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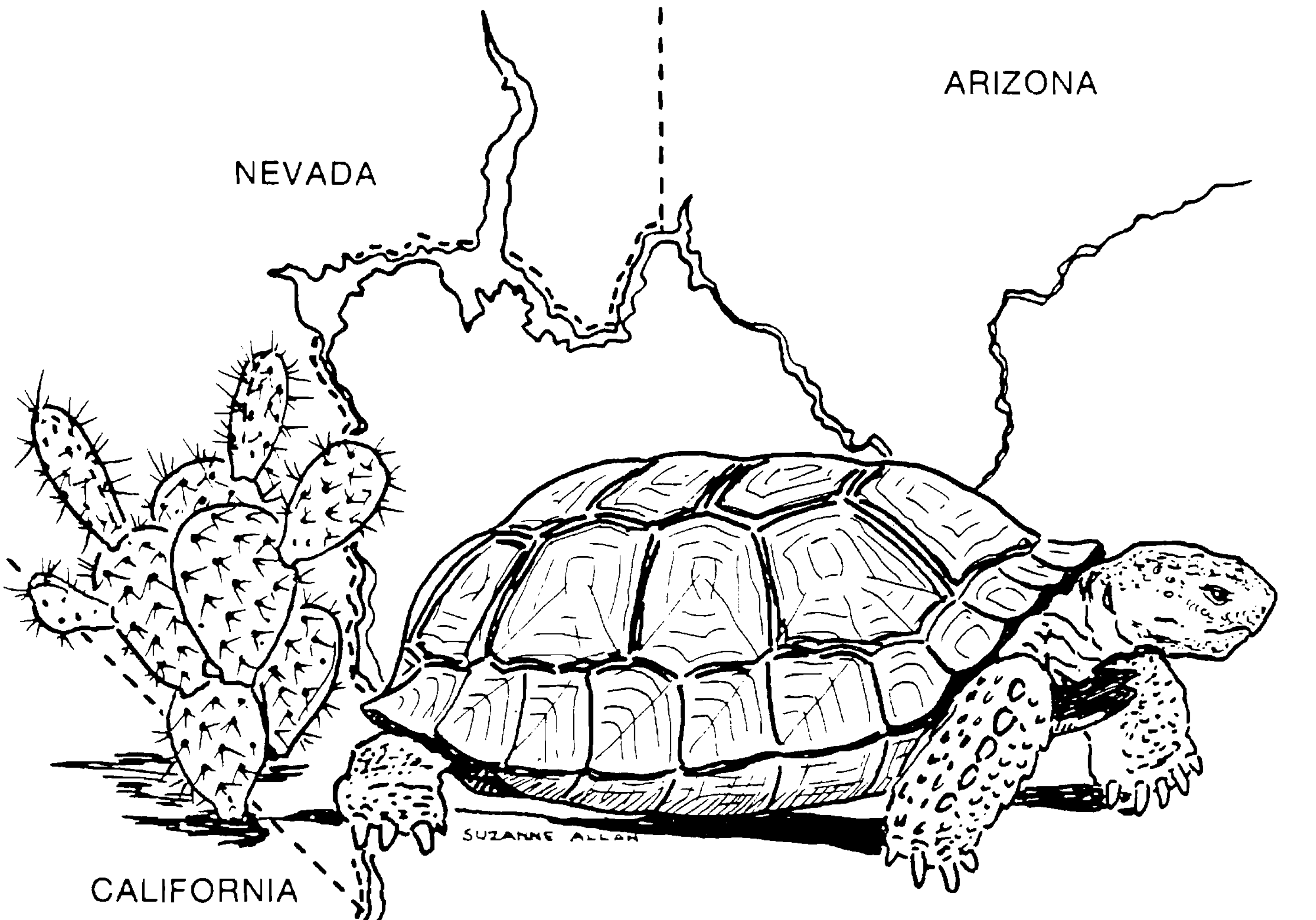


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# Desert Tortoise Council Proccedings of the 1996 Symposium

## CONTENTS

*Articles:*

# Comparison of Impacts and Mitigation Measures Along Three Multi-state Linear Construction Projects

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*Abstract*— **Various types of linear facilities have been constructed during recent years in the Mojave Desert of California and Nevada. Three multi-state projects that allow comparisons of impacts to desert tortoise (*Gopherus agassizii*), and of required mitigation measures are a 1988 fiber optic cable route from Las Vegas, NV to Rialto, CA; a 1991 natural gas pipeline through southern Utah and Nevada to Daggett, CA; and 1993–1995 transmission line from the vicinity of Boulder City, NV to Victorville, CA. The magnitude of impacts to desert tortoise varied among the projects due to the scale of the projects and the type of construction methodology necessary. Since 1988, mitigation measures required by regulatory agencies have increased and become refined. The standard average amount of tortoise habitat disturbed per km of route varied, with the gas pipeline (2.3 ha/km) causing the most disturbance, and the fiber optic cable (0.5 ha/km) and transmission line (0.9 ha/km) routes substantially less. The incidental take total during construction was high (29) for the gas pipeline route, compared to the fiber optic route (1) and transmission line route (3). Differences in take can be attributed to construction type and implementation of mitigation. The amount and sophistication of mitigation required has increased since 1988 due in large part to the desert tortoise becoming a California state- and federal-listed threatened species. Mitigation in 1988 consisted primarily of construction monitoring, relocation of tortoises, and compensation for disturbance to tortoise habitat only on federal land. Significant measures added since then have included pre-construction surveys, worker education, compensation for disturbance throughout tortoise habitat, and limited habitat revegetation/rehabilitation. Those that have added to the effectiveness of monitoring include the pre-construction surveys, worker education, and monitoring of compliance with mitigation measures. Intensive monitoring during construction is a costly undertaking, but can result in successful relocation of many individual tortoises, depending on the type of construction project and season of year.**

Rapid growth in human population and the continued urbanization of southern California and southern Nevada have resulted in construction of large-scale linear projects. In particular, the expanding human population has caused the need for energy projects, such as transmission lines (Pearson 1986). Brum et al. (1983) estimated that by the year 2000, transmission line and pipeline projects would disturb 675 $mi^2$ of desert habitat.

Three multi-state linear projects have allowed comparisons of impacts to desert tortoise, and mitigation measures developed to reduce such impacts. Those projects include a fiber optic cable, natural gas pipeline, and transmission line. Literature reviews by Luke et al. (1991) and Grover and DeFalco (1995) have included a limited number of references on impacts due to construction. Discussion of impacts due to these projects is included in this paper to add to the state of the knowledge.

Mitigation measures for projects in desert tortoise habitat have "evolved" since the federal listing of the species (U.S. Dept. Interior 1989, 1990). This is true for construction projects in general, as well as the three specific projects discussed in this paper.

## DESCRIPTION OF PROJECTS

All three projects traversed similar areas in the Mojave Desert from the vicinity of Las Vegas, NV to the Barstow/Daggett area of CA (Fig. 1). In particular, the three projects were located in Bureau of Land Management (BLM) Utility Corridor D from the CA/NV border west to the vicinity of Daggett. The routes differed from one another west of Daggett/Barstow and east of the CA/NV border. Individual routes are described below.

*Fiber Optic Cable.*—The fiber optic cable was built during June–August 1988 along a 370 km route from Las Vegas, NV to Rialto, CA (Fig. 1). Vegetation types traversed were primarily creosote bush scrub, desert saltbush scrub, and Joshua tree woodland. Construction began at opposite ends of the route and progressed toward the middle. As

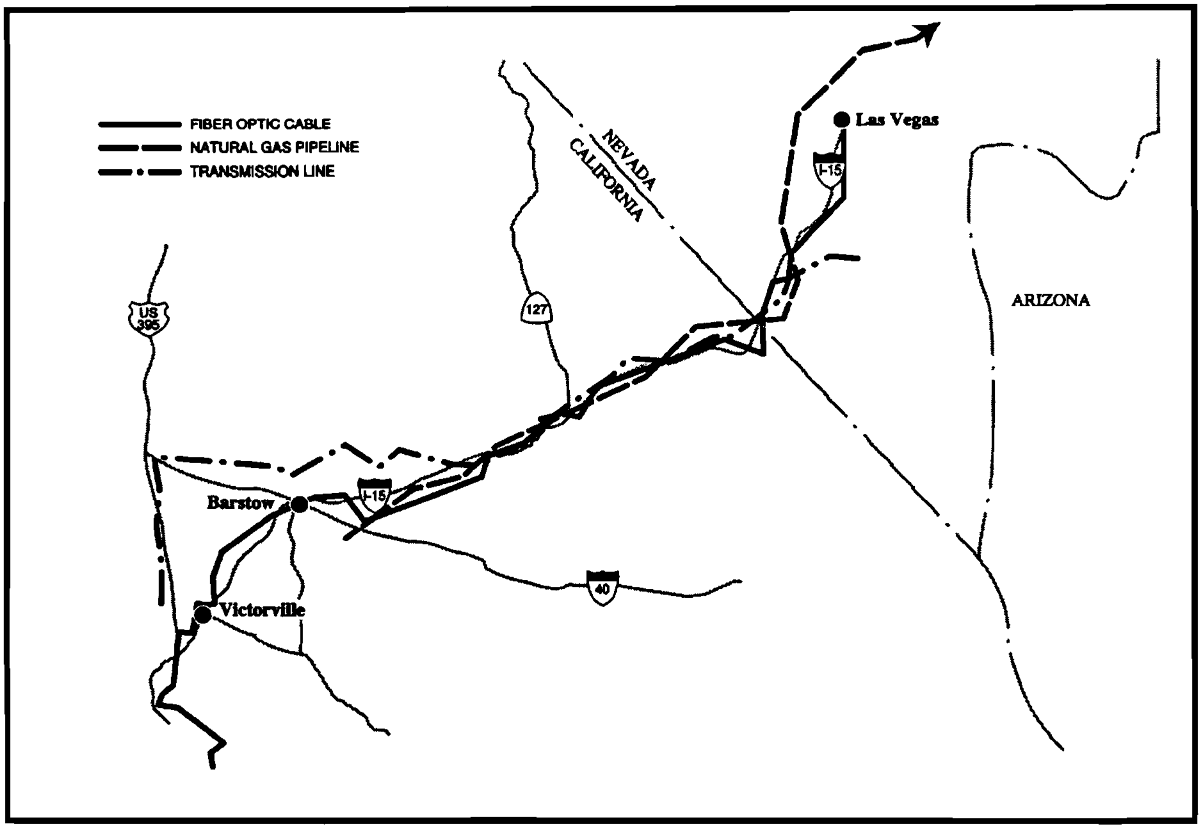


FIG. 1. Locations of three multi-state, linear projects constructed in desert tortoise habitat including fiber-optic cable (1988), natural gas pipeline (1991), and transmission line (1993–1995).

such, construction sites were separated by up to 150 km. Habitat disturbance due to construction was generally limited to a 4–7 m wide zone. The width of the construction zone, however, was substantially greater in some areas, such as large desert washes, where the cable was buried at a greater depth, resulting in disturbance of up to 100 m in width.

The fiber optic cable was built prior to listing of the Mojave population of the desert tortoise as threatened or endangered. Consequently, monitoring for tortoises during construction did not occur throughout the route, but was focused on portions totalling 156 km that traversed relatively higher densities, as indicated by Berry and Nicholson (1984).

*Natural Gas Pipeline.*—A 36 in (91.4 cm) diameter natural gas pipeline was constructed during January – December 1991 from southwestern WY to Daggett, CA. Tortoise monitoring results for this project were previously reported by Olson et al. (1992a, b). Approximately 393 km of the total route crossed desert tortoise habitat from southern UT to Daggett, CA. Vegetation types involved included creosote bush scrub, desert saltbush scrub, Joshua tree woodland, and blackbrush scrub. Construction occurred at multiple locations, often in UT, NV, and CA simultaneously. Lengths of open trench, up to 32 km in length, occurred throughout much of the project. The standard construction zone was mostly 23–30 m in width, however many extra work spaces were required, which increased the total amount of disturbance to tortoise habitat. With the exception of very short lengths in urban areas, the entire length of the pipeline route in tortoise habitat was monitored during construction.

*Transmission Line.*—A 500 kV alternating current transmission line was constructed during 1993–1995 from the Mead/McCullough substation near Boulder City, NV to a switching station in Adelanto, CA. The route crossed 323 km of desert tortoise habitat. Vegetation types disturbed were similar to those described for the natural gas pipeline. Unlike the other two projects, the disturbance associated with the transmission line was discontinuous. Most disturbance occurred within 0.4 ha squares where towers were constructed and erected, and in the vicinities of wire stringing, tensioning, and pulling sites. Monitoring during construction occurred throughout tortoise habitat along the route.

### Project Impacts

Potential project impacts were assessed prior to construction by literature and project description review, as well as field surveys. Actual impacts were evaluated during construction monitoring and post-construction review of the projects.

In order to assess differences in the magnitude of impacts caused by the projects, the following types were focused upon: (1) habitat disturbance; (2) tortoise burrows collapsed; (3) tortoises handled (the equivalent of harassment take); and (4) tortoises killed due to construction activities (lethal take).

Impacts to desert tortoises and tortoise habitat were greatest for the natural gas pipeline and least for the fiber optic cable. Habitat disturbance is reported here as ha/km because the projects are of different lengths. Due to differences in information available among the projects, habitat disturbance caused by access roads is not included. The rate of disturbance along the natural gas pipeline was more than two times as high as along the transmission line and more than four times as high as the fiber optic cable (Table 1). However, if the impact of access roads were available for this analysis, it is likely that the difference between the pipeline and transmission line would be greatly reduced. The transmission line required a greater number of new access roads from existing roads to the work sites. The disturbance due to the fiber optic cable would remain comparatively small, even if disturbance due to access roads were factored in. The differences among the projects in direct impacts to tortoises were even greater. Large numbers of tortoise burrows were collapsed along the pipeline (1,889) and transmission line (639) routes, compared to only 1 along the fiber optic cable route. Similarly, tortoises handled (to remove them from the vicinity of construction activity) during the pipeline and transmission line projects were orders of magnitude higher than the fiber optic cable project. Those differences are substantial even when the lengths of routes monitored are considered. Nearly the entire lengths of the pipeline (393 km) and transmission line (323 km) routes were monitored, compared to only 156 of the 370 km of the fiber optic cable route.

Construction of the pipeline also resulted in the highest number of tortoises killed (lethal take). The lethal take of tortoises during pipeline construction was more than seven times as great as the other two projects combined. It should be noted that the high number of lethal take occurred despite much higher coverage by tortoise monitors. The maximum number of biologists monitoring

Table 1. Impacts to desert tortoise due to construction of a fiber optic cable, NV-CA, 1988; natural gas pipeline, UT-NV-CA, 1991; and transmission line, NV-CA, 1993–1995.

| Type of impact | Type of construction project | | |
|---|---|---|---|
| | Fiber optic cable | Natural gas pipeline | Transmission line |
| Standard width of habitat disturbance (m) | 4–7 | 23–30 | Discontinuous disturbance |
| Average habitat disturbance (ha/km), excluding access roads | 0.5 | 2.3 | 0.9 |
| Desert tortoise burrows collapsed | 1 | 1,889 | 639 |
| Desert tortoise killed | 1 | 29 | 3 |
| Desert tortoise killed per ha of disturbance | 0.01 | 0.03 | 0.01 |

construction for tortoises at one time were 12 for the fiber optic cable, 15 for transmission line, and 88 for the pipeline.

There were several reasons for the substantially higher disturbance due to pipeline construction. The scale of the project was much larger. The standard disturbance zone was much wider as indicated in Table 1. The additional area of disturbance was necessary to accommodate the large open trench and associated spoil pile, as well as the high number of vehicles, equipment, and workers on the job. Construction activity at a specific location was present for a much longer time along the pipeline route than along the fiber optic cable or transmission line. Although the transmission line was constructed during portions of three years, there were large gaps in time between construction stages at each location.

The amount of lethal take placed in the context of amount of habitat disturbance indicates the relatively large scale of pipeline construction. Using absolute numbers, the lethal take of tortoises was nearly nine times higher than the transmission line and nearly 30 times higher than the fiber optic cable (Table 1). However, when the amount of tortoise habitat disturbed is factored in (take/ha of disturbance), the amount of take on the pipeline route was only three times as high. Overall, pipeline construction resulted in a higher number of tortoises killed and a much greater amount of tortoise habitat disturbed.

The pipeline had less flexibility in project design, and implementation. Even small alterations to the route were difficult and costly. In nearly all cases, tortoise burrows in the construction zone could not be avoided by route changes. In contrast there was a fair degree of flexibility in the placement of transmission line towers to avoid burrows. The fiber optic cable had the greatest amount of flexibility, which is supported by the fact that only 1 burrow required collapsing prior to construction (Table 1).

Two additional factors affected impacts to tortoises, particularly the totals for harassment and lethal take. The fiber optic cable was constructed during a period of time that included several years of less–than–average rainfall. The other two linear projects were constructed during years of average to above–average rainfall. The amount of precipitation may have influenced the level of tortoise activity, which in turn was reflected in the numbers of tortoises handled during the construction projects. The most important factor, however, appears to have been the timing of construction. Of the three projects, only the pipeline project involved a peak in construction activity (March – June) that coincided with the peak in tortoise activity. The combination of the scale of the project and the timing of construction during a period of high tortoise activity resulted in the high numbers of tortoise handled (401) and killed (29).

As described earlier, the number of tortoises killed was high along the pipeline route despite a large crew of monitors. The high number of monitors prevented many additional lethal take, but probably contributed to the higher total by compiling a more accurate count of project-related deaths. Several carcasses were found days to weeks after time of death in locations such as spoil piles. Such discoveries were made only because a large monitoring crew was utilized.

## Mitigation Measures

Measures for projects completed prior to listing of the tortoise were limited primarily to monitoring construction activities for tortoise, moving tortoises when necessary, and reporting incidental lethal take to agency representatives. The sources of measures prior to listing (such as those for the fiber optic cable) were stipulations in BLM right-of-way grants and some California Department of Fish and Game (CDFG) permits and approval, such as conditions attached to California Fish and Game Code, Section 1601–1603 Streambed Alteration Agreements.

Later, the tortoise became federally listed, first as endangered via the emergency rule (U.S. Dept. Interior 1989), then as threatened via the standard listing process (U.S. Dept. Interior 1990). Along with the listed status of the tortoise came the requirement of formal endangered species consultation for projects. Biological Opinions issued as part of the consultation process have included terms and conditions, the current principal sources of mitigation measures for construction projects. Terms and conditions in Biological Opinions have increased in number and refinement over time. Since 1990, the tortoise has also been a California state listed threatened species, which has resulted in another source of protective measures for the species in the form of conditions attached to California Fish and Game Code Section 2081 Management Authorization. The pipeline and transmission

TABLE 2. Required pre-construction mitigation measures, fiber optic cable, NV-CA, 1988; natural gas pipeline, UT-NV-CA, 1991; and transmission line, NV-CA, 1993–1995.

| Pre-construction measure | Fiber optic cable | Natural gas pipeline | Transmission line |
|---|---|---|---|
| Compensation throughout tortoise habitat | – | X | X |
| Monitor training program | – | X | X |
| Relocation of tortoises to artificial burrows only | X | – | X |
| Relocation of tortoises to artificial or natural burrows | – | X | – |
| Crushing or exclusion of burrows following tortoise removal | – | X | X |
| Standardized pre-construction surveys (e.g., 45-d, 48-hr) | – | X | X |
| Changes in pre-construction surveys protocol by season | – | X | X |

line projects were constructed subsequent to federal and California state listing of the tortoise. A comparative discussion of required measures for the three linear projects follows.

*Pre-construction Measures.*—Of the measures required for the fiber optic cable, few occurred prior to construction. Because the project was completed prior to listing of the tortoise, implementation of protective measures focused on lands in federal and state ownership and in areas where tortoise densities were previously reported as high and very high (Berry and Nicholson 1984). As such, monitoring during construction and the compensation for disturbance to tortoise habitat were not required throughout the length of the route.

Some measures that have subsequently become routine, such as standardized pre-construction surveys and training programs for monitors, were not required (Table 2). Both were accomplished during the project, but on an informal, voluntary basis.

Construction of the pipeline brought about several pre-construction measures that have continued through current projects. The first formal monitor training workshop was developed. A system of pre-construction surveys was established that included two surveys, one 45 d in advance of construction and another within 48 hrs of construction. The surveys allow monitors to find tortoise burrows, remove tortoises as necessary, then excavate and backfill the burrows well in advance of construction.

The transmission line project included pre-construction measures that were similar to those required for the pipeline. There were minor changes in the timing of pre-construction surveys and the manner in which tortoises could be relocated from occupied burrows found in the construction zone.

*During Construction.*—The largest increase in number of mitigation measures on linear construction projects are those required during construction (Table 3). Most of the measures developed since the listing of the tortoise have been in two general areas:

- Measures involving limitation and reporting of incidental take; and
- Measures to preclude or reduce impacts to tortoises, including impacts to habitat.

*Limitation and Reporting of Take.*—No limits on lethal take (tortoises killed) and harassment take

TABLE 3. Required mitigation measures to be implemented during construction of a fiber optic cable, NV-CA, 1988; natural gas pipeline, UT-NV-CA, 1991; and transmission line, NV-CA, 1993–1995.

| Construction measure | Fiber optic cable | Natural gas pipeline | Transmission line |
|---|---|---|---|
| Seasonal restrictions on construction | – | X | – |
| Monitoring throughout desert tortoise habitat | – | X | X |
| Construction only with monitor present | X | X | X |
| Vehicle access restrictions | X | X | X |
| Vehicle speed limit | – | X | X |
| Litter control | – | X | X |
| Cleanup of fluid spills | – | X | X |
| Reporting of incidents to agencies | – | X | X |
| Worker education | – | X | X |
| Lethal take limit | – | X | X |
| Handling (harassment) limit | – | X | (X)[1] |
| Carcass disposition requirements | – | X | (X)[1] |
| Reporting of lethal take to agencies | X | X | X |
| Special circumstances | – | X | X |

[1]Measure revised after initiation of project

(tortoises handled) were imposed on the fiber optic project, which was completed prior to listing of the tortoise. Limits were placed on both the pipeline and transmission line projects. During the pipeline project, as the number of tortoises approached the harassment limit, monitors were forced to continually observe some tortoises, rather than relocate them out of the construction zone. In contrast, the limit on the number of tortoises that could be handled for the transmission line project was dropped, a modification that allowed more efficient use of monitors.

Two other changes in take procedures were made during the transmission line project. First, procedures for marking tortoises were streamlined compared to the pipeline project. Second, agency approval was granted to leave tortoise carcasses in the field, rather than try to place them in institutional collections. Both changes increased the amount of time that biologists had for monitoring elsewhere in the construction zone. If possible, carcasses that represent incidental lethal take due to projects should be made available for research purposes. For future projects, agencies such as BLM, should be contacted regarding additional research outlets for carcasses (see Recommendations).

*Attempts to Preclude or Reduce Impacts to Tortoises and Tortoise Habitat.*—During construction of the fiber optic cable, measures in this category were limited primarily to the requirement of tortoise monitors during construction and the restriction of construction vehicles and equipment to approved areas (Table 3). Primary measures required for the pipeline and transmission line projects included control of litter in construction zones, vehicle speed limits, cleanup of fluid spills, worker education, and the requirement to report violations of terms and conditions to designated agency representatives on a weekly basis. Some have been effective, such as worker education and litter control; others (such as vehicle speed limits and restriction of construction to a particular season of the year) are difficult to enforce and do not represent efficient use of monitor time.

One measure listed in Table 3 with potential to be very valuable is "Special Circumstances." It is not a measure unto itself, but represents the opportunity for agencies and project proponents to modify existing or develop new measures, as necessary, during construction of a project.

*Post-construction Measures.*—This is the stage of a project with perhaps the most potential for mitigation measure development/refinement. The number of required measures increased slightly from one project to the next. Following construction of the fiber optic cable, required measures included an on-the-ground review of disturbance and submittal of a report to the agencies (Table 4). In addition, "construction-type" reclamation was required. That type of reclamation was comprised of recontouring and cleanup of construction materials. No revegetation was required.

Following pipeline construction, additional required measures were a review of the effectiveness of measures within the post-construction report and revegetation of some sensitive plant species. The latter included transplanting of cactus and yuccas and reseeding of four other species (described in Hiatt et al. 1993). Although some revegetation effort was required, no provision was made for follow-up monitoring of the reseeding and transplanting to assess rate of success.

Primary post-construction measures added to the transmission line route were: (1) the requirement to assess within the report the effectiveness *and* the level of compliance with measures; and (2) the requirement to prepare a road closure plan for access routes not needed after construction. The latter is an excellent addition to post-construction measures. New and improved routes left open following construction provide additional access for off-road vehicles and the accompanying spread of habitat disturbance.

Two measures that were not required for any of the three projects included revegetation of plants other than cactus, yuccas, and rare species, and a requirement of follow-up monitoring to assess the success of revegetation efforts (Table 4).

## Recommendations

Based on this review of the three linear construction projects, the following general recommendations are presented.

### Pre–construction

TABLE 4. Required post-construction mitigation measures, fiber optic cable, NV-CA, 1988; natural gas pipeline, UT-NV-CA, 1991; and transmission line, NV-CA, 1993–1995.

| Post-construction measure | Fiber optic cable | Natural gas pipeline | Transmission line |
|---|---|---|---|
| Review of disturbance | X | X | X |
| Reporting of monitoring activities, effectiveness | X | X | X |
| Review of compliance with measures | – | – | X |
| Construction-type reclamation | X | X | X |
| Revegetation of sensitive plants | – | X | X |
| Revegetation of common plants | – | – | – |
| Follow-up monitoring of revegetation | – | – | – |

*Monitor training.*—Training programs for monitors should be developed on a project-specific basis, incorporating important points learned from previous projects.

*Pre-construction surveys.*—Recent papers such as Roberts et al. (1994) have emphasized the need for efficient, practical mitigation, particularly when pre-construction surveys are involved. Although the pre-construction surveys discussed in this paper differ somewhat from those in the Roberts et al. (1994) paper, the general principle is applicable. More than 90 percent of the burrows are found during the initial pre–construction surveys. As such, it is recommended that consideration be given to delete the second survey. Monitors present during construction will be able to locate and examine the small number of burrows not found during the initial survey.

*Continue to encourage minimization of habitat disturbance in the project design stage.*—Consolidation of parking/staging/unloading areas and other extra work spaces should be maximized, especially if there are existing disturbed areas that can be used. Access routes should utilize existing roads to the extent possible.

## Construction

*Worker education.*—Programs should continue. Monitoring requirements were more easily explained during formal, mandatory presentations for the pipeline and transmission line projects, than in informal situations for the fiber optic cable.

*Focus the monitoring effort.*—Again, in an effort to increase efficiency of mitigation, monitoring of construction should focus on areas where possible take of tortoises is highest, including open trenches and areas of greatest equipment activity. Monitoring the compliance of measures such as vehicle speed limits and immediate cleanup of fluid spills should be de-emphasized.

*Reduction in the number of worker vehicles.*—Continued innovation is needed to reduce the number of vehicles in the construction area, especially those transporting workers to and from the site. Workers' vehicles were responsible for a substantial number of tortoise deaths during pipeline construction, yet were very difficult to monitor.

*Disposition of tortoise carcasses.*—Agencies should be contacted prior to the start of construction, as well as during construction, to determine if there are research needs for carcasses. Planning will be needed to properly store and ship carcasses.

## Post-construction

*Post-construction reports.*—Post-construction reports should continue to be submitted to agency representatives. An emphasis should be placed on discussion within the paper of the *effectiveness and practicality* of mitigation measures. Feedback to agencies is essential if required measures are to continue to improve in effectiveness and efficiency.

*Road closure.*—A valuable addition to the transmission line measures was a requirement to close roads no longer needed after construction. Cost-effective, innovative procedures need to be developed to discourage use of new areas by off-road vehicles.

*Evaluation of habitat recovery, success of revegetation efforts.*—Many papers have been presented since the 1970s (e.g., Vasek et al. 1975a, b; Webb and Wilshire 1980) concerning slow recovery of desert habitats after man-caused disturbance. Yet, none of the three linear project reviewed here required an examination of the disturbance zone in years following construction. Certainly, if revegetation is required, follow-up monitoring would provide valuable data, as would monitoring to assess the extent of natural recovery.

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# Preliminary Data Analysis from Three Desert Tortoise Long-term Monitoring Plots in Arizona: Sheltersite Use and Growth

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***Abstract***— **We present preliminary results from data collected from three long-term desert tortoise (*Gopherus agassizii*) monitoring plots in the Sonoran Desert of Arizona. The Eagletail Mountains, Granite Hills, and Little Shipp Wash plots were each surveyed, in cooperation with the U.S. Bureau of Land Management (BLM) and the U.S. Fish and Wildlife Service, annually from 1990–94. The Eagletail and Little Shipp plots had been previously surveyed for BLM, resulting in six years of data for those plots. Available sheltersites may be a limiting resource for these populations; females use other females' burrows less often than expected. Growth rates are similar between sexes and populations, but males reach larger size than females at Little Shipp (and possibly at the Eagletails); Granite Hills tortoises reach smaller size than those at both the Eagletails and Little Shipp. The growth data presented in this paper can be used to investigate patterns in tortoise size distributions, in addition to providing important information relative to desert tortoise life history and population regulation.**

The Arizona Game and Fish Department, in cooperation with the U.S. Bureau of Land Management (BLM) and the U.S. Fish and Wildlife Service, has amassed a data set from five to six years of monitoring surveys at three desert tortoise plots in Arizona. The Eagletail Mountains, Granite Hills, and Little Shipp Wash monitoring plots were each surveyed annually from 1990 through 1994 (Shields et al. 1990; Hart et al. 1992; Woodman et al. 1993, 1994, 1995); the Eagletails and Little Shipp plots were also each surveyed once prior to 1990 (Schneider 1981; Shields and Woodman 1987). These plots have generally been surveyed as standard BLM 60 day, one-mi$^2$ plots, although the protocol at the Eagletails has been modified slightly (Hart et al. 1992; Woodman et al. 1993, 1994, 1995). The plots are located in Maricopa, Pinal, and Yavapai Counties (Eagletails, Granite Hills, and Little Shipp, respectively); physical descriptions can be found in reports cited above.

These surveys represent the longest studies of individual Sonoran Desert tortoise populations to date. Almost 450 tortoises have been captured and marked on these plots since 1980: 79 at the Eagletails, 162 at Granite Hills, and 197 at Little Shipp. This paper represents the beginning synthesis of these data and focusses on aspects of sheltersite use and individual growth and their relationship to demography and population dynamics.

## MATERIALS AND METHODS

We compared cumulative sex ratios of tortoises ≥180 mm MCL (straight midline carapace length) for all surveys at each plot to an expected 1:1 ratio with the log-likelihood ratio test ($G$ test; Sokal and Rohlf 1995) and tabulated burrow use data for each of the three plots. The burrow data were collected between 1992–1994 at the Eagletail Mountains and Little Shipp Wash and 1993–1994 at the Granite Hills. These dates reflect the years that permanent, aluminum tags were epoxied to sheltersites. We investigated the relationship between desert tortoises and sheltersites in two ways. First, we tabulated the number of times two or more tortoises were found at a sheltersite at the same time; these were recorded as male/male, female/female, male/female, etc. Instances of the same tortoise combination occurring in the same burrow were deleted. Otherwise, the data include multiple observations of individual tortoises and burrows. Second, we reviewed tortoise capture histories at each sheltersite to determine the sex of tortoises using individual shelters at any time since the burrows were tagged. We tabulated shelters used by males only, females only, and by both sexes, these data include the cases of tortoises sharing burrows at the same time. We used the $G$ test to compare the pattern of burrow use between the sexes against an expected distribution of 1:2:1 (multiple males:males and females:multiple females). We then compared the number of burrows used by

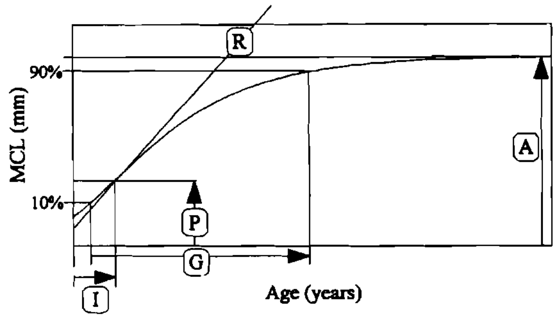


FIG. 1. Statistics computed from Richards growth curve. $A$ = the asymptotic carapace length, $R$ = the weighted mean growth rate, $I$ = the time to grow from hatching to the inflection point of the curve, $P$ = the percent of $A$ reached at the inflection point of the curve, and $G$ = the time to pass from 10% to 90% of total growth.

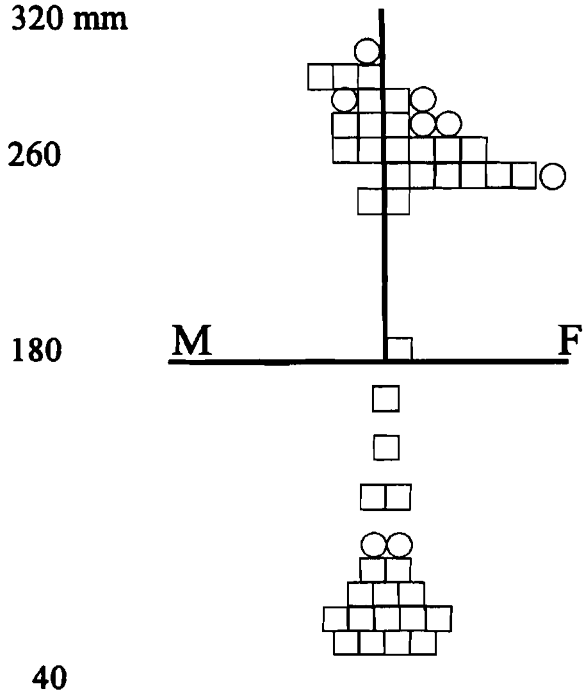


FIG. 2. Size distribution for the Eagletail Mountains desert tortoise plot in 1994. Squares represent individuals captured within plot boundaries, and circles represent individuals captured outside plot boundaries.

multiple males to the number used by males and females and the number of burrows used by multiple males to the number used by multiple females; we used a Bonferroni $\alpha = 0.025$ for the latter two tests (Sokal and Rohlf 1995). In cases where more than two tortoises used a particular burrow, we coded the sex-combination frequency so that no burrow was counted more than once. For example, if a burrow was used by two males and one female, we added 0.5 to the multiple-male frequency and 0.5 to the male female frequency. We excluded juvenile captures from these analyses.

We used the mark-recapture data to construct growth curves for each sex within each population. We input the first and last MCL for every tortoise captured in more than one year into a nonlinear regression analysis. Individuals <180 mm MCL in both years were included in the curves for both sexes. We used Richards' (1959) equation modified by Bradley et al. (1984) and the mark-recapture interval equation given by Schoener and Schoener (1978):

$$\mathrm{MCL} = A(1 + [m - 1]e^{-k(t - I)})^{1/(1 - m)} \qquad 1)$$

and

$$\mathrm{MCL}_2 = A(1 - e^{-kt}[1 - (\mathrm{MCL}_1^3/A^3)^{1 - m}])^{1/(3 - 3m)} \qquad 2)$$

where $A$ = asymptotic carapace length, $m$ = a shape constant, $k$ = intrinsic growth rate, $t$ = time interval between first and last captures, and $I$ = the time to reach the inflection point in the curve. We used the estimates of $A$, $k$, and $m$ derived from the interval equation (equation 2) to solve for $I$ in equation 1 in order to complete the growth equation and develop a curve. In so doing, we set $t = 0$ and estimated MCL = 46 mm at hatching (unpublished data). We computed 95% "support plane" confidence intervals for $A$, $k$, and $m$, which are the maximum symmetrical confidence intervals about the parameters regardless of the values of the other parameters (Marquardt 1964). We considered parameter estimates to be different if these intervals did not overlap. We also computed the following, more biologically meaningful statistics (Bradley et al. 1984; Richards 1959): weighted mean growth rate ($R$), percentage of asymptotic size achieved at inflection ($P$), and time to pass from 10% to 90% total growth ($G$). These statistics, illustrated in Fig. 1, are defined as follows:

$A$ = the raw parameter value from the curve
$R = k/m$
$P = m^{1/(1 - m)}$
$G = \ln([1 - 0.10^{1 - m}]/[1 - 0.90^{1 - m}])/k$

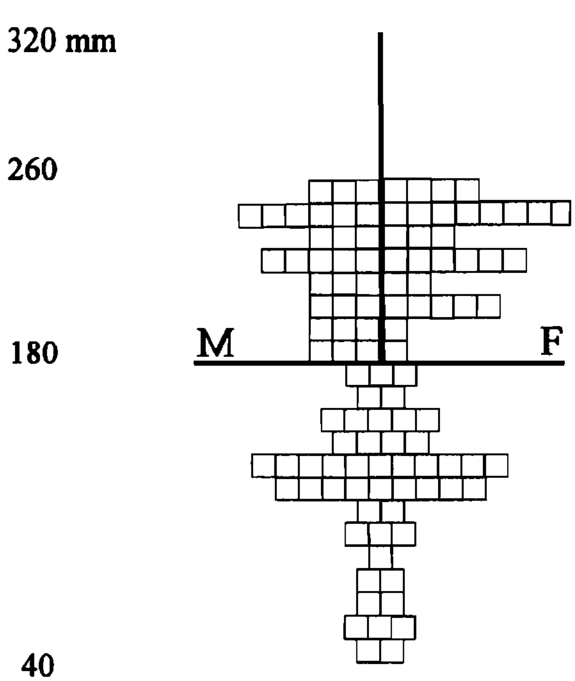


FIG. 3. Size distribution for the Granite Hills desert tortoise plot in 1994. Squares represent individuals captured within plot boundaries, and circles represent individuals captured outside plot boundaries.

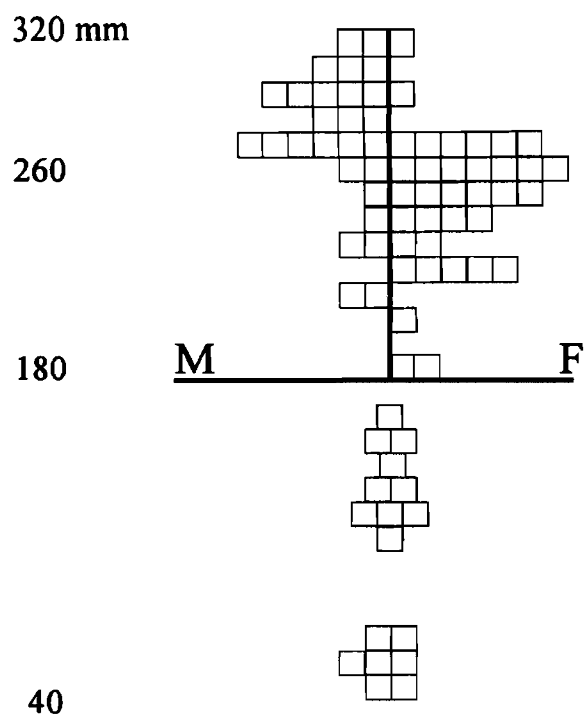


FIG. 4. Size distribution for the Little Shipp desert tortoise plot in 1994. Squares represent individuals captured within plot boundaries, and circles represent individuals captured outside plot boundaries.

TABLE 1. Observations of more than one tortoise at a single shelter, 1992–94 at the Eagletails and Little Shipp plots and 1993–94 at the Granite Hills plot. Total obs. is the total number of observations of tortoises at burrows. Percentages are percent of all multi-tortoise observations within each plot.

| | | | Multi-tortoise observations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plot | Tagged burrows | Total obs. | MF | MM | FF | MMF | MFF | FU | UU | Total |
| Eagletails | 48 | 109 | 3[a] | 2 | 1 | 1 | 1 | – | 1 | 9[a] |
| | | | 33% | 22% | 11% | 11% | 11% | – | 11% | |
| Granite Hills | 92 | 138 | 6 | – | – | – | – | 1 | – | 7 |
| | | | 86% | – | – | – | – | 14% | – | |
| Little Shipp | 175 | 321 | 20[a] | 7 | 2 | 2 | – | – | – | 31[a] |
| | | | 65% | 23% | 6% | 6% | – | – | – | |
| Total | 315 | 568 | 29 | 9 | 3 | 3 | 1 | 1 | 1 | 47 |
| | | | 62% | 19% | 6% | 6% | 2% | 2% | 2% | |

[a]Does not include repeated observations of the same two tortoises in the same shelter

Unfortunately, measures of variance and confidence intervals for *R*, *P*, and *G* must be computed with jackknife or bootstrapping procedures. Bradley et al. (1984) had developed a jackknife program to estimate these statistics, but the program is not available for modern computers (D. W. Bradley pers. comm.), and other methods were unavailable to us at this time. Therefore, we only present the point estimates for these parameters for illustrative purposes.

## Results

*Demography.*—Tortoise size distributions for the last survey of each plot are illustrated in Figs. 2–4. The Eagletail population is the smallest of the three studied, with about 30 adult tortoises (Fig. 2). The observed sex ratio was significantly skewed toward females in 1990 (Shields et al. 1990), but the cumulative sex ratio over the six years surveyed did not differ from 1:1 ($P>0.05$). A large gap in the size distribution has been characteristic of this population since it was first surveyed in 1987, and the size distribution appears to be slightly skewed toward larger males (Fig. 2).

The Granite Hills population contains about 70 adult tortoises distributed evenly between males and females ($P>0.10$; Fig. 3). Many more small tortoises have been captured at this plot than at others, and adults at Granite Hills reach a smaller maximum size than those at the other two sites. The Little Shipp population contains about 100 adults, and again, the cumulatative sex ratio was not significantly different than 1:1 ($P>0.05$; Fig. 4). Males generally seem to reach a larger maximum size than females, and there is a slight gap in the distribution similar to that at the Eagletail plot, but much larger for males than females (Fig. 4).

*Burrow use.*—Fifty-two sheltersites have been

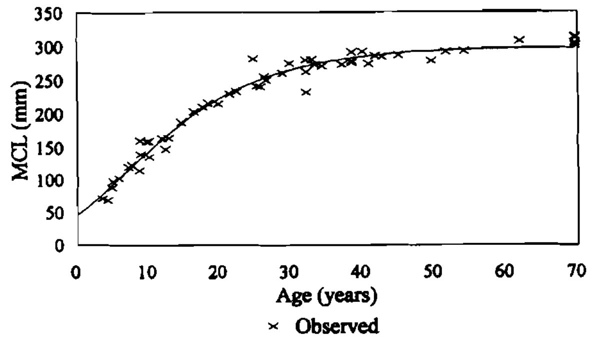


Fig. 5. Representive Richards growth curve for a population of desert tortoise. This particular curve was estimated for male tortoises at the Little Shipp plot, $n = 54$, $r^2 = 0.98$.

Table 2. Frequency of different tortoises using individual burrows between 1992–94 at the Eagletails and Little Shipp plots and 1993–94 at the Granite Hills plot. Gender combinations are not mutually exclusive, e.g, a burrow used by two males and one female would be recorded under both MM and MF. Numbers in parentheses are frequencies coded so that each burrow is only counted once. Observations involving unsexed tortoises are not included.

| Plot | Tagged burrows | Multi-tortoise burrows | MM | MF | FF |
|---|---|---|---|---|---|
| Eagletails | 48 | 15 | 8 | 9 | 4 |
| | | 31% | (6.3) | (6.3) | (2.3) |
| Granite Hills | 92 | 14 | 4 | 11 | 2 |
| | | 15% | (3.5) | (9.5) | (1.0) |
| Little Shipp | 175 | 55 | 22 | 43 | 10 |
| | | 31% | (14.0) | (34.0) | (7.0) |
| Total | 315 | 84 | 34 | 63 | 16 |
| | | 27% | (23.8) | (49.8) | (10.3) |

permanently marked at the Eagletails, 94 at Granite Hills, and 190 at Little Shipp. Of these, 48, 92, and 175, respectively, have been verified as being utilized by tortoises (tortoises seen in the shelter or on the apron). Frequencies of multiple tortoise observations at tagged shelters are given in Table 1. By far, most observations of more than one tortoise at the same shelter involve a single male with a single female (62% across the three plots). Only 25% of all observations involved multiple males at the same shelter, and fewer (8%) involved multiple females. Repeated observations of the same male-female combination at the same individual burrow occurred once at the Eagletails in 1993 and once at Little Shipp between 1993 and 1994. Twenty tortoises were found sharing burrows with other tortoises on more than one occassion (12 males, 8 females). Of these, six males were found sharing burrows three to five times each, and 17 of their 23 co-occupants were female. No females have yet been found sharing burrows more than twice.

Eighty-four of the tagged burrows at the three plots have been used by more than one adult tortoise at some time since the burrows were tagged (Table 2). The distribution of multiple males, males and females, and multiple females using the same burrow did not differ between plots ($P>0.5$), so we pooled the data for the following tests. The overall

TABLE 3. Richards growth curve parameter estimates for desert tortoises at the Eagletails, Granite Hills, and Little Shipp plots. Parameters are defined in the text. Confidence intervals are 95% "support plane" intervals (Marquardt 1946) except Germano's (1994) jack-knifed confidence intervals. Signifcant differences between sexes within plots are shown with an asterisk.

| Sex | A (mm) | k | m | R | P | G (yrs) | I (yrs) |
|---|---|---|---|---|---|---|---|
| *Eagletails* | | | | | | | |
| Males | 288 | 0.14 | 1.24 | 0.11 | 0.41 | 24.0 | 6.0 |
| | 271–305 | 0.01–0.27 | 0.56-1.92 | | | | |
| Females | 268 | 0.28 | 1.76 | 0.16 | 0.48 | 14.4 | 4.7 |
| | 259–277 | 0.10–0.46 | 0.96–2.56 | | | | |
| *Granite Hills* | | | | | | | |
| Males | 244 | 0.22 | 1.71 | 0.13 | 0.47 | 18.1 | 5.3 |
| | 231–257 | 0.08–0.36 | 0.86–2.56 | | | | |
| Females | 243 | 0.15 | 1.37 | 0.11 | 0.43 | 23.5 | 5.2 |
| | 232–254 | 0.09–0.21 | 0.78–1.96 | | | | |
| *Little Shipp* | | | | | | | |
| Males | 299* | 0.09 | 0.94 | 0.10 | 0.36 | 33.6 | 6.4 |
| | 280–318 | 0.03–0.15 | 0.49–1.39 | | | | |
| Females | 267* | 0.21 | 1.35 | 0.16 | 0.42 | 16.7 | 4.2 |
| | 258–276 | 0.10–0.32 | 0.72–1.98 | | | | |
| *Germano (1994)* | | | | | | | |
| Both | 270[a] | 0.11 | 0.94 | 0.11 | 0.36 | 29.9 | 6.1 |
| | | | | 0.09–0.12 | 0.31–0.40 | 28.4–31.6 | |

[a]Upper decile carapace length

pattern of burrow use was significantly different than random ($P<0.05$) as a result of females using other females' burrows less often than expected ($P<0.025$). Males use other male and female burrows randomly ($P<0.50$).

*Growth*.—Residuals were distributed more or less randomly in growth analyses for each sex at each plot, so transformation of the raw data was unnecessary. Figure 5 illustrates a representative curve developed with the Richards model and shows a good fit. Parameter estimates are given in Table 3. Males reach larger sizes at Little Shipp than females, and the support plane confidence intervals for each sex at the Eagletails only narrowly overlap. Both males and females at Granite Hills reach smaller sizes than tortoises at the Eagletails and Little Shipp. Estimates for $k$ and $m$ do not differ within or among plots. Even though variance estimates are not available for the estimates of $R$, $P$, and $G$, these estimates also appear to be similar within and among plots.

## Discussion

These growth data are the first for individual desert tortoise populations in the Sonoran Desert. Germano (1994) also used the Richards model to develop a growth curve for Sonoran Desert tortoises, and even though he pooled data from across the Sonoran Desert, his parameter estimates are generally similar to ours (Table 3). In summary, our preliminary results indicate that the weighted mean growth rate ($R$) is approximately the same ($\approx 0.13$) for males and females at each population, and they reach about 45% of their maximum size before growth begins to slow. Maximum sizes, however, differ between sexes and among populations. Hart (1996) found that individuals in northern populations tend to reach larger sizes than individuals in southern populations. He included four populations in his analysis in addition to the Granite Hills, Eagletails, and Little Shipp, and found that large-individual populations occurred north of the Gila River. Similarities and differences in individual growth between sexes and populations will become more clear with additional statistical analyses, particularly when variance estimates for parameters $R$, $P$, and $G$ are derived with resampling techniques.

O'Connor et al. (1994) combined data from three studies and found that female desert tortoises had smaller home ranges than males, suggesting that our lack of observations of females using other females' burrows may be an artifact of relatively small, non-overlapping home ranges for females compared to males. However, they found that females at their Mojave Desert site had overlapping home ranges with up to six other females, and Bulova (1994), tracking the same tortoises, found that females shared burrows with other females less often than males with males or males with females. Other short-term studies have shown the same burrow use pattern in both the Mojave (Burge 1977) and Sonoran Deserts (Bailey 1992), but this is the first study to indicate that females may avoid other females' burrows whether or not those burrows are occupied. Only 23 observations of agonistic behavior have been made at the three plots in our study since 1990 (all between males; Shields et al. 1990; Hart et al. 1992; Woodman et al. 1993, 1994, 1995), but it appears that if females are not overtly territorial, they may otherwise be segregating themselves from each other.

Burrows may be a limiting resource in populations in the Sonoran Desert. For example, Woodman et al. (1995) noted that some individual tortoises have been located in the same burrows during all six annual surveys at the Eagletails, and they suggested that sheltersite fidelity may be a result of the low number of quality shelters available. If this is true, the number of adult tortoises in the population may represent population carrying capacity, and small adults may be forced out of the population, creating the gap in the size distribution (Fig. 2). This was similarly suggested by Hart et al. (1992) and Woodman et al. (1993, 1994). Little Shipp may also be at carrying capacity with more available sheltersites supporting a larger population size; the larger gap in the male size distribution (Fig. 4) could be a result of their larger maximum size compared to females.

Alternatively, low recruitment in the past could cause gaps in current adult size distributions. There may be fewer young adult tortoises in these populations to maintain additional burrows. Additional research could resolve these hypotheses by tracking groups of juvenile tortoises. For example, by using the growth curve data and a formula analagous to $G$, we determined that the time for the relatively large group of juvenile tortoises at the Eagletails (indicated at the bottom of Fig. 2) to grow from about 30% (1994 size) to about 75% (across the 180 mm line) of the asymptotic size should be six to seven years. If the population is not at carrying capacity, more of these tortoises should show up in the adult population around year 2000 or 2001 than necessary to replace adult mortalities. However, if these tortoises did not appear in the adult population at that time, it would be necessary to determine whether this was a result of density-independent mortality or emigration.

An additional possible explanation for gaps in tortoise size distributions is that tortoises are at their maximum rate of growth in those size ranges. Tortoises would be in that size range for a relatively short period of time, thus occurring in lower frequencies. However, our estimates indicate that tortoises reach their maximum growth rates at four to six years of age and 104–129 mm MCL (36–48% asymptotic size; Table 3), before they reach the gap in the size distribution. These estimates may be somewhat low, since relatively few tortoises <100 mm (2–5 at the 3 plots) have been recaptured and included in the growth analysis. Additional recaptures of small tortoises will improve the shape of growth curves and produce more accurate parameter estimates. Regardless of the above hypotheses, the growth data presented in this paper will be important to desert tortoise management by aiding in the completion of accurate life tables for populations in Arizona.

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# Survey of the Motivational Aspects of Desert Tortoise Caretaking

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***Abstract.***—**This study investigates the possibility that humans who maintain desert tortoises in a captive setting experience significant psychological benefit from the caretaking experience. Using data from previously published surveys, a species-appropriate instrument, the Tortoise Caretaking Questionnaire (TCQ), utilizing 20 Likert-like questions was developed to examine ten motives for caretaking. The TCQ also contained a brief demographic section. Each motive was analyzed with respect to strength, age, gender and tortoise rank (compared with other household pets). Two thousand three hundred and seventy-eight questionnaires were distributed and 496 were returned; of these, 490 were deemed usable. All motives were shown to be significant and with one exception, females expressed stronger levels of each than did males. Younger respondents tended to rank tortoises higher than other pets whereas older respondents ranked them lower. Future research is suggested to investigate the longitudinal and other aspects of tortoise caretaking.**

The desert tortoise (*Gopherus agassizii*) has been the focus of much controversy in the desert southwest of the United States. In recent times this controversy has included such factors as the status of animals and diminishing habitat due to rapid urban development. There are political, social, and institutional disagreements over methods of protection and preservation. Additionally, the potentially fatal disease (*Mycoplasma agassizii*) presents another complication that has to be considered.

One consequence of this controversy has been an increase in the numbers of persons who want to adopt the tortoise as a household pet. Undoubtedly, altruism contributes to the increase since news releases often preface the word tortoise with "endangered" or "threatened." However, the researchers believed that altruism could not alone account for the motives of caretakers. It was reasoned that caretakers must derive some psychological benefit from their endeavors. Thus, the question becomes: What are the motives that induce people to adopt these animals as pets and specifically, do those motives influence tortoise adoption?

Some preliminary answers lie in the use of pets in therapeutic settings among psychiatric patients, elderly residents of rest or retirement homes, and with children in a variety of situations. Animal assisted therapy was documented as early as 1792 (Brickel 1986). Controlled observational studies of human interaction with pets and their objective effects on human health was begun at the Center for the Interaction of Animals and Society at the Veterinary School of the University of Pennsylvania in 1977 (Beck and Katcher 1983). Measured physiological responses indicated decreased mortality rate from heart disease, lower blood pressure and hypertension, lower stress levels and decreases in loneliness and depression. Levinson (1962) found enhanced therapeutic progress with children when he induced his pet dog as a co-therapist. Others (Kongable et al. 1989, Chinner and Dalziel 1991, Granger and Carter 1991, and Haughie et al. 1992) have found that companion animals enhance social interaction, improve functioning (Draper et al. 1990), provide emotional support (Netting et al. 1987), and increase morale and self-esteem (Hoffman 1991).

It is evident that much of this human-animal interaction research has been conducted in clinical and institutional settings. The more common household pets such as dogs, cats, and rabbits were utilized. The literature contains very few references to other species, especially reptiles. Yet the popularity of reptiles including snakes, turtles, lizards, and tortoises is evident in the existence of magazines (e.g., *Reptiles*, or *Reptile & Amphibian*) and in herpetology clubs and organizations throughout the United States. Curiosity and altruism, by themselves, cannot account for this widespread interest.

The majority of scientific reports on human-reptile interaction are anecdotal (Ross 1974). Bowers and Burghardt (1972) discussed human/reptile relationships along with examples where reptiles are perhaps able to recognize specific humans, particularly caregivers. They cite anecdotal documentation dating back to the 19th century of alligator and tortoise behavior suggestive of possible affectionate behavior toward certain humans. They also discuss cases of Aldabaran and Galápagos tortoises at the Philadelphia Zoo who have been known to seek attention and neck scratching from a particular human who is familiar to them.

The behavioral repertoire of reptiles would appear more limited in a human/animal interaction as compared with other household pets. Yet, a bond of some magnitude must be present. Oral reports of caretakers frequently include aspects of anthropomorphism, humor, and affection. Although the benefits derived from tortoise caretaking may be more subtle than those associated with other pets, the investigators believed that similar motives were present. If true, the questions to be asked included not only which motives were involved, but also the strength of the motive, the influence of age and gender of the caretaker, and the comparative regard given the tortoise. In summary, the twofold purpose of this study was to investigate the motives of desert tortoise caretakers and to determine whether caretaking promoted psychological benefits that have been noted to occur with other animals.

## Methods

*Subjects.*—Survey participants were obtained through the Tortoise Group newsletter mailing list. Tortoise Group is a nonprofit organization based in Las Vegas, Nevada, which provides information regarding both captive and wild desert tortoises as well as adoption services to the Southern Nevada area. Published three times annually, the newsletter goes out to members and over 2000 other individuals or businesses which are on the mailing list. Permission to include the Tortoise Caretaker Questionnaire (TCQ) was obtained from the group's Board of Directors and the survey was included in the May, 1995, mailing. Two thousand three hundred seventy-eight surveys were thus distributed.

*Questionnaire.*—A review of the relevant literature and existing human/animal companion bond measurement instruments revealed two instruments that could be modified to meet the needs of the research. Written permission was obtained from T. Horvath, Ph.D., of the University of Windsor, Ontario, Canada to use items in a whole or altered form from the survey included in the article *Backyard Feeders: Not Entirely for the Birds* (Horvath and Roelans 1991). Written permission was also obtained from D. I. Templer, Ph.D., to use items from his Pet Attitude Scale (Templer et al. 1981) in an appropriate manner. Horvath and Roelans (1991) established their motive categories by statistically comparing the mean scores for 18 items in their survey. A motive was assumed to have validity if the item means for selected pairs of items did not differ significantly; thus, they would have measured a common factor. This was found to be true in all motive categories with the exception of "Relaxation." It was decided by the present investigators to include the paired statements that formed the basis for the motive "Relaxation" in order that we might compare the data obtained with tortoises to that obtained by Horvath and Roelans (1991) for birds. Similarly, Templer, et. al. (1981) found the factor "love and interaction" accounted for 84.6% of the variance among Pet Attitude Scale (PAS) items. The highest factor loading came from two items on the PAS that were revised in the TCQ to read as items #10 and #1 1 (see Appendix 1) in the current survey.

The survey and scale cited above pertain to the more commonly encountered animals, e.g., dogs, cats, or birds. Their importance to us resided in the delineation of motives for those subjects interacting with animals. Further, the respective authors reported sufficient correlation between paired questions to allow us to assume their validity would carry over when only minor changes were introduced. This latter aspect was especially useful considering the differences in the animal populations that were being investigated. Unlike other household pets, desert tortoises are most often kept in captivity in an outdoor setting and display seasonal rhythms that limit the interaction process. The challenge was to produce a questionnaire that would differ little from those previously published yet still be relevant to the interactions between the human caretaker and the captive desert tortoise.

The TCQ was developed by utilizing items from Horvath and Roelans (1991) and Templer, et al. (1981), and modifying them for our research. A typical modification was the substitution of the word "tortoises" for "birds" in Horvath and Roelans statement: "I feel that the birds add beauty to the environment." In its final form, the TCQ consisted of 20 Likert-like statements to which the subjects could answer "Strongly Disagree" (scale = l) to "Strongly Agree" (scale = 5). Ten motives were established from the paired statements. The motives obtained from Horvath and Roelans were: *Aesthetic, Anthropomorphism, Sharing, Entertainment, Feel Needed, Escape, Companionship, Duty,* and *Relaxation* (see Table 1 and Appendix 1). The one category obtained from Templer, et al. (1981) was Love/Interaction. Finally, the TCQ contained a brief demographic section to allow the respondent to designate age, gender, the presence and kinds of other pets, and the relative importance of the tortoise compared with those pets.

## RESULTS

Of the 2,378 questionnaires distributed, 496 were returned (21%); of these 490 were deemed usable. Four hundred seventy-two respondents identified their gender (67% female, 33% male). The actual number of subjects in the different analyses varied since those who chose not to answer a specific question were not included in that portion of the analysis. Thus, $n$ ranged from a high of 490 to a low of 401. The age of the primary caretakers ranged from 4 years to 94 years with a mean of 47.9 and standard deviation of 13.0. Eighty-six percent of the respondents indicated ownership of other pets, including dogs, cats, horses, birds, snakes, gerbils, ferrets, turtles, iguanas, wolves, tarantulas, snails, llamas, rats, mice, goats, a monkey, and an eel. These respondents were asked to rank the tortoise in comparison with their other pets on a scale of Importance: Less = l, Equal = 2, More = 3 (see Appendix 1). The mean ranking was 2.08, (standard deviation = 0.40), indicating a slight but significant preference for the tortoise (two-tailed $z = 4.44$, $P \leq 0.01$).

Following Horvath and Roelans' (1991) procedure, each of the ten motives was examined by combining the results of two nonadjacent statements measuring the same motive. In the current study, this was accomplished by creating a new set of variables (the motives) formed by the contribution of one half of the raw data, case by case, from each of the two appropriate statements. The results as shown in Table 1 reflect the resulting correlations as well as individual and pair means. An analysis of variance comparison of response means of males and females to each motive is shown in Table 2. With the exception of the motive "Sharing," males differed significantly from females in the strength of the various motives examined. Males are noted to have consistently lower means than females in all motives.

Multiple regression was carried out for all ages and ranking of tortoise importance (when compared with other household pets) with age as the independent variable and tortoise rank as the dependent (n = 458, df + 1, 456). The results ($r = 0.11923$, $P \leq 0.01$) indicate a preference by younger caretakers (*age range* = 4.0–47.9 yrs) to rank the tortoise higher in importance than older caretakers (*age range* = 48.0–94.0 yrs). Thus, age of caretaker is a predictor of the relative importance given to the tortoise. To test this ranking, respondents were divided into two groups. The first group contained all respondents younger than the mean (47.9 yrs) while the second group contained those older. A $F$-test for the difference between the groups revealed that the two groups did indeed differ ($t = 1.654$, $P \leq 0.05$).

TABLE 1. Correlations of survey items grouped by motives with mean & paired mean.

| Rank | Motive | n | r | *P* | Item mean | SD | Paired mean |
|---|---|---|---|---|---|---|---|
| 1 | *Duty* | 488 | 0.597 | <0.01 | | | 4.58 |
| | Item #8 | 489 | | | 4.67 | 0.55 | |
| | Item #13 | 488 | | | 4.49 | 0.72 | |
| 2 | *Aesthetics* | 487 | 0.422 | <0.01 | | | 4.53 |
| | Item #1 | 489 | | | 4.57 | 0.69 | |
| | Item #20 | 487 | | | 4.49 | 0.80 | |
| 3 | *Sharing* | 472 | 0.469 | <0.01 | | | 4.38 |
| | Item #3 | 475 | | | 4.36 | 0.71 | |
| | Item #18 | 482 | | | 4.25 | 0.63 | |
| 4 | *Anthropomorphism* | 481 | 0.505 | <0.01 | | | 4.36 |
| | Item #2 | 488 | | | 4.47 | 0.80 | |
| | Item #19 | 482 | | | 4.25 | 0.70 | |
| 5 | *Entertainment* | 485 | 0.571 | <0.01 | | | 4.30 |
| | Item #4 | 488 | | | 4.35 | 0.77 | |
| | Item #17 | 487 | | | 4.25 | 0.70 | |
| 6 | *Relaxation* | 486 | 0.654 | <0.01 | | | 4.17 |
| | Item #9 | 489 | | | 4.26 | 0.71 | |
| | Item #12 | 487 | | | 3.98 | 0.83 | |
| 7 | *Companionship* | 486 | 0.598 | <0.01 | | | 4.14 |
| | Item #7 | 489 | | | 4.44 | 0.72 | |
| | Item #14 | 486 | | | 3.84 | 0.98 | |
| 8 | *Feel needed* | 488 | 0.660 | <0.01 | | | 4.02 |
| | Item #5 | 488 | | | 4.00 | 0.91 | |
| | Item #16 | 488 | | | 4.05 | 0.93 | |
| 9 | *Escape* | 483 | 0.643 | <0.01 | | | 3.85 |
| | Item #6 | 485 | | | 3.82 | 0.96 | |
| | Item #15 | 486 | | | 3.89 | 0.95 | |
| 10 | *Love/Interaction* | 481 | 0.431 | <0.01 | | | 3.84 |
| | Item #10 | 484 | | | 3.49 | 1.05 | |
| | Item #11 | 487 | | | 4.19 | 0.90 | |

## DISCUSSION

The percentage of respondents having other pets (86%) suggests that tortoise caretakers, as a group, have a high regard and fondness for animals. Although the questionnaire did not contain a "comments" section, many respondents spontaneously wrote statements indicating a special affection for the desert tortoise. Some reported having had the same tortoise for up to 35 years. One female respondent stated she had successfully administered "mouth-to-mouth" resuscitation after her tortoise fell into a pool. Some expressed concern about the fate of their tortoises should something happen to them. Several solved that problem by noting they had provided for their tortoises (one respondent had 33) by naming them in their wills. Those with several different kinds of pets frequently remarked about how well they all "got along." Those caretakers with dogs and cats noted

TABLE 2. Analysis of variance comparison of response means of males and females to each motive.

| Motive | M | F | Significance[a] | |
|---|---|---|---|---|
| *Duty* | 4.46 | 4.65 | <0.01 | $t = 3.41$ |
| *Aesthetics* | 4.45 | 4.57 | <0.01 | $t = 2.05$ |
| *Sharing* | 4.33 | 4.43 | <0.06[b] | $t = 1.82$ |
| *Anthropo* | 4.26 | 4.43 | <0.01 | $t = 3.42$ |
| *Entertain* | 4.19 | 4.37 | <0.01 | $t = 2.81$ |
| *Relaxation* | 4.08 | 4.23 | <0.05 | $t = 2.21$ |
| *Companion* | 3.97 | 4.22 | <0.01 | $t = 3.49$ |
| *Feel needed* | 3.48 | 4.13 | <0.01 | $t = 3.45$ |
| *Escape* | 3.74 | 3.93 | <0.05 | $t = 2.30$ |
| *Love/Inter* | 3.52 | 3.98 | <0.01 | $t = 4.99$ |

[a]two-tailed *t*-test
[b]not significant

that after an initial period of being curious, these pets came to regard the tortoise as full members of the household.

An interesting result of the study was the finding that males responded with less agreement to each statement and each motive than did females. This result might be attributed to males being slightly more "emotionally distant" from pets than females, in that they may prefer pets with whom they can interact more readily. Schenk, et al (1994), reported a lower mean for fathers on the PAS compared to mothers or adolescents. It is an area considered for future research.

Another surprising trend was that younger caretakers ranked the tortoise as more important than other pets whereas older respondents did not. It may be that the uniqueness of the tortoise appeals more to younger persons.

Unlike Horvath and Roelans' (1991) research on birds that found the motive *Duty* near the bottom in importance, the respondents in this study ranked it the highest. This may be attributable to the publicity given the plight of the desert tortoise although a few owners indicated tortoises had been a part of their household for 10 or more years. Alternately, since Horvath and Roelans' research involved wild birds, the contact with individual animals probably varied daily. This contrasts with our respondents having more frequent contact with a specific animal for which they have assumed responsibility. Consequently, *Duty* would be reinforced with the tortoise on a continual basis.

Somewhat surprising was the strong ranking of *Aestheticism*. It has been suggested that most other pets commonly found in homes lack an element of "wildness" or a "raw nature" quality that is associated with reptiles. Tortoises would appear to appeal to those who wish to relate more strongly with the natural elements of the desert and are a reminder of that aspect even in an urban environment. This supports previous writings which suggest that humans can find a connection to nature through animals (Drengson 1990 and Levinson 1984).

The third strongest motive, *Sharing*, was supported by a number of respondent comments indicating that responsibility for the caretaking of tortoises was held by all members of the household. Comments also included statements that the tortoise recognized various household residents and responded to neck scratching and vocalizations in a positive manner, thus supporting previous anecdotal evidence and contributing to the motive *Anthropomorphism* being the fourth in strength.

*Relaxation*, the motive with the greatest pair-mean difference in Horvath and Roelans' (1991) study was found to rank sixth in the current study. The items contributing to this motive (#9, #12) correlated sufficiently ($r = 0.654$, $P \leq 0.01$) to suggest that perhaps the form of the interaction as well as the different animal being investigated contributed to the current finding.

Of the ten motives examined, the weakest and apparently most controversial was *Love/Interaction*. We believe, in review, that we contributed to this finding. Templer et al.'s (1981) motive was derive from the factor loadings of four statements, two of which related to "love" and two more to "interaction." Our error was to include only those statements that related to the latter, thus diminishing the category as a measure of "love" and emphasizing the "interaction." A more appropriate motive name would have been "Interaction."

The two statements that formed the basis of this motive (*Love/Interaction*) induced a number of negative comments written alongside. The implication was that it was "silly," or "fruitless" to try to communicate with a tortoise. This is the reverse of the finding of Templer, et al (1981) whose research indicated this to be a strong factor in their Pet Attitude Scale. It is suggested that pet owners value their tortoises in a somewhat different manner than other pets, recognizing their comparatively diminished behavioral responses. Notably, the range of responses on Item #10, " I have occasionally communicated with a tortoise and understood what it was trying to say" (item $m = 3.49$, SD = 1.05), suggested that different respondents had a wide variation of perceptions regarding whether the tortoise was able to be actively involved in some type of communicative expression. That they "love" their tortoises is evident from the survey and the unsolicited comments but the "interaction" takes forms other than those associated with dogs or cats. "Tortoise watching," indicating a more passive behavior on the part of the caretaker, is frequently noted and is certainly fueled by such motives as *Aestheticism, Anthropomorphism,* and *Relaxation*. As one respondent noted, "A cup of tea and a half hour of tortoise watching is better than medicine."

It would appear that the motives supported by this survey indicated that tortoise caretakers do derive some forms of psychological benefit from such ownership. *Entertainment* and *Relaxation* were found to be strong motives. However, the major benefit would appear to be associated with the feeling of contributing to the well being of a special and unique animal, of being closer to nature, and sharing the duties and pleasures with other members of the family. It is noted that the rank order of the motives are different from rankings as reported by other researchers, but the difference does not appear to effect the level of concern and affection with which the tortoise is held. It is further recognized that the respondents in this survey were members of a population that could be biased favorably toward the tortoise. This is probably true, however the intent was to find out why people adopt the desert tortoise and these caretakers have provided us with some answers. Whether the data can be generalized to other groups of pet owners is unclear although the motives and rewards of tortoise ownership appear to differ from general pet ownership only in the form rather than the degree.

Future research focusing on the bond of human/tortoise relationships has many possibilities. Topics worthy of investigation might include more specific and in depth questioning of people who indicate a significant emotional investment in their tortoises, or the effects of attitudes toward desert tortoises before and after educational programs, particularly involving the actual presence of a live desert tortoise as part of the educational process. Investigation centered on the similarities or differences between caretakers of captive desert tortoises and non-caretakers in attitudes toward wild desert tortoise habitat may have broader conservation applications. Longitudinal investigation of the caretakers' interaction with desert tortoises before and after adoption may provide further information regarding people's attitudes, expectations, and relationships to the tortoises.

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## APPENDIX 1

*Tortoise Caretaking Questionnaire.*— The 20 Likert-like statements which made-up the Tortoise Caretaking Questionnaire are listed below. Subjects could answer "Strongly Disagree" (scale = 1) to "Strongly Agree" (scale = 5).

1) I feel that tortoises add beauty to the environment. 2) I believe that the tortoises appreciate the food I put out for them. 3) I enjoy calling another member of my family to see the tortoises and what they are doing. 4) I find the antics of the tortoises endlessly fascinating. 5) Providing food for the tortoises gives me a sense of being needed. 6) Time seems to fly when I am watching the tortoises. 7) The tortoises come to be like old friends to me. 8) I feel responsible for the well-being of the tortoises. 9) Watching the tortoises is relaxing. 10) I have occasionally communicated with a tortoise & understood what it was trying to express. 11) I frequently talk to my tortoises. 12) I feel calmer after watching the tortoises for a few minutes. 13) I feel that it is my duty to provide food for the tortoises. 14) The tortoises provide me with companionship. 15) Watching the tortoises makes me forget my problems for a while. 16) I feel good knowing that the tortoises can depend on me to put out some food for them. 17) I find that it is nice to be able to stop what I am doing and watch the tortoises for a while. 18) Other people in my family also enjoy watching the tortoises. 19) I believe that the tortoises enjoy being provided a tortoise salad. 20) I think the world would be a less attractive place without tortoises.

In addition to the questions above each survey included the following questions: 1) Age of caretaker; 2) Gender of caretaker; 3a) Do you have other household pets; 3b) If yes to 3a, what types of pets; 4) I regard the tortoises as having (circle one) LESS EQUAL MORE N/A importance in comparison to my other pets.

# The Clark County Desert Tortoise Conservation Plan: Progress Report - March 1996

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In the Desert Tortoise (Mojave Population) Recovery Plan (Recovery Plan), the range of the Mojave population of the desert tortoise was divided into six recovery units (RUs), based on genetics, morphology, ecology and behavior (FWS 1994). Clark County lies within portions of two RUs, the Northeast Mojave RU and the Eastern Mojave RU. The recovery strategy calls for designating desert wildlife management areas (DWMAs) within each of the six RUs and implementing recovery actions within the DWMAs. In Clark County, it is anticipated that DWMAs will be designated on lands managed by the Bureau of Land Management (BLM), National Park Service (NPS), and Fish and Wildlife Service (FWS).

*Terms of the Permit.*—On September 20, 1994, Clark County, the cities within the county, and the Nevada Department of Transportation (NDOT) applied for an "incidental take" permit under the authority of section 10(a)(1)(B) of the Endangered Species Act. The permit was issued by the Service on July 11, 1995, and became effective August 1, 1995. It allows incidental take of desert tortoises for a period of 30 years on 111,000 acres of non-Federal land in Clark County, and 2,900 acres of land associated with NDOT activities in Clark, Lincoln, Esmeralda, Mineral, and Nye Counties, Nevada. The 113,900 acres where take is authorized represents approximately 20 percent of the 525,000 acre permit area (non-Federal lands in Clark County) and approximately 3.3 percent of the 3.5 million acres of tortoise habitat in Clark County.

The impacts of the authorized take will be minimized and mitigated by implementation of the Clark County Desert Conservation Plan (DCP; Regional Environmental Consultants 1994). The DCP is funded by a $550.00 per-acre fee for habitat disturbance. The DCP will provide $1.35 million per year, and up to $1.65 million per year for the first 10 years, to fund recovery actions, primarily within proposed DWMAs within Clark County. The BLM, NPS, FWS, and Nevada Division of Wildlife (NDOW) are signatories, along with the permittees, on the implementing agreement because of their role as land management agencies.

*Mitigation Measures.*—Local ordinances have been enacted to impose the $550.00 per-acre mitigation fee. Mitigation measures in support of tortoise recovery focus on tortoise habitat on federally managed lands to minimize the impact to private property.

A conservation easement on 85,000 acres within the Piute-Eldorado DWMA was purchased by the DCP from Boulder City. Since livestock grazing was identified as incompatible with tortoise recovery, negotiations are ongoing for acquisition of grazing privileges from willing sellers. Grazing allotments already acquired are being maintained in non-use status and managed for tortoise recovery.

A variety of management activities are being funded by the DCP, including provision of two BLM rangers for law enforcement within proposed DWMAs and one NPS ranger for portions of Lake Mead National Recreation Area (Lake Mead NRA) contributing to the DWMA. One NDOW ranger will be hired to patrol the Boulder City Conservation Easement (BCCE) area. The impact of roads, which fragment tortoise habitat and increase human access (and potential human impacts), is being addressed through mapping, evaluating, designating as open or closed,and signing roads. At Lake Mead NRA designation, and signage continues; within the BCCE, designation is complete and signing will occur in May; and on Bureau lands, roads are being mapped.

The Recovery Plan identified mortality of tortoises along roadways as a reason for declines in tortoise populations. Therefore, the DCP funded research on the effectiveness of a variety of tortoise barriers, and is developing a field testing plan. Roads within DWMAs are being prioritized for installation of barriers based on traffic volume and tortoise population density. A pilot barrier installation project, using volunteers, is planned for the Piute-Eldorado DWMA.

*Minimization Measures*—To minimize take, the DCP includes a provision for the voluntary survey and removal of tortoises from sites to be developed. Clark County provides a free pick-up service for tortoises found in harm's way or removed from sites slated for development. As of March (1996), 580 tortoises were being held at the Clark County transfer and holding facility awaiting translocation, adoption or transfer to approved research or educational programs. As of April 1996, 78 tortoises had been provided to adoption programs and 160 hatchlings had been provided to research. A translocation research plan has been approved, staff is being hired, and equipment ordered. A component of the translocation research plan includes a site where large numbers of tortoise will be released. The environmental assessment for fence construction at this site is underway.

To minimize take associated with NDOT projects, work areas are fenced and inspected for tortoises; any tortoise found is removed from harm's way. NDOT is also developing a worker education program.

A public information and education program has been developed to: (1) Inform the public of the terms of the permit; (2) enlist public support; and (3) encourage compatible use of the desert. Components of this program include a video on the DCP; information boards displayed throughout the county; fact sheets on developer responsibilities and the translocation project; and speakers for a variety of organizations. In addition, a tortoise hotline was established to provide frequently requested information; posters at bus stop shelters provide the hotline number. To educate children about the tortoise and its desert habitat, a curriculum is being developed for use in the public schools. In addition, speakers are available to address classes and provide stickers and patrol cards the students can take home. The Desert News, a colorful brochure written for all age levels, is provided to schools and libraries.

To educate people that may be using and enjoying the desert, kiosks are planned for the DWMAs, a tortoise display has been constructed at the visitor center at Red Rock National Conservation Area (Red Rock NCA), and another is being developed for the visitor's center at Lake Mead NRA. The annual emergence of "Mojave Max," the official spokes-tortoise, is always an event at Red Rock NCA. The DCP also co-sponsors "Outdoor Nevada," a new public television program on Nevada environmental issues and recreational opportunities.

*Monitoring.*—A study of tortoise dispersal and demography was recently completed at Lake Mead NRA, where continued tortoise monitoring is being funded. In some areas, raven predation accounts for the loss of many young tortoises; a study was conducted in the Piute-Eldorado valley to assess the extent of mortality from ravens.

The DCP is overseen by the Administrator and the Implementing and Monitoring (I&M) Committee, which includes representatives of Federal, State, and local government agencies and special interest groups. The I&M Committee reviews annual progress reports, biennial management plans and budgets, funding requests, and tortoise disposition and land disturbance reports, and generally provides a forum for tortoise and desert issues in Clark County. The FWS works closely with the Administrator and this committee.

*Multiple Species Inventory and Protection.*—The Recovery Plan encourages an ecosystem-based multispecies approach to reserve design. To reduce the likelihood of future listings, the DCP provides for the inventory and protection of potentially rare species. Currently projects are ongoing to assess chuckwalla status, distribution, and habitat needs; inventory phaenopepla and the mesquite-acacia community it inhabits; study southwest willow flycatcher nesting and predation by cowbirds; install gates to protect California leaf-nosed bat colonies; determine relic leopard frog distribution and status, and provide protection; restore the Muddy River to enhance populations of Virgin River chub and Moapa speckled dace; evaluate the genetics of California bearpaw poppy populations; inventory BLM lands for rare plants; and survey for three-cornered milk-vetch and sticky buckwheat, two rare plants.

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# Activities and Role of the Desert Tortoise Management Oversight group in Tortoise Conservation

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On behalf of the other members of the Desert Tortoise Management Oversight Group (MOG), I am pleased to report on the activities and role of the MOG in tortoise conservation. The MOG was established in 1989 to coordinate agency planning and management activities on behalf of the tortoise, and to implement the management prescriptions called for in the Bureau of Land Management's (BLM) Desert Tortoise Range-wide Plan. The overall goal of the Range-wide Plan is "... to manage habitat so as to ensure that viable desert tortoise populations exist on public lands. This will be accomplished through cooperative resource management aimed at protecting the species and its habitat." The scope of the Range-wide Plan includes both the Sonora and Mojave tortoise populations, and the coordination and conservation objectives of the MOG apply to both the Sonora and Mojave populations.

The original membership of the MOG consisted of the four BLM State Directors from Arizona, California, Nevada, and Utah; the four State Fish and Game Directors from these states; the three Fish and Wildlife Service (FWS) Regional Directors that share tortoise management responsibilities; and a BLM Washington Office representative. After the recovery plan for the Mojave tortoise population was approved, the FWS asked the MOG to take a leadership role in coordinating implementation of agency activities directed toward achievement of recovery plan objectives. Toward this end, the membership of the MOG was recently expanded to include the National Park Service (NPS), National Biological Service, and representatives of the affected Army, Air Force, Navy, and Marine Bases. Thus, the focus has shifted somewhat from the original emphasis on BLM's Range-wide Plan to coordinating implementation of the recovery plan, as well as conserving the Sonora population and its key public land habitats.

To provide the MOG with technical support in establishing priorities and coordinating agency tortoise conservation efforts, an interstate technical advisory committee and numerous *ad hoc* working groups have been created over the years as the need has arisen to tackle specific issues.

*Current Focus and Areas of Emphasis.*—The principal focus of cooperating agencies now is on developing or amending land use plans to identify and delineate Desert Wildlife Management Areas (DWMAs) and proposing changes as needed to achieve recovery plan objectives. The recovery plan recommends the general areas where DWMAs should be located, but leaves the task of delineating the DWMA boundaries to the land management agencies, in coordination with FWS, State wildlife agencies, local stakeholders, and other interested parties. The principal agency mechanism for implementing recovery plan tasks is through amendments to existing resource management plans (BLM) or general management plans (NPS) or through the development of broader bioregional plans in conjunction with local government (e.g. the West Mojave Coordinated Management Plan).

Numerous working groups have been established to develop resource management plans, land use plan amendments, and coordinated management plans for selected geographical subunits of the Mojave Desert. These planning efforts, which involve all six tortoise recovery units, include: (a) Arizona Strip District Resource Management Plan, (b) Caliente Management Framework Plan, (c) Stateline Resource Management Plan, (d) Clark County Habitat Conservation Plan, (e) Lake Mead National Recreation Area General Management Plan, (f) Mojave National Preserve General Management Plan, (g) Northern and Eastern Mojave Coordinated Management Plan, (h) Northern and Eastern Colorado Coordinated Management Plan, (i) West Mojave Coordinated Management Plan, (j) Washington County Habitat Conservation Plan, and (k) Dixie Resource Management Plan. Progress reports will be given for some of these ongoing agency planning efforts by other speakers later in the program.

Because all of the proposed DWMAs cross ownership and political boundaries to some extent, efforts are being made to coordinate with local governments, affected State and Federal agencies, private organizations and individuals, and other interested parties to the maximum extent practicable. The focus of these bioregional plans is on maintaining the integrity of the ecosystems upon which the tortoise and other target species depend, without regard to the political boundaries. As bioregional plans or land use plan amendments are completed for the different recovery units, the specific tasks recommended in the recovery plan will be assigned to the appropriate cooperator, and the responsible party will carry out such tasks to the extent that future agency budgetary, personnel, and policy constraints allow.

After the preferred tortoise reserve strategies have been selected, periodic monitoring will be required in each recovery unit to document whether recovery is being achieved. The strip transect and study plot techniques commonly used in the past to track tortoise occurrence and relative abundance are generally not suitable for generating reliable and economical tortoise density estimates on a regional scale. The method suggested in the recovery plan may be cost prohibitive. A more economical means of developing statistically credible estimates of tortoise densities within and outside the DWMAs is needed. Reaching consensus on an affordable methodology for estimating tortoise densities is a high priority need and a major challenge facing agency cooperators during an era of declining budgets at all levels of government.

At the broader ecosystem scale, the Department of Defense (DOD) and Department of Interior have undertaken a major initiative to develop a natural resources database for the Mojave Desert. This project, funded largely with DOD legacy funds, will help fulfill several of the priority information needs identified in the tortoise recovery plan.

*Products and Contributions From Prior MOG Coordination Efforts.*—The major contribution from earlier MOG coordination efforts has been the instilling of a range-wide view toward tortoise planning and management activities. This has been reflected in the Section 7 consultation process, mapping of tortoise habitat categories, compensation guidelines to offset project impacts, law enforcement activities, research needs and priorities, tortoise data analysis standards, and public outreach.

The listing of the Mojave population of the desert tortoise created a major new workload for Federal agencies to complete the interagency consultations required by Section 7 of the Endangered Species Act. Such formal consultations are required to ensure that no Federal action is authorized that would jeopardize the continued existence of the desert tortoise. The MOG established two working groups to streamline the interagency consultation process and to develop a consistent approach among the four different States and three different Fish and Wildlife Service regions. By identifying several types of recurring activities that could be handled through "programmatic" Section 7 consultations, the formal consultation workload has declined from over 60 tortoise consultations in the early 1990's to less than half that today.

Most Section 7 consultations involving the desert tortoise have required off-site compensation as a means of offsetting on-site project impacts. To develop a more consistent approach on the application of compensation to projects affecting the desert tortoise, the MOG created a special working group to address this issue. A report prepared for and approved by the MOG set standards concerning the kind and amounts of compensation required to offset project impacts. Since 1989, cooperating agencies have acquired over 10,000 acres of tortoise habitat in California using tortoise compensation funds and carried out numerous management actions in Nevada, including the retirement of grazing privileges on several allotments that overlay tortoise critical habitat.

On the acquisition front (exclusive of compensation), cooperating agencies have continued efforts this past year to acquire private inholdings within the Desert Tortoise Natural Area (DTNA) and Chuckwalla Bench Area of Critical Environmental Concern. More than 25,000 acres of tortoise habitat has been acquired in tortoise consolidation areas in the DTNA and Chuckwalla Bench using Land and Water Conservation Fund monies. An additional 25,200 acres have been acquired by exchange (20,200) or purchase (5,000) in the West Mojave Land Tenure Adjustment area.

Several of the research needs identified in the recovery plan involve the continuation or refinement of projects initiated in the late 1980's by cooperating State and Federal agencies, universities, and private organizations. Since 1989, agency tortoise research activities have been coordinated through local and regional committees and priorities for agency funding have been established by the MOG. Numerous papers (more than 40 that I am aware of) are now reaching the publication, or advanced peer review, stage as a result of the project proposals that were developed, reviewed, and funded by MOG cooperators beginning in the early 1990's.

Many of the proposed DWMAs contain public lands that have been used in the past for recreation, camping, hiking, hunting, off-highway vehicle play, mining, and agriculture. The recovery plan recommends that cooperating agencies start an aggressive and widespread outreach effort "... in schools, museums, hunting clubs, and in BLM and National Park Service visitor centers and interpretative sites, etc. to inform the public about the status of the desert tortoise and its recovery needs." The public outreach program recommended in the recovery plan would expand the effort begun under BLM's Desert Tortoise Rangewide Plan. Pursuant to that plan, each State with tortoise habitat has developed a public outreach plan and has begun its implementation. Numerous brochures, posters, maps, videos, slide programs, portable exhibits, roadside displays, handbooks, and educational packets have been prepared by cooperating agencies and disseminated to a variety of target audiences.

To promote a consistent approach toward law enforcement among cooperating agencies, the MOG created a special task force to provide guidance on recommended investigatory procedures and to facilitate communications among enforcement, management, and biological personnel. The objective is to ensure that applicable State and Federal laws are consistently enforced on both public and private lands throughout the range of the tortoise. One product of this working group is a "Law Enforcement Guide for the Desert Tortoise," which is being used by law enforcement personnel in California as the primary reference document for enforcing State and Federal laws designed to protect the desert tortoise.

*Future Challenges.*—Looking ahead, the cooperating agencies of the MOG are faced with several major challenges in seeking to carry out recovery plan tasks and accomplish recovery plan objectives. These include:

- Securing the support of local government and private stakeholders in ongoing agency planning efforts directed toward recovery plan implementation.

- Surviving the lawsuits, administrative appeals, and legislative tinkering that loom as potential obstacles to the development and implementation of bioregional plans or land use plan amendments intended to achieve recovery plan objectives.

- Reaching consensus on an affordable methodology for measuring tortoise density and abundance inside and outside Desert Wildlife Management Areas and achieving continuity in data gathering and analysis through the lean budget years.

- Keeping a critical mass of researchers, law enforcement personnel, wildlife biologists, and resource specialists on board during lean budget years to protect key tortoise populations/habitats and implement priority recovery plan tasks.

- Maintaining the capability to manage public lands and wildlife populations effectively in an era of declining agency budgets.

Overcoming these potential obstacles will require an unprecedented level of cooperation, perseverance, hard work, efficiency in carrying out agency missions, and sharing of the burden with private partners, as well as a fair amount of good luck. It is my hope and expectation that the survival of the desert tortoise will be assured through the spirit of cooperation and hard work that was begun with efforts to implement the Range-wide Plan and that will need to be pursued even more diligently in the future if we are to achieve recovery plan objectives.

## Developing the Northern and Eastern Colorado Desert Coordinated Management Plan

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At the core of purpose for the Northern & Eastern Colorado Desert Coordinated Management Plan (Plan) is the 1990 listing of the desert tortoise as a threatened species and the need to implement the U.S. Fish & Wildlife Service's 1994, Desert Tortoise (Mojave Population) Recovery Plan (DTRP), which provides guidance for design and management of Desert Wildlife Management Areas

(DWMAs). The Plan covers 5.5 million acres located in the southeastern part of the California Desert, includes Sonoran and Mojave ecosystems, and three recovery units: Chemehuevi, Chuckwalla, and part of Joshua Tree. The Plan will directly affect federal public land management by the Bureau of Land Management (BLM), the U.S. Marine Corps (USMC) for Chocolate Mountains Gunnery Range, and the eastern half of Joshua Tree National Park (NPS), which together administer 81% of the planning area. The Plan will implement Title VIII of the California Desert Protection Act, which requires that the Secretaries of Defense and Interior work together to manage natural resources on the Chocolate Mountains Gunnery Range.

Issues addressed during scoping include recovery of the desert tortoise, management of all species and habitats, land ownership pattern for both manageability and economic development, needs and opportunities for resource uses, feral burros along the Colorado River, and routes of travel. However these issues are resolved, Plan decisions must provide assurance that DTRP goals will be met and that adequate protection will be provided for other species and habitats.

The potential for agreement in resolving issues is enhanced by the variety of cooperating agencies and public interests that are intimately involved, through development of inventories and methodologies for key resources and programs, and use of BLM's geographic information system (GIS) for analyses and modeling.

Cooperating agencies include the three noted above plus the U.S. Fish & Wildlife Service, National Biological Service, U.S. Geological Survey (USGS), and California Department of Fish & Game. Twenty–three Interest Group Committee (IGC) members, representing 12 categories, are integrated into the planning process and meet/review work with staff at all meetings. Catellus Development Corp. which owns 30% of the private land is cooperating. A considerable amount of mutual respect and trust has been developed among IGC and staff. Everyone is encouraged to become involved in the process through attending public meetings and communication with IGC members.

The Plan will basically serve as a coordinated, in-depth biological resources element that will replace biological elements in the current land use plans of BLM, NPS and the USMC. Plan decisions will be both zone general and on-the-ground specific. The latter will include habitat projects, routes of travel designation, and land tenure adjustment. The Plan (including Section 7 consultation) will coordinate management for all the federal lands. To varying extent the current land use plans will be amended. Plan decisions will provide the biological basis for managing wilderness areas, which comprise over one-third of the planning area. The opinion at this time of the cooperating agencies is that Plan decisions need not apply to private lands, but local agencies are invited to participate to whatever degree they see fit, particularly to help effect a workable land tenure adjustment.

The biological methodology begins with a mapping of plant communities and builds with lithology, hydrology, landforms, waters, elevation, and more. Nearly all waters have been located by global positioning system (GPS) technology. Species locations are added along with predicted locations from life histories. Prescriptions will have basis in specific species and habitats.

The routes of travel methodology is based on a 100% on-the-ground inventory. Modeling with hydrology information will hopefully allow consideration of washes in the designation process. Route designation is an issue primarily on BLM-managed lands and will be considered for access and recreational touring. The inventory is available for study at various offices or for purchase on 7.5' maps from a local vendor. Minerals methodology is based upon BLM-developed mineral potential. USGS will review and verify BLM's work as well as develop economic analyses.

Major scheduling milestones include public review of Plan alternatives at the beginning of 1997 and public review of a draft Plan/EIS in mid-1997. An in-depth handout on the Plan is available. Included are lists of the data coverages to be developed, species of concern, and public reading rooms.

## Anthropogenic Impacts on Desert Soils

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As the population of the United States continues to grow, human encroachment into our fragile desert ecosystems has increased dramatically. In a historical context, the first major human impact on the deserts of the southwestern United States was the introduction of domestic livestock. Unlike the grasslands of the Great Plains region, most of our desert regions evolved in the absence of vast herds of migrating ungulates. When domestic livestock were introduced, they changed the structure and function of many western ecosystems forever. More recently, over the last half-century, military and recreational vehicular traffic have contributed significantly to the impacts on desert lands.

Livestock and vehicles have both direct and indirect effects on various soil parameters. Perhaps the most widely studied of these effects is soil compaction. A soil becomes compacted when external pressures realign soil particles into a more dense arrangement, thus forcing air and water out of the matrix. The degree of soil compaction is governed by the extent of the external pressure, the cushioning effect of vegetation, soil texture, and soil moisture. Static pressures from typical anthropogenic sources may range from 1.7 $kg/cm^2$ for a cow to 3.5 $kg/cm^2$ or more for a 4-wheel drive truck. Surprising to some, the static pressure of a modern M1 tank is only about 1.0 $kg/cm^2$. Where vegetation is present, it serves to distribute the weight over a larger area, thus reducing the pressure on the soil. As a general rule, finer textured soils have greater porosity than coarser textured soil, and are thus more susceptible to compaction. Susceptibility to compaction also increases as soil moisture content increases, but only up to point. In saturated soils, the pores are full of water, thus preventing their collapse.

Traffic by livestock and vehicles may also directly affect the structure of the soil, particularly near the surface where soil aggregates are crushed. This is especially problematic in arid soils because the formation of soil aggregates is dependent in large part on soil organic matter content. Arid soils are typically low in organic matter content, thus the loss of aggregation can be a long term effect. Traffic on wet, fine-textured soil may deform the surface into an impermeable glaze. The net effect is similar to that of disaggregation, *i.e.*, the transmission of air and water through the soil is diminished.

Soil compaction and deformation, and the concomitant reduction in aeration and water infiltration, can have a negative impact on vegetation. Compacted soil can be a physical barrier to root growth, thus preventing plants from reaching necessary water and nutrients. In addition, to the degree that oxygen and water are limited in a compacted or deformed soil, plant growth is retarded. This is particularly important in desert ecosystems where water is often the primary limiting factor for plant growth.

There are other negative side effects of soil compaction. Water that cannot infiltrate into a compacted soil collects on the surface and runs off. It carries with it soil particles that have been dislodged or disaggregated by the same forces that compacted the soil. Moving water exerts erosive forces that dislodge additional soil particles. The net result can be extensive soil erosion. Many of our Western landscapes are permanently scarred by rills, gullies, and arroyos resulting from the denudation and soil compaction that were caused, in turn, by overgrazing and off–road vehicular traffic.

Over the past two decades there has been considerable discussion in the western United States regarding the merits of intensive rotational grazing systems as a means of enhancing the economic returns of the ranching industry. Under such systems, it is purported that stocking rates can be increased dramatically while maintaining a stable ecosystem. Some supporters of the systems have made claims that the "hoof action" or "herd effect" inherent in short-term high-density grazing systems has a beneficial effect on the soil surface by breaking up surface crusts, thus enhancing water infiltration and preparing the soil for seedling germination. An extensive review of the scientific literature, however, reveals no support for such hypotheses. The type of grazing system has little effect on infiltration rates and soil erosion. Stocking rate is the primary factor determining the hydrologic consequences of grazing. As stocking rates increase, infiltration of water into the soil decreases while runoff and soil erosion increase.

Of particular noteworthiness on desert soils is the occurrence of microphytic soil crusts. Variously referred to as cryptogamic or biological crusts, they are formed by microbial filaments and mucilaginous exudates of various surface-dwelling microphytes (algae, cyanobacteria, fungi, lichens, mosses, etc.) that bind soil particles into a stable, aggregated surface. Microphytic crusts are resistant to wind and water erosion. With increasing aridity and concomitant decline in the abundance of vascular plants, the ecological roles of microphytic crusts become increasingly important. Unfortunately, the crusts are easily disturbed by livestock trampling, vehicular traffic, and fire, leaving the soil exposed to the erosive forces of wind and water.

Natural recovery of microphytic crusts on desert soils can span decades. It has been estimated that complete recovery could take as long as 30–40 yrs for cyanobacteria, 45–85 yrs for lichens and 250 yrs for mosses. The time required for recovery is dependent on the nature, degree and spatial distribution of the damage. Recovery from soil compaction can also require long periods of time. After 50 yrs, some tracks produced by armored vehicles while training for World War II are still visible in parts of the Mojave Desert. And the soil beneath the tracks is still highly compacted. Natural amelioration of compacted soil generally results from freezing and thawing, moisture-induced shrinking and swelling of the montmorillonitic clay component, and biological activity. As all of these processes occur at a relatively low rate in desert soils, it is not surprising to see estimates of recovery that extend beyond the century mark.

## Functioning of Mycorrhizae in Natural and Disturbed Arid Ecosystems

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Mycorrhizae are an association between roots of plants and certain species of fungi that are mutually beneficial. The plants have increased growth rate, improved water relations, and increased nutrient uptake when they are mycorrhizal, while the fungi receive carbohydrates from the plants (Allen 1991). In the past, and sometimes even today ecologists and land managers felt that we could ignore the fungi and other soil organisms because they are a part of the natural system, and will return naturally to disturbed ecosystems. This is only true until the land is damaged beyond the capacity to which natural successional processes can repair it. Then we need to consider the ecology of the microorganisms, especially those that disperse slowly. Mycorrhizal fungi are among those that are fairly slow to disperse, sometimes taking several years before they will return to a site in numbers that are sufficient to improve plant growth and ecosystem redevelopment.

Land disturbances that reduce the mycorrhizal fungi to levels so low, that natural recovery processes do not operate on human time scales, include any that remove or alter the topsoil. Severe erosion, mining, construction, compaction from vehicular activity, heavy grazing, vegetation removal, and others will either remove, reduce, or alter the species composition of mycorrhizal fungi. The success of planted or recolonizing plants depends upon: 1) the rate at which the fungi move back into the disturbance, 2) the types and species of mycorrhizal fungi, 3) the mycorrhizal dependence of the plants, and 4) edaphic factors. Because of these interacting factors, a prescription for restoration that includes inoculation with mycorrhizal fungi should be undertaken with caution, as not all situations warrant this rather expensive prescription. Each of these factors is considered below.

*Recolonization rates of mycorrhizal fungi.*— Recolonization rates of mycorrhizal fungi vary with the intensity and size of the disturbance, and with the distance from the nearest source of inoculum. The intensity of disturbance determines whether there is any inoculum left in the soil, and whether the soil has been altered and is no longer suitable for mycorrhizae. For instance, the mycorrhizal soil spore density and the root infection were low in 30 yr old mine spoils in Wyoming that had not been topsoiled or replanted (Waaland and Allen 1987). Alternatively, root infection was lower, but spore densities were as high in revegetated topsoiled mine spoil as in native sites after 2-3 yrs. Mycorrhizal fungi recolonized a 1 km$^2$ glacial till outwash plain in Alaska within 1 yr (Allen and Helm, pers. obser.), but it took five years before conifers on the Pumice Plain at Mt. St. Helens became mycorrhizal (Allen 1988). Until they became infected, the conifer seedlings died. Thus inoculation would be worthwhile at Mt. St. Helens, and would need to be considered on a case by case basis for mine spoil, depending upon the size, degree of disturbance, and soils.

*Types and species of mycorrhizal fungi.*—There are seven types of mycorrhizal fungi, two of which are most abundant worldwide. These are the arbuscular mycorrhizae (AM, also known as vesicular-arbuscular, VAM) and the ectomycorrhizae (EM). EM fungi are found almost exclusively on woody plants, and do not occur in true deserts. They are found in semiarid lands, such as on pines in pinyon juniper woodland. AM fungi are found on herbaceous as well as woody plants, and are the only type found in deserts. Within these types can be found many species, each of which may cause different growth responses by their host plants. Transplant studies have shown that plants grown with inocula taken from different locations may have either greater or lesser responses than plants with local inoculum (Allen et al. 1991). However, transplanted inoculum may not necessarily survive on a new site regardless of how successful plant growth is (Weinbaum et al. *in press*).

*Mycorrhizal dependence of plants.*—Different plants have different degrees of dependence upon mycorrhizae. Some 10% of plants do not form mycorrhizae at all, typically weedy annuals in the Chenopodiaceae, Brassicaceae, Amaranthaceae, and others. These species colonize readily after disturbance in arid lands where the soil inoculum has been disrupted. Mycorrhizal plants may be facultatively or obligately dependent upon their fungal symbionts. Facultatively mycorrhizal plants are those that may on occasion be found without mycorrhizae, but will grow and survive better with infection. Obligately mycorrhizal plants will die without the fungi. Ectomycorrhizal plants are typically obligately mycorrhizal, as are many tropical tree species (Allen et al. 1995). Most desert plants are probably facultatively AM mycorrhizal, with a range of growth reponses to infection. However, I am not aware of studies on species such as trees of microphyll woodlands to test their mycorrhizal dependence. Like the related tropical legumes, they may be obligately mycorrhizal, or nearly so. Where mycorrhizal fungi have been disrupted and cannot be inoculated economically, one solution for revegetation is to plant facultatively mycorrhizal species. Most grasses are facultative, and perhaps for this reason they are the most successful species in revegetation efforts.

*Edaphic factors.*—The soil also plays a role in determining the importance of mycorrhizal fungi. Mycorrhizal fungi are most effective in promoting plant growth in soils of low extractable nutrients, but with reasonable levels of total (unavailable) nutrients. Many of the desert soils in the western U.S. have such soil conditions, especially for phosphorus which is typically limiting for plant growth. However, there are some soils, such as in the Great Basin and in southern California, where soil available P is relatively high, and growth studies have shown that mycorrhizal responses are small (Di and Allen 1991, Nelson and Allen 1993). Thus inoculation is not as critical to promote plant phosphorus uptake in these soils. However, other studies have shown the importance of mycorrhizae for water uptake in field conditions (Allen and Allen 1986), so managing the land to promote mycorrhizae is still important even if the soils are relatively rich in nutrients.

*Conclusions.*—In recent years, prescriptions for restoration more frequently call for inoculation with mycorrhizal fungi. This is a heartening change in attitude that shows that land managers are more aware of the importance of mycorrhizae for plant growth and survival. The next step is to assure that inoculum is not prescribed when it is not necessary, such as in very small disturbances, in high inoculum soils, for facultatively mycorrhizal plants, or in nutrient rich soils. Nor should the wrong species of mycorrhizal fungi be prescribed. An understanding of the functions of mycorrhizae will be most important for restoration of degraded lands that are habitat for special status species such as the desert tortoise.

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## Soil Biota Changes Along a Disturbance Gradient: Impacts on Vegetation Composition and Prospects for Restoration

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The desert tortoise is under pressure on several fronts, including outdoor recreational vehicles, upper respiratory tract infections, habitat decline and degradation, and most notably, domestic grazing (Berry, 1978). Cattle grazing has been charged with altering vast tracts of western rangeland. Two important impacts of cattle grazing are changes in soil characteristics and shifts in vegetation.

Soil compaction and reduced water infiltration are two consequences of cattle hoof traffic, and both have obvious detrimental impacts on vegetation, particularly in semi-arid and arid regions. Trampling has also been shown to severely damage cryptobiotic crusts (Anderson et al., 1982). These crusts provide benefits to western rangelands including increased soil stability and nutrient availability (MacGregor and Johnson, 1971; Kleiner and Harper, 1972; Belnap and Gardner, 1993). The nutrients supplied by crusts can increase nutrient levels in associated vegetation, making the vegetation more valuable forage for desert tortoises (McArthur et al. 1992; Belnap 1995).

Foraging pressure and preferences of cattle have shifted vegetation from perennial bunchgrasses to annual exotics: While annuals are an important part of the desert tortoise's diet, some have indicated that populations feeding on exotic annuals tend to be in poor condition. Also, desert tortoises feed for only brief periods of time in the spring and fall, putting them in direct competition with cattle for the available forage. Finally, the loss of perennials drastically reduces available food sources for fall foraging (Berry, 1978). Better understanding of cattle impacts on communities and methods for reversing these impacts will be important to saving the desert tortoise.

Recently a study was performed looking at the changes in vegetation and soil biota along a known gradient of grazing disturbance. The study was observational in nature with the objective of better understanding how past disturbances may have altered soil biota and what impacts these alterations may have had on vegetation. The information gleaned from this study is being used in experimental bunchgrass restoration plots employing soil biota manipulations as a means of encouraging native plant communities.

The study was located in the Needles District of Canyonlands National Park, UT. Four sites were selected based on previous grazing history and vegetative communities. The vegetative communities ranged from previously ungrazed native bunchgrass stands to cheatgrass dominated stands with a history of heavy, year round grazing. Vegetation surveys were performed for each site and soil samples were analyzed for cryptobiotic crust presence, bacteria, fungi, protozoa, and nematodes. Differences in soil biota composition and cryptobiotic crust presence were investigated at the site level. Potential differences in soil biota distribution, or heterogeneity of soil biota across sites, was also investigated.

Results of the study showed striking differences between sites free of cheatgrass and those with cheatgrass. There was an overall decline in cryptobiotic crust presence and heterogeneity of soil biota with the presence of cheatgrass. Bacteria showed the most significant response to site differences. Both total and active numbers declined as site degradation increased. Also, bacteria were predominantly located in the cryptobiotic crust components of the soil, and were therefore more severely impacted as the crust declined. The restoration component of this project focuses on altering soil biota through manipulations of carbon availability. Carbon manipulations were applied to cheatgrass stands in an effort to create a soil biota composition that would be favorable to native bunchgrass plantings. The plant used in this study was Indian ricegrass. Results from restoration efforts are still preliminary. However, it appears that the treatments applied all increased bacterial presence (sugar additions, burning, and litter removal), and also favor Indian ricegrass. This information supports the idea that shifts in vegetation resulting in exotic dominated stands can alter soil biota compositions and create conditions unfavorable to native plants.

Cattle grazing cannot be directly implicated in the vegetative shifts on the four study sites. However, all four sites have similar (some identical) soil types and climatic inputs. Also, all four sites were historically dominated by native bunchgrasses. Grazing seems to be the largest disturbance and is known to have been applied at different intensities and for different durations across the four sites. The types of communities dominant where grazing was heaviest are also characteristic of that sort of disturbance.

Changes in the soil biota across the sites cannot be tied directly to the past cattle disturbance nor to the shifts in vegetation as this study was not experimental and did not test those hypotheses. However, any disturbance that compacts soil, reduces water infiltration, and alters the composition of the aboveground community is going to alter the soil biota. Studies have shown that soil biota and vegetation associations can be both specific and beneficial (Alexander, 1961, Burgess and Raw, 1967, Wilkinson, et al., 1994). Research that results in methods utilizing this knowledge can only have positive impacts on improving habitat for the desert tortoise.

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## Potentially Toxic Metals and Minerals in Liver and Kidney of Desert Tortoises in California


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As part of a study of 27 ill, dying or dead desert tortoises, *Gopherus agassizii*, from the Mojave and Colorado Deserts of California, the concentrations of up to 20 trace elements were determined in fresh sections of liver and kidney. The number of elements analyzed per tissue depended on mass of tissue available. Element analyses, with the exception of mercury and selenium, were conducted by inductive coupled plasma emission spectroscopy or graphite furnace atomic absorption spectrophotometry. Mercury concentration was determined by cold-vapor atomic absorption spectrophotometry and selenium by gas-liquid chromatography/electron capture detection. The range, mean, standard deviation, and number of tortoises evaluated for each element are given. When concentrations were below the sensitivity for the instrument, a mean could not be determined.

*LIVER*.—Copper (1–75 ppm; 12.2 ± 16.4; N=27), iron (82–3300 ppm; 910 ± 793; N=27), selenium (0.065–1.05 ppm; 0.45 ± 0.24; N=17), cadmium (0.11–2.64 ppm; 0.70 ± 0.62; N=27), lead(0.024–2.5 ppm; 0.41 ± 0.76; N=27), mercury (0.031–0.848 ppm; 0.260 ± 0.261, N=22), zinc (8.5–140 ppm; 41.5 ± 34.9; N=16), arsenic (<1.0 or 2.0 ppm; N=27), phosphorus (900–4000 ppm; 2577 ± 806; N=13), chromium (0.1–3.2 ppm; 0.55 ± 0.79; N=13), magnesium (85–380 ppm; 196 ± 96; N=12), vanadium (<0.1–1.3 ppm; 0.33 ± 0.35; N=12), sodium (425–3700 ppm; 1687 ± 972; N=13), cobalt (<0.1–0.17), manganese (0.23–1.9 ppm; 1.10 ± 0.49; N=14), molybdenum (0.48–5.1 ppm; 1.68 ± 1.28; N=13), calcium (64–870 ppm; 321 ± 279; N=11), nickel (<0.5–3.0 ppm; 0.87 ± 0.73; N=13), tin (<0.1–0.22 ppm; N=13) and barium (0.13–4.3 ppm; 0.72 ± 1.06; N=13).

*KIDNEY*.—Copper (1.6–4.4 ppm; 2.27 ± 0.79; N=10), iron (16–210 ppm; 47 ± 57; N=10), cadmium (0.05–8.59 ppm; 1.69 ± 1.84; N=27), lead (0.012–3.8 ppm; 0.37 ± 0.96; N=27), mercury (0.016–0.306 ppm; 0.105 ± 0.088; N=18), zinc (17–210 ppm; 48.2 ± 49.4; N=17), arsenic (<1.0 or 2.0 ppm; N=13), phosphorus (1700–3200 ppm; 2600 ± 473; N=10), chromium (<0.1–0.66 ppm; 0.27 ± 0.17; N=9), magnesium (140–280 ppm; 171 ± 40; N=10), vanadium (<0.1–1.4 ppm; 0.28 ± 0.38; N=10), sodium (1400–4700 ppm; 2050 ± 927; N=10), cobalt (<0.1–0.44 ppm; 0.18 ± 0.11; N=9), manganese (0.77–2.1 ppm 1.26 ± 0.44; N=12), molybdenum (0.50–3.6 ppm; 1.33 ± 0.88; N=9), calcium(82–1300 ppm; 323 ± 342; N=10), nickel (<0.5–0.89 ppm; 0.54 ± 0.12; N=10), tin (<0.1 ppm; N=10) and barium (0.16–1.9 ppm; 0.55 ± 0.53; N=10).

The concentration of an element was considered elevated if it was greater than 2 standard deviations above the mean for that element. This approach was conservative, as all but two tortoises in this group were ill. Of two tortoises killed by vehicular trauma, one had elevated renal iron, probably associated with internal hemorrhage. One or more elements excluding arsenic, tin, phosphorus, and manganese were elevated in 15 of the remaining 25 tortoises. Of five tortoises from the southern Mojave Desert, four had elevated concentrations of at least one element, including mercury, cadmium, selenium, nickel, iron, vanadium, cobalt, and molybdenum. All five tortoises from the central Mojave Desert had at least one elevated concentration of lead, cadmium, zinc, copper, chromium, sodium, and calcium. Of four tortoises from the eastern Mojave Desert, one had elevated mercury, and one had elevated cadmium, molybdenum, barium, magnesium, and calcium. Of three tortoises from the western Mojave Desert, two had elevated mercury, one of which also had elevated iron and copper. Of four tortoises from the northern Colorado Desert, one had elevated lead, one had elevated chromium and nickel, and one (struck by vehicle) had elevated iron. None of six tortoises from the eastern Colorado Desert had elevated concentrations of elements in the liver or kidney; but one tortoise had elevated plasma selenium. Although many of elements listed are essential, all can be toxic in high concentrations. Approximately 2/3 of these tortoises had fungal, *Mycoplasma*, or bacterial infections of skin, shell, respiratory tract, and other viscera. Six tortoises with elevated mercury, cadmium, or lead had lesions of liver and kidney degeneration, and liver atrophy. Two of three tortoises with high cadmium had urolithiasis; one of these tortoises had severe kidney disease. Both tortoises with elevated concentrations of nickel had lesions of cutaneous dyskeratosis. Other elevated elements found in tortoises with cutaneous dyskeratosis were molybdenum, magnesium, barium, cadmium, calcium, chromium, and selenium (in plasma). The desert tortoise is a non-migratory, territorial species with a relatively long life span, making it an excellent candidate to serve as a biomonitor of environmental pollution and a sentinel of potential environmentally-related diseases in the California deserts.

## Dispersal and Reconnaissance Movements by Desert Tortoises

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*Abstract.*—Animals make long distance movements for several reasons including to: locate mates, hibernate, and find more suitable habitat for mating, laying eggs, rearing young, and foraging. Tortoises have been documented on several occasions as taking long distance movements, but the reasons of these are unknown. Four explanations are likely: reconnaissance, dispersal, searching for reproductive opportunities, and moving to an area with better resources.

Between 1991 and 1995, we studied desert tortoises movements by attaching radio transmitters to 56 tortoise and attempting to locate them two to four times per week during each spring. Twenty-three of our 56 (41%) transmittered animals are known to have taken long-distance movements covering from 0.8 to 14 linear km within a single season. However our sample is biased towards movers because, since 1992, transmitters were selectively attached to newly found animals, which are more likely to be in the act of taking a long-distance movement when found. Twenty-two of the 23 (96%) animals were subadults or immatures, and one was an adult male. Nine of the 15 (60%) that could be sexed were males. Only one subsequently returned to a known home range. The data indicate that the majority of our study tortoises taking long distance movements likely did so for the purpose of dispersal, although we do not know if they were returning to their natal areas.

Information on dispersal and long-distance movements are important for the management of desert tortoises because they affect population viability analyses, preserve design, impact analyses, and mitigation design.

## A Radio Transmitter Attachment Technique For Desert Tortoise Research

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*Abstract.*—Radio transmitters are essential tools for studying desert tortoise (*Gopherus agassizii*) movements, foraging ecology, reproduction, and relocation. How a radio transmitter is attached to a desert tortoise may affect the transmitter's transmission range and the animal's behavior, growth, survival, and reproductive success. We present step-by-step directions on a successful method we used to attach transmitters to 54 desert tortoises. By running the antenna through sections of tubing, each one attached to a separate scute, we minimized the transmitter's effect on tortoise growth. To increase the transmission range, we attached the antenna to the vertebral scutes and let it trail behind the tortoise. Finally, the use of putty epoxy helped to streamline the process and prevent detachment of transmitters. After adopting this method, we observed no new shell deformations, no transmitters were lost, and transmitter range was increased by approximately 20% over the more commonly used method of running the antenna along the marginal scutes.

## An Automated System for Studying Movements of Desert Tortoises

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*Abstract.*—Many marking methods have been used to study the behavior and ecology of desert tortoises. A safe, automated system, using passive integrated transponder (PIT) tags is described for

studying the movements of tortoises and other animals past specific points of interest, such as burrows, watering holes, or narrow dispersal corridors. The system was designed to run maintenance-free for several months; be secure from vandalism and environmental damage; be solar powered; and record the identity, date, and time of the passage of animals past a 2.4 m wide area. The system was designed for monitoring the behavior of desert tortoises, but can be easily adapted to other similar wildlife applications.

## Desert Tortoise Behavioral Responses to Barriers

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*Abstract.*—In an experiment to test tortoise responses toward different types of barriers, 28 pens were constructed from several different materials. We observed behavioral responses of single adult tortoises in each pen over periods of 4 to 14 d and collected over 5600 observations on 280 tortoises. We evaluated tortoise behaviors across barrier types using Kruskal-Wallis tests ($n$=280, df = 13). Tortoises spent more time walking in contact with see-through barriers than solid barriers. Larger mesh sizes of wire mesh fences elicited more head and/or limbs activity through the barrier. Males pushed against see-through barriers more than solid barriers. More direction reversals and escapes occurred with wire mesh designs and low (20 cm) solid barriers. Fifteen different animals ($n$=280) escaped enclosures, of which 13 were males suggesting they were more likely to escape. Most tortoises that did escape did so repeatedly. Tortoises escaped by exploiting observed weaknesses in barriers (36%) rather than by climbing over it (38%). No animals climbed over 46 cm barriers, one climbed over a 36 cm barrier, and the rest escaped at lower heights. Probability of escape was correlated with larger tortoise size (maximum carapace length) as escaped tortoises were larger than average size. A direct relationship existed between time in a pen and escape likelihood with the probability of escape increasing sharply on day 8. From a behavioral perspective, solid barriers at least 46 cm high proved to be the most effective barriers to desert tortoises.

## Cost Analysis and Engineering Considerations for Desert Tortoise Barriers

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*Abstract.*—As a part of a research project to evaluate methods of reducing desert tortoise mortality along roadways, we compared costs and engineering criteria of alternative fence materials. Materials included four sizes of welded wire mesh, hardware cloth, plastic mesh fence, galvanized rolled steel, pre-cast concrete panels, and extruded concrete curb. We considered cost elements of material and equipment, labor, contractor profit and overhead and based our costs on construction of 10 linear miles of continuous barrier along a roadway. Welded wire mesh fencing appeared to provide the best balance for tortoise-proof barriers given currently available materials. However, if the price of concrete structures could be reduced they would be preferred because they are superior from a behavioral perspective, more durable, and more effective. We found that tortoise-proof barriers should be at least 18 in (46 cm) high and most should be buried about 6 in (15 cm) deep. Extruded concrete curb is the fastest barrier material to construct while concrete barriers, in general, are much more durable than other barriers with their lifespan estimate of 50 years. Wire mesh barriers were considered the most visually aesthetic because they are less visible.

## Alternatives to Gates for Openings in Tortoise-Proof Barriers: Escape and Entrapment Potential for Juvenile Tortoises and Other Species in Mesh Barriers

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*Abstract.*—Openings in tortoise-proof barriers along roadways are inevitable. An example of such an opening is where a gate occurs in a fenced roadway. An effective barrier system must prevent or reduce the likelihood of tortoises crossing these openings. We designed and conducted experiments on several "tortoise guard" structures similar in concept to cattle guards. While no tested design was 100% effective, we learned enough to design a tortoise guard that we think would be effective. Another approach studied to prevent tortoise egress through unfenced areas or reduce tortoise pacing along a barrier was a diversion structure. Two designs were tested, a straight and curved diversion structure. We found that the diversion structures were ineffective at achieving either goal.

No mortality of tortoises or other species was observed during the three month project. Incidental observations of species interactions with barriers ($n$=70) and morphometric measurements of museum specimens of common desert reptiles suggested that particular barrier types would have different effects on specific species. Smaller wire meshes could entrap smaller reptile species and block larger species. Larger wire meshes would allow passage of smaller reptile species but could entrap larger species. Solid barriers would not allow any reptile species to pass. None of the 46 cm barriers tested impeded the travel of small mammals. Juvenile tortoises could pass through the two largest wire mesh sizes (5.1 x 5.1 cm and 5.1 x 10.2 cm) and possibly, but unlikely, through the 2.5 x 5.1 cm mesh. However, the frequency of juvenile tortoises encountering barriers in a wild population along a highway is presently unknown but may be infrequent considering the small home range of juveniles.

## The Clark County Desert Conservation Plan

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*Abstract.*—On July 11, 1995, the U.S. Fish and Wildlife Service (Service) issued a permit to Clark County, Nevada, including cities within the county, and the Nevada Department of Transportation (NDOT) under the authority of section 10(a)(1)(B) of the Endangered Species Act. Effective August 1, 1995, the permit allows "incidental take" of desert tortoises for a period of 30 years on 111,000 acres of non-Federal land in Clark County, and 2,900 acres of land associated with NDOT activities in Clark, Lincoln, Esmeralda, Mineral, and Nye Counties, Nevada. The impacts of the authorized take will be minimized and mitigated by implementation of the Clark County Desert Conservation Plan (Plan). The Plan is funded by a $550 per acre fee for habitat disturbance. Funding proposals are reviewed by the Implementing and Monitoring Committee, which includes representatives of federal, state, and local government agencies and special interest groups. The Service works closely with this committee.

Mitigation and minimization measures being implemented are consistent with the Desert Tortoise (Mojave Population) Recovery Plan and include: increased law enforcement; road designation, signing, closure, and rehabilitation; field testing of road barriers; prioritization of roads for placement of barriers; purchase of a conservation easement; maintenance of grazing allotments in non-use; monitoring tortoise populations, a pick-up service and tortoise holding facility; development and implementation of a tortoise translocation program; and provision of a public information and education program. Mitigation measures in support of tortoise recovery will focus on tortoise habitat on federally managed lands to minimize the impact to private property.

# Development of Long-Term Management and Recovery Program for the Pilot Knob Grazing Allotment in the Central Mojave Desert

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*Abstract.*—In November of 1995, the Desert Tortoise Preserve Committee (DTPC) closed escrow on the purchase of 550 ha (1,360-acres) of Superior-Cronese Critical Habitat for the desert tortoise in the central Mojave Desert, completing the single largest land transaction in the Committee's 22-yr history. The Committee made the purchase in cooperation with another conservation organization, a silent partner for the project. More significant than the land itself, the acquired habitat serves as the "base property" for a 19,830 ha (49,000-acre) cattle grazing allotment on federal land. As part of the purchase, the DTPC acquired all grazing privileges, water rights, structures, and range improvements.

Known as Pilot Knob, the allotment is located 40 km (25 mi) SE of Ridgecrest and 37 km (23 mi) E of the eastern boundary of the Desert Tortoise Research Natural Area in San Bernardino County, California. The allotment extends from 792 m (2600 ft) in saltbush scrub through diverse creosote bush scrub and needlegrass steppe, to Joshua tree grasslands and blackbrush to 1429 m (4687 ft) on high mesas.

The DTPC is actively working with the Bureau of Land Management (BLM) and Naval Air Weapons Station to develop interim and longterm management programs to promote recovery of desert tortoise populations, Critical Habitat, and ecosystems in general within the allotment. The BLM committed to work with the DTPC to permanently retire the grazing permit, an action which will require amendments to land management plans. The DTPC has placed a temporary host/interpreter structure on the allotment and is seeking volunteers and monetary support for this new and challenging project. The existing water tanks, pipelines, and windmills offer numerous opportunities for manipulative research on restoring cattle-grazed desert habitats.

# Abundances of Birds, Lizards, and Black-Tailed Hares Inside and Outside of the Desert Tortoise Research Natural Area, California

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*Abstract.*—The abundance of birds was estimated from point counts made inside and outside of the Desert Tortoise Research Natural Area in May, July, and December of 1994 and 1995. Two areas were studied, one near the northeastern boundary (elev. 880 m) and the other near the southern boundary (elev. 710 m) of the Natural Area. The abundance of birds was higher inside compared to outside of the Natural Area during all six sampling periods, and was significantly higher ($P \leq 0.03$) during all but May 1994 and December 1995. The repeated-measures analysis of variance for this two-year sampling interval was highly significant ($P \leq 0.0001$). Species richness was higher inside of the Natural Area during all of the sampling periods except July 1994, when it was virtually the same inside and outside. Differences in species richness were significant ($P \leq 0.01$) during May 1994, May 1995, and July 1995. Again, the repeated-measures analysis of variance was highly significant ($P \leq 0.0001$). The higher bird abundance and species richness inside compared to outside of the Natural Area was slightly more pronounced in 1995 compared to 1994.

Lizard abundance was estimated along transects at the northeastern and southern sites during July 1994, May 1995, and July 1995. The abundance of lizards was higher inside compared to outside of the Natural Area during all three sampling periods, significantly higher during May and July 1995 ($P \leq 0.01$). The repeated-measures analysis of variance for this two-year sampling interval was highly significant ($P \leq 0.0001$). Species richness was higher inside compared to outside of the Natural Area during all three sampling periods, and was significantly higher ($P \leq 0.05$) during July 1994 and May 1995. The repeated-measures analysis of variance for this two-year sampling interval was moderately significant ($P \leq 0.09$). The higher abundance of lizards inside compared to outside

of the Natural Area was much more pronounced in 1995 compared to 1994. In contrast, species richness was prominently greater inside in 1994.

The abundance of black-tailed hares was estimated at the northeastern site by counting the number of fecal pellets within two-hundred forty 25 x 50 cm samples during April 1994 and 1995. The average number of fecal pellets was 130% higher ($P \leq 0.002$) outside compared to inside of the Natural Area during both years. The repeated-measures analysis of variance for the two sampling periods was significant ($P \leq 0.005$).

These results add to a growing body of data which consistently show that the abundance and species diversity of nocturnal rodent, bird, and lizard communities are higher inside compared to outside of the Natural Area. The mechanisms responsible for these differences are unknown, but are likely due to the influence of off-highway vehicle use and sheep grazing outside of the fenceline. The greater abundance of black-tailed hares outside compared to inside of the Natural Area may be explained by their preference for the lower cover of woody shrubs which is generally encountered there. In summary, it appears that the exclusion of off-highway vehicles and sheep grazing inside of the Natural Area appears to have been of overwhelming benefit to the diverse vertebrate community present.

## Global Change and Desert Ecosystems

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*Abstract.*—Global climate change as a result of the potential future "greenhouse warming" of Earth's atmosphere will affect the distribution and function of natural ecosystems throughout the world. Several models suggest that during a transient period of climatic adjustment, mid-continental ecosystems are likely to experience significant drought (Rind et al. 1990), potentially expanding the area of desert at the expense of semiarid grassland habitats (Smith and Shugart 1993). In desert habitats, seasonal changes in the amount and distribution of precipitation may alter the relative growth of annual plants that are important tortoise food items. Changes in the distribution of vegetation will cause changes in ecosystem function, including biogeochemical processes (Schlesinger et al. 1990). For example, we can expect an increase in the amount of wind erosion and soil transport from landscapes that lose plant cover (Musick and Gillette 1990; Abrahams et al. 1994). Patterns of runoff on desert piedmonts may assume increasing importance in determining plant growth and distribution in critical areas of tortoise habitat (Schlesinger and Jones 1984).

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# Effects of Cattle Grazing on the Foraging Ecology of Desert Tortoises: Implications for Grazing Management in the Mojave Desert

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*Abstract.*—Food resources available to desert tortoises change sporadically both seasonally and annually in the Mojave Desert. Intensity and frequency of these natural fluctuations can greatly affect food acquisition rates, which in turn can affect the net utilizable energy and nutrients available to tortoises. By removing plant biomass from the environment, cattle grazing can potentially impose further limitations on food availability. I examined whether tortoises alter food habits to compensate for cattle grazing and whether rates of food acquisition are reduced by cattle grazing, by comparing the foraging ecology and behavior of desert tortoises in grazed and protected habitat in the eastern Mojave Desert of California.

Biomass of spring annuals exceeded 224 kg/ha (200 lbs/acre) in 1992, and was approximately 78 kg/ha (70 lbs/acre) in 1993. Biomass of annuals was similar in grazed and ungrazed plots in both years. Diets consisted of green annual forbs (80% of intake in both years), and 17% to 20% cacti (1993 and 1992, respectively). Perennial shrubs and grasses, and annual grasses constituted less than 2% of tortoise diets in both years. Tortoises foraging in protected and grazed areas acquired food at similar rates in both years. In 1992, duration of foraging bouts were similar for tortoises foraging in grazed and protected areas, but in 1993 duration of foraging bouts were greater for tortoises foraging in a grazed area compared those in a protected area.

Stocking rates of cattle during spring of 1992 and 1993 (0.66 Animal Unit-Month $km^{-2}$ $mo^{-1}$) did not cause adverse changes in the foraging ecology of desert tortoises. Although dietary overlap between cattle and tortoises was great, food abundance was sufficient in spring of both years to prevent food competition. During years when spring annuals are lacking, livestock grazing may have a more observable effect on tortoise foraging and nutrition, when tortoises must rely on over-utilized perennial grasses. Continued nutrition research will enhance our understanding of the effects of livestock grazing to desert tortoises, and will bolster the scientific credibility of conservation and recovery plans designed to protect tortoise populations.

# Testing Hypotheses about Wildland Fires in the Western Mojave Desert: Results of Experimental Burns Conducted in August 1995

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*Abstract.*—During August of 1995, one 2.25 ha experimental fire was set at each of these sites: the Fremont-Kramer Desert Wildlife Management Area (DWMAs) near California City, the Superior-Cronese DWMA near Hinkley, and the Ord-Roadman DWMA at Stoddard Ridge, California. Temperatures within the three fires generally increased with distance from the surface of the mineral soil and were higher beneath *Larrea tridentata* shrubs than intershrub spaces. Temperatures varied by about 400% between the three fires, with the overall average being 200°C at 10 cm above the soil surface, 200°C at 5 cm, 128°C at 0 cm, and 72°C at –2 cm. While seeds can tolerate some degree of heating, most probably could not survive the temperatures reached at 5 and 10 cm above the surface of the soil.

The pattern of burning at all three sites was very patchy with fire spreading downwind when the amount of dry annual plant biomass in the intershrub spaces was sufficiently high and continuous. The dry fuel within intershrub spaces was primarily composed of *Schismus* sp. and, at the Ord-Rodman burn site, also *Bromus rubens*. Fire often moved through *Schismus* in a very rapid and flashy manner, spreading through intershrub spaces between patches of higher fuel loads located under woody shrubs. Fire crept more slowly through *Schismus* when wind speed was low, relative humidity was high, and *Schismus* biomass in intershrub spaces was relatively low and discontinuous.

While flame lengths, temperatures, and resi-

dency times may be minimal, the burning of intershrub fuel dominated by *Schismus* can play a critical role in the perpetuation and spread of fires. Compared to *Schismus, Bromus rubens* produces the longer flame lengths, higher temperatures, and longer residency times that ultimately lead to the death of perennial plants. However, the function of *Schismus* in carrying fires across the landscape may be critical in the initial establishment of an alien-annual-grass/fire cycle and the type-conversion of native desert plant communities to alien Mediterranean annual grassland. Changes in the fire regime of the western Mojave Desert may not have occurred without the combined invasions of *Schismus* and *Bromus rubens* into the region.

## On The Spatial Pattern Of Soil Nutrients In Desert Ecosystems[1]

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*Abstract.*—We examined the spatial distribution of soil nutrients in desert ecosystems of the southwestern United States to test the hypothesis that the invasion of semiarid grasslands by desert shrubs is associated with the development of "islands of fertility" under shrubs. In grasslands of the Chihuahuan Desert of New Mexico, 35-76% of the total spatial variation in soil N was found at distances < 20 cm, which may be due to local accumulations of soil N under *Bouteloua eriopoda* - a perennial bunchgrass. The remaining variance is found over distances extending to 7 m, which is unlikely to be related to nutrient cycling by grasses. In adjacent shrublands, in which *Larrea tridentata* has replaced these grasses over the last century, soil N is more concentrated under shrubs and autocorrelated over distances extending to 1.0–3.0 m, similar to mean shrub size and reflecting local nutrient cycling by shrubs. A similar pattern was seen in the shrublands of the Mojave Desert of California. The distribution of soil nitrogen on a desert piedmont of the Coxcomb Mountains, Riverside County, California, is strongly autocorrelated with the size and distribution of *Larrea tridentata*. Soil $PO_4$, Cl, $SO_4$, and K also accumulate under desert shrubs, whereas Rb, Na, Li, Ca, M,g and Sr are usually more concentrated in the intershrub spaces. Changes in the distribution of soil properties may be a useful index of desertification in arid and semiarid grasslands worldwide. Ongoing changes in the semiarid grasslands of New Mexico may be analogous to past changes in soil nutrient distributions that have occurred in the Mojave Desert.

[1]The full report of these investigations is scheduled to appear in Ecology in March 1996

## Impact of Soil Surface Disturbance on Cyanobacterial-lichen Soil Crusts in Deserts of the Southwest United States

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*Abstract.*—Cyanobacterial-lichen soil crusts can be an important source of fixed nitrogen for desert ecosystems. Impact of surface disturbance on nitrogenase activity was compared in five biogeographic regions. Disturbed crusts in the Colorado Plateau region were dominated by the non-heterocystic cyanobacteria and the soil lichen *Collema tenax*. Disturbed crusts in the Great Basin, Mojave, Sonoran, and Chihuahuan Deserts were dominated by heterocystic cyanobacteria and the soil lichen *C. tenax*. Experimental disturbances included footprints, mountain bikes, raking, tracked vehicles, and wheeled vehicles in sandy and fine-textured soils. Initial reduction of nitrogenase activity varied from 0–100%. The Colorado Plateau sites showed the least resistance, with reductions ranging from 40–92%, and an average reduction of 71%. Great Basin site reductions varied from 24–61%, with an average of 43%; Sonoran reductions ranged from 5–43%, with an average reduction of 19%; and Chihuahuan sites ranged from 0–64%, with an average reduction of 31%.

Gypsiferous soils were disturbed with wheeled vehicles at Colorado Plateau and Chihuahuan Desert sites. These soils were chosen because of their great soil strength relative to sandy or silty soils. Initial reductions of nitrogenase activity were much lower than seen for soils with lower soil strength, ranging from 0–48% at the Colorado Pla-

teau site and 0–14% at the Chihuahuan site. There was no significant difference between the two sites.

Recovery of nitrogenase activity was measured 3 yrs after disturbance at the Colorado Plateau and Great Basin sites. Colorado Plateau crusts show slower recovery (16%) than Great Basin crusts (29–52%). It is hypothesized that the Great Basin region evolved with greater surface disturbance than the Colorado Plateau, and that composition of the soil micro flora reflects this. The role of disturbance in the evolution of species composition of soil crusts will be discussed.

The chemical and biological microstructure of crusts from the Colorado Plateau site was characterized using soil microprobes. Oxygen evolution was concentrated in the top 0.6 mm of the soil surface. Photosynthetically active radiation levels dropped dramatically at deeper depths. Cyanobacteria lacking UV-protective pigments were seen to actively avoid higher radiation levels, while this was not seen in pigmented species. While zones of biomass concentrations changed with light conditions, most cyanobacterial biomass was in the surface 2 mm of the soil. Activity of the cyanobacteria was shown to increase soil pH from 8 to 10.5.

Susceptibility of differentially disturbed crusts to wind erosion was measured with a portable wind tunnel. It was found that while undisturbed crusts produced no sediment at the highest wind speeds typical for this region, 1–5 yr old crusts produced sediment at wind speeds that were less than monthly high wind speeds in this region. Consequently, disturbed areas are capable of producing sediment for at least 5 years. When sand was added to the air stream in the wind tunnel to imitate the sandblasting effect of wind-blown sand on adjacent soil surfaces, winds equivalent or less than average monthly high speeds quickly removed the top 1-2 mm of soil surfaces of both disturbed and undisturbed crusts. This would potentially impact and/or remove much of the cyanobacterial biomass concentrated at the soil surface.

## Cryptobiotic Crusts and Their Influence on Annual Plants and the Desert Tortoise

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*Abstract.*—Organic crusts that form on soil surfaces in southwestern North America are assemblages of algae, cyanobacteria, bacteria, lichens, and mosses and various metabolic by-products cemented into a semi-permeable soil surface. Cryptobiotic soil crusts cover land surfaces over large parts of desert ecosystems, but their interrelationships with higher organisms have not been well studied. The presence of undisturbed crusts tends to retard wind and water erosion and enhance soil nutrients such as nitrogen and phosphorus in the spaces between shrubs. As a result, crusts may encourage seedling establishment of vascular plants and indirectly influence the invertebrate, rodent, and reptile populations that utilize herbaceous plants as a source of food.

We report on the influence of cryptobiotic crusts on the nutrient composition of annual plants in southwestern Utah (Upper Virgin River Recovery Unit, UVR), and southeastern Utah (Canyonlands National Park, CNP) associated with crust-covered and bare soils. Aboveground production of plants and potential water stress were also measured for plants collected at UVR. In addition, foraging movements of the desert tortoise (*Gopherus agassizii*) were monitored at UVR to determine whether tortoises selectively forage on annual plants growing on crusts.

Concentrations of nitrogen in the annual plants *Festuca octoflora, Streptanthella longirostris,* and a short-lived perennial, *Mentzelia multiflora,* have been shown to be 13–31% greater in plants growing on crusts than in those on bare soils at CNP. However, the annual plants *Bromus rubens, Cryptantha pterocarya, Erodium cicutarium,* and *Eriophyllum wallacei* at UVR generally had lower concentrations of nitrogen in plants growing on crusts than those on bare soils. Pre-dawn and mid-

day xylem pressure potential was generally lower in plants of *B. rubens* and *Descurania pinnata* rooted in crusts, suggesting these plants were more water-stressed than those on bare soils. The abundance of aboveground production was typically greater on crusts than bare soils at UVR. Thus, nutrients and water distributed within a greater biomass of annual plants growing on cryptobiotic crusts may explain why these plants have lower concentrations of nutrients and were more water-stressed than those on bare soils at this site.

Tortoises at UVR avoided cryptobiotic crusts while foraging for annual plants. Tortoises spent less time cropping plants, took fewer bites of vegetation, and sampled from fewer individual annual plants growing on crusts than was expected in the habitat. Conversely, tortoises consumed more annual plants on bare soils than was expected. Forage selection may have been driven by nutrient concentrations of annuals; however, nutrient requirements and the mechanism driving diet choice are still unknown for the desert tortoise. Differences in plant size and abundance, and the hotter thermal environment on crusts may also explain avoidance of crusts as a soil substratum for plant forage.

## Impacts of Soil Surface Trampling: A Case Study in Arches National Park

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*Abstract*.—Maintaining soil stability and normal water and nutrient cycles in desert systems can be critical in avoiding desertification. These particular ecosystem processes are threatened by trampling of livestock and people, and by off-road vehicle use. At Arches National Park, an adjacent disturbed and undisturbed *Coleogyne* (blackbrush) stand was compared.

Frequency and cover of vascular and non-vascular plants and litter were recorded for both disturbed and undisturbed areas. Frequency and cover of litter, lichens, and mosses were significantly lower in the disturbed area. Grass herbaceous plant cover and frequency was significantly lower. Shrub cover was not significantly different between the two areas, while shrub frequency was higher in the undisturbed area. Exotic plant cover was significantly higher in the disturbed area.

In the disturbed area, soil compaction and disruption of cryptobiotic soil surfaces (composed of cyanobacteria, lichens, and mosses) resulted in decreased water availability to plants through decreased water infiltration; increased albedo resulting in decreased surface temperatures; accelerated soil loss through wind and water erosion; and decreased diversity and quantity of soil biota. In addition, nutrient cycles were altered through the cessation of nitrogen and carbon inputs from the biological soil crusts and probable slowed decomposition of plant material due to absence of soil biota. As a result, plants in the disturbed area had lowered biomass and nutrient concentrations in vascular plant tissue.

Plant community architecture was greatly altered in the disturbed area when compared to the undisturbed area. Although total shrub cover was not significantly different, the spatial arrangement was different. In the disturbed area, there were fewer, larger shrubs on hummocks two times as high when compared to the undisturbed area. In addition, perennial interspace plants in the undisturbed area had been replaced by annual plants in the disturbed area. As a consequence, cover for small mammals had been dramatically decreased in the disturbed area. Travel from shrub to its nearest neighboring shrub was four times as far in the disturbed area than in the undisturbed area. Also, the perennial vegetative cover once present in the shrub interspace was gone, resulting in greater exposure for animals crossing that space. As a result, trampling resulted in small mammals being away from cover for longer periods of time.

Recovery of deserts soils from surface disturbances can be slow. Recovery from compaction is estimated to take several hundred years. Recovery rates for soil bacterial and fungal populations are not known. Return of soil crusts' ability to stabilize soils is estimated to be 40–100 yrs. Return of nitrogen input to pre-disturbance levels 15–50 yrs. Recovery of crusts can be hampered by large amounts of moving sediment, and re-establishment can be extremely difficult where large areas have been disturbed.

## The Effects of Poaching Desert Tortoises in the Western Mojave Desert: Evaluation of Landscape and Local Impacts

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*Abstract.*—We evaluated effects of poaching on the desert tortoise, *Gopherus agassizii,* and its critical habitat in the western Mojave Desert using law enforcement records, visual observations of suspected poachers, signs of excavated tortoise burrows from a 2.6 km² plot, and demographic data from two 2.6 km² plots. Evidence of poaching surfaced in the mid-1980s. Between 1991 and 1995 several Cambodian nationals were arrested with 29 tortoises, and several other Asians were observed in suspicious behaviors. Recent immigrants and their cultural habits may pose new threats to the tortoise and possibly other threatened and endangered species.

On a landscape scale, strip transects were walked in 1995 to look for suspicious excavations of tortoise burrows. One hundred four strip transects were initiated from dirt roads and walked into open desert in four study areas encompassing 970 km². Suspicious excavations were observed on 16% of the transects. On the same transects, 235 burrows were counted and 7.7% of the burrows showed signs of having been excavated by humans. The greatest number of excavated burrows were observed in two areas: (1) a polygon formed by Highway 58 in the north, Harper Lake Road on the east, Shadow Mountain Road on the south, and Highway 395 on the west; and (2) a polygon 8–16 km south of Barstow and to the east of Highway 247.

On a local scale, data from study plots indicate that tortoises have been removed from populations for at least 10 yrs and at least some of their burrows have been excavated by humans. Between 1986 and 1990 Glenn Stewart undertook a relocation project northeast of Kramer Junction. He indicated that 29% of radio-transmittered tortoises were probably poached. At another, long-term desert tortoise study site south of Kramer Junction, our work indicates that poaching probably began in the mid-1980's and has continued through 1995. The adult tortoise population decined in density by 70% between 1982 and 1995. Because insufficient shell-skeletal remains of adults were located to account for the missing tortoises, we infer that a substantial portion of the adult loss is due to poaching. In 1995, every tortoise burrow on the study plot was evaluated: 23% ($N$ = 166) showed signs of recent, suspicious excavations. More excavated burrows were found near dirt roads (*x distance* = 115 m, SD=85 m) than undisturbed burrows (*x distance* = 168.7 m, SD=127m), but differences were not statistically significant.

Using the data from strip transects and from the study plots, we estimate that > 2,000 tortoises have been removed from the four study areas. The high density of dirt and paved roads permit easy access to people seeking tortoises on the surface or in burrows.

## Health Studies of Free-Ranging Mojave Desert Tortoises in Utah and Arizona

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*Abstract.*—Desert tortoises (*Gopherus agassizii*) are long-lived reptiles found in the deserts of the southwestern United States. Concerns in 1989 over declines in the Mojave desert tortoise population prompted a 5-year health study of two free-ranging populations in the eastern Mojave Desert: the first from City Creek, Washington County, Utah, and the second from Littlefield, Mohave County, Arizona. We captured and radio-tagged 92 tortoises from 1989–93, then recaptured them 3 times a year. To examine blood chemistry, bacteria, and for upper respiratory tract disease, we immobilized each tortoise and collected blood, nasal aspirate, cloacal and throat swabs, and fecal matter. Tortoise blood chemistry values differed ($P < 0.001$) between sites and sexes, and among seasons and years. Females had higher ($P < 0.05$) levels of cholesterol,

## The Effects of Poaching Desert Tortoises in the Western Mojave Desert: Evaluation of Landscape and Local Impacts

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## Health Studies of Free-Ranging Mojave Desert Tortoises in Utah and Arizona

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limiting 1) the size of the ovary, coelom, and nutrient reserves in the body, and 2) nutrient intake during spring. Females at Cantil were larger than females at Goffs and produced larger eggs than did females at Goffs. After correcting for body size, Cantil females produced larger but fewer eggs than did Goffs females. This tendency for larger females, larger eggs, and fewer eggs being produced in the western Mojave Desert may be due to the Mojave Desert rainfall pattern. The timing of clutches was also important to reproductive output. Females that laid their first clutch of eggs by about May 21 were able to produce a second clutch during that year.

Reproductive output at Cantil was not affected by 1) irrigation, 2) tortoise relocation, or 3) whether females had antibodies to *Mycoplasma agassizii*. The lack of differences may have resulted from 1) the heavy winter rainfall and abundant winter annuals, and 2) not measuring reproductive output until three years after starting the irrigation and relocation treatments.

## Mycoplasmal Infections in Wildlife: Lions and Tigers and Bears: Oh My!

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*Abstract.*—Mycoplasmal infections are known to cause economically important respiratory infections, arthritis, and mastitis in domestic animals. However, relatively little information is known about the role of mycoplasmas in wildlife and their potential for disease in these hosts. Upper Respiratory Tract Disease (URTD) in both the desert and gopher tortoises has been the best characterized mycoplasmal disease in wild animals. Mycoplasmas were isolated in 1989 from a respiratory disease epidemic in harbor seals. These mycoplasma species cause heavy damage to the ciliary epithelium in tracheal organ cultures and also induce cytopathic effects in seal kidney cell lines. Experimental infections produced a number of adverse effects.

Mycoplasmas have been isolated from a number of avian species (wild turkeys, buzzards, saker falcons, griffon vultures), most of which do not have evidence of clinical disease. Most recently, *Mycoplasma gallisepticum*, a common poultry pathogen, has been associated with a severe disease outbreak in house finches in the Northeastern U.S. In view of the ocular lesions seen in URTD, it is particularly intriguing that the clinical picture presented in these finches is conjunctivitis leading to possible blindness. Eye involvement may be underestimated in assessment of clinical signs of mycoplasmosis.

Our group has been involved in a recent outbreak of septic arthritis in alligators in which a large number of alligators died. An apparently new species of mycoplasma was recovered from arthritic joints, lung, and even cerebrospinal fluid. A similar disease has been reported in crocodiles from Zimbabwe but we do not know if the causative agent is the same as that in the alligator outbreak.

Both mycoplasmal and ureaplasmal species have been isolated from a number of felines. We have recently sequenced the 16S rRNA genes of all the known feline mycoplasmal species. We have isolated mycoplasmal species from the oral cavity of a Florida panther and from the gastric lining of cheetahs. The clinical relevance of these isolates is not known.

It is becoming apparent that mycoplasmas colonize mucosal surfaces of a variety of animals. The disease potential in most of these hosts will probably be difficult, if not impossible, to elucidate. Limited availability of the host for use in transmission studies coupled with the dearth of funding for such studies will preclude research in many of these potential diseases.

## Antibody levels to *Mycoplasma agassizii* in the DTNA, Goffs, and Ivanpah populations: Summary of 1994 vs 1995 values

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*Abstract.*—Serum samples were obtained as part of an ongoing study monitoring three populations of desert tortoises in California. In previ-

ous years, antibody levels to *Mycoplasma agassizii* were elevated in the Desert Tortoise Natural Area (DTNA) population with recent increases seen in the Ivanpah and, to a lesser extent, the Goffs populations. The DTNA population had experienced declines in the tortoise population, much of which occurred prior to initiation of the antibody monitoring project. Seasonal effects were noted as well, with antibody levels lowest in the winter, but elevated in summer months. In the past two years, a reversal of these trends was noted. Antibody levels were still higher in DTNA than in the other two populations ($P \leq 0.001$) but no seasonal effects were noted (see Table 1).

This trend in decreased antibody levels might suggest that the disease potential is decreasing in these populations. However, closer analysis of the tortoises contributing to the survey revealed a number of significant changes in the 94-95 period. Many of the animals samples in these two years were newly added to the study. In DTNA, 13 animals were added (8 males, 5 females). In both Goffs and Ivanpah, 6 new animals were added. In Ivanpah, four males and two females were added; additions to Goffs were all female. This implies that a minimum of 28% to > 60% of animals surveyed were new to the study. Although the current monitored tortoises may not reflect the past history of these populations, they actually could provide valuable insight into the current and future potential for spread or diminishment of disease in these locations.

## Dose Response Study of *Mycoplasma agassizii* Infection in Gopher Tortoises

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*Abstract.*—A study was conducted to test the hypothesis that the progression of upper respiratory tract disease (URTD) caused in tortoises by *Mycoplasma agassizii*, and tortoise immune responses during URTD, depend on the dose of *Mycoplasma* to which the tortoises are exposed. Twenty-two ELISA-, culture-, and PCR-negative, healthy adult gopher tortoises were divided into four groups plus a sentinel. Tortoises were individually housed in 21-$m^2$ outdoor enclosures. Four control tortoises were inoculated intranasally with sterile broth, six were inoculated with approximately $10^1$ CFU of *M. agassizii* strain 723 (low dose), six were inoculated with $10^3$ CFU (medium dose), and five were inoculated with $10^5$ CFU (high dose). For perspective, the etiology of the disease was first demonstrated with experimental doses of approximately $10^8$ CFU. Blood and nasal flush samples were obtained at bi-weekly intervals up to 8 wk PI and at 12 wk PI. Tortoises from each dosage group were euthanized and necropsied at approximately 16 wk PI. Least-squares analyses of variance detected no differences in the rate of onset or severity of clinical signs of URTD, or in ELISA val-

Table 1. Antibody levels to *Mycoplasma agassizii* in the DTNA, Goffs, and Ivanpah populations for 1994 and 1995. Values are expressed as the mean ELISA value ± SD. The number of tortoises sampled is given in parentheses.

| Season | DTNA | Goffs | Ivanpah |
|---|---|---|---|
| Winter 1994 | 0.297 ± .28 (14) | 0.044 ± .02 (19) | 0.052 ± .02 (18) |
| Spring 1994 | 0.321 ± .39 (13) | 0.045 ± .03 (20) | 0.058 ± .03 (19) |
| Summer 1994 | 0.311 ± .35 (13) | 0.052 ± .02 (16) | 0.066 ± .02 (21) |
| Fall 1994 | 0.213 ± .24 (13) | 0.051 ± .03 (19) | 0.060 ± .02 (20) |
| Winter 1995 | 0.199 ± .24 (17) | 0.039 ± .03 (18) | 0.041 ± .02 (20) |
| Spring 1995 | 0.294 ± .32 (16) | 0.047 ± .03 (18) | 0.051 ± .02 (20) |
| Summer 1995 | 0.363 ± .39 (15) | 0.066 ± .04 (17) | 0.008 ± .03 (20) |
| Fall 1995 | 0.273 ± .29 (21) | 0.055 ± .03 (18) | 0.054 ± .03 (20) |

ues among the three dosage groups. Nasal discharge, ocular discharge, palpebral edema, conjunctivitis, and IgM and IgG immune responses of tortoises which received even the lowest dose of mycoplasma were as pronounced as those of tortoises which were inoculated with $10^8$ CFU in other studies. No control or sentinel tortoises became ill or seroconverted. These results indicated that the minimum infectious dose for *M. agassizii* strain 723 was fewer than 10 mycoplasma CFU, a dose that probably can be directly transmitted by tortoise social interaction or by fomites. The minimum infectious doses of other strains may be different than that of strain 723.

## Natural Transmission of Upper Respiratory Tract Disease: Horizontal, Vertical, or Both?

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*Abstract.*—A pairing study was implemented to investigate the potential for and timing of transmission of *Mycoplasma agassizii* between adult tortoises (horizontal transmission) and from parent to offspring (vertical transmission). Fifteen female-male pairs of gopher tortoises, five negative controls and 10 with one member positive for infection with or exposure to *M. agassizii*, were established in August, 1994. In October, 1994, March and August, 1995, tortoises were photographed and assessed clinically, and blood and nasal flush samples were collected. An aliquot of the flush sample was analyzed by polymerase-chain reaction (PCR); the remainder was cultured for-mycoplasma. Serum was analyzed by an enzyme linked immunosorbent assay (ELISA) for antibodies against *M. agassizii*. In May, 1995, four control and four exposed females were induced to oviposit; eggs or hatchlings were collected from the pens of five other exposed females. Cloacal swab samples were collected from the induced females during laying, and 25 eggs from 11 clutches were processed for mycoplasma culture, PCR, and ELISA. Chorioallantoic/amniotic fluid was collected from each egg at hatching and processed for culture and PCR. Blood samples were collected from hatchlings by cardiocentesis within 2 weeks of hatching and processed for ELISA. Horizontal transmission was documented by development of clinical signs of Upper Respiratory Tract Disease in six initially uninfected tortoises, with recovery by culture and PCR detection of *M. agassizii* in flushes and seroconversion in five of the six tortoises. No evidence of vertical transmission of mycoplasma was detected by culture or PCR, although the sample size of infected females was small. No eggs or hatchlings from ELISA-negative females had detectable antibody levels. Eggs and/or hatchlings from 5 ELISA-positive females were positive for antibodies. Samples will be collected in 1996 from adults, hatchlings, and eggs.

## Nutritional Research of the Desert Tortoise: Synopsis of a Workshop

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*Abstract.*—Food ingestion and digestion represent one of the closest interactions an animal can have with its environment. Because all animals must harvest and process food from their environment to survive and reproduce, nutrition research is fundamental to developing and evaluating the success of conservation and recovery programs of threatened animals. Recognizing this, the National Biological Service sponsored a Desert Tortoise Nutrition Workshop in October, 1995. The goals of the workshop were to (1) facilitate communication between scientists active in tortoise nutrition research, by sharing current research findings and discussing critical issues; (2) synthesize knowledge of tortoise nutrition for land and wildlife managers; and (3) determine what is known and what needs further investigation, in order to enhance recovery programs of wild populations. We highlight some of the important research findings and topics of agreement and controversy from 30 contributors. Four major areas of tortoise research were explored: (1) foraging ecology and diets of wild

tortoises; (2) effects of nutrition on survivorship, growth, and reproduction; (3) food quality, nutrient requirements, and digestive physiology; and (4) food acquisition, optimal diet, and food selection. We encourage attendees of the Desert Tortoise Council Symposium to sign our mailing list to receive a Program and Abstracts booklet from the Workshop, and to receive updated information for the book on nutrition of desert tortoises we will publish with University of Nevada Press. This book will easily double the number of peer-reviewed, published manuscripts on desert tortoise nutrition that exist to date.

## Localized Mid-Summer Rainfall: Its Effects on Perennial Plant Phenology, and Importance to the Desert Tortoise (*Gopherus agassizii*)

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*Abstract.*—In August of 1994, 48 mm of rainfall occurred in a localized summer storm in the eastern Mojave Desert in Ivanpah Valley. On September 17, 1994, green vegetative growth resulting from this rain was observed over a 23 km$^2$ area in Ivanpah Valley, San Bernardino County, California. The vegetation that responded was annual and perennial. Ninety-five percent of creosote bushes (*Larrea tridentata*) produced some new green leaves on branch tips, and 55% of the plants sampled had flowered or set fruit. Burro-bush (*Ambrosia dumosa*) and Anderson's thornbush (*Lycium andersonii*) leafed out to a moderate extent (88% of the burrobush, and 94% of the Anderson's thornbush, respectively). Galleta grass (*Hilaria rigida*) greened up at the base, sending out new stems, with some plants producing seed heads, particularly those plants that were in the small washlets. By comparison, at 4.8 km northeast of the green-up area, only 0.8 mm of precipitation fell. This rainfall did not trigger any observable germination of annuals, or any new growth of perennial shrubs or galleta grass.

Prior to this rainfall, tortoises inhabiting Ivanpah Valley had not consumed green food since spring of 1993. The tortoises that resided within the localized rainfall area consumed the fresh green growth of galleta grass, as determined from the content of newly deposited scats which appeared green in color. In contrast, tortoise scats collected in the dry area were dark brown or blackish, and contained numerous glochids from cacti.

Occurrence of localized rainfall typical of summer rainfall in the eastern Mojave Desert is strongly influenced by convection and the orographic effects produced by nearby mountain ranges. The relatively small, low mountain ranges surrounding Ivanpah Valley (max elev of 2296 m in the New York Mountains, and 1879 m in the Ivanpah Mountains), may regularly influence the geographic distribution of rainfall within Ivanpah Valley. Such orographic rainfall patterns may have short- and long-term effects upon the vegetation, and may be partially responsible for the patchy distributions of tortoises in desert environments.

## Summer Selection of Shelter Sites by the Desert Tortoise, *Gopherus agassizii*

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*Abstract.*—Body temperatures of tortoises in shelter sites were monitored for the effect of shelter sites on body temperature during the 1995 summer season in the Maricopa Mountains of Arizona. Forty-three shelter sites were selected along the NE slopes of the Espanto Range in an area that is currently being used by a known population of tortoises. Tortoise mannequins were placed in shelters and allowed to reach a thermal equilibrium with the environment. The mannequins internal temperature readings were then compared to the internal temperature of tortoises in shelter sites. Only six of the 43 sites monitored were used by tortoises. These six sites were shown to be cooler than most of the tested sites not used by tortoises.

## Can Burrows and Scats be Used as

# Robust Estimators for the Distribution and Density Patterns of Desert Tortoise Populations on Landscape Scales?

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*Abstract.*—The estimation of the distribution and density patterns of desert tortoise populations on landscape scales has been a formidable task for four important reasons: 1) the magnitude of the spatial scales involved, 2) the typical low densities found in tortoise populations, 3) the patchy (clumped) nature of tortoise populations, and 4) the fossorial behavior of tortoises with resulting low levels of surface activity. Since actual tortoises are difficult to find compared to their much more abundant and more readily visible sign, scats and/or burrows are much more economical to sample than actual tortoises. However, the use of surrogate measures to assess or monitor wildlife populations has universally been criticized on issues of relevancy, accuracy, or precision. Desert tortoise managers and researchers have also expressed strong criticism on the use of tortoise sign for monitoring tortoise densities. However, statistically valid empirical field data based on unbiased robust sampling designs are lacking to support or reject the hypothesis that tortoise sign density can be used as a substitute for actual tortoise density. In this research, a sampling design was developed that estimated the density of tortoises, carcasses, burrows, and scats on landscape scales. The resulting database could be used to statistically examine and model the relationships among the spatial occurrences of these four parameters. The models used to test these relationships were Linear Regression, Multiple Regression, Logistic Regression, and Monte Carlo Resampling and Replacement. A sampling algorithm was developed to locate unbiased systematic, and random survey transects. Square transects were used that were 4 km long by 60 m wide. Each sampling plot was 9 km$^2$ and contained four survey transects. Five plots were located at Marine Corps Air Ground Combat Center in the southern Mojave Desert, and three plots were located at Joshua Tree National Park in the northwestern Sonoran Desert. Statistical modeling revealed that both burrow and scat counts were strongly positively correlated with the occurrence of tortoises on survey transects.

# Evaluating Desert Tortoise Populations on Two Study Plots in the Lake Mead National Recreation Area

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*Abstract.*—As part of a population monitoring program, demographic surveys of desert tortoises (*Gopherus agassizii*) on two (1.6 km$^2$) study plots in the Lake Mead National Recreation Area were conducted each spring from 1992 through 1995. Study sites were located within, or contiguous to, areas listed as critical tortoise habitat by the U.S. Fish and Wildlife Service. Surveys were conducted using standard 60-day techniques. Because recapture rates were small for surveys conducted within any particular year, closed mark-recapture estimates of adult tortoise (MCL > 179 mm) populations were made over two spring seasons using tortoises captured during one year as the marked cohort for the following year. To evaluate the assumption that populations were closed during the two-season sampling periods, movements of radio-equipped tortoises were analyzed to determine the percentage of animals that remained on a study plot during consecutive spring surveys from 1993 through 1995. We found that of 14 monitored tortoises on study plots during 1993 surveys, 13 were located at least once on their respective plots during spring, 1994. Of 33 monitored tortoises within plot boundaries during 1994 surveys, all were located at least once on their respective study plots during the 1995 surveys. Although some tortoises moved on and off plots during spring surveys, the percentage of radio-monitored tortoises having some probability of capture during two consecutive spring surveys was sufficiently high to suggest that estimates made over two years were as legitimate as those made during a single year. Average adult population estimates were 60 tortoises at one site and 67 tortoises on the other. Death rates of adult tortoises, estimated using the population estimates and known mortalities, were less than 2% on both sites. These low death rates, coupled with estimates of recruitment into the adult size classes, indicated that the population on one site was relatively stable while the population on the other was possibly increasing during the study period.

## Education of the Public Concerning the Desert Tortoise Plight (What Captive Tortoises Can Do To Assist in this Program)

DARLENE POND, *Reno Tur-Toise Club, P.O. Box 8783, Reno, Nevada 89507.*

*Abstract.*—Education of the public is vital to the survival of the desert tortoise. The establishment of a Native Nevada Habitat complete with desert tortoises, by teachers and students of the Fremont Elementary School, Carson City, Nevada has impressed students of several schools, their parents and friends as well as the local community.

Introduction of tortoises from the Northern Nevada Desert Tortoise Adoption Program has proved to be an interesting on-hands science project capturing the interest of thousands of people who otherwise would not have ever seen a tortoise, and certainly would not know its environmental requirements. The students even hatched eggs and are studying the hatchlings.

## The Making of a Natural Nevada Habitat for the Education of Fremont Students

DONNA HATAWAY, *Fremont Elementary School, 1511 Firebox Road, Carson City, Nevada 89701.*

*Abstract.*—The habitat came about from a county extension promotion called Grow Lab, wherein the classroom grows native Nevada plants. We thought it would be beneficial if the students could see the plants growing outside in a habitat as natural as possible to the real Nevada environment. We made a 844 $m^2$ (9,083 $ft^2$) courtyard at our new school into a habitat designed by Dick Post, County Extension Professor at University of Nevada, Reno. A habitat team comprised of students leads tours and enforces rules.

The habitat represents several climate areas including desert (playa), hills to the east of Carson City with pinion and juniper forests; the Sierra montane, an area between the valley floor and the pine forests of the Sierra Nevada Mountains; and the mountains themselves, replete with a waterfall, a creek, and a pond. The habitat has opened environmental educational opportunities that have exceeded our expectations.

## Introduction of the Desert Tortoises into the Fremont Native Nevada Habitat

DONNA HATAWAY, *Fremont Elementary School, 1511 Firebox Road, Carson City, NV 89701*

*Abstract.*—After plants were in place in the habitat, we introduced lizards and insects and then Mr. Richard Marty of the Reno Tur-Toise Club toured our habitat and suggested desert dortoises could live there. He taught us how to take care of them and in April, 1995, three of them were introduced to the habitat.

The tortoises created a lot of excitement and soon we were giving tours to other schools as well as members of the community and at open house. We had to establish rules and make sure people followed them as one of the tortoises was stepped on and her leg broken. We felt we had failed in our responsibility to see to the tortoises' safety.

One of the females, Cactus Cate, dug a nest and laid eggs, which we hatched in the classroom. We made the eggs, hatching and hatchling care another science project and think we established a first: hatching a member of a threatened species at a school. Our study of desert tortoises and hatching babies is one of the most exciting experiences of our lives. It helped us realize our responsibility for enhancing nature's plan for the animals of our earth. We are confident we will be able to present ideas to work for environmental success on our planet in the future.

# Influence of Field Enclosures on Activities, Microhabitat Use, and Survivorship of Juvenile Desert Tortoises

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*Abstract.*—Differences in activity budgets between two groups of juvenile desert tortoises (*Gopherus agassizii*) raised in a 0.4 ha predator-proof field enclosure (60 x 60 m), were studied during May, June, and July, 1994 and 1995 at Ft. Irwin Study Site in the Central Mojave Desert. Tortoises were significantly more active in 1995, a year with above average rainfall in contrast to 1994, a drought year (ANOVA, foraging: $P \leq 0.0166$; walking/foraging: $P \leq 0.0169$; resting: $P \leq 0.0001$; and other behaviors: $P \leq 0.0003$, df=1, $n$=8). No significant differences were found between tortoises released to adjacent habitat and tortoises maintained inside the enclosure suggesting precipitation and plant productivity determine activity levels. Utilization of microhabitats were highly significant between group, year, month, with year/group and year/month interactions suggesting microhabitat differences inside and outside the enclosure. Actively released tortoises were subject to human manipulation in their dispersion from the enclosure. Passive release allowed tortoises to wander out of the enclosure through small apertures around the bottom of the fenceline. Survivorship of actively released tortoises after three months was 89% ($n$ = 9), only 38% of passively released juveniles ($n$ = 8) survived the same period, indicating the former method can best maximize survival of released juveniles.

# Serologic Survey of Desert Tortoises, *Gopherus agassizii*, in and Around the National Training Center, Fort Irwin, California, for Exposure to *Mycoplasma agassizii*, the Causative Agent of Upper Respiratory Tract Disease

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*Abstract.*—The bacteria, *Mycoplasma agassizii*, is the causative agent of a chronic upper respiratory tract disease (URTD) of desert tortoises, both in captivity and in the wild. Epizootics of URTD have been seen at multiple sites in the Mojave Desert of the southwest United States. An enzyme linked immunosorbent assay (ELISA) has been developed specifically for use in desert tortoises to determine exposure to *M. agassizii*. Data is slowly accumulating on prevalence of exposure to this organism in certain wild populations. To add to the data base, commencing in June 1993, samples were collected from desert tortoises in and around the National Training Center, Fort Irwin, California. Tortoises were sampled from the following locations: 1) captive tortoises in Barstow, CA.; 2) captive tortoises in Ft. Irwin Park and at Ft. Irwin Veterinary Clinic; 3) FISS site (southeastern Fort Irwin boundary); 4) Tiefort Mts.; and 5) North Alvord Mts. Clinical signs of URTD have been seen in captive tortoises in Barstow, and tortoises in Ft. Irwin Park and Ft. Irwin Veterinary Clinic; 14 of 25 tortoises sampled from these locations were seropositive for exposure to *M. agassizii*. However, only four of 52 tortoises sampled from the FISS site were seropositive, and none of 11 tortoises sampled from the Tieforts were seropositive. From the North Alvords, 32 tortoises were sampled, of which 4 were seropositive; one of the seropositive tortoises also had a nasal discharge. To date, of the 95 wild tortoises sampled, eight were found to be seropositive, four of which were from the North Alvords. Nasal samples from tortoises in these locations are currently being collected and evaluated by a recently developed polymerase chain reaction technique to determine pres-

ence of *M. agassizii*. This work was supported by the Department of the Army on Contract No. DAKF04–93–M–1079.

## Color, Calcium, and Insect Choice Trials of Captive Juvenile Desert Tortoises (*Gopherus agassizii*)

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*Abstract.*—Captive-bred juvenile desert tortoises (*Gopherus agassizii*) were placed in a trial arena to study feeding preferences regarding color, calcium, and insects. Each day a different set of five tortoises was tested for a duration of one hour. Only the first bump or bite on a food item was recorded.

When presented with choices of colored food, the observed preference was green > yellow > red > orange. When presented with a choice between colored food and eggshell the observed preference was eggshell > green > yellow. When presented with a choice between colored food and cuttlebone the observed preference was cuttlebone > green > yellow. When presented with a choice between colored food and insects the observed preference was crickets > mealworms > green. These results suggest that juvenile desert tortoises may prefer some food colors over others and may consume insects opportunistically. This information may prove valuable for future captive breeding programs and for selecting an inoculation medium for disease vaccination.

## Hatchling Tortoise Requirements for Food, Energy, and Water

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*Abstract.*—Rates of growth and rates of energy metabolism and water flux (using doubly labeled water) were measured in hatchling desert tortoises (*Gopherus agassizii*) kept in large fenced enclosures in their natural habitat during the first two years of their life. We calculated rates of food consumption from energy budgets, and estimated water intake from the diet and from drinking rain water. When active, hatchlings used energy and water at rates similar to those expected for desert reptiles of their size, but they conserved water and energy effectively during dry seasons. They increased mass about 30% each year, growing from 34 g in 1992 to 55 g in 1994. During its first two years of life, a typical hatchling tortoise used a total of about 175 g (dry matter) of food, equivalent to about 350 g fresh vegetation ($^3/_4$ lb). Hatchlings showed much variation in rates of energy and water metabolism between months within seasons, between seasons within years, and between years as well. The primary environmental factors cueing this variation apparently were temperature, rainfall, and the presence of green, succulent plant food. Metabolic rates peaked in late spring, and rates of water intake were high when green annual plants were available in spring and when rain fell in summer. During winter hibernation deep in burrows, tortoises were relatively inert, having very low rates of energy metabolism and water loss, and they lost little body mass. Rainless periods in summer appeared to be the most stressful times, as hatchlings lost mass then, and were dehydrating, even though they reduced their energy and water requirements by retreating into their burrows. Hatchling survival may be threatened in dry years, when few annual plants germinate, and summer rains are unavailable. Conservation efforts that improve availability and abundance of annual plants can benefit hatchling tortoises.

## The Thermal Environment of Juvenile Desert Tortoises at Ft. Irwin National Training Center

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*Abstract.*—The desert tortoise (*Gopherus agassizii*) inhabits the deserts of the southwestern United States and is listed as threatened throughout most of its range. A description of the thermal environment is important to understanding the thermal requirements of tortoises, and is also an important tool for predicting the recruitment of juveniles into adult populations. Insight into the thermal ecology of adult dessert tortoises is available through Zimmerman et al. (1994). We monitored meteorological and environmental parameters at an enclosure for juvenile tortoises on Ft. Irwin National Training Center, CA, and monitored tortoise behavior for one year. Juveniles used sunny microsites more frequently in spring, and shaded microsites more frequently in summer. When tortoises were found associated with shrubs, they typically occupied the area beyond the dripline rather than positioning beneath the canopy. Body temperatures ($T^b$) were within the range of observed operative environmental temperatures ($T_e$). Tortoises shifted the time of above-ground activity as spring progressed into summer. A shift from a unimodal activity period in spring to a bimodal activity period in summer coincided with a change in the minimum available $T_e$. When the minimum available $T_e$ exceeded the body temperature at which tortoises entered burrows, tortoises were no longer present above ground. Thus, $T_e$ was a useful predictor of population activity. For juvenile tortoises, an accurate evaluation of the thermal environment leads to predicting the potential time juveniles can spend above ground, which in turn affects foraging time, growth, and recruitment of juveniles out of predation-vulnerable size classes.

LITERATURE CITED

ZIMMERMAN, L.C., M.P. O'CONNOR, S.J. BULOVA, J.R. SPOTILA, S.J. KEMP, AND C.J. SALICE. 1994. Thermal ecology of desert tortoises in the eastern Mojave Desert: Seasonal patterns of operative and body temperatures, and microhabitat utilization. Herpetological Monographs. 8:45–59.

## Evaluation of Methods for Monitoring Common Raven Abundance

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*Abstract.*—Common raven (*Corvus corax*) populations have increased considerably in recent years in the deserts of southwestern United States. The increases are probably caused by a rise in human population densities in the desert and they may be responsible for increased raven predation on juvenile desert tortoises (*Gopherus agassizii*). As subsidized predators, ravens benefit from food, water, and other subsidies provided by human activities. Several actions have been recommended by the Bureau of Land Management and other entities to reduce raven use of anthropogenic resources in order to reduce raven predation on tortoises. Any such effort should be accompanied by data supporting the connection between resources and raven population increases as well as a well-designed program to monitor for success of the management action.

To formulate recommendations on how raven populations should be monitored, we evaluated the results of two surveys. Our objectives were to: 1) determine minimum adequate sample sizes necessary to make valid statistical inferences; 2) evaluate temporal trends to determine the necessary time spans to be covered by monitoring programs; and 3) to make recommendations on protocols that should be used on future monitoring efforts. Additional work using different survey methods is necessary to evaluate different methodologies and to develop a final recommended protocol.

# 1996 Awards

## Desert Tortoise Council
## 1996 Annual Award

DESERT TORTOISE PRESERVE COMMITTEE

## Desert Tortoise Council
## 1996 Special Award

This special award is presented for significant contributions toward determining the association of *Mycoplasma agassizii* with Upper Respiratory Tract Disease in wild desert tortoises. With this knowledge, appropriate management strategies can be developed to protect and preserve the desert tortoise throughout its range.

ELLIOTT R. JACOBSON
PAUL KLEIN
ISABELLA SCHUMACHER
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HANK ADAMS

## Desert Tortoise Council
## 1996 Certificates of Accomplishment

TOM EGAN, Bureau of Land Management — Land acquisition, conservation

JANET EUBANKS, Bureau of Land Management — Land acquisition

SCOTT EUBANKS, Bureau of Land Management — Land acquisition

TOM GEY, Bureau of Land Management — Land acquisition

CAROLYN KAMEEN, National Biological Service — Support services for conservation and symposium

## Desert Tortoise Council Symposium
## Best Student paper 1996
## (A Three-way Tie)

MATT BROOKS — *Testing hypotheses on wildland burns*

GRACE S. MCLAUGHLIN — *Natural transmission of URTD: horizontal, vertical, or both?*

E. KAREN SPANGENBERG — *Influence of field enclosures on activities, microhabitat use, and survivorship of juvenile tortoises*