Draft Revised Recovery Plan

for the

Mojave Population of the Desert Tortoise

(*Gopherus agassizii*)

October 16, 2007

Agency/Stakeholder Review Draft

Note that this is a preliminary, courtesy-review draft of a working document. Comments are solicited to help craft the final draft recovery plan prior to formal public comment.

Disclaimer

Recovery plans delineate reasonable actions that are believed to be required to recover and protect listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes with the assistance of recovery teams, contractors, State agencies, Tribal agencies, and other affected and interested parties. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific actions and may not represent the views nor the official positions or approval of any individuals or agencies involved in recovery plan formulation, other than our own. They represent our official position *only* after they have been signed by the Regional Director or Director as *approved*. Recovery plans are reviewed by the public and submitted to peer review before we adopt them as approved final documents. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

LITERATURE CITATION OF THIS DOCUMENT SHOULD READ AS FOLLOWS:

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Plan Preparation

This Recovery Plan was prepared by our Desert Tortoise Recovery Office in coordination with the Desert Tortoise Science Advisory Committee, the U.S. Institute for Environmental Conflict Resolution, the Center for Collaborative Policy, the Redlands Institute at the University of Redlands, and two Desert Tortoise Management Oversight Group recovery planning workgroups.

Desert Tortoise Recovery Office
Roy C. Averill-Murray, Jody Fraser, Kimberleigh Field, Linda Allison, Sandy Marquez

Science Advisory Committee
Kristin Berry, U.S. Geological Survey; Peter Hudson, Penn State University; Earl McCoy, University of South Florida; Katherine Ralls, Smithsonian Institution; Michael Reed, Tufts University; Robert Steidl, University of Arizona; C. Richard Tracy, University of Nevada-Reno.

U.S. Institute for Environmental Conflict Resolution
Mike Eng, Joan Calcagno, Pat Lewis

Center for Collaborative Policy
Austin McInerny, Greg Bourne, Dale Schafer

Redlands Institute
Jordan Henk, Lisa Benvenuti, Paul Burgess, Monica Hally, Thomas Leuteritz, Naicong Li, Philip Murphy (Infoharvest), Serene Ong, Nathan Strout

Arizona-Nevada-Utah Working Group
Arizona Game and Fish Department: Cristina Jones
Bureau of Land Management: Bob Douglas, Elroy Masters, Richard Spotts
Clark County: Marci Henson, Sue Wainscott
Lake Mead National Recreation Area: Ross Haley
Mohave County: Buster Johnson
Nevada Department of Wildlife: Polly Conrad, Cris Tomlinson
Quadstate County Government Coalition: Bill Lamb
University of Arizona: Rob Grumbles
University of Nevada-Reno: Maria Ryan
Southern Utah University: Nicole Frey
U.S. Fish and Wildlife Service: Michael Burroughs, Renee Chi, Jeff Servoss
U.S. Geological Survey: Phil Medica
Utah Division of Wildlife Resources: Ann McLuckie
Washington County: Bill Mader

California Working Group
Bureau of Land Management: Mark Massar, Russell Scofield
California Department of Fish and Game: Rebecca Jones

Joshua Tree National Park: Paul DePrey
Mojave Desert Ecosystem Program: Clarence Everly
Mojave National Preserve: Larry Whalon
Quadstate County Government Coalition: Gerry Hillier
University of California-Davis: Karl MacArthur
U.S. Fish and Wildlife Service: Brian Croft
U.S. Geological Survey: Kristin Berry
U.S. Marine Corps: Brian Henen, Manual Joia

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Bureau of Indian Affairs: David Wooten
Bureau of Land Management: S. Borchard, S. Florence, M. Herder, L. LaPre, E. Lorentzen, C. Ronning
Clark County: T. Wheaton
Defenders of Wildlife: M. Skuja, C. Wilkerson
Edwards Air Force Base: S. Collis, M. Hagan, D. Reinke, R. Wood
Mojave National Preserve: D. Hughson
Off Road Business Association: J. McGarvie
U.S. Fish and Wildlife Service: R. Bransfield, P. Henson, J. Hohman, J. Krueger, J. Rorabaugh, A. Salveter, S. Spangle, R. Williams
T. Egan

Executive Summary

CURRENT SPECIES STATUS

The Mojave population of the desert tortoise (*Gopherus agassizii*) (all tortoises north and west of the Colorado River in Arizona, Utah, Nevada, and California) was listed as Threatened on April 2, 1990. A recovery plan was published in June 1994 together with a supplement identifying proposed Desert Wildlife Management Areas. The species has a recovery priority number of 5C, which, determined in accordance with the Recovery Priority Criteria, is based on a high degree of threat; a low potential for recovery, based on current uncertainties about various threats and our ability to manage them; taxonomic classification as a species; and potential conflict with development or other forms of economic activity (U.S. Fish and Wildlife Service 1983).

HABITAT REQUIREMENTS AND LIMITING FACTORS

Desert tortoises occupy a variety of habitats from flats and slopes dominated by creosote bush (*Larrea tridentata*) scrub at lower elevations to rocky slopes in blackbrush (*Coleogyne ramossissima*) and juniper (*Juniperus* spp.) woodland ecotones at higher elevations. Desert tortoises occur from below sea level to an elevation of 2,225 meters (7,300 feet). Throughout most of the Mojave Desert, tortoises occur most commonly on gently sloping terrain with sandy-gravel soils and where there is sparse cover of low-growing shrubs, which allows establishment of herbaceous plants. Soils must be friable enough for digging of burrows, but firm enough so that burrows do not collapse. Optimal habitat for the desert tortoise in the Mojave Desert has been characterized as creosote bush scrub where precipitation ranges from 5 to 20 centimeters (2 to 8 inches), the diversity of perennial plants is relatively high, and production of ephemerals is high.

The vast majority of threats to the desert tortoise or its habitat are associated with human land uses. Since the 1994 Recovery Plan was published, research with regard to many of these issues has provided substantive information relative to individual threats, but few of the implicit correlations between threats and declining desert tortoise populations have been further established or solidified. A “silver bullet” has not been identified to suggest that a particular threat, or a subset of the threats, can be targeted for desert tortoise recovery to the exclusion of attention to other threats. The assessment of the 1994 Recovery Plan emphasized the need for a greater appreciation of the implications of multiple, simultaneous threats facing tortoise populations and a better understanding of the relative contribution of multiple threats on demographic factors. The approach of focusing on *individual* threats may not have produced expected gains toward desert tortoise recovery since 1994 because multiple threats act simultaneously to suppress tortoise populations at any given location within the species’ range. However, determining the relative importance of different threat factors and how these factors work synergistically is challenging. Elucidating cause and effect relationships is particularly difficult with long-lived, relatively uncommon species. We continue, however, to gain insight and knowledge with respect to many of the threats that are thought to influence desert tortoise populations.

RECOVERY STRATEGY

The recovery strategy consists of a multi-faceted approach with several key elements:

1. Implement a formal adaptive management program through which information gained while implementing the following strategic elements is used to revise and improve the recovery plan and recommend management actions on a regular basis;

2. Protect and manage existing populations and habitat, instituting habitat restoration where necessary;

3. Augment depleted populations through a strategic program;

4. Monitor progress toward recovery;

5. Conduct applied research and modeling in support of recovery efforts within a strategic framework; and

6. Develop, support, and build partnerships to facilitate recovery.

RECOVERY GOALS, OBJECTIVES, AND CRITERIA

The goal of the recovery plan is recovery and delisting of the desert tortoise. For the desert tortoise to be recovered, the recovery criteria must be met within each recovery unit. Delisting by recovery unit or another subset of the species will not occur unless distinct population segments (or another "significant portion of the range") are subsequently designated by a formal rule-making process.

Recovery Objective 1 (Demography). Maintain self-sustaining populations of desert tortoises within each recovery unit into the future.

> **Recovery Criterion 1.** Rates of population change (λ) for desert tortoises within each recovery unit are increasing over 25 years (a single tortoise generation).
>
> > Recovery Criterion 1a. The lower 90 percent confidence limit for each recovery unit estimate of λ based on data from range-wide monitoring efforts exceeds 1. All size classes of tortoises must be well represented to ensure adequate recruitment.
> >
> > Recovery Criterion 1b. The lower 90 percent confidence limit for each estimate of λ based on data from vital rates (recruitment, survival) from demographic study areas within each recovery unit exceeds 1.

Recovery Objective 2 (Distribution). Maintain well-distributed populations of desert tortoises throughout each recovery unit.

> **Recovery Criterion 2.** Distribution of desert tortoises throughout each recovery unit is increasing over 25 years. The lower 90 percent confidence limit for the slope of the trend of the proportion of sites occupied (ψ) within each recovery unit exceeds 0.

Recovery Objective 3 (Habitat). Ensure that habitat within each recovery unit is protected and managed to support long-term viability of desert tortoise populations.

> **Recovery Criterion 3a.** Unless or until tortoise population viability is ensured, the quantity of desert tortoise habitat within all existing desert tortoise conservation areas is maintained with no net loss.

> **Recovery Criterion 3b.** The condition of desert tortoise habitat within each recovery unit is demonstrably improving.

Recovery Objective 4 (Threats). Threats to the viability of desert tortoise populations are mitigated sufficiently to ensure persistence of the species within each recovery unit.

> **Recovery Criterion 4.** Knowledge of, and abatement strategies for, threats to desert tortoise populations are sufficient to determine that these threats do not cumulatively place the species at risk of becoming endangered in the foreseeable future. Management plans or cooperative agreements have been implemented within each recovery unit to ensure maintenance of Recovery Criteria 1 through 3. Each plan or agreement must contain:
>
> a) explicit management actions to address threats to the persistence of desert tortoise populations within that recovery unit;
>
> b) strategies to ensure that the management plan is evaluated and revised regularly based on new information collected through targeted research;
>
> c) a system to track the implementation of management actions; and
>
> d) assurances that the plan will continue to be implemented.

RECOVERY ACTIONS

The desert tortoise is a wide-ranging species inhabiting a large geographic range; therefore, recovery actions will be tailored to regional ecological and socio-political conditions within each recovery unit. The top-level recovery actions are as follows:

1. Implement an adaptive management program.
   1.1 Revise and continue development of a recovery decision support system.

1.2 Revise recovery tasks in coordination with Recovery Implementation Teams and the Desert Tortoise Management Oversight Group as pertinent new information becomes available.
1.3 Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions.
1.4 Incorporate scientific advice for recovery through the Science Advisory Committee.

2. Protect and manage existing populations and habitat.
   2.1 Minimize human-associated mortality of desert tortoises.
   2.2 Reduce factors contributing to disease.
   2.3 Establish/continue environmental education programs.
   2.4 Increase law enforcement.
   2.5 Restrict, designate, close, and fence roads.
   2.6 Restore desert tortoise habitat.
   2.7 Install and maintain urban or other barriers.
   2.8 Sign and fence boundaries of sensitive or impacted areas.
   2.9 Secure lands/habitat for conservation.
   2.10 Restrict competitive off-highway vehicle events within desert tortoise habitat.
   2.11 Connect functional habitat.
   2.12 Manage mining.
   2.13 Manage landfills.
   2.14 Reduce raven predation on tortoises.
   2.15 Manage horses and burros.
   2.16 Manage livestock grazing.

3. Augment depleted populations through a strategic program.
   3.1 Develop protocols and guidelines for the augmentation program.
   3.2 Identify sites at which to implement population augmentation efforts.
   3.3 Obtain tortoises for use in augmentation efforts.
   3.4 Implement translocations in target areas to augment populations using a scientifically rigorous, research-based approach.

4. Monitor progress toward recovery.
   4.1 Monitor desert tortoise population growth.
   4.2 Monitor the extent of tortoise distribution in each recovery unit.
   4.3 Track changes in the quantity and quality of desert tortoise habitat over time.
   4.4 Quantify the presence and intensity of threats to the desert tortoise across the landscape.

5. Conduct applied research and modeling in support of recovery efforts within a strategic framework.
   5.1 Determine demographic characteristics of healthy desert tortoise populations.
   5.2 Determine factors that influence the distribution of desert tortoises.
   5.3 Conduct research on the restoration of desert tortoise habitat.

5.4 Improve models of threats (and threat mitigation) and desert tortoise demographics.
5.5 Conduct research on desert tortoise diseases and their effects on tortoise populations.

6. Develop, support, and build partnerships to facilitate recovery.
   6.1 Establish regional, inter-organizational Recovery Implementation Teams to coordinate implementation of recovery actions.

TOTAL ESTIMATED COST OF RECOVERY

The costs of recovery implementation provided below are rough estimates, and actual budgets will have to be determined through future planning efforts and as each task is undertaken. Cost estimates are unavailable for several actions, such as research, due to uncertainties in the scope and magnitude of the specific action. Recovery Implementation Teams should guide recovery action priorities and develop updated budget projections within each recovery unit through the use of an updated/improved decision support system.

Costs (thousands of dollars)

FY 1	FY 2	FY 3	FY 4	FY 5
8,735	8,595	8,470	8,470	8,470
Total estimated cost over 25 years				$160,240,000

DATE OF RECOVERY

If recovery actions are implemented promptly and are effective, recovery criteria could be met in no fewer than 25 years (approximately 2033).

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I. Background

INTRODUCTION

We, the United States Fish and Wildlife Service, listed the desert tortoise on the Beaver Dam Slope in Utah as Threatened under the Endangered Species Act of 1973, as amended, and designated critical habitat in 1980 (U.S. Fish and Wildlife Service [USFWS] 1980). In 1984, we were petitioned by the Defenders of Wildlife, Natural Resources Defense Council, and Environmental Defense Fund to list the species as Endangered. The following year, we determined that listing the desert tortoise as Endangered was warranted, but higher priorities precluded any action.

On August 4, 1989, new information on mortality resulted in the emergency listing of desert tortoises north and west of the Colorado River (excluding the Beaver Dam Slope) as Endangered (USFWS 1989). On April 2, 1990, we listed the entire Mojave population (all tortoises north and west of the Colorado River in Arizona, Utah, Nevada, and California) as Threatened (USFWS 1990), and a recovery plan was published in June 1994 (USFWS 1994a). Previously, the species had a recovery priority number of 8C, which, determined in accordance with the Recovery Priority Criteria, is based on a) moderate degree of threat, b) high potential for recovery, c) taxonomic classification as a species, and d) potential conflict with development or other forms of economic activity (USFWS 1983). Based on the updated information in this recovery plan, the recovery priority number is reclassified as 5C, which indicates a) a high degree of threat, which has increased since 1994; b) a low potential for recovery, based on current uncertainties about various threats and our ability to manage them; c) taxonomic classification as a species; and d) potential conflict with development or other forms of economic activity (USFWS 1983).

The 1994 Recovery Plan described a strategy for recovering the Mojave population of the desert tortoise, which included the identification of six recovery units, recommendations for a system of Desert Wildlife Management Areas (DWMAs) within the recovery units, and development and implementation of specific recovery actions, especially within DWMAs. Establishment of recovery units and DWMAs was intended, in part, to facilitate an ecosystem approach to land management and desert tortoise recovery, as stipulated by section 2(b) of the Endangered Species Act (USFWS 1994a).

In Arizona, both the Mojave and Sonoran populations of desert tortoise are considered Species of Greatest Conservation Need under Arizona's Comprehensive Wildlife Conservation Strategy: 2005-2015 (Arizona Game and Fish Department 2006). Desert tortoises are also protected under the Arizona Revised Statutes Title 17 laws and the Reptile and Amphibian Regulations 2007-2008, under which it has been unlawful to collect this species since 1989. In California, state laws have been in place since 1939 to protect the desert tortoise. The species was listed as Threatened under the California Endangered Species Act in 1989 and is considered a Species at Risk under California's Wildlife Action Plan (Bunn *et al.* 2006). The California Department of Fish and Game manages approximately 12,950 hectares (32,000 acres) of land for the conservation of the desert tortoise, and additional lands continue to be acquired as mitigation

for projects that result in impacts to the species. In Nevada, the desert tortoise is protected under the Nevada Administrative Code 503.080, wherein the species is listed as a State protected reptile further classified as threatened in Nevada, and collection is prohibited under section 503.093. The desert tortoise is also considered a Species of Conservation Priority under the Nevada Wildlife Action Plan (Abele *et al.* 2006), which is being implemented by the Nevada Department of Wildlife. Desert tortoises are listed as State Endangered in Utah, where collection and importation are prohibited. Possession is controlled, meaning one must have a Certificate of Registration prior to possession of an individual animal. The species is protected under the Utah Division of Wildlife Resources Administrative Rule R657-53 and is considered a Species of Greatest Conservation Need under the Utah Comprehensive Wildlife Conservation Strategy: 2005-2015 (Gorrell *et al.* 2005).

The U.S. General Accounting Office report, *Endangered Species: Research Strategy and Long-Term Monitoring Needed for the Mojave Desert Tortoise Recovery Program* (General Accounting Office [GAO] 2002), found that the listing decision, critical habitat designation, and recommendations in the recovery plan were reasonable, given the available information. However, the effectiveness of actions since taken by Federal agencies and others to benefit desert tortoises is unknown. Because much was still unknown about the severity of specific threats to desert tortoises at the time the plan was developed, its recommendations were made without establishing priorities that would reflect differences in the seriousness of the threats. The General Accounting Office recommended that we develop and implement a coordinated research strategy for linking land management decisions with research results. In response to the General Accounting Office report, we initiated a review of the 1994 Recovery Plan.

In March 2003, we impaneled the Desert Tortoise Recovery Plan Assessment Committee to conduct a thorough review of the Recovery Plan in the context of scientific and analytical advances made since its publication in 1994. The assessment (Tracy *et al.* 2004) identified strategies that would promote a more cohesive, scientifically powerful recovery program. Taking recommendations of the General Accounting Office report and 2004 assessment, we established the Desert Tortoise Recovery Office (DTRO). The DTRO was created to address population declines and focus on recovery of the species. The DTRO concentrates on research, monitoring, recovery plan implementation, and recovery permitting, rather than on regulatory issues, and serves as the central point of contact through which these activities are coordinated. The DTRO assists in the coordination between land managers and research scientists, the interagency Desert Tortoise Management Oversight Group, and the California Desert Managers Group, as well as other local, state, or regional working groups.

Together with the Desert Tortoise Management Oversight Group, we recognized that recommendations contained in the assessment and a subsequent stakeholder assessment (U.S. Institute for Environmental Conflict Resolution and Center for Collaborative Policy 2006) would benefit the recovery plan revision process through the collaboration of scientists, managers, and stakeholders. Thus, a collaborative effort resulted in this revised recovery plan for the Mojave population of the desert tortoise.

SPECIES DESCRIPTION AND TAXONOMY

The desert tortoise is a large, herbivorous reptile that occurs in the Mojave and Sonoran deserts in southern California, southern Nevada, Arizona, the southwestern tip of Utah, and Sonora and northern Sinaloa, Mexico. The designated Mojave population of the desert tortoise includes those animals living north and west of the Colorado River in the Mojave Desert of California, Nevada, Arizona, and southwestern Utah, and in the Sonoran (Colorado) Desert in California (USFWS 1990; USFWS 1994a).

The generic assignment of the desert tortoise has gone through a series of changes since its original description by Cooper (1863) as *Xerobates agassizii*. It has also been referred to in the literature as *Scaptochelys agassizii*. Currently, the accepted scientific name is *Gopherus agassizii* (Campbell 1988; Crumly 1994). Differentiation between the Mojave and Sonoran assemblages of the desert tortoise are supported via multiple forms of evidence (Weinstein and Berry 1987; Lamb *et al.* 1989; Lamb and Lydehard 1994; Berry *et al.* 2002; Van Devender 2002a). Recent data also support the hypothesis that the two assemblages are separate species (Murphy *et al.* submitted; Berry *et al.* 2002; Van Devender 2002b). Although fewer data are available to compare Sinaloan desert tortoises to the Sonoran and Mojave assemblages, the Sinaloan population is considerably more isolated, and differentiation in mitochondrial DNA is considerable (Lamb *et al.* 1989; Van Devender 2002b).

Desert tortoises reach 20 to 38 centimeters (8 to 15 inches) in carapace length and 10 to 15 centimeters (4 to 6 inches) in shell height. Hatchlings emerge from eggs at about 5 centimeters (2 inches) in length. Adults have a domed carapace and relatively flat, unhinged plastrons. Their shells are high-domed and greenish-tan to dark brown in color with tan scute centers. Adult desert tortoises weigh 3.6 to 6.8 kilograms (8 to 15 pounds). The forelimbs have heavy, claw-like scales and are flattened for digging. Hind limbs are more elephantine (Ernst *et al.* 1994).

Two other tortoise species in the genus *Gopherus* occur in the United States, and another occurs in Mexico. The Texas tortoise (*Gopherus berlandieri*) occurs in southern Texas and northeastern Mexico, and the gopher tortoise (*Gopherus polyphemus*) occurs in southwestern South Carolina, Florida, Georgia, Alabama, Mississippi, Louisiana, and extreme southeastern Texas. The fourth species is the Bolson tortoise (*Gopherus flavomarginatus*), which is found in a very small area in Chihuahua and Durango, Mexico. The desert tortoise is distinguished from the other three species by a combination of characters that are described in detail in the final listing rule and 1994 Recovery Plan (USFWS 1990; USFWS 1994a). For additional information regarding the morphological characteristics and distinguishing features of these species, refer to Ernst *et al.* (1994) and the references cited therein.

Desert tortoises that belong to the Sonoran population could be confused with tortoises of the Mojave population. Because there are only minor visual differences between the animals in these populations, we determined at the time of listing that the Sonoran population also warranted protection as a threatened species under section 4(e) of the Endangered Species Act (similarity of appearance) when located outside of its natural range.

This level of protection would eliminate the need for law enforcement personnel to determine the origin of each individual when conducting enforcement activities under section 9 of the Endangered Species Act (USFWS 1990).

POPULATION TRENDS AND DISTRIBUTION

The Mojave population of the desert tortoise includes those animals living north and west of the Colorado River in the Mojave Desert of California, Nevada, Arizona, and southwestern Utah, and in the Sonoran (Colorado) Desert in California. This region has been the focus of most early research on desert tortoises (see Tracy *et al.* 2004). Studies in this early period focused on basic biology and demography, and were largely centered in areas with high densities of tortoises. These high-density areas were used to establish permanent (long-term) study plots that have been researched at various intervals through the present while some low-density plots were discontinued (Berry 1984; K. Berry, U.S. Geological Survey, pers. comm. 2003, as reported in Tracy *et al*. 2004). While a substantial body of data has been collected from long-term study plots and other survey efforts over the years, the nature of their placement is generally regarded as a factor limiting demographic and trend conclusions only to those specific areas. Tracy *et al.* (2004) concluded that estimating precise long-term trends of desert tortoise populations, habitat, and/or threats was not feasible based on the combined suite of existing data and analyses. Instead, these data provide general insight into the range-wide status of the species, but show appreciable declines at the local level in many areas (Luke *et al.* 1991; Berry 2003; Tracy *et al.* 2004).

Tracy *et al.* (2004) evaluated the data amassed between 1979 and 2002 from permanent study plots throughout the range of the species, including available density estimates, associated confidence limits, and survey methods. This evaluation revealed differences between survey protocols, *i.e.*, not all plots were sampled in all years, and not all data were calculated or collected for plots that were sampled in some years. Other confounding factors included plot locations that do not correspond to a design addressing specific hypotheses about management actions or threats and non-random plot locations within larger regional areas. Considering the above caveats, Tracy *et al.* (2004) used existing long-term data to explore regional and recovery-unit-level analyses, and to develop within-population spatial analyses at various scales on the landscape and in different management units. For the trend analyses, permanent study plots were treated as random samples across the region, and a weighted general linear model to derive more precise density estimates was developed.

Tracy *et al.* (2004) concluded that the apparent downward trend in desert tortoise populations in the western portion of the range that was identified at the time of listing is valid and ongoing. Results from other portions of the range were inconclusive, but recent surveys of some populations found too few tortoises to even produce population estimates, suggesting that declines may have occurred more broadly. The analyses also suggest that trend estimates using study plots (as opposed to line distance transects) are not likely to have sufficient power to detect subtle trends in populations and more extensive transect sampling is necessary to support a robust research and monitoring program and supplement the existing dataset.

In an attempt to refine the long-term monitoring program for the desert tortoise, annual range-wide population monitoring using line distance transects began in 2001 and is the most comprehensive effort undertaken to date to ascertain densities across the range of the species (USFWS 2006a). The monitoring program is designed to detect long-term population trends, so density estimates from any brief time period (*e.g.*, 2001 to 2005) would be expected to detect only catastrophic declines or remarkable population increases. Therefore, following the first 5 years of the long-term monitoring project, the goal was not to document trends within this time period, but to gather information on baseline densities and annual and regional (between recovery unit) variability. This baseline information can also be used to refine the monitoring design because it includes estimates for transect-to-transect variability in tortoise counts as well as regional variability in detection functions (USFWS 2006a).

Total length of transects surveyed ranged between about 2,977 kilometers (1,850 miles) in 2001 to 8,851 kilometers (5,500 miles) in 2005, with variation between years resulting from changes in survey technique and available funding. Density estimates of adult tortoises varied among recovery units and years. Only if this variability is associated with consistent changes between years will intermediate-length monitoring (*i.e.*, less than 25 years) describe important trends. For instance, considerable decreases in density were reported in 2003 in the Eastern Colorado and Western Mojave recovery units, with no correspondingly large rebound in subsequent estimates (Table 1). This will not be interpretable until we have more years of information on underlying variability that may affect our interpretation of these first years of data. Over the first 5 years of monitoring, tortoises were least abundant in the Northeast Mojave Recovery Unit (0.84 to 3.01 tortoises/kilometer^2 [2.18 to 7.80 tortoises/mile^2]; USFWS 2006a), and the highest reported densities occurred in the Upper Virgin River Recovery Unit (16.88 to 30.11 tortoises/kilometer^2 [43.72 to 77.98 tortoises/mile^2]; McLuckie *et al.* 2007).

Distributional patterns are available from preliminary spatial analyses in Tracy *et al.* (2004). Their analyses revealed areas with higher probabilities of encountering both live and dead tortoises. In the western Mojave, concentrations of dead tortoises without corresponding concentrations of live tortoises generally correspond to the same areas where declines have been observed in the past, namely the northern portion of the Fremont-Kramer critical habitat unit and the northwestern part of the Superior-Cronese critical habitat unit. Limited data revealed large areas where dead tortoises, but no live tortoises, were found in the Piute-Eldorado Valley and northern Coyote Springs Valley, Nevada, and the western and southern portions of the Ivanpah Valley critical habitat unit. Most other recently sampled areas (mostly within critical habitat) reveal continued tortoise presence, although local population declines are known within some of these areas, such as the Beaver Dam Slope, Arizona.

Collectively, these analyses, based on different combinations of data, suggest that implementation of specific management actions over time has not abated declines of, or resulted in detectable increases in, desert tortoise populations across much of the range. The evidence of localized declines has not been offset by detectable increases in numbers of individuals or higher densities. The life history of the species (*i.e.*, delayed reproductive maturity, low reproductive rates, and relatively high mortality early in life) means that observing relatively rapid increases in populations is highly unlikely, even over the 23-year monitoring period evaluated. In addition,

threats that are difficult to manage, such as disease and invasion of habitats by non-native invasive species, probably have large negative effects on populations, and desert ecosystems may require extended time for natural recovery once impacts are removed.

Please refer to the *Desert Tortoise Recovery Plan Assessment* (Tracy *et al.* 2004) for a detailed description of the population trend and distribution analyses described above. In addition, *Range-wide Monitoring of the Mojave Population of the Desert Tortoise: 2001-2005* (USFWS 2006a) provides information regarding the current monitoring effort.

Table 1. Summary of density estimates for each of the 1994-designated recovery units. "Adult tortoises" is the number of adults and subadults (midline carapace length ≥180mm). See USFWS (2006a) for additional details.

Recovery Unit	Year	No. of Transects	Length (km)	Adult Tortoises	Encounter Rate	Std Error	Density (km^2)	Std Error	Coefficient of Variation (%)	95% Confidence Interval	
										Low	High
Northeast Mojave	2001	136	254.8	9	0.035	0.012	2.32	0.786	34.0	1.20	4.45
	2002	75	293.2	3	0.010	0.006	0.84	0.476	56.6	0.29	2.40
	2003	189	699.2	39	0.056	0.008	3.01	0.465	15.4	2.22	4.08
	2004	96	947.3	18	0.019	0.004	1.42	0.342	24.2	0.88	2.27
	2005	166	1754.4	40	0.023	0.004	2.15	0.400	18.6	1.50	3.10
Eastern Mojave	2001	224	371.6	17	0.046	0.012	3.00	0.784	26.2	1.81	4.98
	2002	284	1120.4	56	0.050	0.008	4.11	0.797	17.0	2.94	5.72
	2003	59	215.1	11	0.051	0.016	2.76	0.874	31.7	1.49	5.12
	2004	140	1511.2	113	0.075	0.010	5.57	0.750	13.4	4.28	7.26
	2005	165	1839.5	108	0.059	0.006	5.54	0.656	11.8	4.39	6.99
Eastern Colorado	2001	205	328.0	54	0.165	0.025	10.80	1.712	15.9	7.91	14.73
	2002	104	416.7	42	0.101	0.019	8.28	1.670	20.2	5.58	12.30
	2003	108	431.7	32	0.074	0.014	4.00	0.774	19.3	2.74	5.85
	2004	132	1414.0	102	0.072	0.009	5.38	0.684	12.7	4.18	6.91
	2005	91	1094.3	74	0.068	0.011	6.38	1.062	16.6	4.60	8.86
Northern Colorado	2001	201	321.6	39	0.121	0.020	7.95	1.390	17.5	5.65	11.19
	2002	–	–	–	–	–	–	–	–	–	–
	2003	112	445.2	54	0.121	0.020	6.55	1.122	17.1	4.67	9.17
	2004	76	835.9	79	0.095	0.014	7.04	1.099	15.6	5.17	9.59
	2005	94	1128.8	94	0.083	0.010	7.86	1.005	12.8	6.11	10.12
Western Mojave	2001	865	1384.0	160	0.116	0.010	7.58	0.710	9.4	6.31	9.11
	2002	547	2176.8	188	0.086	0.008	7.10	0.756	10.6	5.77	8.73
	2003	522	2083.2	218	0.105	0.008	5.65	0.499	8.8	4.75	6.72
	2004	166	1867.9	133	0.071	0.008	5.31	0.663	12.5	4.15	6.78
	2005	229	2746.6	173	0.063	0.006	5.95	0.612	10.3	4.86	7.28

Table 1. Continued.

Recovery Unit	Year	Transects	Length (km)	Adult Tortoises	Encounter Rate	Std Error	Density (km^2)	Std Error	Coefficient of Variation (%)	95% Confidence Interval	
										Low	High
Upper Virgin River[1]	2001	159	313.8	168	0.535	0.069	30.11	4.16	13.83	22.95	39.51
	2002	–	–	–	–	–	–	–	–	–	–
	2003	157	309.1	96	0.311	0.038	16.88	2.17	12.84	13.11	21.72
	2004	–	–	–	–	–	–	–	–	–	–
	2005	155	304.5	136	0.45	0.05	21.77	3.17	14.57	16.36	28.95

[1]Data from McLuckie *et al.* (2007).

LIFE HISTORY AND ECOLOGY

Desert tortoises are well adapted to living in a highly variable and often harsh desert environment. They spend much of their lives in burrows, emerging in late winter or early spring. They typically remain active through the spring and often emerge again after summer storms. Mating occurs both during spring and fall (Black 1976; Rostal *et al.* 1994). During activity periods, desert tortoises eat a wide variety of herbaceous vegetation, particularly grasses and the flowers of annual plants (Berry 1974; Luckenbach 1982; Esque 1994). During periods of inactivity, they reduce their metabolism and water loss and consume very little food. Adult desert tortoises lose water at such a slow rate that they can survive for more than a year without access to free water of any kind and can apparently tolerate large imbalances in their water and energy budgets (Nagy and Medica 1986; Peterson 1996a,b; Henen *et al.* 1998).

The size of desert tortoise home ranges varies with respect to location and year (Berry 1986) and also serves as an indicator of resource availability and opportunity for reproduction and social interactions (O'Connor *et al.* 1994). Females have long-term home ranges that are approximately half that of the average male, which range from 10 to 80 hectares (25 to 200 acres) (Burge 1977; Berry 1986). Over its lifetime, each desert tortoise may require more than 3.9 square kilometers (1.5 square miles) of habitat and may make forays of more than 11 kilometers (7 miles) at a time (Berry 1986).

In drought years, the ability of tortoises to drink while surface water is available following rains may be crucial for survival (Nagy and Medica 1986). During unfavorable periods, desert tortoises decrease surface activity and remain mostly inactive or dormant underground (Duda *et al.* 1999), which reduces water loss and minimizes energy expenditures (Nagy and Medica 1986). Duda *et al.* (1999) showed that home range size, number of different burrows used, average distances traveled per day, and levels of surface activity were significantly reduced during drought years.

Tortoises are long-lived and grow slowly, requiring 13 to 20 years to reach sexual maturity, and have low reproductive rates during a long period of reproductive potential (Turner *et al.* 1984; Bury 1987; Germano 1994). The number of eggs as well as the number of clutches that a female desert tortoise can produce in a season is dependent on a variety of factors including environment, habitat, availability of forage and drinking water, and physiological condition (Turner *et al.* 1986, 1987; Henen 1997; McLuckie and Fridell 2002). Success rate of clutches has proven difficult to measure, but predation appears to play an important role in clutch failure (Germano 1994). Bjurlin and Bissonette (2004) found that nest predation was highly variable. They surmised that the regular presence of researchers may facilitate predator detection of desert tortoises and that systematic studies should be undertaken to better understand predator behavior as it relates to research activities (Bjurlin and Bissonette 2004).

The most complete account of the biology, ecology, and natural history of the desert tortoise is that of Woodbury and Hardy (1948), wherein details regarding reproduction, growth and development, longevity, food habits, behavior, movement patterns, and general adaptations to desert conditions are provided for a population on the Beaver Dam Slope of Utah. Further

information on the range, biology, and ecology of the desert tortoise is also available in Bury *et al.* (1994), Ernst *et al.* (1994), Van Devender (2002c), and collected papers in Chelonian Conservation and Biology (2002, Vol. 4, No. 2).

HABITAT CHARACTERISTICS

The desert tortoise occurs in the broadest latitudinal range, climatic regimes, habitats, and biotic regions of any North American tortoise species (Auffenberg and Franz 1978; Bury 1982; Patterson 1982; Bury *et al.* 1994; Germano 1994). The species occupies a variety of habitats from flats and slopes dominated by creosote bush (*Larrea tridentata*) scrub at lower elevations to rocky slopes in blackbrush (*Coleogyne ramossissima*) and juniper (*Juniperus* spp.) woodland ecotones at higher elevations (Bury *et al.* 1994). Desert tortoises occur from below sea level to an elevation of 2,225 meters (7,300 feet) (Luckenbach 1982). Luckenbach (1982) also states that the most favorable habitat occurs at elevations of approximately 305 to 914 meters (1,000 to 3,000 feet); however, based on current information and data from recent range-wide monitoring efforts, the species has consistently been documented above 914 meters (3,000 feet) and as far as 1,493 meters (4,900 feet) at the Nevada Test Site (USFWS 2006a; USFWS unpublished data).

Throughout most of the Mojave Desert, tortoises occur most commonly on gently sloping terrain with sandy-gravel soils and where there is sparse cover of low-growing shrubs, which allows establishment of herbaceous plants (Germano *et al.* 1994; USFWS 1994a). Soils must be friable enough for digging burrows, but firm enough so that burrows do not collapse (USFWS 1994a). During the winter, tortoises will opportunistically use burrows of various lengths, deep caves, rock and caliche crevices, or overhangs for cover (Bury *et al.* 1994). Optimal habitat for the desert tortoise in the Mojave Desert has been characterized as creosote bush scrub in which precipitation ranges from 5 to 20 centimeters (2 to 8 inches), where a diversity of perennial plants is relatively high, and production of ephemerals is high (Luckenbach 1982; Turner 1982; Turner and Brown 1982; Germano *et al.* 1994).

The Mojave Desert is relatively rich in winter annuals, which serve as an important food source for the desert tortoise. Tortoises will also forage on perennial grasses, woody perennials, and cacti as well as non-native species such as red brome (*Bromus rubens*) and red-stem filaree (*Erodium cicutarium*). Ninety percent of the precipitation that facilitates germination of important forage species for desert tortoise occurs in winter and sometimes in the form of snow (Germano *et al.* 1994). Tortoises in the eastern Mojave Desert are more likely to be subjected to freezing temperatures in winter and prolonged drought than tortoises in the Sonoran Desert and Sinaloan region where freezing temperatures are rare and rainfall is more predictable (Germano 1994).

The U.S. Geological Survey is developing a habitat model for most of the Mojave Desert north and west of the Colorado River using 16 environmental variables such as precipitation, geology, vegetation, and slope (Fig. 1). The model is based on desert tortoise occurrence data from sources spanning more than 80 years, especially including data from the 2001 to 2005 range-wide monitoring surveys (USFWS 2006a), using 3,753 tortoise presence points to develop the model and 938 points to test the model. The final model is expected to be available soon and will contribute substantially to management efforts.

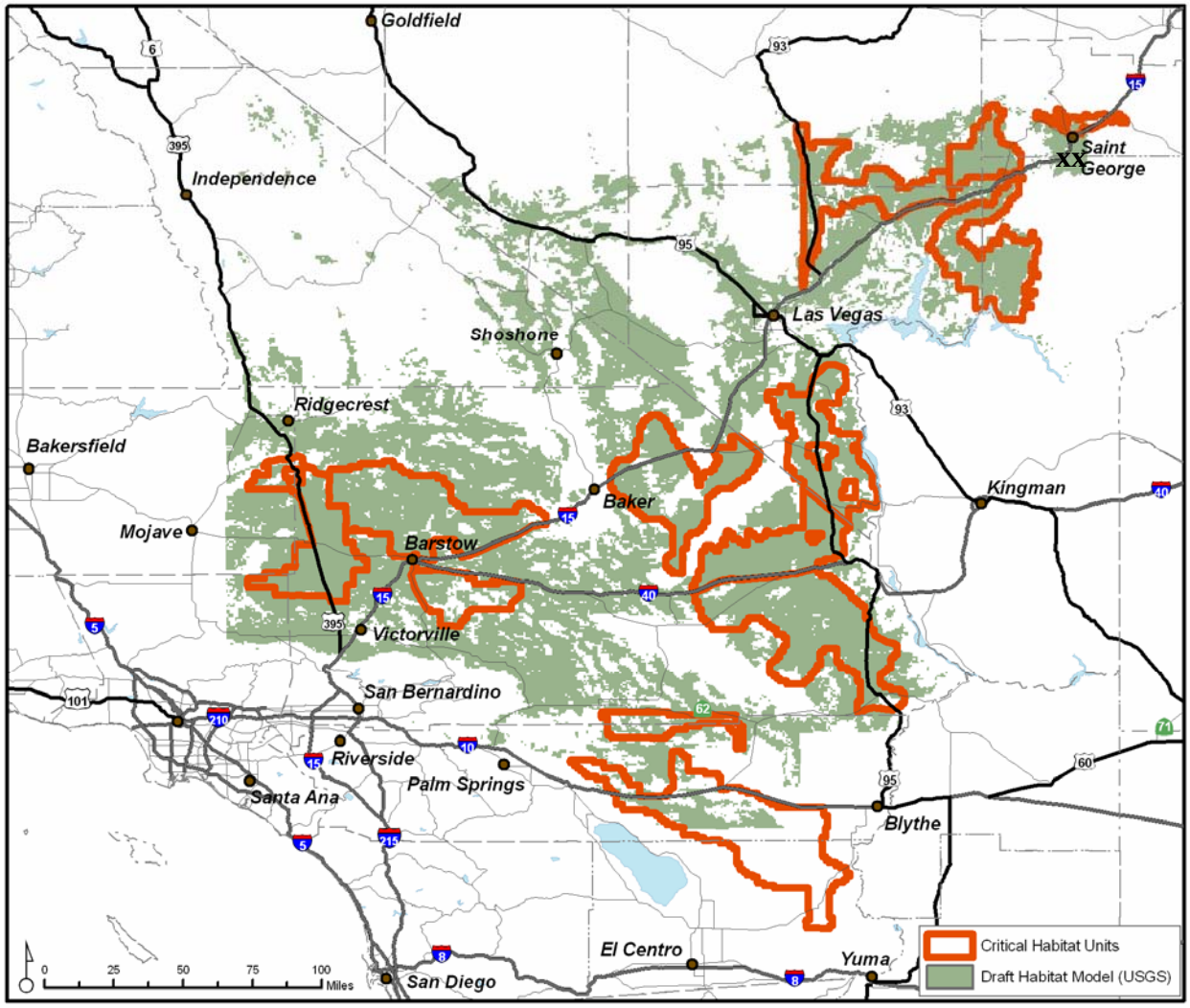

Figure 1. Draft U.S. Geological Survey habitat model. xx indicates an area described by the model but known not to support desert tortoises (Bury *et al*. 1994). Note that areas in the southern, western, and extreme northeastern ends of the range were not included in the habitat model, and the model does not reflect urbanization or other anthropogenic habitat modifications.

The desert tortoise's range, outside the listed Mojave population, extends into the Sonoran Desert, where tortoises occur in the lower Colorado River valley, Arizona uplands, plains of Sonora, and the central Gulf Coast; the species has not been documented in northeastern Baja California (Germano *et al.* 1994). As in the Mojave Desert, creosote bush is a dominant species, although this dominance is tempered by the relatively high abundance of several tree species (Turner and Brown 1982; Germano *et al.* 1994). In the Sonoran Desert, tortoises tend to inhabit the bajadas and rocky slopes and are not common in the valleys (Germano 1994; Averill-Murray and Averill-Murray 2005). Desert tortoises are also found in the Sinaloan thornscrub, which is a transitional habitat between the Sonoran Desert and Sinaloan deciduous forest where the vegetation is dominated by drought-resistant shrubs and deciduous trees. The Sinaloan deciduous forests are differentiated from the thornscrub by taller plants with larger leaves and fewer thorny or succulent species (Germano *et al.* 1994; Fritts and Jennings 1994).

CRITICAL HABITAT

Under section 3 of the Endangered Species Act, critical habitat is defined as the specific areas that have been deemed necessary for the conservation of the species, that support the primary constituent elements required for the species survival, and that may require special management considerations or protection. The 1994 Recovery Plan identified general areas as proposed Desert Wildlife Management Areas where recovery efforts for the desert tortoise would be focused (Brussard *et al.* 1994; USFWS 1994a). Based on the draft recovery plan, we designated critical habitat on February 1994, encompassing over 2,428,114 hectares (6,000,000 acres) in portions of the Mojave and Colorado deserts (Fig. 1; Table 2). This designation includes primarily Federal lands in southwestern Utah, northwestern Arizona, southern Nevada, and southern California (USFWS 1994b).

Table 2. Critical habitat by state and land ownership in hectares (1 hectare=2.47 acres) (Brannon 2000).

State **Management**	**Arizona**	**California**	**Nevada**	**Utah**	**Total**
Bureau of Land Management	116,691	1,024,356	451,146	35,521	1,627,714
National Park Service	17,241	360,931	39,453	0	417,625
Bureau of Reclamation	71	0	1,519	0	1,590
Forest Service	0	0	0	18	18
Department of Defense	0	156,347	168	0	156,515
Tribal Land	0	0	0	797	797
State Land	0	4,133	0	1,574	5,707
Fish and Game	3,067	19,677	13	8,383	31,140
Private Land	940	290,063	1,509	5,789	298,301
Water	117	0	310	0	427
Total	138,127	1,855,507	494,118	52,082	2,539,834

Primary constituent elements for the desert tortoise are those physical and biological attributes that are necessary for the long-term survival of the species. At the time critical habitat was designated, these elements were identified as sufficient space to support viable populations within each of the six recovery units and provide for movement, dispersal, and gene flow; sufficient quantity and quality of forage species and the proper soil conditions to provide for the growth of such species; suitable substrates for burrowing, nesting, and overwintering; burrows, caliche caves, and other shelter sites; sufficient vegetation for shelter from temperature extremes and predators; and habitat protected from disturbance and human-caused mortality (USFWS 1994b).

Glossary of terminology relating to desert tortoise habitat:

Desert Wildlife Management Areas (DWMA) - General areas recommended by the 1994 Recovery Plan within which recovery efforts for the desert tortoise would be concentrated. DWMAs had no specific legal boundaries in the 1994 Recovery Plan. The Bureau of Land Management formalized the general DWMAs from the 1994 Recovery Plan through its planning process and administers them as Areas of Critical Environmental Concern (see below).

Critical Habitat – Specific, legally defined areas that have been deemed necessary for the conservation of the desert tortoise, that support the primary constituent elements required for desert tortoise survival, and that may require special management considerations or protection. Critical habitat for the desert tortoise was designated in 1994, largely based on proposed DWMAs in the draft Recovery Plan.

Area of Critical Environmental Concern (ACEC) – Specific, legally defined, public land designation where special management is needed to protect and prevent irreparable damage to important historical, cultural, scenic values, fish and wildlife, and natural resources (in this case, the desert tortoise) or to protect life and safety from natural hazards. Designated critical habitat and ACEC boundaries generally, but not always, coincide along legal boundaries.

REASONS FOR LISTING AND CONTINUING THREATS

In determining whether to list, delist, or reclassify (change from endangered to threatened status, or *vice versa*) a taxon under the Endangered Species Act, we evaluate the role of five factors potentially affecting the species. These factors are:

A) The present or threatened destruction, modification, or curtailment of its habitat or range;

B) overutilization for commercial, recreational, scientific, or educational purposes;

C) disease or predation;

D) the inadequacy of existing regulatory mechanisms; and

E) other natural or manmade factors affecting its continued existence.

These factors are not always constant within or between populations, as the status of the species changes through time. Documented threats to the Mojave population of the desert tortoise were described in the final listing rule in 1990 as they pertain to the five listing factors (USFWS 1990) and in the 1994 Recovery Plan (USFWS 1994a).

The vast majority of threats to the desert tortoise or its habitat are associated with human land uses. Since the 1994 Recovery Plan was published, research with regard to many of these issues has provided substantive information relative to individual threats such as disease and

invasion of habitat by non-native invasive species, but few of the implicit correlations between threats and declining desert tortoise populations have been further established or solidified (Boarman 2002). A "silver bullet" has not been identified to suggest that a particular threat, or a subset of the threats, can be targeted for desert tortoise recovery to the exclusion of attention to other threats. The assessment of the 1994 Recovery Plan emphasized the need for a greater appreciation of the implications of multiple, simultaneous threats facing tortoise populations and a better understanding of the relative contribution of multiple threats on demographic factors (*i.e.*, birth rate, survivorship, fecundity, and death rate; Tracy *et al.* 2004). The approach of focusing on individual threats may not have produced expected gains toward desert tortoise recovery since 1994 because multiple threats act simultaneously to suppress tortoise populations at any given location within the species' range. However, determining the relative importance of different threat factors and how these factors work synergistically is challenging. Elucidating cause and effect relationships is particularly difficult with long-lived, relatively uncommon species. We continue, however, to gain insight and knowledge with respect to many of the threats that are thought to influence desert tortoise populations. The following provides a brief overview of the threats to the desert tortoise and its habitat as categorized by the five listing factors. A more detailed discussion of these threats is contained in Appendix A.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Since the 1800s, portions of the desert southwest occupied by desert tortoises have been subject to a variety of impacts that cause habitat loss, fragmentation, and degradation, thereby threatening the long-term survival of the species (USFWS 1994a). Some of the most apparent threats are those that result in mortality and permanent habitat loss across large areas, such as urbanization, and those that fragment and degrade habitats, such as proliferation of roads and highways, off-highway vehicle activity, grazing, and habitat invasion by non-native invasive species. Indirect impacts to desert tortoise populations and habitat are also known to occur in areas at their interface of intense human activity (Berry and Burge 1984; Berry and Nicholson 1984).

Another threat that has come to the forefront is the increased frequency of wildfire due to the invasion of desert habitats by non-native plant species. Changes in plant communities caused by alien plants and recurrent fire they support negatively affect the desert tortoise by altering habitat structure and species composition of their food plants (Brooks and Esque 2002). Off-highway vehicle activity, roads, grazing, agricultural uses, and other activities contribute to the spread of non-native species and the direct loss and degradation of habitats.

Land exchanges and transfers may result in loss of desert tortoise habitat, increased fragmentation, and displacement of resident desert tortoises, because habitat that is exchanged out of Federal ownership is at greater risk of development, a permanent negative impact on the new private holdings (Sievers *et al.* 1988). Energy and mineral development and extraction also pose a significant threat to desert tortoises through habitat loss and fragmentation (Lovich and Bainbridge 1999; Boarman 2002). In the California Desert, applications for solar energy facilities in 2007 total nearly 202,343 hectares (500,000 acres) because of an emphasis on

advancing alternative energy sources. In Nevada, energy development is also a potential threat, where a coal-fired power plant has been proposed north of Mesquite.

Landfills and other waste disposal facilities potentially affect desert tortoises and their habitat through fragmentation and permanent loss of habitat, spread of garbage, introduction of toxic chemicals, increased road kill of tortoises on access roads, and increased predator populations (Boarman 2002). Military operations that have taken place in the Mojave Desert since as early as 1859 can result in impacts to tortoises and their habitats and are often coupled with impacts associated with large human settlements (*i.e.*, illegal collection of tortoises, trash dumping, increased raven populations, domestic predators, off-highway vehicle use, increased exposure to disease, and increased mortality) (USFWS 1994a; Boarman 2002).

Other activites that may impact the species include non-motorized recreation such as camping, hunting, target shooting, rock collecting, hiking, horseback riding, biking, and sight-seeing. These activities bring with them many of threats associated with increased human presence, such as loss of habitat from development of recreational facilities, handling and disturbance of tortoises, increased road kill and vandalism of tortoises, increased raven predation, degradation of vegetation, and soil compaction (USFWS 1994a; Boarman 2002). Desert habitats are also disturbed by construction and maintenance of linear utility corridors and ancillary facilities and to some degree by vandalism and harvest of vegetation for personal or economic purposes.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Despite legal protection under Federal and State laws, vandalism and collection of desert tortoises by humans for food or as pets were cited as potential threats to the species, and commercial collecting was at one time considered significant (USFWS 1994a). While illegal collection of desert tortoises still occurs and such collection could possibly impact local populations, there is little quantitative evidence specific to this threat (Boarman 2002).

Research projects that will provide information to guide management and recovery of the desert tortoise but may result in loss of individuals and are permitted under section 10 of the Endangered Species Act. These permits include terms and conditions to minimize injury and mortality of individuals.

C. Disease or Predation

Two diseases have been implicated in negatively affecting desert tortoise populations: upper respiratory tract disease (Jacobson *et al.* 1991) and cutaneous dyskeratosis or shell disease (Jacobson *et al.* 1994). Other diseases or infections have also been identified in tortoises including herpesvirus, shell necrosis, bacterial and fungal infections, and urolithiasis (bladder stones) (Homer *et al.* 1998), but little information is available regarding the distribution of these maladies or the magnitude of their effect within or among desert tortoise populations (Boarman 2002). Additional research is needed to clarify the role of disease in desert tortoise population dynamics relative to other threats.

The role of environmental toxicants in desert tortoise health and susceptibility to disease has recently been suggested as a significant source of mortality. Illegal dumping of hazardous wastes in the California deserts appears to be increasing, which may expose tortoises to increased levels and possible consumption of toxic substances and affect populations on a localized level where these activities are concentrated (Boarman 2002).

The common raven is a predator of the desert tortoise that benefits from resource subsidies associated with human activities. For instance, ravens obtain food in the form of organic garbage from landfills and trash containers, water from sewage ponds and municipal areas, and nesting substrates on billboards, utility towers, bridges, and buildings (Boarman *et al.* 2006). Other avian predators of the desert tortoise include red-tailed hawks, golden eagles, loggerhead shrikes, American kestrels, burrowing owls, and greater roadrunners (Boarman 1993). Coyotes, kit foxes, mountain lions, ground squirrels, and free-roaming dogs are known mammalian predators (Boarman 2002; M. McDermott, Southern Nevada Environmental, Inc., pers. comm. 2006). Invertebrate predators of eggs and hatchling tortoises include native fire ants.

D. Inadequacy of Existing Regulatory Mechanisms

The final listing rule acknowledged that all four states within the range of the Mojave population of the desert tortoise have laws in place to protect the species. In addition, a great deal of effort has been dedicated to planning by the various land management agencies whose jurisdictions include desert tortoise habitat. Many of the existing plans include language specific to protection of the species, such as limiting off-highway vehicle use and competitive/organized events, grazing, vegetation harvest, and collection of desert tortoises. However, management agencies frequently do not have sufficient funding to enforce their regulations.

E. Other Natural or Manmade Factors Affecting its Continued Existence

Global climate change and drought are potentially important long-term considerations with respect to recovery of the desert tortoise. The Earth's climate has warmed by nearly 1.5 degrees Fahrenheit over the past 100 years (Walther *et al.* 2002), and anthropogenic emissions of greenhouse gases play a major role in this process (Weltzin *et al.* 2003). There is now sufficient evidence that recent climatic changes have affected a broad range of organisms with diverse geographical distributions (Walther *et al.* 2002). While little is known regarding direct effects of climate change on the desert tortoise or its habitat, predictions can be made about how global and regional precipitation regimes may be altered and the consequences of these changes (Weltzin *et al.* 2003; Seager *et al.* 2007). Such predictions need to be developed specifically for the desert tortoise to help inform recovery efforts.

Another potential threat facing the desert tortoise is the unauthorized breeding of pet tortoises, which can lead to pressures on wild tortoise populations as well as management agencies. Wolff and Seal (1993) noted that disease spread by the release of captive-bred animals and relocation of wild animals are a major concern in conservation biology. Captive releases have the potential to introduce disease into wild populations of desert tortoises and may also result in genetic contamination.

Please refer to Appendix A for a more detailed discussion of the threats to the desert tortoise and its habitat briefly described above.

CONSERVATION EFFORTS

While precise correlations between the multitude of threats and desert tortoise populations have not been clearly elucidated, a great deal of effort has been put forth by research scientists and land managers to actively conserve the species. For instance, substantive datasets pertaining to disease, non-native invasive plant species, and fire have been assembled over the years that will inform decisions relative to recovery of the desert tortoise and its habitats. On-the-ground conservation actions such as land acquisitions, installing protective fencing, retiring grazing allotments, limiting off-highway vehicle access, and implementing restoration projects have been important recovery and management efforts based on what we do know about threats to the desert tortoise at this time (see GAO 2002). The following are examples of existing guidance and strategies to further resource conservation.

Wildlife Conservation Strategies

In 2000, Congress enacted the State Wildlife Grants Program to fund activities that benefit species of concern and their habitats. To receive funding under this program, state wildlife agencies must have completed a wildlife action plan (or comprehensive wildlife conservation strategy) for our approval by 2005. All four states where the Mojave population of the desert tortoise occurs are currently implementing these strategies to guide species and habitat management through 2015 (Gorrell *et al.* 2005; Abele *et al.* 2006; Arizona Game and Fish Department 2006; Bunn *et al.* 2006).

Each state has identified conservation priorities and recommendations that are both species and habitat specific. Some of these actions include, but are not limited to, the following:

- Improve stewardship on federally managed lands to protect wildlife diversity;
- work cooperatively with landowners/permittees by providing financial and technical assistance (through incentive programs) for conservation projects;
- work with city and county planners to incorporate wildlife values in urban/rural development plans;
- promote design and construction of overpasses, underpasses, or culverts to increase permeability of existing or planned roads;
- identify and protect key wildlife corridors for landscape connectivity;
- reduce off-highway vehicle damage to wildlife habitats;
- encourage revegetation and restoration of existing unauthorized roads and trails;
- improve efforts and partnerships for control existing occurrences of invasive species and prevent new introductions;
- rehabilitate burned and disturbed areas with native plants;
- pursue projects to limit spread of disease to sensitive wildlife populations;
- use fencing and/or increased law enforcement presence to reduce unauthorized use and access to sensitive habitats; and,

- implement a statistically robust range-wide monitoring program and adaptive management framework that captures population trends and impacts to the species.

Federal Land Management Plans

Land use management plans provide guidance and establish a mechanism by which Federal agencies implement actions on lands under their purview. Throughout the range of the desert tortoise, multiple Federal agencies are involved in the long-term management and conservation of the species as part of their respective missions. These include the Bureau of Land Management, National Park Service, Bureau of Indian Affairs, U.S. Fish and Wildlife Service, Bureau of Reclamation, U.S. Forest Service, Department of Defense, and Department of Energy.

Within the range of the desert tortoise, the following programmatic level documents are currently in place or in preparation. Many of the respective plans include language specific to the protection and conservation of natural resources including desert tortoises and their habitats. These are often supplemented by more specific guiding documents, such as habitat management plans or wilderness management plans:

Bureau of Land Management:

- Arizona Strip Resource Management Plan Revision, Grand Canyon-Parashant National Monument Management Plan (jointly managed with the National Park Service), and Vermilion Cliffs National Monument Management Plan; Proposed Resource Management Plan/Final Environmental Impact Statement (BLM and National Park Service [NPS] 2007)
- California Desert Conservation Plan of 1980 as amended (BLM 1999a)
- Northern and Eastern Mojave Desert Management Plan (BLM 2002a)
- Northern and Eastern Colorado Desert Coordinated Management Plan (BLM 2002b)
- West Mojave Plan (BLM *et al.* 2005)
- Tonopah Resource Management Plan (BLM 1997)
- Las Vegas Resource Management Plan (BLM 1998a)
- Red Rock Canyon National Conservation Area Resource Management Plan (BLM 2001)
- Sloan Canyon National Conservation Area Resource Management Plan (BLM 2006)
- Nevada Test and Training Range Resource Management Plan (BLM 2004)
- Caliente Management Framework Plan (BLM 2000)
- St. George Resource Management Plan (BLM 1999b)

Fish and Wildlife Service:

- Desert National Wildlife Refuge Comprehensive Conservation Plan (USFWS in preparation)

National Park Service:

- Joshua Tree National Park General Management Plan, as amended (NPS 2000a)
- Death Valley National Park General Management Plan (NPS 2002a)
- Mojave National Preserve General Management Plan (NPS 2002b)

- Lake Mead National Recreation Area, Arizona and California, Strategic Plan Fiscal Year 2001-2005 (NPS 2000b)

U.S. Forest Service:

- General Management Plan for the Spring Mountains National Recreation Area, An Amendment to the Land and Resource Management Plan (U.S. Forest Service 1996)

Department of Defense:

- National Training Center at Fort Irwin Integrated Natural Resources Management Plan (U.S. Army 2001)
- Edwards Air Force Base Integrated Natural Resources Management Plan (U.S. Air Force 2001)
- Marine Corps Logistics Base, Barstow, Integrated Natural Resources Management Plan (Tierra Data, Inc. 2005)
- Marine Corps Air Ground Combat Center, Twentynine Palms, Integrated Natural Resources Management Plan and Environmental Assessment, Fiscal Year 2002-2006 (U.S. Marine Corps 2002)
- Naval Air Weapons Station, China Lake, Comprehensive Land Use Management Plan and Integrated Natural Resources Management Plan (Naval Air Weapons Station, China Lake and BLM 2004)
- Yuma Training Range Complex, Arizona and California (U.S. Navy 2001)
- Draft Nellis AFB and Nevada Test and Training Range Integrated Natural Resources Management Plan (U.S. Air Force 2007)

Among the most important recovery actions implemented pursuant to the 1994 Recovery Plan has been formalizing Desert Wildlife Management Areas (DWMAs) through Federal land use planning processes (Fig. 2). Particularly on Bureau of Land Management lands, DWMAs are administered and designated as Areas of Critical Environmental Concern (ACEC; BLM 1998a, 1999b, 2000, 2002a, 2002b, BLM *et al.* 2005, BLM and NPS 2007). These ACECs define specific management areas based on the general DWMA recommendations in the 1994 Recovery Plan. Boundaries of the ACECs were refined slightly from the critical habitat designation based on various management and biological considerations. DWMAs/ACECs, together with National Park Service lands, designated wilderness areas, and other lands under conservation management provide an extensive network of habitat under direct or indirect (*e.g.*, wilderness areas outside desert tortoise ACECs) management for desert tortoise conservation (Fig. 2).

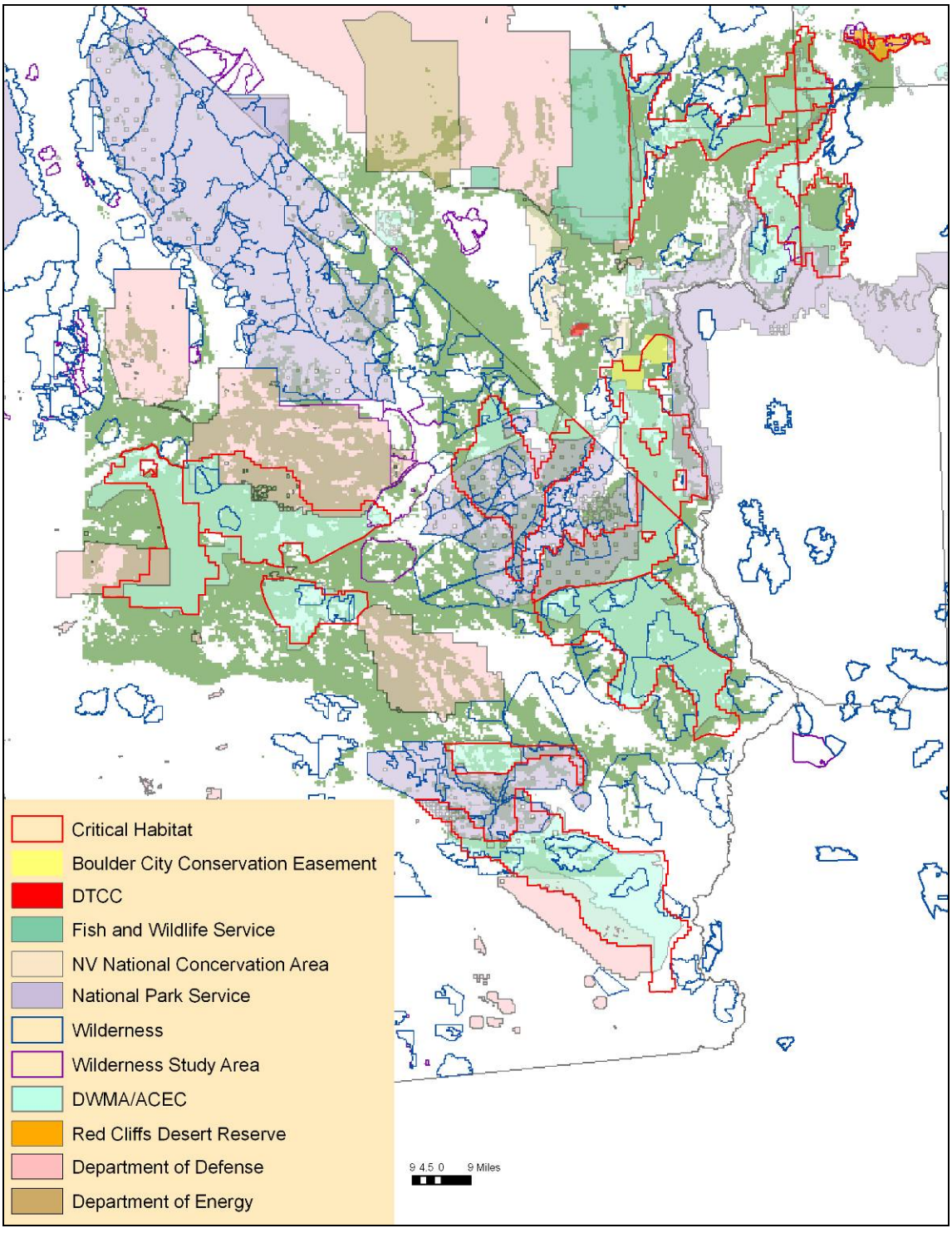

Figure 2. Conservation areas within the range of the Mojave population of the desert tortoise, plus Department of Defense and Department of Energy lands, overlaid over the draft U.S. Geological Survey habitat map (in green). Note that areas in the southern, western, and extreme northeastern ends of the range were not included in the habitat model, and the model does not reflect urbanization or other anthropogenic habitat modifications. DWMA/ACEC = Desert Wildlife Management Areas and Areas of Critical Environmental Concern.

The most recent example of landscape-scale conservation was the Bureau of Land Management's designation of ACECs and wildlife habitat areas under the Arizona Strip Resource Management Plan Revision and Grand Canyon-Parashant National Monument Management Plan (BLM and NPS 2007). On the Arizona Strip, wilderness was proposed on 87,100 hectares (215,345 acres) adjacent to the Parashant National Monument and on 14,120 hectares (34,900 acres) within the field office jurisdiction; areas with wilderness characteristics that will be managed to maintain or protect resource values were also identified. Nearly 68,800 hectares (170,000 acres) are designated as ACECs on the Arizona Strip, which directly benefits the desert tortoise and its habitat. The Resource Management Plan contains the following goals:

- The Mojave population of desert tortoise would be recovered and delisted.
- There would be no net loss in the quality or quantity of desert tortoise habitat within the ACECs or wildlife habitat areas.
- Desert tortoise populations within the ACECs and DWMAs would be healthy and self-sustaining. Populations would be stable or increasing. Population declines would be halted.
- Desert tortoise populations outside of the ACECs and wildlife habitat areas would be healthy and stable. Declines in the wildlife habitat areas would be minimized to the extent possible through mitigation.
- Desert tortoise habitat would provide sufficient forage and cover attributes to support thriving populations of the species.
- Habitat connectivity would be maintained, providing sufficiently frequent contact between tortoises to maintain genetic diversity.

One of the most extensive land and resource management plans currently in place was developed for the 10,117,141-hectare (25,000,000-acre) California Desert Conservation Area. In 1976, Congress passed the Federal Land Policy Management Act to direct the management of the public lands of the United States. Under that law, the California Desert Conservation Area was established and includes 4,856,228 hectares (12,000,000 acres) of public lands administered by the Bureau of Land Management. The California Desert Conservation Area Plan of 1980 as amended provides guidance relative to the use of the public lands and resources of the California Desert Conservation Area, including economic, educational, scientific, and recreational uses, in a manner that enhances wherever possible, and does not diminish the environmental, cultural, and aesthetic values of the desert and its productivity. Under the California Desert Conservation Area Plan, all state and federally listed species and their habitats are to be managed so that the continued existence of each is not jeopardized. Consultation for federally listed species would be conducted as appropriate (BLM 1999a).

The California Desert Conservation Area Plan was subsequently amended by region, which generally corresponded to the recovery units delineated in the 1994 Recovery Plan. The Northern and Eastern Mojave Desert Management Plan (BLM 2002a), the West Mojave Plan (BLM *et al.* 2005), and the Northern and Eastern Colorado Desert Coordinated Management Plan (BLM 2002b) all designated DWMAs and included new management measures for desert tortoise conservation.

The California Desert Conservation Area also encompasses the 10,117-hectare (25,000-acre) Desert Tortoise Natural Area, which was established in the western Mojave Desert in 1972. The Mojave National Preserve was created under the California Desert Protection Act in 1994 for which a general management plan was drafted in 2002 (NPS 2002b). The California Desert Protection Act also expanded the boundaries of both Death Valley and Joshua Tree National Parks and designated millions of acres of wilderness, which eliminated vehicle access to these areas.

Many of the actions recommended in the 1994 Recovery Plan have been incorporated into the land and resource management plans identified above, particularly within DWMAs/ACECs. Tracy *et al.* (2004) summarized the level of implementation of the management recommendations by reviewing land and wildlife managers' responses to surveys asking what recovery actions had been implemented. However, the survey responses were not explicit enough to quantify the level of implementation for each specific recovery action; therefore, the results only speak to whether or not some action had been taken. In addition, research and monitoring have not been targeted to evaluate the effectiveness of these actions (Boarman and Kristan 2006), and ongoing population monitoring has been performed at a regional scale rather than a local implementation scale. The main conclusion was that improved reporting and quantification of recovery actions is necessary to more accurately assess the progress of desert tortoise recovery (Tracy *et al.* 2004).

Grazing Removal and Limitations

A specific example of landscape-scale conservation of desert tortoise habitat was the removal of grazing and the implementation of seasonal grazing restrictions on several allotments within designated critical habitat on public lands. This was identified in the 1994 Recovery Plan as an important component in the recovery of the species. For example, in 1995 the Desert Tortoise Preserve Committee and The Wildlands Conservancy bought the 550-hectare (1,360-acre) Blackwater Well Ranch in northwestern San Bernardino County and gained control (and is seeking retirment) of grazing on the 19,830-hectare (49,000-acre) Pilot Knob cattle grazing allotment. Together with the Bureau of Land Management, we initiated various planning efforts in California that resulted in the removal of grazing on hundreds of thousands of acres within the California portions of the Mojave and Sonoran deserts (BLM 2002a,b; BLM *et al.* 2005; USFWS 2005, 2006b). In addition, national Bureau of Land Management grazing administration regulations became effective in 1996, which provided direction for states to develop Standards for Rangeland Health and Guidelines for Grazing Management on Bureau of Land Management Lands (BLM 1996). All of the states within the range of the desert tortoise have incorporated standards and guidelines into their management plans.

Under the West Mojave Plan (BLM *et al.* 2005), grazing has been retired on several allotments mostly within designated critical habitat or Desert Wildlife Management Areas (DWMAs). Additional restrictions such as season of use and forage type (ephemeral or perennial) have also been instituted on some allotments within the plan area. Fort Irwin, which lies within the West Mojave Plan area, purchased fee lands within three cattle allotments in the Western Mojave Recovery Unit to partially offset the effects of its base expansion, and the Bureau of Land Management subsequently retired these allotments. The Bureau of Land

Management has removed grazing from at least four other allotments in the plan area. Collectively, over 307,560 hectares (760,000 acres) in the West Mojave Plan area have been retired from grazing (USFWS 2006b).

Where grazing will continue within the West Mojave Plan area, the Bureau of Land Management has identified a number of conservation prescriptions to be implemented within cattle and sheep allotments, which include existing Regional Public Land Health Standards and Guidelines for Grazing Management, utilization restrictions, guidelines for grazing both within and outside of desert tortoise habitats and DWMAs, terms and conditions of existing Fish and Wildlife Service biological opinions, and new management prescriptions contained in the plan (BLM *et al.* 2005; USFWS 2006b).

The Northern and Eastern Mojave Desert Management Plan removed or restricted grazing on approximately 126,260 hectares (312,000 acres) within DWMAs in the Northeastern and Eastern Mojave recovery units, which constitutes all but about 5,261 hectares (13,000 acres) of critical habitat in the Shadow Valley and Ivanpah Valley DWMAs. One relatively small allotment within the Ivanpah Valley DWMA will remain open with some utilization restrictions, and all ephemeral allotments within DWMAs will be terminated (USFWS 2005).

The Northern and Eastern Colorado Desert Coordinated Management Plan established two DWMAs that encompass over 647,500 hectares (1,600,000 acres). Only one allotment remains within designated critical habitat or a DWMA. Approximately 8,090 hectares (20,000 acres) of this active allotment was closed to grazing due to high tortoise densities, and in other portions of the allotment, utilization restrictions and season of use requirements will be implemented. (USFWS 2005).

Under the Mojave National Preserve General Management Plan, grazing has been removed on nine allotments and remains active on another two (D. Hughson, NPS, pers. comm. 2007). The overall management goal is to completely remove grazing on the entire Preserve through voluntary relinquishment by lessees or acquisition of grazing permits and water rights by conservation organizations. As the acquisition process moves forward, and for permit holders unwilling to sell, grazing will continue. These activities will be managed according to Bureau of Land Management allotment management plans and National Park Service grazing management plans, together with additional restrictions designed to give resource protection priority over grazing (NPS 2002).

At the time the Las Vegas Resource Management Plan was drafted in 1998, there were 53 grazing allotments within the Las Vegas District of the Bureau of Land Management. Of those, 39 were proposed for closure pursuant to the 1994 Recovery Plan recommendations, leaving 3 outstanding and 11 actively managed under restrictions designed to achieve specific resource management objectives. No grazing was to occur within Areas of Critical Environmental Concern (ACECs; BLM 1998a). Under the Clark County Multiple Species Habitat Conservation Plan (MSHCP) and its predecessor (see discussion below), which lies within the Las Vegas District of the Bureau of Land Management, the County has been actively purchasing the rights to permanently remove grazing from over 809,370 hectares (2,000,000 acres) of public lands within and outside of DWMAs (J. Bair, USFWS, pers. comm. 2007).

Under the Caliente Management Framework Plan Amendment, all allotments or portions of allotments within ACECs were closed to livestock grazing (85,996 hectares [212,500 acres]). Outside ACECs, season of use on all perennial allotments was established through allotment evaluation and multiple-use decision processes. It was determined for areas outside ACECs, livestock use could occur between March 15 and October 15 provided forage utilization does not exceed 40 percent for key perennial grasses, forbs, and shrubs (BLM 2000).

Allotment closures and restrictions were also instituted on the Bureau of Land Management Arizona Strip District within ACECs and within the National Monuments (BLM 1998b; BLM 2007a). However, livestock grazing will continue to be authorized on portions of 11 allotments that support desert tortoise habitat. Grazing activities will be limited in these areas through utilization restrictions and season of use requirements. Ecological site inventory data are expected to serve as the baseline for range conditions and utilization is not to exceed 45 percent of the current year's growth. Overall, conditions must meet the Bureau of Land Management's Standards for Rangeland Health and National Park Service's Vital Sign Standards (BLM 2007a).

Land Acquisitions and Habitat Conservation Plans (HCPs)

Land acquisitions and transfers may negatively impact desert tortoises and their habitats when the lands are targeted for development associated with urban expansion. On the other hand, these transactions may result in conservation benefits. For instance, since 1986, California Department of Fish and Game has acquired over 12,950 hectares (32,000 acres) of desert tortoise habitat within critical habitat, and additional lands with endowment fees have been and continue to be acquired through mitigation for projects that impact tortoise habitats. To ensure management of these lands, endowment fees are collected for each parcel acquired (Steele and Jones 2006). In addition, under the Southern Nevada Public Lands Management Act, approximately 1,500 hectares (3,725 acres) within occupied or suitable desert tortoise habitat have been purchased since 2000 through the land acquisition program for environmentally sensitive lands (BLM 2007b).

In 1999, The Wildlands Conservancy facilitated the purchase of nearly 242,810 hectares (600,000 acres) under their California Desert Land Acquisition Project. It also funded land exchanges that resulted in the addition of over 14,160 hectares (35,000 acres) into six Bureau of Land Management wilderness areas and gifted an additional 11,330 hectares (28,000 acres) of acquired lands to Joshua Tree National Park. The acquisition of these lands will ensure landscape-level conservation into the future and will provide habitat connectivity and reduce the potential for fragmentation (The Wildlands Conservancy 2007).

The Department of the Army purchased approximately 40,100 hectares (99,100 acres) of lands formerly owned by the Catellus Development Corporation and fee lands within three cattle allotments in the Western Mojave Recovery Unit to partially offset the effects of its base expansion; the Bureau of Land Management subsequently retired these allotments. This mitigation resulted in the relinquishment of grazing on over 129,500 hectares (320,000 acres) (R. Bransfield, U.S. Fish and Wildlife Service, pers. comm. 2007).

Several HCPs have been developed within desert tortoise habitat that include provisions for acquisitions and transfers that would meet the objectives of the HCP as well as secure conservation lands for tortoises. However, land acquisition is an expensive, time-consuming task. For example, 61 separate actions were necessary to acquire just over 3,760 hectares (9,300 acres) within the 25,090-hectare (62,000-acre) Red Cliffs Desert Reserve, which was established to provide protection for the desert tortoise and its habitat under the 1996 Washington County HCP in Utah. Approximately 2,995 hectares (7,400 acres) remain to be acquired within the present boundaries of the Reserve. The approximate value of the lands acquired stands at $87,073,000 (not adjusted for present value) (J. Crisp, BLM, pers. comm. 2007).

In southern Nevada, the Clark County Multiple Species Habitat Conservation Plan (MSHCP) was already in progress at the time the Southern Nevada Public Lands Management Act was enacted (see Appendix A: Land Acquisitions, Exchanges, and Transfers). The Clark County MSHCP superseded the Desert Conservation Plan, which was prepared in response to the Federal listing of the desert tortoise as a threatened species. The MSHCP plan area encompasses a total of 169,160 hectares (418,000 acres) (all of Clark County and, for the Nevada Department of Transportation, portions of Nye, Lincoln, Mineral, and Esmeralda counties, Nevada) (RECON 2000). The underlying purpose of the MSHCP is to achieve a balance between the long-term conservation of listed species and natural resources that are an important part of the natural heritage of Clark County and the economic development of Clark County (USFWS 2000a). As additional mitigation under the MSHCP, Clark County secured a 34,800-hectare (86,000-acre), long-term conservation easement (50 years) from Boulder City.

Under the Clark County MSHCP, site-specific conservation management strategies were required for each of the DWMAs within the county; these include Coyote Springs, Gold Butte, Mormon Mesa, and Piute-Eldorado (Clark County 2007a,b,c,d, respectively). The purpose of each conservation management strategy is to guide species and habitat management using a coordinated, adaptively managed approach. Each strategy identifies management actions, protective measures, restoration efforts, public outreach and education, inventory and monitoring actions, applied research actions, and impact mitigation measures that will direct conservation of tortoises and their habitats.

Habitat Conservation Plans are in development for other parts of southern Nevada. The Southeastern Lincoln County HCP is in the final planning stages. The plan area totals 720,400 hectares (1,780,140 acres), of which 311,365 hectares (769,400 acres) is desert tortoise habitat. Approximately 9,090 hectares (20,000 acres) of the tortoise habitat within the plan area will be developed over a 30-year time frame. The focus of this plan is to provide a mechanism to allow orderly growth and development north of Mesquite and urban expansion in the Alamo area in Lincoln County (J. Brown, USFWS, pers. comm. 2007). Efforts to develop a HCP for the Coyote Springs Valley in Lincoln County are also in the final planning stages. This plan includes allowing development of 8,680 hectares (21,454 acres) over 40 years while setting aside a 5,570-hectare (13,767-acre) reserve for the desert tortoise and other sensitive species. In addition, mitigation fees paid by the applicant for the loss of desert tortoise habitat would be used to fund management of the reserve and desert tortoise research. A short-term HCP is also being developed for activities around the town of Pahrump in Nye County. As in Clark County, this

plan will be superseded by a long-term HCP that will address the portions of the county within the range of the tortoise, including Pahrump.

The Coachella Valley MSHCP in Riverside County, California would establish conservation areas and a reserve system for species and natural communities covered under the plan, including the desert tortoise. These lands constitute approximately 301,855 hectares (745,900 acres) within the 485,620-hectare (1,200,000-acre) plan area boundary. About 206,790 hectares (511,000 acres) of desert tortoise habitat lies within the areas identified for conservation under the Coachella Valley MSHCP, with about 65,150 hectares (161,000 acres) not yet secured for these purposes. The conserved lands include the 9,090-hectare (20,000-acre) Coachella Valley Preserve that was established in 1986 for Coachella Valley fringe-toed lizard (*Uma inornata*). Over 26,300 hectares (65,000 acres) (12 percent of all habitat and 28 percent of non-Federal land within the plan area) are subject to disturbance under the plan. This constitutes about 4,450 hectares (11,000 acres) of what is considered "core" habitat for various species as described in the Coachella Valley MSHCP. This plan is currently in the final planning stages (Coachella Valley Association of Governments 2007).

The California Desert Conservation Area Plan Amendment for the Coachella Valley specifically commits the Bureau of Land Management to conserving at least 99 percent of vegetation community types on the lands it administers within the MSHCP reserve system. In the portion of the MSHCP area where the Northern and Eastern Colorado Desert Coordinated Management Plan applies to federal land, new surface disturbance is cumulatively limited to 1 percent of the federal portion of each critical habitat unit, which is consistent with the other large regional plans (Coachella Valley Association of Governments 2007; BLM 2002c).

Other Activities

Over 404,685 hectares (1,000,000 acres) of Mojave Desert vegetation burned in wildfires in 2005 and 2006, fueled largely by invasive, non-native grasses. About half of the areas burned supports desert tortoise habitat, and if this trend continues, native plant communities and much of the diversity of the Mojave Desert ecosystem may eventually be lost. Because of this recent devastating fire activity in the Mojave Desert, research scientists, land managers, and regulators have come together to develop an initiative designed to protect intact, functional habitats and restore key areas that have burned. This initiative would be a collaborative effort among Federal, state, and local jurisdictions and would focus on fire management and habitat protection and restoration.

During the summer of 2005, wildfires burned approximately 36,180 hectares (89,400 acres) within the Pakoon Basin of the Grand Canyon Parashant National Monument; about 14,570 hectares (36,000 acres) are located within the Gold Butte-Pakoon critical habitat unit for the desert tortoise. As a result, the Arizona Strip District of the Bureau of Land Management initiated soil stabilization and revegetation efforts of desert tortoise habitats using a variety of treatments, including aerial seed application, mechanical seed incorporation, and grazing exclusion (fencing). Rehabilitation objectives and success criteria will be developed, and invasive species establishment will be controlled. Treatments within each area affected by the fires will be monitored at either existing or new monitoring sites through 2009 (USFWS 2006c).

In addition, we issued a memo to the Desert Tortoise Management Oversight Group in May 2006 recommending that when feasible, implementing fire suppression techniques that minimize impacts to the habitat is desirable; however, reduction of total acreage lost to fire, especially in critical habitat, through the use of mobile attack with engines, fireline construction with bulldozers, aerial fire retardant, or other necessary techniques should be prioritized.

The U.S. Fish and Wildlife Service is undertaking efforts to reduce human subsidies of food, water, and nest sites to the common raven in the California desert. Current activities designed to reduce raven predation on desert tortoises include reducing trash availability at landfills, removing illegal dumps, fencing along highways to reduce road-kills, and installing perch guards on fences at the Desert Tortoise Natural Area. The program also provides immediate protection to hatchling and juvenile desert tortoises by identifying and removing ravens that have preyed or attempted to prey on desert tortoises. The environmental assessment we recently released provides a full description of the proposed activities (USFWS *et al.* 2007).

In addition, Bureau of Land Management's West Mojave Plan includes a series of recommendations to reduce raven predation on the desert tortoise including, but not limited to, control of solid and organic wastes and standing water at and outside of sanitary landfills; encourage livestock operators to reduce availability of food sources for ravens; limit availability of nesting and perch substrates, especially in the urban interface; selective removal of problem ravens especially within the Desert Tortoise Natural Area, critical habitat units, and head-starting sites; conduct additional research on raven life history, behavior, and efficacy of control methods; and implement adaptive management and public education programs (BLM *et al.* 2005).

The California Desert Managers Group oversees a program to develop and implement an information and education campaign about the desert tortoise to build public support for, and involvement in, its recovery. The Clark County (Nevada) Desert Conservation Program also includes an education component that targets communities in southern Nevada and extends into portions of Arizona. The outreach efforts attempt to inform the public about desert tortoise conservation issues through brochures, surveys and feedback, and educational materials for schools.

BIOLOGICAL CONSTRAINTS AND NEEDS

The biological constraints that were identified in the 1994 Recovery Plan remain important considerations in current and future recovery planning and implementation. Desert tortoises possess a combination of life history and reproductive characteristics that affect the ability of populations to survive external threats. For instance, this long-lived species requires 13 to 20 years to reach sexual maturity and has low reproductive rates during a long period of reproductive potential (Turner *et al.* 1984; Bury 1987; Germano 1994). Also, similar to other turtles, desert tortoises experience relatively high mortality early in life. These factors make recovery of the desert tortoise more difficult, and 1 or 2 good years of reproductive success do not signal a trend toward recovery any more than several poor ones signal inevitable extirpation (USFWS 1994a). Delayed but prolonged reproduction is advantageous where availability of resources is unpredictable and juvenile survival rates are highly variable, but

even moderate downward fluctuations in adult survival rates can result in rapid population declines. Thus, high survivorship of adult desert tortoises is critical to its persistence, and the slow growth rate of this species can leave it susceptible to extirpation events in areas where adult survivorship has been reduced (USFWS 1994a).

Another factor integral to desert tortoise recovery is maintaining the genetic and ecological variability known to exist within and among populations. This variation is necessary to allow tortoises to adapt to changes in the environment over time (USFWS 1994a). Finally, because desert tortoises occupy large home ranges, the long-term persistence of extensive, unfragmented habitats is essential for the survival of the species. Contiguous native vegetation communities provide shrubs for cover and annuals for forage. The loss or degradation of these habitats to urbanization, habitat conversion from frequent wildfire, or other ground-disturbing activities places the desert tortoise at increased risk of extirpation.

II. Recovery Program

A. RECOVERY STRATEGY

Recovery of the desert tortoise has been and will continue to be complex and challenging in part because tortoise populations face a wide range of threats. There are few data available to evaluate the effects of these threats on tortoise demography or to even rank the relative effects of threats on the declines of tortoise populations. Because desert tortoises require over a decade to reach sexual maturity, have temporally variable reproduction, and juveniles have variable but low survival rates, tortoise populations will be naturally slow to increase in response to strategies designed to ameliorate anthropogenic impacts. These life history characteristics, combined with reduced populations, make it difficult to assess relative impacts of individual threats. As a result, efforts have been and should continue to be made to address as many threats as possible with available resources. Maintaining high survivorship of adult desert tortoises was identified as the key factor in the recovery of the desert tortoise in the 1994 Recovery Plan. In the current plan, we recognize that additional measures are needed. The current recovery strategy consists of a multi-faceted approach with several key elements:

1. Implement a formal adaptive management program through which information gained while implementing the following strategic elements is used to revise and improve the recovery plan and recommend management actions on a regular basis;

2. Protect and manage existing populations and habitat, instituting habitat restoration where necessary;

3. Augment depleted populations in a strategic manner;

4. Monitor progress toward recovery;

5. Conduct applied research and modeling in support of recovery efforts within a strategic framework; and

6. Develop, support, and build partnerships to facilitate recovery.

These elements are not independent of each other, but each is inter-connected with the others. For example, the adaptive management program (Element 1) forms the backbone of the recovery program, which is guided and implemented through interagency/stakeholder partnerships (Element 6). Through these two elements, habitat management (Element 2) and population augmentation (Element 3) actions will be prioritized, implemented, and reported. Monitoring (Element 4) effects of these specific actions, as well as progress toward overall recovery, will again feed into the adaptive management system and inform managers on recovery progress. Finally, applied research and modeling (Element 5) will help us better understand desert tortoise ecology and better define our expectations of management actions (Fig. 3). Proactive implementation of actions contained within these strategic elements will result in more visible progress toward recovery of the desert tortoise. Likewise, mitigation of activities harmful to desert tortoises should draw on the suite of opportunities provided by these elements, with flexibility to apply an action most appropriate to the situation. Each strategic element is described more fully below, but the recovery program does not provide a "cookbook" of prescriptions that will ensure recovery of the desert tortoise. Instead, this program establishes a process by which recovery can be achieved.

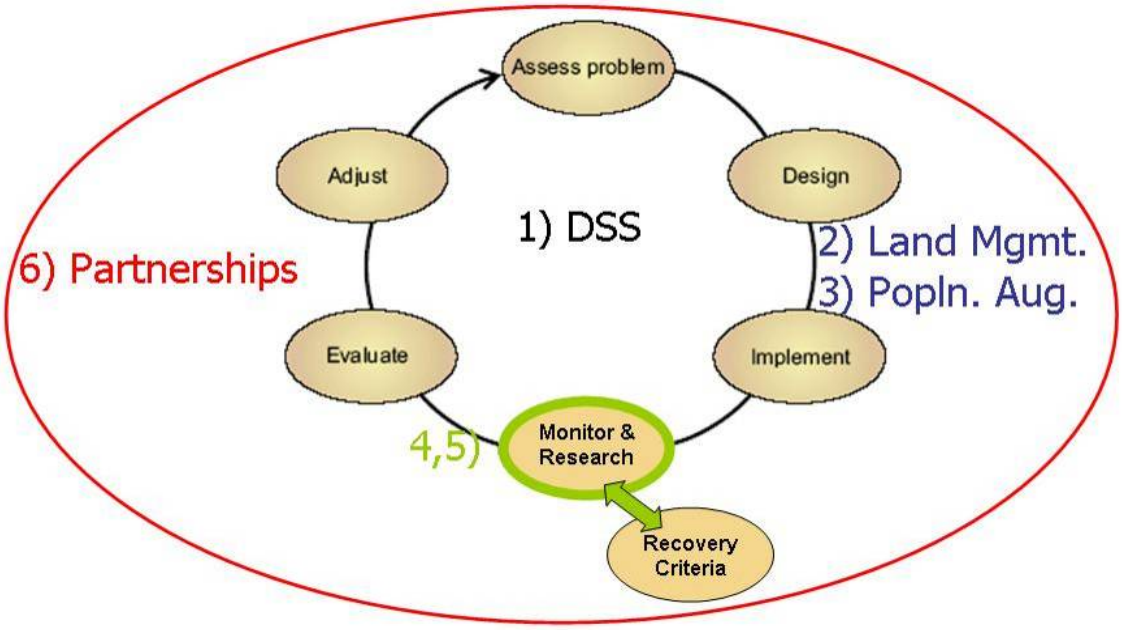

Figure 3. Schematic representation of strategic elements within the Desert Tortoise Recovery Program.

Strategic Element 1: Implement a Formal Adaptive Management Program

Integrating the results of the recovery program into a formal adaptive management program is critical to recovering the desert tortoise and serves as the foundation of an effective recovery plan if successfully implemented. Using research and monitoring to revise management efforts on an *ad hoc* basis is inefficient and has contributed to slow progress in the recovery of

desert tortoise since 1994. The Department of Interior technical guide on adaptive management provides an operating definition adopted from the National Research Council:

> *Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders* (Williams *et al*. 2007).

Adaptive management is a structured approach to decision making that emphasizes accountability and explicitness in decision making (Williams *et al.* 2007). Critical to successful adaptive management is the development of conceptual models that link management actions to predicted responses by desert tortoise populations or their habitat. Implementing a formal adaptive management program, integrated among agencies as much as possible, will enable us to continually update and improve models and the accuracy of predictions regarding the effects of management actions. Realistic expectations of adaptive management should recognize, however, that the life history of desert tortoises and the complex interactions among tortoise populations, habitat, and threats will typically result in extended learning cycles over which improvements in understanding and management will occur. Therefore, we should not expect rapid cycles of implementation-monitoring-evaluation-adjustment.

Given the complexities of desert tortoise recovery described above, fully *active* adaptive management, which vigorously pursues learning through management under structured experimental designs (Williams *et al.* 2007), will not always be possible. In these cases, *passive* adaptive management can be used to focus monitoring programs on resource status and other system attributes that are useful for improved understanding over time (Schwarz 1998; Williams *et al.* 2007). Assessment of monitoring results is still used to implement management interventions in a learning process. In either case, use of structured decision making and a decision support system will facilitate the process (Ralls and Starfield 1995; Rauscher 1999; Williams *et al.* 2007). The recovery decision support system will incorporate a range-wide, geospatial database of current management activities, threats, and tortoise populations, providing managers a better framework for implementing successful recovery actions. Through the incorporation of conceptual models and research and monitoring results (Element 5), the decision support system will provide an explicit, well-documented process for making decisions.

Importantly, adaptive management requires an ongoing commitment of executive leadership, including management involvement and funding throughout the life of the recovery effort (Williams *et al.* 2007). The Desert Tortoise Recovery Office (DTRO) will serve as the focal point for coordinating among agencies and researchers, through Recovery Implementation Teams (Element 6), to maintain and improve the decision support system. Finally, the DTRO

will continue to chair the Science Advisory Committee, which serves in an advisory role to us, to the interagency Desert Tortoise Management Oversight Group, and to the Recovery Implementation Teams to ensure that recovery action plans, recovery action effectiveness, research and monitoring, and recovery plan revision meet rigorous scientific standards.

Strategic Element 2: Protect and Manage Existing Populations and Habitat

Since 1994, desert tortoise habitat has continued to be lost or severely degraded, keeping tortoise populations in a precarious state, including those that may not be currently in decline. As a result, protecting existing populations and habitat is paramount. However, applying uniform, highly restrictive regulations across the entire Mojave population is unfeasible, even if we knew the precise mechanisms affecting population declines at each site. Therefore, aggressive management needs to be applied within existing tortoise conservation areas or other important areas identified by Recovery Implementation Teams (Element 6) to ensure that populations remain distributed throughout the species' range. Tortoise conservation areas capture the diversity of the Mojave population of the desert tortoise within each recovery unit, conserving the genetic breadth of the species and providing a margin of safety for the species to withstand catastrophic events. The decision support system (Element 1) should be used by the Recovery Implementation Teams to guide management both inside and outside conservation areas, according to different opportunities or constraints within different areas. In addition to habitat management recommendations, specific recommendations for managing desert tortoise populations relative to disease have been developed by the Science Advisory Committee (Appendix B) and are incorporated herein.

"Tortoise conservation areas" include desert tortoise habitat within critical habitat, Desert Wildlife Management Areas, Areas of Critical Environmental Concern, wildlife refuges, National Park Service lands, and private conservation areas or easements.

Strategic Element 3: Augment Depleted Populations through a Strategic Program

Population augmentation in conjunction with threat abatement, restoration (Element 2), and research (Element 5) designed to investigate the effectiveness of these actions could be beneficial to recovery of the desert tortoise. Augmentation is a means to gain both insights into causes of declines and to increase the rate at which decimated populations could be revived. It is important to realize that if mechanisms of tortoise population declines remain in effect, simply increasing population numbers in the wild through augmentation will not result in recovery. Augmentation will not be a long-term strategy for conservation of the desert tortoise, but rather a short-term strategy to affect change more rapidly than possible through natural processes.

A strategic augmentation program will be composed of several elements, all of which must account for factors such as genetics and disease. One part of the program will involve the head-starting of young in captivity. Head-starting will allow young to reach sizes at which they are less vulnerable to certain threats, such as predation by ravens, prior to translocation. Currently, experiments in head-starting are taking place at several locations in California. Research at the National Training Center's Fort Irwin Study Sites (FISS 1 and FISS 2), Edwards Air Force Base, and the Marine Corps Air Ground Combat Center at Twentynine Palms has laid a strong foundation from which to build upon (see Morafka *et al.* 1997; Dickson *et al.* 2006;

Henen *et al.* 2007), and facilities at these sites will likely be important in a collaborative head-starting effort. Head-starting facilities are lacking in Nevada, but proposals are being developed to use the Desert Tortoise Conservation Center in Las Vegas as the site for new facilities servicing several surrounding recovery units. The DTRO will coordinate development of guidelines and protocols for the head-starting of desert tortoises range-wide in accordance with our controlled propagation policy (USFWS 2000b).

Another element will involve the actual translocation of tortoises to pre-selected sites. The efficacy of translocation itself has been questioned over the years. Early studies did not provide sufficient evidence to support or refute translocation as a conservation strategy (see Berry 1974; Cook *et al.* 1978; Cook 1983). More recent studies have shown initial success in translocation to be high (Nussear 2004; Field *et al.* 2007). Again, the DTRO will coordinate the development of translocation guidelines and protocols to be implemented range-wide, taking into account guidelines for addressing disease issues in translocation developed by the Science Advisory Committee (Appendix B). Finally, an augmentation strategy will be developed. As part of this strategy, locally depleted or extirpated populations, particularly within conservation areas, will be identified. Translocation and head-starting efforts will be used to augment (or re-establish) these populations in conjunction with elevated threat management and/or habitat restoration (Element 2) or directed research on the factors affecting success of the augmentation (Element 5).

Strategic Element 4: Monitor Progress toward Recovery

Monitoring is a fundamental requirement for adaptive management (Element 1). It is one process by which information is updated and the success of recovery actions can be evaluated. This information can be used adaptively – to refine management during the course of recovery – and also will be required to evaluate progress toward achieving recovery criteria, as well as when delisting is specifically under consideration. Monitoring activities described in this plan are therefore tied directly to individual recovery criteria. Recovery progress will be measured by monitoring trends in tortoise distribution, abundance, and population growth. The quantity and quality of habitat and the distribution of threats across the landscape also will require monitoring over time.

The protracted life history and longevity of the desert tortoise, as well as the long time frame necessary for desert restoration, require long-term monitoring to measure success. However, evaluations at 5-year intervals will identify potential trends, will feed into 5-year status reviews, and will provide an opportunity to adjust management based on any observed trends. Effectiveness monitoring of specific management actions is also needed (Boarman and Kristan 2006), but this is dealt with as an applied research question (Element 5). It is also important that monitoring be conducted as an integrated effort, coordinated through the DTRO, to ensure that efficiency of the recovery program and progress review is maximized. Consistent agency reporting through the decision support system (Elements 1 and 6) will help identify correlations between management efforts or threat reduction and tortoise populations, which can signify successful management.

Strategic Element 5: Conduct Applied Research and Modeling in Support of Recovery Efforts within a Strategic Framework

Although scientists have studied desert tortoises for over a decade, many important questions remain unanswered. In particular, we have a relatively poor understanding of how some human activities interact with ecological factors to affect tortoise populations and what threat-abatement measures might counteract those effects. As mentioned above, the desert tortoise's life history makes it difficult to tease apart relative impacts of individual threats (although some impacts, such as habitat loss, are fairly straightforward in that they eliminate populations completely). As a result, studying most individual threats/management actions in isolation from other possible threats/actions is impractical. However, such topics should be studied experimentally whenever possible. Given the difficulties surrounding applied ecological research on the desert tortoise, ecological models should be co-developed with management actions to make and test predictions about tortoise population responses to threats or management actions. These models then can be modified as new information becomes available (Element 1). Finally, similar to the coordination required of the monitoring program (Element 4), research should be coordinated through the DTRO (with advice from the Science Advisory Committee) to ensure that the highest priority questions are addressed first and that the entire recovery program can be leveraged from timely research results.

Strategic Element 6: Develop, Support, and Build Partnerships to Facilitate Recovery

Implementing a recovery plan for a species with a wide distribution and facing such complex challenges requires many cooperators and diverse partnerships. The DTRO will serve as the focal point for coordinating recovery action implementation in cooperation with the Desert Tortoise Management Oversight Group. The DTRO will work with regional Recovery Implementation Teams consisting of managers, stakeholders, and scientists to secure necessary resources, implement recovery actions on the ground, compile results into the range-wide decision support system (Element 1), and step the decision support system down to the local or regional level, as necessary. The Recovery Implementation Teams also will facilitate education and outreach activities to build support for, understanding of, and compliance with the recovery program. Organization of Recovery Implementation Teams may vary by region or recovery unit depending on logistical practicalities among the representatives; for example, a single team may cover more than one recovery unit if those units are comprised largely of the same cooperating partners.

Recovery Units

Recovery of the desert tortoise will follow a geographic approach. Recovery units represent the genetic, behavioral, morphological, and ecological diversity of the desert tortoise considered necessary for the long-term sustainability of its populations. For the desert tortoise to be recovered, the recovery criteria (described below) must be met within each recovery unit. The desert tortoise is a wide-ranging species inhabiting a large geographic range, so recovery actions will be tailored to regional ecological and socio-political conditions within each recovery unit, with most recovery actions focused on existing tortoise conservation areas. The recovery units

should not be confused with "distinct population segments" (DPSs). Vertebrate populations that are "discrete" and "significant" under the Service's DPS policy (USFWS 1996) and designated as DPSs can be considered for listing or delisting. Recovery plans cannot designate a DPS; this requires a formal rule-making process. If recovery and delisting by DPS (or any other "significant portion of the range" as specified under the Endangered Species Act) is deemed desirable in the future, information provided in our recovery unit descriptions and elsewhere in this plan may help define appropriate areas for a potential delisting rule.

A **recovery unit** is a special unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery of the entire listed entity, *i.e.*, recovery units are *individually necessary* to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the *entire listed entity*. Recovery units, if used, should collectively cover the entire range of the species. However, note that evaluation of recovery criteria and implementation of most recovery actions will be focused within existing tortoise conservation areas.

Background. The 1994 Recovery Plan identified six recovery units: Upper Virgin River, Northeastern Mojave, Eastern Mojave, Eastern Colorado, Northern Colorado, and Western Mojave (Fig. 4). When the recovery units were delineated initially, genetic, morphological, ecological, and behavioral differences were identified at a species-wide scale (*e.g.*, Woodbury and Hardy 1948; Burge 1977; Jennings 1985; Turner *et al.* 1986; Weinstein and Berry 1987; Lamb *et al.* 1989; Glenn *et al.* 1990; Germano 1993; Lamb and Lydehard 1994; Britten *et al*. 1997; Wallis *et al.* 1999; Averill-Murray 2002; Averill-Murray *et al.* 2002a; Averill-Murray *et al.* 2002b). Within the Mojave population, finer-scale genetic, morphological, ecological, and behavioral differentiation was acknowledged in the 1994 Recovery Plan (USFWS 1994a). Three closely related demes were identified in the Mojave population using a parsimony approach to compare the relative mitochondrial DNA differences in restriction fragment length polymorphisms exhibited by the North American tortoise species (Lamb *et al.* 1989). Additional variation in habitat type and ecosystem interactions (including those influenced by humans), life history characteristics, and physiology, morphology, and behavior contributed to the identification of the original six recovery units.

Additional fine-scale genetic studies were recommended at the time of the recovery plan assessment to enhance the best available data to delineate recovery units (Tracy *et al.* 2004). Since that time, two population genetic assessments have been completed and are in the process of being published in the peer-reviewed literature (Hagerty *et al.* in prep; Murphy *et al.* accepted). *The Science Advisory Committee is currently reviewing the available information before final recommendations are made to revise recovery unit boundaries*.

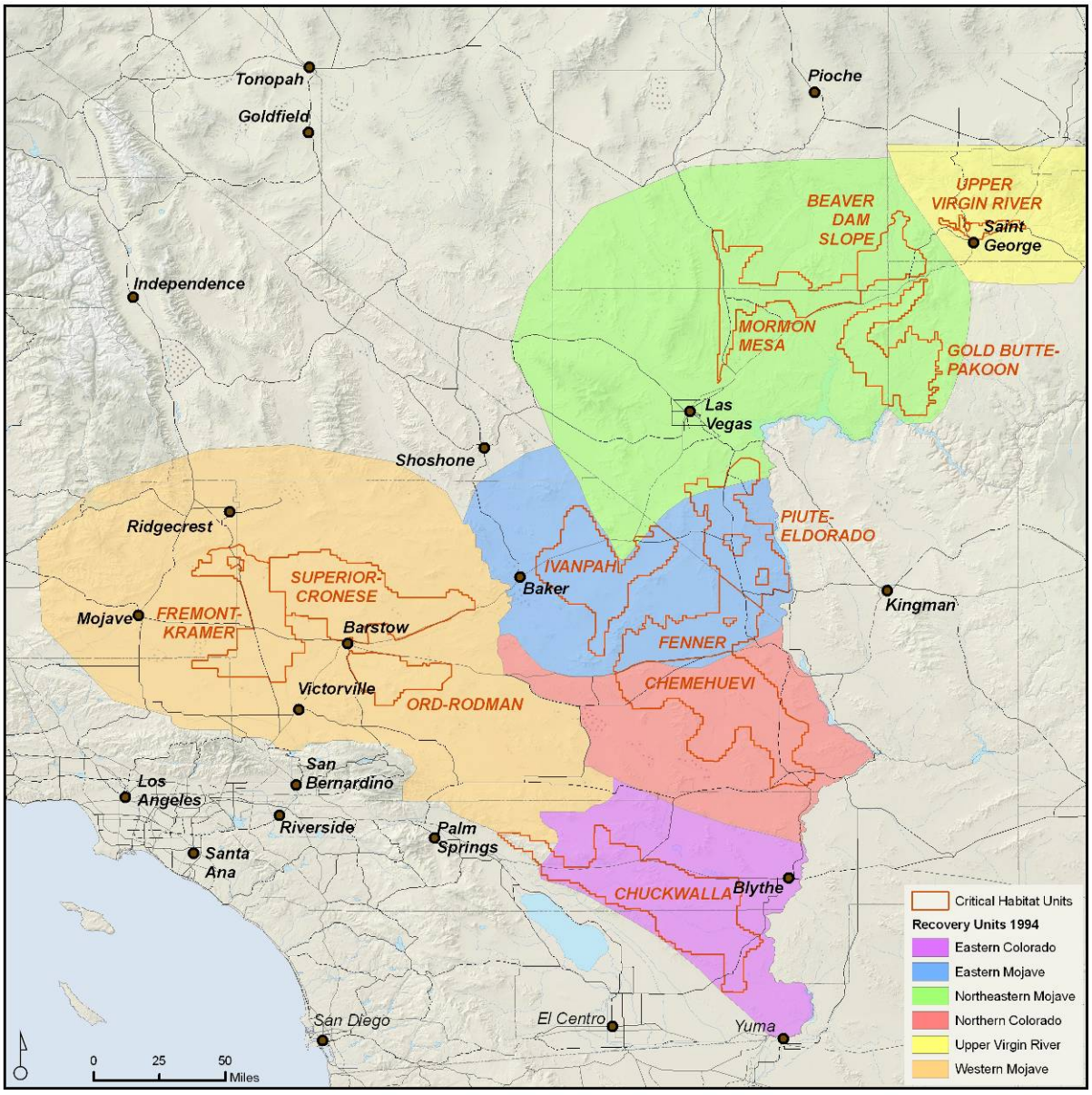

Figure 4. Recovery units delineated in the 1994 Recovery Plan.

B. RECOVERY GOAL, OBJECTIVES, AND CRITERIA

Downlisting or delisting is warranted when a listed species no longer meets the definition of threatened or endangered under the Endangered Species Act. We set recovery criteria to serve as objective, measurable guidelines to assist us in determining when a species has recovered to the point that the protections afforded by the Endangered Species Act are no longer necessary. However, the actual change in listing status is not solely dependent upon achieving the recovery criteria set forth in a recovery plan; it requires a formal rule-making process based upon an analysis of the same five factors considered in the listing of a species (Reasons for Listing and Continuing Threats). The recovery criteria presented in this recovery plan thus represent our best

assessment of the conditions that would most likely result in a determination that delisting of the desert tortoise is warranted as the outcome of a formal five-factor analysis in a subsequent regulatory rule-making.

Definitions according to section 3 of the Endangered Species Act.

Endangered Species – Any species that is in danger of extinction throughout all or a significant portion of its range.

Threatened Species – Any species that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

Recovery criteria:

- can be viewed as the targets by which progress toward achievement of recovery objectives can be measured;
- should address
    - representation - conserving the breadth of the genetic makeup of the species to conserve its adaptive capabilities,
    - resiliency - ensuring that each population is sufficiently large to withstand stochastic events, and
    - redundancy - ensuring a sufficient number of populations to provide a margin of safety for the species to withstand catastrophic events;
- must include the management or elimination of threats, addressing the five statutory (de-) listing factors; and
- must be measurable and objective (but they need not all be quantitative).

Recovery Goal

The goal of the recovery plan is recovery and delisting of the desert tortoise.

Recovery Objectives and Criteria

Recovery objectives and criteria are outlined below, followed by more detailed explanation and rationale.

Recovery Objective 1 (Demography). Maintain self-sustaining populations of desert tortoises within each recovery unit into the future.

Recovery Criterion 1. Rates of population change (λ) for desert tortoises within each recovery unit are increasing over 25 years (a single tortoise generation).

Recovery Criterion 1a. The lower 90 percent confidence limit for each recovery unit estimate of λ based on data from range-wide monitoring efforts exceeds 1.

All size classes of tortoises must be well represented to ensure adequate recruitment.

Recovery Criterion 1b. The lower 90 percent confidence limit for each estimate of λ based on data from vital rates (recruitment, survival) from demographic study areas within each recovery unit exceeds 1.

Recovery Objective 2 (Distribution). Maintain well-distributed populations of desert tortoises throughout each recovery unit.

Recovery Criterion 2. Distribution of desert tortoises throughout each recovery unit is increasing over 25 years. The lower 90 percent confidence limit for the slope of the trend of the proportion of sites occupied (ψ) within each recovery unit exceeds 0.

Recovery Objective 3 (Habitat). Ensure that habitat within each recovery unit is protected and managed to support long-term viability of desert tortoise populations.

Recovery Criterion 3a. Unless or until tortoise population viability is ensured, the quantity of desert tortoise habitat within all existing desert tortoise conservation areas is maintained with no net loss.

Recovery Criterion 3b. The condition of desert tortoise habitat within each recovery unit is demonstrably improving.

Recovery Objective 4 (Threats). Threats to the viability of desert tortoise populations are mitigated sufficiently to ensure persistence of the species within each recovery unit.

Recovery Criterion 4. Knowledge of, and abatement strategies for, threats to desert tortoise populations are sufficient to determine that these threats do not cumulatively place the species at risk of becoming endangered in the foreseeable future. Management plans or cooperative agreements have been implemented within each recovery unit to ensure maintenance of Recovery Criteria 1 through 3. Each plan or agreement must contain:

a) explicit management actions to address threats to the persistence of desert tortoise populations within that recovery unit;

b) strategies to ensure that the management plan is evaluated and revised regularly based on new information collected through targeted research;

c) a system to track the implementation of management actions; and

d) assurances that the plan will continue to be implemented.

Rationale

The following narrative describes the basis for the recovery objectives and criteria.

Recovery Objective/Criterion 1 (Demography). *This objective and associated criteria emphasize increasing desert tortoise populations over 25 years (a tortoise generation).* The approach taken by these criteria is to estimate population change (λ) on a recovery-unit-wide scale through measures of population size, density, or occupancy (probability that randomly sampled sites are occupied by the desert tortoise; MacKenzie *et al*. 2006) (Criterion 1a). It also seeks to validate the recovery-unit-wide estimates through more intensive study of the underlying recruitment and survival rates on smaller scales within recovery units (Criterion 1b). Note that the geographic area over which range-wide trends in desert tortoise populations are monitored includes all potential desert tortoise habitat within existing tortoise conservation areas (see Recovery Action 4.1.1).

"Potential desert tortoise habitat" is defined here as the forthcoming U.S. Geological Survey habitat model, regardless of current occupancy by desert tortoises.

Basing the criteria on trends has an important advantage over setting specific target numbers (*e.g.*, 40 tortoises/kilometer^2 [104 tortoises/mile^2]). Measuring population trends accounts for ecological differences between geographic areas that may underlie different initial population levels in those areas. For example, historic natural population densities probably differed between the Upper Virgin River and Colorado Desert recovery units (USFWS 2006a), so a single target density would not apply to both areas.

Although a convention exists in general to consider 95 percent confidence intervals, natural variability in population size and measurement would make it extremely difficult to detect all but the largest population increases. Instead, we propose use of a narrower 90 percent confidence band, which nonetheless affords assurance that detected trends are meaningful. Evaluations at 5-year intervals will allow an assessment of statistical power based on the observed variability, an evaluation of potential trends and age structures, and an opportunity to adjust management based on those trends.

The further step of specifically confirming that recruitment and survival are at increasing levels will be important to ensure that populations are able to maintain their size or trajectory upon delisting. However, measuring recruitment and survival across the entire range of the tortoise is logistically difficult and prohibitively expensive. Therefore, the concept of "demographic study areas" is introduced to focus sampling efforts at a scale at which statistically defensible trends of the desired population parameters can be measured (see Recovery Actions 4.1.2, 5.1). The number, size, and sampling frequency of demographic study areas remain to be defined in coordination with the Science Advisory Committee, but they should be small relative to the size of each recovery unit, and they should be representative of each recovery unit. Existing permanent study plots may be incorporated into the set of demographic study areas within each recovery unit, if appropriate. Measuring recruitment and survivorship rates within demographic study areas within each recovery unit addresses the recovery concepts of representation and resiliency.

Recovery Objective/Criterion 2 (Distribution). *This objective and associated criterion emphasize increasing the distribution of desert tortoises (within conservation areas) over 25 years*. Recovery Criterion 1 focuses on population growth. Recovery Criterion 2 supplements monitoring rates of population change by focusing on the distribution of tortoises across the landscape. The 1994 Recovery Plan only indirectly addresses this issue by recommending enough habitat be conserved to ensure viable tortoise populations, but did not directly address population processes acting across the spatial scale of entire recovery units. Criterion 2 emphasizes that any increase in tortoise numbers occurs across the recovey unit, with an overall increase in tortoise distribution, as measured by occupancy (MacKenzie *et al.* 2006) (Fig. 5). An average increase in tortoise density in a recovery unit reflected by growth only in highly localized areas would not reflect recovery.

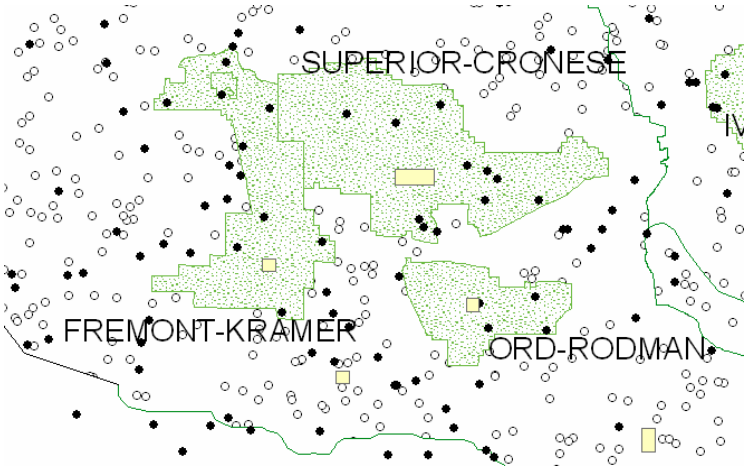

Figure 5. Example of hypothetical occupancy pattern. Stippled green polygons = critical habitat; filled circles = samples with at least 1 tortoise observation; open circles = samples with no tortoise observations; yellow boxes = hypothetical demographic study areas. Recovery Criterion 2 stipulates that tortoise occupancy across the entire recovery unit increases (not necessarily the same samples, just the overall level).

This recovery objective provides for representative, resilient, and redundant populations. Although habitat is explicitly addressed by Recovery Objective 3, implicit in Objective 2 is the maintenance of sufficient habitat to sustain tortoises on the landscape. That is, increasing tortoise distributions, even if augmented by translocation or head-starting, can only be achieved by managing habitat appropriately. As with Recovery Criterion 1, the geographic baseline over which desert tortoise occupancy is monitored includes all potential tortoise habitat within tortoise conservation areas (see Recovery Action 4.2). The baseline will help ensure that habitat loss does not result in a comparison of similar relative measures of tortoise occupancy across smaller absolute areas in the future.

Recovery Objective/Criterion 3 (Habitat). *This objective and associated criteria emphasize maintaining and improving the quality of desert tortoise habitat within existing conservation areas*. Habitat is the suite of resources (food, shelter) and environmental conditions (abiotic variables such as temperature and biotic variables such as competitors and predators)

that determine the presence, survival, and reproduction of a population (Caughley and Sinclair 1994). Quality of habitat can affect reproductive success and survival of individuals occupying the habitat (Pulliam 1996), and declining populations typically require intensive habitat management to stabilize and reverse trends. Much is known about what constitutes desert tortoise habitat, and a range-wide model of habitat for the Mojave population of the desert tortoise is nearing completion (K. Nussear, U.S. Geological Survey, pers. comm. 2007). However, we currently lack the methodology to monitor changes in the quantity and quality of habitat, especially in the face of rapid urbanization, invasion by exotic plants, and increasing frequency and magnitude of fires.

In order to manage desert tortoise habitat well enough to meet Objectives 1 and 2, we must be able to link habitat data to tortoise demographic data via statistical modeling (see Recovery Action 5.2). Information from this type of model will allow us to identify minimum conditions for potential tortoise occupancy and, therefore, to analyze occupancy as a function of habitat characteristics. Until we have refined models linking tortoise habitat to population viability, Criterion 3a establishes a target for no net loss of current habitat depicted by the model within tortoise conservation areas. Criterion 3b emphasizes improving habitat quality within each recovery unit.

"No net loss" of tortoise habitat is considered here as the complete or absolute removal of elements necessary for desert tortoise occupation, such as complete grading or paving of the landscape so that no food or shelter resources are available, or other identified thresholds of habitat quality below which the minimum conditions for desert tortoise occupation are not met.

It will be important to define parameters that relate to the quality of desert tortoise habitat (see Recovery Action 5.2.2) and to develop and implement a system for tracking habitat quality over time. In particular, thresholds need to be identified below which habitat degradation fails to provide the minimum conditions for potential occupancy, especially due to fires, for example. Habitat degradation or loss in some areas should be balanced with habitat acquisition or restoration of degraded habitat in other areas, as specified in the West Mojave Plan for example (BLM *et al.* 2005:2-39), thus achieving the no-net-loss standard and maintaining tortoise occupancy through maintenance of (quality) available habitat. Development of a GIS "ledger" of habitat status, accounting for restored areas on the positive side and degraded or lost areas on the negative side, would enable managers to quantitatively measure the amount of occupied habitat, the amount of newly available (restored) habitat for tortoises to disperse into, the rate that restored habitat is occupied, and effectiveness of the restoration (e.g., BLM 2002b:Appendix G). Through the Recovery Implementation Teams (Recovery Action 6.1), management agencies should report habitat status on their lands based on a habitat/demography model. The geographic baseline over which trends in habitat quantity and quality will be monitored includes all potential desert tortoise habitat within tortoise conservation areas (see Recovery Action 4.3).

Until better population/habitat viability models are developed (see Recovery Action 5.2.4), land managers should also strive to limit the loss of desert tortoise habitat outside conservation areas as much as possible. Mitigation for habitat impacts could include a variety of options outside conservation areas, including habitat acquisition as well as restoration of degraded habitat in other areas or recovery units, contributions to research, or facilitating population augmentation programs.

Actions or projects occurring outside tortoise conservation areas should be evaluated under existing section 7 and 10 processes to prevent negative impacts in adjacent areas and creating edge effects within the conservation areas. This approach recognizes the need for large natural areas to accommodate stochastic events (*i.e.*, resiliency). Tortoise conservation areas should be as undisturbed as possible and include intensive restoration or other management (*e.g.*, weed management), as necessary. Modeling should help better quantify what proportion of the habitat needs to be occupied or is available to be occupied for population sustainability.

Recovery Objective/Criterion 4 (Threats). *This objective and associated criterion emphasize effectively managing threats to desert tortoise populations*. This recovery objective incorporates the concept of conservation-reliant species and the need for ongoing management for these species (Scott *et al.* 2005). Even though a wide range of threats affect desert tortoises and their habitat (and some such as disease and fire have attracted much recent attention), very little is known about their demographic impacts on tortoise populations or the relative contributions each threat makes to tortoise mortality (Tracy *et al.* 2004). Therefore, specific and meaningful threats-based recovery criteria cannot be identified at this time.

In Criterion 4, we assume that threat mitigation will have been successful if Recovery Objectives 1 through 3 have been met (taking into consideration any head-starting or translocation efforts). While it is important to understand as much as possible about the direct links between threats and tortoise population response (*i.e.*, cause and effect), the number of potential threats affecting desert tortoises and the nature of the species' life history (especially long generation time) may make it impractical to reach this level of understanding completely. However, evaluating the extent and intensity of threats across the landscape over time will allow recovery efforts to be better tailored to specific areas in conjunction with information gained through research (see Recovery Action 4.4). Specific recovery actions, including research, must be implemented to identify sets of threats that contribute to a greater number of mortality mechanisms or affect size structure or fecundity. Experimental (or, in some cases, observational) studies should be applied to specific plots or areas to better understand the relationship of threats, management actions, and tortoise populations (Recovery Actions 5.3 through 5.5).

The relative strengths of hypothesized connections between threats and mortality must also be evaluated (some individual linkages may be more important than multiple linkages from other threats). This assessment should be based on data from research designed specifically to elucidate relationships between threats and mortality. As quantitative information on threats and tortoise mortality is obtained, effective management actions can be identified, prioritized, and implemented through land use plans, cooperative agreements, etc., as recommended by this recovery criterion. In addition, new information may contribute to the development of more specific threats-based recovery criteria during future recovery plan review and revision.

C. RECOVERY ACTIONS

The following narrative outline describes specific recovery actions within each strategic element listed in the recovery strategy. Table 3 identifies the listing factors and recovery objectives addressed by each major recovery action.

1. Implement an Adaptive Management Program

1.1 Revise and continue development of a recovery decision support system.

A preliminary decision support system has been developed (Appendix C) and will be used to identify and prioritize recovery actions relative to managing desert tortoise populations and habitat (see Protect and Manage Existing Populations and Habitat, below). Due to the lack of data on the effects of individual threats on tortoise demography, this initial decision support system is based largely on information collected from workgroups convened during the recovery planning process or other sources, simple preliminary models, and the expert opinion of approximately 20 individuals from the tortoise science and management community (see Appendix C). In addition, the data input into the decision support system are only partially complete, and virtually no synthesis of recovery actions that have been implemented pursuant to the 1994 Recovery Plan has been performed. Thus, the current outputs of the decision support system are very preliminary and cannot be regarded as absolutes. However, the objective of applying the decision support system at this time is not an attempt to represent certainties about the relationship between tortoise populations, habitat, threats, and management, but instead to establish a "rapid prototype" that will identify key assumptions and allow evaluation of the relative importance of different assumptions, components, or gaps in the model (Starfield 1997; Nicolson *et al.* 2002).

The models contained within this rapid-prototype decision support system should be regularly updated with additional information and refined to achieve the goals that a) ensure the overall decision support system is clearly partitioned into a suite of models with clear purposes, b) ensure all models or components are transparent and comprehensible, and c) the sensitivity of model output to different parameter values and assumptions is adequately tested. It is especially critical to continue to update the underlying data in the decision support system with a range-wide, geospatial database of current management activities, landscape information on threats, habitat quality and quantity, and tortoise populations. In addition to contributing to models, maintaining an up-to-date database will facilitate reporting of implementation progress.

1.2 Revise recovery tasks in coordination with Recovery Implementation Teams and the Management Oversight Group as pertinent new information becomes available.

This recovery plan outlines recovery tasks based on the best information currently available. However, continued research and monitoring may lead to the identification of new or modified tasks or different priorities among tasks than currently recognized. Recovery Implementation Teams should identify priorities and specific tasks pertinent to their region and should engage the Desert Tortoise Management Oversight Group on a regular basis to review and modify recovery implementation as needed (see 6.1).

1.3 Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions.

Federal and State land managers should amend planning documents as needed to facilitate implementation of this recovery plan. Broad land-use plans, such as Bureau of Land Management resource management plans, may not need revision, as they often include language stipulating that agencies will strive to implement recovery for federally listed species. Program-level or area-specific plans, such as habitat management plans, wilderness plans, and ACEC plans, are an opportunity to work with stakeholders to build in detailed planning at local levels. We encourage land managers to coordinate closely with Recovery Implementation Teams (see 6.1) on any revisions of such plans.

1.4 Incorporate scientific advice for recovery through the Science Advisory Committee (SAC).

The DTRO should continue to work directly with the SAC and meet at least annually to review progress in research and monitoring and other recovery plan accomplishments. The SAC should make new recommendations, as needed, based on progress in implementing the recovery plan. Annual SAC meetings should include an opportunity for stakeholder/manager interaction to provide direct feedback and information exchange.

2. Protect and Manage Existing Populations and Habitat

2.1 Minimize human-associated mortality of desert tortoises.

Desert tortoise mortality should be minimized as much as possible, especially within tortoise conservation areas. Where it cannot be avoided, mitigation measures should be drawn from the suite of actions recommended in this recovery plan, including habitat acquisition or restoration, contributing to research or population augmentation programs, or other measures depending on the available needs and opportunities. Note that other State or Federal agency policies/ regulations may impose specific measures or process to determine appropriate mitigation.

2.2 Reduce factors contributing to disease (particularly upper respiratory tract disease).

Strategies for managing natural populations depend on the disease status of the population, deemed broadly as a) uninfected, b) recently infected with infection spread, or c) infection status endemic. An endemic-status population is defined as one where the proportion that is seropositive is above zero and remains stable over time. Additional background and details can be found in Appendix B.

2.2.1 All tortoises found in the wild that may be released captives should be used for breeding, adoption, or research program unless they are determined to not be infected and are genetically acceptable for that population.

2.2.2 No action should be taken to remove infectious or seropositive individuals from natural populations, particularly where data indicate the disease status of that population is endemic.

2.2.3 In populations known to be uninfected, individual tortoises exhibiting clinical signs of acute infection should be removed for further testing, but should be returned to the point of capture if diagnostic tests confirm they are uninfected. Acute infections are defined as those exhibiting a nasal or ocular discharge at an inappropriate time of year.

The prototype decision support system, using information provided by managers during recovery planning workshops, produced preliminary recovery action priorities relative to protecting and managing desert tortoise populations and habitat for each recovery unit (Appendix C-7). These priorities may change as new information is gained through research and monitoring or as additional existing information is integrated into the decision support system (Strategic Element 1). A challenge in developing the prototype decision support system was making the list of recovery actions more operational. Several actions listed in the 1994 Recovery Plan overlap with one another, and it was clear from the recovery planning workshops that various actions meant different things to different people.

Not all actions are mutually exclusive of one another. Several are complementary and can be implemented in tandem. Part of the complementary nature of recovery actions is a result of whether they can be categorized as policy-based or management-based actions. Policy-based recovery actions are typically one-time decisions that establish protocols, rules, or regulations, but involve little on-the-ground activity other than law enforcement to ensure compliance. Management-based actions are on-the-ground activities intended to improve conditions for desert tortoise populations or their habitat.

Nonetheless, the following outline includes 1) high-priority, range-wide actions output by the decision support system for implementation in the short term, 2) additional high-priority actions for particular recovery units, and 3) actions currently identified as lower priority by the decision support system. The outline includes some modification based on manager input at the recovery planning workshops. Regional Recovery Implementation Teams (6.1) should revise or reprioritize the recovery tasks identified below through refinement of the decision support system and as new information becomes available (1.2). Refinement of the decision support system should also continue to clarify and operationalize recovery action terminology.

Note in the following narrative that the boundaries of the recovery units are still under review. Reference to specific named recovery units is preliminary and for illustrative purposes only.

High-priority, range-wide recovery actions include the following:

2.3 Establish/continue environmental education programs.

Environmental education, identified as a high priority in all recovery units, is a preventative action that can be used to reduce stakeholder conflict before it happens. Aggressive and widespread efforts in schools (such as the Mojave Max program in Clark County, Nevada), museums, hunting clubs, and in Bureau of Land Management and National Park Service visitor centers and interpretive sites are needed to inform the public about the status of the desert tortoise and its recovery needs.

Interpretive kiosks or visitor centers should be used to disseminate information about the desert tortoise and the need for regulated access and use of habitat. The Desert Tortoise Conservation Center in Las Vegas should be developed into a regional education and research facility for these purposes. Education programs should include such subjects as husbandry and adoption programs for captive tortoises, the importance of discouraging unauthorized breeding of desert tortoises in captivity, and the illegality of releasing captive tortoises into wildlands. Education efforts should be focused on groups that use the desert on a regular basis, such as rock-hounds and off-highway vehicle enthusiasts. A permit system for access to sensitive areas would offer one way to educate desert recreationists. Additional educational tools include public service announcements, news releases, informational videos, brochures and newsletters, websites, and volunteer opportunities.

2.4 Increase law enforcement.

People may conduct illegal activities either because they are unaware of the laws, they do not realize the consequence of their behavior, or they enjoy some personal benefit that outweighs the risk of being caught. Increased law enforcement presence was recognized as a high priority in all recovery units and includes enforcing regulations pertinent to the specific recommendations to protect tortoises or their habitat listed below. Increasing fines and establishing agreements between agencies to enforce regulations across jurisdictional lines would also improve the effectiveness of law enforcement efforts. An increased law enforcement presence need not be restricted to commissioned peace officers, but could also include “rangers” or other personnel with a physical presence in the field that would make contact with public land users, communicate with law enforcement officers, and conduct other activities, as necesssary (*e.g.*, minor restoration or trash removal). The following is a list of illegal activities known to negatively affect the desert tortoise and warrant increased enforcement.

2.4.1 Unauthorized off-road vehicle travel.

Across all recovery units, this aspect of law enforcement was recognized as the most important. Impacts from off-highway vehicle use include mortality of desert tortoises on the surface and below ground; collapsing of desert tortoise burrows; damage or destruction of plants used for food, water, and thermoregulation; damage or destruction of the mosaic of cover provided by vegetation; damage or destruction of soil crusts; soil erosion; proliferation of weeds; and increases in numbers and locations of wildfires. Unauthorized off-highway vehicle use also results in increased human access and associated impacts such as vandalism.

The following unauthorized activities are typically more localized and more common near urban or rural development.

2.4.2 Vandalism of tortoises.

Vandalism refers to the "purposeful killing or maiming of tortoises" (Luke *et al.* 1991). Particularly, vandalism takes the form of shooting, crushing, driving over, flipping over, and decapitating tortoises. Shooting (also called "plinking"), by far, is the most prevalent form of vandalism on desert tortoises (Boarman 2002). Preventing the discharge of firearms, except for hunting authorized by state game and fish departments, in problem or other sensitive areas could help minimize this problem.

2.4.3 Unauthorized breeding and release of captive tortoises.

Captive release of tortoises (not limited to desert tortoises) poses numerous problems to wild host populations. Examples include genetic pollution, hybridization between populations and possibly other tortoise species, the potential for introducing or spreading disease (*e.g.*, upper respiratory tract disease), and disturbance to the social structure of the host population. Unauthorized breeding and release of pet desert tortoises particularly contributes to genetic pollution and disease spread. Placement of excess tortoises in adoption or translocation programs places a large burden (*e.g.*, cost of pick-up services, health testing, placement efforts) on resources that would otherwise be available for more productive recovery efforts. New state or local regulations may be necessary to prohibit unauthorized breeding of desert tortoises.

2.4.4 Uncontrolled dogs.

Domestic and feral free-roaming dogs are documented threats to captive and wild tortoises. With the growing number and sizes of cities, towns, and settlements in the desert, this type of threat is increasing and will be difficult to control. Dogs singly, and in packs, often roam miles from home, dig up, and injure desert tortoises. This action entails implementing

measures to control off-leash dogs (domestic dogs should at least be within sight and voice control), live-trapping free-ranging dogs, and developing free-ranging dog management plans.

2.4.5 Dumping and littering.

Dumping and littering subsidizes predators and can introduce toxic chemicals or hazardous materials to the environment.

2.5 Restrict, designate, close, and fence roads.

Paved highways, unpaved and paved roads, trails, and tracks have significant impacts on desert tortoise populations and habitat. In addition to providing many opportunities for accidental mortality, they also provide access to remote areas for collectors, vandals, poachers, and people who do not follow vehicle-use regulations. Substantial numbers of desert tortoises are killed on paved roads. Roads also fragment habitat and facilitate invasion of non-native vegetation.

2.5.1 Establishment of new roads should be avoided to the extent practicable within desert tortoise habitat on public lands, especially within tortoise conservation areas.

2.5.2 Existing roads should be designated as open, closed, or limited.

This action is especially pertinent for closed or limited designations, which can help mitigate impacts mentioned above. Maintenance of route designation signs may also be required due to vandalism.

2.5.3 Non-essential or redundant routes should be closed, especially within tortoise conservation areas.

Emergency closures of dirt roads and routes may also be needed to reduce human access and disturbance in areas where human-caused mortality of desert tortoises is a problem.

2.5.4 Tortoise-barrier fencing should be installed, according to specifications provided in Appendix D, and maintained along highways in desert tortoise habitat.

Fencing roads was identified as particularly high priorities in the Upper Virgin River Recovery Unit and Western Mojave Recovery Unit (particularly along parts of US-395, I-40, and SR-247). Other areas in California in need of fencing include parts of US-95, I-10, I-15, I-40, redundant roads within Mojave National Preserve and Joshua Tree National Park, and the Union Pacific rail line in the Eastern Mojave/Northern Colorado Recovery Unit. Many roads have already been fenced in Clark County, Nevada, but remaining areas include US-93 from

I-15 to Pahranagat, SR-75 (Valley of Fire Road) from I-15 to State Park Boundary, SR-168 from I-15 to US-93, Cal-Nev-Ari (tie in fencing to US-95), and Cottonwood Cove Road. Alternatives to fencing may be investigated in areas of high-maintenance (*e.g.*, subject to flash flooding) or viewshed concern. Culverts and underpasses should be incorporated into road-fencing projects to minimize the fragmenting effects of the road (2.11).

2.5.5 While graded roads typically need not be fenced, berms should be maintained such that tortoises do not get trapped in the roadbed.

This has been identified as a particular issue in the Eastern Colorado and Eastern Mojave/Northern Colorado recovery units, as well as throughout the Mojave National Preserve.

2.6 Protect intact desert tortoise habitat.

Land disturbances should be precluded or minimized as much as possible within tortoise conservation areas, and fires should be aggressively suppressed throughout the Mojave/Colorado Deserts to contain the grass-fire cycle. Minimizing the size and intensity of fires will ease subsequent restoration efforts (2.7), even in previously burned areas. Fire suppression would also minimize direct and indirect effects on individual tortoises. Identifying and mapping priority areas and developing a fire plan for habitat protection, fire-crew access, and the use of natural or created fuel breaks could help limit response time and fire spread.

2.7 Restore desert tortoise habitat.

Habitat restoration is a countermeasure to many of the impacts discussed above, such as grazing, military operations, off-highway vehicle use, roads and trails, construction, mining, burros, invasive species, fire, environmental contaminants, and utility corridors. As such, this action is highly prioritized within all recovery units, although the specific restoration activities may vary by recovery unit and management agency. A first step in restoration is assessing habitat status and desired conditions, then targeting restoration (or protection) efforts to meet those conditions. Natural recovery of severely degraded desert scrub is expected to occur over centuries, not decades, so active restoration efforts will be required in such areas. Restoration may be facilitated by placement of vertical structure even in severe situations, which may help prevent additional degradation. However, the science of restoration and re-vegetation of the Mojave Desert ecosystem is in its infancy.

In general, because of the uncertainties and costs associated with revegetation and the long periods required for natural recovery, the first priorities in habitat conservation should be to minimize land disturbance and protect remaining, intact habitats (2.6). Even so, incentive programs to restore habitat through habitat

rehabilitation credits or mitigation banking could be used to encourage persons or entities to rehabilitate degraded habitat (BLM *et al.* 2005). Several restoration activities warrant specific attention below, although methods for successful implementation for most need to be developed or refined.

2.7.1 Eradicate or suppress invasive weeds.

Methods for weed suppression or eradication on large scales are currently unavailable, but the use of herbicides or other measures may be particularly appropriate on smaller scales in tortoise conservation areas.

2.7.2 Revegetate degraded areas with native plants of high nutritive quality to desert tortoises, as well as shrubs needed for cover.

Given the vast scales of recent wildfires, post-fire rehabilitation should be approached strategically toward areas determined to have a higher likelihood of successful restoration, considering fire severity, soil types, biological connectivity of native source plants, etc. This action may also be appropriate for smaller-scale applications such as obscuring closed roads and mitigating utility corridor disturbances.

2.7.3 Remove toxicants and unexploded ordnance.

Areas with elevated levels of elemental toxicants associated with mining, other industrial operations, unexploded ordnance, and unauthorized dump sites should be identified and remediated where possible.

The actions listed above comprise the top five actions identified by the provisional decision support system for the Lower Virgin River, Northeastern Mojave, Amargosa, Eastern Mojave/Northern Colorado, and Western Mojave recovery units. Additional high-priority recovery actions are listed below for the Upper Virgin River and Eastern Colorado recovery units, as well as the Western Mojave Recovery Unit (given the intensity of anthropogenic pressures faced by that unit). These actions also typically appeared as mid-level priorities for the other recovery units and should be addressed as higher priority actions are implemented, as part of elevated management within tortoise conservation areas, or as other opportunities or needs arise.

2.8 Install and maintain urban or other barriers (Upper Virgin River and Western Mojave recovery units).

Urban development indirectly affects desert tortoise populations through spillover of human impacts, such as unauthorized off-highway vehicle use and free-roaming dogs, into the surrounding habitat. This action entails installing and maintaining appropriate barriers at the urban-wildland interface or adjacent to other uses incompatible with desert tortoise populations (particularly adjacent to

tortoise conservation areas). Depending on the particular impacts of interest, the actual type of barrier may differ. For example, tortoise-proof fencing (Appendix D) may be sufficient adjacent to aqueducts or off-highway vehicle areas, but larger fences or block walls may be necessary adjacent to urban development to limit off-highway vehicle use and free-roaming dogs. Priority areas identified for this action include:

1) around the Red Cliffs Desert Reserve in the Upper Virgin River Recovery Unit and

2) around the Desert Tortoise Natural Area, Helendale, Barstow/Dagget, Yucca Valley, Joshua Tree, and Twentynine Palms, as well as adjacent to the Johnson Valley Open Area, in the Western Mojave Recovery Unit.

Barriers around new developments (*e.g.*, Coyote Springs Valley) in the Lower Virgin River Recovery Unit, the edges of the Las Vegas metropolitan area in the Northeastern Mojave Recovery Unit, and around the town of Goffs in the Eastern Mojave/Northern Colorado Recovery Unit ranked as mid-level priorities in the decision support system.

2.9 Sign and fence boundaries of sensitive or impacted areas (Upper Virgin River and Western Mojave recovery units).

This action entails marking boundaries of particularly sensitive or heavily impacted areas with signs and fencing to regulate authorized use and to discourage unauthorized use. This can include marking boundaries of protected areas, research sites, off-highway vehicle routes, roads, military lands, and parks. Signs or kiosks may also be used to for educational purposes and to raise awareness.

2.10 Secure lands/habitat for conservation (Upper Virgin River, Eastern Colorado, and Western Mojave recovery units).

This action counters habitat loss and protects tortoises, provided it is suitable habitat or can serve as corridors or buffers. However, given the vast amount of desert tortoise habitat already under Federal management or primary conservation use, this action should focus on particularly sensitive areas that would connect functional habitat or improve management capability of the surrounding area. Land acquisitions should include surface and subsurface mineral rights whenever possible. Conservation agreements could also be developed to protect desert tortoise habitat in such areas.

Land managers should coordinate with the Department of Defense on efforts such as the Readiness and Environmental Preparedness Initiative and the Army Compatibility Use Buffer program to acquire lands that would serve a dual purpose of preventing encroachment on military installations and conserving desert tortoise habitat.

Areas of particular emphasis for this recovery action include the Western Mojave Recovery Unit and inholdings within National Parks. In addition, consolidating private lands within the Red Cliffs Desert Reserve is important for habitat connectivity.

The following actions typically ranked as mid- to lower-level priorities and should be addressed as higher priority actions are implemented, as part of elevated management within tortoise conservation areas, or as other opportunities or needs arise.

2.11 Restrict competitive off-highway vehicle events within desert tortoise habitat.

This action refers to large- or small-scale competitive races involving up to thousands of motorcycles and other off-highway vehicles. Prior to the implementation of current permitting and management practices (see for example BLM 1998a), competitive off-highway vehicle events led to the widening of old routes, creation of new routes, camping and staging by race participants and observers in unauthorized areas, littering, and inability of race monitors to prevent unauthorized activities. This action entails prohibiting or minimizing the effects of such events within tortoise habitat; limiting the number of events per year, limiting events to the winter season, and limiting the number of participants per event; and ensuring all participants stay on designated roads.

2.12 Connect functional habitat.

Connecting fragmented habitat helps to maintain gene flow between isolated populations. This action improves species fitness by maintaining biodiversity, allowing populations to interbreed, and providing access to larger habitats (Forman *et al.* 2003). Roads and urban areas form barriers to movement and tend to create small, local populations which are much more susceptible to extinction than large, connected populations (Wilcox and Murphy 1985). This action was of consistently moderate priority among recovery units. It entails connecting desert tortoise habitat wherever enough habitat exists, particularly through corridors of natural habitat for large-scale connectivity, as well as culverts for smaller-scale connectivity across fenced roads and railroads.

2.13 Manage mining.

Impacts from mining can include habitat destruction and direct mortality from off-road exploratory travel; habitat loss to road and development construction, leachate ponds, tailings, and trash; introduction of toxins; fugitive dust and soil erosion; development of ancillary facilities to support large mining operations; temporary (short- or long-term oil and gas leases) use of public lands; and refuse of stakes and wire from seismic testing. Therefore, mining should be withdrawn (if feasible) from or otherwise limited through mining plans of operations within

tortoise conservation areas or where indirect effects from adjacent areas would affect these areas.

2.14 Manage landfills.

Landfills can impact tortoise populations by removing habitat, spreading garbage, introducing toxic chemicals, through road kills by vehicles going to and from the landfill, and through predator proliferation. Predator proliferation is considered the most significant of these impacts with landfills providing food subsidies for ravens and coyotes, leading to more young that move into adjacent tortoise habitat in the spring to prey upon tortoises (Boarman 2002). Proper landfill management (including dumps and sewage ponds) can help reduce several threats to tortoises especially from ravens (Boarman and Kristan 2006). This action entails reducing or eliminating the use of authorized landfills by tortoise predators, siting new landfills outside of desert tortoise habitat, and/or precluding new landfills within 5 miles of existing tortoise conservation area boundaries.

2.15 Reduce raven predation on tortoises.

Predation by the common raven is focused on younger age classes of the desert tortoise. During the first 5 to 7 years of life, the tortoise shell is incompletely ossified; it is soft and easy to puncture and open. Several other recovery actions address raven population management by limiting human subsidies (*e.g.*, food obtained at landfills and from roadkills). This action emphasizes more direct raven-control programs to reduce predation on juvenile tortoises. Control methods can include targeted removal of known tortoise predators by shooting or trapping (live or lethal), as well as nest removal.

2.16 Manage horses and burros.

Wild horses and burros alter desert tortoise habitat through soil compaction and vegetation change (Boarman 2002). Tortoises and horses/burros may also compete for the same food. This action entails excluding horses and burros by fencing and/or removal. For example, the California Desert Managers Group has been coordinating among member agencies since 1998 to substantially remove horses and burros from outside herd management areas. Herds have been zeroed out in most critical habitat and efforts are continuing to reduce their numbers. Within the Las Vegas District of the Bureau of Land Management, all herd management areas are at appropriate management levels and herds outside of herd management areas have been zeroed out.

2.17 Manage livestock grazing.

Grazing by livestock (cattle and sheep) affects desert tortoises through crushing animals or their burrows, destroying or altering vegetation (which may introduce weeds and change the fire regime), altering soil, and competition for food (Boarman 2002). Many cattle and sheep allotments have already been retired

within desert tortoise habitat, but this action entails continued exclusion of livestock grazing by fencing, removing trespass cattle, retiring allotments, and prohibiting supplemental feeding, especially where it still occurs within tortoise conservation areas. More flexible grazing practices, such as allowing or reducing grazing during specific times of the year (*e.g.*, after ephemeral forage is gone or winter only) or under certain environmental conditions (*e.g.*, following a specified minimum amount of winter rain) would be most appropriate outside conservation areas, but should be used experimentally to investigate the compatibility of grazing with desert tortoise populations.

3. Augment Depleted Populations through a Strategic Program

3.1 Develop protocols and guidelines for the population augmentation program, including those specific to head-starting and translocation.

Specific guidelines and protocols should be developed with other permitting agencies and experts, drawing from knowledge gained through recent research into head-starting and translocation.

3.2 Identify sites at which to implement population augmentation efforts.

Populations to be augmented should be identified based upon knowledge of population trends and threats in the area, unique opportunities to learn about augmentation techniques or threats through a research-based program, and feasibility. Data from previous population monitoring efforts, including a spatial analysis (Nussear in prep.), and recent advances in genetics will facilitate selection of the target areas.

3.3 Obtain tortoises for use in augmentation efforts.

3.2.1 Secure facilities for head-starting tortoises.

Several groups in California have begun research into head-starting techniques. Currently, facilities exist at the National Training Center's Fort Irwin Study Sites (FISS 1 and FISS 2), Edwards Air Force Base, and Marine Corps Air Ground Combat Center at Twentynine Palms. These facilities may be used and additional facilities will need to be constructed. For example, the addition of facilities in the Las Vegas area could serve several surrounding recovery units. The existing Desert Tortoise Conservation Center could be renovated to house such facilities in a secure location.

3.2.2 Obtain adult tortoises for generation of progeny.

Tortoises used in the head-starting program will be of known origin and of the genotype that inhabits the specific areas to be augmented. Depending on several factors, breeding colonies may be maintained in captivity, or

wild females may be periodically captured and released after collection of eggs.

3.2.3. Head-start progeny.

Maintain progeny in captivity as specified in guidelines developed under 3.1.

3.2.4. Obtain adult tortoises for translocation.

Some adult tortoises removed from construction sites or other disturbed areas may be suitable for translocation to target areas. Refer to guidelines developed under 3.1.

3.4 Implement translocations in target areas to augment populations using a scientifically rigorous, research-based approach.

Translocation and head-starting efforts should be implemented in conjunction with directed research on the factors affecting success of the augmentation, including methodological factors, but especially including factors related to management of habitat and threats. Refer to guidelines developed under 3.1 for information on target areas.

4. Monitor Progress toward Recovery

The ability to describe range-wide trends depends on developing reliable, adequate, and consistent funding. A key recommendation of the General Accounting Office's audit of the desert tortoise recovery program was that the Departments of the Interior and Defense work with other agencies and organizations "to identify and assess options for securing continued funding for range-wide population monitoring" (GAO 2002). Rather than developing monitoring based on annual budgeting considerations, implementing the GAO's recommendation (for example, through 5-year time frames) will allow effective planning, contracting, and hiring to be implemented under a long-term study plan. The following recovery actions parallel the recovery criteria described earlier, helping ensure that progress toward recovery is measured effectively.

4.1 Monitor desert tortoise population growth.

Trends in tortoise populations can be assessed either by directly enumerating the number of tortoises, or by estimating the rate of births, deaths, and related recruitment into each age or size class so that the resulting trend in population growth can be determined.

4.1.1 Monitor the number of tortoises in each recovery unit.

The number of tortoises in each recovery unit is related to the density of tortoises estimated by line distance sampling techniques. It can also be

related to the extent of the habitat occupied by tortoises and how that extent expands or contracts over time (see 4.2). Either approach can relate changes in an index (density or occupancy) to changes in time to estimate the population growth rate, lambda. Either density or occupancy will focus on particular size classes, often neglecting the smallest size class, for instance. This approach therefore assumes that if the focal size class is increasing, this is because it is recruited from and contributing to the neighboring size classes, which must also be increasing. When evaluating an endangered species, however, this assumption should be validated by independent evidence that the other size classes are recruiting as well.

4.1.2 Use demographic rates in key areas of each recovery unit (*i.e.*, demographic study areas) to independently estimate population growth in each recovery unit.

Demographic (vital) rates describe the proportion of each size class, for instance, that grows into the next size class and/or produces offspring in a given time period. These rates also include mortality rates, estimating the proportion of each size class that dies during that time interval. These rates allow us to describe how a population changes from one time period to the next. Because the total number of tortoises changes from one time period to the next, dynamic models should be used to provide an independent estimate of the population growth rate, lambda.

4.2 Monitor the extent of tortoise distribution in each recovery unit.

Monitoring changes in desert tortoise distribution by estimating occupancy of tortoises entails investigating the most feasible scale at which occupancy would be evaluated, as well as the number of visits to a given site that would be needed to estimate detection probability if tortoises are present. Taken together and repeated over the years of the recovery program, occupancy estimation would provide a description of the rates at which tortoises are being locally extirpated from occupied habitat as well as recolonizing currently unoccupied habitat across the range. Occupancy estimation, if feasible, would also provide another estimate of lambda.

4.3 Track changes in the quantity and quality of desert tortoise habitat over time.

A baseline for tracking habitat quantity across each recovery unit will exist with the habitat model specified in this revised recovery plan (5.2.1). A system for describing trends in habitat quality over time should be integrated as conditions affecting habitat quality are identified (see 5.3.2). Remote sensing and GIS data, validated by ground truthing as necessary, can be used to quantify the loss or restoration of habitat against the baseline (for instance, habitat completely lost to urbanization, degraded by wildfires, or authorized for use as rights-of-way or energy projects).

4.4 Quantify the presence and intensity of threats to the desert tortoise across the landscape.

Remote sensing, GIS data, ground truthing, and other surveys should be used to update and refine information on threats presented in the background of this recovery plan and used in the initial decision support system (1.1). This information will allow recovery efforts to be better tailored to specific areas while being incorporated with additional information gained through research and monitoring.

5. Conduct applied research and modeling in support of recovery efforts within a strategic framework

5.1 Determine demographic characteristics of healthy desert tortoise populations (stable age distribution).

Research on demographic study areas should document age distributions sufficiently to determine the stable age distribution, especially including the proportion of juveniles represented in a stable age distribution.

5.2 Determine factors that influence the distribution of desert tortoises.

5.2.1 Validate and refine the desert tortoise habitat model.

The desert tortoise habitat model should be completed within the first year of publication of this recovery plan. Data collected from the range-wide monitoring program or other surveys, especially those outside currently designated critical habitat, should be used to refine the model.

5.2.2 Determine characteristics that contribute to the relative condition (*e.g.*, high, medium, or low quality) of desert tortoise habitat.

Variation in desert tortoise habitat quality likely contributes to habitat-specific demographic rates (*e.g.*, higher recruitment in habitats with nutritious forage and few ravens; see Pulliam 1996) and occupancy. Some environmental factors, such as water available from rainfall, may be beyond the scope of management, but identifying specific, measurable characteristics of habitat that contribute to high rates of survival, reproduction, and recruitment is important to inform effective recovery efforts. Information from this recovery action is essential to meeting Recovery Criterion 3b relative to ensuring that habitat quality increases over the next 25 years. Research in this area should identify:

5.2.2.1 landscape attributes or features, if any, that cause clumping of desert tortoises; and

5.2.2.2 minimum conditions for potential desert tortoise occupancy.

5.2.3 Model desert tortoise demography relative to habitat condition to determine the proportion of habitat that needs to be occupied (or is available to be occupied) for recovery.

As habitat-specific demography is clarified (5.3.2), population models should be developed to refine estimates of habitat quantity and tortoise occupancy necessary to sustain populations into the future. Models should incorporate predicted effects of climate change on desert tortoise demography, as well as on the current composition of tortoise habitat. Information from this recovery action is essential to refining Recovery Criterion 3a relative to the amount of habitat needed to meet the conditions for delisting.

5.2.4 Determine the importance of corridors and physical barriers to desert tortoise distribution and gene flow.

Determining the importance of corridors and barriers will allow population models to be made spatially explicit relative to current land management (*e.g.*, population and habitat fragmentation due to roads and urbanization) and potential distributional shifts resulting from climate change.

5.3 Conduct research on the restoration of desert tortoise habitat.

5.3.1 Evaluate the effectiveness of different restoration methods.

The science of restoration and revegetation of desert ecosystems is in its infancy, and more work is necessary to identify effective restoration methods in order to successfully implement Recovery Action 2.5.

5.3.2 Identify methods to eradicate exotic, invasive plants within desert tortoise habitat.

Invasive plants are a significant threat to desert tortoise habitat and populations across the species' range. Research is needed to identify methods for weed suppression or eradication in order to successfully implement Recovery Action 2.5.1.

5.3.3 Correlate habitat restoration with desert tortoise population status.

The response of tortoise populations to restoration efforts should be evaluated, especially as habitat-specific demography is clarified (5.3.2). This action may also be implemented in coordination with population augmentation (3.1 through 3.4) and monitoring demographic study areas (4.1.2).

5.4 Improve models of threats, threat mitigation, and desert tortoise demographics.

The decision support system (1.1) requires information on how threats affect desert tortoise populations and how management actions abate those threats. This information has currently been incorporated in the decision support system in a very rudimentary way.

5.4.1 Develop conceptual and quantitative models of threats.

Models of desert tortoise threats are needed to clarify interactive relationships between threats and to identify critical synergies that contribute to population declines. In addition, the demographic effects of individual threats and suites of threats on desert tortoise populations should be determined experimentally whenever possible.

5.4.2 Develop and test models of the effectiveness of management actions.

The corollary of modeling and experimentally investigating threats is determining the effectiveness of threat mitigation by specific management actions. Recovery Implementation Teams should identify and secure funding for applied research on the effectiveness of recovery actions based on local priorities. Conceptual models should be developed for all recovery actions, and these models should be quantified with new research and monitoring information, as it becomes available.

5.5 Conduct research on desert tortoise diseases and their effects on tortoise populations.

The first three recommendations below arise from the working hypothesis that mycoplasmosis-induced die-offs are initiated by environmental stressors (see Appendix B for more information).

5.5.1 Determine whether population declines through environmental stress are less severe when *Mycoplasma* is absent.

5.5.2 Determine if desert tortoises exposed to simulated drought conditions become more susceptible to infection and more infectious.

5.5.3 Determine whether diets high in alien plants increase susceptibility to disease, as well as infectiousness.

5.5.4 Identify the virulent and less virulent strains of *Mycoplasma* circulating in wild and captive populations and monitor temporal and spatial change in prevalence in relation to host genetic status and environmental stressors.

Identification of genes expressing toxin production and the circumstances when these genes are expressed could be a fruitful area of research. Studies examining the level of cross immunity between strains and variation in resistance in relation to the plane of nutrition and availability of water would be of great assistance. This research aims to examine the presence and variation in *Mycoplasma* strains with the aim of containing virulent strains.

5.5.5 Identify which individual tortoises are shedding, how they shed (*i.e.*, transmit), when they shed and, for how long they shed infectious *Mycoplasma* particles. Identify whether individuals removed from drought-stressed areas or areas with severely deteriorated habitats continue to shed *Mycoplasma* and for how long.

This research will identify in more detail seasonal forces of infection, the period of infectiousness, and how infectiousness varies under different circumstances.

5.5.6 Undertake trials to determine if it is possible to cure individuals with *Mycoplasma* infections, even if only feasible in captive individuals.

Preliminary veterinary trials with mixed antibiotics have met with some success and could be extended.

5.5.7 Examine the behavior of infectious tortoises in comparison to uninfected tortoises in the wild. Obtain estimates of contact rate according to sex, age, and season.

This research will help us understand the most critical epidemiological parameters associated with transmission and, with other data, allow us to produce a predictive model of outbreak.

5.5.8 Create a comprehensive disease-tortoise population model that incorporates the above information.

A disease-tortoise population model could be used to anticipate outbreaks and patterns of spread.

5.5.9 Evaluate other known or emerging diseases for effects on desert tortoise populations.

Less is known about other diseases that have been identified in the desert tortoise (*e.g.*, herpesvirus, cutaneous dyskeratosis). Continued study of *Mycoplasma* will help to form a model that will facilitate investigations of other diseases. In the meantime, surveys or pathological study of other diseases should be conducted within the context of other threats (*e.g.*, 5.4.1)

6. Develop, Support, and Build Partnerships to Facilitate Recovery

6.1 Establish regional, inter-organizational Recovery Implementation Teams to coordinate implementation activities of the recovery plan.

Implementation of this recovery plan throughout the four-state range of the desert tortoise is a daunting prospect. However, if approached from a regional or local level, recovery becomes much more possible. Therefore, regional Recovery Implementation Teams (RITs) should be established upon publication of the recovery plan. RITs should build off the recovery plan by developing action plans and budget needs with priorities for management based on an updated decision support system (scaled down to recovery unit or jurisdictional levels; 1.2). Priorities for studying the effectiveness of management actions (5.4.2) should be included in these action plans. Recovery Implementation Teams should also identify areas not included within existing tortoise conservation areas that may warrant focused management efforts to ensure recovery of the desert tortoise within their respective recovery units. Throughout recovery implementation, the DTRO and RITs should emphasize the collation of up-to-date information on threats and recovery actions into the decision support system (1.1) and range-wide recovery database.

Regional or local RITs should include representatives of the Desert Tortoise Management Oversight Group and could be formed as new independent teams or may be working groups within existing organizations, such as the California Desert Managers Group or Southern Nevada Agency Partnership. In any case, RITs should involve communities and the public broadly in the recovery effort. Both technical experts and stakeholders should be represented. Regional/local leadership of RITs is preferred, but the DTRO should help coordinate or facilitate the teams through its regional recovery coordination staff. RITs should annually report progress on recovery implementation and provide recommendations for research and management to the Management Oversight Group.

Table 3. Reference table connecting major recovery actions to listing factors and recovery objectives. Recovery actions are categorized according to each strategic element of the recovery program. Subactions for each major recovery action are not listed (see the recovery narrative).

	Recovery Action	Listing Factor	Recovery Objective
1.	**Implement an adaptive management program**		
1.1	Revise and continue development of a recovery decision support system.	All	All
1.2	Revise recovery tasks in coordination with RITs and the Desert Tortoise Management Oversight Group as pertinent new information becomes available.	All	All
1.3	Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions.	All	All
1.4	Incorporate scientific advice for recovery through the Science Advisory Committee.	All	All
2.	**Protect and manage existing populations and habitat**		
2.1	Minimize human-associated mortality of desert tortoises.	All	All
2.2	Reduce factors contributing to disease.	C	1,2,4
2.3	Establish/continue environmental education programs.	All	All
2.4	Increase law enforcement.	A-D	All
2.5	Restrict, designate, close, and fence roads.	A-D	All
2.6	Protect intact desert tortoise habitat.	A,E	3,4
2.7	Restore desert tortoise habitat.	A,E	3,4
2.8	Install and maintain urban or other barriers.	A-C	All
2.9	Sign and fence boundaries of sensitive or impacted areas.	A,B	3-4
2.10	Secure lands/habitat for conservation.	A	3
2.11	Restrict competitive off-highway vehicle events within desert tortoise habitat.	A,B	All
2.12	Connect functional habitat.	A	2-4
2.13	Manage mining.	A,C	All
2.14	Manage landfills.	A,C	1,3,4
2.15	Reduce raven predation on tortoises.	C	1,4
2.16	Manage burros and horses.	A	3-4
2.17	Manage livestock grazing.	A	3-4
3.	**Augment depleted populations through a strategic program**		
3.1	Develop protocols and guidelines for the augmentation program.	All	1-2
3.2	Identify sites at which to implement population augmentation efforts.	All	1-2

Table 3. Continued.

	Recovery Action	Listing Factor	Recovery Objective
3.3	Obtain tortoises for use in augmentation efforts.	All	1-2
3.4	Implement translocations in target areas to augment populations using a scientifically rigorous, research-based approach.	All	All
4.	**Monitor progress toward recovery**		
4.1	Monitor desert tortoise population growth.	All	1
4.2	Monitor the extent of tortoise distribution in each recovery unit.	All	2
4.3	Track changes in the quantity and quality of desert tortoise habitat over time.	A,D,E	3
4.4	Quantify the presence and intensity of threats to the desert tortoise across the landscape.	All	4
5.	**Conduct applied research and modeling in support of recovery efforts within a strategic framework**		
5.1	Determine demographic characteristics of healthy desert tortoise populations.	All	1
5.2	Determine factors that influence the distribution of desert tortoises.	All	2,3,4
5.3	Conduct research on the restoration of desert tortoise habitat.	A,E	3,4
5.4	Improve models of threats (and threat mitigation) and desert tortoise demographics.	All	1,3,4
5.5	Conduct research on desert tortoise diseases and their effects on tortoise populations.	C	1,2,4
6.	**Develop, support, and build partnerships to facilitate recovery**		
6.1	Establish regional, inter-organizational RITs to coordinate implementation activities of the recovery plan.	All	All

Listing Factors:
- **A.** The present or threatened destruction, modification, or curtailment of its habitat or range
- **B.** Overutilization for commercial, recreational, scientific, or educational purposes
- **C.** Disease or predation
- **D.** The inadequacy of existing regulatory mechanisms
- **E.** Other natural or manmade factors affecting its continued existence

Recovery Objectives:
1. Maintain self-sustaining populations of desert tortoises within each recovery unit into the future.
2. Maintain well-distributed populations of desert tortoises throughout each recovery unit.
3. Ensure that habitat within each recovery unit is protected and managed to support long-term viability of desert tortoise populations.
4. Threats to the viability of desert tortoise populations are mitigated sufficiently to ensure persistence of the species within each recovery unit.

III. Implementation Schedule

The implementation schedule outlines the tasks discussed in Part II and indicates task numbers, priorities, durations, estimated costs, and partners that may be involved in implementing the task. When accomplished, these tasks would enable the desert tortoise to be delisted. The costs for each task are rough estimates, and actual budgets will have to be determined when each task is undertaken (TBD = to be determined). Cost estimates are unavailable for several actions, such as research, due to uncertainties in the scope and magnitude of the specific action. Recovery plans are non-regulatory documents, and as such, identified partners are not obligated to implement recovery tasks. Cost estimates do not commit funding by any agency.

Action priorities in the implementation schedule are assigned as follows:

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in species population numbers or habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery of the species.

We have attempted to provide an overall priority for each recovery action that applies across recovery units. However, threats, and therefore the importance of recovery actions that ameliorate those threats, vary by recovery unit. A preliminary assessment of threats by recovery unit is presented in the decision support system description in Appendix C, and Recovery Implementation Teams should guide recovery action priorities and develop updated budget projections within each recovery unit through the use of an updated/improved decision support system.

Task duration in Column 4 indicates the number of years estimated to complete the task. A *Continuing* task will continue to be conducted once implemented. An *Ongoing* task is one that is already being conducted.

The Responsible Party indicates the lead agency or agencies identified for a particular task and includes the full suite of local, state, and Federal land and wildlife management agencies within the desert tortoise's range (= Land Managers). Other stakeholders or organizations (included in "All") may also contribute to particular recovery actions. However, other parties may also have significant roles in different tasks, and (as mentioned above) the listing of a party does not require the identified party to implement the action(s) or to secure funding for implementing the action(s).

Implementation Schedule **Costs (thousands of dollars)**

	Recovery Action	Priority	Duration (years)	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
1.	**Implement an adaptive management program**									
1.1	Revise and continue development of a recovery decision support system.	1	Ongoing	USFWS (All)	50	10	5	5	5	175
1.2	Revise recovery tasks in coordination with RITs and the Desert Tortoise Management Oversight Group as pertinent new information becomes available.	2	Continuing	All	TBD	TBD	TBD	TBD	TBD	TBD
1.3	Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions.	3	Continuing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
1.4	Incorporate scientific advice for recovery through the Science Advisory Committee.	3	Ongoing	USFWS (All)	5	5	5	5	5	125
2.	**Protect and manage existing populations and habitat**									
2.1	Minimize human-associated mortality of desert tortoises.	2	Continuing	All	0	0	0	0	0	0[1]
2.2	Reduce factors contributing to disease.	2	Continuing	All	10	10	10	10	10	250
2.3	Establish/continue environmental education programs.	2	Ongoing	All	100	100	100	100	100	2,500
2.4	Increase law enforcement.	2	Ongoing	Land Managers	1000	1000	1000	1000	1000	25,000
2.5	Restrict, designate, close, and fence roads.	2	Ongoing	BLM, NPS	1000	1000	1000	1000	1000	10,000
2.6	Protect intact desert tortoise habitat	2	Continuing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
2.7	Restore desert tortoise habitat.	2	Continuing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
2.8	Install and maintain urban or other barriers.									
	Upper Virgin River Recovery Unit	2	2	WC HCP[2]	100	100				200
	Western Mojave Recovery Unit	2	5	Land Managers	200	200	200	200	200	1,000
	Remainder of desert tortoise range	3	5	Land Managers	500	500	500	500	500	2,500
2.9	Sign and fence boundaries of sensitive or impacted areas.									
	Upper Virgin River Recovery Unit	2	Ongoing	WC HCP[2]	20	20				40
	Western Mojave Recovery Unit	2	Ongoing	Land Managers	100	100	100	100	100	600
	Remainder of desert tortoise range	3	Ongoing	Land Managers	600	600	600	600	600	3,500

Implementation Schedule Continued **Costs (thousands of dollars)**

	Recovery Action	Priority	Duration (years)	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
2.10	Secure lands/habitat for conservation.									
	Upper Virgin River, Eastern Colorado, and Western Mojave recovery units	2	Ongoing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
	Remainder of desert tortoise range	3	Ongoing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
2.11	Restrict competitive off-highway vehicle events within desert tortoise habitat.	3	Ongoing	BLM	50	50	50	50	50	1,250
2.12	Connect functional habitat.	3	Ongoing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
2.13	Manage mining.	3	10	BLM	100	100	100	100	100	1,000
2.14	Manage landfills.	3	Ongoing	Counties	100	100	100	100	100	2,500
2.15	Reduce raven predation on tortoises.	3	Ongoing	Land Managers	100	100	100	100	100	2,000
2.16	Manage burros and horses.	3	Ongoing	BLM, NPS	500	500	500	500	500	12,500
2.17	Manage livestock grazing.	3	Ongoing	BLM	100	100	100	100	100	2,500
3.	**Augment depleted populations through a strategic program**									
3.1	Develop protocols and guidelines for the population augmentation program.	2	1	USFWS	50					50
3.2	Identify sites at which to implement population augmentation efforts.	2	1	USFWS	50					50
3.3	Obtain tortoises for use in augmentation efforts.	2	10	USFWS, DOD, Mojave NP	500	500	500	500	500	5,000
3.4	Implement translocations in target areas to augment populations using a scientifically rigorous, research-based approach.	2	15	USFWS, Land Managers			TBD	TBD	TBD	TBD
4.	**Monitor progress toward recovery**									
4.1	Monitor desert tortoise population growth.	2	Ongoing	USFWS (All)	1,500	1,500	1,500	1,500	1,500	37,500
4.2	Monitor the extent of tortoise distribution in each recovery unit.	2	Continuing	USFWS (All)	1,500	1,500	1,500	1,500	1,500	37,500
4.3	Track changes in the quantity and quality of desert tortoise habitat over time.	2	Continuing	USFWS (All)	TBD	TBD	TBD	TBD	TBD	TBD

Implementation Schedule Continued **Costs (thousands of dollars)**

	Recovery Action	Priority	Duration (years)	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
4.4	Quantify the presence and intensity of threats to the desert tortoise across the landscape.	2	Continuing	USFWS (All)	TBD	TBD	TBD	TBD	TBD	TBD
5.	**Conduct applied research and modeling in support of recovery efforts within a strategic framework**									
5.1	Determine demographic characteristics of healthy desert tortoise populations.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.2	Determine conditions for success of head-starting and translocation.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.3	Determine factors that influence the distribution of desert tortoises.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.4	Conduct research on the restoration of desert tortoise habitat.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.5	Improve models of threats and desert tortoise demographics.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.6	Conduct research on desert tortoise diseases and their effects on tortoise populations.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
6.	**Develop, support, and build partnerships to facilitate recovery**									
6.1	Establish regional, inter-organizational RITs to coordinate implementation activities of the recovery plan.	1	Continuing	USFWS (All)	500	500	500	500	500	12,500
FY Totals (These totals are minimum cost estimates that do not include TBD costs.)					8735	8595	8470	8470	8470	
Grand Total										**$160,240,000**

[1]Costs for minimizing mortality are not included because these costs are typically required by regulatory processes, rather than as proactive recovery actions.
[2]Washington County, Utah, HCP.

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Appendix A

THREATS TO DESERT TORTOISE AND ITS HABITAT SINCE THE TIME OF LISTING

Below is a synopsis of the threats that were introduced in the 1994 Recovery Plan. A substantive body of data has been accumulated since 1994 for some of the threats, but others remain relatively unstudied. New information is provided where available, and all of the threats warrant continued attention and data collection that will inform management actions and recovery implementation through the use of a range-wide database and decision support system.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Urbanization. Urban development directly affects desert tortoise populations through fragmentation and permanent loss of habitat. The portions of the desert southwest occupied by desert tortoises have been subject to episodic human settlements and associated impacts since the mid to late 1800s (USFWS 1994). Urbanization within desert ecosystems continues to take place at a rapid pace (Table A-1), and currently more than 30 million people live in close proximity to the desert, which is popular with recreationists (Berry *et al.* 2006). On July 1, 2006, there was an estimated 299,400,000 people in the U.S. This was an increase of over 50 million persons or 20.4 percent since April 1, 1990, and much of this growth is occurring in the desert southwest (Byerly and Deardorff 1995; U.S. Census Bureau 2007a).

Population growth and urban development in the California desert, which supports the most designated critical habitat for the desert tortoise, continue to expand into previously undisturbed areas, putting intense pressures on the natural resources in the region. St. George, Utah, was the fastest-growing metropolitan area in the U.S. between 2000 and 2006, with growth of 39.8 percent. Las Vegas, Nevada, grew 29.2 percent, making it one of the top five fastest-growing areas during this time period (U.S. Census Bureau 2007a). In fact, the population of the Las Vegas metropolitan area nearly doubled between 1995 and 2005, as more than 5,000 newcomers continue to move to the Las Vegas area every month. If the current growth trends continue, the metropolitan area will have 2,058,000 residents by 2010. The growth rate is projected to slow to approximately 7 percent per year in the longer term (2020 through 2025) as the economy matures and fewer new hotels are added (Clark County Department of Aviation 2006).

Rapid growth is not limited to metropolitan areas. Mohave County, Arizona, grew 66 percent between 1994 and 2006, and Nye County, Nevada, grew 97 percent during the same time period (Table A-1). The Beaver Dam/Littlefield community (within the Virgin River Basin) on the Arizona Strip supported some 1,580 persons in 2000. This area saw more than 200 percent growth between 1990 and 2000. Given this rapid growth rate, the population for the basin in 2010 will be between 3,000 and 4,000 persons (S. Donahue, Mohave County, pers. comm. 2007).

Table A-1. Human population growth in the states and counties within the range of the Mojave population of the desert tortoise between 1994 when the Recovery Plan was published and 2006.

State/Counties	1994 Population Estimate[1]	2006 Population Estimate[2]	Percent Change
Arizona	4,147,561	6,166,318	48.7
Mohave	116,320	193,035	66.0
California	31,317,179	36,457,549	16.4
Imperial	136,248	160,301	17.7
Inyo	18,450	17,980	-2.5
Kern	608,858	780,117	28.1
Los Angeles	9,048,129	9,948,081	9.9
Riverside	1,354,966	2,026,803	49.6
San Bernardino	1,553,732	1,999,332	28.7
Nevada	1,456,388	2,495,529	71.4
Clark	938,611	1,777,539	89.4
Esmeralda	1143	790	-30.9
Lincoln	3849	4738	23.1
Nye	21,648	42,693	97.2
Utah	1,930,436	2,550,063	32.1
Washington	65,520	126,312	92.8

[1] Byerly and Deardorff 1995
[2] U.S. Census Bureau 2007b

Desert tortoise habitats continue to be heavily impacted by urbanization and associated human activities. Lovich and Bainbridge (1999) identified various types of anthropogenic impacts from which desert ecosystems may take 50 to 300 years to recover to predisturbance plant cover levels. However, areas that have experienced permanent habitat loss due to intense urbanization will never be restored or recovered. In addition, urban environments have indirect impacts on desert tortoise populations and habitat at their interface with the desert (Berry and Burge 1984; Berry and Nicholson 1984). Unconfined pets may kill or wound tortoises (see Predation), and unauthorized collecting of desert tortoises may affect populations. Indiscriminate use of firearms and off-highway vehicles, dumping of trash, and removal of vegetation or unimproved road proliferation are activities that occur in and beyond the urban-desert interface that may result in injury and mortality to tortoises and degradation of their habitats. Habitat fragmentation resulting from infrastructure associated with urbanization such as residential fencing, roads, and railroad tracks, can greatly inhibit desert tortoise movements (Edwards *et al.* 2004; Brooks and Lair 2005). These barriers to movement and population connectivity have implications to exchange of genetic material, which can lead to inbreeding, and may result in mortality of individuals (Boarman and Sazaki 1996) (see Roads).

Paved and Unpaved Roads, Routes, Trails, and Railroads. Vehicular roads, routes, and trails are the most common type of human disturbance observed in desert ecosystems, and much emphasis has been placed on understanding the impacts these linear features have on arid environments (Brooks and Lair 2005). Brooks and Lair (2005) cite vehicular routes as one of the biggest challenges to land managers in the desert southwest, especially as they relate to the conservation status of the desert tortoise.

Direct and indirect impacts of roads and railroads on desert tortoise populations are well documented and include habitat and population fragmentation and degradation as well as mortality of individual tortoises (USFWS 1994, Boarman 2002). Paved and unpaved roads serve as corridors for urbanization and dispersal of invasive species and provide access to recreation; railroads also facilitate urbanization and the spread of non-native plants. Roads and railroads also act as barriers to movement. Railroads are similar to roads as sources of mortality for desert tortoises, as they can become caught between the tracks causing them to overheat and die or be crushed by trains (U.S. Ecology 1989).

Direct effects to desert tortoise habitat from roads, routes, trails, and railroads occur during initial stages of construction or off-highway vehicle route/trail establishment when vegetation and soils are lost or severely degraded. Construction of these features can result in physical and chemical changes to soils within the roadway as well as in adjacent areas (Brooks and Lair 2005). In addition, roadside vegetation is often more robust and diverse because of enhanced hydrological conditions, which attracts tortoises and puts them at higher risk of mortality (Boarman *et al.* 1997).

Hoff and Marlow (2002) demonstrated that there is a detectable impact on the abundance of desert tortoise sign adjacent to roads and highways with traffic levels from 220 to over 5,000 vehicles per day. That is, the extent of the detectable impact was positively correlated with the measured traffic level; the higher the traffic counts, the greater the distance from the road reduced tortoise sign was observed (Hoff and Marlow 2002). This supports LaRue (1993) and Boarman *et al.* (1997), wherein depauperate desert tortoise populations were observed along highways. Subsequent research shows that populations may be depressed in a zone at least as far as 0.4 kilometers (0.25 miles) from the roadway (Boarman and Sazaki 2006). Hoff and Marlow (2002) also surmised that unpaved access roads with lower traffic levels may have significant effects on tortoises. Desert tortoise populations may also be indirectly affected by road corridors through fragmentation of habitat and limitation of an animal's ability to migrate and disperse (Boarman *et al.* 1997). Subsequently, populations may become isolated and at higher risk of localized extirpation from stochastic events or from inbreeding depression (Boarman *et al.* 1997; Boarman and Sazaki 2006).

Boarman *et al.* (1997) attempted to discern the utility of fences and culverts in reducing desert tortoise mortality along highways and whether or not the animals would use culverts for crossing linear corridors. Data suggest fences may reduce mortality of desert tortoises as well as other wildlife species; however, population fragmentation may only be exacerbated by fences especially if the tortoises do not readily utilize culverts for crossing the road (Boarman *et al.* 1997).

Spread of Invasive Plants. Construction and maintenance of roadways facilitates changes in plant species composition and diversity. Non-native, invasive species and edge-associated species often become dominant along these linear features, which serve as corridors for weed dispersal (Boarman and Sazaki 2006). Vegetation removal and manipulation and addition of soils in preparation of road construction, as well as grading of unpaved roads, create areas of disturbance that allow weedy species to

become established and proliferate (Gelbard and Belnap 2003). Vehicles serve as a major vector in dispersal of exotic species along roadways (Brooks and Lair 2005).

Near Canyonlands National Park in Utah, cover of cheatgrass (*Bromus tectorum*) was three times greater along paved roads than four-wheel-drive tracks, and richness and cover of exotic species were more than 50 percent greater and native species richness 30 percent lower at interior sites along paved roads than four-wheel-drive tracks. There appears to be a correlation between the level of road improvement (*i.e.*, paved, improved, unpaved) and the level of invasion by exotics (Gelbard and Belnap 2003). As previous studies show (LaRue 1993; Boarman *et al.* 1997; Hoff and Marlow 2002; Boarman and Sazaki 2006), the greater the distance from the road, the more desert tortoise sign is observed. Similarly, the cover and richness of exotic species decreases as distance from the road increases (Boarman and Sazaki 2006).

As natural areas are impacted by linear features such as roads, routes, trails, and railroads, previously intact, contiguous habitats become degraded and fragmented, and non-native invasive species play a more integral role in ecosystem dynamics. For instance, increases in plant cover due to the proliferation of exotics have altered fire regimes throughout the Mojave Desert region (Brooks 1999; Brooks and Esque 2002; Esque *et al.* 2003; Brooks *et al.* 2004) (see Invasive Species and Fire).

Predator Subsidies. In the desert southwest, common raven populations have increased over the past 25 years (greater than 1000 percent), probably in response to increased human populations and anthropogenic changes to the landscape (Boarman and Berry 1995; Boarman *et al.* 1995; Boarman *et al.* 2006). Linear features such as roads and utility corridors and other urban sites such as landfills and sewage ponds have been shown to attract common ravens (*Corvus corax*), red-tailed hawks (*Buteo jamaicensis*), and turkey vultures (*Cathartes aura*) (Knight and Kawashima 1993; Boarman *et al.* 1995; Knight *et al.* 1999). The presence of roads may encourage opportunistic species because road-killed animals are a reliable food source (Camp *et al.* 1993; Boarman and Sazaki 2006). In addition to using human-based resources, ravens are known to be capable predators that prey on small vertebrates and invertebrates, including desert tortoises, especially juveniles (Kristan and Boarman 2003).

Off-Highway Vehicles. Off-highway vehicle activities take many forms, from organized events, large- or small-scale competitive races involving up to thousands of motorcycles (*e.g.*, the Barstow to Las Vegas motorcycle competition), to casual family activities. Organized events and off-highway vehicle tours are now reviewed and permitted by land managers. Generally, an education component and speed limitations are requirements of the permit. Unauthorized off-highway vehicle use continues to be of concern and present a variety of threats to the desert tortoise.

Impacts from off-highway vehicle use include mortality of tortoises on the surface and below ground, collapsing of desert tortoise burrows, damage or destruction of annual and perennial plants and soil crusts, soil erosion, proliferation of weeds, and increases in numbers and locations of wildfires. Damage to or destruction of shrubs and burrows can lead to disruption of desert tortoises' water balance, thermoregulation, and energy requirements and the loss of

annual plants reduces the availability of food (USFWS 1994). One of the most significant ecological implications of off-highway vehicle routes is the exacerbation of erosion and changes in drainage patterns (Brooks and Lair 2005).

Bury and Luckenbach (2002) compared habitat, abundance, and life history features of desert tortoises on one unused, natural area and a nearby area used heavily by off-highway vehicles. The unused, natural area had 1.7 times the number of live plants, 3.9 times the plant cover, 3.9 times the number of desert tortoises, and 4 times the active tortoise burrows than the area used by off-highway vehicles. The two largest tortoises in the off-highway vehicle use area had mass less than would be expected from seasonal fluctuations. Despite the lack of pre-disturbance data for the off-highway vehicle area and the patchy distribution of tortoises, the areas furthest from concentrated off-highway vehicle activity (pit areas) still reflected the least amount of habitat impact and supported more tortoises (Bury and Lukenbach 2002).

Jennings (1997) found that desert tortoises are vulnerable to negative effects from off-highway vehicles because of their habitat preferences. Tortoises in a study at the Desert Tortoise Natural Area spent significantly more time traveling and foraging in hills and washes than on the flats. Tortoises use washes for travel, excavation of burrows, and foraging, and at least 25 percent of the forage plants were found to occur within washes. Hills and washes are also favored by users of motorcycles, trail bikes, all-terrain vehicles, and other four-wheel vehicles. Therefore, because tortoises prefer washes and hills, they are more vulnerable to direct mortality from off-highway vehicles than if they used the habitat randomly. Additionally, off-highway vehicle use in these habitats causes degradation of vegetation and loss of forage species important in the desert tortoise diet (Jennings 1997).

Surface disturbance from off-highway vehicle activity can cause erosion and large amounts of dust to be discharged into the air. Recent studies on surface dust impacts on gas exchanges in Mojave Desert shrubs showed that plants encrusted by dust have reduced photosynthesis and decreased water-use efficiency, which may cause decreased primary production during seasons when photosynthesis occurs (Sharifi *et al.* 1997). Sharifi *et al.* (1997) also showed reduction in maximum leaf conductance, transpiration, and water-use efficiency. Leaf and stem temperatures were also shown to be higher in plants with surface dust. These effects may also impact desert annuals, an important food source for tortoises.

Off-highway vehicle activity can also disturb fragile cyanobacterial-lichen soil crusts, a dominant source of nitrogen in desert ecosystems (Belnap 1996). Belnap (1996) showed that anthropogenic surface disturbances may have serious implications for nitrogen budgets in cold-desert ecosystems, and this may hold true for the hot deserts that tortoises occupy. Soil crusts also appear to be an important source of water for plants, as they were shown to have 53 percent greater volumetric water content than bare soils during the late fall when winter annuals are becoming established (DeFalco *et al.* 2001). DeFalco *et al.* (2001) found that non-native plant species comprised greater shoot biomass on crusted soils than native species, which demonstrates their ability to exploit available nutrient and water resources. Once the soil crusts are disturbed, invasion by non-native plant species may ensue, and as they become established, native perennial and annual plant species may be out-competed (DeFalco *et al.* 2001; D'Antonio and Vitousek 1992). Invasion of non-native plants can affect the quality and quantity of plant

foods available to desert tortoises, and thereby affect nutritional intake (see Invasive Plants). Increased presence of invasive plants can also contribute to increased fire frequency (see Fire).

Despite the many observations that have been documented and reported, statistical correlation between off-highway vehicle impacts and reduced desert tortoise densities continues to be lacking (Boarman 2002). However, it is evident that off-highway vehicle activities remain an important source of habitat degradation and could result in reductions in desert tortoise densities (Boarman 2002).

Invasive Plants. Proliferation of invasive plants is increasing in the Mojave and Sonoran deserts and is recognized as a significant threat to desert tortoise habitat. Many species of non-native plants from Europe and Asia have become common to abundant in some areas, particularly where disturbance has occurred and is ongoing. As non-native plant species become established, native perennial and annual plant species may decrease, diminish, or die out (D'Antonio and Vitousek 1992).

Land managers and field scientists identified 116 species of alien plants in the Mojave and Colorado deserts (Brooks and Esque 2002). Some of the more common non-native or native weedy species found within the Mojave region include: redstem filaree (*Erodium cicutarium*), bassia (*Bassia hyssopifolia*), sand bur (*Ambrosia acanthicarpa*), western ragweed (*Ambrosia psilostachya* var. *californica*), common spikeweed (*Hemizonia pungens*), pineapple weed (*Matricaria matricarioides*), fiddleneck (*Amsinckia intermedia*, *A. tessellata*), flixweed (*Descurania sophia*), tumble mustard (*Sisymbrium altissimum*), London rocket (*S. irio*), Russian thistle (*Salsola iberica*), turkey mullein (*Eremocarpus setigerus*), and horehound (*Marrubium vulgare*) (Tierra Madre 1991; BLM files). Annual grasses include: red brome (*Bromus rubens*), cheatgrass or downy brome, barley (*Hordeum glaucum*, *H. jubatum*, *H. leporinum*), split grass (*Schismus barbatus*), and Arab grass (*S. arabicus*). Sahara and Mediterranean mustard (*Brassica tournefortii and Hirschfeldia incana*, respectively) are relatively new, but rapidly spreading, non-native winter annuals invading the desert southwest (LaBerteaux 2006).

Increased levels of atmospheric pollution and nitrogen deposition related to increased human presence and combustion of fossil fuels can cause increased levels of soil nitrogen, which in turn may result in significant changes in plant communities (Aber *et al.* 1989). Many of the alien annual plant taxa in the Mojave region evolved in more fertile Mediterranean regions and benefit from increased levels of soil nitrogen, giving them a competitive edge over native annuals. Studies at three sites within the central, southern, and western Mojave Desert indicated that increased levels of soil nitrogen can increase the dominance of alien annual plants and promote the invasion of new species in desert regions. Furthermore, increased dominance by alien annuals may decrease the diversity of native annual plants, and increased biomass of alien annual grasses may increase fire frequency (Brooks 2003).

Nutrition. Invasion of non-native plants can also affect the quality and quantity of plant foods available to desert tortoises, and thereby affect nutritional intake. Desert tortoises are generally quite selective in their choices of foods (Burge 1977; Nagy and Medica 1986; Turner *et al.* 1987; Avery 1992; Henen 1992; Jennings 1992, 1993; Esque 1992, 1994), and in some areas the preferences are clearly for native plants over the

weedy non-natives. Nutritional intake has been shown to affect growth rates in juvenile desert tortoises (Medica *et al.* 1975) and female reproductive output (Turner *et al.* 1986, 1987; Henen 1992).

As native plants are displaced by non-native invasive species in some areas of the Mojave Desert, exotic plants can be a necessary food source for some desert tortoises. However, introduced plants may not be as nutritious as native plants. Recent studies have shown that calcium and phosphorus availability are higher in forbs than in grasses and that desert tortoises lose phosphorus when feeding on grasses but gain phosphorus when eating forbs (Hazard *et al.* 2002). In a comparative study on the nutritional qualities of native vs. non-native grasses and forbs commonly consumed by desert tortoises (Indian ricegrass [*Achnatherum hymenoides*] vs. split grass; desert dandelion [*Malacothrix* spp.] vs. redstem filaree), the nutritional value of the two grasses was similar, but both grasses had much lower nutritional value than the forbs. Furthermore, if tortoises consume just enough food to satisfy their energy needs (as in other vertebrate groups), then the native forbs provide significantly more nitrogen and water than the non-native forbs (Nagy *et al.* 1998).

In the Mojave Desert, many food plants are high in potassium (Minnich 1979), which is difficult for desert tortoises to excrete due to the lack of salt glands that are found in other reptilian herbivores such as chuckwallas (*Sauromalus obesus*) and desert iguanas (*Dipsosaurus dorsalis*) (Minnich 1970; Nagy 1972). Reptiles are also unable to produce osmotically concentrated urine, which further complicates the ability for desert tortoises to expel excess potassium (Oftedal and Allen 1996).

Oftedal (2002) determined that Mojave tortoises are vulnerable to disease due to their need to obtain sufficient water and nitrogen from food plants to counteract the negative effects of dietary potassium. Only high quality food plants (as expressed by the Potassium Excretion Potential, or PEP, index) allow substantial storage of protein (nitrogen) that is used for growth and reproduction, or to sustain the animals during drought. Foraging studies have demonstrated that juvenile Mojave tortoises are highly selective while foraging, selecting both the plant species and plant parts that are have the highest PEP value. Impacts to vegetation (such as livestock grazing, invasion of exotic plants, and soil disturbance) that affect the abundance and distribution of high PEP plants may result additional challenges for foraging desert tortoises (Oftedal *et al.* 2002).

Tracy *et al.* (2006a) hypothesized that the desert tortoise may experience negative effects when switching forage species. The researchers found that the digestive efficiency for grass (*Bromus* spp.) and forbs (*Erodium* spp.) was significantly reduced to about half during the first 5 days after tortoises were switched onto the new diets, implying that as the vegetative components of tortoise habitats change, tortoise diets will also change, and they may not be able to efficiently extract necessary nutrients.

Tracy *et al.* (2006b) also quantified the rates of passage of digesta in young desert tortoises in relation to body size and diet quality. They observed that, compared to adults, young, growing tortoises need higher rates of nutrient assimilation to support their higher

metabolic rates. Juvenile desert tortoises also forage selectively by consuming plant species and plant parts of higher quality (Oftedal *et al.* 2002) and pass food through the gut more quickly (Tracy *et al.* 2006b). Hence, their findings of differential passage rates suggest that it is beneficial for young tortoises to specialize on low-fiber diets, as this would allow for more efficient uptake of nutrients. In addition, habitat disturbances (*e.g.*, invasion of annual grass weeds) that favor species with little nutritional value and preclude access to low-fiber foods may negatively impact the physiological and behavioral ecology of young desert tortoises. Adults, on the other hand, may be better adapted to tolerate low-quality foods for a longer period of time because of their lower metabolism, more voluminous guts compared to subadults, and consequent longer retention times (Tracy *et al.* 2006b).

Increasing Fuel Load. The proliferation of non-native plant species has contributed to an increase in fire frequency in tortoise habitat by providing sufficient fuel to carry fires, especially in the intershrub spaces that are mostly devoid of native vegetation (Brown and Minnich 1986; USFWS 1994; Brooks 1998; Brooks and Esque 2002). Invasive annual grasses and forbs increasingly spread over the desert floor, resist decomposition, and provide flash fuel for fires. Brooks (1999) found that alien annual grasses contributed most to the continuity and biomass of dead annual plants and to the spread of summer fires compared to native forbs. Red brome in particular has contributed to significant increases in fire frequency since the 1970s (Kemp and Brooks 1998; Brooks *et al.* 2003; Brooks and Berry 2006). Once fires occur, opportunities for invasion and proliferation of weeds increase (Brown and Minnich 1986). Changes in plant communities caused by alien plants and recurrent fire negatively affect the desert tortoise by altering habitat structure and species composition of their food plants (Brooks and Esque 2002).

Brooks and Berry (2006) found that while alien plant species comprised only a small fraction of the total annual plant flora, they were the dominant component of the annual plant community biomass. For instance, in 1995, a high rainfall year, alien annuals accounted for 6 percent of the flora and 66 percent of the biomass; in 1999, a low rainfall year, aliens comprised 27 percent of the flora and 91 percent of the biomass. Annual species dominate the non-native flora, with red brome, split grass, and redstem filaree being the most widespread and abundant, representing 99 percent of the alien biomass (Brooks and Berry 2006).

Evidence of disturbance was a more reliable indicator of alien dominance than was native plant diversity or productivity (Brooks and Berry 2006). Brooks and Berry (2006) also found that there were strong environmental correlations between dirt road densities and richness and biomass of redstem filaree as well as between the size and frequency of fires and biomass of red brome. An altered fire regime in the desert southwest resulting from changes in species composition has tremendous implications for the quality and quantity of desert tortoise habitat across the species' range.

Fire. Fire has the potential to be an important force governing habitat quality and persistence of desert tortoises. Tortoises can be killed or seriously injured due to burning and

smoke inhalation during fire events. The extent of the direct impacts experienced by tortoises is influenced by tortoise activity at the time of fire, (whether inside or outside burrow), depth of burrow (to afford protection), fire intensity (amount of heat generated), speed of fire (how quickly it moves through an area), and patchiness (extent of an area burned) (Esque *et al.* 2003). Early-season fires may be more threatening than summer fires because desert tortoises are active above ground and more vulnerable to direct effects of fire. Fire can also compromise the quality of tortoise habitat by reducing the available resources that provide shelter, cover, and nutrition (key forage plants) for tortoises.

Natural fire regimes have been altered due to profuse invasions of non-native grasses throughout much of the range of the desert tortoise. The biomass of weedy species has increased remarkably in the desert southwest as a result of disturbance from vehicles, grazing, agriculture, urbanization, and other human land uses (Brooks and Berry 1999; Brooks and Esque 2002; Brooks *et al.* 2003; Brooks and Berry 2006; Brooks and Matchett 2006). Fuel loads that consist of dense annual grasses make it more likely for fire to become hot enough to damage native shrubs, which are poorly adapted to fire and poor colonizers (Tratz and Vogl 1977; Tratz 1978). Ultimately, recurrent fire can result in conversion of shrublands to annual grasslands, which can be devastating for desert tortoises that depend upon shrubs for cover (Brooks and Esque 2002).

Years of high rainfall promote the growth of invasive annuals that increase the fine fuel loads, but high rainfall also increases food and water availability for desert tortoises. Desert tortoise reproduction also increases in high rainfall years, and unfortunately, small hatchlings are more vulnerable to fire than larger tortoises, and tortoises in general are more vulnerable to fire when they are above ground foraging. Thus, the high rainfall episodes that are important to maintaining healthy desert tortoise populations may also create the highest fire risk (Brooks and Esque 2002).

Plant litter produced by alien annual grasses decomposes more slowly than native annuals and accumulates during successive years, thus providing an excess of fine fuels that sustains and spreads fires throughout the desert ecosystem (Brooks 1999). Historical fire intervals of 30 to greater than 100 years have been shortened to an average of 5 years in some areas of the Mojave Desert, due to the invasion of exotic grasses. Additionally, fires can increase the frequency and cover of exotic annual grasses within 3 to 5 years of a fire event, thus promoting the continuity of this grass/fire cycle that shortens the fire interval (Brooks *et al.* 1999; Brooks and Esque 2002; Brooks and Minnich 2006). Increased levels of surface-disturbing activities, rainfall, and atmospheric nitrogen and carbon dioxide may also increase the dominance of alien plants and frequency of fires in the future (Brooks and Esque 2002; Brooks *et al.* 2003).

The most striking changes have been observed in the middle elevations dominated by creosote bush, Joshua tree (*Yucca brevifolia*), and blackbrush (*Coleogyne ramosissima*), where most of the fires in the region occurred between 1980 and 2004 (Brooks and Matchett 2006). The combination of enough cover of native vegetation to carry a fire and the accumulation of fuels from non-native annual grasses following years of above average rainfall may result in significantly larger fires at shorter return intervals than normally expected in this zone. Lower elevations are less susceptible to larger fires because of the natural lack of native species' cover, and upper elevations may experience larger fires as they generally support enough native fuels to

carry large fires (Brooks and Matchett 2006). Brooks and Matchett (2006) advise, however, that additional research is necessary to confirm their results due to a limited dataset, and that longitude, elevation, and regional climatic conditions may cause substantial variation in observations.

A particularly bad fire year in the Mojave Desert was in 2005, when numerous wildfires burned over 202,343 hectares (500,000 acres) of habitat across the range of the desert tortoise, 55,442 hectares (137,000 acres) of which are designated critical habitat (2.1 percent of all designated critical habitat). The fires affected three of the six desert tortoise recovery units, including the Upper Virgin Recovery Unit, the Northeastern Mojave Recovery Unit, and the Eastern Mojave Recovery Unit (Table A-2). Within the Upper Virgin Recovery Unit, the Upper Virgin River critical habitat unit was burned. Within the Northeastern Mojave Recovery Unit, three critical habitat units were impacted: 18,922 hectares (46,757 acres) (23 percent) of the Beaver Dam Slope critical habitat unit, 25,279 hectares (62,466 acres) (13 percent) of the Gold Butte-Pakoon critical habitat unit, and 6,297 hectares (15,559 acres) (4 percent) of the Mormon Mesa critical habitat unit. Within the Eastern Mojave Recovery Unit, 62 hectares (154 acres) (less than 1 percent) in the Piute-Eldorado and 431 hectares (1,065 acres) (less than 1 percent) in the Ivanpah critical habitat units burned. Although it is known that tortoises were burned and killed in the fires, tortoise mortality estimates are not available. In 2006, about 20,234 hectares (50,000 acres) of desert tortoise habitat burned, which includes less than 8,094 hectares (20,000 acres) of desert tortoise critical habitat.

Table A-2. Approximate area of desert tortoise habitat burned in each recovery unit during 2005 (does not encompass all of the critical habitat units; 1 hectare=2.47 acres) (BLM 2006).

Recovery Unit	Habitat Burned (hectares)	Percent Habitat Burned	CH* Burned (acres)	Percent CH Burned
Upper Virgin River**	4,227	< 19	4,227	19
Northeastern Mojave***	202,343	10	50,497	11
Eastern Mojave	2,428	< 1	493	<1
Western Mojave	0	0	0	0
Northern Colorado	0	0	0	0
Eastern Colorado	0	0	0	0
Total	**208,998**	-	**55,217**	-

* CH = critical habitat

** Estimates only for Upper Virgin River; GIS data analysis needed

***Potential habitat was mapped and calculated as Mojave Desert less than 4,200 feet in elevation minus playas, open water, and developed and agricultural lands.

Studies were conducted in five burned areas within the range of the desert tortoise to determine immediate effects of the fire and fire suppression tactics and to monitor the recovery of habitats (Esque *et al.* 1994, 2003). Between 16 to 81 hectares (40 and 200 acres) were surveyed for wildlife remains on each fire via walking transects 9 to 15 meters (30 to 50 feet) apart. Desert tortoise mortality was documented at 0 to 7 per transect, but live tortoises were also observed. There were statistically significant losses of perennial cover, but some fires left unburned patches of vegetation that can serve as refugia for tortoises and plants. These refugia may be important to the long-term recovery of burned desert ecosystems. No destroyed burrows

or desert tortoise mortalities were observed in surveys of routes used for off-road fire suppression activities in Utah, indicating that carefully planned and monitored fire suppression maneuvers can help stop the spread of damaging wildfires and reduce immediate and long-term tortoise mortality (Esque *et al.* 1994, 2003).

Land Acquisitions, Exchanges, and Transfers. Land exchanges and transfers may result in loss of desert tortoise habitat, increased fragmentation, and displacement of resident desert tortoises. Tortoise habitat that is exchanged out of Federal ownership is at greater risk of development, resulting in loss of habitat on the new private holdings (Sievers *et al.* 1988). At the same time, transactions may be executed in the interest of securing additional lands targeted for conservation of the desert tortoise and other sensitive species or habitats (see Conservation Efforts).

In 1988, Bureau of Land Management exchanged 11,758 hectares (29,055 acres) of public land in the Coyote Springs Valley in southern Nevada to Aerojet-General Corporation for private wetlands in Florida for wildlife conservation under the Nevada-Florida Land Exchange Authorization Act. In addition, 5,571 hectares (13,767 acres), which are surrounded by the 11,758 hectares (29,055 acres), were leased to Aerojet for an initial term of 99 years with a 99-year extension. Coyote Springs Investments purchased the lands in 1998 and their development in Clark County will result in the loss of 2,785 hectares (6,881 acres) (1.6 percent) of designated critical habitat within the Mormon Mesa critical habitat unit and take of up to 645 desert tortoises. This loss of desert tortoise habitat is addressed in the Clark County Multiple Species Habitat Conservation Plan (MSHCP). Coyote Springs Investment also plans to develop most of the remaining private land, 8,682 hectares (21,454 acres) of desert tortoise habitat (Mormon Mesa critical habitat unit) in adjacent Lincoln County. The lands identified for development as well as the 5,571 hectares (13,767 acres) of leased lands, which would become a reserve for the desert tortoise and used as mitigation for loss of tortoise habitat, are being addressed under a separate MSHCP.

Under the Western Mojave Land Tenure Adjustment Project, approximately 21,044 hectares (52,000 acres) of land within desert tortoise critical habitat have been acquired by the Bureau of Land Management, and approximately 6,880 hectares (17,000 acres) outside of designated critical habitat have been transferred out of Federal management since 1990. The overall ratio of acquired to disposed habitat of the desert tortoise is expected to be approximately 2.3:1 at the completion of the Western Mojave Land Tenure Adjustment Project.

The Southern Nevada Public Lands Management Act of 1998, as amended (Public Law [PL]-105-263), provides for the "disposal of certain Federal lands in Clark County, Nevada, and for the acquisition of environmentally sensitive lands in the State of Nevada." The law was enacted partly to address the Bureau of Land Management's extensive and complicated land management responsibilities of disjunct parcels that are interspersed with or adjacent to private land in the Las Vegas Valley and the rapid urbanization taking place in the valley. In order to "promote responsible and orderly development in the Las Vegas Valley, certain of those Federal lands should be sold by the Federal Government based on recommendations made by local government and the public" (PL-105-263). This legislation provided the mechanism for significant changes to take place in the Las Vegas area relative to human occupation in the Mojave Desert.

A series of other related public laws have connections to the Southern Nevada Public Lands Management Act and facilitate the transfer or disposal of public lands, including the Lincoln County Conservation, Recreation, and Development Act of 2004 (PL-108-424); the Lincoln County Land Act of 2000 (PL-106-298); the Clark County Conservation of Public Land and Natural Resource Act of 2002 (PL-107-282); the Fiscal Year 2004 Appropriations Act amending the Southern Nevada Public Lands Management Act (PL -105-263); the Lake Tahoe Restoration Act; the Mesquite Lands Act of 1986 (PL-99-548) and 1988 and PL-104-208 (1996 amendment to the Mesquite Lands Act of 1988); the Ivanpah Valley Airport Public Lands Transfer Act of 2000; and the Federal Land Transaction Facilitation Act of 2000.

Grazing. Livestock grazing (sheep and cattle as well as horses and burros) is known to have direct and indirect impacts on the desert tortoises and their habitats through trampling, direct mortality either while above ground or in burrows, and causing degradation of vegetation and soils (Boarman 2002). The magnitude of the threat on desert tortoise populations remains unclear, and the degree of impact depends on a number of factors including, but not limited to, resiliency of soil and vegetation types, type of stock, stocking rates, season of use, and years of use with and without rest (USFWS 1994). Other factors that interact with livestock grazing and can affect the degree and extent of impacts to desert tortoises include introduction and spread of weeds, previous grazing-induced changes in vegetation, fire, drought, and other land uses (USFWS 1994).

Oldemeyer (1994) suggests that the primary evidence that grazing adversely affects desert tortoises relates to an overlap in food habits of livestock and tortoises. Reduced cover of shrubs and annual forbs has also been attributed to grazing activities. Studies in the eastern Mojave Desert on foraging behavior and food preferences of range cattle and desert tortoises also showed that a dietary overlap (spatial and temporal) exists and that this overlap is greatest in the spring when fresh annuals are at their peak biomass and densities. Food competition is expected to be greatest when annual plants start to dry in the spring, before cattle and tortoises switch to other forage plants (Avery and Neibergs 1997).

Avery and Neibergs (1997) observed direct and indirect interactions between cattle and tortoises. Their study indicates that grazing during winter may destroy a large percentage of active tortoise burrows. Tortoises tried unsuccessfully to enter completely destroyed burrows and entered and used partially destroyed burrows. They noted that tortoises outside an ungrazed cattle exclosure spent more nights outside of burrows than tortoises within the exclusion area, due to more destroyed burrows in the grazed area. In a study on translocated tortoises in the northwest Mojave Desert, one tortoise was found alive in its hibernation burrow which had been crushed by cattle. It was assumed that the tortoise would have died if it had been left in the crushed burrow (Nussear 2004). Tortoises whose home ranges are located in areas of heavy cattle grazing may experience increased risk of mortality, increased energetic costs, and changes in activity time budgets (caused by additional time and effort required to build new burrows).

Studies at the Desert Tortoise Natural Area showed that both abundance and diversity of native plants and animals is higher inside than outside of the protected desert tortoise habitat (Brooks 2000). It should be noted that the Desert Tortoise Natural Area has received limited protection since 1973, but has been effectively protected from sheep grazing and off-highway

vehicle use through the installation of exclusion fencing for the last ten years. Further comparative studies of fenced and unfenced areas with similar land use restrictions are needed to evaluate the effectiveness of fencing as a management tool.

Comparative studies of historically grazed and never-grazed grasslands in southeast Utah (Neff *et al.* 2005) showed that grazing can continue to impact soil biogeochemical characteristics three decades after grazing had been removed. Reduced soil nutrient levels in the historically grazed site compared to the never-grazed site were attributed to erosion of nutrient-rich fine soil materials due to disturbance, in this case caused by grazing practices. Soil organic matter, carbon and nitrogen content, and microbial biomass were also lower in the historically grazed site. The decline of organic matter content may be attributed to the destruction of biological soil crusts or long-term changes in vegetation cover/composition. This study illustrates the sensitivity of arid land biogeochemical processes to land use change and the need for a better understanding of potential long-term impacts from grazing practices in the southwestern United States. Furthermore, wind erosion may contribute significantly to loss of soil nutrient content and should be considered in management of arid land ecosystems (Neff *et al.* 2005).

Agriculture. Lands in the Mojave Desert have been used for agricultural purposes since the early nineteenth century when peoples of the Mohave Tribe planted crops within the floodplain of the Colorado River to sustain their populations (Mojave Desert.net 2007). The 1994 Recovery Plan stated that the most significant effect agriculture has on desert tortoises is loss of habitat. Since the 1950s, losses of tortoise populations have been attributed to urbanization and agriculture in the western Mojave Desert in the Indian Wells, Antelope, Victor, Apple, Lucerne, and Johnson valleys (Berry and Nicholson 1984). Once converted to agricultural fields, the habitat becomes unsuitable to tortoises for foraging or burrowing. Agricultural activities may also result in drawdown of the water table, introduction of invasive plants, production of fugitive dust, and possible introduction of toxic chemicals (Koehler 1977; Wilshire 1980; Berry and Nicholson 1984). Additionally, agricultural fields can support ravens, which prey upon juvenile tortoises (Knowles *et al.* 1989a,b; Camp *et al.* 1993; Knight *et al.* 1999). Old agricultural fields are often invaded by non-native, invasive species, which compete with native plants for resources and may reduce the abundance and diversity of the native species that provide shelter and food for desert tortoises (Hobbs 1989; USFWS 1994).

Energy and Mineral Development. Exploration for and development of energy and mineral resources results in habitat fragmentation and permanent habitat loss due to haul roads, ancillary facilities, leachate ponds, and mine tailings. Additional impacts to the desert tortoise may result from development of facilities necessary to support large mining operations, fugitive dust and soil erosion, and introduction of toxins (see Disease). Tortoises may be killed during activities such as exploration, construction and ongoing operations, and maintenance (USFWS 1994; Boarman 2002). At the time the 1994 Recovery Plan was drafted, it was estimated that 41 percent of high density tortoise habitat throughout the species' range was leased or partially leased for oil or gas, and 2 percent was directly impacted by mining operations or leased for geothermal development (Luke *et al.* 1991; USFWS 1994).

The extent of impacts to desert tortoise habitat and effects to tortoise populations from energy and mineral development are still not well documented. Cumulative impacts of multiple

mining-related disturbances combined with increased development to support those operations may pose the most significant threat through habitat loss (Lovich and Bainbridge 1999; Boarman 2002). In the California Desert, no oil and gas development has yet occurred, but applications for solar and wind energy facilities total nearly 202,343 hectares (500,000 acres) because of an emphasis on advancing alternative energy sources. The Bureau of Land Management in California has committed to excluding these projects from designated critical habitat and Desert Wildlife Management Areas, but dozens of projects have been sited (proposed) within non-critical desert tortoise habitat. The energy development process remains quite fluid, with applicants submitting multiple requests to modify their projects or withdrawing their applications altogether (J. Crisp, Bureau of Land Management, pers. comm. 2007).

Landfills. An estimated 27 authorized sanitary landfills and waste disposal facilities are known from the California deserts, with 11 of those in the west Mojave Desert (Boarman 2002). In other urban areas throughout the range of the tortoise, all communities produce waste that must be transported to appropriate facilities. Landfills and other waste disposal facilities potentially affect desert tortoises and their habitat through fragmentation and permanent loss of habitat, spread of garbage, introduction of toxic chemicals, increased road kill of tortoises on access roads, and increased predator populations (Boarman 2002). With the exception of raven predation, which is considered one of the most important consequences of landfills, negative effects on tortoises associated with the presence of landfills have not been quantified (Boarman 2002). Also see the section on listing factor C, Disease and Predation, for a detailed discussion.

Military Operations. Military operations in the Mojave Desert have taken place since as early as 1859 (USFWS 1994; Boarman 2002). Military activities that impact desert tortoises and their habitats can be categorized as: (1) construction, operation, and maintenance of bases and support facilities (air strips, roads, etc.); (2) development of local support communities, including urban, industrial, and commercial facilities; (3) field maneuvers including tank traffic, air to ground bombing, static testing of explosives, littering with unexploded ordnance, shell casings, and ration cans; and (4) distribution of chemicals. These activities result in degradation and permanent loss of desert tortoise habitat and are often coupled with impacts associated with large human settlements in the desert (*i.e.*, collection of tortoises, trash dumping, increased raven populations, domestic predators, off-highway vehicle use, increased exposure to disease, and increased mortality) (USFWS 1994).

The military bases and test ranges in the Mojave Desert include the Nevada Test and Training Range, Nellis Air Force Range, Edwards Air Force Base, George Air Force Base (decommissioned; currently the Southern California Logistic Airport and Federal prison), Twentynine Palms Marine Corps Air Ground Combat Center, Barstow Marine Corps Logistics Bases (includes the Yermo Annex, Main Base at Nebo, and the Marine Corps Rifle Range), Fort Irwin National Training Center, China Lake Naval Air Weapons Station, the Mojave B and Randsburg Wash Test Ranges, and Cuddeback Aerial Gunnery Range (closed). The Chocolate Mountains Aerial Gunnery Range is the primary base affecting desert tortoise habitat in the Colorado Desert (USFWS 1994).

All of the threats associated with military activities described above continue to threaten desert tortoises and their habitat. The expansion of military bases and activities into previously

unused areas occupied by desert tortoises also threatens the species. In 2004, we issued a biological opinion to the Department of the Army for the use of additional training lands at the National Training Center. This action will result in the loss or degradation of approximately 76,081 hectares (188,000 acres) of desert tortoise habitat, including approximately 30,351 hectares (75,000 acres) within the Superior-Cronese critical habitat unit, and the translocation of several hundred desert tortoises from harm's way. To date, the Department of the Army has purchased approximately 40,104 hectares (99,100 acres) of lands formerly owned by the Catellus Development Corporation and portions of cattle allotments in the western Mojave Desert as partial mitigation for the expanded training areas (R. Bransfield, U.S. Fish and Wildlife Service, pers. comm. 2007). The Bureau of Land Management subsequently retired these allotments and removed grazing on over 129,499 hectares (320,000 acres). A plan has also been developed to guide the translocation of tortoises in the expansion area (Esque *et al.* 2005).

Non-motorized Recreation and Miscellaneous Human Activities. Non-motorized recreation includes activities such as camping, hunting, target practice, rock collecting, hiking, horseback riding, biking, and sight-seeing. While there are no data correlating these activities with impacts to the desert tortoise, it may be surmised based on visitor use days that these activities bring with them many of threats associated with increased human presence, such as loss of habitat from development of recreational facilities, handling and disturbance of tortoises, increased road kill and vandalism of tortoises, and increased raven populations (USFWS 1994; Boarman 2002). Off-trail use can degrade habitat by damaging vegetation and cryptogamic crusts (Belnap 1996) and compacting soils.

Very few studies have been conducted to date to document the effects of non-motorized activities to desert tortoises. One study measured the effect of surface disturbance from foot, bike, and vehicle tracks on the nitrogenase activity in cyanobacterial-lichen soil crusts, a dominant source of nitrogen for cold-desert ecosystems (Belnap 1996). Results showed that the levels of nitrogenase activity were reduced between 30-100 percent, depending on the degree of soil disruption and the microbiotic composition of the soils (Belnap 1996). This study demonstrated that anthropogenic surface disturbances may have serious implications for the nitrogen budgets in cold-desert ecosystems. The reduction in net primary productivity and changes in species composition can affect the availability and diversity of forage species used by desert tortoises.

Utility Corridors. By 1994, most critical habitat units had one or more power lines, natural gas pipelines, fiber optic cables, and/or communication sites within their proposed boundaries. Disturbances are usually linear in nature and the zone of disturbance in utility corridors can vary in width from 50 to 100 feet to several hundred yards, depending on the number of transmission lines (USFWS 1994). Impacts to desert tortoise habitat and individuals occur both during initial construction as well as during long-term maintenance activities (Boarman 2002). Additionally, utility corridors are often used by the public for off-highway vehicle and recreational access. LaRue and Dougherty (1999) performed an evaluation of results of over 230 biological opinions issued by our southern California and Nevada offices and found that 80 percent of the tortoises reportedly killed in these two states were found along utility corridors. Most of these mortalities resulted from a few large projects during the construction phases, and very few tortoises have been killed during utility maintenance projects (R.

Bransfield, U.S. Fish and Wildlife Service, pers. comm. 2007). While tortoises may be observed within these corridors, continual vehicular use along access roads may alter use by tortoises both for foraging and movement or result in road-kills (Boarman 2002). Utility towers also provide nesting substrate to avian predators, such as ravens and red-tailed hawks.

Vandalism and Harvest of Vegetation. Vandalism and harvest of vegetation were identified as potential threats to desert tortoises and their habitats in the 1994 Recovery Plan. Harvest of vegetation includes the removal of vegetation for personal or economic purposes (*i.e.*, use in landscaping or sale for profit), and vandalism of vegetation is considered the deliberate destruction of vegetation (*i.e.*, shooting, crushing). While these activities may still occur on a relatively small scale and may pose some threat on a localized level, there is no recent documentation that indicates this activity poses a significant or widespread threat to tortoise populations throughout their range.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Collection by Humans. Some of the threats to the desert tortoise identified in the 1994 Recovery Plan include the deliberate removal of desert tortoises by humans for use as food items (Berry and Nicholson 1984; Swingland and Klemens 1989; Schneider and Everson 1989; Ditzler 1991; BLM files) and collection and commercial trade for pets (Berry and Nicholson 1984; St. Amant 1984; Berry and Burge 1984). Collection of desert tortoises by humans for food or as pets was cited as a potential threat to the species, and commercial collecting was at one time considered significant (USFWS 1994). Desert tortoises are protected from collection under both Federal and State law in all states; however, the legal status has not always served as a deterrent to this activity (Boarman 2002). For example, nine cases of illegal collection were documented from the Red Cliffs Desert Reserve, Washington County, Utah, between May 2003 and May 2006, including four cases within 5 weeks during 2006 (A. McLuckie, Utah Division of Wildlife Resources, pers. comm. 2006). While illegal collection of desert tortoises still occurs and such collection could possibly impact local populations, little quantitative evidence exists to support conjecture that this is a significant threat causing declines in the Mojave populations (Boarman 2002). Also, the wide distribution of the species coupled with the need for additional law enforcement officers and wardens on the ground contributes to the limited data specific to this threat.

Vandalism. Little additional information regarding vandalism of desert tortoises has been obtained since the 1994 Recovery Plan. Postmortem forensic analysis determined that 14.3 percent of 635 carcasses collected at 11 of 27 California desert sites between 1976 and 1982 showed evidence of gunshots. This type of vandalism was significantly higher from the west Mojave than from the east Mojave or Colorado Desert (Berry 1986), which may be a function of the proximity of human populations in the west Mojave region compared to that in the east Mojave or Colorado Desert.

Research Activities. We permit various research activities that will inform management and recovery of the desert tortoise but may result in injury or mortality during implementation.

The following activities are permitted with terms and conditions to minimize injury and potential mortality of individuals:

- Population monitoring, which involves free-ranging tortoises that are subject to pursuit, capture, and handling to determine weight, size, sex, and are marked for recapture;
- epidemiological studies, which involves general health assessments and disease-related investigations (blood samples and nasal lavages may be collected; moribund tortoises may be collected from the wild and occasionally euthanized);
- research on recruitment and survivorship of younger age classes of desert tortoises, which includes marking of individuals using notching/clipping of marginal scutes, insertion of PIT tags, and attachment of radio transmitters or other hardware in accordance with USFWS-approved protocol; and pursuit and capture of study animals during monitoring activities;
- research on impacts of grazing, road density, barriers, human-use levels, restoration, augmentation and translocation on desert tortoise population dynamics, which may include many of the activities and associated effects described above;
- research on nutritional and physiological ecology of various age classes of desert tortoise, which includes many of the types of activities and associated effects previously described. In addition, captive tortoises may be injected with labeled or tritiated water in association with physiological studies; and
- research on reproductive behavior and physiology, which includes many of the types of activities and associated effects previously described and involve both free-ranging and captive desert tortoises.

Despite the inherent risk associated with activities covered under recovery permits, incidental injury or mortality of any desert tortoises is not expected; however, if this should occur, the permit will be suspended until the circumstances surrounding the incident are reviewed and appropriate procedures are in place to prevent further injury or mortality. In any given year, we generally issue fewer than 15 recovery permits for the desert tortoise. Because of the emphasis that we, through the Desert Tortoise Recovery Office, intend to place on recovery-related research activities pertaining to the desert tortoise, the number of permits issued may increase over the next few years.

Potential stress from handling may vary depending on the amounts of time, frequency, and activity involved. Invasive procedures associated with obtaining physiological data can cause significant stress to individuals (Berry *et al.* 2002a). Female tortoises that void their bladders during handling may be at a reproductive disadvantage, and overall, tortoises that urinated during handling had lower survival than those that did not (Averill-Murray 2002).

C. Disease or Predation

Disease. Disease is a natural phenomenon within wild animal populations, and epidemic outbreaks can have catastrophic effects on small or declining populations. Two diseases have been implicated in negatively affecting desert tortoise populations: upper respiratory tract disease (Jacobson *et al.* 1991) and cutaneous dyskeratosis or shell disease (Jacobson *et al.* 1994). Herpesvirus has also been suspected of having population-level impacts, but little data are

available to support or refute this hypothesis (Berry *et al.* 2002b; Origgi *et al.* 2002). Other diseases or infections have also been identified in tortoises including shell necrosis, bacterial and fungal infections, and urolithiasis (bladder stones) (Homer *et al.* 1998), but little information is available regarding the distribution of these maladies within or among desert tortoise populations (Boarman 2002). Likewise, only correlative studies have linked upper respiratory tract disease or cutaneous dyskeratosis to population declines (Berry 1997). Additional research is needed to clarify the role of disease in desert tortoise population dynamics relative to other threats.

At least two pathogenic species of *Mycoplasma* have been identified (*M. agassizii* and *M. testudineum*) that are known to cause upper respiratory tract disease in desert and gopher tortoises (Brown *et al.* 1994, 1999, 2001, 2002; Berry 1997; Jones *et al.* 2005). The pathogens are likely transmitted by contact with an infected individual or aerosols. Once infected, tortoises may develop lesions in the nasal cavity, excessive nasal discharge, swollen eyelids, sunken eyes, and ultimately lethargy and possible death (Jacobson *et al.* 1991; Schumacher *et al.* 1997; Homer *et al.* 1998; Berry and Christopher 2001). Boarman (2002) notes, however, that these clinical signs may be symptomatic of other conditions such as dehydration or infection with herpesvirus. An enzyme-linked immunosorbent assay (ELISA) serological test is available to determine exposure to the pathogens (Schumacher *et al.* 1993; Wendland *et al.* accepted), and a polymerase chain reaction test has been developed to determine active infection (Brown *et al.* 1995); however, in-depth epidemiological study is necessary to more thoroughly understand the factors involved in the spread and virility of the disease in the wild (Boarman 2002).

Because the release or escape of infected captive tortoises has been implicated as a potential cause of outbreaks of upper respiratory tract disease in natural populations in the Mojave, Johnson *et al.* (2006) evaluated captive tortoises in Barstow, California, to determine pathogen exposure. Anti-*Mycoplasma* antibodies were present in 82.7 percent of the tortoises tested (n=179), and anti-herpesvirus antibodies were observed in 26.6 percent of the animals (n=109). A positive link was also established between tortoises with anti-*Mycoplasma* antibodies and the severity of clinical signs of upper respiratory tract disease, as well as with age class, with adults being more likely to be positive. However, this linkage was not observed with herpesvirus exposure. These results indicate that captive tortoises released into the wild may be a source of infection for natural populations (Johnson *et al.* 2006).

Jones *et al.* (2005) found, however, that captive tortoises do not appear to serve as a reservoir for upper respiratory tract disease in the Sonoran population of desert tortoise. They did find higher incidence of disease in suburban areas around Tucson, Arizona, which suggest that urbanization is a stressor that may contribute to disease outbreaks. Reasons for the susceptibility of tortoises to upper respiratory tract disease remain speculative and require further study (Boarman 2002); additional insights and recommendations relative to this disease are provided by the Science Advisory Committee in Appendix B.

Little is known about the causes of cutaneous dyskeratosis, which manifests itself as lesions along scute sutures of the plastron, and sometimes on the carapace, then spread to the scutes themselves. This disease has been associated with declines on the Chuckwalla Bench in California; however, the extent to which it contributes to mortality of desert tortoises remains unclear (Jacobson *et al.* 1994). Toxins in the environment and nutritional deficiencies have been

implicated in causing shell disease (Jacobson *et al.* 1994; Homer *et al.* 1998); however, there are few data to support this linkage (see Toxicants).

Toxicants. Illegal dumping of hazardous wastes in the California deserts appears to be increasing, which may expose tortoises to increased levels and possible consumption of toxic substances. Garbage, litter, and toxic spills may affect tortoises on a localized level where these activities are concentrated (Boarman 2002). Toxicant load in the environment may also be a factor that influences the susceptibility of tortoises to diseases and mortality. Tortoises that died of mycoplasmosis at the Desert Tortoise Natual Area in 1989 through 1990 had 11 times the mercury content in their livers than tortoises from a control area (Jacobson *et al.* 1991). Some necropsies showed elevated levels of arsenic in scutes (Seltzer and Berry 2005).

Fugitive dust containing toxicants that affect tortoises may be released from anthropogenic sites such as mines, roads, construction, and other sites. Chaffee and Berry (2006) collected soil, stream sediment, and plant samples at 6 tortoise habitat study areas in the Mojave and Colorado deserts. They analyzed samples for up to 66 different elements to determine their distribution and abundance at a regional and local level and identify potential sources of toxicants in desert tortoise habitats. Some anomalies, such as high concentrations of arsenic, mercury, and lead, were attributed to mining and vehicle exhaust. Soil and plant anomalies for arsenic extended more than 9 miles from existing mine sites, and mercury was detected more than 3 miles from mine tailings. Traces of lead were found more than 13 miles from a paved road and have likely been redistributed by vehicle exhaust, wind, and rain events. Elevated levels of these elements have been observed in ill tortoises found in these areas; however, additional research is necessary to ascertain the direct effects of elemental toxicants on desert tortoise health and their susceptibility to disease (Chaffee and Berry 2006).

Predation. The common raven is a predator of the desert tortoise that benefits from resource subsidies often associated with human uses (Boarman *et al.* 2006). For instance, ravens obtain food in the form of organic garbage from landfills and trash containers, water from sewage ponds and municipal areas, and nesting substrates on billboards, utility towers, bridges, and buildings (Boarman *et al.* 2006). Road-kills can also serve as a potential food resource for desert tortoise predators. The use of anthropogenic nesting substrates facilitates increased predation of juvenile tortoises, especially within about 0.4 kilometers (0.25 miles) of the raven nest (Boarman 2002; Kristan and Boarman 2003).

In the mid-1980s, the remains of juvenile desert tortoises were collected in the West Mojave near nesting or perch sites used by ravens. It was determined that of the 190 specimens collected, raven predation could be attributed to the deaths of 185 (97 percent) (Boarman 2002). Additional efforts to quantify predation by ravens in the western Mojave have been undertaken, however, tortoise populations are difficult to estimate, and sampling of neonate and juvenile populations is not straightforward (Berry 1985; Berry and Turner 1986; Shields 1994) so it may not be accurate to evaluate these numbers in the context of overall tortoise demography (Boarman 2002). Nevertheless, the potential impact to desert tortoise populations from raven predation remains a conservation concern, as subsidized predators are able to persist in large numbers despite declines in their prey base, thereby putting at great disadvantage the prey species that are unable to rebound from predation pressures (Kristan and Boarman 2003).

Raven numbers were shown to decrease with distance from urban sites, placing tortoises that occur in the urban interface at higher risk of predation (Kristan and Boarman 2003). This risk also increases with the numbers of ravens in the vicinity, and the distribution of breeding and non-breeding ravens is likely to influence the patterns of predations across the landscape. Breeding ravens tend to disperse more evenly across suitable habitats, whereas non-breeding birds are concentrated around anthropogenic sites. This suggests that occupied desert tortoise habitats distant from population centers and the urban interface experience reduced predation pressures from ravens (Boarman *et al.* 1993; Boarman 2002; Kristan and Boarman 2003).

Ravens are not the only avian predator of the desert tortoise. Red-tailed hawks, golden eagles (*Aquila chrysaetos*), loggerhead shrikes (*Lanius ludovicianus*), American kestrels (*Falco sparverius*), burrowing owls (*Athene cunicularia*), and greater roadrunners (*Geococcyx californianus*) have also been implicated in tortoise predation, although available data are minimal (Boarman 1993). Coyotes (*Canis latrans*), kit foxes (*Vulpes macrotis*), mountain lions (*Felis concolor*), ground squirrels (*Citellus* spp., and free-roaming dogs are known mammalian predators (Boarman 2002; M. McDermott, Southern Nevada Environmental, Inc., pers. comm. 2006). However, few data exist that quantify the impact of mammalian predation on desert tortoises. Invertebrate predators of eggs and hatchling tortoises include native fire ants (K. Nagy, University of California-Los Angeles, pers. comm. 2006).

D. Inadequacy of Existing Regulatory Mechanisms

The final listing rule acknowledged that all four states within the range of the Mojave population of the desert tortoise have laws in place to protect the species. In addition, a great deal of effort has been dedicated to planning by the various land management agencies whose jurisdictions include desert tortoise habitat. Many of the existing plans include language specific to protection of the species, such as limiting off-highway vehicle use and competitive/organized events, grazing, vegetation harvest, and collection of desert tortoises. However, the land management agencies frequently do not have sufficient funding to enforce their land use regulations (Table A-3). The number of law enforcement officers or game wardens on-the-ground does not necessarily translate into protection of the species, as personnel are often spread across vast landscapes and have multiple resource responsibilities.

E. Other Natural or Manmade Factors Affecting its Continued Existence

Climate Change. The Earth's climate has warmed by nearly 1.5 degrees Fahrenheit over the past 100 years (Walther *et al.* 2002), and anthropogenic emissions of greenhouse gases play a major role in this process (Weltzin *et al.* 2003). While this warming is not uniform with regard to time and space, the rate of warming during the last 30 years has generally been greater than at any other time during the last 1,000 years. In many regions there is an asymmetry in warming, as well as precipitation, which is likely to contribute to variation in ecological dynamics across ecosystems. There is now sufficient evidence that recent climatic changes have affected a broad range of organisms with diverse geographical distributions (Walther *et al.* 2002). Interactions between altered precipitation patterns and other aspects of global change are likely to affect natural and managed terrestrial ecosystems. For example, climate models predict that Joshua

trees will no longer be able to persist within Joshua Tree National Park through the 21st century (Cole *et al.* 2005). While little is known regarding direct effects of climate change on the desert tortoise and its habitat, predictions can be made about how global and regional precipitation regimes may be altered and the consequences of these changes (Weltzin *et al.* 2003; Seager *et al.* 2007).

Table A-3. Law enforcement (LE) resources within desert tortoise habitat by agency.

Responsible Agency/Unit[1]	Number of LE Officers	Number of Vacancies (if applicable)	Number of Acres (approx.)
BLM-California Desert District[2]	43	4	10,400,000
Barstow Field Office	8	0	3,000,000
El Centro Field Office	12	0	1,400,000
Needles Field Office	6	2	3,300,000
Palm Springs – South Coast Field Office	9	2	1,700,000
Ridgecrest Field Office	8	0	1,800,000
BLM-Arizona Strip Field Office[3]	3	1	2,000,000
BLM-NPS Grand Canyon-Parashant National Monument[4]	3 BLM 2 NPS	0	1,100,000
BLM-Las Vegas and Ely Field Offices[5]	14 (Vegas) 1 (Ely)	?	3,000,000 726,000
BLM-St. George Field Office[6]	1	0	630,000
NPS-Mojave National Preserve[7]	9	4	1,400,000
NPS-Joshua Tree National Park[8]	10	4	790,000
NPS-Death Valley National Park[9]	14	?	3,300,000
NPS-Lake Mead National Recreation Area[10]	16	?	1,500,000
USFWS-Desert National Wildlife Refuge Complex[11]	5	2	1,600,000
US Forest Service-Spring Mountains National Recreation Area[12]	3	2	317,000
Arizona Game and Fish Department[13]	2	?	
California Department of Fish and Game[14]	16	3	
Nevada Department of Wildlife[15]	16	3	
Utah Division of Wildlife Resources[16]	4	0	
Clark County MSHCP-Boulder City Conservation Easement[17]	1	0	86,000

[1] Information provided via electronic mail or personal communication (July, August 2007) from the following:
[2] Jim Abbott, Bureau of Land Management California State Office
[3] Scott Florence, Bureau of Land Management Arizona Strip District
[4] Kathleen Harcksen, Bureau of Land Management Grand Canyon-Parashant National Monument
[5] Elroy Masters, Bureau of Land Management Nevada State Office
[6] Jim Crisp, Bureau of Land Management St. George Field Office
[7] Debra Hughson, Kirk Gebicke, National Park Service, Mojave National Preserve
[8] Paul DePrey, Curt Sauer, National Park Service Joshua Tree National Park
[9] David Ek, National Park Service Death Valley National Park
[10] Bill Dickinson, National Park Service Lake Mead National Recreation Area
[11] Cynthia Martinez, USFWS Desert National Wildlife Refuge Complex
[12] David Leveille, USFS Humboldt-Toiyabe National Forest
[13] Cristina Jones, Luke Thompson, Arizona Game and Fish Department
[14] Rebecca Jones, Mike McBride, California Department of Fish and Game
[15] Polly Conrad, Fred Henson, Nevada Department of Wildlife
[16] Ann McLuckie, Utah Division of Wildlife Resources
[17] Sue Wainscott, Clark County
? Information not provided or not available.

Climatic regimes are believed to influence species' distributions through species-specific physiological thresholds of temperature and precipitation tolerance. Warming temperatures and altered precipitation patterns may result in distributions shifting toward the poles and/or to higher elevations, depending on resource availability (Walther *et al.* 2002). We may expect this response in the desert tortoise, thereby reducing the viability of lands currently identified as "refuges" or critical habitat for the species. Seager *et al.* (2007) ran a series of climate models and simulations on the precipitation history and future of the southwestern United States and parts of northern Mexico that consistently showed a severe drying trend in this region throughout the 21st century, especially in areas where evapotranspiration exceeds precipitation.

Experiments in Nevada at the Free-Air Carbon Dioxide (CO_2) Enrichment Facility to predict the possible complex ecological and biogeochemical changes in semidesert ecosystems caused by increasing atmospheric CO_2 have been ongoing since 1997 (Hamerlynck *et al.* 2000; Smith *et al.* 2000; Huxman and Smith 2001). Because deserts are both water- and nutrient-limited systems and native plants are so slow growing, it is still too early to say with any confidence how even the most intensively studied desert shrub communities of the southwestern United States will respond to rising CO_2 (Lioubimtseva and Adams 2004). However, results from the Free-Air CO_2 Enrichment Facility site demonstrate that cheatgrass responds to increases in CO_2 such that it is far more productive than native plants during wet years (Smith *et al.* 2000). As discussed in the Fire section, non-native annual grass invasions are known to increase the frequency and intensity of fires, which has a dramatic negative effect on desert water cycles and wildlife habitat (Hamerlynck *et al.* 2000).

Direct climatic effects on growth and development, spatial distribution, and species interactions are apparent in amphibians and reptiles, which, in common with other ectotherms, are heavily influenced by environmental conditions. Both seasonal temperature and humidity affect their reproductive physiology and population dynamics (Walther *et al.* 2002). It remains unclear how regional changes in climate may affect the desert tortoise; however, some observations relative to drought have been documented in the past.

Drought. Drought is a normal phenomenon in the Mojave Desert (Peterson 1994a; Hereford *et al.* 2006). Desert tortoises have been inhabitants of this region for over 10,000 years and have adapted to variable conditions (Nagy and Medica 1986; Peterson 1994a,b, 1996a; Henen 1997). Extended periods of drought, however, have the potential to affect desert tortoises and their habitats through physiological effects to individuals (*i.e.*, stress) and limited forage availability. Unlike some other desert vertebrates, tortoises acquire much of their water and maintain overall positive energy balance by drinking free water (Peterson 1996a).

The effect of drought on demographic parameters of tortoise populations (*i.e.*, birth, death, recruitment, and growth rates) is not well understood (Avery *et al.* 2002; Boarman 2002). However, studies have attributed dehydration, malnutrition, and starvation; reduced reproduction output in females; altered behavior such as failure to seek shelter, reduced movement, and surface activity (O'Connor *et al.* 1994; Homer *et al.*

1996; Duda *et al.* 1999; Berry *et al.* 2002b); and increased susceptibility to predation and disease (Peterson 1994a,b) to periods of drought.

Since 1975, a tortoise population on the Beaver Dam Slope in Arizona and Utah experienced high mortality, where malnutrition caused by reduced nutrient availability was considered responsible for osteoporosis and subsequent mortality. Increased mortality in the Ivanpah Valley in 1981 and 1982 was attributed to drought conditions (Turner *et al.* 1984), and abnormally high levels of mortality were recorded in the east and west Mojave Desert during a three-year drought period (1988 through 1990). Deaths in the Ivanpah Valley study site were attributed to drought-induced starvation and dehydration (Turner *et al.* 1984).

Research conducted in the early 1980s indicated a strong correlation between clutch frequency (the number of clutches produced by a female in one reproductive season) and biomass of annual plants used by tortoises for food (Turner *et al.* 1986, 1987). Studies conducted at five sites (Joshua Tree National Park, Mojave National Preserve, Palm Springs, Piute Valley, and St. George) supported the results in Turner *et al.* (1984, 1986, 1987). Studies indicated that in high-rainfall years with corresponding abundant food plant availability, more females reproduced and reproducing females laid more clutches per reproductive season, compared with low-rainfall years (Lovich *et al.* 1999). Clutch size (number of eggs per clutch) was relatively constant regardless of conditions; however, Avery *et al.* (2002) noted that females at higher elevations receiving a greater annual rainfall had a larger mean clutch size.

Recent studies also indicate that even a relatively short-term drought combined with little or no annual biomass can cause a severe reduction in adult tortoise survival. A study of adult tortoise survival rates at two sites in the eastern Mojave desert (near or adjacent to Piute-Eldorado critical habitat unit) attributed die-offs in 1996 to a period of drought that began in the summer of 1995, coupled with failure of annual vegetation production in 1996 (Longshore *et al.* 2003). During three years of no or minimal annual biomass production (1996, 1997, and 1999), adult tortoises experienced depressed survival. In 1996, 30 percent of the radio-monitored adults died following a drought that began in the summer of 1995. While the researchers obtained no physiological evidence, these deaths likely resulted from dehydration (Longshore *et al.* 2003).

At the time the 1994 Recovery Plan was written, there was less consideration of the potentially important role of drought in the desert ecosystem, particularly regarding desert tortoises. Since then, studies have documented the vulnerability of juvenile (Wilson *et al.* 2001) and adult tortoises (Peterson 1994a, 1996b; Henen 1997; Lovich *et al.* 1999; Longshore *et al.* 2003) to drought.

Garbage, Trash, and Balloons. Turtles and tortoises are known to eat non-food objects, such as rocks, balloons, plastic, and other garbage. Such objects can become lodged in the gastrointestinal tract or entangle heads and legs, causing injury or death (Burge 1989; USFWS 1994). Unauthorized deposition of refuse is prevalent near towns, cities, and settlements in remote areas as well as in the urban interface. However, based on current available data, garbage and litter do not

appear to be a widespread or major threats to tortoise populations, except through the attraction of ravens and other subsidized predators. This indirect effect may contribute to a more important problem (Boarman 2002).

Noise and Vibration. The 1994 Recovery Plan cited noise and vibration as having potentially significant effects on desert tortoise's behavior, communication, and hearing apparatus (USFWS 1994). Very limited additional data have been obtained specific to this potential. Studies on the effects of flight noise from jet aircraft and sonic booms on hearing, behavior, heart rate, and oxygen consumption of desert tortoise concluded that hearing loss and physiological changes are not likely to be dangerous during occasional short-term exposures and that the results cannot be extrapolated directly to chronic exposures over a tortoise's lifetime. The authors caveat their results by saying they are "best viewed as a first-order effort to determine the effects of subsonic and supersonic aircraft noise on a desert reptile" and that changes in tortoise activity with repeated exposure to aircraft noise should be investigated under natural conditions, including during food and water deprivation, torpor, or exposure to dangers such as rivals and predators (Bowles *et al.* 1999).

Unauthorized Propagation of Pet Tortoises. Unauthorized breeding of pet tortoises can lead to pressures on wild tortoise populations, as well as management agencies. Wolff and Seal (1993) noted that the implications of infectious disease spread by the release of captive-bred animals and relocation of wild animals are a major concern in conservation biology. Captive releases have the potential to introduce disease into wild populations of desert tortoises and may also result in genetic contamination. Because of population declines in the Desert Tortoise Natural Area in the 1980s, hundreds of animals showing clinical signs of upper respiratory tract disease were removed and evaluated (Jacobson *et al.* 1995). Hardenbrook (1992) reported that the highest prevalence of clinical signs of upper respiratory tract disease was observed in tortoises removed from areas where previous releases of captive animals had occurred. In addition, the labor and financial resources that are expended to address offspring produced in captivity could otherwise be focused toward recovery efforts.

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Appendix B

UNDERSTANDING DISEASE IN DESERT TORTOISE POPULATIONS: A BRIEF SUMMARY OF KNOWLEDGE AND RECOMMENDATIONS PERTINENT TO CONSERVATION

by

The Desert Tortoise Science Advisory Committee
(Peter Hudson, Kristin Berry, C. Richard Tracy, Earl McCoy, Katherine Ralls, Michael Reed, and Robert Steidl)

Taking into account recent research presented to the committee by
Kenneth Hunter and Mary Brown

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Introduction

The objective of this document is to identify what is understood about the dynamics of infectious diseases in desert tortoises and to propose recovery recommendations and research activities that would be of direct assistance to the recovery of the desert tortoise.

To date the available evidence indicates that upper respiratory tract disease, as caused by the etiological agents *Mycoplasma agassizii* and *M. testudineum*, is probably the most important infectious disease for desert tortoises in terms of the impact it has on the size of desert tortoise populations. Less is known about other diseases that have been identified in the desert tortoise (*e.g.*, herpesvirus, cutaneous dyskeratosis), and we hope that continued study of *Mycoplasma* will help to form a model that will facilitate investigations of other diseases. We are aware that *Mycoplasma* spp. in other hosts are associated with a range of secondary respiratory tract infections and may also influence the susceptibility of the host to parasitic agents that infect other parts of the body. Indeed, there remains the possibility that other virulent infections may cause population declines, but at this point in time the putative cause of upper respiratory tract disease is a consequence of infection with *Mycoplasma*.

Mycoplasma are bacteria in the Class Mollicutes, which characteristically have no cell wall, have small genomes, and require cholesterol to grow in culture. We do not know if *Mycoplasma* grows more rapidly in stressed hosts because they have more cholesterol or because the host is immuno-suppressed as a consequence of hormonal changes. Several species of *Mycoplasma* are pathogenic in humans, including *M. pneumoniae*, an important cause of the respiratory disorder pneumonia, but spillover from one host species to another is unlikely because *Mycoplasma* species are usually highly host-specific. In desert tortoises there are two

species, the better known *M. agassizii* and the more recently identified *M. testudineum;* we use the term *Mycoplasma* to refer to both of these infections unless otherwise stated, but clearly we need to know more about the virulence, transmissibility, and interaction between the two species before we can provide separate recommendations for each pathogen.

A summary of important observations on *Mycoplasma*

The following summary is based on experimental and observational studies of both the desert tortoise and the gopher tortoise.

1. *Mycoplasma agassizii* is the putative cause of upper respiratory tract disease in desert and gopher tortoises. Koch's Postulates have been satisfied for this pathogen and for *M. testudineum*.
2. *Mycoplasma* appears to be highly virulent in some populations; at times the infection appears acute, although at other times the infections are chronic or may even appear quiescent. We know there are multiple strains of *Mycoplasma* and suspect several circulate within some populations. Variation in virulence and expression of toxin genes may account for some of the variation in observed die-offs between populations. Theoretically, there is a possibility that increased virulence could be selected for amongst tortoises kept in captivity as a consequence of social structure, good condition, and high density, and these more virulent strains could then be introduced into the wild; however, clear evidence in support of this hypothesis is lacking.
3. There is circumstantial evidence to suppose that environmentally induced trauma, particularly drought, inadequate nutrition, and toxicants will lead to reduced resistance to disease, increased bacteremia (live bacteria in the blood stream), increased transmission of disease, presence of visible acute disease symptoms, high tortoise mortality, and population declines. We suspect from the information we have seen that these environmentally induced effects are more important to the manifestation of acute disease outbreaks than variation in virulence between strains, but further research is needed to test between these hypotheses. Indeed, the two hypotheses are not mutually exclusive, and both may be acting at different times.
4. An enzyme-linked immunosorbent assay (ELISA) has been used to detect the presence of antibodies to *Mycoplasma.* Recently, the ELISA has been refined by conversion to the titer system with a sensitivity of 98.5 percent and a specificity of 99.9 percent. A proportion of seropositive tortoises do exhibit moderate to severe clinical signs of disease, and these are usually culture positive.
5. Our epizootiological understanding of the dynamics of infection is derived from ELISA tests, which simply tell us if an individual has been exposed and thus considered seropositive. The ELISA does not tell us if an individual is indeed infected, could be infectious, or may have been infected and has cleared the infection. Indeed, the evidence is that the development of acquired immunity does not clear the infection but keeps the infection level in check.
6. Seropositive tortoises have not been recorded from all populations, but the definition of seropositive and sample size (hence power) varies greatly between studies, making comparisons difficult. More insight on the timing and dynamics of this infection could be obtained if studies recorded sero-positivity in relation to an age estimate. There is

evidence that some populations in remote areas appear uninfected, although showing disease-free status requires large sample sizes and careful tests. In general, some populations appear to have an endemic and often chronic infection whereby we see relatively constant levels of seropositivity in the range of 20-25 percent. Other populations exhibit an increasing proportion of seropositive individuals, and these often exhibit acute infections with severe signs of disease and mortality with high level of seropositivity in the range of 50-75 percent for a relatively short period.

7. There is interesting evidence that desert tortoises, previously unexposed to infection, carry natural antibodies against *Mycoplasma*. This finding, if confirmed, could be of immense importance in understanding the dynamics and causes of acute infection and may indeed help with managing the disease in natural populations.

The putative explanation of the dynamics of *Mycoplasma* infections in desert tortoise populations

1. First working hypothesis: Die-offs of tortoises associated with mycoplasmosis are initiated by environmental stressors including drought, reduced nutrition, and toxicants that cause chronic physiological stress in an individual and thereby increase susceptibility and transmission, so generating an epidemic outbreak of acute disease. Note that many of these stressors are caused by anthropogenic activities that have reduced the plane of nutrition or reduced availability of water, and these stressors may well have a negative impact on population change in the absence of mycoplasmosis. By definition. any mycoplasmosis induced die-offs can only occur when the pathogen is present in the population, and introduction of the pathogen or a new strain could also lead to an epidemic in susceptibles.

   Predictions from this hypothesis include:
   a. Outbreaks do not occur in unstressed populations.
   b. Stressed tortoises are more susceptible to infection, and chronically infected individuals are more likely to be infectious.
   c. Die-offs will be less extreme when *Mycoplasma* is absent.

   Specific research questions arising from this hypothesis include:
   a. Are population declines through environmental stress less severe when *Mycoplasma* is absent?
   b. Do tortoises exposed to simulated drought conditions become more susceptible to infection and increase bacteria shedding?
   c. Do tortoises on a low plane of nutrition have increases in susceptibility and infectiousness?

2. A second hypothesis, which is not mutually exclusive to the first, is that there are multiple strains of *Mycoplasma*, and these vary in virulence and transmissibility such that when introduced into a naïve tortoise populations cause significant die-offs.

   Predictions from this hypothesis include:

a. Die-offs are associated with novel strains of *Mycoplasma* and not previously circulating strains.
b. Outbreaks occur more often in populations subject to tortoise introductions.
c. Outbreaks can occur during periods when the population is not subject to environmental stress.

Specific research questions arising from this hypothesis:

a. Does exposure to an avirulent strain provide protection against more virulent strains?
b. Are virulent strains more common in captive-held than wild tortoises?

Some tortoise management activities that influence disease spread

1. The release of infected tortoises either from captivity or the translocation of tortoises from one site to another can introduce *Mycoplasma* or new strains that may invade naïve populations and cause a significant die-off.
2. The removal of recovered individuals from a population can increase contact rate between infected and susceptible hosts so initiating an epidemic. In this respect, we have concerns that the Desert Tortoise Conservation Center in Clark County (NV) euthanizes all seropositive individuals that have been collected from the wild or submitted as captives.
3. Improvement of habitat, such as the control of invasive plants and the reduction in environmental stressors, will reduce the impact of disease-induced die-offs.

Recommendations for the control of *Mycoplasma* disease and to aid recovery of the desert tortoise

Recommendations relating to translocation:

1. Do not translocate animals during or after a period of drought or severe environmental stress. Translocation should consider both the state of the habitat the tortoises were taken from and the state of the habitat the tortoises are introduced into. For example, exceptional plant productivity may immediately follow a drought year and may provide suitable translocation conditions, although the same conditions following a catastrophic fire may only provide exotic forage species which would not be suitable for translocation. *This recommendation will reduce the chances of inadvertently initiating an epidemic when animals may be transmitting or are highly susceptible to infection.*
2. Undertake a full health evaluation (details in Appendix B-1) of all tortoises prior to translocation. This should include two ELISA tests for *Mycoplasma*, undertaken at 6-week intervals. Animals should be tested for important secondary infections. This will become important when a suitable test for herpesvirus becomes available. *The use of 2 ELISAs reduces the likelihood of false results. A full health evaluation will help to ensure translocated animals are healthy and supported by additional screening for pathogens.*
3. Seronegative (and culture-negative) animals with no other outward signs of compromised health can either be relocated or allocated to research or breeding programs as appropriate.

4. Further tests should be undertaken on all seropositive individuals. This is subject to protocols being developed by Dr. Ken Hunter, University of Nevada-Reno, which could help distinguish between individuals that are ELISA-positive and infected from individuals that are ELISA-positive and uninfected. Uninfected ELISA-positive animals can be used in research, breeding, and even release programs. Infected ELISA-positive animals can be used in breeding and research programs, but cannot be released to supplement wild populations. Under the advice of a veterinarian, some individuals with an acute infection should be euthanized, but detailed post-mortem information on the histopathology of disease should also be obtained. *This recommendation helps to prevent the selective euthanasia of animals with high levels of immunity that may well be the most resistant individuals in the wild and ensures that maximum information on the disease is obtained from every individual sacrificed.*
5. Existing protocols for handling tortoises need to be revised to incorporate new and better methods to reduce stress and hence susceptibility to infection. For example, protocols need to incorporate methods to reduce voiding of bladders. At the same time, protocols need to evaluate the research and management activities that could potentially increase the likelihood of exposure. This could include reducing the contact rates of individuals after handling.
6. The research program noted in these recommendations should include:
    a. A study on the sub-lethal effects of infection on fecundity and survival of tortoises (ELISA –ve, +ve infected, +ve uninfected). This will help to identify suitable females for breeding programs and provide data on the impact of infection of long term abundance. *This research will help identify which individuals should be included in the breeding program.*
    b. Seasonal monitoring of shedding rate of bacteria in infected individuals to identify which time of year, age, and sex cohort is responsible for transmission. *This research will help us identify which cohorts may be infectious and indicate possible intervention strategies in wild populations that could be instigated to stop temporal and spatial spread of disease and indeed novel* Mycoplasma *strains.*

Recommendations relating to head-starting:

We define head-starting as the rearing of uninfected juveniles in captivity before their release into a population of similar genetic structure for the express purposes of increasing the size of that breeding population and/or improving its age structure.

1. All captive-bred offspring must be kept separated from infected tortoises by impermeable barriers and care taken to ensure these individuals are not exposed. *This is to prevent infection of young tortoises before release.*
2. There is a high priority for breeding individuals from small, rapidly declining and genetically distinct populations. *While not all fecund and infected tortoises may enter the breeding program, this will ensure the genetic variation of wild populations is maintained that may prove important in the development of resistance against diverse* Mycoplasma *strains*.

3. Animals without a known origin should not be used in a breeding program, but could be used in research programs and be included in an adoption program. *This will prevent mixing of genotypes and the release of genetically susceptible individuals into areas which do not match local* Mycoplasma *strains.*

Recommendations relating to the Desert Tortoise Conservation Center:

1. Euthanizing seropositive individuals should stop immediately, unless the animals exhibit acute disease symptoms and is suffering and euthanasia is recommended by a veterinary surgeon. *This recommendation will prevent the removal of potentially highly resistant individuals from wild populations, improve the head-starting/breeding program, and provide individuals for research into the disease. We seek to maximize the information obtained from euthanized tortoises and to obtain insight into the biology of this disease.*
2. All animals handled at the Desert Tortoise Conservation Center require a health evaluation using full diagnostic tests as outlined in Appendix B-1. *Seropositive individuals deemed suitable for a breeding program will provide a substantial increase in the number available for head-starting. Moreover, this approach will help protect the genetic variation observed in wild tortoise populations.*
3. Establish an advisory research group to oversee and develop research priorities and protocols. *Our recommendations are broad, and a more focused research protocol which takes account of the logistic difficulties is required.*
4. The increased demands on feeding and caring for tortoises will require an increase in resources allocated to the Desert Tortoise Conservation Center. Increased veterinary and professional care and new pens and research facilities will also be necessary. *We seek further input from others with knowledge to help develop what is needed.*

Recommendations for managing natural populations:

1. Strategies for managing natural animal populations depend on the disease status of the population, deemed broadly as a) uninfected, b) recently infected with infection spread, or c) infection status endemic. An endemic population is defined here as one where the proportion that is seropositive is above zero and remains stable over time.
2. Release of tortoises in general: Do not release infected individuals into the wild. Improved educational strategies and assistance are needed, so the general public is aware that pet/captive tortoises should not be released. Assistance could include the use of a phone hotline, the free collection of pet tortoises no longer wanted, and an approved adoption program. Consideration should also be given to increased fines for release of captive animals. *This recommendation is aimed specifically at preventing the inadvertent or deliberate release of potentially infectious or highly susceptible individuals into a vulnerable population*.
3. All tortoises that can be identified in the wild as released individuals without a health check should be removed from the wild and enter a breeding, adoption, or research program unless they meet the criteria of not infected and genetically acceptable for that population. These tortoises can be identified by characteristic marks of captivity, such as the presence of a hole in the carapace, nail polish, or other distinguishing features. *This*

recommendation aims to remove infectious or highly susceptible individuals from the wild that may help fuel an epidemic outbreak.

4. We recommend no action be taken to remove infectious or seropositive individuals from natural populations, particularly where the data indicate the disease status of that population is endemic. *This recommendation seeks to prevent the removal of naturally resistant individuals or individuals that have acquired resistance of infection from wild populations. Resistant individuals within a population can help slow down or even prevent disease spread.*
5. In populations known to be uninfected, where statistical power indicates this is <2 percent, individual tortoises exhibiting clinical signs of acute infection can be removed for further testing, but should be returned to the point of capture if found to be uninfected by diagnostic tests. Uninfected populations that have recently become infected should be carefully monitored with the removal of all individuals exhibiting acute infections. We define acute infections here as those exhibiting a nasal or ocular discharge at an inappropriate time of year. *This recommendation seeks to prevent an epidemic that could cause significant mortality of highly susceptible tortoises.*

Priority research recommendations focused at reducing disease-induced die-offs:

1. Specific research questions arising from the working hypothesis described above (*i.e.*, mycoplasmosis-induced die-offs are initiated by environmental stressors) include:
   a. Are population declines through environmental stress less severe when *Mycoplasma* is absent?
   b. Do tortoises exposed to simulated drought conditions become more susceptible to infection and more infectious?
   c. Do diets high in alien plants increase susceptibility and infectiousness, or do tortoises feeding on diets high in native plants (*e.g.*, with high levels of protein or potassium excretion potential) have lower susceptibility and infectiousness?
2. Identify the virulent and less virulent strains circulating in wild and captive populations and monitor temporal and spatial change in prevalence in relation to host genetic status and environmental stressors. Identification of genes expressing toxin production and the circumstances when these genes are expressed could be a fruitful area of research. Studies examining the level of cross immunity between strains and variation in resistance in relation to the plane of nutrition and availability of water would be of great assistance. *This research aims to examine the presence and variation in* Mycoplasma *strains with the aim of containing virulent strains.*
3. Identify which individuals are shedding, how they shed, when they shed and, for how long they shed infectious *Mycoplasma* particles. Identify whether individuals removed from drought-stressed or severely deteriorated habitats continue to shed *Mycoplasma* and for how long. *This research will identify in more detail seasonal forces of infection, the period of infectiousness, and how it varies under different circumstances.*
4. Undertake trials to find if it is possible to cure individuals of *Mycoplasma* infections, even if only feasible in captive individuals. Preliminary veterinary trials with mixed antibiotics and anti-inflammatory steroids have met with some success and could be extended.

5. Examine the behavior of infectious tortoises in comparison to uninfected tortoises in the wild. Obtain estimates of contact rate according to sex, age, and season. *This research will help us understand the most critical epidemiological parameters associated with transmission and, with other data, allow us to produce a predictive model of outbreak.*

Appendix B-1. Health protocol for Desert Tortoises following Berry and Christopher (2001)

The standard protocol evaluates clinical signs of disease and trauma and should also include ELISA and polymerase chain reaction tests and cultures for *Mycoplasma agassizii* and *M. testudineum*.

During the health evaluation, the tortoise is evaluated for posture and behavior, whether appropriate for the situation or typical of poor health, as well as general appearance of the head, limbs, and shell (*e.g.*, signs of muscle wasting, dehydration, low weight). The chin glands, eyes, nares, and beak are examined for characteristic clinical signs of health, including drainage, edema, presence of mucus (dried or wet), discoloration, and crusts. The mouth should be opened and examined for lesions or plaques.

For most characteristics a standard veterinary ranking system should be used: none, mild, moderate, and severe. The shell , limbs, and head are rated for clinical signs of cutaneous dyskeratosis, necrosis, and trauma. For these variables, distribution, severity, and chronicity are important factors and are each rated separately.

This protocol has proved useful for research of health and disease. It can also be of use in evaluating both wild and captive tortoises for determining disposition for research, translocation, adoption, and necropsy programs. For example, captive tortoises or those in ex-urban settings exhibit higher rates of trauma and thus may not be suitable for immediate translocation or adoption, even if otherwise healthy. Captive and ex-urban tortoises also are more likely to be sero- and culture positive for one or more species of *Mycoplasma.* Tortoises with moderate to severe shell disease may be especially suitable for research and nutritional programs.

Insert Health Protocol

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Appendix C

DRAFT DECISION SUPPORT SYSTEM FOR DESERT TORTOISE RECOVERY: A TOOL FOR EVALUATING RECOVERY ACTION EFFECTIVENESS

August 29, 2007

INTRODUCTION

Purpose of this Appendix

This appendix describes the processing steps, data inputs, and outputs of a prototype decision support system developed for the Fish and Wildlife Service's Desert Tortoise Recovery Office (DTRO) to aid in the revision and implementation of the recovery plan for the desert tortoise. The decision support system is the product of a larger process to consult land managers with jurisdiction over desert tortoise habitat through a series of recovery planning workshops. This document describes what data were collected from land managers and how those data were used.

The DTRO decision support system identifies and prioritizes recovery actions that are most likely to ameliorate threats to tortoise populations at any geographic extent within the tortoises' range. To do this, the decision support system relies primarily on GIS data of the spatial extent of threats. These data were compiled partly through existing (published) sources and partly through manager consultation. The decision support system also makes use of managers' understanding of recovery action-threat relationships (*i.e.*, what are the most appropriate actions given a set of threats faced by the species?) and the relationship between threats and tortoise mortality (some threats are more deadly than others). Future versions of the decision support system may permit managers to conduct gap analysis on their current/planned recovery actions or to evaluate actions in terms of their near- vs. long-term contribution to recovery. The decision support system may also be used to develop prioritizations that account for economic, political, and operational constraints that managers face when implementing recovery.

Background on Decision Support Systems

Decision making as an area of study originates in organization science (Simon 1960). Decision support systems are computer technologies used to support complex decision-making in organizations (Keen and Morton 1978). These technologies involve an interactive system which uses decision rules, models, databases, and formal representations of the decision maker(s)' requests to indicate specific actions to solve problems. It thus assists complex decision processes and increases their efficiency (Ekbia 2004).

Initially, decision support system was used mostly by small groups of experts. However, this led to mistrust by other stakeholders because they had not been involved in the process. Inevitably, decision-making had been inhibited by the perceived 'black-box' nature of the process (Feick and Hall 2004; Ekbia and Reynolds 2006). Decision support systems must be able to take on a plethora of viewpoints from stakeholders with differing objectives, resources, and knowledge.

Decision support system systems have therefore evolved from a 'closed' expert-oriented to an 'open' user-oriented technology. This trend has stimulated movement towards using technology to increase the democratization and transparency of the decision-making process via public participation (Ekbia and Reynolds 2006; Malczewski 2006).

Decision Support System Road Map

The remainder of this appendix describes the processing steps, data inputs, and outputs of the decision support system. The following flow chart diagram (Fig. C-1) illustrates the overall modeling process. It can be used as a "road map" to the text description that follows. While the diagram may seem complex, each component essentially represents a separate model, with its own scientific or management utility. Each model is leveraged on the previous to produce the overall assessment of risk to desert tortoise populations and management priorities to mitigate that risk. It is important to note that this is a provisional system, and most of the incorporated models are based on preliminary subjective analysis and expert opinion. However, each model is transparent and can be evaluated and revised independently of the others as new information or better models become available. In addition, sensitivity analyses still need to be conducted to determine the relative importance of different assumptions (*e.g.*, relative impacts of threats to tortoise demography or relative effectiveness of recovery actions on abating threats) and to identify priorities for model improvement. In fact, one value of this prototype system is that the relative importance of the various components can be evaluated in light of the big picture (Nicholson *et al.* 2002). The prototype is presented here precisely because there is no better alternative available (Starfield 1997). The steps and component models can be summarized as follows:

- Spatial Threats Model: integrate threats data and associate with degrees of threat

- Tortoise mortality models
  - Threat-Mortality Interaction Model: estimate the contribution of each threat to mortality mechanisms
  - Relative Mortality Model: estimate the contribution of each mortality mechanism to overall mortality
  - Demographic Impact Model: estimate contributions of each threat to overall demographic impact (*e.g.*, mortality)

- Models of the risk to tortoise populations on the ground
  - Single Risk/Threat Model: combine degrees of threat with demographic impact ('deadliness;' its contribution to mortality) to estimate severity of each threat to the population
  - Pre-action Aggregate Risk Model: estimate the aggregate measure of the risk posed to the population by all threats

- Recovery action models
  - Recovery Action Effectiveness Model: estimate the effectiveness of recovery actions in mitigating threats

    - Recovery Action Risk Reduction Model: combine the estimated risk to populations with recovery action effectiveness to estimate the reduction in risk
    - Post-action Aggregate Risk Model: estimate the aggregate measure of the risk posed to the population by all threats *after* management actions are applied

- Spatial Summary/Prioritization: prioritize recovery actions by their estimated effectiveness in risk reduction

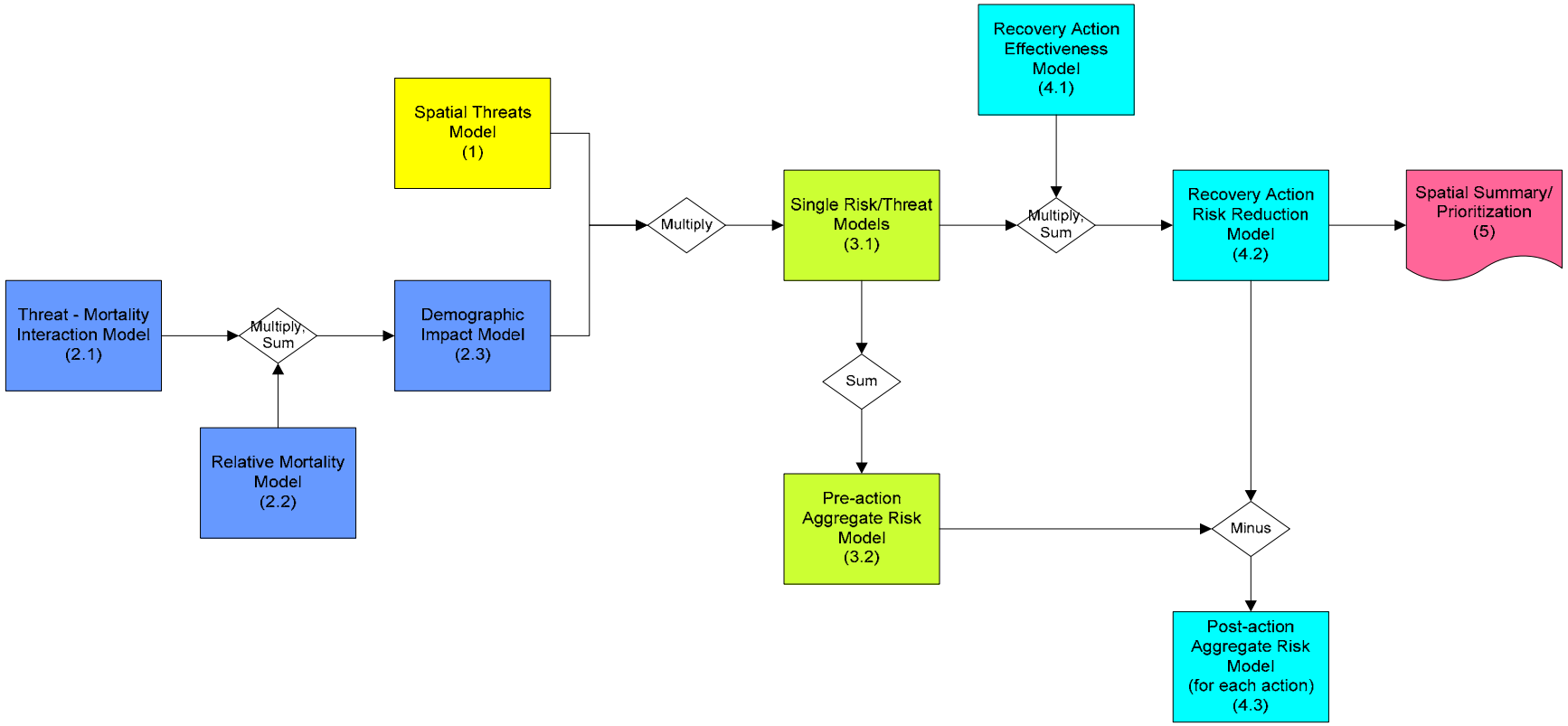


Figure C-1. Flowchart illustrating the decision support system for desert tortoise recovery. The numbers in the boxes refer to section numbers in the text.

Spatial Threats Model (1)

1. INTEGRATE THREATS DATA AND ASSOCIATE WITH DEGREES OF THREAT

The Spatial Threats Model involves two steps. The first step adds a 'degree of threat' rating to each geographic threat data layer. This rating is derived from a threats-mapping exercise, during which land managers were asked to answer a series of questions about threats they were familiar with (Table C-1). The second step integrates GIS threat layers from multiple sources into a single layer representing each threat. Sources of threat data included previously published datasets and maps that managers created during the threats-mapping exercise. Appendix C-1 contains a list of data sources included in the model.

Table C-1. Questions and possible responses on the threats questionnaire completed by managers during recovery planning workshops.

Threat Characteristic	**Question**	**Possible Responses**
Intensity	How would you describe the overall intensity of the threat at this location?	Low, Medium, High, Unknown
Trend	In general, how has the threat at this location changed over time?	Increasing, Decreasing, Stable, Unknown
Frequency	In general, how frequently does this threat occur at this location?	Rarely (almost never occurs) Occasionally (occurs from to time) Often (occurs frequently) Constantly (always present) Unknown

The decision support system combines the threats information contributed by the managers with data collected from published sources. Where the published data sources lacked information about degree of threat, a default, intermediate rating was assigned to these data layers. Figure C-2 illustrates how degree of threat was assigned to geographic features. The final step in assigning degree of threat was to normalize output values to a percentage scale (0-1). Outputs for subsequent steps in the model were also summarized in this manner. This technique allows for the comparison of threat severity both before and after an action is taken.

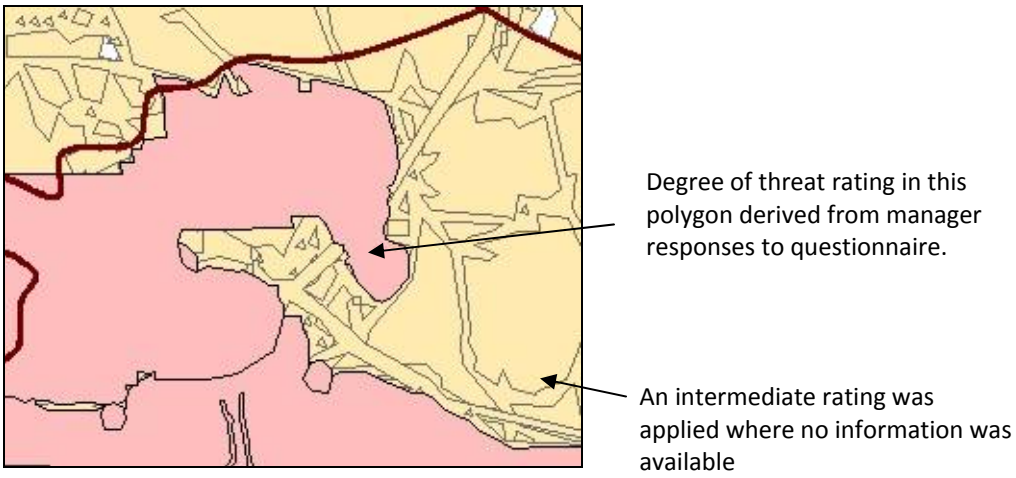
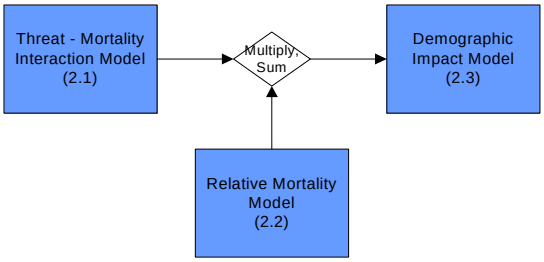


Figure C-2. Method for assigning degree of threat to threat polygons.

2. Estimate Contribution of Each Threat to Overall Demographic Impact



Estimating the ultimate relative impact of the various threats to tortoise populations involves rating the 'deadliness' of each threat with regard to tortoise demography. This is accomplished by combining two submodels: 1) the Threat-Mortality Interaction Model, which estimates the contribution of each threat to specific mortality mechanisms (relative to population-level effects; for example, a threat responsible for the mortality of 100 adult tortoises has greater demographic impact than another threat responsible for the mortality of 100 hatchlings because few of these hatchlings would naturally contribute to the adult population), and 2) the Relative Mortality Model, which estimates the contribution of each mortality mechanism to overall tortoise mortality.

2.1 Estimate the contribution of each threat to mortality mechanisms

The Threat-Mortality Interaction Model uses a threat interaction survey developed by the Science Advisory Committee and DTRO. This survey is intended to assist in analyzing how, and the extent to which, various potential threats interact with each other and how they contribute to tortoise mortality. Survey responses relate to range-wide (or recovery unit-wide) threat conditions and are not specific to more localized areas. Data from 35 respondents from the tortoise science and management community were available at the time of decision support system development. In the survey, respondents were asked to rate the effect of individual threats on individual mortality mechanisms (Fig. C-3).

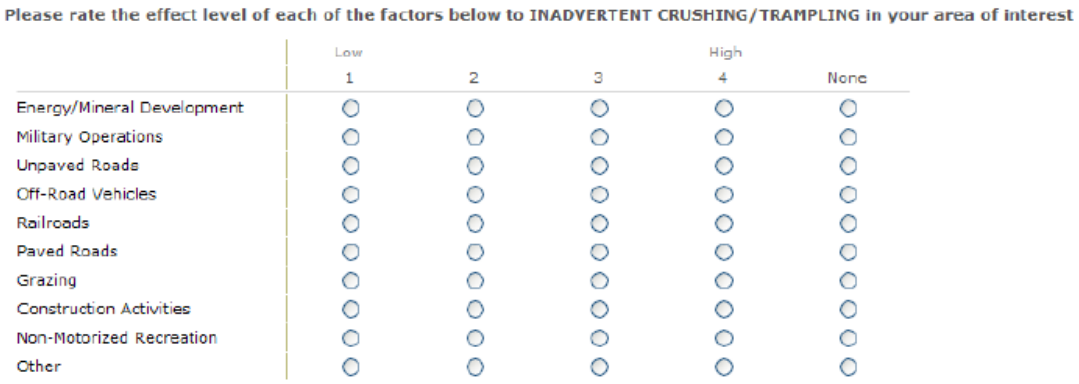


Figure C-3. The threats interaction survey asked respondents to rate the influence of threats on mortality mechanisms on a scale of 1 (low) – 4 (high). These ratings were used to derive a rating for each threat's contribution to all mortality mechanisms.

Following is a list of the mortality mechanisms respondents considered in the survey. This list includes factors most *directly* responsible for tortoise mortality and population declines (as opposed to indirect factors that contribute to one or more of these mortality mechanisms).

Catastrophic, permanent habitat loss
Burial
Inadvertent crushing/trampling
Burning
Dehydration
Nutritional compromise (starvation)
Disease
Drowning
Falling
Predation - ravens
Predation - free-roaming dogs
Predation - other
Collection
Vandalism (shooting, mutilation, crushing)

Using the survey responses, the decision support system team calculated an average contribution of each threat to all mortality mechanisms. When determining a threat's contribution to a mortality mechanism, both direct and indirect threat contributions were considered, as illustrated in Fig. C-4. Appendix C-2 further illustrates how direct and indirect threat contributions to mortality are estimated.

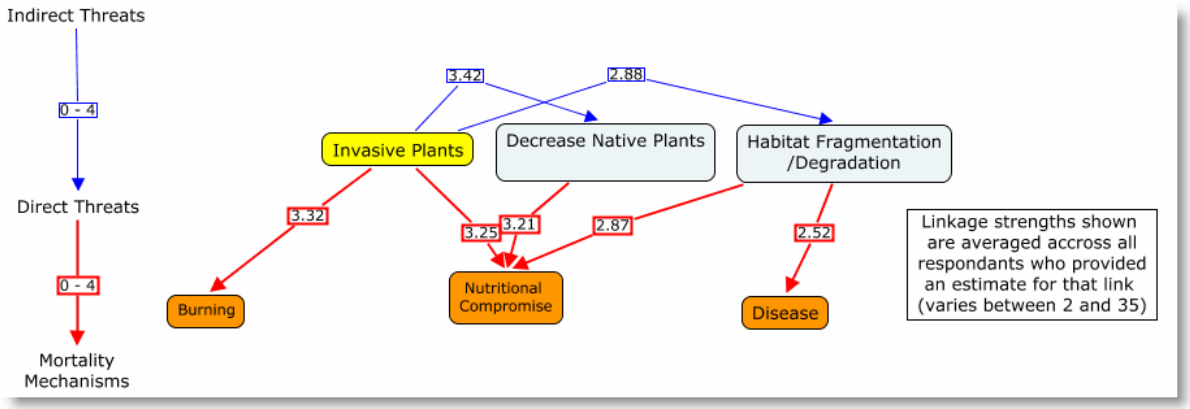


Figure C-4. Illustration of how direct and indirect threats contribute to mortality mechanisms from the perspective of the threat, Invasive Plants.

2.2 Estimate the contribution of mortality mechanisms to overall mortality

In the Relative Mortality Model, each mortality mechanism was assigned a weight that described its significance relative to its demographic impact. To illustrate this point, if in a given year 25 percent of a population of tortoises died, what were the direct causes of death, and how do these causes compare with one another in terms of total numbers? To generate this weight, DTRO staff independently rated each mortality mechanism in a pair-wise fashion. This yielded a relative weight for each mortality mechanism. Appendix C-3(a) includes the complete list of pair-wise ratings.

Pair-wise comparisons were completed for each mortality mechanism combination. These pair-wise ratings were analyzed using an Analytical Hierarchy Process (Saaty 1992), which resulted in an overall set of relative weights for each mortality mechanism (Appendix C-3[b]). Note that these same weights could be developed with a larger group of scientists or managers or replaced with quantitative data from future research to provide more reliable results.

2.3 Calculate the contribution of each threat to overall mortality

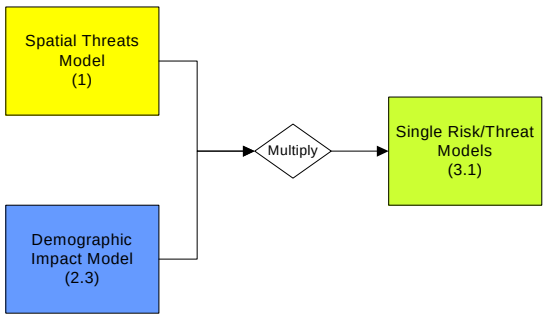
This step produces the Demographic Impact Model by combining the results from the previous steps to derive an overall weighted score for each threat. That score describes the contribution of a single threat to overall tortoise mortality. Table C-2 illustrates how each factor was combined. Appendix C-4 includes a complete table of these results.

Table C-2. Illustration of how overall threat contribution to mortality is calculated.

Single Threat	**Contribution to Mortality Mechanism**	**Mortality Mechanism (MM)**	**percent Contribution of MM to overall Mortality**	**Overall Contribution of Threat to Mortality**
Invasive Plants	20.61%	Burning	9%	20.61% x 9% = 1.86%
Invasive Plants	16.93%	Nutritional Compromise	4%	16.93% x 4%= 0.68%
Invasive Plants	1.72%	Disease	7%	1.72% x 7% = 0.02%
Total Estimated Contribution of *Invasive Plants* to Desert Tortoise Mortality				**2.56%**

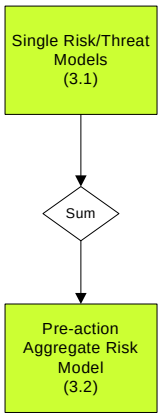
3. MODEL RISK TO POPULATIONS

3.1 Combine Degree of Threat with Mortality Factor to Estimate Threat Severity



This step creates the Single Risk/Threat Model by combining the measures of degree of threat described in Section 2 with the threat contribution to mortality in Section 3. This step yields a severity rating for each threat to desert tortoise populations within a geographic area of

interest (*e.g.*, recovery unit). The rating represents both degree of threat (intensity and frequency) and the mortality risk associated with that threat, as calculated in the previous step.



3.2 Estimate Aggregate Threat Severity

This step provides a synoptic view of threats across the tortoises' range. It is a GIS processing step that involves summing each threat layer using the severity ratings developed in the previous step (3.1). The output is an aggregate rating of threat (risk) posed to desert tortoise reported at the spatial unit of 1 square kilometer across the tortoises' range (Fig. C-5).

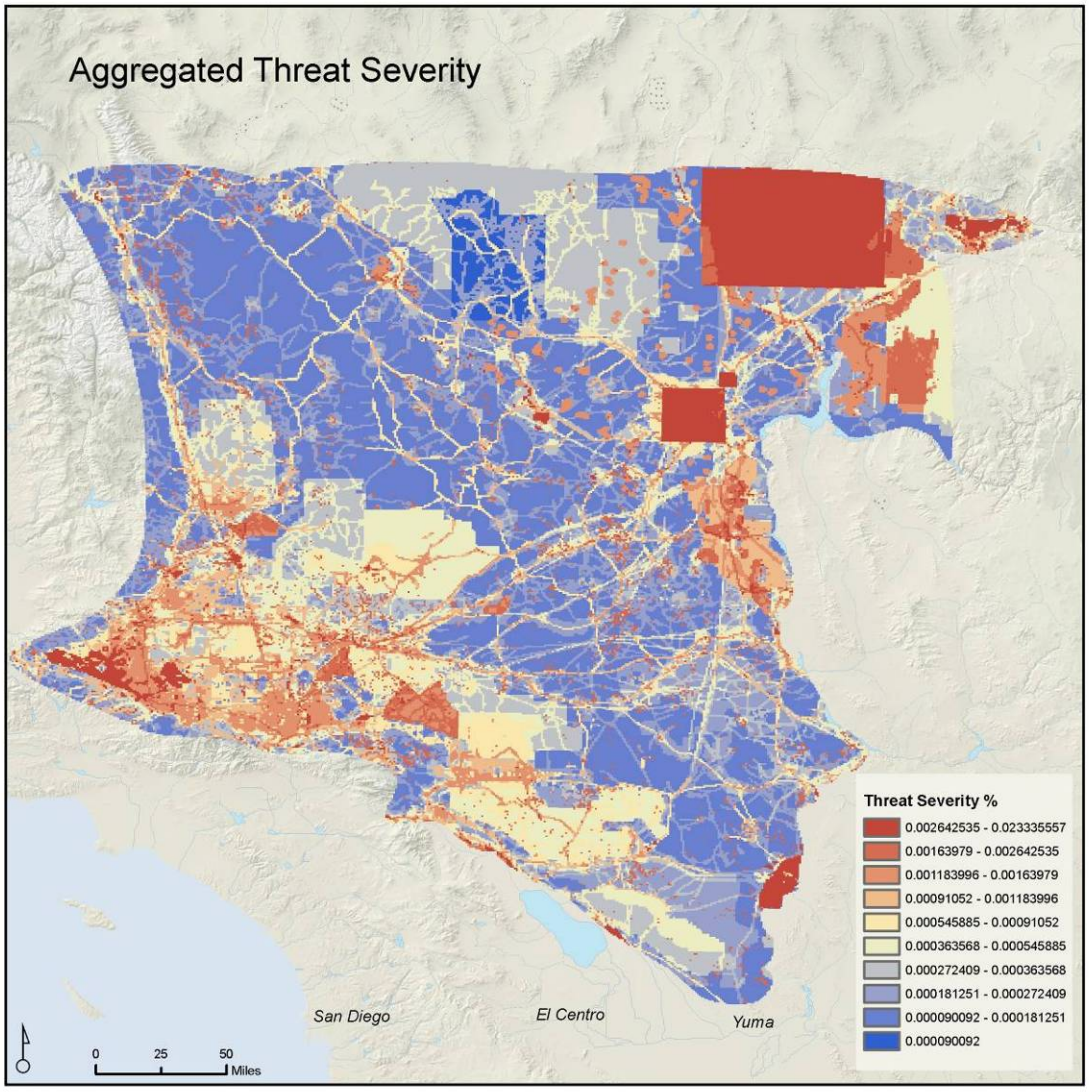
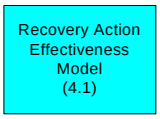


Figure C-5. Aggregated severity of threats across the range of the Mojave population of the desert tortoise estimated from the prototype decision support system. Warmer colors indicate greater severity of threats to the tortoise. *Note that this representation is preliminary and is based on incomplete data and provisional underlying models.*

4. Estimate Effects of Recovery Actions



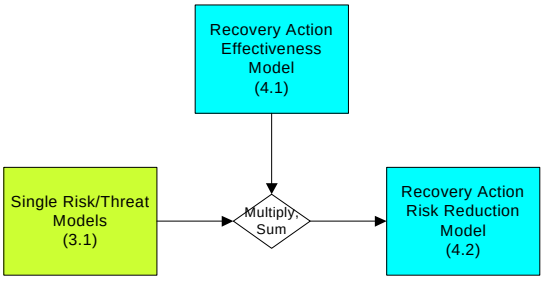
4.1 Effectiveness of Action on Threat

The Recovery Action Effectiveness Model is a table that relates recovery actions to the threats they address. It was developed with manager input during the recovery planning workshops. During each workshop, managers were asked to rate the relationship between recovery actions and threats on a scale of high, medium, and low, where high meant that the action was well suited to addressing a particular threat. A fourth option, "not applicable," indicated no relationship between an action and a threat. Responses from each manager on each threat-action combination were converted to a numeric range and averaged to derive an overall rating for each action on each threat. Figure C-6 illustrates the results of that exercise, and a complete table of these ratings is included in Appendix C-5.

RECOVERY ACTIONS/THREATS	AGRICULTURE	AIR POLLUTION	CAPTIVE RELEASES	COLLECTION	DESIGNATED OHV AREAS	DISEASE
Close Roads		1	3	1.5		1
Connect Functional Habitat						1
Control Ravens						
Designate Roads		1	3	1.5		1
Environmental Education	3	1	2.67	2.25	2.5	1.5
Fence Roads			1	3		1

Figure C-6. Land managers rated the strength of relationships between recovery actions and threats in terms of effectiveness using a HIGH (3) to LOW (1) scale. These ratings were used to calculate the relative expected effect of an action on a threat in the decision support system.

4.2 Threat Severity (Risk) Reduction as a Result of an Action



The Recovery Action Risk Reduction Model combines the threat severity (risk) before an action is implemented with a factor representing the effectiveness of that action on a given threat. The result of this calculation yields an estimated reduction of a threat as a result of an action. When the estimated reduction of each threat present in an area is summed, the result is a total estimated reduction caused by single action on all threats in that area. This calculation is performed for each potential action. Figure C-7 illustrates this calculation, and Appendix C-6 includes a table showing total threat (risk) reduction for each recovery unit.

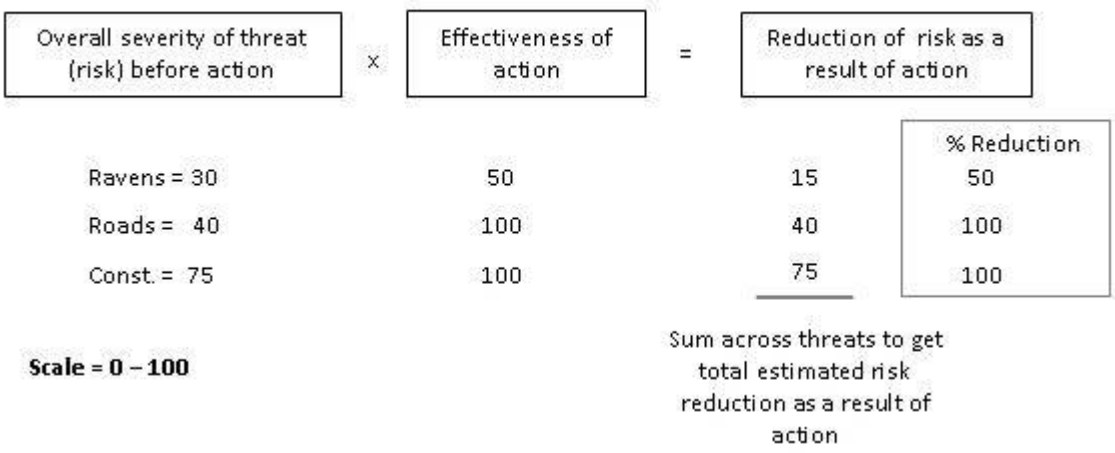
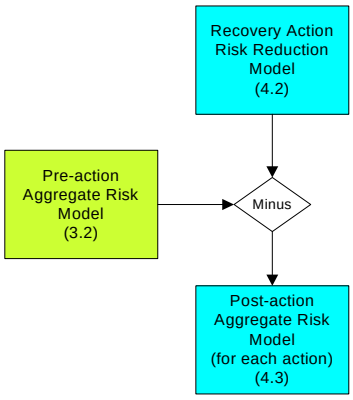


Figure C-7. Illustrative example of how the reduction in risk as a result of an action is calculated.

4.3 Estimate Aggregate Measure of the Risk Posed to the Population by All Threats *After* Recovery Actions are Implemented



This step provides a synoptic view of remaining threat risk across the tortoises' range after individual recovery actions are implemented. It is a GIS processing step that involves subtracting the estimated reduction of a threat as a result of an action (4.2) from the aggregate risk model produced in 3.2. The output is a visual representation of the aggregate rating of threat (risk) posed to desert tortoise reported at the spatial unit of 1 square kilometer across the tortoises' range (Fig. C-8).

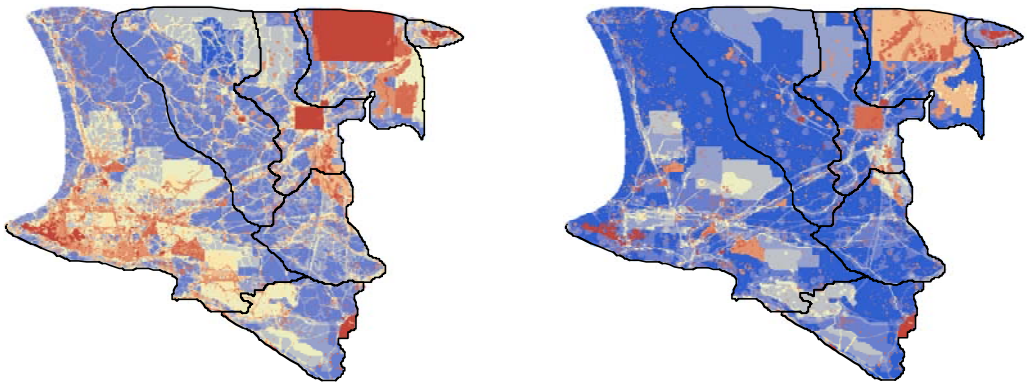
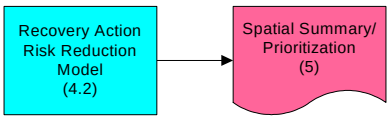


Figure C-8. Expected risk reduction as a result of the hypothetical action of closing roads across the range of the desert tortoise. The map on the left represents the aggregate threat severity (risk) from Fig. C-5, and the map on the right represents post-action threat severity (risk) as a result of the hypothetical action of closing all roads. Warmer colors indicate greater severity of threats to the tortoise. *Note that this representation is hypothetical, preliminary, and is based on incomplete data and provisional underlying models.*

4.4 Implementation Effort (Optional)

This component of the model may be used for 'if-then' scenarios where land managers want to envision the amount of threat reduction they might expect to see when an action is implemented only partially. For example, a land manager may use this feature to see how much he/she can reduce the threat of invasive species by removing 50 percent of invasive plants from an area rather than 100 percent of them. This type of calculation can be associated with implementation cost (*i.e.*, how much will a $15,000 investment in weed control reduce the threat of invasive species in a given area?) and other management-related factors. Since the primary goal of the decision support system is to recommend comprehensive actions for the recovery plan, this feature has not yet been implemented in the current model. By default, the model assumes that each action is implemented to its fullest possible extent.

5. PRIORITIZE RECOVERY ACTIONS



When the estimated risk reduction is calculated for all possible actions within a given area, these can then be prioritized according to total risk reduction, as illustrated in Table C-3. Complete recovery action rankings for each recovery unit are provided in Appendix C-7.

Table C-3. Highest and lowest ranked recovery actions by risk reduction in the Upper Virgin River Recovery Unit.

ACTION	UPPER VIRGIN RIVER	RANK
Law Enforcement	5.51	1
Fence Roads	4.75	2
Environmental Education	4.58	3
:	:	:
Manage Burros/Horses	0.01	16
Install Railroad Barriers	0.00	17
Remove Toxicants / Unexploded Ordnance	0.00	18

6. POTENTIAL ALTERNATIVE APPLICATIONS OF THE DECISION SUPPORT SYSTEM

There are several alternative uses of the decision support system that may be worthwhile at an operational level by land managers. Following is a partial description.

6.1 Conduct GAP Analysis of Existing Management Actions

The decision support system can be used to compare the effects of a variety of management actions on threats in any geographic unit. Specifically, the prioritized list and maps of recovery actions produced by the decision support system can be compared to existing management actions to identify gaps in management prescriptions for a given area.

6.2 Comparing Actions with Near- And Long-Term Implications for Recovery

In its current state, the decision support system prioritizes actions that would lead to decreases in tortoise mortality (population effects). In some cases, however, it may be advantageous to prioritize actions based on effect on habitat, since habitat response is generally considered to be observable in shorter time periods than tortoise population effects. In effect, this type of assessment would guide managers toward actions for which the effects can be observed earlier in the recovery process.

With some basic modifications, the decision support system could be used to prioritize actions based on their potential effectiveness at protecting or restoring tortoise habitat. This would be done by selecting only actions that directly impact habitat to be run in the model. These results may be compared to the mortality based assessment to identify how well actions rate according to both habitat and population effects (Fig. C-9).

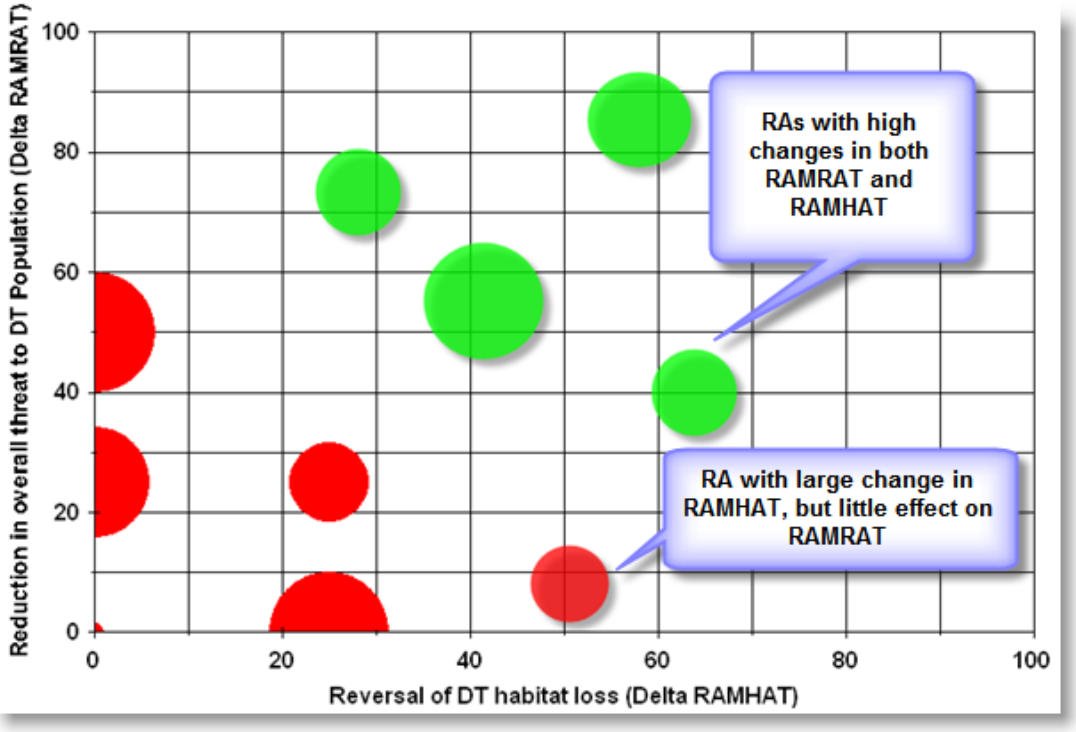


Figure C-9. Illustration of how recovery actions can be assessed in terms of mortality risk reduction (RAMRAT) and benefit to tortoise habitat (RAMHAT).

6.3 Land Manager Prioritization Model

The outputs of this model can be incorporated into a land manager decision support system to help them develop their own prioritizations. This would incorporate management constraints into the overall recovery action recommendations. Including implementation effort, which would affect the recommended actions, land managers could input their own actions, rate their effectiveness, weight their own mortality mechanisms and threat contributions, and run the model to get customized outputs of risk reduction.

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Appendices

C-1. Threat Layers Used in the DTRO Decision Support System

C-2. Threat-Mortality Interaction Model

C-3. Relative Mortality Model

C-4. Demographic Impact Model

C-5. Recovery Action Effectiveness Model

C-6. Post-action Risk Reduction Model

C-7. Prioritized Recovery Actions by Recovery Unit

Appendix C-1. Threat Layers Used in the DTRO Decision Support System

This table lists the threat data sources used in the prototype decision support system. Confidence Level indicates the relative confidence or precision of each data source. Published data sources typically have higher confidence levels than layers generated at workshops. 0 indicates data not available, but the threat is listed as a placeholder. Incorporation of additional, new, or revised data will improve the decision support system model output.

Threat Type	Data	Soure	Date	Confidence Level
Agriculture	Land Use and Land Cover for the Southwest US, Agriculture	USGS	1990	H
Air Pollution	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
Captive Releases	Captive Release Zone	Redlands Institute, Univ. Redlands	2007	L
Collection	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
Designated OHV Areas	Disturbance, points - Lake Mead NRA	NPS, Lake Mead NRA	2005	H
	Disturbance, lines - Lake Mead NRA	NPS, Lake Mead NRA	2005	H
	Disturbance, polygons - Lake Mead NRA	NPS, Lake Mead NRA	2005	H
	CA Open OHV Areas	BLM	2001	H
	AZ & NV OHV Areas	Redlands Institute, Univ. Redlands	2007	H
Disease	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	0
Energy/Mineral Development	MAS/MILS mineral location	USGS	1998	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	H
Fire	Recovery Units Fire Risk Area	Redlands Institute, Univ. Redlands	2007	L
Free-Roaming Dogs	Feral Dog Zone	Redlands Institute, Univ. Redlands	2007	H
Grazing	CA Grazing Allotments	BLM	2007	H
	NV Grazing Allotments March 2005	BLM, Nevada State Office	2005	L
	AZ Livestock Grazing Allotments	BLM, Arizona Strip District Office	2007	L
	CA Herd Management Area	BLM, Sacramento, CA	1999	L
	NV Herd Areas	BLM, Nevada State Office	unknown	L
	AZ BLM wild horse and burro herd areas	Arizona BLM Field Offices	2000	L
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	H
Invasive Plants	Weed Sentry 2004 infestation, *Brassica*,	Clark Co., NV	2004	H

	Bromus			
	Weed Sentry 2005 infestation, *Brassica*, *Bromus*	Clark Co., NV	2005	H
	Brassica tournefortii locations, Lake Mead NRA	NPS, Lake Mead NRA	2006	H
	Prob. Finding *Brassica*, 2005 LDS Survey	Jill Heaton, UNR	2005	M
	Prob. Finding *Bromus*, 2005 LDS Survey	Jill Heaton, UNR	2005	M
	Prob. Finding *Schismus*, 2005 LDS Survey	Jill Heaton, UNR	2005	M
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
Military Operations	SW US Military Bases	US Army Corps of Engineers, Engineer Research and Development Center	2005	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
Non-Motorized Recreation	Mohave Non-Motorized Recreation	Redlands Institute, Univ. Redlands	2007	M
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
Other Predators	CA, AZ, NV, UT Other Predators	Redlands Institute, Univ. Redlands	2007	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
Off-Road Vehicles	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
Paved Roads	Arizona Strip Transportation	BLM, Arizona Strip District Office	2007	H
	Roads - Mojave Desert	Mojave Desert Ecosystem Project	1998	H
	BLM Routes	BLM	2001	H
Railroads	Railroads of the Southwest US	USGS	1998	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	H
Ravens	Raven Nest Field Survey, 1990-1997	Bill Boarman	1997	H
	Raven Nest Field Survey, 2004	Redlands Institute, Univ. Redlands	2004	H
	Raven Nest Field Survey, 2005	Redlands Institute, Univ. Redlands	2005	H
	NV Raven Locations	Nevada Department of Wildlife	2003	H
	Clark Co. Raven Locations	USDA-ADC	2005	H
	Clark Co. Raven Survey	Clark County, NV	unknown	H
	Estimated Number of Ravens, 2005 LDS Survey	Jill Heaton, UNR	unknown	M

	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
Supplemental Water Sources	Water Development Sites, Guzzlers	Nevada Department of Wildlife	2005	L
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
Toxicants	US Toxic Release Inventory	EPA	2007	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
Unpaved Roads	Arizona Strip Transportation	BLM, Arizona Strip District Office	2007	H
	Roads - Mojave Desert	Mojave Desert Ecosystem Project	1998	H
	BLM Routes	BLM	2001	H
Urbanization	US Census Urbanized Areas	Department of Commerce, Census Bureau, Geography Division	2004	H
	20 Year Urban Growth, 2020	California Resources Agency	2000	H
	50 Year Urban Growth, 2050	California Resources Agency	2000	H
	Mojave Urban Growth 2020	Desert Research Insitute	2000	H
	Clark County BLM Disposal Lands - Rural	Comprehensive Planning, Clark County, NV	2007	H
	Clark County BLM Disposal Lands	Comprehensive Planning, Clark County, NV	2004	H
	Nevada Disposal Lands	BLM	2005	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
Utlity Corridors	Southern California Utility Lines	Environmental Systems Research Institute (ESRI)	1993	H
	SW Electrical - detailed lines	US Department of Energy	unknown	H
	SW Electrical - main lines	US Department of Energy	unknown	H
	US Natural Gas lines	US Department of Energy	unknown	H
	US Natural Gas lines	PennWell MAPSearch	unknown	H
	Energy Corridor - centerline	US Department of Energy	unknown	H
	Energy Corridor - 1500ft buffer	US Department of Energy	unknown	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	M
Vandalism		Redlands Institute, Univ. Redlands	2007	M

Waste Disposal	Landfills, West Mojave Planning Area	Redlands Institute, Univ. Redlands	2003	M
	AZ Landfills, Mohave Co., AZ	Mohave County, AZ, Public Works, Engineering Division	2005	H
	Waste Disposal - California Desert Managers Group Dump Database	CA Desert Managers Group	unknown	H
	CA Solid Waste Faciclities 2002	California Integrated Waste Management Board	2002	H
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007	L

Appendix C-2. Threat-Mortality Interaction Model

This model starts with the estimates from 35 respondents on the strength of linkage ("effect level") between different land uses/threats/activities to other threats and mortality mechanisms on a scale of 0 (no link) to 4 (Very High link). The respondents represented a wide variety of habitat units and expertise. Their responses were averaged over all estimates provided for a particular linkage – so sometimes the average was over 30 estimated values, sometimes only two.

From the threats interaction survey, we estimate for each threat:

- The direct (in red in Figure C2-A below) contributions to Mortality Mechanisms
- The indirect (in blue in Figure C2-A below) contributions to other threats

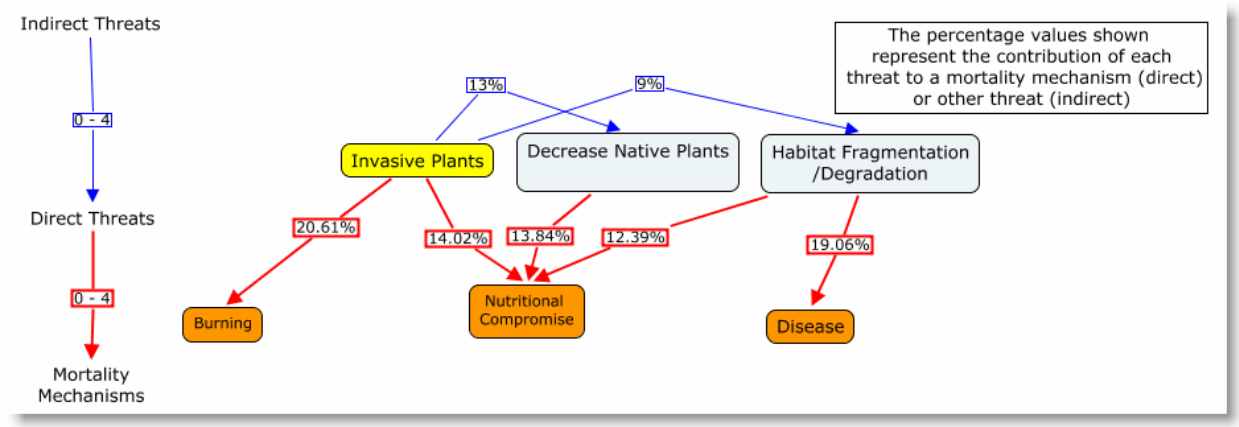
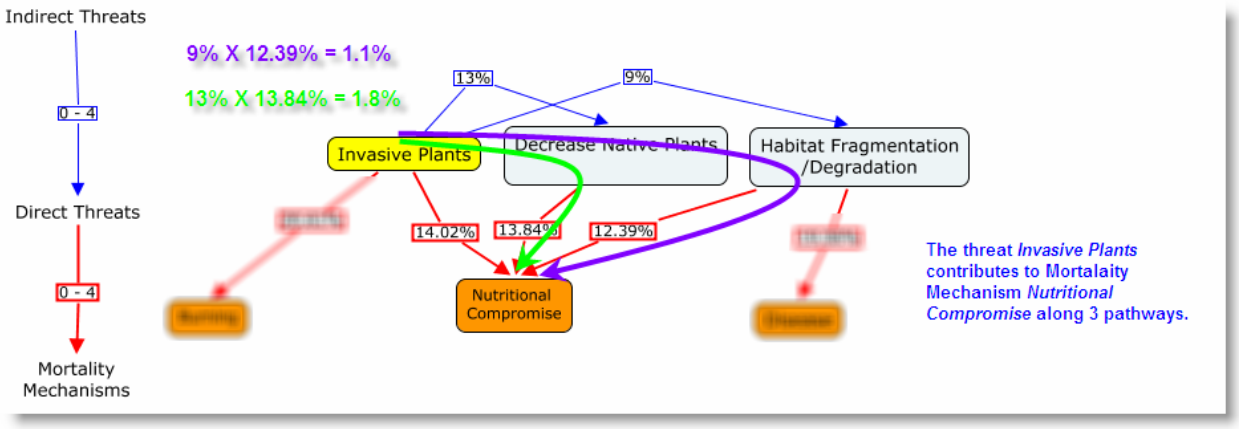


Figure C2-A: Direct and indirect contributions of the threat Invasive Species to mortality.

Handling Indirect Threats

When one threat contributes to another direct threat, to get the contribution of that indirect link to the actual mortality mechanism, we multiply the percentage contribution of the indirect link by the contribution of the direct threat link to the Mortality Mechanism. For example, in Fig. C2-A, the contribution of the indirect link of Invasive Plants to Decrease Native Plants on the mortality mechanism Nutritional Compromise is 13 percent * 13.84 percent = 1.8 percent. Repeat that calculation for all links, direct and indirect, and sum the resulting contributions, and we have an estimate for the overall contribution of each single threat to that mortality mechanism (Fig. C2-B).



C2-B. Direct and indirect contributions of the threat Invasive Species to mortality.

In Tabular form, the total contribution (direct and indirect) of the threat Invasive Plants to the mortality mechanism Nutritional Compromise, is calculated as follows:

Start threat	**Intermediate threat**	**Mortality Mechanism**	**Overall Link Contribution**
Invasive Plants	None - direct	Nutritional Compromise	14.02%
Invasive Plants	Decrease Native Plants	Nutritional Compromise	13% x 13.84% = 1.80%
Invasive Plants	Habitat Fragmentation/ Degradation	Nutritional Compromise	9% x 12.39% = 1.11%
Total (direct + indirect**) Contribution of *Invasive Plants* to Nutritional Compromise**			**16.93%**

APPENDIX C-3. RELATIVE MORTALITY MODEL

Table C3-A. Pairwise comparison of mortality mechanisms on a scale of 1 (low) to 9 (high). For example, habitat loss is estimated to contribute to desert tortoise mortality by a factor of 9 times that of drowning.

habitat loss	8	:	1	burial	**burial**	1	:	9	crushing
	6	:	1	crushing		1	:	6	burning
	6	:	1	burning		1	:	4	dehydration
	8	:	1	dehydration		1	:	3	starvation
	9	:	1	starvation		1	:	5	disease
	5	:	1	disease		1	:	1	drowning
	9	:	1	drowning		1	:	1	falling
	9	:	1	falling		1	:	2	predation - ravens
	8	:	1	predation - ravens		1	:	2	predation - dogs
	9	:	1	predation - dogs		1	:	3	predation - other
	8	:	1	predation - other		1	:	1	removals
	9	:	1	removals		2	:	1	shooting/vandalism
	9	:	1	shooting/vandalism					
crushing	4	:	1	burning	**burning**	1	:	1	dehydration
	4	:	1	dehydration		2	:	1	starvation
	6	:	1	starvation		1	:	1	disease
	2	:	1	disease		6	:	1	drowning
	9	:	1	drowning		6	:	1	falling
	8	:	1	falling		5	:	1	predation - ravens
	6	:	1	predation - ravens		3	:	1	predation - dogs
	3	:	1	predation - dogs		3	:	1	predation - other
	7	:	1	predation - other		4	:	1	removals
	7	:	1	removals		6	:	1	shooting/vandalism
	8	:	1	shooting/vandalism					
dehydration	2	:	1	starvation	**starvation**	1	:	2	disease
	2	:	1	disease		4	:	1	drowning
	5	:	1	drowning		2	:	1	falling
	5	:	1	falling		2	:	1	predation - ravens
	4	:	1	predation - ravens		2	:	1	predation - dogs
	3	:	1	predation - dogs		1	:	4	predation - other
	1	:	3	predation - other		2	:	1	removals
	3	:	1	removals		2	:	1	shooting/vandalism
	5	:	1	shooting/vandalism					
disease	6	:	1	drowning	**drowning**	1	:	1	falling
	5	:	1	falling		1	:	4	predation - ravens
	2	:	1	predation - ravens		1	:	3	predation - dogs
	2	:	1	predation - dogs		1	:	4	predation - other
	1	:	2	predation - other		1	:	2	removals
	3	:	1	removals		1	:	1	shooting/vandalism
	5	:	1	shooting/vandalism					

Table C3-A. Continued.

falling	1	:	3	predation - ravens	**predation - ravens**	2	:	1	predation - dogs
	1	:	2	predation - dogs		1	:	2	predation - other
	1	:	5	predation - other		2	:	1	removals
	1	:	1	removals		2	:	1	shooting/vandalism
	1	:	1	shooting/vandalism					
predation - dogs	1	:	4	predation - other	**predation - other**	6	:	1	removals
	1	:	1	removals		1	:	1	shooting/vandalism
	1	:	1	shooting/vandalism					
removals	6	:	1	shooting/vandalism					

Table C3-B. Estimated relative contribution of each mortality mechanisms to overall mortality, calculated from Table C3-A using the principal eigenvalue method from AHP (Saaty 1992).

Mortality Mechanism	**Percent Contribution**
Catastrophic Permanent Habitat Loss	32 %
Inadvertent crushing/trampling	17 %
Burning	9 %
Predation - Other	8 %
Dehydration	7 %
Disease	7 %
Nutritional Compromise	4 %
Collection	4 %
Predation - Ravens	3 %
Predation - free-roaming dogs	3 %
Vandalism	2 %
Burial	2 %
Falling	2 %
Drowning	1 %

Appendix C-4. Demographic Impact Model

This model estimates the contribution of each single threat to overall desert tortoise mortality by multiplying

the total contributions (direct and indirect) of each threat to individual mortality mechanisms from C-2,

BY

the relative contribution of each mortality mechanism to overall desert tortoise mortality (Table C3-B).

We calculate this product for each mortality mechanism to which the threat contributes (directly and/or indirectly) and sum over them to get the overall contribution of that single threat to desert tortoise mortality. In the following Table we do that for the sample threat, Invasive Plants:

Single threat	**Mortality Mechanism**	**Overall Contribution to Mortality**
Invasive Plants	Burning	9% x 20.61% = 1.86%
Invasive Plants	Nutritional Compromise	4% x 16.93% = 0.68%
Invasive Plants	Disease	7% x 19.06% X 9% = 0.02%
Total Estimated Contribution of *Invasive Plants* to Desert Tortoise Mortality		**2.56%**

The following table lists the estimated Contributions to Overall Mortality for each threat/action that was included in the threats interaction survey. The numbers in Table C4-A are fed directly into the GIS system to calculate threat severity maps.

Table C4-A. Contribution of threats to overall DT mortality. *Note that this table is based on incomplete data and provisional underlying models.*

Threat	Contribution to Overall Mortality
Urbanization	14.1 %
Paved Roads	14.1 %
Construction Activities	12.3 %
Energy/Mineral Development	8.0 %
Unpaved Roads	7.0 %
Recreation	7.0 %
Off-Road Vehicles	6.6 %
Transportation Networks	6.0 %
Drought	5.9 %
Military Operations	5.3 %
Physical Structures	5.3 %
Agriculture	4.7 %
Other	4.2 %
Supplemental Food Sources	4.0 %
Supplemental Water Sources	4.0 %
Utility Corridors/Networks	3.6 %
Fire	2.9 %
Invasive Plants	2.6 %
Non-Motorized Recreation	2.3 %
Grazing	2.2 %
Major Waste Disposal (Landfills, etc.)	2.2 %
Disease	2.2 %
Habitat Fragmentation/Degradation	1.7 %
Release Of Captives	1.4 %
Railroads	1.4 %
Nutritional Compromise	1.4 %
Chemical Contaminants	1.1 %
Ranching	1.1 %
Research	0.9 %
Decrease Native Plants	0.9 %
Land Exchanges/Transfers	0.6 %
Surface Dust	0.5 %
Air Pollution	0.5 %
Garbage/Trash	0.5 %
Mine Shafts/Pits	0.0 %

Appendix C-5. Recovery Action Effectiveness Model

This model estimates the effectiveness on a scale of 1 (low) to 3 (high) of individual recovery actions in mitigating specific threats to desert tortoise populations. The scores are averaged from manager rankings provided at recovery planning workshops.

RECOVERY ACTIONS/THREATS	AGRICULTURE	AIR POLLUTION	CAPTIVE RELEASES	COLLECTION	DESIGNATED OHV AREAS	DISEASE	DROUGHT	DROWNING	ENERGY/MINERAL DEVELOPMENT (Incl. mine shafts/pits)	FIRE	FREE-ROAMING DOGS	GRAZING	INVASIVE PLANTS	MILITARY OPERATIONS
Close Roads		1	3	1.5		1				2.5			1	
Connect Functional Habitat (incl. acquisitions + culverts)						1	1		2				1	
Control Ravens														
Designate Roads		1	3	1.5		1				2.5			1	
Environmental Education	3	1	2.67	2.25	2.5	1.5	1		1.67	2.75	2.75	2	2.25	1
Fence Roads			1	3		1	1						1	
Install Aqueduct Barrier								3						
Install Railroad Barriers														
Install Urban/Other Barriers				3		1	1				3		1.5	
Law Enforcement	1	1	3	3	3	2.67	1	1	1	2.00	2.33	2	1	
Manage Burros/Horses												1	1	
Manage Grazing	1											2	3	
Manage Landfills		3												
Remove Toxicants/Unexploded Ordnance														3
Restore Habitat	3				3	2	2		2	2.33			2.67	2
Restrict Competitive/Organized Events		2		1		1				2			1.5	
Secure Habitat	2			2	2				2			2		2
Sign/Fence Boundaries			3	2		1	1			2	2		1	
Withdraw Mining		2							3				2	

RECOVERY ACTIONS/THREATS	NON-MOTORIZED RECREATION	OTHER PREDATORS (non-raven/dogs)	PAVED ROADS	RAILROADS	RAVENS	SUPPLEMENTAL WATER SOURCES	TOXICANTS	UNAUTHORIZED OFF-ROAD VEHICLES USE	UNPAVED ROADS	URBANIZATION	UTLITY CORRIDORS	VANDALISM (*e.g.*, shooting, mutilation, crushing)	WASTE DISPOSAL (landfills/garbage dumps/waste water treatment)
Close Roads	1.5		3		2			2	3	3		2	
Connect Functional Habitat (incl. acquisitions + culverts)										1	2		
Control Ravens					3								
Designate Roads	1.5		3		2			2	3	3		2	
Environmental Education	2	3	2		2.5		3	2.5	3			2.67	3
Fence Roads			2						3			3	
Install Aqueduct Barrier													
Install Railroad Barriers				3									
Install Urban/Other Barriers	3							3		3		3	
Law Enforcement	2	1	1		1	1.5	1	2.00	1			3.00	
Manage Burros/Horses													
Manage Grazing												1	
Manage Landfills					3	3	3						3
Remove Toxicants/Unexploded Ordnance							3						
Restore Habitat	3	1						3	3		3	2	
Restrict Competitive/Organized Events	2						3	2	2			1.5	
Secure Habitat	2			3				2		2.33			2
Sign/Fence Boundaries	3						1	3				3	
Withdraw Mining							3		2			1	

Appendix C-6. Post-action Risk Reduction Model

This model estimates the relative reduction in overall risk to desert tortoise populations within each recovery unit from individual recovery actions. Values represent relative risk reduction calculations between recovery actions within recovery units (values are not comparable between recovery units). Recovery actions sorted in decreasing relative importance for each recovery unit are provided in Appendix C-7. *Note that recovery units are still under review. Reference to specific named recovery units herein is preliminary and*

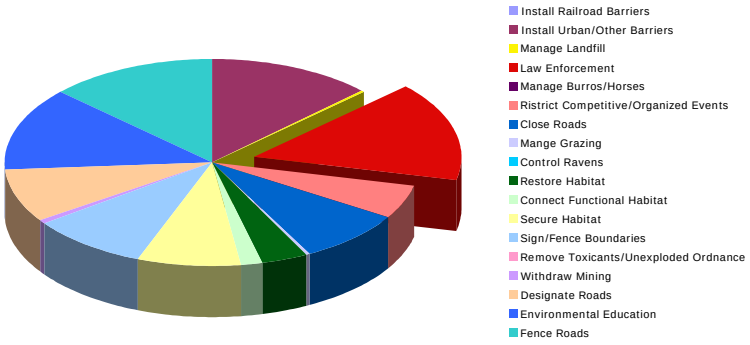
Action	Upper Virgin River	Lower Virgin River	Amargosa	Eastern Mojave/ Northern Colorado	Eastern Colorado	Western Mojave	North-eastern Mojave
Install Railroad Barriers	0.00	0.12	0.06	0.10	0.10	0.51	0.11
Install Urban/Other Barriers	4.56	13.63	0.77	1.36	0.63	4.41	2.45
Manage Landfill	0.20	5.63	0.62	0.70	0.64	1.58	1.63
Law Enforcement	5.54	13.35	4.22	2.72	2.38	15.36	5.67
Manage Burros/Horses	0.01	0.49	0.13	0.21	0.17	0.49	0.16
Restrict Competitive/Organized Events	1.92	8.20	2.55	1.77	1.62	6.88	2.65
Close Roads	3.05	14.22	5.13	3.22	2.19	19.81	4.91
Mange Grazing	0.06	2.01	0.37	0.59	0.97	2.23	0.40
Control Ravens	0.01	1.81	0.03	0.23	0.03	0.71	0.18
Restore Habitat	1.32	14.81	5.47	3.41	4.20	19.37	5.48
Connect Functional Habitat	0.51	4.25	0.89	0.96	0.78	4.07	1.73
Secure Habitat	2.97	8.89	2.29	1.47	1.99	10.29	2.15
Sign/Fence Boundaries	3.26	10.95	2.24	1.73	1.20	6.08	2.71
Remove Toxicants/Unexploded Ordnance	0.00	0.64	1.21	0.01	0.42	2.73	0.99
Withdraw Mining	0.21	2.84	1.97	1.56	1.56	7.37	1.40
Designate Roads	3.05	14.22	5.13	3.22	2.19	19.81	4.91
Environmental Education	4.62	16.44	7.09	4.19	4.67	27.05	6.20
Fence Roads	4.75	4.51	2.32	1.25	0.80	9.89	2.35

Appendix C-7. Prioritized Recovery Actions by Recovery Unit

The sections below sort the Post-action Risk Reduction Model (Appendix C-6) into prioritized lists of recovery actions for each recovery unit. The pie charts illustrate the relative reduction in overall risk to desert tortoise populations within each recovery unit for each recovery action.

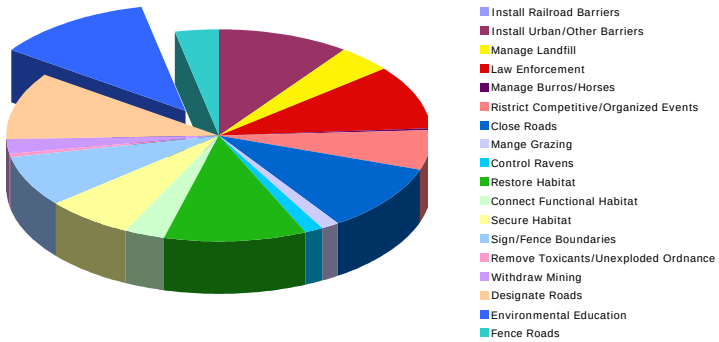
Upper Virgin River

Law Enforcement
Fence Roads
Environmental Education
Install Urban/Other Barriers
Sign/Fence Boundaries
Close Roads
Designate Roads
Secure Habitat
Restrict Competitive/Organized Events
Restore Habitat
Connect Functional Habitat
Manage Landfill
Withdraw Mining
Manage Grazing
Control Ravens
Manage Burros/Horses
Remove Toxicants/Unexploded Ordnance
Install Railroad Barriers



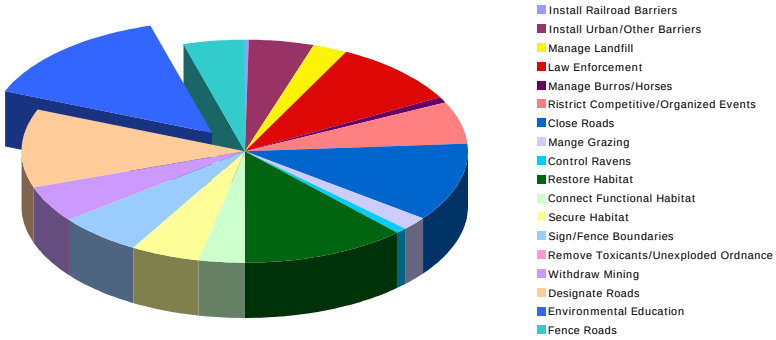
Lower Virgin River

Environmental Education
Restore Habitat
Close Roads
Designate Roads
Law Enforcement
Install Urban/Other Barriers
Sign/Fence Boundaries
Secure Habitat
Restrict Competitive/Organized Events
Manage Landfill
Connect Functional Habitat
Fence Roads
Withdraw Mining
Manage Grazing
Control Ravens
Remove Toxicants/Unexploded Ordnance
Manage Burros/Horses
Install Railroad Barriers



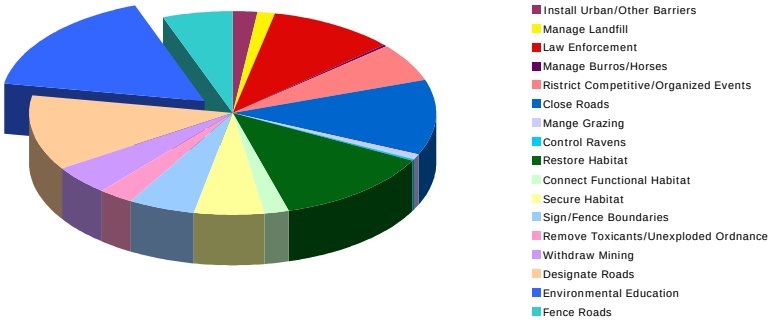
Northeastern Mojave

Environmental Education
Law Enforcement
Restore Habitat
Close Roads
Designate Roads
Sign/Fence Boundaries
Restrict Competitive/Organized Events
Install Urban/Other Barriers
Fence Roads
Secure Habitat
Connect Functional Habitat
Manage Landfill
Withdraw Mining
Remove Toxicants/Unexploded Ordnance
Manage Grazing
Control Ravens
Manage Burros/Horses
Install Railroad Barriers



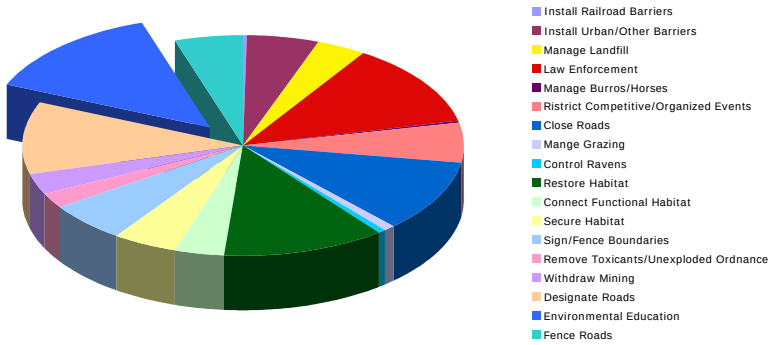
Amargosa

Environmental Education
Close Roads
Designate Roads
Restore Habitat
Law Enforcement
Restrict Competitive/Organized Events
Fence Roads
Sign/Fence Boundaries
Secure Habitat
Remove Toxicants/Unexploded Ordnance
Withdraw Mining
Install Urban/Other Barriers
Manage Landfill
Manage Grazing
Connect Functional Habitat
Manage Burros/Horses
Install Railroad Barriers
Control Ravens



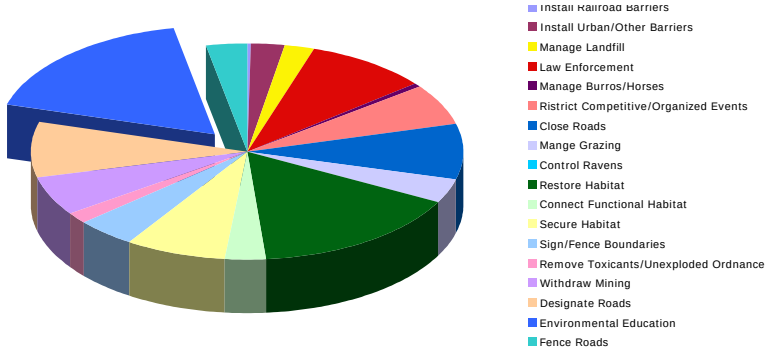
Eastern Mojave/Northern Colorado

Environmental Education
Restore Habitat
Close Roads
Designate Roads
Law Enforcement
Withdraw Mining
Secure Habitat
Restrict Competitive/Organized Events
Sign/Fence Boundaries
Connect Functional Habitat
Install Urban/Other Barriers
Fence Roads
Manage Landfill
Manage Grazing
Control Ravens
Manage Burros/Horses
Install Railroad Barriers
Remove Toxicants/Unexploded Ordnance



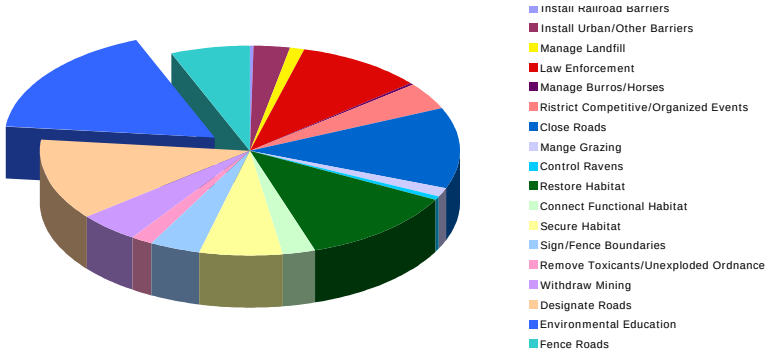
Eastern Colorado

Environmental Education
Restore Habitat
Law Enforcement
Secure Habitat
Withdraw Mining
Close Roads
Designate Roads
Restrict Competitive/Organized Events
Connect Functional Habitat
Sign/Fence Boundaries
Manage Grazing
Fence Roads
Manage Landfill
Install Urban/Other Barriers
Remove Toxicants/Unexploded Ordnance
Manage Burros/Horses
Install Railroad Barriers
Control Ravens



Western Mojave

Environmental Education
Close Roads
Designate Roads
Restore Habitat
Law Enforcement
Fence Roads
Secure Habitat
Restrict Competitive/Organized Events
Sign/Fence Boundaries
Withdraw Mining
Install Urban/Other Barriers
Connect Functional Habitat
Remove Toxicants/Unexploded Ordnance
Manage Grazing
Manage Landfill
Control Ravens
Install Railroad Barriers
Manage Burros/Horses



Appendix D

RECOMMENDED SPECIFICATIONS FOR DESERT TORTOISE EXCLUSION FENCING (SEPTEMBER 2005)

These specifications were developed to standardize fence materials and construction procedures to confine tortoises or exclude them from harmful situations, primarily roads and highways. Prior to commencing any field work, all field workers should comply with all stipulations and measures developed by the jurisdictional land manager and the U.S. Fish and Wildlife Service for conducting such activities in desert tortoise habitat, which will include, at a minimum, completing a desert tortoise education program.

Fence Construction

Materials

Fences should be constructed with durable materials (*i.e.,* 16 gauge or heavier) suitable to resist desert environments, alkaline and acidic soils, wind, and erosion. Fence material should consist of 1-inch horizontal by 2-inch vertical, galvanized welded wire, 36 inches in width. Other materials include: Hog rings, steel T-posts, and smooth or barbed livestock wire. Hog rings should be used to attach the fence material to existing strand fence. Steel T-posts (5 to 6-foot) are used for new fence construction. If fence is constructed within the range of bighorn sheep,

6-foot T-posts should be used (see New Fence Construction below). Standard smooth livestock wire fencing should be used for new fence construction, on which tortoise-proof fencing would be attached.

Retrofitting Existing Livestock Fence

Option 1 (see enclosed drawing). Fence material should be buried a minimum of 12 inches below the ground surface, leaving 22-24 inches above ground. A trench should be dug or a cut made with a blade on heavy equipment to allow 12 inches of fence to be buried below the natural level of the ground. The top end of the tortoise fence should be secured to the livestock wire with hog rings at 12 to 18-inch intervals. Distances between T-posts should not exceed 10 feet, unless the tortoise fence is being attached to an existing right-of-way fence that has larger interspaces between posts. The fence must be perpendicular to the ground surface, or slightly angled away from the road, towards the side encountered by tortoises. After the fence has been installed and secured to the top wire and T-posts, excavated soil will be replaced and compacted to minimize soil erosion.

Option 2 (see enclosed drawing). In situations where burying the fence is not practical because of rocky or undigable substrate, the fence material should be bent at a 90E angle to produce a lower section approximately 14 inches wide which will be placed parallel to, and in direct contact with, the ground surface; the remaining 22-inch wide upper section should be placed vertically against the existing fence, perpendicular to the ground and attached to the existing fence with hog rings at 12 to18-inch intervals. The lower section in contact with the ground should be placed within the enclosure in the direction of potential tortoise encounters and level

with the ground surface. Soil and cobble (approximately 2 to 4 inches in diameter; can use larger rocks where soil is shallow) should be placed on top of the lower section of fence material on the ground covering it with up to 4 inches of material, leaving a minimum of 18 inches of open space between the cobble surface and the top of the tortoise-proof fence. Care should be taken to ensure that the fence material parallel to the ground surface is adequately covered and is flush with the ground surface.

New Fence Construction

Options 1 or 2 should be followed except in areas that require special construction and engineering such as wash-out sections (see below). T-posts should be driven approximately

24 inches below the ground surface spaced approximately 10 feet apart. Livestock wire should be stretched between the T-posts, 18 to 24 inches above the ground to match the top edge of the fence material; desert tortoise-proof fencing should be attached to this wire with hog rings placed at 12 to 18-inch intervals. Smooth (barb-less) livestock wire should be used except where grazing occurs.

If fence is constructed within the range of bighorn sheep, two smooth-strand wires are required at the top of the T-post, approximately 4 inches apart, to make the wire(s) more visible to sheep. A 20 to 24-inch gap must exist between the top of the fence material and the lowest smooth-strand wire at the top of the T-post. The lower of the top two smooth-strand wires must be at least 43 inches above the ground surface.

(72-inch T-posts: 24 inches below ground + 18 inches of tortoise fence above ground + 20 to 24-inch gap to lower top wire + 4 inches to upper top wire = 66 to 70 inches).

Inspection of Desert Tortoise Barriers

The risk level for a desert tortoise encountering a breach in the fence is greatest in the spring and fall, particularly around the time of precipitation including the period during which precipitation occurs and at least several days afterward. All desert tortoise fences and cattleguards should be inspected on a regular basis sufficient to maintain an effective barrier to tortoise movement. Inspections should be documented in writing and include any observations of entrapped animals; repairs needed including bent T-posts, leaning or non-perpendicular fencing, cuts, breaks, and gaps; cattleguards without escape paths for tortoises or needed maintenance; tortoises and tortoise burrows including carcasses; and recommendations for supplies and equipment needed to complete repairs and maintenance.

All fence and cattleguard inventories should be inspected at least twice per year. However, during the first 2 to 3 years all inspections will be conducted quarterly at a minimum, to identify and document breaches, and problem areas such as wash-outs, vandalism, and cattleguards that fill-in with soil or gravel. GPS coordinates and mileages from existing highway markers should be recorded in order to pinpoint problem locations and build a database of problem locations that may require more frequent checking. Following 2 to 3 years of initial inspection, subsequent inspections should focus on known problem areas which will be inspected more frequently than twice per year. In addition to semi-annual inspections, problem areas prone to wash-outs should be inspected following precipitation that produces potentially fence-damaging water flow. A

database of problem areas will be established whereby checking fences in such areas can be done efficiently.

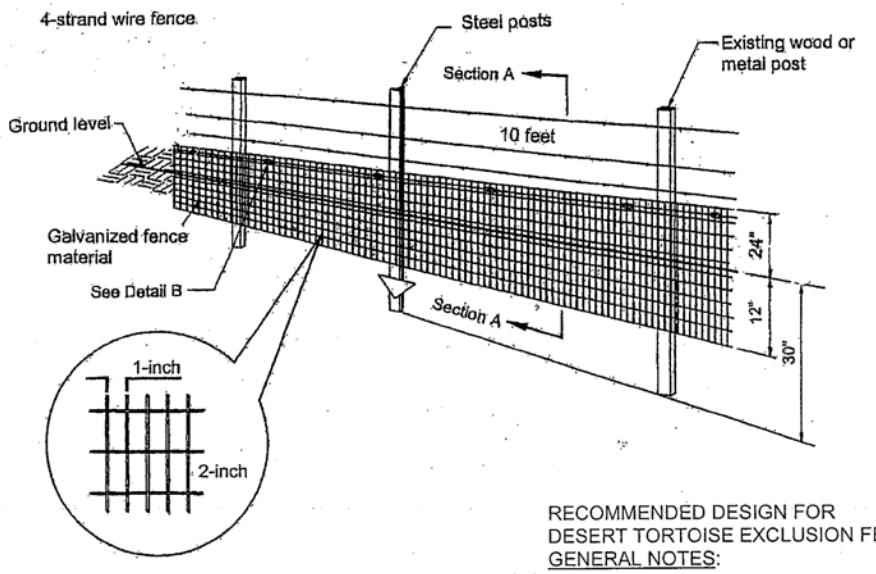
Repair and Maintenance of Desert Tortoise Barriers

Repairs of fence wash-outs: (1) realign the fence out of the wash if possible to avoid the problem area, or (2) re-construct tortoise-proof fencing using techniques that will ensure that an effective desert tortoise barrier is established that will not require frequent repairs and maintenance.

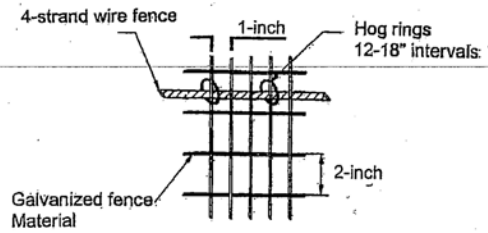
Gaps and breaks will require either: (a) repairs to the existing fence in place, with similar diameter and composition of original material, (b) replacement of the damaged section to the nearest T-post, with new fence material that original fence standards, (c) burying fence, and/or (d) restoring zero ground clearance by filling in gaps or holes under the fence and replacing cobble over fence constructed under Option 2. Tortoise-proof fencing should be constructed and maintained at cattleguards to ensure that a desert tortoise barrier exists at all times.

All fence damage should be repaired in a timely manner to ensure that tortoises do not travel through damaged sections. Similarly, cattleguards will be cleaned out of deposited material underneath them in a timely manner. In addition to periodic inspections, debris should be removed that accumulates along the fence. All cattleguards that serve as tortoise barriers should be installed and maintained to ensure that any tortoise that falls underneath has a path of escape without crossing the intended barrier.

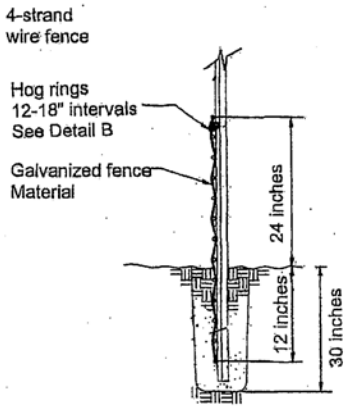
DESERT TORTOISE EXCLUSION FENCE (2005)



DETAIL A



DETAIL B



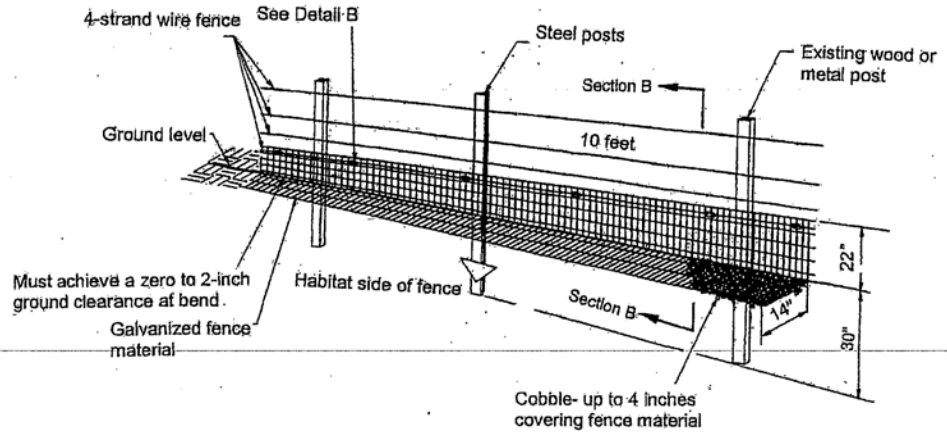
SECTION A

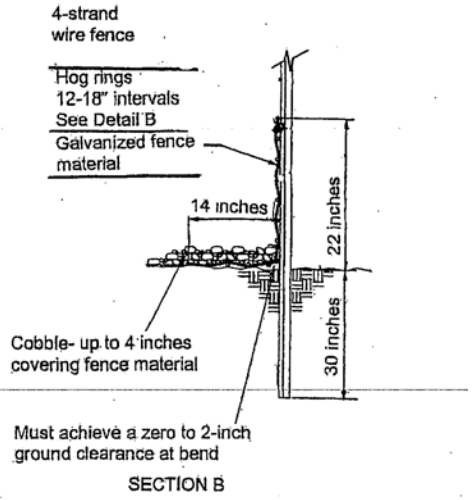
RECOMMENDED DESIGN FOR
DESERT TORTOISE EXCLUSION FENCE
GENERAL NOTES:

1. Ensure that fence posts and materials conform to the standards approved by the U.S. Fish and Wildlife Service.
2. Ensure that the height above ground level is no less than 18 inches and no higher than 24 inches.
3. Ensure that the depth of fence material below ground level is about 12 inches but no less than 6 inches. (See SECTION A above)
4. Install additional steel posts when span between existing fence posts exceed 10 feet.
5. Attach fence material to existing fence or wire using hog rings at 12-inch intervals.
6. Fasten fence material to posts with 3 tie wires with a wire near the top, bottom, and center of the fence material.
7. Backfill trenches with excavated material and compact the material.
8. Attach fence material to all gates. Ensure that clearance at base of gate achieves zero ground clearance.
9. Substitute smooth wire for barbed wire if additional support wires are necessary.
10. The number and placement of support wires may be modified to allow sheep and deer to pass safely.
11. Erosion at the edge of the fence material where the fence crosses washes may occur and requires appropriate and timely monitoring and repair.
12. Tie the fence into existing culverts and cattleguards when determined necessary to allow desert tortoise passage underneath roadways.

FOR BEDROCK OR CALICHE SUBSTRATE

1. Use this fence design (see below) only for that portion of the fence where fence material cannot be placed 6 inches below existing ground level due to presence of bedrock, large rocks or caliche substrate.
2. Ensure that the fence height above ground level is no less than 22 inches.
3. Ensure that there is a zero to 2-inch ground clearance at the bend.
4. Ensure that the bent portion of the fence is lying on the ground and pointed in the direction of desert tortoise habitat.
5. Cover the portion of the fence that is flush with the ground with cobble (rocks placed on top of the fence material to a vertical thickness up to 4 inches).
6. When substrate no longer is composed of bedrock or caliche, install fence using design shown above.





SECTION B