eventually leading to improved knowledge-based approaches to management and treatment of desert tortoise populations.

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DEFENSE DEPARTMENT PARTICIPATION IN DESERT TORTOISE MANAGEMENT

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Most tortoise research has taken place either on Department of Defense (DOD) lands or with military funding. DOD has been an active participant in the Desert Managers Group, the West Mojave Coordinated Management Plan, and the Desert Tortoise Management Oversight Group. A formal committee of military land managers has been formed and meets regularly to coordinate our actions.

DOD is committed to long-term tortoise management and delisting. As an agency, we highly recommend that other agencies follow our lead. Without cooperative effort throughout the tortoises range, we will not be able to achieve the goals of the approved Recovery Plan. DOD encourages regional efforts to control predators, including participation from municipalities, counties, and NGOs, including the Desert Tortoise Council.

The Sikes Act requires all installations to complete and implement an Integrated Natural Resources Management Plan (INRMP). These plans detail research and land management goals for five years and they are completed with the cooperation of the USFWS and the appropriate state wildlife management agency. This presentation will primarily focus on these and other "desert-wide" issues, such as sustainable training, encroachment, and the loss of habitat to urban development. The presentation is intended to complement the installation-specific papers that will be presented later in the meeting.

DESERT TORTOISE REPRODUCTION AND HOME RANGE AT SAGUARO NATIONAL PARK, TUCSON, ARIZONA

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In 2001 and 2002, we studied reproduction in female desert tortoises at two sites at Saguaro National Park, in Tucson, Arizona by using ultrasound and x-radiography. We also tracked tortoises of both sexes regularly with radiotelemetry through the active season. Weather patterns were quite different between years, possibly leading to differences in reproductive effort. In 2001, following a period of above-average rainfall, 71% of monitored females developed egg clutches, and mean clutch size was 6.9 eggs (range, 1-9). In 2002, after an extended dry spell, 25% of monitored females produced egg clutches, and mean clutch size was 4.6 eggs (range, 3-6). There appears to be no correlation between midline carapace length (MCL) or sex and home range size. However, home range size appeared to vary between years, possibly as a response to changes in rainfall levels.

MONITORING THE DESERT TORTOISE: NEEDS FOR THE PRESENT AND FUTURE

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Transect sampling is currently the standard method for estimating population density of the federally listed desert tortoise. Estimates of population density from transect sampling requires accurate estimates of the probability that tortoises are available to be seen (Go), and it requires accurate estimates of the detectability of tortoises (Pa) that are available to be seen. Each of these parameters depends upon other variables including daily and seasonal influences

on tortoise behavior and activity, observer differences in different habitats, local and regional differences in physiognomy and vegetation, annual differences in rainfall and food resources, and more. Small inaccuracies in these parameters caused by different levels of the mechanistic determining variables make obtaining precise estimates of tortoise population density very difficult, Furthermore, estimating detectability of tortoises using "distance sampling" techniques requires too much of such a sparsely populated species. Additionally, statistical power analyses of density estimates of desert tortoise suggest that it would be very difficult to estimate population density under the best of circumstances. This is not an unusual circumstance as scientists monitoring bald eagles and other large species with ponderous population dynamics have faced similar challenges to obtaining density estimates and analyses of population trends. However, direct calibration of detectability, and sampling along transects in a way that creates replication may allow accurate and precise estimates of population density using the transect methods.

Even after we have good estimates of population density, those estimates need to be used to calculate population sizes. Furthermore, modern monitoring has additional elements other than estimates of population size. Monitoring needs to assemble data on (1) population size, (2) habitat for the focal species, and (3) threats to the species and ecosystems. Additionally, monitoring needs to be hypothesis based, and accumulate data on management actions. Thus, the efficacy of management actions such as highway fencing, removing domestic grazers, allowing further habitat fragmentation through urbanization, allowing increased population densities of feral dogs, etc. all need to be experimentally monitored through scientifically defensible protocols. Thus, an effective monitoring program will have more elements than we have currently in order to inform management of the species and to gather data necessary for future delisting when delisting criteria are all met.

DIET SELECTION: THE NUTRITIONAL WISDOM HYPOTHESIS

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Classical foraging theory focuses on energy acquisition, and individuals of some species appear to forage so as to maximize net energy acquisition. Herbivores have many nutritional needs (in addition to energy), and their requirements may not be met simultaneously when tortoises forage for energy. The question remains, "how do herbivores meet their many nutritional needs?" "Nutritional wisdom" has been suggested as a trait by which animals obtain a nutritionally balanced diet. The hypothesis proposes "specific hungers" permitting a sensing of nutrients in the diet, and selection of a diet with elements required. However, few studies have demonstrated the ability to forage for particular elements although exceptions include foraging with appetites for sodium and water in rats and moose respectively.

An alternative hypothesis is that diet preferences are shaped through learned food aversions. This model posits that animals learn to avoid foods that can induce illness such as foods containing secondary compounds or diets deficient in, or excessive in, nutrients. While dietary aversions have been demonstrated in rats, coyotes, and other carnivorous animals, the mechanisms underlying this strategy may be difficult to detect in herbivores. Many herbivores consume a variety of plant species over time, and the rates at which food passes through the gut can be up to several weeks, which makes it difficult for the animals to discriminate which of the food items eaten caused their illness. Thus, it seems unlikely that herbivores could discriminate which foods should induce an aversion. Experience, or learned preference, has also been proposed as an explanation for diet selection for particular nutrients. However, studies have generally failed to demonstrate the ability to learn, or acquire diet preferences for specific nutrients.

While the mechanisms are not well defined, large mammalian herbivores have been shown to select diets more nutritious and less toxic than the range of available foods. The idea that herbivores select a diet based on nutrient composition, or that they possess a nutritional wisdom, is frequently implied but seldom tested. Despite our primitive understanding of how herbivores forage and attain their nutritional needs, many investigators studies still invoke "nutritional wisdom" as a possible mechanism underlying diet selection in the desert tortoise.

We have conducted analyses of diet selection in the desert tortoise to address the question, "Can tortoises select diets with nutrient content differing from that which would be obtained if foraging occurred at random with respect to food availability?" We analyzed tortoise foraging by using plant biomass as an indicator of the relative availability of food species, and the proportion of bites of each food species as a measure of the diets of individual tortoises. We compared diets selected by tortoises in relation to food available in the habitat. Then we compared the nutrient composition of the diets to the composition of diet that could be selected at random from the same habitat. From this analysis, we investigated whether it is possible to forage non-randomly with respect to nutrients by asking if a plant nutrient falls outside the 95% confidence limit for a random distribution of that nutrient. Secondly, we asked if there are plants that differ from the random distribution, and do tortoises preferentially select those plants. With high variation both among and within plants over time and space, it is unclear if tortoises could perceive differences and respond to those differences during and throughout the activity season. Additionally the quantity of nutrients within a plant correlate, and that tortoises foraging maximally for protein almost certainly maximize other nutrients and minimize fiber.

DESERT TORTOISE (*GOPHERUS AGASSIZII*) MORTALITY SURVEYS AND PARAECOLOGY TRAINING ON COMCÁAC (SERI) LANDS, SONORA, MEXICO

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ABSTRACT

The desert tortoise (*Gopherus agassizii*) is culturally significant to the Comcáac (Seri) Indians of Sonora, Mexico. In response to reports by the Comcáac Indians of high desert tortoise mortality on Tiburón Island, Gulf of California, we conducted a tortoise mortality survey at one island site in October 2001 and two mainland sites in October 2002 within the Comcáac territory. As part of an ongoing educational program, the paraecology training program, conducted by the Center for Sustainable Environments, Northern Arizona University, researchers trained a team of Comcáac field researchers to conduct tortoise surveys and to handle tortoises safely. We observed high and recent mortality at all sites indicating that the tortoise die-off is occurring beyond U.S. populations. These findings raise questions about the status of the southern populations of the species. Assessing the extent of the die-off and the health of these populations will allow for better-informed management decisions throughout the desert tortoise's range.

The Comcáac (Seri) Indians are a small fishing-based community on the coast of the Gulf of California in Sonora, Mexico. The desert tortoise and its habits are the subject of many songs and stories within the Comcáac culture. The archaic Comcáac name for the desert tortoise is *xtamoosni*. The name comes from the root *moosni* that is the generic name for all turtles and tortoises, including *Chelonia mydas* and includes the prefix "*xta*-" which implies "of the land." This name suggests Baja California origin for the Comcáac. The names most commonly used to refer to the desert tortoise now are its two nicknames *ziix hehet cöqiij* (thing that sits among plants), and *ziix catotim* (thing that slowly scoots along)(Felger et al. 1981, Nabhan 2002). These names and words for ecological terms show the extent of traditional ecological knowledge found in the modern culture and in the language itself. Some examples are words meaning burrow, plastron, carapace, and hibernation.

The cultural importance of the species led to our including it in the paraecology training program. As part of an ongoing educational program, the paraecology training program, conducted by the Center for Sustainable Environments, Northern Arizona University, a team of Comcáac field researchers were trained on tortoise survey and handling techniques. The desert tortoise study on Comcáac Indian territories was started before 2001, when the Comcáac reported to Nabhan that as they were surveying and hunting for desert bighorn they noticed many tortoise remains on Tiburón Island. This initial observation led to a collaborative effort between Northern Arizona University, the Comcáac Tribe, and a group of scientists led by Vaughn. In October 2001, American researchers and Comcáac who participated in the original surveys with Osorio and Bury (1982) collaborated on a desert tortoise mortality survey on Tiburón Island, and in October 2002 we expanded the study to include adjacent mainland areas.

Throughout its range (Figure 1), the desert tortoise has suffered declines. Averill-Murray (2001) reported that desert tortoise populations appear to be stable within the Sonoran Desert in Arizona. Populations show a low incidence of Upper Respiratory Tract Disease (URTD) symptoms, but high incidence of cutaneous dyskeratosis. Populations in the Mojave Desert have suffered dramatic declines in the presence of these diseases. Population declines observed on Comcáac lands appear to be following the trends of the Mojave Desert.

MATERIALS AND METHODS

The methods for the paraecology training involved providing the students with materials in Spanish. We provided the students with standard data sheets used in demographic studies of desert tortoises in the U.S. including live capture form, health profile form, and a shell-skeletal remain form (Appendices). We also provided a shell wear class key and a brief natural history of the desert tortoise.

Mortality surveys were conducted at three sites. A fourth site was set up, though not surveyed (Campo Español). The study sites were established within current Comcáac territory that extends from just south of Punta Chueca to north of Desemboque, and includes Tiburón Island (Figure 2).

In October 2001, we established sites at Caracol and Campo Español on Tiburón Island. In October 2002, we established study sites at Punta Tepopa and Rancho II. The Caracol site is located the central portion of Tiburón Island, 4.8 km from the eastern shore. Elevation on

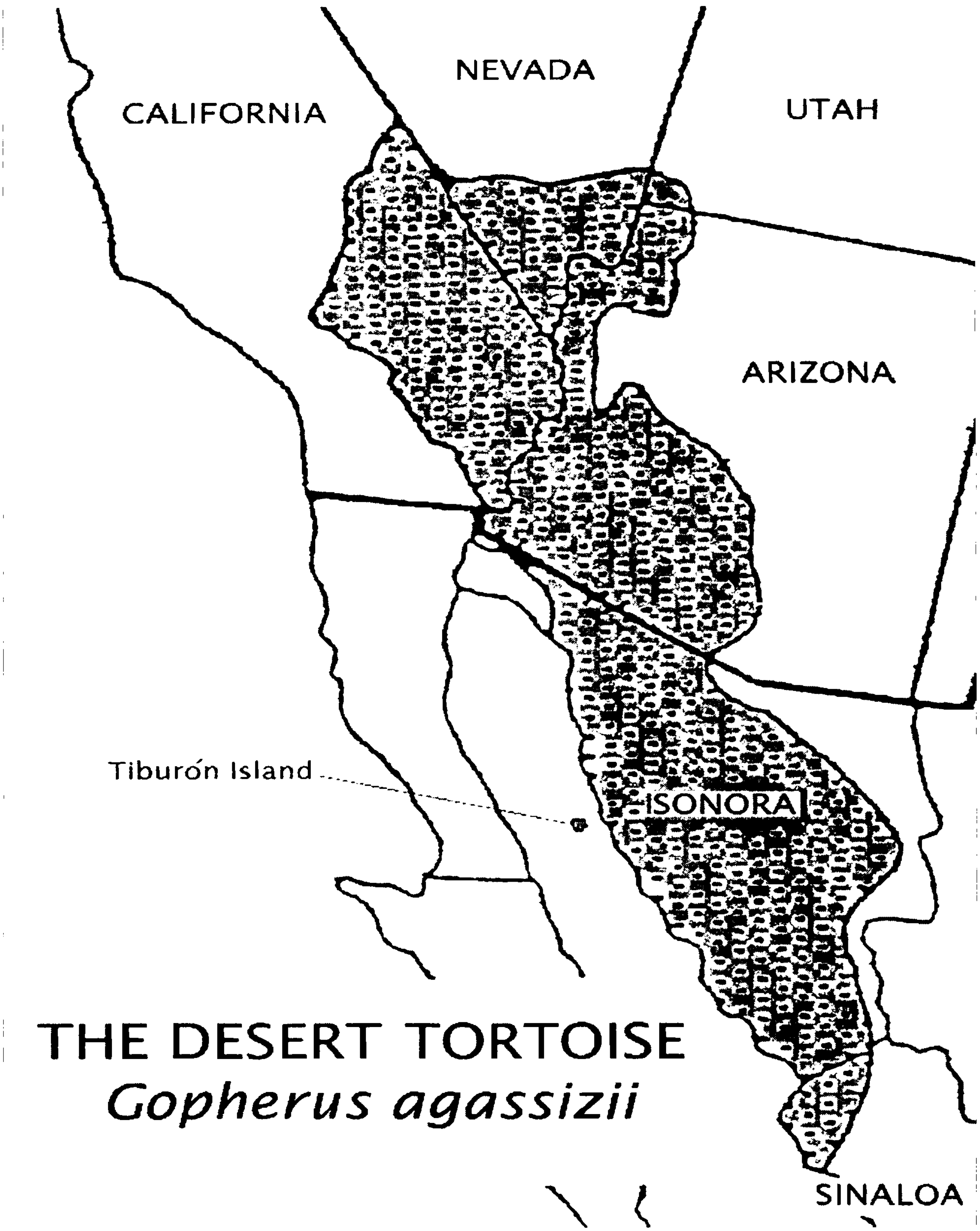

Figure 1. Map of the range of the desert tortoise in the U.S. and Mexico.

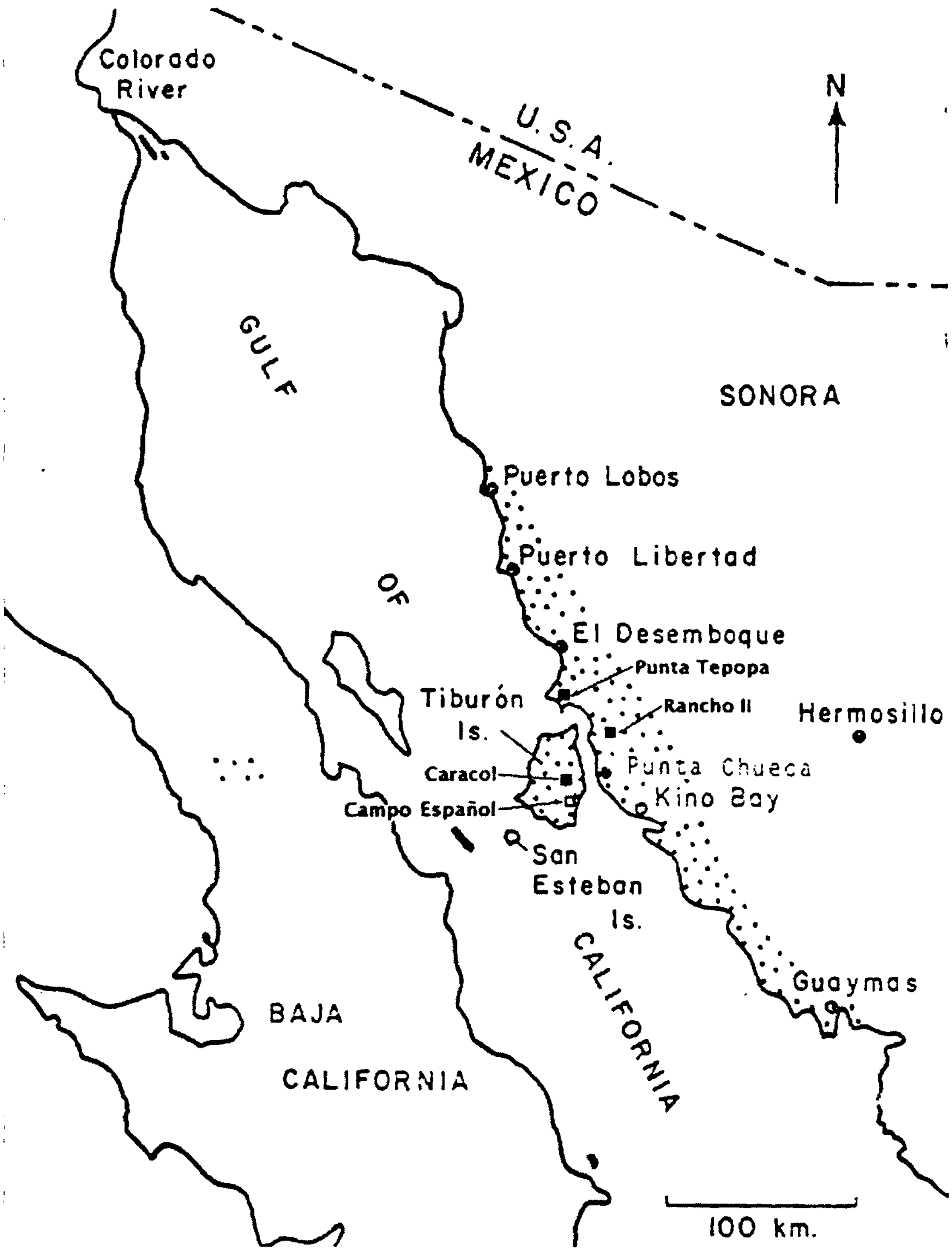

Figure 2. Map of the Comcáac Territory and desert tortoise study sites from 2001 and 2002, Sonora, Mexico.

the site ranges from 100 to 300 m. We located the Rancho II site 18 km north of the Comcáac village of Punta Chueca and 4.5 km east of the Sea of Cortez with an elevation range of 250 to 450 m. The Punta Tepopa site is located on the south side of the isolated mountain range on the Tepopa peninsula with an elevation range of 100 to 200 m and 2.5 km from the Sea of Cortez. We established the Campo Español site near the eastern shore on the southern portion of the island at 100 to 200 m elevation and 1.5 km from the Canal de Infernillo.

The Punta Tepopa plot is 0.5 km^2 while the others are 1 km^2. We established the plots in 100 x 100 m grid cells using handheld GPS units. We placed rebar sheathed by 3.3 m PVC pipe at each grid cell corner. We covered the plots by walking 10 m wide transects. We conducted a single coverage on each plot. All researchers gathered to process all live and dead tortoises encountered. Processing consisted of completing all information on the data sheets (Appendices).

RESULTS

Education

As a result of this study, 14 paraecology students learned how to set up study plots, fill out survey forms, process live tortoises and shell-skeletal remains, and learned basic tortoise ecology. The traditional ecological knowledge was not the focus of these surveys but was transmitted by elders at separate training sessions.

Mortality

The results of the mortality analysis (Figure 3) in 2001, on the Caracol plot on Tiburón Island, we found 30 dead and 10 live tortoises. On the mainland in 2002 on the Rancho II plot we found 13 dead and 9 live tortoises. On the Punta Tepopa Plot we found 6 dead and 10 live tortoises. We might have found more remains; however, the steep, draining topography of the Tepopa site may readily wash remains down slope and bury them.

The estimated time since death for most of the tortoise shell-skeletal remains found at the three study sites was less than four years (Figure 4). On the Caracol site 29 of the 30 tortoise remains we observed were from animals that died within the last four years. On Rancho II site 11 of the 13 died within the last four years, and on the Punta Tepopa site two of the six died within the last four years. Of the 50 shell-skeletal remains found on Caracol, Rancho II, and Punta Tepopa 43 appeared to have died between 1997 and 2002.

Although we did not survey the Campo Español site, the Comcáac stockpiled the shell-skeletal remains of over 25 tortoises in a wash. They collected these remains about one

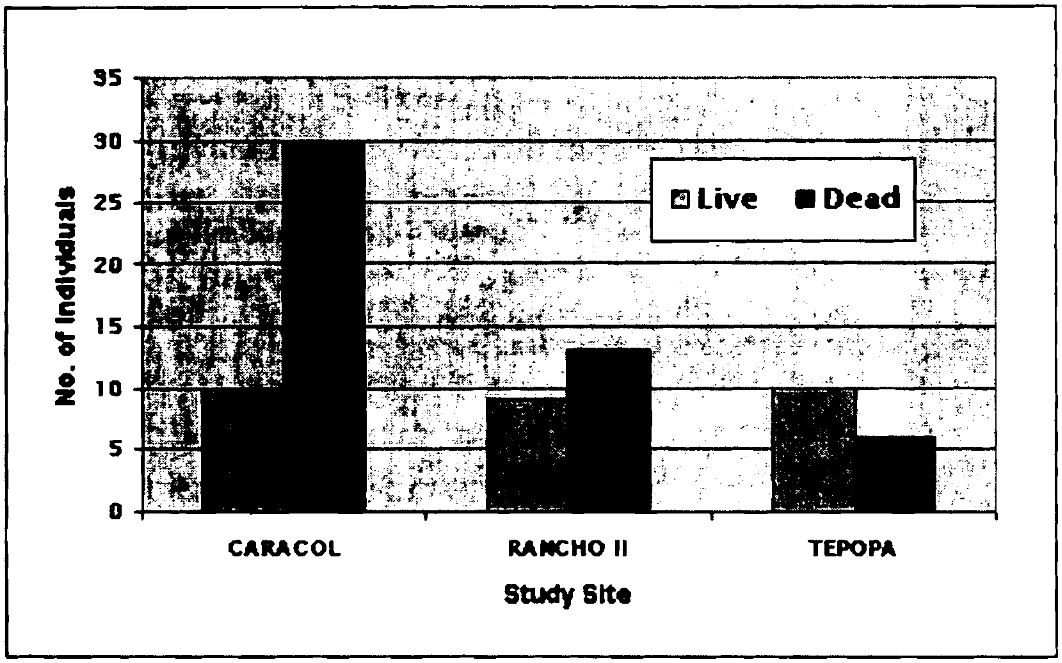

Figure 3. Comparison of live and dead tortoises at three study sites from 2001 and 2002 in Comcáac Territory, Sonora, Mexico.

kilometer east of the plot earlier in 2001. In October of 2001 a tropical storm hit the region and washed most of the remains down the wash and out to sea.

Sex Ratios of Live Tortoises

On Caracol we encountered seven females, two males and one immature (Figure 5). On Rancho II we found four females, four males, and one immature. On Punta Tepopa, we found ten adult females eight of which were found inside a single rock shelter.

Health of Live Tortoises

We observed no evidence of shell disease on any of the tortoises on either the island or the mainland. We observed no apparent evidence of upper respiratory disease in any of the live tortoises on the island or on the Rancho II study plot, however we observed one adult tortoise with green nasal exudate on the road to Rancho II approximately 1 km west of the plot.

On the Punta Tepopa study plot six of the ten tortoises we found showed evidence of URTD. Symptoms exhibited included swollen eyes and a dried, white crust around the mouth, severe

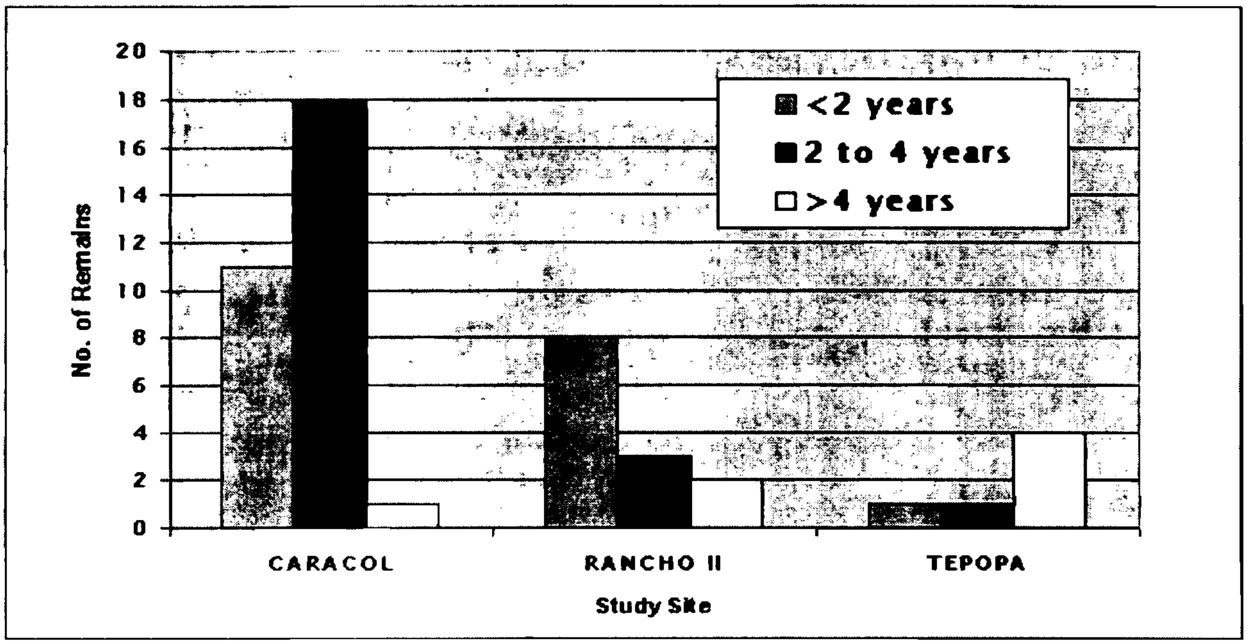

Figure 4. Comparison of the time since death for shell-skeletal remains found at three study sites from 2001 and 2002 in Comcáac Territory, Sonora, Mexico.

head swelling restricting ability to fully open eyes, swelling of the lower palpebra, and ocular and nasal discharge. Of the eight communal females, five showed signs of disease.

DISCUSSION

More than one-third of the tortoise's geographic range lies south of the U.S.-Mexico border in northwestern Mexico (Figure 1). Aside from a general distribution and basic ecology there is limited knowledge on the status of the populations in Mexico. The 2001 to 2002 mortality surveys are the most in depth research conducted on the current status of desert tortoises in Mexico.

If we consider Osorio and Bury's estimate of 67 tortoises per km² for the Caracol region, 29 dead animals over the past five years is cause for concern. The Comcáac have reported a recent die-off of equal severity throughout Tiburón Island where tortoises occur. The 2002 surveys show that mainland populations may be in trouble as well.

The most important question we are faced with is "what is causing the die-off in these remote, relatively, undisturbed populations?" There is no livestock grazing on the island and no

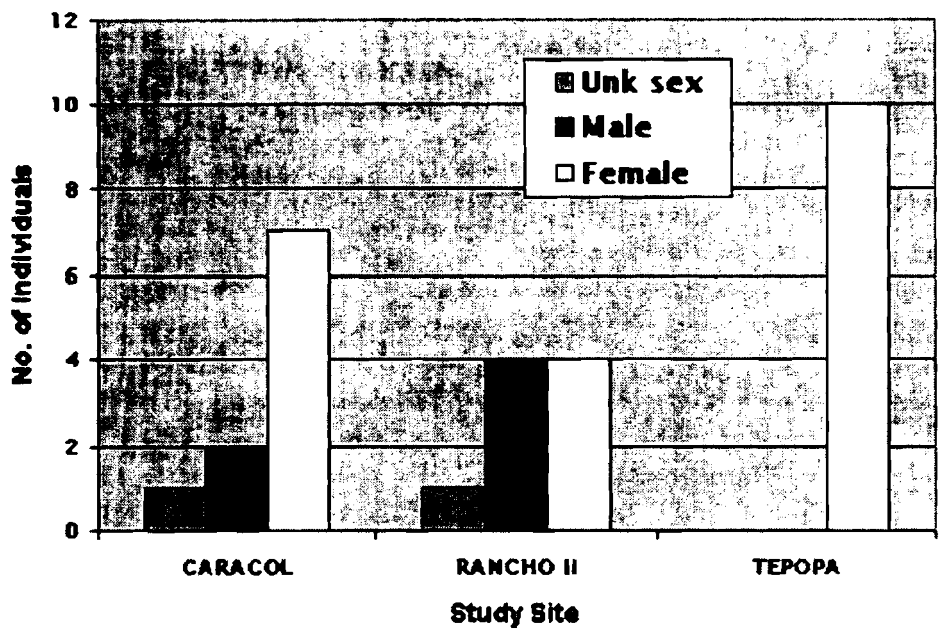

Figure 5. Sex ratios of desert tortoises at three study sites from 2001 and 2002 in Comcáac Territory, Sonora, Mexico.

locally, widespread invasive plant species on either the island or the mainland. In comparison to other areas of the Sonoran Desert or the Mojave, impacts are minimal.

The reason for the die-off is not known. The die-off could be associated with drought conditions. The weather station at the Prescott Field Station in nearby Kino recorded below average precipitation over the past decade. Another possible cause for the die-off is disease. We observed clinical signs of disease, but without more intensive health studies, linking high mortality rates to disease is difficult. The stress of drought in combination with disease may be the cause of disease. Other unknown causes for this catastrophic die-off may have yet to be discovered.

Through the paraecology program the Comcáac have become aware of the health problems in other geographic locations and some members of the tribe have expressed interest in conducting blood work to investigate the health status of the tortoise in Comcáac territory. With the cooperation of the tribe, the Mexican government, and experienced researchers, this future work could present evidence that would clarify some of the disease questions that have remained even with extensive research on the northern populations of tortoise.

In conclusion, we must determine the extent of the die-off in Mexico as well as we have in the U.S. Looking only at northern populations, we get a limited picture. More intensive research of the southern populations may provide reasons for the decline that have evaded us thus far.

ACKNOWLEDGMENTS

We would like to thank Dalia Alicia Castillo Meza, Ernesto Molina Villalobos, David Lopez Palma, Katherine Sides, Naima Taylor, and Laurie Monti. We also sincerely thank all of the volunteers without whom this project wouldn't have happened: Eli Bernstein, Steve Boland, Chris Halley, Chereka Keaton, Adam Klatzker, Cathy Mueller, Laura Pavlisack, Colin Spake, Liz Smith, Kiea Wright, Betsy Wirt, and Ryan Young. Thanks to Rachel Woodard for providing us with photos and diagrams of ill tortoises to share with the Comcáac, and Ed LaRue, Roy Averill-Murray, and Tim Shields for their comments on the 2001 island work. We give a special thanks to Dr. Alice Karl for her insight and for volunteering on the project two years in a row. Thanks to all of the Comcáac paraecology program participants: Carlos Mendez Romero, Reina Molino Romero, Humberto Romero Morales, Mayra Estrella Astorga, Saul Torres Morales, Jose Ramon Torres Molina, Blanca Alberto Montaño, Martín Enrique Barnett Morales, Ana Maria Morales Ortega, Romelia Barnett Diaz, Jose Luiz Lopez Morales, Gonzalo Saul Torres Morales, Fernando Morales Ortega, and Francisco Molina Sesma.

This paper is dedicated to Dr. Charles H. Lowe. He is missed.

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Appendix A: Hoja de Datos para Tortugas del Desierto Vivas (Live form)

Trabajador ____________________
Nombre del área de estudio ____________________
Coordenadas (referencia de la esquina al sudoeste)
___ m (Norte) ___ m (Este) Numero de Cuadricula ___
☐ Dentro del área ☐ Fuera del área
Estado ____________________
País ____________________

Numero de Identificación de la tortuga __________
Año marcado por la primera vez __________
Verificación de identificación
Tipo de captura ________ Sexo ________
Fecha (día/mes/año) __________
Tiempo empezando __________
Tiempo acabando __________

LOCALIDAD DE TORTUGA

Tipo de madriguera	**En la madriguera**	**No en la madriguera**
☐ madriguera de tierra	entrando	☐ expuesto al sol
☐ madriguera con poca profundidad (no cubre la concha completamente)	saliendo	☐ en la sombra
	☐ a la entrada	
	adentro	otra situación _____
☐ cueva de caliche		
☐ cueva de piedra		

DATOS DE LA MADRIGUERA

orientación __________
profundidad ________ anchura ________
altura _____ tipo de protección/techo _____
localidad __________

TIPO DE ESTUDIO

☐ investigación primera
☐ investigación segunda
☐ investigación para buscar tortugas __ juveniles
☐ otro tipo ________

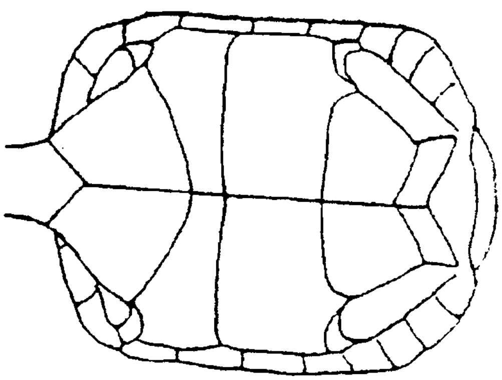
ACTIVIDAD DE LA TORTUGA

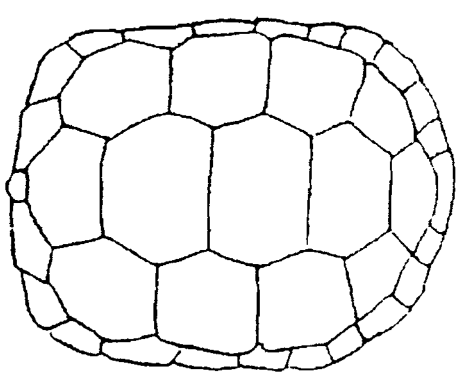
☐ descansando ☐ caminando ☐ Interacción con otra tortuga
☐ asoleando ☐ comiendo ☐ Interacción con otros animales

Vegetación consumido espécimen colectado (si no sabe el especie)

Identificación de la otra tortuga _____ Sexo de la otra tortuga _____
Especie __________

Describa interacción __________





MEDIDAS DEL CUERPO

LMC _____ (longitud máximo carapacho)
LPM _____ (longitud plastron muesca)
LPP _____ (longitud plastron punta)
M3 _____ (marginal 3 izquierdo a derecha)
M4 _____ (marginal 4 izquierdo a derecha)
M 7-8 _____ (marginal 7-8 izquierdo a derecha)
Altura _____
Anchura máxima en _____

Peso (g) _____
Excremente (g) _____
Peso total (g) _____

Crecimiento nuevo presente Crecimiento nuevo ausente
Numero con epoxia presente Numero con epoxia ausente
Otras notas

Photo: Rollo _______ Cuadro _______

Appendix B: Forma de Salud para la Tortuga del Desierto (Health form)

Trabajador ____________________
Nombre del área de estudio ____________________
☐ Dentro del área ☐ Fuera del área
Numero de Cuadricula ____________________
Estado ____________________
País ____________________
Clase de deterioración del carapacho ____________________

Numero de Identificación de la tortuga ____________________
Año marcado por la primera vez ____________________
Longitud máxima ____________________
Tipo de captura __________ Sexo __________
Fecha (día/mes/año) ____________________
Tiempo empezando ____________________
Tiempo acabando ____________________

PICO y ORIFICIOS de la NARIZ	SI	NO	¿
Pico/orificios de la nariz	☐	☐	☐
Pico/nariz húmedo	☐	☐	☐
Exudado nasal presente	☐	☐	☐
Color del exudado: claro	☐	☐	☐
opaco	☐	☐	☐
blanco	☐	☐	☐
amarillo	☐	☐	☐
verde	☐	☐	☐
Burbujeo en los orificios de la nariz	☐	☐	☐
Un orificio de la nariz obstruido	☐	☐	☐
Los dos orificios de la nariz obstruidos	☐	☐	☐
Tierra en la nariz o en el pico	☐	☐	☐
Tierra en los orificios de la nariz	☐	☐	☐
PATAS DELANTERAS (adyacente a la cara)			
Tierra seca en las patas delanteras	☐	☐	☐
Humedad en las patas delanteras	☐	☐	☐
Exudado seco en las escamas[1]	☐	☐	☐
Escamas quebrandose[2]	☐	☐	☐
RESPIRACION			
Suave	☐	☐	☐
Timbre asmático	☐	☐	☐
Rasposo	☐	☐	☐
OJOS y GLÁNDULAS de la BARBA			
Ojos/párpados blanqueados o descolorados	☐	☐	☐
Párpados hinchados	☐	☐	☐
Ojos/párpados mojados	☐	☐	☐
Secretando fluido de los ojos	☐	☐	☐
Ojos sumidos	☐	☐	☐
Ojos claros, brillantes	☐	☐	☐
Ojos opacos	☐	☐	☐
Glándulas de la barba superando	☐	☐	☐
INTEGUMENTO[3]			
Integumento opaco	☐	☐	☐
Integumento brilloso	☐	☐	☐
Elasticidad normal	☐	☐	☐
Piel pelando anormalmente	☐	☐	☐
POSTURA y COMPORTAMIENTO			
Alerto y responsivo	☐	☐	☐
Letárgico	☐	☐	☐
Puede retirar apretadamente dentro la concha	☐	☐	☐
Extremidades, cabeza colgando laxo, débil	☐	☐	☐

CAVIDAD ORAL[4]	SI	NO	¿
Observado			
Secretando fluido	☐	☐	☐
Membrana color de rosa	☐	☐	☐
Membranas pálidas, blancas	☐	☐	☐
Tiene mal aliento	☐	☐	☐
	☐	☐	☐
EVIDENCIA de ENFERMEDAD de la CONCHA o del HUESO			
Lesiones presentes			
Lesiones activos	☐	☐	☐
Lesiones curados	☐	☐	☐
Laminilla de los escudos pelándose	☐	☐	☐
Escudos perdidos o pelando	☐	☐	☐
Picaduras (pero no de otro animal)	☐	☐	☐
Escudos deprimidos o con concavidades	☐	☐	☐
Areas fungales	☐	☐	☐
	☐	☐	☐
EVIDENCIA de TRAUMA			
Cabeza			
Gular	☐	☐	☐
Patas delanteras	☐	☐	☐
Patas traseras	☐	☐	☐
Concha	☐	☐	☐
Reemplazo de hueso/escudo	☐	☐	☐
Describe:__________	☐	☐	☐

____
____
____

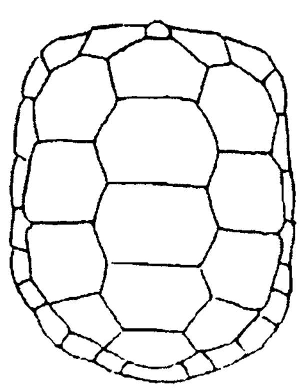
Tierra: mojada__ húmeda seca__
Ultimo precipitación (día/mes/ año)
____

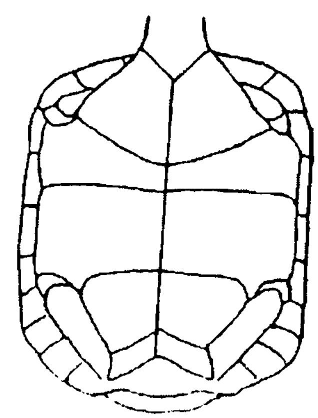
Orina (vol.) ____________________
color ____________________
viscosidad ____________________
Partículas ____________________
color ____________________
Espécimen de fluido de los orificios nasales ____________________
Cantidad de piquetes con aguja ____
Tiempo de los piquetes con aguja ___
Localidad ____________________
PCV% ____________________
Otros especímenes obtenidos ______
Describa/dibuje parásitos ________
____
Otras notas ____________________
____

LEYENDA para el DIAGRAMA

Picaduras en el integumento y/o la concha
Enfermedad de la concha
Trauma
Garrapatas

DIBUJE: forma del gular, localidad de las muescas, trauma o lesiones en la concha, enfermedad de la concha, anormalidades de la concha, concavidades de los escudos. Dibuje de nuevo cada año del estudio.





OTRAS NOTAS: ____________________

Notas al pie de la pagina: 1 - Integumento brilloso, brilloso con exudado seco. 2 - El integumento se puede fracturar por el efecto del exudado. 3 - Difícil, pero trata. Para elasticidad normal, con cuidado estire la piel en una de las extremidades, nota que pronto la piel vuelve a su posición normal. 4 - Importante. No trate de abrir la boca. Haga observaciones opurtunisticamente si la tortuga habré su boca.

Appendix C: Hoja de Datos para Desechos de la Concha Esqueléticos (Shell-skeletal remain form)

Colector ______________________
Procesor ______________________
Nombre del área de estudio ______________________
☐ Dentro del área ☐ Fuera del área
Numero de Cuadricula ______________________
Coordenadas (referencia de la esquina al sudoeste)
__________ m (Norte) __________ m (Este)
Fecha colectada (día/mes/año) ______________
Referencia de foto: Rollo _____ Cuadro _____
Desechos dañados durante colección ______________________

Numero del Cadáver ______________ Sexo ______
Categoría de los desechos:
cuerpo entero ☐ concha entera ☐ concha parcial
pocos fragmentos ☐ en excremento (de otro animal)
Numero de la tortuga viva ____________ Marcado ☐
Ultima fecha visto vivo (día/mes/año) ____________
LMC (longitud máximo del carapacho) ________ Medido ☐ Estimado ☐
Tiempo desde la muerte: <1 mes ☐, <1 año ☐, 1-2 años ☐, 2-4 años ☐, 4 años ☐
Año estimado de la muerte ______________________

LOCALIDAD DE LOS DESECHOS

	Si	No	Describa
Expuesto			________
debajo un arbusto			________
en arroyo			________
parcialmente enterado			________
en madriguera de tortuga			________
junto con otros huesos/conchas			________
otra situación			________

CONDICIÓN DE LOS DESECHOS

Partes presente:	parte	entero	nada
Cabeza			
pata delantera izquierda			
pata delantera derecha			
pata trasera derecha			
pata trasera izquierda			
anillo óseo pectoral			
anillo óseo pélvico			
cola			
vísceras			

EXPOSICIÓN AL SOL

__________ %

POSICIÓN DE LOS DESECHOS

derecho
volteado
desarticulado/quebrado
esparcido
otra situación
Describa __________

EVIDENCIA POR LA CAUSA DE MUERTE POR TRAUMA Y/O EVIDENCIA DE ANIMALES ALIMENTANDOS DE LA CARROÑA

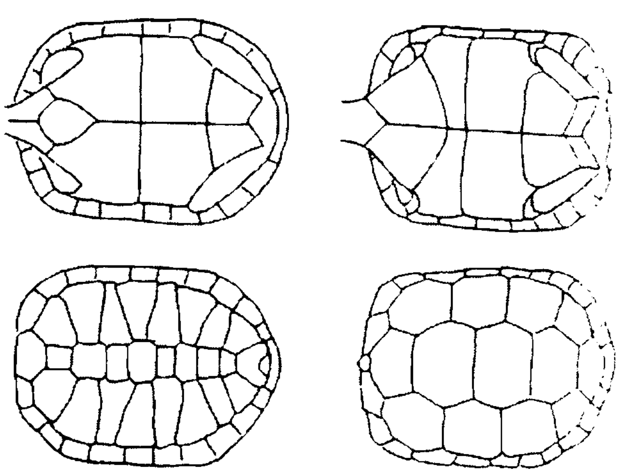
	Si	No	Quizas	Describa
Escudos fracturados				___% ________
Escudos desarticulados				___% ________
Huesos de la concha fracturados				___% ________
Huesos de las extremidades/cráneo Fracturados				___% ________
Huesos de la concha desarticulados				___% ________
Otros huesos fracturados				___% ________
Concha aplastada				________
Punción de dientes (de un predator)				# ________
Punción de un pico (de un predator)				# ________
Marcado con mascaduras (mamifero grande)				________
Marcado con mascaduras (roedor)				________
Huellas/excremento de predator				________
Nido/percha/madriguera de predator				________
Huellas/excremento de ganado				________
Huellas de vehiculo/camino/calle				________
Herida de balazo				________
Manchas de sangre o orina				________
Otra situación				________

DIAGRAMA DE LOS HUESOS Y PARTES DE LA CONCHA PRESENTES

ESCUDOS:
Completos _____ Numero de fragmentes no identificados _____
HUESOS:
Completos _____ Numero de fragmentes no identificados _____

EVIDENCIA QUE EL CARCAJE FUE CONSUMIDO POR UN ANIMAL QUE SE ALIMENTA DE CARROÑA:

Describa ______________________



LEYENDA

Pedasos presentes y intactos
Mordidas de predator
Pedasos presentes pero quebrados o desarticulados
No presente

Conclusión preliminar de la causa de muerte ______________________

THE CLARK COUNTY DESERT CONSERVATION PROGRAM: EMBRACING ADAPTIVE MANAGEMENT AND EFFECTIVENESS MONITORING

Lewis Wallenmeyer

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The Clark County Desert Conservation Program stems from the 1989 Federal listing of the desert tortoise as a threatened species. Since then, the program has evolved through development and implementation of a Short-term Desert Conservation Plan for desert tortoise, a Long-term Habitat Conservation Plan for desert tortoise, and finally, beginning in January 2001, a large step to the Clark County Multiple Species Habitat Conservation Plan. Two of the most challenging aspects of program management are: (1) developing and implementing program-specific adaptive management principles and practices, and (2) increasing our ability to monitor the effects of management actions and the effectiveness of conservation actions, including habitat restoration, species and habitat inventory, and research activities. As part of the Desert Tortoise Council panel addressing management issues, this brief talk will describe the status and challenges of adaptive management and effectiveness monitoring for the Clark County program.

STATUS OF DESERT TORTOISE RECOVERY

Bob Williams

Field Supervisor, U. S. Fish and Wildlife Service, 1340 Financial Blvd., Reno, NV 89502, 775-861-6300

The U.S. Fish and Wildlife Service's responsibilities for administering the Endangered Species Act include oversight of recovery efforts, which requires substantial coordination and cooperation between various agencies and stakeholders. The status of desert tortoise recovery is provided to the Desert Tortoise Council, Desert Managers Group, and Management Oversight Group on an annual or semi-annual basis. In 2002, the Service contacted resource managers and requested a summary of completed and ongoing recovery, monitoring, and research actions for the Mojave population of the desert tortoise. Redlands Institute compiled the responses to the request and prepared summary documents for each of the six recovery units. Other important desert tortoise activities of management concern for 2002 include the conclusion of the GAO evaluation of the basis for listing the desert tortoise as threatened, the effectiveness of recovery actions, monitoring, and costs and benefits of desert tortoise recovery actions. The Service prepared a response to a desert tortoise Congressional Directive for 2001 and a successful disease workshop was convened in Soda Springs, California. The future of the desert tortoise recovery program will be discussed with emphasis on shortcomings identified in the GAO report with limited resources to accomplish recovery. In 2003, the Service proposes to convene additional workshops, evaluate the existing tortoise monitoring program, and organize a team of scientists and agency representatives to assess the 1994 recovery plan. The Team would recommend potential revisions for discussion at the Desert Tortoise Management Oversight Group and Desert Managers Group before undertaking a plan revision.

BURROW TRANSMITTER

Ryan Young

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During the 2002 Littlefield study plot in Arizona, I developed a modification to a transmitter/receiver system to assist in monitoring tortoises in burrows that were either too far in to remove or high temperatures discouraged processing during the initial encounter. I call it the burrow transmitter. It is a remote sensing technique used to monitor tortoise activity in burrows. The burrow transmitter can be used to monitor multiple burrows, provide information regarding tortoise activity in response to temperature changes, decrease harassment associated with probes, and is a more sterile technique. The applications of the burrow transmitter include construction monitoring projects, G_0 work on line distance, focal animal studies, plot work, and other wildlife projects.