U.S. Fish & Wildlife Service

Draft Revised Recovery Plan for the Mojave Population of the Desert Tortoise

(Gopherus agassizii)

Draft Revised Recovery Plan

for the Mojave Population of the

Desert Tortoise (*Gopherus agassizii*)

Region 8, California and Nevada
U.S. Fish and Wildlife Service
Sacramento, California

Approved: ____

Region 8 Director
U.S. Fish and Wildlife Service

Date: ____

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:

U.S. Fish and Wildlife Service. 2008. Draft revised recovery plan for the Mojave population of the desert tortoise (*Gopherus agassizii*). U.S. Fish and Wildlife Service, California and Nevada Region, Sacramento, California. 209 pp.

Additional copies may be obtained from:

Field Supervisor
Nevada Fish and Wildlife Office
U.S. Fish and Wildlife Service
1340 Financial Boulevard, Suite 234
Reno, Nevada 89502

On-line: http://www.fws.gov/endangered/recovery/index.html#plans

PLAN PREPARATION

This Recovery Plan was prepared by the Desert Tortoise Recovery Office in coordination with the Desert Tortoise Science Advisory Committee and the Redlands Institute at the University of Redlands.

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

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

ACKNOWLEDGMENTS

The U.S. Institute for Environmental Conflict Resolution, the Center for Collaborative Policy, and two Desert Tortoise Management Oversight Group recovery planning workgroups provided extensive assistance and input into the development of the revised recovery plan.

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

Center for Collaborative Policy, California State University-Sacramento
Austin McInerny, Greg Bourne, Dale Schafer

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

The following individuals contributed materially to one or more Science Advisory Committee meetings: M. Brown, University of Florida; T. Esque, L. Gass, K. Nussear, and K. Phillips, U.S. Geological Survey; B. Hagerty, J. Heaton, K. Hunter, and F. Sandmeier, University of Nevada-Reno; and B. Murphy, Royal Ontario Museum.

In addition to previously named individuals, the following people participated in recovery planning workshops, provided comments, or otherwise contributed to the Recovery Plan:

Bureau of Indian Affairs: D. Wooten
Bureau of Land Management: S. Borchard, R. Clementsen, S. Florence, M. Herder, L. LaPre, E. Lorentzen, C. Ronning, A. Styles
California Department of Fish and Game: S. Harris, S. Juarez, B. Kinney, T. Moore, D. Racine
California Department of Transportation: A. Manee
California – Imperial, Kern, and San Bernardino counties: W. Leimgruber, D. Maben, J, McQuiston, B. Mitzelfelt, R. Scott
Department of Defense: A. Bedlion, S. Collis, M. Hagan, T. Mull (Tybrin Corp.), D. Reinke, C. Rognan, B. Turner, R. Wood
Kaibab Paiute Tribe: C. Bulletts, L. Skrzynski
National Park Service: N. Darby, D. Hughson, A. Staley, M. Vamstad
Nevada - Clark and Nye counties: L. Bice, M. Hamilton, P. Kiakopoulos, S. Kokos, M. Henson, T. Wheaton
Smithsonian Institution: R. Fleischer, E. Latch, and the genetics discussion group
Southern Nevada Water Authority: A. Bennett, C. Doyle
U.S. Fish and Wildlife Service: R. Bransfield, D. Elam, M. Fris, P. Henson, J. Hohman, J. Krueger, J. McBride, J. Rorabaugh, A. Salveter, S. Spangle, R. Williams
Utah - Washington County: A. Gardner
Private individuals and non-governmental organizations: I. Anderson, L. Belenky, M. Brower, M. Connor, C. Doyle, T. Egan, T. Frewin, B. Haley, B. Hughes, P. Kahn, J. McDonnell, M. McDonnell, J. McGarvie, J. Moore, C. Oathout, K. Ostler, J. Pantuso, E. Phillips, L. Rivera, D. Schaffy, M. Skuja, C. Sprofera, Y. Takagi, C. Vargas, C. Wilkerson

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. Critical habitat was also designated in 1994 in all four states supporting the species. Based on information in this recovery plan, the recovery priority number is classified as 6C and is predicated upon 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) listed population below the species level; and d) potential conflict with development or other forms of economic activity (USFWS 1983). We anticipate that implementation of this revised recovery plan will resolve key uncertainties about threats and management, thereby improving recovery potential.

HABITAT REQUIREMENTS AND LIMITING FACTORS

Desert tortoises occupy a variety of habitats from flats and slopes dominated by *Larrea tridentata* (creosote bush) scrub at lower elevations to rocky slopes in *Coleogyne ramosissima* (blackbrush) and *Juniperus* spp. (juniper) 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. Typical habitat for the desert tortoise in the Mojave Desert has been characterized as *Larrea tridentata* 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. The threats identified in the 1994 Recovery Plan, and that formed the basis for listing the tortoise as a threatened species, continue to affect the species. However, despite clear demonstration that these threats impact individual tortoises, there are few data available to evaluate or quantify the effects of threats on desert tortoise populations. While current research results can lead to predictions about how local tortoise abundance should be affected by the presence of threats, quantitative estimates of the magnitude of these threats, or of their relative importance, have not yet been developed. Thus, a particular threat or subset of threats with discernable solutions that could be targeted to the exclusion of other threats has not been identified for the desert tortoise. In this revised recovery plan, we underscore the need to build on our understanding of individual threats, yet place new emphasis on understanding their multiple and synergistic effects due to the failure of simple threat models to inform us about tortoise abundance.

The desert tortoise requires 13-20 years to reach sexual maturity, has low reproductive rates during a long period of reproductive potential, and individuals experience relatively high mortality early in life. These factors make recovery of the species difficult. Even moderate downward fluctuations in adult survival rates can result in rapid population declines. Thus, high survivorship of adult desert tortoises is critical to the species' persistence, and the slow growth rate of populations can leave them susceptible to extirpation events in areas where adult survivorship has been reduced. Another factor integral to desert tortoise recovery is maintaining the genetic and ecological variability within and among populations to allow tortoises to adapt to changes in the environment over time. Because desert tortoises occupy large home ranges, the long-term persistence of extensive, unfragmented habitats is essential for the survival of the species. The loss or degradation of these habitats to urbanization, habitat conversion from frequent wildfire, or other landscape-modifying activities place the desert tortoise at increased risk of extirpation.

RECOVERY STRATEGY

The 1994 Recovery Plan described a strategy for recovering the desert tortoise, which included the identification of six recovery units, recommendations for a system of Desert Wildlife Management Areas within the recovery units, and development and implementation of specific recovery actions. Maintaining high survivorship of adult desert tortoise was identified as the key factor in recovery. We recognize that the most significant challenge in the implementation of the 1994 Recovery Plan was not the number or types of actions implemented, but rather the coordination, description, documentation and evaluation of implementation of the actions. As a result, the revised strategy emphasizes partnerships to direct and maintain focus on implementing recovery actions and a system to track implementation and effectiveness of recovery actions. Strategic elements within a multi-faceted approach designed to improve the 1994 Recovery Plan are:

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

2. Protect 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.

6. Implement a formal adaptive management program.

The Desert Tortoise Management Oversight Group will be the partnership (Element 1) responsible for providing "executive-level" support and direction for recovery implementation, thus tying the entire program together. Regional Recovery Implementation Teams will include a member of the Desert Tortoise Recovery Office to provide guidance and coordination to land/wildlife managers and stakeholders on the teams, which will be responsible for developing step-down recovery-action plans and implementing those actions on the ground. The adaptive management program (Element 6) provides a formal framework with which the partnerships can make better, more informed, and more explicit decisions. Through the partnership and adaptive management elements, habitat management (Element 2) and population augmentation (Element 3) actions will be prioritized, implemented, and reported. Aggressive management needs to be applied within existing tortoise conservation areas, as defined herein, or other important areas identified by Recovery Implementation Teams. 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.

RECOVERY GOALS, OBJECTIVES, AND CRITERIA

The goals of the recovery plan are recovery and delisting of the desert tortoise. The recovery criteria represent our best assessment of the conditions that would most likely result in a determination that delisting of the desert tortoise is warranted. Recovery criteria should ideally include the management or elimination of threats, addressing the five statutory (de-)listing factors. However, even though a wide range of threats affect desert tortoises and their habitat, very little is known about their demographic impacts on tortoise populations or the relative contributions each threat makes to tortoise mortality. Therefore, specific and meaningful threats-based recovery criteria cannot be identified at this time. In the meantime, we assume that threat mitigation will have been successful if the current recovery criteria have been met (taking into consideration any head-starting or translocation efforts). 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. As quantitative information on threats and tortoise mortality is obtained, more specific threats-based recovery criteria may be defined during future recovery plan review and revision.

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 are increasing (*i.e.*, $\lambda > 1$) over 25 years (a single tortoise generation), as measured
>
> a) by extensive, range-wide monitoring across tortoise conservation areas within each recovery unit, and
>
> b) by direct monitoring and estimation of vital rates (recruitment, survival) from demographic study areas within each recovery unit.

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

Recovery Criterion 2. Distribution of desert tortoises throughout each tortoise conservation area is increasing over 25 years (*i.e.*, $\psi > 0$).

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 3. The quantity of desert tortoise habitat within all desert tortoise conservation areas is maintained with no net loss until tortoise population viability is ensured. When parameters relating habitat quality to tortoise populations are defined and a mechanism to track these parameters established, the condition of desert tortoise habitat should also be demonstrably improving.

RECOVERY ACTIONS

The recovery actions for each strategic element are as follows:

1. Develop, Support, and Build Partnerships to Facilitate Recovery
- **1.1.** Establish regional, inter-organizational Recovery Implementation Teams to prioritize and coordinate implementation of recovery actions.

2. Protect Existing Populations and Habitat
- **2.1.** Protect intact desert tortoise habitat.
- **2.2.** Reduce factors contributing to disease (particularly upper respiratory tract 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 off-highway vehicle events within desert tortoise habitat.
- **2.11.** Connect functional habitat.
- **2.12.** Limit mining and minimize its effects.
- **2.13.** Limit landfills and their effects.
- **2.14.** Reduce excessive predation on tortoises.
- **2.15.** Minimize impacts from horses and burros.
- **2.16.** Minimize livestock grazing.

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.
- **3.2.** Identify sites at which to implement population augmentation efforts.
- **3.3.** Secure facilities and 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.
- **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.** Characterize stable age distributions of stable or increasing 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, threat mitigation, and desert tortoise demographics.
- **5.5.** Conduct research on desert tortoise diseases and their effects on tortoise populations.
- **5.6.** Resolve population structure of the desert tortoise across its range.

6. Implement an Adaptive Management Program
- **6.1.** Revise and continue development of a recovery decision support system.
- **6.2.** Develop/revise recovery action plans.
- **6.3.** Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions.
- **6.4.** Incorporate scientific advice for recovery through the Science Advisory Committee.

TOTAL ESTIMATED COST OF RECOVERY

$159,000,000 plus additional costs that cannot be estimated at this time.

DATE OF RECOVERY

If recovery actions are implemented promptly and are effective, including continued implementation of the current monitoring program, recovery criteria could be met by approximately 2025.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

I. BACKGROUND

A. INTRODUCTION

1. Listing History

We, the United States Fish and Wildlife Service, listed the desert tortoise (*Gopherus agassizii*) 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, according to 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 updated information, the recovery priority number has been reclassified as 6C and is predicated upon 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) listed population below the species level; and d) potential conflict with development or other forms of economic activity (USFWS 1983). With regard to the “low potential for recovery” as defined in the Recovery Priority Criteria, we anticipate that implementation of this revised recovery plan will resolve key uncertainties about threats and management, thereby improving recovery potential.

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).

2. Management

The Desert Tortoise Management Oversight Group was established in 1988 to coordinate agency planning and management activities affecting the desert tortoise and to implement the management actions in the Bureau of Land Management’s Desert Tortoise Rangewide Plan. Charter members of the Management Oversight Group included the four Bureau of Land

Management State Directors from Arizona, California, Nevada, and Utah; the four State Fish and Game Directors from these States; the three Fish and Wildlife Service Regional Directors that share tortoise management responsibilities; and a Bureau of Land Management Washington Office representative. Membership was subsequently expanded to include representatives of the National Park Service, Biological Resources Division of the U.S. Geological Survey, and officials of the four branches of the military (Army, Air Force, Navy, and Marine Corps) that have Mojave tortoise habitat. County governments within the range of the desert tortoise were also included in 2007.

The original charter of the Management Oversight Group called for it to review a variety of topics, including a) standardize procedures for the analysis and interpretation of tortoise information, b) report on management actions completed for the benefit of the desert tortoise, c) recommend funding priorities, d) identify areas lacking sufficient information for habitat management, e) identify research needs to resolve management issues, f) identify threats and conflicts, g) complete annual status or progress reports, h) coordinate existing laws and guidance, and i) review ongoing research. Subsequent to the listing of the Mojave population as Threatened and following the publication of the recovery plan in 1994, the Management Oversight Group assumed a leadership role in coordinating agency activities directed toward recovery plan implementation.

The California Desert Managers Group was organized to provide a forum for government agencies to work together to conserve and enhance the California deserts. The Desert Managers Group is comprised of field-level managers from agencies and county governments with land and resource management or regulatory responsibilities in the California deserts. It also includes the U.S. Geological Survey, which serves in a scientific support role to the managers. The Group's 5-year plan includes several topics related to desert tortoise management.

Like the Desert Managers Group, the Southern Nevada Agency Partnership does not focus specifically on desert tortoise issues, but was formed as an interagency partnership to address various initiatives including litter clean-up, volunteerism, resource protection, recreation, science and research, outdoor recreation education, law enforcement, and other issues. This partnership is comprised of the Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Forest Service.

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 over 19,670 hectares (48,000 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, 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).

3. Recovery Plan Review and Revision

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. Unfortunately, the effectiveness of actions implemented by Federal agencies and others to benefit desert tortoises was not monitored adequately and remains largely unknown. Because much was unknown about the severity of specific threats to desert tortoises at the time the plan was written, the recommendations were made without establishing priorities that would reflect differences in the seriousness of the threats. The General Accounting Office report recommended that we develop and implement a coordinated research strategy for linking land management decisions with research results. Without such a strategy, recovery of the desert tortoise would be left to chance rather than informed decisions based on science. In response, 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) concluded that the 1994 Recovery Plan was fundamentally strong but could benefit substantially from modification. The assessment also 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) in 2004. The DTRO's staff focuses solely on the desert tortoise and its recovery. The DTRO coordinates recovery planning and implementation, research, monitoring, and recovery permitting, while working closely with those Service biologists focusing on regulatory issues. The DTRO assists in the coordination among land managers, research scientists, the interagency Desert Tortoise Management Oversight Group, the California Desert Managers Group, and other local, state, or regional working groups. To complement the DTRO, we assembled a Desert Tortoise Science Advisory Committee in 2005. This committee is composed of seven scientists from diverse yet highly relevant backgrounds (see Plan Preparation) who are charged with providing recommendations relative to desert tortoise recovery implementation and approach, such that rigorous scientific standards are met. The scope of the Science Advisory Committee's recommendations to date has included recovery criteria, threats assessment, effectiveness monitoring, and key research.

Based on recommendations in the recovery plan assessment, the Desert Tortoise Management Oversight Group recognized that the recovery plan should be revised with collaboration from scientists, managers, and stakeholders (Tracy *et al*. 2004), and an assessment of stakeholder input on recovery planning for the desert tortoise was conducted (U.S. Institute for Environmental Conflict Resolution and Center for Collaborative Policy 2006). To allow for broad participation, the Science Advisory Committee formed the base team for the scientific foundations, while government and non-government stakeholders were invited to participate and engage on management issues through various workshops, open houses, and review drafts of this plan. Thus, a collaborative effort resulted in this revised recovery plan for the Mojave population of the desert tortoise.

B. SPECIES DESCRIPTION AND TAXONOMY

The desert tortoise is a large, herbivorous (plant-eating) reptile that occurs in the Mojave and Sonoran deserts in southern California, southern Nevada, Arizona, and the southwestern tip of Utah in the U.S., as well as Sonora and northern Sinaloa in 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, including morphology, ecology, and genetics (Weinstein and Berry 1987; Lamb *et al.* 1989; Lamb and Lydehard 1994; Berry *et al.* 2002a; Van Devender 2002a,b; Murphy *et al*. 2007). 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 (upper shell) 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 (lower shell). Their shells are high-domed and greenish-tan to dark brown in color with tan scute (horny plate on the shell) 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 Mexican 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.

Although there are significant differences genetically and ecologically, desert tortoises that belong to the Sonoran population could be confused visually 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 eliminates 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).

C. 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 was the target of most early research on desert tortoises (see Tracy *et al.* 2004). Studies during 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 studied at various intervals from 1979 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). However, historic estimates of desert tortoise density or abundance do not exist at the range-wide or regional level for use as a baseline. While a substantial body of data has been collected from long-term study plots and other survey efforts over the years, plot placement is generally regarded as a factor limiting demographic and trend conclusions only to those specific areas. Tracy *et al.* (2004) concluded that estimating accurate long-term trends of desert tortoise populations, habitat, and/or threats across the range 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 and show appreciable declines at the local level in many areas (Luke *et al.* 1991; Berry 2003; Tracy *et al.* 2004). For example, 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 produce population estimates (*e.g.*, 2000 survey of the Beaver Dam Slope, Arizona), suggesting that declines may have occurred more broadly.

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 (1999 in the Upper

Virgin River Recovery Unit; McLuckie *et al*. 2002) and is the first comprehensive effort undertaken to date to estimate 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 from 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 monitoring 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). Until the underlying variability that may affect our interpretation of these first years of data can be identified, inferences as to the meaning of these data should not be made. Over the first 5 years of monitoring, tortoises were least abundant in the Northeast Mojave Recovery Unit (1 to 3 tortoises per kilometer^2 [2 to 8 tortoises per mile^2]; USFWS 2006a), and the highest reported densities occurred in the Upper Virgin River Recovery Unit (17 to 30 tortoises per kilometer^2 [44 to 78 tortoises per mile^2]; McLuckie *et al.* 2002, 2006).

Patterns of tortoise distribution 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, areas with concentrations of dead tortoises without corresponding concentrations of live tortoises were generally 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 observed in the Piute-Eldorado Valley and northern Coyote Springs Valley, Nevada, and the western and southern portions of the Ivanpah Valley, California, 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, do not suggest that implementation of specific management actions over time has abated declines of, or resulted in detectable increases in, desert tortoise populations across most of the range. The evidence of localized declines has not been offset elsewhere 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) is such 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

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]	1999	158	306.5	150	0.49	0.07	27	3.92	14.5	21	37
	2000	153	302.0	162	0.54	0.07	30	4.36	14.5	23	40
	2001	159	313.8	168	0.535	0.069	30.11	4.16	13.8	22.95	39.51
	2002	–	–	–	–	–	–	–	–	–	–
	2003	157	309.1	96	0.311	0.038	16.88	2.17	12.8	13.11	21.72
	2004	–	–	–	–	–	–	–	–	–	–
	2005	155	304.5	136	0.45	0.05	21.77	3.17	14.6	16.36	28.95

[1]Data from McLuckie *et al.* (2002, 2006).

habitats by non-native invasive species, probably have large negative effects on populations, and desert ecosystems require long periods of 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.

D. 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, even during their seasons of activity. In late winter or early spring, they emerge from over-wintering burrows and typically remain active through fall. Activity does decrease in summer, but tortoises often emerge after summer rain 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 use more than 3.9 square kilometers (1.5 square miles) of habitat and may make periodic 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 (set of eggs laid at a single time) 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 a population of desert tortoises 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. These characteristics of tortoises do vary with changes in habitat and environment, and further information on the range, biology, and ecology of the desert tortoise is available in Bury and Germano (1994), Ernst *et al.* (1994), Luckenbach (1982), Van Devender (2002c), and collected papers in Chelonian Conservation and Biology (2002, Vol. 4, No. 2).

E. 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 *Larrea tridentata* (creosote bush) scrub at lower elevations to rocky slopes in *Coleogyne ramosissima* (blackbrush) and *Juniperus* spp. (juniper) woodland ecotones (transition zone) at higher elevations (Germano *et al.* 1994). Records of desert tortoises range 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) (USFWS 2006a; USFWS unpublished data). In fact, surveys at the Nevada Test Site revealed that tortoise sign (*e.g.*, scat, burrows, tracks, shells) was more abundant on the upper alluvial fans and low mountain slopes than on the valley bottom (Rautenstrauch and O'Farrell 1998). Current rangewide monitoring strategies do account for the possibility of tortoises occurring in mountainous habitats.

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 (non-woody) plants (Germano *et al.* 1994; USFWS 1994a). Soils must be friable (easily crumbled) 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). Typical 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 *Bromus rubens* (red brome) and *Erodium* *cicutarium* (red-stem filaree). 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 winter temperatures 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 has developed a draft 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 (Figure 1) (Esque *et al.*, in prep.). 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 by providing a range-wide quantification of desert tortoise habitat that can help direct where management actions should be implemented, as well as providing a basis for documenting trends in habitat impacts or loss.

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, *Larrea tridentata* is a dominant species in areas occupied by tortoises, 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 bajadas (slope at the base of a mountain) and steep, 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).

F. CRITICAL HABITAT

Under section 3 of the Endangered Species Act, **critical habitat** is defined as the specific areas supporting those physical and biological features that are essential for the conservation of the species and that may require special management considerations or protection (Box 1). 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; Box 1). Based on the draft recovery plan, we designated critical habitat in February 1994, encompassing over 2,428,114 hectares (6,000,000 acres) in portions of the Mojave and Colorado deserts (Figure 1; Table 2). This designation includes primarily Federal lands in southwestern Utah, northwestern Arizona, southern Nevada, and southern California (USFWS 1994b).

Primary constituent elements for the desert tortoise are those physical and biological attributes that are necessary for the long-term survival of the species. These elements were identified as sufficient space to support viable populations within each of the six recovery units and to 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 (hard layer of subsoil typically containing calcium carbonate) 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).

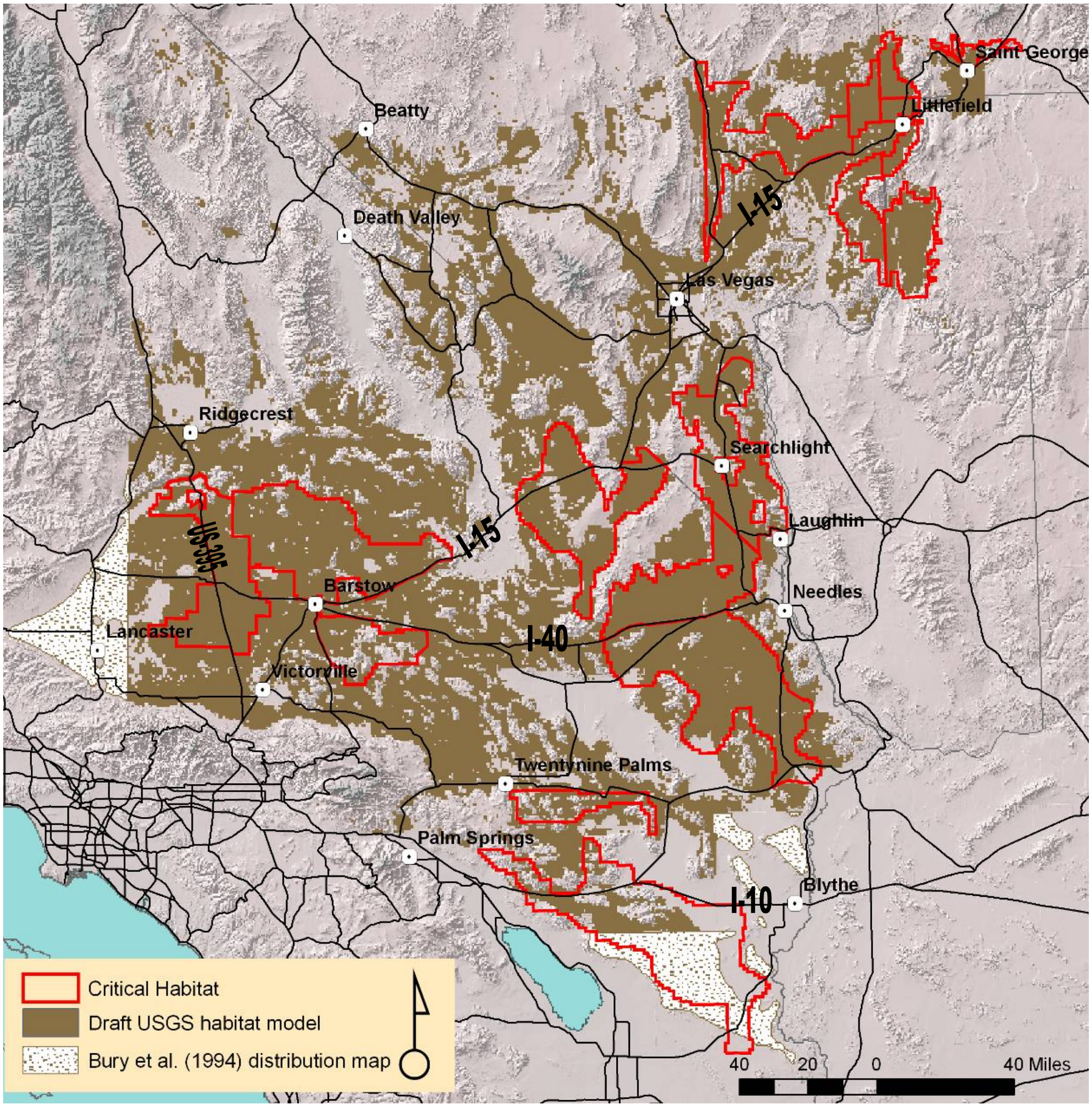


Figure 1. Desert tortoise critical habitat overlaid on the draft U.S. Geological Survey habitat model (Esque *et al.*, in prep.). Areas not included in the habitat model are shown as desert tortoise distribution from Bury *et al*. (1994).

Box 1. 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 are essential for the conservation of the desert tortoise, that support physical and biological features essential 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, Bureau of Land Management 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.

Table 2. Critical habitat by state and land management 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

G. 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.

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 threats identified in the 1994 Recovery Plan, and that formed the basis for listing the tortoise as a threatened species (GAO 2002), continue to affect the species. Extensive research shows that all of these individual threats directly kill or indirectly affect tortoises. Research has also clarified many mechanisms by which these threats act on tortoises. However, despite the clear demonstration that these threats impact individual tortoises, there are few data available to evaluate or quantify the effects of threats on desert tortoise populations (Boarman 2002). While current research results can lead to predictions about how local tortoise abundance should be affected by the presence of threats, quantitative estimates of the magnitude of these threats, or of their relative importance, have not yet been developed. Thus, a particular threat or subset of threats with discernable solutions that could be targeted to the exclusion of other threats has not been identified for the desert tortoise.

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. In this revised recovery plan, we underscore the need to build on our understanding of individual threats, yet place new emphasis on understanding their multiple and synergistic effects (interacting so that the combined effect is greater than the sum of individual effects) due to the failure of simple threat models to inform us about tortoise abundance. The following narrative 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.

1. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range (Factor A)

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 (Berry *et al.* 1996; Boarman and Sazaki 2006; Avery 1997; Jennings 1997; Boarman 2002). Indirect impacts to desert tortoise populations and habitat are also known to occur in areas that interface with 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 (USFWS 1994a; Brooks 1998). Changes in plant communities caused by non-native plants and recurrent fire can negatively affect the desert tortoise by altering habitat structure and species available as 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 (Brooks 1995; Avery 1998).

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 *et al.* 1995; Kristan and Boarman 2001). Military operations have taken place in the Mojave Desert since 1859 and can affect tortoises and their habitats similarly to other large human settlements (*i.e.*, illegal collection of tortoises, trash dumping, increased raven (*Corvus corax*) populations, domestic predators, off-highway vehicle use, increased exposure to disease, and increased mortality) (USFWS 1994a; Krzysik 1998; Boarman 2002).

2. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes (Factor B)

Despite legal protection under Federal and State laws, deliberate maiming or killing of tortoises (previously referred to as vandalism) and collection of desert tortoises by humans for food or as pets were cited as potential threats to the species (USFWS 1994a). Data and anecdotal observations indicate that collection for personal or commercial purposes was justifiably considered significant in the past (USFWS 1994a). While illegal collection of desert tortoises still occurs and such collection could possibly impact local populations, there is no quantitative estimate of the magnitude of this threat (Berry *et al.* 1996; Boarman 2002).

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

3. Disease or Predation (Factor C)

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; Berry *et al.* 2002b; Origgi *et al.* 2002), 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 contaminants in directly inducing toxicosis-related diseases (*i.e.* liver diseases) and increasing susceptibility to infectious diseases has recently been suggested as a significant source of mortality, but further investigation is required to confirm that hypothesis (Homer *et al.* 1994, 1996; Berry 1997; Boarman 2002). Illegal dumping of hazardous wastes in the California deserts 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).

Desert tortoises, particularly hatchlings and juveniles, are preyed upon by several native species of mammals, reptiles, and birds. The common raven has been the most highly visible predator of small tortoises, while coyotes have been commonly implicated in the deaths of adult tortoises. The population-level effects of these or any of the other predators are unknown. Except for extreme predation events brought on by unusual circumstances, predation by native predators alone would not be expected to cause dramatic population declines. This reiterates the importance of combined and synergistic effects of threats. For example, predation pressure by ravens is increased through elevated raven populations as a result of resource subsidies associated with human activities. 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 (*Buteo jamaicensis*), golden eagles (*Aquila chrysaetos*), loggerhead shrikes (*Lanius ludovicianus*), American kestrels (*Falco sparvarius*), burrowing owls (*Athene cunicularia*), and greater roadrunners (*Geococcyx californianus*) (Boarman 1993). Coyotes (*Canis latrans*), kit foxes (*Vulpes macrotis*), mountain lions (*Felis concolor*), ground squirrels (*Spermophilus* spp.), and free-roaming dogs are some of the known mammalian predators (Bjurlin and Bissonette 2001; Boarman 2002; M. McDermott, Southern Nevada Environmental, Inc., pers. comm. 2006, K. Nagy, University of California-Los Angeles, pers. comm. 2006). Invertebrate predators of eggs and hatchling tortoises include native fire ants (Nagy *et al.* 2007).

4. Inadequacy of Existing Regulatory Mechanisms (Factor D)

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 multiple-use mandates under which the agencies function require a complex balance between conservation and use of public lands, and management agencies frequently do not have sufficient funding to enforce their regulations. Also, state wildlife/endangered species permitting requirements do not specifically address impacts to habitat, making mitigation of impacts to potentially unoccupied but suitable habitat difficult.

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 into the private sector is at greater risk of urban development (Sievers *et al.* 1988; but see Conservation Efforts, Land Acquisitions and Habitat Conservation Plans, below). Energy and mineral development and extraction also pose a significant threat to desert tortoises through habitat loss and fragmentation (Luke *et al.* 1991; Lovich and Bainbridge 1999; LaRue and Dougherty 1999). 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, habitat lost through energy development is also a potential threat, where various energy development projects have been proposed and applications have been submitted for solar power facility right-of-ways on over 53,800 hectares (133,000 acres) of potential desert tortoise habitat.

5. Other Natural or Manmade Factors Affecting its Continued Existence (Factor E)

Global climate change and drought are potentially important long-term considerations with respect to recovery of the desert tortoise. 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 specific 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).

The Intergovernmental Panel on Climate Change has suggested that increasingly reliable regional climate change projections are now available as the result of improved modeling capabilities and advanced understanding of climate systems (Christensen *et al*. 2007). Twenty-one Atmosphere-Ocean General Circulation Models were run to predict regional temperature and precipitation in 2080 through 2099 as changed from conditions that occurred between 1980 and 1999. Generally, predictions for the geographic range of the desert tortoise's listed population suggest a 3.5 to 4.0º C (6.3 to 7.2º F) increase in annual mean temperature, with the greatest increases occurring in summer (June-July-August mean up to 5º C (9º F) increase) (Christensen *et al*. 2007). Precipitation will likely decrease by 5 to 15 percent annually in the region, with winter precipitation decreasing in the range of 5 to 20 percent (Christensen *et al*. 2007). Because germination of the tortoise's food plants is highly dependent on cool season rains, the forage base could be reduced due to increasing temperatures and decreasing precipitation in winter. Further predictions need to be developed specifically for the desert tortoise to help inform recovery efforts.

Other activities 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 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 deliberate maiming or killing of tortoises, increased raven predation, degradation of vegetation, and soil compaction (USFWS 1994a; Averill-Murray 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 (LaRue and Dougherty 1999; Olson 1996).

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 is 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.

H. CONSERVATION EFFORTS

While precise correlations between the multitude of threats and desert tortoise populations have not been clearly shown, 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 be used to 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.

1. 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 needed to complete a Service approved wildlife action plan (or comprehensive wildlife conservation strategy). 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 controlling 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.

2. 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. In addition to Federal land use plans, counties and local jurisdictions draft general plans to guide their activities.

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] 2007a)
- 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 2006)
- 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, Fiscal Years 2007-2011 (U.S. Marine Corps 2006)
- 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; Box 1) through Federal land use planning processes (Figure 2). Particularly on Bureau of Land Management lands, DWMAs are administered and designated as **Areas of Critical Environmental Concern** (ACEC; Box 1; BLM 1998a, 1999b, 2000, 2002a, 2002b, BLM *et al.* 2005, BLM and NPS 2007). These ACECs define specific management areas based on the general recommendations for DWMAs in the 1994 Recovery Plan. Boundaries of the ACECs were refined slightly from the critical habitat designation based on various management and biological considerations. The Bureau of Land Management DWMAs/ACECs, together with National Park Service lands, designated wilderness areas, other lands allocated for resource conservation, as well as restricted-access military lands provide an extensive network of habitats that are managed either directly or indirectly (*e.g.*, wilderness areas outside desert tortoise ACECs) for desert tortoise conservation (Figures 2 and 3).

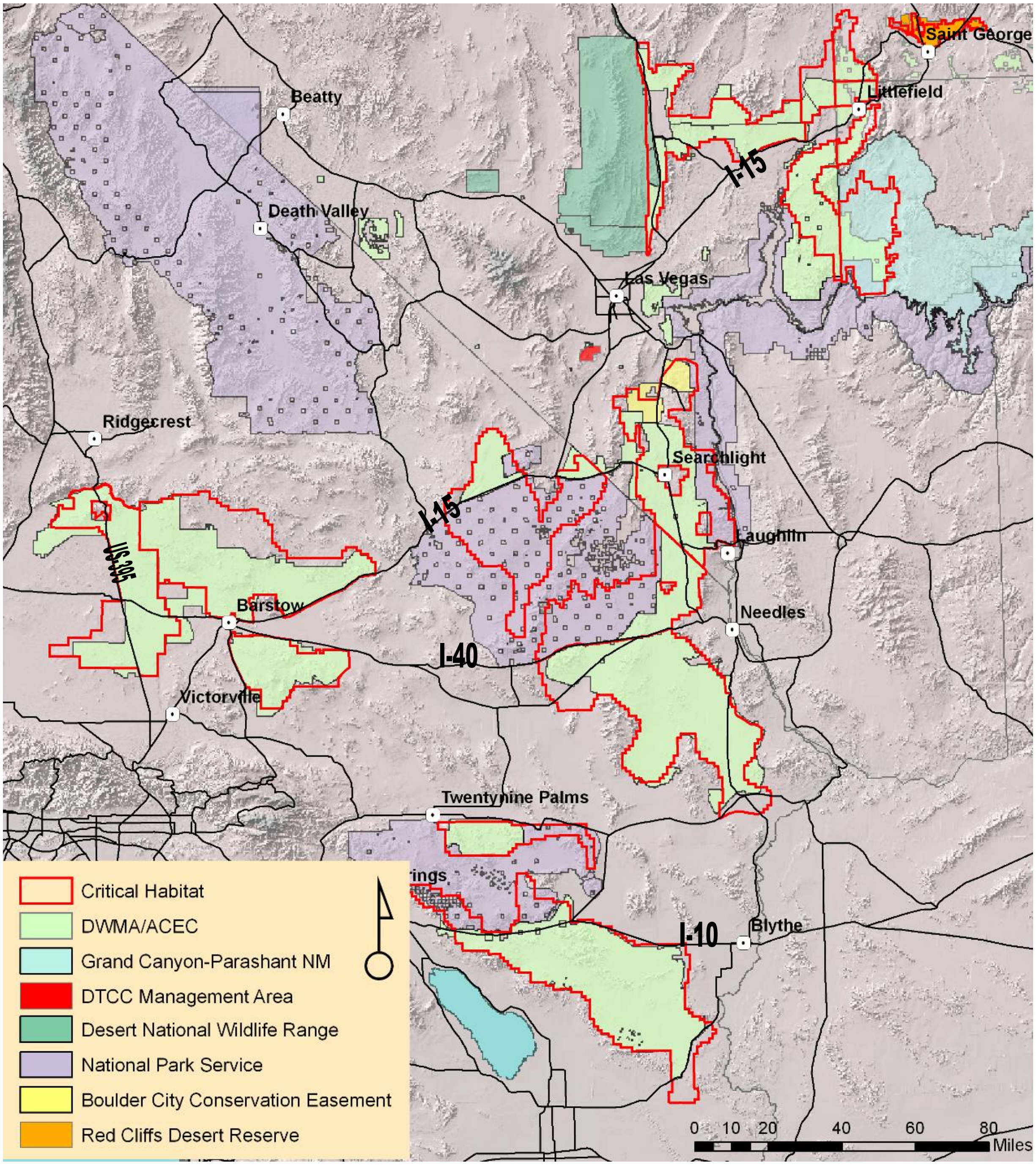


Figure 2. Desert tortoise conservation areas (see Box 2). DWMA = Desert Wildlife Management Area; ACEC = Areas of Critical Environmental Concern; DTCC = Desert Tortoise Conservation Center.

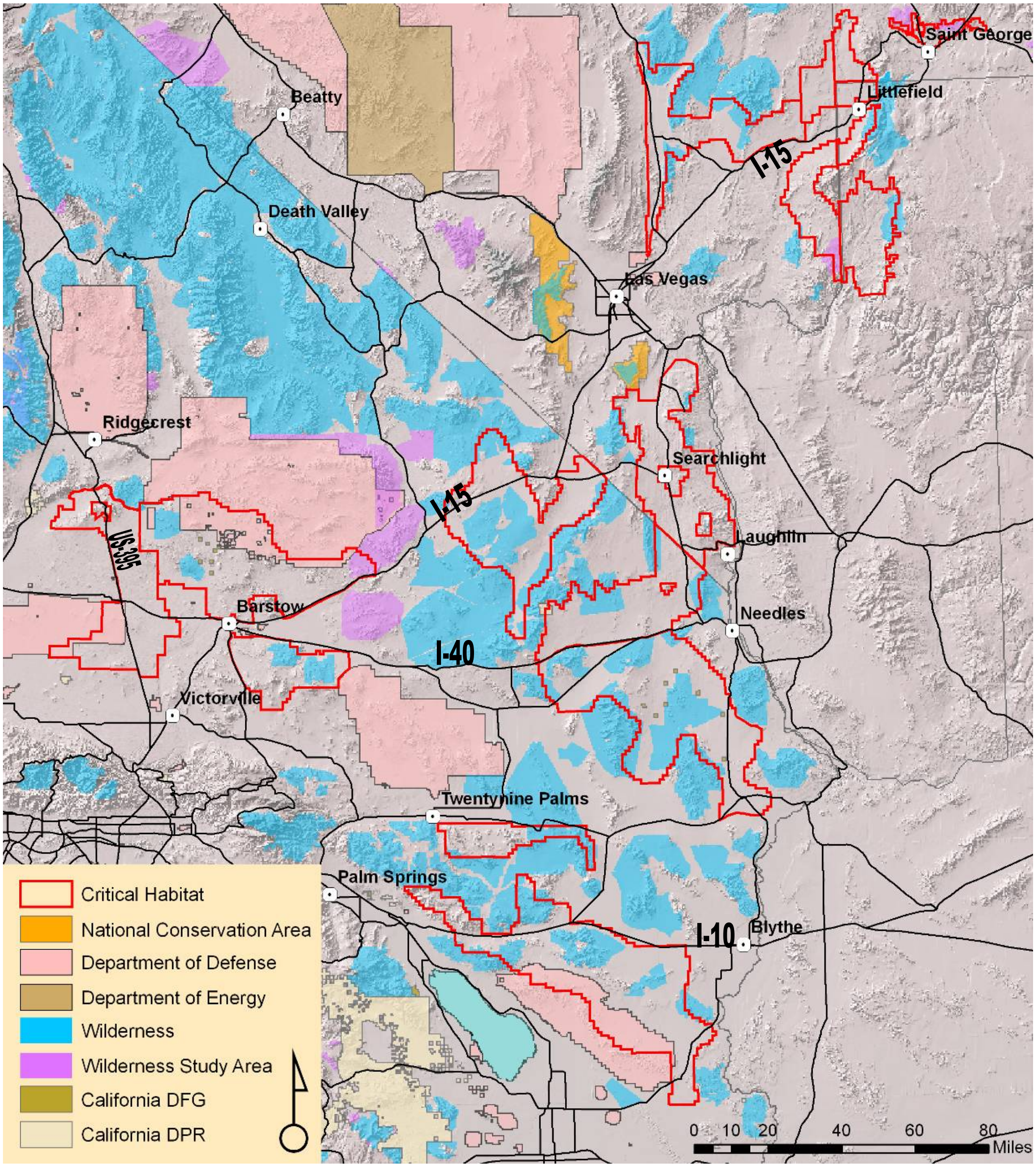


Figure 3. Additional land designations providing conservation benefits to the desert tortoise in relation to critical habitat and major highways. Conservation areas for other species not shown (*e.g.,* Mohave ground squirrel [*Spermophilus mohavensis*], *Mimulus mohavensis* [Mojave monkeyflower]) may also provide benefit to the desert tortoise. DFG = Department of Fish and Game; DPR = Department of Parks and Recreation.

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, lands managed to maintain wilderness characteristics were proposed on 87,100 hectares (215,345 acres) within the Grand Canyon-Parashant National Monument and on 14,120 hectares (34,900 acres) within the Arizona Strip field office's area of responsibility. 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).

3. 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 retirement) 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 nearly 1,214,000 hectares (3,000,000 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 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 (BLM 2002a) 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 (BLM 2002b) 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 (NPS 2002b), 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 2002b).

Since 1994, the Bureau of Land Management and U.S. Forest Service have closed 70 ephemeral grazing allotments in Clark and southern Nye counties totaling over 2,023,400 hectares (5,000,000 acres). Approximately 22,600 hectares (56,000 acres) currently remain available for grazing in 5 allotments in Clark and southern Nye counties (E. Masters, BLM, pers. comm. 2007). According to the Las Vegas Resource Management Plan, no legal grazing occurs within Areas of Critical Environmental Concern in Clark County and southern Nye County (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 (Lincoln County, Nevada), 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 is 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; grazing use is limited to October 15 through March 15, generally coinciding with desert tortoise inactivity. Ecological site inventory (basic inventory of present and potential vegetation on BLM rangelands) 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).

4. 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 urban development. On the other hand, these transactions may result in conservation benefits. For instance, since 1986, California Department of Fish and Game has acquired over 19,670 hectares (48,000 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 (see Appendix A: Land Acquisitions, Exchanges, and Transfers), 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 the National Training Center 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 for private lands 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 completed in 2000. 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 purchased 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 also being developed 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).

Within the region covered by the West Mojave Plan (BLM *et al.* 2005), a MSHCP is currently being drafted for development on approximately 1,214,000 hectares (3,000,000 acres) of private lands. This plan may cover as many as 15 species, including the desert tortoise. The MSHCP is still in the planning stages and the specific goals and objectives have yet to be determined.

Unfortunately, while desert tortoise population monitoring has occurred in association with the Washington County HCP and Clark County MSHCP, in particular, the duration of monitoring efforts has been insufficient to date to observe detectable, large-scale increases in tortoise populations or habitat condition (see Population Trends and Distribution). Continued management and focused monitoring, similar to the recovery strategy outlined below, are required to determine whether the HCPs are meeting their objectives.

5. 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 agency biologists in Arizona, Nevada, and Utah have come together to develop an initiative designed to protect intact, functional habitats and restore key areas that have burned. This initiative is a collaborative effort among Federal, state, and local jurisdictions and will 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.

We are currently undertaking efforts to reduce human subsidies of food, water, and nest sites to the common raven in the California desert. 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 removing or modifying nesting and roost sites. 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.* 2008).

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, controlling solid and organic wastes and standing water at and outside of sanitary landfills; encouraging livestock operators to reduce availability of food sources for ravens; limiting availability of nesting and perch substrates, especially in the urban interface; selectively removing problem ravens especially within the Desert Tortoise Natural Area, critical habitat units, and head-starting sites; conducting additional research on raven life history, behavior, and efficacy of control methods; and implementing 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.

I. BIOLOGICAL CONSTRAINTS AND NEEDS

The biological constraints that were identified in the 1994 Recovery Plan (*i.e.*, life history and reproductive characteristics and maintenance of genetic and ecological variability) 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 the species' persistence, and the slow growth rate of populations can leave them 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 (USFWS 1994a). 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 landscape-modifying activities place 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. 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 and extended time periods for recovery of desert ecosystems, also make it difficult to assess relative impacts of individual threats.

The 1994 Recovery Plan described a strategy for recovering 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 focused within the DWMAs. Maintaining high survivorship of adult desert tortoise was identified as the key factor in recovery. We recognize that the most significant challenge in the implementation of the 1994 Recovery Plan was not the number or types of actions implemented, but rather the coordination, description, documentation, and evaluation of implementation of the actions (Tracy *et al*., 2004). As a result, the revised strategy described herein emphasizes partnerships to direct and maintain focus on implementing recovery actions and a system to track implementation and effectiveness of recovery actions. Strategic elements within a multi-faceted approach designed to improve the 1994 Recovery Plan are:

1. Develop, support, and build partnerships to facilitate recovery;

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

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.

1. Strategic Element 1: 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. As noted above, we believe the most significant challenge in the implementation of the 1994 Recovery Plan was not the number or types of actions implemented, but rather the coordination, description, documentation and evaluation of implementation of the actions. The revised recovery plan emphasizes partnering across jurisdictional boundaries through standing Recovery Implementation Teams to maintain focus on implementing and tracking recovery actions. Therefore, this element relies on the successful establishment of regional, long-term Recovery Implementation Teams comprised of land managers, stakeholders, and scientists that will work together to develop recovery-action plans, prioritize recovery actions on the ground, secure necessary resources, and compile results into a range-wide database and decision support system that can be applied at the local level (Element 6). The Recovery Implementation Teams will also facilitate education and outreach activities to build support for, understanding of, and compliance with the recovery program. Organization of Recovery Implementation Teams will likely be based on recovery units, but it may vary depending on logistical practicalities among the representatives. Our Desert Tortoise Recovery Office will serve as the focal point for coordinating Recovery Implementation Teams in cooperation with the Desert Tortoise Management Oversight Group.

2. Strategic Element 2: Protect Existing Populations and Habitat

Since 1994, desert tortoise habitat has continued to be lost or severely degraded (*e.g.*, by urbanization, fire, invasive plants; see Appendix A), 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. The recommended actions in the 1994 Recovery Plan formed a logical basis for recovery (GAO 2002), and little information since 1994 contradicts these recommendations (Boarman and Kristan 2006). In fact, due to slow growth rates of individuals and populations, insufficient time has elapsed over which detectable increases in desert tortoise populations could be realistically expected. In any case, applying uniform, highly restrictive regulations across the entire Mojave population is not feasible, even if we knew the precise mechanisms affecting population declines at each site. Therefore, aggressive management as generally recommended in the 1994 Recovery Plan needs to be applied within existing **tortoise conservation areas** (Box 2) or other important areas identified by Recovery Implementation Teams (Element 1) 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. Especially given uncertainties related to the effects of climate change on desert tortoise populations and distribution, we consider tortoise

> **Box 2. "Tortoise conservation areas,"** collectively depicted in Figure 2, include desert tortoise habitat within critical habitat, Desert Wildlife Management Areas, Areas of Critical Environmental Concern, Grand Canyon-Parashant National Monument, Desert National Wildlife Range, National Park Service lands, Red Cliffs Desert Reserve, and other conservation areas or easements managed for desert tortoises.

conservation areas to be the minimum baseline within which to focus our recovery efforts. Much of the land contained within existing tortoise conservation areas is managed under multiple-use directives. It must also be recognized that activities occurring on lands beyond the boundaries of existing tortoise conservation areas can affect tortoise populations and the effectiveness of conservation actions occurring within the conservation area boundaries. Agencies must work within the context of their respective land use plans to determine how to effectively implement recovery actions contained within this plan.

Recovery Implementation Teams should use the decision support system (Element 6) to guide management both inside and outside tortoise conservation areas, according to different opportunities or constraints within different areas and jurisdictions. While recovery efforts may be prioritized within existing desert tortoise conservation areas, populations, habitats, and actions outside of these areas may also contribute to (or hamper) recovery of the species, and their importance is in no way diminished (other local, State, or Federal regulations may apply to actions potentially impacting tortoises and habitat outside tortoise conservation areas). For example, Department of Defense lands are subject to more dramatic changes in management or use than other Federal lands depending on the changing national security situation. However, the value of military lands to conservation has long been recognized. Similarly, wilderness designation on public lands entails restrictions on the types of activities that may be conducted there, precluding or otherwise limiting several forms of active management activities. Military lands, wilderness areas, and other land designations with conservation objectives include a great deal of desert tortoise habitat outside of and contiguous with tortoise conservation areas (see Figure 3), making them valuable components of the recovery landscape. 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.

3. Strategic Element 3: Augment Depleted Populations through a Strategic Program

Because of the intractable nature of discriminating specific effects of threats on desert tortoise populations, we are placing an emphasis on proactively bolstering populations where possible. Augmentation will be approached experimentally, in terms of both the continued development and evaluation of techniques and the use of augmentation to help us assess specific threats and recovery actions (Tracy *et al*. 2004; Armstrong and Seddon 2007). Population augmentation in conjunction with threats management and restoration activities (Element 2) and research (Element 5) designed to investigate the effectiveness of these actions is a means to both gain insights into causes of declines and to increase the rate at which depleted populations could be revived. It is important to realize that if the causes of tortoise population declines are not addressed, 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 increase populations more rapidly than possible through natural processes.

An augmentation strategy will be developed that identifies locally depleted or extirpated populations, particularly within desert tortoise conservation areas. Translocation and head-starting (described below) 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 strategy (Element 5).

Head-starting and translocation are fundamental aspects of the augmentation program. Both must account for factors such as genetics and disease. Head-starting is raising of young in captivity to allow them to reach sizes at which they are less vulnerable to certain threats, such as predation by ravens, before translocation to the wild. 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 on which to build (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 Arizona, Nevada, and Utah, 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 Desert Tortoise Recovery Office 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).

Augmentation also involves 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 (Field *et al.* 2000; Nussear 2004; Field *et al.* 2007). Again, the Desert Tortoise Recovery Office 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).

4. Strategic Element 4: Monitor Progress toward Recovery

Monitoring is a fundamental requirement for adaptive management (Element 6). 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, to evaluate progress toward achieving recovery criteria, and to help evaluate whether delisting the species may be appropriate. While the 1994 Recovery Plan focused exclusively on monitoring desert tortoise populations, a multi-dimensional monitoring program is necessary to assess the status of tortoise populations, habitat, and threats (Tracy *et al.* 2004). Monitoring activities described in this plan are therefore tied directly to individual recovery criteria related to these the status of populations, habitat, and threats. 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 habitat restoration in the desert, 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) and is discussed below as applied research.(Element 5). It is also important that monitoring be conducted as an integrated effort, coordinated through the Desert Tortoise Recovery Office, to ensure that efficiency of the recovery program and review of its progress are 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.

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

In this plan we update the research recommendations from the 1994 Recovery Plan with new priorities. Although scientists have studied desert tortoises for over 3 decades, 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 6). Finally, similar to the coordination required of the monitoring program (Element 4), research should be coordinated through the Desert Tortoise Recovery Office (with advice from the Science Advisory Committee and input from the Recovery Implementation Teams) to ensure that the highest priority questions are addressed first and that the entire recovery program can be leveraged from timely research results.

6. Strategic Element 6: Implement a Formal Adaptive Management Program

Integrating the results of recovery actions 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. Even though the 1994 Recovery Plan called for regular updates based on new information, a formal process for accomplishing this task was not established. 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 (implementation-monitoring-evaluation-adjustment) 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. In many cases, intermediate or indirect benchmarks may be needed to measure progress.

Given the complexities of desert tortoise recovery described above, fully *active* adaptive management that 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 on resource status and other system attributes (Schwarz 1998; Williams *et al.* 2007). An assessment of the monitoring results can then be applied to on-the-ground management actions as we continue to learn and better understand the recovery needs of the species. In either case, the use of structured decision making and a decision support system will facilitate the adaptive management process (Ralls and Starfield 1995; Rauscher 1999; Williams *et al.* 2007). A decision support system is an interactive system that computes the output of a set of models (*e.g.*, effects of a threat on a tortoise population) based on underlying databases (*e.g.*, the spatial extent of the threat, tortoise population, and management actions). In fact, a decision support system will provide a vehicle for implementing adaptive management (Starfield and Bleloch 1991). 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 recognizing and implementing successful recovery actions. Through the use 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). It will also require effective communication among the various groups. Therefore, the Desert Tortoise Recovery Office will serve as the focal point for coordinating among agencies and researchers, through Recovery Implementation Teams (Element 1), to maintain and improve the decision support system. Finally, the Desert Tortoise Recovery Office will continue to coordinate with 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.

7. Synthesis and Implementation

As indicated in the narrative above, these strategic elements are not independent of each other, but each is inter-connected with the others (Figure 4). The Desert Tortoise Management Oversight Group will be the partnership (Element 1) responsible for providing "executive-level" support and direction for recovery implementation, thus tying the entire program together. Regional Recovery Implementation Teams will include a member of the Desert Tortoise Recovery Office to provide guidance and coordination to land/wildlife managers and stakeholders on the teams, which will be responsible for developing step-down recovery-action plans and implementing those actions on the ground. The Recovery Implementation Teams may leverage existing management partnerships such as the California Desert Managers Group or the Southern Nevada Agency Partnership. The Management Oversight Group will review the recovery-action plans, and the Recovery Implementation Teams will report back to the Management Oversight Group on an annual basis to review progress. The Desert Tortoise Recovery Office will provide linkages between the Management Oversight Group, Recovery Implementation Teams, and Science Advisory Committee.

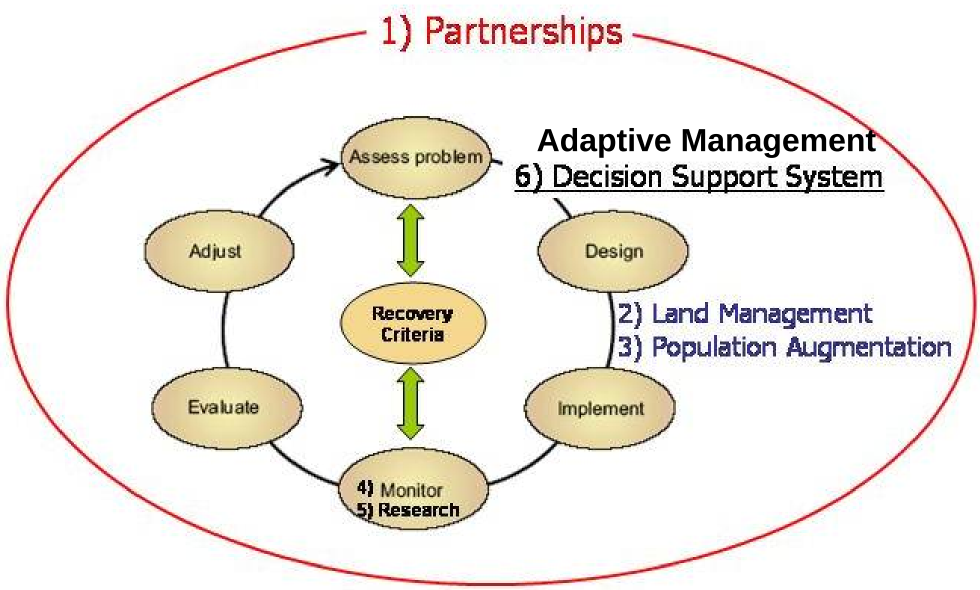


Figure 4. Schematic representation of strategic elements within the Desert Tortoise Recovery Program.

The adaptive management program (including a decision support system; Element 6) provides a formal framework with which the partnerships can make better, more informed, and more explicit decisions. Through the partnership and adaptive management 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. The Desert Tortoise Recovery Office is responsible for reviewing Federal recovery/research permits and for ensuring that permitted research addresses priorities identified by the Recovery Implementation Teams and Science Advisory Committee.

Implementation of recovery actions within each strategic element 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 the flexibility to apply an action most appropriate to the situation. Communication between Fish and Wildlife field offices, the Desert Tortoise Recovery Office, Recovery Implementation Teams, and other agency staff through section 7 and 10 activities will ensure that these activities are consistent with the Recovery Implementation Teams' recovery-action plans and this recovery program.

B. RECOVERY UNITS

Recovery of the desert tortoise will follow a geographic approach, similar to the 1994 Recovery Plan. The desert tortoise is a wide-ranging species inhabiting a large geographic area, so recovery actions will be tailored to regional ecological and socio-political conditions within **recovery units** (Box 3). 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. At this time, we have not determined whether specific areas within the Mojave population of desert tortoise might constitute separate DPSs. Designation of DPSs can only be done through a formal rule-making process. Recovery plans do not designate DPSs. 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.

Box 3. Recovery units for the desert tortoise are special units that are geographically identifiable and are essential to the recovery of the entire listed population, *i.e.*, recovery units are individually necessary to conserve the genetic, behavioral, morphological, and ecological diversity necessary for long-term sustainability of the entire listed population. Recovery criteria (described below) must be evaluated for each individual recovery unit for the entire listed population of the desert tortoise to be considered for delisting.

Recovery units collectively cover the entire range of the species. Critical habitat and other management designations included within "tortoise conservation areas" are focal areas for recovery within each recovery unit. As a result, evaluation of recovery criteria and implementation of most recovery actions will be focused within tortoise conservation areas as defined in Box 2 and Figure 2.

1. Background

The 1994 Recovery Plan identified six recovery units: Upper Virgin River, Northeastern Mojave, Eastern Mojave, Eastern Colorado, Northern Colorado, and Western Mojave (Figure 5).

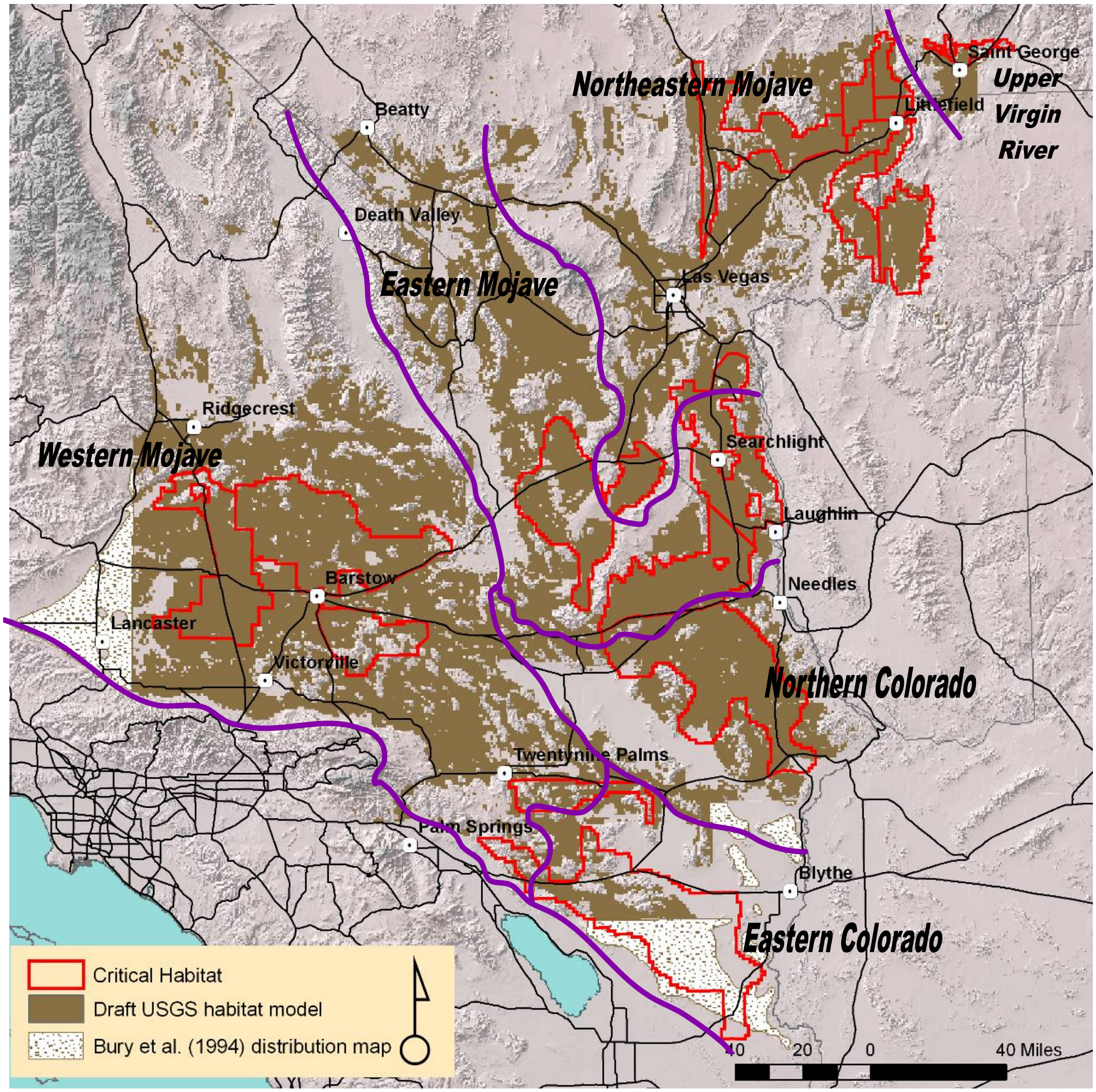


Figure 5. Recovery units as delineated in the 1994 Recovery Plan (outlined in purple).

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). 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 (mtDNA) 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. Further genetic resolution has since been recommended to enhance the best available data to delineate recovery units (Tracy *et al.* 2004). Two population genetic assessments have recently been completed and are in the process of being published (Hagerty and Tracy 2007; Murphy *et al.* 2007). In delineating recovery units for this plan, we considered genetic and ecological variation across the range of the species, as described below.

2. Assessment of Revised Recovery Units

(a) Genetic variation. Gene flow is the result of dispersal accompanied by successful reproduction and incorporation of genes in a population. Ultimately, gene flow governs the amount of genetic connectivity among populations. A lack of gene flow will allow populations to differentiate over time by means of genetic drift and natural selection. Desert tortoises possess characteristics that potentially allow for high levels of gene flow among populations. For example, individuals have the ability to move long distances (Berry 1986; Edwards *et al.* 2004a). The capability for long-distance dispersal, combined with longevity and opportunities to reproduce annually throughout adulthood, indicates high potential for gene exchange outside of local areas. Free genetic exchange will be constrained, however, by the large distributional range of the tortoise given the relatively much smaller home range size and dispersal ability (isolation-by-distance phenomenon; see Allendorf and Luikart 2007:209). Topographic features (*e.g.*, mountain ranges) and other potential barriers (*e.g.*, impassable habitat types, extreme climate conditions) can structure regional populations and lead to variable exchange of migrants among populations.

All recent genetic studies of the desert tortoise have suggested that its population structure is characterized by isolation-by-distance (Britten *et al.* 1997; Edwards *et al.* 2004b; Hagerty and Tracy 2007; Murphy *et al*. 2007). That is, populations at the farthest extremes of the distribution are the most differentiated, but a gradient of genetic differentiation occurs between those populations, across the range of the species. Historically, levels of gene flow among subpopulations were likely high, corresponding to high levels of connectivity among habitat types (Murphy *et al.* 2007). Historically high levels of gene flow are further supported by the fact that multidimensional scaling analysis of DNA microsatellite data depicts a continuous gradient of genetic difference across the range of the desert tortoise (Hagerty and Tracy 2007), and analysis of molecular variance revealed that over 93 percent of the variation occurs within, not among, populations (Hagerty and Tracy 2007; Murphy *et al.* 2007). In addition, with the exception of the Upper Virgin River Recovery Unit, assignment tests incorrectly placed 11 to 45 percent of individuals (Murphy *et al*. 2007), a seemingly high level of immigration between regions to be explained by human-mediated translocations alone, especially given the general failure of such early translocations (Berry 1986). In contrast, greater than 90 percent of gopher tortoises were assigned to the correct genetic assemblage from where they were sampled in Georgia and Florida, where relocations of tortoises have been extensive (Schwartz and Karl 2005).

Based on the distribution of habitat occupied by the Mojave population of the desert tortoise, especially relative to that occupied by the Sonoran population (Figure 1; Germano *et al.* 1994), genetic differentiation within the Mojave population is consistent with isolation by distance in a continuous-distribution model of gene flow. The continuous-distribution model of gene flow describes a situation in which populations of a particular neighborhood size could be identified anywhere (such as the sample sites of Murphy *et al*. 2007), and individuals inside those neighborhoods would represent a panmictic (randomly mating) group (Allendorf and Luikart 2007:209-211). To describe genetic relationships within species, methods require analysis of many individuals sampled across relatively evenly spaced locations. In a more-or-less continuous population, we risk wrongly inferring genetic discontinuities between sampling locations if clusters of individuals are sampled from locations far apart (Allendorf and Luikart 2007:400). As a result of the apparent pattern of gene flow among desert tortoise populations, we use genetic information to validate or reinforce other ecological or topographic boundaries, rather than as the primary means of identifying recovery units.

(b) Ecological variation. Similar to the gradient of genetic differentiation across the desert tortoise's range, the Mojave Desert is itself a transitional vegetation type wedged between the Great Basin and Sonoran deserts (Rowlands *et al*. 1982; Turner 1982; MacMahon 1990). Furthermore, physiographic and biological subdivisions of the Mojave Desert do not coincide (MacMahon 1990). The Colorado Desert (a subdivision of the Sonoran Desert) lies in the southeastern-most part of California and the Mojave population of the desert tortoise's range, and it is recognized as a distinct biome with a different climate relative to the Mojave Desert (Brown 1982). However, separation of the Mojave Desert along its boundary with Sonoran (Colorado) desertscrub is commonly blurred because distinct coincidental breaks in indicator species' ranges are lacking (Turner 1982). In addition, climate variables vary linearly across the range of the desert tortoise (*e.g*., winter:summer rainfall; Figure 6; Table 4). The central Mojave is topographically and climatically transitional between the southwestern and eastern Mojave desert. The south-central Mojave is a transitional region to the Colorado Desert, and the southern half of this region is similar climatically and floristically to the eastern Mojave. Much of the differences in vegetation can be explained by differences in climate (Rowlands 1995). Given the broad or incongruent transitions between identified subdivisions of the Mojave and Sonoran deserts, we minimize the use of these transitions in identifying recovery units where other supporting data are absent.

(c) Recovery unit delineation. Given the generally continuous variation in genetics and biomes across the Mojave desert tortoise's range, our approach in delineating revised recovery units stressed identification of geographic discontinuities or barriers that coincide with any observed variation among tortoise populations. We use these geographic features to define boundaries between units. Several potential barriers are evident from topographic maps and the draft U.S. Geological Survey habitat model (Figure 1). We used differences in genetic, ecological, and physiological characteristics to help highlight boundaries or other differences between units, which is consistent with the argument that demographic, ecological, and behavioral considerations should often be of greater importance than genetic issues alone in the formulation of conservation plans for threatened or endangered species (Avise 2004:486-487).

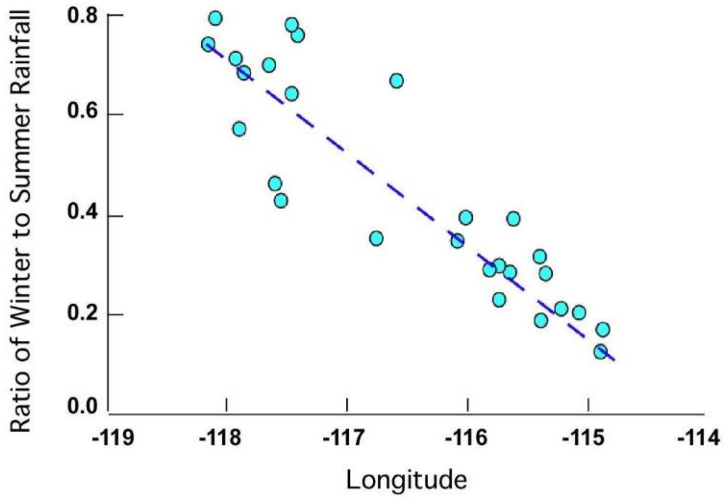


Figure 6. Ratio of rainfall in winter compared to summer in the Mojave Desert. Graph reprinted from Tracy *et al.* (2004).

With the aid of modern GIS tools we are able to map boundaries of each recovery unit (Figure 7) much more precisely than in 1994, although as indicated above, transitions between recovery units are not always as precise on the ground as depicted by lines on a map. We have reduced the number of recovery units from six to five and have changed some boundaries of the 1994 recovery units, as described below. Note that the peripheral boundaries, other than the Colorado River, are more or less arbitrarily depicted in Figure 7 with the intention of encapsulating the entirety of the desert tortoise's current range. Descriptions of vegetation communities and complexes and related desert tortoise ecology are as generally described by Rowlands *et al.* (1982) and USFWS (1994a) except where otherwise noted. Finally, we also note that variation in genetics, behavior, morphology, ecology, or other evidence *within* recovery units emphasizes the need, when evaluating management actions (particularly head-starting and translocation), to consider whether the environmental conditions or habitat type of different populations has been different for many generations. If they have been, this could lead to adaptations even in the face of high gene flow that are important for the long-term persistence of the species (Allendorf and Luikart 2007:415; Murphy *et al*. 2007).

(i) Upper Virgin River Recovery Unit. This recovery unit is equivalent to the original Upper Virgin River Recovery Unit and encompasses all desert tortoise habitat in Washington County, Utah, east of the Beaver Dam Mountains (Figure 8).

The recovery unit includes the Upper Virgin River critical habitat unit and Washington County's Red Cliffs Desert Reserve. Modeled tortoise habitat depicted directly south of the Red Cliffs Reserve and extending into Arizona has either been lost to urbanization or is not known to have ever been occupied (Bury *et al*. 1994).

Recent DNA microsatellite evidence (Hagerty and Tracy 2007) suggests that there is little genetic differentiation between the Upper Virgin River and the neighboring recovery unit, which agrees with earlier evidence from allozyme (protein) and mtDNA markers (Lamb *et al*. 1989; Britten *et al*. 1997), although assignment tests correctly identified this recovery unit for greater than 95 percent of individuals sampled here (Murphy *et al.* 2007). However, unique habitat characteristics and tortoise behavior in this region justify separating the most northern extreme of the tortoise's range, east of the Beaver Dam Mountains, into a separate recovery unit.

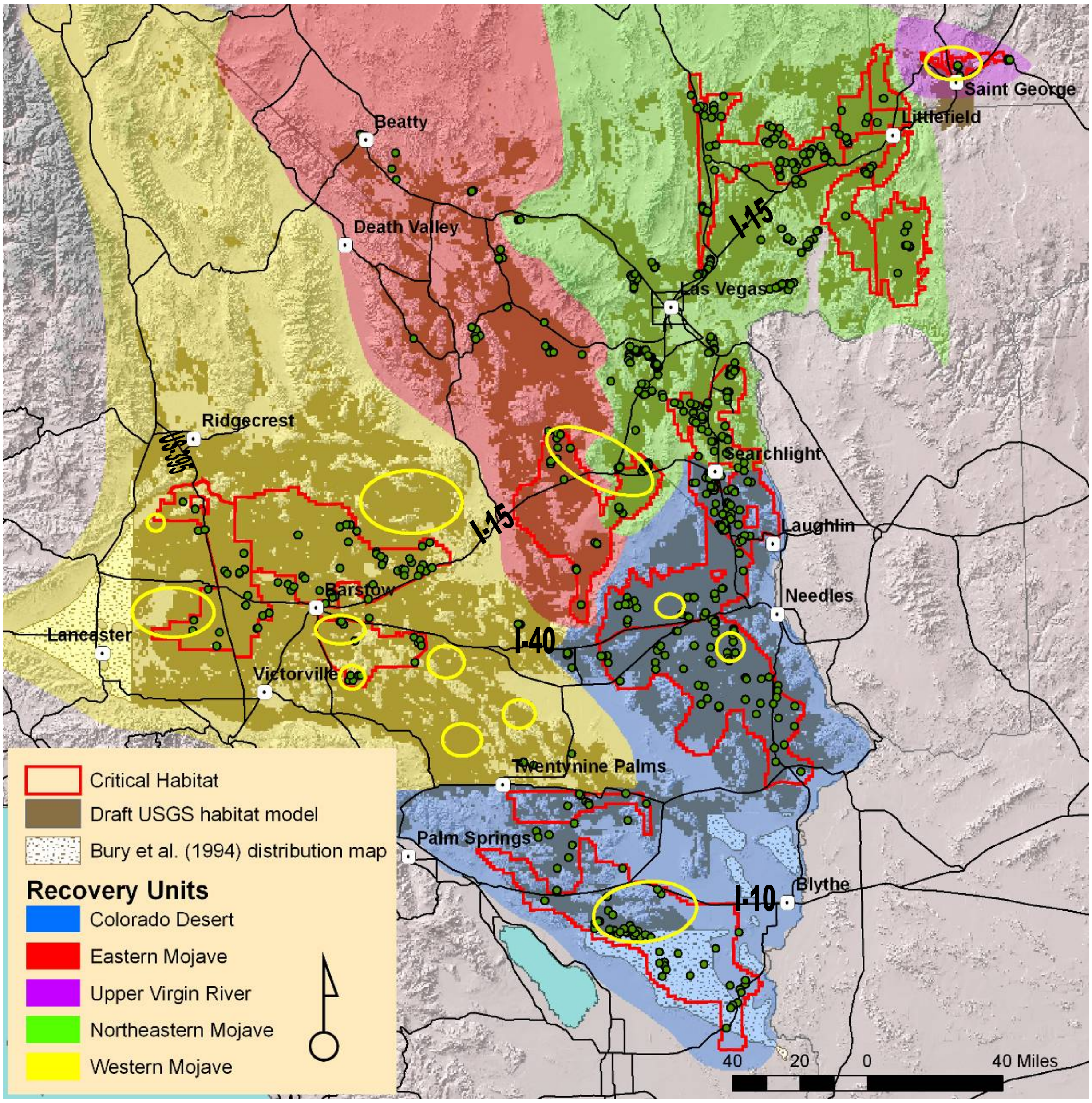


Figure 7. Revised recovery units for the Mojave population of the desert tortoise. Yellow ovals are general sampling areas from Murphy *et al.* (2007). Green dots are sample points from Hagerty and Tracy (2007). Recovery units encompass the entire range of the listed species, so the only "hard" peripheral edge is along the Colorado River; the northern, western, and southern boundaries are defined by the actual distributional limits of the desert tortoise.

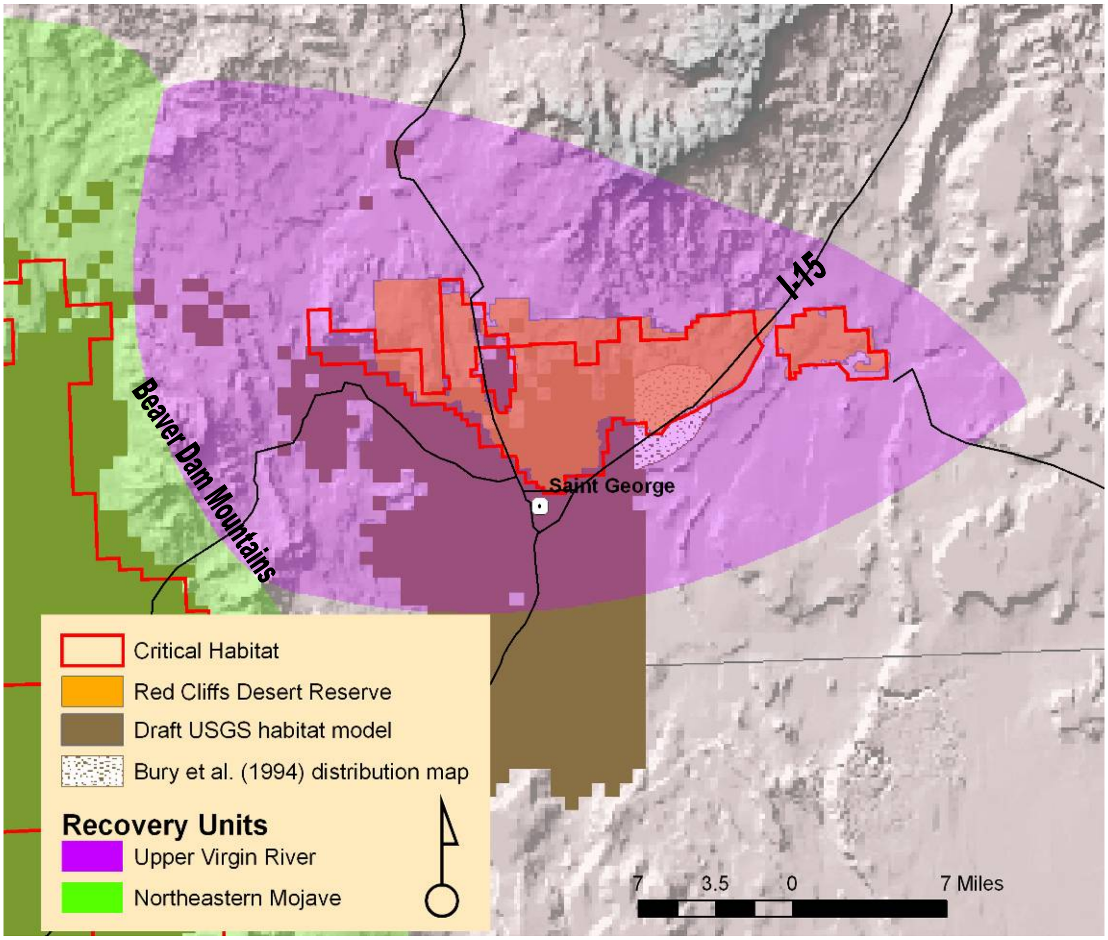


Figure 8. Upper Virgin River Recovery Unit.

The tortoise population in the area of St. George, Utah, is at the extreme northeastern edge of the species' range and experiences long, cold winters (about 100 freezing days) and mild summers (Table 4), during which the tortoises are continually active. Here the animals live in a complex topography consisting of canyons, mesas, sand dunes, and sandstone outcrops where the vegetation is a transitional mixture of sagebrush (*Artemisia* spp.) scrub, creosote bush scrub, blackbrush scrub, and a psammophytic (sandy-soil) community. Desert tortoises often use sandstone and lava caves instead of burrows, travel to sand dunes for egg laying, and use still other habitats for foraging. In contrast to populations at more distant parts of the range, two or more desert tortoises often use the same burrow.

(ii) Northeastern Mojave Recovery Unit. The Northeastern Mojave Recovery Unit is equivalent to the original Northeastern Mojave Recovery Unit, extending into extreme southwestern Utah, northwestern Arizona, and into California's Ivanpah Valley (Figure 9). The east end of the unit extends south from the Beaver Dam Mountains, across the north end of the Virgin Mountains, down to the Colorado River. From the Colorado River at approximately Cottonwood Cove, the southern boundary extends west through Searchlight, down the New York Mountains, curving around to the south end of the

Ivanpah Mountains, up to Mountain Pass. From here, the western boundary extends north-northeast up the spines of the Clark and Spring mountains before hooking back to the northeast through the Specter and Spotted ranges.

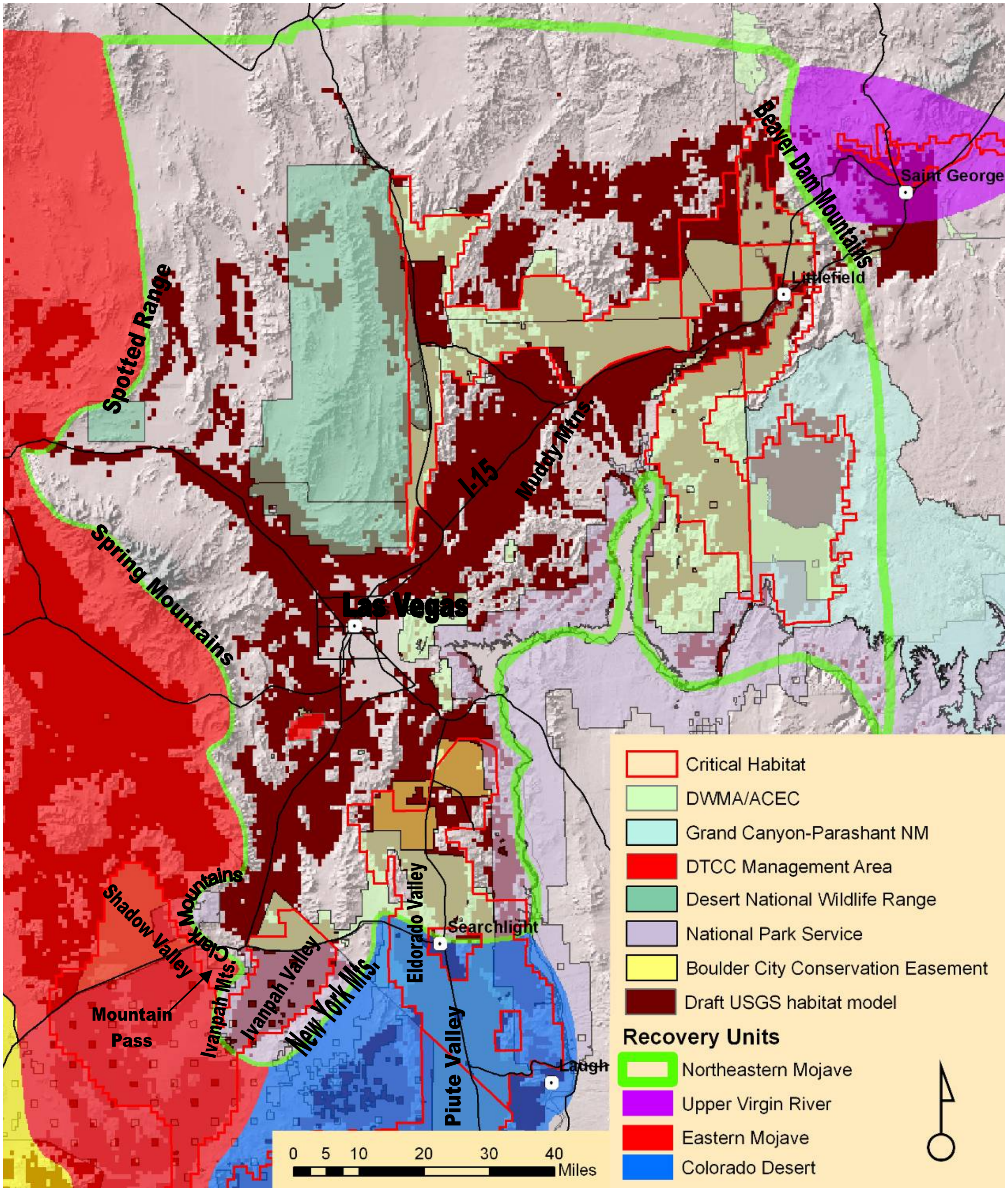


Figure 9. Northeastern Mojave Recovery Unit. DWMA = Desert Wildlife Management Area; ACEC = Areas of Critical Environmental Concern; DTCC = Desert Tortoise Conservation Center.

This recovery unit includes the Beaver Dam Slope, Gold Butte-Pakoon, and Mormon Mesa critical habitat units, as well as the Ivanpah Valley portion of the Ivanpah and the Eldorado Valley portion of the Piute-Eldorado critical habitat units (Figure 9). It also includes Lake Mead National Recreation Area south to Cottonwood Cove, Grand Canyon-Parashant National Monument on the Arizona Strip, the Mojave National Preserve (in Ivanpah Valley), and the Desert National Wildlife Range.

DNA microsatellite data indicate that this unit is genetically similar to the Upper Virgin River Recovery Unit, but the Northeastern Mojave Recovery Unit does contain distinct microsatellite differences compared to the remainder of the range (Hagerty and Tracy 2007). Some variation may occur to the south and west from the Mormon Mesa, but genetic breaks appear to be ambiguous relative to at least semi-permeable topographic barriers to gene flow, such as the Muddy Mountains (Hagerty and Tracy 2007). In the Las Vegas Valley, an allozyme cluster at one locus from populations in the Mormon Mesa critical habitat unit overlaps another cluster identified from populations in Piute Valley (Britten *et al*. 1997). Microsatellite and mtDNA analyses suggest that Searchlight Pass (part of the Highland Range extending into the Newberry Mountains) acts as a barrier between Eldorado and Piute Valleys (Lamb *et al*., 1989; Hagerty and Tracy 2007). Mountain Pass, which is comprised of the Ivanpah and Clark mountain ranges, appears to act as a semi-permeable barrier between Shadow Valley and Ivanpah Valley. The New York Mountains isolate Ivanpah Valley from Eldorado Valley. The Spring Mountains and the Spotted and Specter ranges act as a barrier for the western portion of this unit. A distinct shell phenotype also occurs in the Beaver Dam Slope region (USFWS 1994a; Britten *et al*. 1997), but these tortoises are not genetically isolated from adjacent populations (Bury *et al*. 1994).

Desert tortoises in this recovery unit are generally found in creosote bush scrub communities of flats, valley bottoms, alluvial fans, and bajadas, but they occasionally use other habitats such as rocky slopes and blackbrush scrub. Average daily winter temperatures usually fluctuate above freezing, and summer temperatures are typically a few degrees cooler than the recovery units to the south and west. About 30 to 40 percent of annual rainfall occurs in summer (Table 4). Two or more desert tortoises often den together in caliche caves in bajadas and washes or caves in sandstone rock outcrops, and they typically eat summer and winter annuals, cacti, and perennial grasses.

(iii) Eastern Mojave Recovery Unit. The Eastern Mojave Recovery Unit is approximately equivalent to the original Eastern Mojave Recovery Unit, spanning the Nevada-California border, including Oasis Valley, Amargosa Desert, Pahrump Valley, and extending south into Shadow Valley (Figure 10). From its border with the Northeastern Mojave Recovery Unit down the Spotted, Specter, and Spring mountain ranges to Mountain Pass and the south end of the New York Mountains, the eastern boundary extends down the Providence Mountains to the Granite Mountains. From there the western boundary extends north through the Bristol Mountains, Soda Lake, and Silurian and Death valleys.

The recovery unit includes the east side of Death Valley National Park and much of Mojave National Preserve, as well as the Nevada Test Site and the southwestern end of the Nellis Air Force Range. It also includes most of the Ivanpah Valley critical habitat unit (Figure 10).

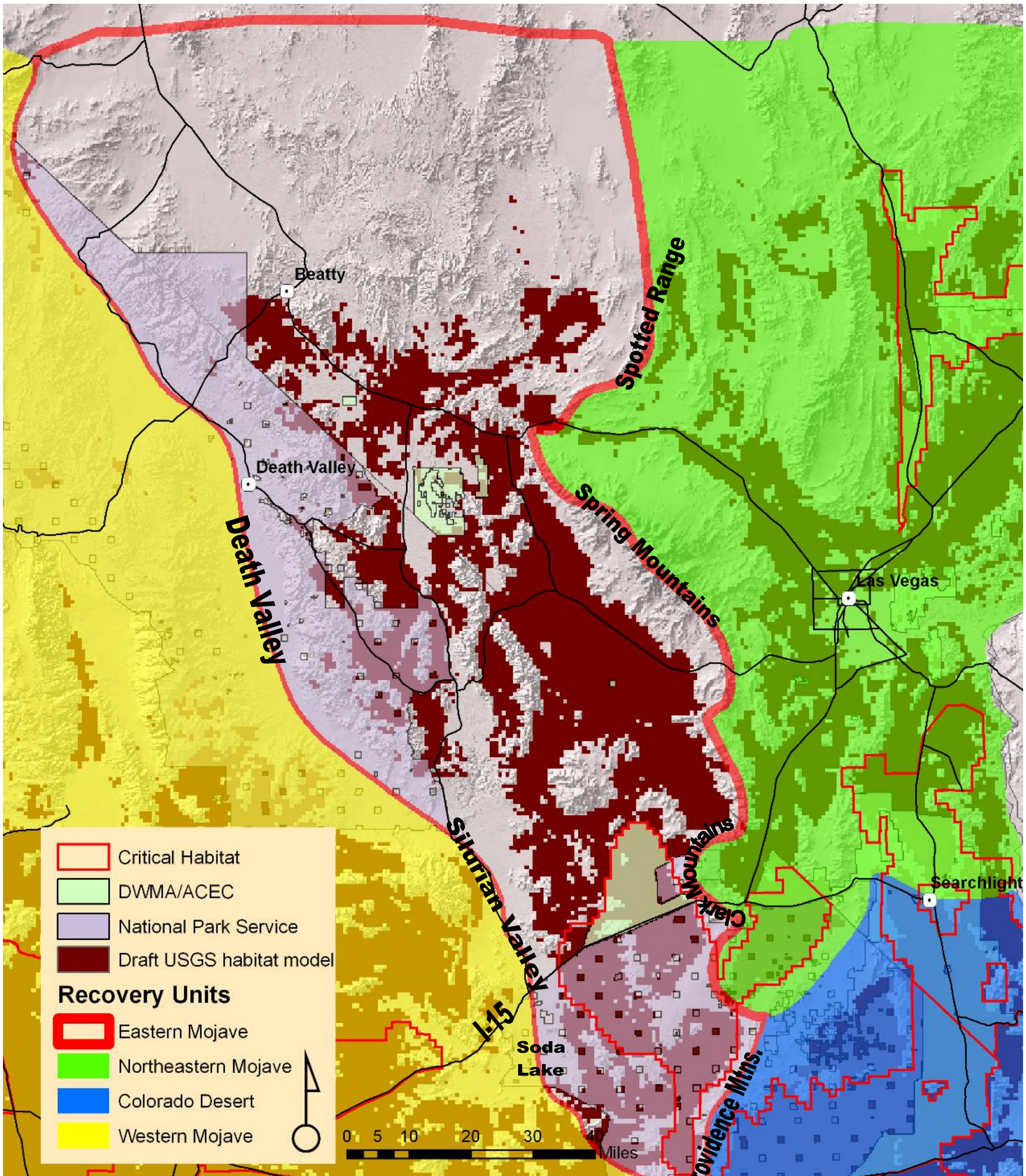


Figure 10. Eastern Mojave Recovery Unit. DWMA = Desert Wildlife Management Area; ACEC = Areas of Critical Environmental Concern.

A majority of this unit had not been sampled previously; however, recent microsatellite data reflect unique nuclear allele frequencies, indicating that this area is isolated from other recovery units (Hagerty and Tracy 2007). Allele frequencies from tortoises at Amargosa Desert and Pahrump Valley sites also form a homogeneous cluster different from other Nevada sites (Britten *et al*. 1997). The Spring Mountains and the Spotted and Specter ranges appear to form a barrier to tortoise movement between the eastern side of the recovery unit and the Northeastern Mojave Recovery Unit. Mountain Pass appears to act as a semi-permeable barrier between Shadow Valley and Ivanpah Valley. The Providence Mountains divide this recovery unit from Fenner Valley and the Colorado Desert Recovery Unit to the east. Saline Valley and Death Valley extending south into Silurian Valley and Soda Dry Lake act as a barrier between this recovery unit and the Western Mojave Recovery Unit. Although gene flow likely occurred intermittently during favorable conditions across this western edge of the recovery unit, this area contains a portion of the Baker Sink, a low-elevation, extremely hot and arid strip that extends from Death Valley to Bristol Dry Lake. This area is generally inhospitable for desert tortoises.

In this section of the Mojave Desert, desert tortoises are often active in late summer and early fall, in addition to spring, reflecting the fact that this region receives up to about 25 percent of its annual rainfall in summer (Table 4) and supports two distinct annual floras on which tortoises can feed. Winter temperatures rarely drop to freezing, except in the higher elevations (Table 4). These desert tortoises occupy a variety of vegetation types and feed on summer and winter annuals, cacti, perennial grasses, and herbaceous perennials. Tortoises den singly in caliche caves, bajadas, and washes, or caves in sandstone rock outcrops. Tortoises at the Nevada Test Site produce fewer eggs than similarly sized tortoises near Goffs in the Colorado Desert Recovery Unit (Mueller *et al*. 1998). Tortoises at the Nevada Test Site grow to the largest reported size (21 centimeter [8.2 inch] carapace length) before reproducing compared to populations in other recovery units (Mueller *et al*. 1998).

(iv) Colorado Desert Recovery Unit. This recovery unit combines the original Eastern Colorado and Northern Colorado recovery units, as well as a portion of the Eastern Mojave Recovery Unit in Piute and Fenner valleys. It is primarily found in California, though it extends into Piute Valley, Nevada, in the northern corner (Figure 11). Piute Valley spans the northern border of the northern Colorado Desert and southern edge of the eastern Mojave Desert. The recovery unit shares its north and west boundaries with the Northeastern Mojave and Eastern Mojave recovery units: west from Cottonwood Cove Road, through Searchlight, down the New York and Providence mountains, to the Granite Mountains. From the Granite Mountains, the boundary extends through the Old Dad and Bristol mountains, southeast through Bristol Lake and Cadiz Valley, to the southern end of the Calumet Mountains. From there, the boundary drops down to and extends west along California State Highway 62 all the way to the San Bernardino Mountains, including the Morongo Basin. The southern boundary circumscribes the tortoise’s range east to the Colorado River.

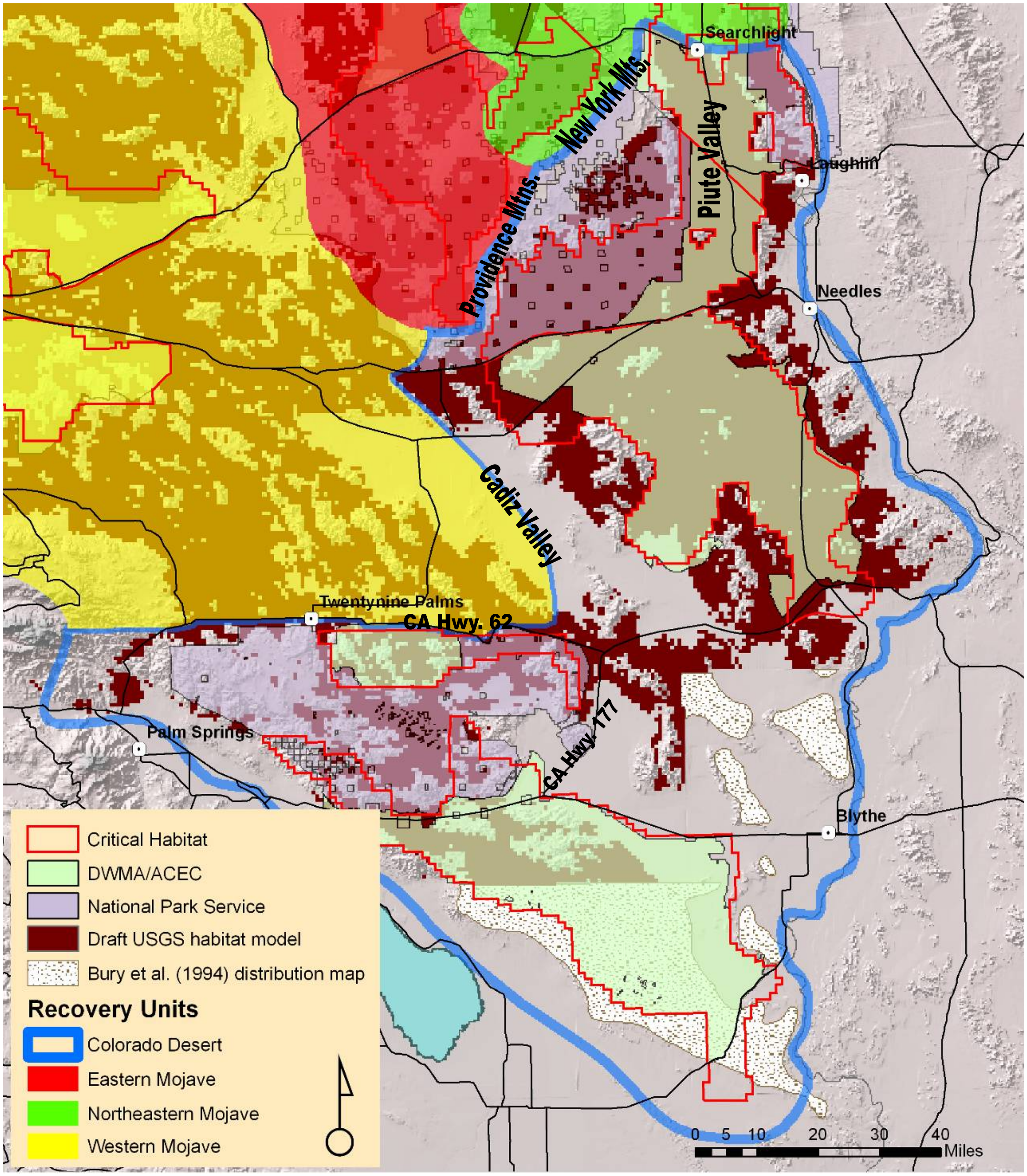


Figure 11. Colorado Desert Recovery Unit. DWMA = Desert Wildlife Management Area; ACEC = Areas of Critical Environmental Concern.

The recovery unit includes the Piute-Eldorado critical habitat unit (south of Eldorado Valley) and the Chemehuevi, Pinto Mountain, and Chocolate Mountain critical habitat units. This unit encompasses the eastern end of Mojave National Preserve, the southernmost limits of Lake Mead National Recreation Area, Joshua Tree National Park, and the Chocolate Mountains Gunnery Range.

Desert tortoises in this recovery unit share mtDNA haplotypes with the Western Mojave Recovery Unit (Lamb *et al*. 1989; Murphy *et al*. 2007) and possess the California shell type (USFWS 1994a). They are differentiated from desert tortoises in the Northeastern Mojave and Western Mojave recovery units at several allozyme loci (Rainboth *et al*. 1989; Britten *et al*. 1997). Microsatellite data also support the boundary between the Colorado Desert Recovery Unit and the Northeastern Mojave and Eastern Mojave recovery units (Hagerty and Tracy 2007; Murphy *et al*. 2007), but less so with the Western Mojave Recovery Unit (Hagerty and Tracy 2007). Inclusion of the Fenner and Piute valleys in this recovery unit, rather than in the Eastern Mojave Recovery Unit as in 1994, is justified by the contiguous habitat and the failure to reliably assign sampled tortoises to the correct site between Fenner and Chemehuevi valleys (Murphy *et al*. 2007).

The prominent Providence and New York mountain ranges, which transect Mojave National Preserve, isolate this recovery unit from the recovery units to the northwest. Searchlight Pass is the northern boundary, which separates Eldorado and Piute valleys. The north half of this recovery unit is separated from the Western Mojave Recovery Unit by the Baker Sink, a low-elevation, extremely hot and arid strip that extends from Death Valley to Bristol Dry Lake and Cadiz Valley. To the south, the transition between the Colorado and Mojave deserts is more subtle. However, urban development along California State Highway 62 now largely separates the two recovery units. While the Baker Sink almost divides this recovery unit in half, as generally reflected in the 1994 Northern and Eastern Colorado recovery units (Figure 5), the Colorado Desert is a distinct biome that encompasses a continuum of climatic and floristic characteristics (Turner 1982) and only subtle differences were originally noted in these recovery unit descriptions (USFWS 1994a). Furthermore, minimal genetic variation is now recognized within the entire Colorado Desert biome (Hagerty and Tracy 2007; Murphy *et al*. 2007). What little genetic variation that has been observed between former Northern and Eastern Colorado recovery units is likely due to an absence of sampling from populations in the central part of the combined unit, south of Highway 62 and east of Highway 177 (*cf*. Allendorf and Luikart 2007:400; Figures 7 and 11). Patchy habitat southeast of the Cadiz Valley appears to provide some linkage between the northern and southern halves of this recovery unit (Figure 11). As a result, we merged these two recovery units.

In the Colorado Desert Recovery Unit, desert tortoises are found in the valleys, on bajadas, desert pavements, rocky slopes, and in the broad, well-developed washes (especially to the south). Vegetation is characterized by relatively species-rich succulent scrub, creosote bush scrub, and blue paloverde (*Parkinsonia florida*)-ironwood (*Olneya tesota*)-smoke tree (*Psorothamnus spinosus*) communities. Tortoises feed on both summer and winter annuals, because this region receives about 1/3 of its annual rainfall in summer (Table 3) and supports two distinct annual floras on which they can feed. Tortoises den singly in burrows under shrubs, in inter-shrub spaces, and washes. Farther north, tortoises are more likely to burrow in caliche caves and washes. The climate is somewhat warmer than in other recovery units, with very few freezing days per year

(Table 3). Tortoises within this recovery unit near Goffs produce relatively smaller eggs, produce more eggs overall, lay their second clutches earlier, and are smaller overall than tortoises in the Desert Tortoise Research Natural Area in the Western Mojave Recovery Unit (Wallis *et al*. 1999). They also produce more eggs than similarly sized females at the Nevada Test Site in the Eastern Mojave Recovery Unit (Mueller *et al*. 1998).

(v) Western Mojave Recovery Unit. This recovery unit is generally equivalent to the original Western Mojave Recovery Unit and is found entirely in California (Figure 12). It includes the central, southwestern, south-central, and part of the northern Mojave regions described by Rowlands *et al*. (1982). The eastern boundary, which it shares with the Eastern Mojave Recovery Unit, extends down Death and Saline valleys, through Soda Lake and the Bristol Mountains, to the Granite Mountains. The eastern boundary continues down the low-lying Baker sink and Cadiz Valley, separating it from the Colorado Desert Recovery Unit. The boundary extends west along California State Highway 62 to the San Bernardino Mountains.

The recovery unit includes the Fremont-Kramer, Superior-Cronese, and Ord-Rodman critical habitat units. The recovery unit also includes the western half of Death Valley National Park, Marine Corps Air Ground Combat Center, Fort Irwin National Training Center, China Lake Naval Weapons Center, and Edwards Air Force Base.

There is conflicting microsatellite evidence concerning the degree of differentiation between the Western Mojave and Colorado Desert recovery units, although genetic differentiation is generally low (Hagerty and Tracy 2007; Murphy *et al*. 2007). However, the Western Mojave Recovery Unit is genetically differentiated from the adjacent Eastern Mojave Recovery Unit (Hagerty and Tracy 2007; Murphy *et al*. 2007). Morphological characteristics and mtDNA from populations in the Western Mojave overlap those in the Colorado Desert Recovery Unit (Lamb *et al*. 1989; USFWS 1994a; Murphy *et al*. 2007). Tortoises in the west Mojave from the Kramer Hills region are differentiated from desert tortoises at in the Chemehuevi Valley in the Colorado Desert Recovery Unit at several allozyme loci (Rainboth *et al*. 1989). There also may be some sub-structuring within the Western Mojave Recovery Unit (Murphy *et al*. 2007), which may be an artifact of discrete sampling within generally continuous habitat (Allendorf and Luikart 2007:400). In addition, up to 40 percent of individuals were incorrectly assigned to the appropriate subpopulation in assignment tests; habitat in California was well connected prior to human development, allowing gene flow to occur over long geographic distances and multiple vegetation types (Murphy *et al*. 2007). The north half of this recovery unit borders the Eastern Mojave Recovery Unit along the Baker Sink, a low-elevation, extremely hot and arid strip that extends from Death Valley to Bristol Dry Lake and Cadiz Valley. To the south, the transition between the Colorado and Mojave deserts is more subtle. However, urban development along California State Highway 62 now largely separates the Western Mojave and Colorado Desert recovery units.

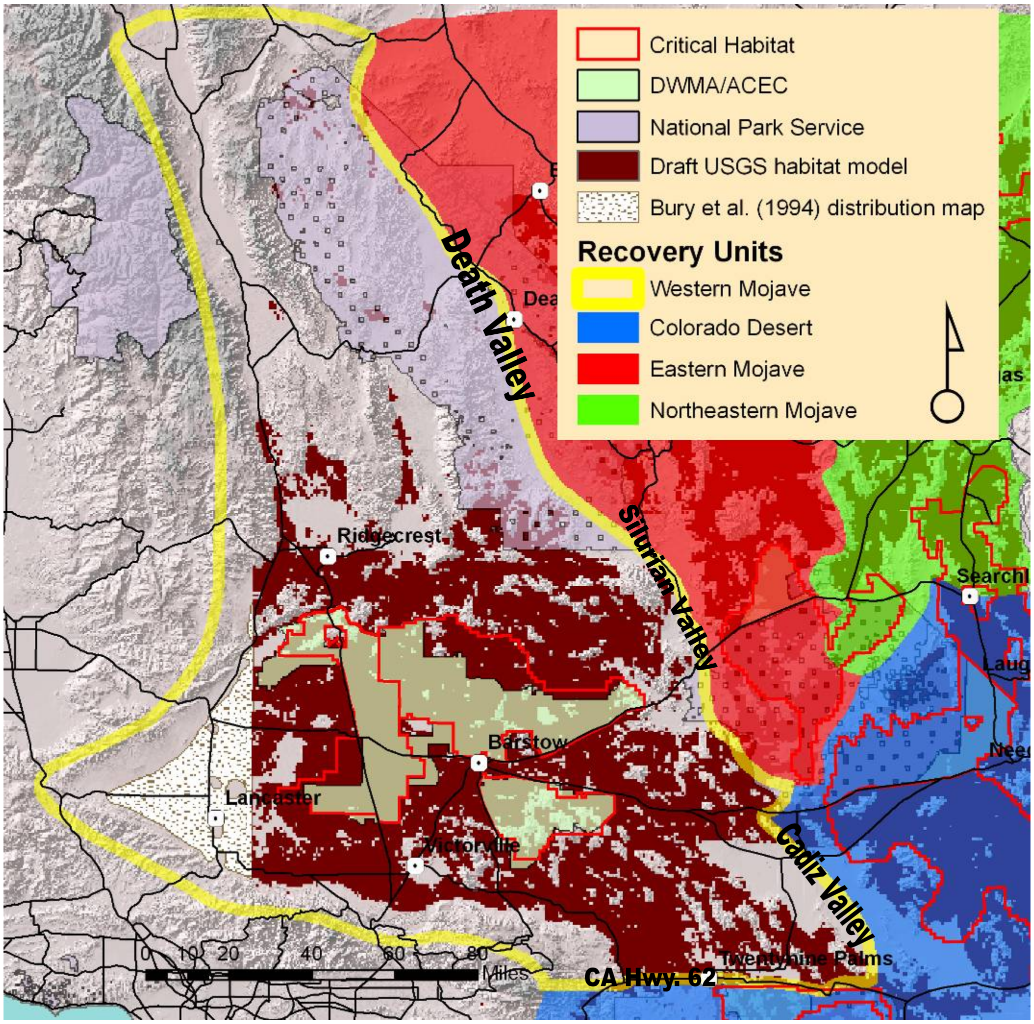


Figure 12. Western Mojave Recovery Unit. DWMA = Desert Wildlife Management Area; ACEC = Areas of Critical Environmental Concern.

A pronounced difference between the Western Mojave and other recovery units, including the closely allied Colorado Desert Recovery Unit, is in timing of rainfall and the resulting vegetation. Most rainfall occurs in fall and winter (Table 3) and produces winter annuals, which are the primary food source of tortoises. The Western Mojave Recovery Unit contains a unique combination of vegetation types, including the Mojave saltbush (*Atriplex* spp.)-allscale (*A. polycarpa*) scrub complex, blackbrush scrub, cheesebush (*Hymenoclea salsola*) scrub, iodinebush (*Allenrolfea occidentalis*)-alkali scrub complex, desert needlegrass (*Achnatherum speciosum*) scrub steppe, big galleta (*Pleuraphis rigida*) scrub steppe, and the Indian ricegrass (*Achnatherum hymenoides*) scrub-steppe complex, extending slightly into the southwestern Colorado Desert (USFWS 1994a). Above-ground activity occurs primarily (but not exclusively) in spring, associated with winter annual production. Thus, tortoises are adapted to a regime of winter rains and rare summer storms. Here, desert tortoises occur primarily in valleys, on alluvial fans, bajadas, and rolling hills. The extreme differences in precipitation and food availability relative to the other recovery units correspond to different foraging and activity patterns, as well as life history characteristics. Tortoises dig deep burrows (usually located under shrubs on bajadas) for winter hibernation and summer estivation due to generally warm summers and cold winters (Table 3). These desert tortoises generally den singly. Tortoises in the Desert Tortoise Research Natural Area within this recovery unit produce relatively larger eggs, produce fewer eggs overall, lay their second clutches later, and are larger overall than tortoises near Goffs in the Colorado Desert Recovery Unit (Wallis *et al*. 1999). Tortoises in the western Mojave Desert have the smallest reported minimum size at first reproduction (less than 18 centimeters [7 inches]) compared to populations in other recovery units (Germano 1994). Behaviorally, western Mojave tortoises are much less active during summer than are tortoises in other recovery units.

Table 3. Climatic summary for weather stations within desert tortoise recovery units. %J-S = percent of precipitation falling in summer; W and S = number of winter and summer days with 2.5 mm precipitation. Some stations are listed more than once where they occur near the boundary of multiple recovery units. Superscripts are initials of recovery units which particular stations border. Table modified from Table E1 in USFWS (1994a).

		Temperature (ºC)				Precipitation (mm)		No. Days with 2.5 mm Ppt	
Station	**Elev (m)**	**Mean Ann Min**	**Mean Jan**	**Mean July Max**	**No. Days Freeze**	**Mean Ann**	**%J-S**	**W**	**S**
Upper Virgin River Recovery Unit									
St. George	823	15.6	-5.3	38.4	96	209.6	29.2	16	4
Northeastern Mojave Recovery Unit									
Littlefield	567	18.2	-1.1	40.3	74	157.5	23.8	15	3
Las Vegas WPAP	659	18.9	-0.1	40.1	46	99.1	40.0	8	3
Boulder City	770	19.4	3.3	38.4	13	137.2	33.4	11	3
Desert NWR	890	16.8	-1.5	38.2	127	103.9	27.1	6	3
Searchlight[CD]	1070	17.5	1.7	36.1	34	208.7	37.3	11	5
Mountain Pass[EM]	1442	---	-2.0	34.8	---	173.0	31.2	---	---
Eastern Mojave Recovery Unit									
Cow Creek	-38	25.1	4.9	46.7	3	49.5	17.4	4	0
Greenland	-51	22.4	3.1	46.6	8	41.4	18.4	4	0
Baker[WM]	319	---	0.9	42.9	---	75.2	20.7	8	1
Beatty	1010	15.3	-2.4	37.5	88	118.0	14.9	11	2
Mountain Pass[NM]	1442	---	-2.0	34.8	---	173.0	31.2	---	---
Colorado Desert Recovery Unit									
Thermal	-37	22.8	3.9	41.8	12	70.1	21.4	4	1
Indio	3	22.9	3.4	41.6	15	79.8	19.7	4	0
Blythe	81	22.2	2.0	42.2	12	100.3	32.7	5	1
Palm Springs	128	22.3	4.4	42.2	12	138.9	11.2	9	2
Parker Res	225	23.3	5.3	42.3	1	129.3	32.8	8	3
Needles	278	22.5	4.7	42.3	6	111.8	33.9	7	3
Iron Mtn	281	23.0	5.6	42.1	2	79.5	20.1	5	2
Eagle Mtn	297	23.0	5.6	41.0	1	82.8	36.5	5	1
Hayfield	418	21.1	3.4	40.5	15	95.6	31.9	6	1
Twentynine Palms[WM]	602	19.7	1.6	37.2	29	104.4	36.3	5	4
Joshua Tree[WM]	838	---	---	---	---	123.7	23.4	---	---
Searchlight[NM]	1070	17.5	1.7	36.1	34	208.7	37.3	11	5

Table 3. Continued.

Station	Elev (m)	Temperature (°C) Mean Ann Min	Mean Jan	Mean July Max	No. Days Freeze	Precipitation (mm) Mean Ann	%J-S	No. Days with 2.5 mm Ppt W	S
Western Mojave Recovery Unit									
Baker[EM]	319	---	0.9	42.9	---	75.2	20.7	8	1
Trona	517	18.9	-0.6	41.3	47	82.0	8.4	8	0
Twentynine Palms[CD]	602	19.7	1.6	37.2	29	104.4	36.3	5	4
Barstow	653	17.7	-0.4	39.1	57	108.5	27.2	10	2
Lancaster	717	16.1	-1.9	37.4	80	124.2	2.9	11	0
Inyokern	744	17.6	-1.1	39.4	65	90.7	5.6	8	0
Palmdale AP	767	15.8	-1.6	36.7	81	139.2	3.2	12	0
Buckus Ranch	806	16.6	-1.2	37.0	67	162.9	5.5	12	1
Palmdale	809	16.5	-2.7	36.6	60	130.8	3.7	12	0
Joshua Tree[CD]	838	---	---	---	---	123.7	23.4	---	---
Mojave	846	---	-0.7	37.4	---	128.5	8.1	---	---
Victorville	871	15.3	-2.7	35.4	84	135.7	5.6	9	0
Lucerne Valley	919	15.8	-2.4	38.9	104	108.2	18.1	10	3
Fairmont	933	15.7	2.2	32.6	29	376.7	2.3	20	0
Hesperia	974	---	---	---	---	157.7	6.3	---	---
Randsberg	1076	17.2	1.6	36.7	33	149.6	9.9	11	1
Valyermo	1129	13.9	-2.5	40.3	103	263.3	7.6	13	1
Llano	1164	16.1	0.9	34.5	44	174.8	7.9	13	2
Haiwee	1166	15.5	-1.3	37.0	73	150.6	9.6	8	2
Wildrose RS	1250	---	-1.6	35.1	---	185.2	19.8	---	---
Kee Ranch	1318	---	---	---	---	167.6	9.2	7	2

C. 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.

Box 4. 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.

The recovery criteria can be viewed as the targets (rather than strict rules) by which progress toward achievement of recovery objectives can be measured. The revised criteria address a) representation (conserving the breadth of the genetic makeup of the species to conserve its adaptive capabilities), b) resiliency (ensuring that each population is sufficiently large to withstand stochastic events), and c) redundancy (ensuring a sufficient number of populations to provide a margin of safety for the species to withstand catastrophic events). Recovery criteria must be measurable and objective, but they need not all be quantitative.

Importantly, recovery criteria should also include the management or elimination of threats, addressing the five statutory (de-)listing factors. However, 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 (Boarman 2002; Tracy *et al.* 2004). As described previously, the facts that desert tortoises require over a decade to reach maturity, they have temporally variable reproduction, and juveniles have low survival rates, make 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). Therefore, specific and meaningful threats-based recovery criteria cannot be identified at this time. For example, we lack quantitative data on the specific contribution of raven predation, disease, or other individual threats on tortoise population declines. A specific criterion to reduce raven predation by a specified amount may ultimately be unnecessary as we learn more about, and better manage, other particular threats.

In the meantime, threats are addressed in the recovery actions outlined in the next section, and we assume that threat mitigation will have been successful if the current recovery criteria 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 3.4, 5.4, 5.5).

The relative strengths of postulated 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, more specific threats-based recovery criteria may be defined during future recovery plan review and revision, and effective management actions can be identified, prioritized, and implemented through land use plans, cooperative agreements, or other recovery management agreements. In fact, given the list of – and uncertainty surrounding the relative importance of – threats to the desert tortoise, the desert tortoise may well fit within the concept of a conservation-reliant species, requiring ongoing, concerted management efforts even after our recovery criteria have been achieved (Scott *et al*. 2005).

1. Recovery Goal

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

2. Recovery Objectives and Criteria

Recovery objectives and criteria are outlined below, followed by more detailed explanation and rationale. Note that the recovery criteria generally will be measured within tortoise conservation areas or other areas identified by Recovery Implementation Teams (see Recovery Action 1), and they are not independent of each other but must be evaluated collectively. Recovery does not depend on absolute numbers of tortoises or comparisons to pre-listing estimates of tortoise populations, but rather the reversal of downward population trends and elimination or reduction of threats that initiated the listing.

(a) 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 are increasing (*i.e.*, $\lambda > 1$) over 25 years (a single tortoise generation), as measured

a) by extensive, range-wide monitoring across tortoise conservation areas within each recovery unit, and

b) by direct monitoring and estimation of vital rates (recruitment, survival) from demographic study areas within each recovery unit.

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

Recovery Criterion 2. Distribution of desert tortoises throughout each tortoise conservation area is increasing over 25 years (*i.e.*, $\psi > 0$).

(c) 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 3. The quantity of desert tortoise habitat within all desert tortoise conservation areas is maintained with no net loss until tortoise population viability is ensured. When parameters relating habitat quality to tortoise populations are defined and a mechanism to track these parameters established, the condition of desert tortoise habitat should also be demonstrably improving.

3. Rationale

(a) Recovery Objective/Criterion 1 (Demography). *This objective and associated criteria emphasize the need to increase desert tortoise populations across tortoise conservation areas in each recovery unit over 25 years (a tortoise generation). Achievement of these criteria will indicate that all listing factors (A-E) will have successfully been addressed.*

The original listing of the desert tortoise was based on documented downward trends in a number of populations rather than on absolute numbers of tortoises being below a threshold level (USFWS 1990). In addition, while we have some historical information on desert tortoise densities within some localized areas, no historical (pre-listing) information exists on regional population levels. Therefore, evidence that the ecological processes maintaining tortoise populations have been sufficiently restored to warrant consideration for delisting will be based on observation of a positive population trend over 25 years. Basing the criteria on trends has an advantage over setting specific target numbers (*e.g.*, 40 tortoises per kilometer^2 [104 tortoises per mile^2]), because absolute tortoise numbers may show considerable variation between regions as a result of ecological differences or other factors, but a positive population trend is a clear indication that mechanisms leading to recovery are in place and that recovery is occurring. For example, there is evidence that historic natural population densities differed between the Upper Virgin River and Colorado Desert recovery units (USFWS 2006a), but the reason for different population densities is not known. There is no reason to think that a single target density should be applied to all recovery units, yet attempting to set unique targets for each recovery unit would not be prudent given the lack of data on both historic population numbers and what numbers would constitute sustainable populations in the current environment. However, if all areas demonstrate a positive population trend regardless of actual population counts, the interpretation will be that recovery is occurring.

The way ecologists estimate whether a population is increasing or decreasing is by using a variable called lambda (λ), which indicates population change. When λ is greater than one, the population is considered to be increasing and when it is less than one, the population is decreasing. Several kinds of data (*e.g.*, counts of individuals, recruitment and survival rates) can be used to derive estimates of λ. This is reflected in our use of two recovery criteria here. Recovery Criterion 1a is based on data that are relatively easy to gather over large areas using range-wide monitoring with counts of individuals (*i.e.*, line distance sampling), while Recovery Criterion 1b is based on data that are more difficult to gather but that may give us a more precise indication of population change using vital rates such as recruitment and survival from demography study areas, as described more fully below.

Natural variability in population size and inherent measurement error make it extremely difficult to detect realistic natural increases (*i.e.*, less than 2 percent per year) in desert tortoise populations in as few as 25 years (USFWS 2006a). For this and other reasons, the Science Advisory Committee recommended the recovery criteria rely on a suite of measures instead of relying primarily on a single quantitative estimate that is difficult to measure in a species with a low intrinsic growth rate and is difficult to detect. At the same time, the Science Advisory Committee proposed using a 90 percent confidence band ($\alpha = 0.10$) to describe population trends. For an increasing trend, the lower 90 percent confidence limit for each estimate of λ should exceed 1. This precision level makes it possible to distinguish a small (less than 2 percent per year) trend from a non-growth trend, but is still fairly conservative. Although a convention exists to use 95 percent confidence intervals ($\alpha = 0.05$) for many statistical tests, setting $\alpha = 0.10$ has the conservative effect of guarding against incorrectly concluding a decline in tortoise density has not occurred at the expense of a slightly increased possibility that an increasing or declining trend is "detected" when, in fact, the population is stable (Shrader-Frechette and McCoy, 1993). Anderson and Burnham (1996), proposed $\alpha = 0.15$ for this monitoring program at the time they proposed the design. The Science Advisory Committee also noted that combined use of independent measures of recovery (population trends, habitat quantity and quality, threat abatement) provides additional assurance that detected trends are meaningful.

<u>Range-wide monitoring (Criterion 1a)</u>. The number of tortoises in each recovery unit is related to the density of tortoises estimated by line distance sampling techniques (USFWS 2006a). It can also be related to the extent of the habitat occupied by tortoises and how that extent expands or contracts over time (*e.g.*, Royle *et al*. 2005; see Recovery Criterion 2). Either approach can relate changes in an index (density or occupancy) to changes in time to estimate the population growth rate, λ. 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, hence we will also 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).

<u>Vital rates (Criterion 1b)</u>. Validating that vital rates are at increasing levels will be important to ensure that populations are able to maintain their size or trajectory upon delisting.

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, λ.

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, 5.1). The number, size, and sampling frequency of demographic study areas remain to be defined in coordination with the Science Advisory Committee and Recovery Implementation Teams, 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.

(b) Recovery Objective/Criterion 2 (Distribution). *This objective and associated criterion emphasize increasing the distribution of desert tortoises (within tortoise conservation areas) over 25 years. As such, it applies to Listing Factor A, the present or threatened destruction, modification, or curtailment of the tortoise's habitat or range*.

Recovery Criterion 1 focuses on population growth. Recovery Criterion 2 focuses on the distribution of tortoises across the landscape. The 1994 Recovery Plan only indirectly addressed this issue by recommending enough habitat be conserved to ensure viable tortoise populations, but it did not directly address population processes acting across the spatial scale of entire recovery units. The purpose of Criterion 2 is to prevent range contraction of the desert tortoise. To detect changes in desert tortoise distribution, we will monitor the ratio of sampling points at which tortoises are detected across tortoise conservation areas within each recovery unit (Figure 13). The probability that randomly sampled sites are occupied by the desert tortoise is referred to as occupancy (indicated by ψ; MacKenzie *et al.* 2006). Similar to λ in Recovery Criterion 1, we specify that the lower 90 percent confidence limit be used to evaluate the slope of ψ within each recovery unit (which must exceed 0). An average increase in tortoise density in a recovery unit reflected by growth only in highly localized areas, while tortoises in other areas are extirpated, would not reflect recovery.

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. Establishing a precise geographic baseline across all lands within tortoise conservation areas 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.

(c) Recovery Objective/Criterion 3 (Habitat). *This objective and associated criterion emphasize maintaining desert tortoise habitat within desert tortoise conservation areas, but are not meant to diminish the importance of populations and habitat outside the conservation areas. Therefore, they directly apply to Listing Factor A, the present or threatened destruction, modification, or curtailment of the tortoise's habitat or range.*

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 or extirpated 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 (T. Esque, U.S. Geological Survey, pers. comm. 2007).

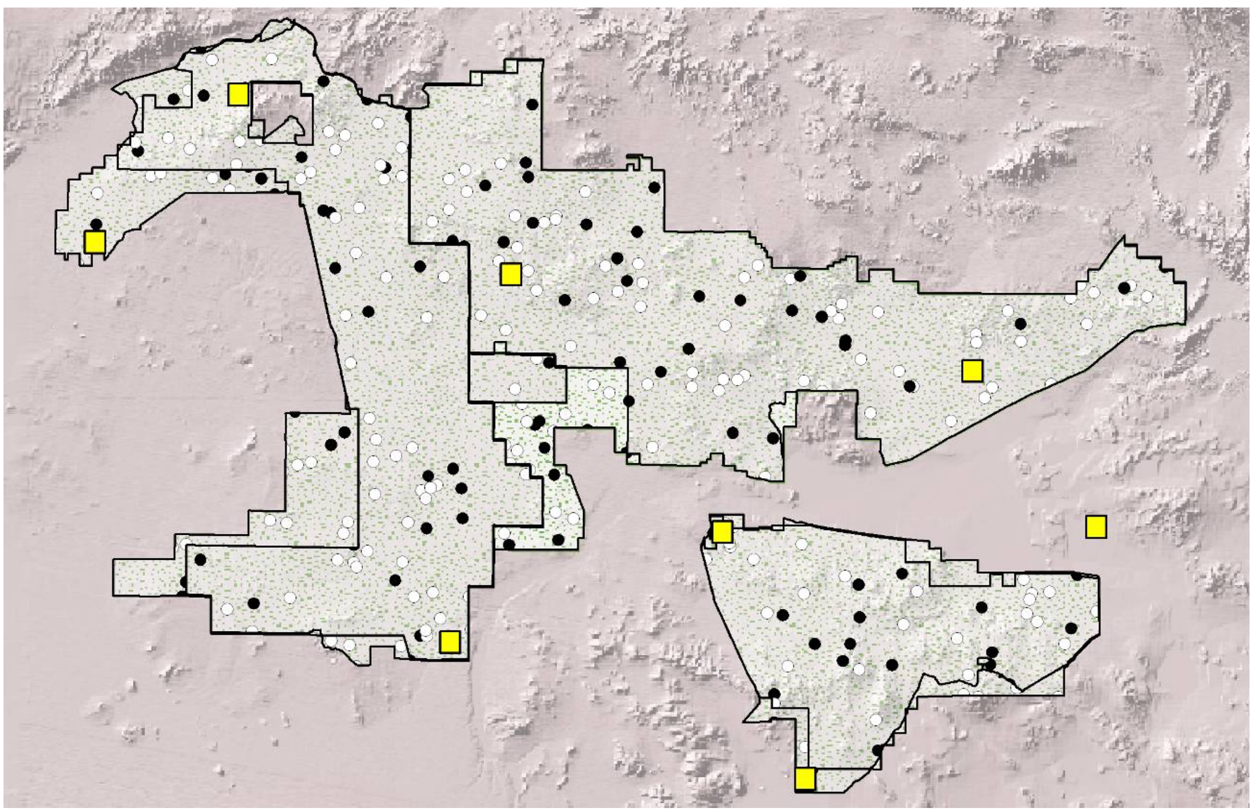


Figure 13. Example of hypothetical occupancy pattern. Stippled green polygons = tortoise conservation areas; filled circles = samples with at least 1 tortoise observation; open circles = samples with no tortoise observations; yellow boxes = hypothetical demographic study areas. Recovery Criterion 2 stipulates that tortoise occupancy increases (not necessarily the same samples, just the overall level).

Criterion 3 establishes a target for **no net loss** (Box 5) of current habitat *within tortoise conservation areas*. The geographic baseline over which trends in habitat quantity will be monitored includes all **potential desert tortoise habitat** (Box 5) within tortoise conservation areas at the time of publication of the final, revised recovery plan (see Recovery Action 4.3). This baseline will be "memorialized" in a range-wide recovery database (managed by the Desert Tortoise Recovery Office) by applying the final U.S. Geological Survey habitat model to habitat data at the time the recovery plan is published, in coordination with Recovery Implementation Teams (see Recovery Action 6.1). **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), thus achieving the no-net-loss standard and maintaining tortoise occupancy through maintenance of (quality) available habitat. However, the target for no net loss established by Recovery Criterion 3 may be relaxed on a *limited*, case-by-case basis, if we determine that greater recovery benefits can be achieved through other means than replacing every acre of lost habitat with another acre elsewhere. Given that tortoise conservation areas include both designated critical habitat and BLM's Desert Wildlife Management Areas and Areas of Critical Environmental Concern, which do not always coincide, the Recovery Implementation Teams will refine and recommend the geographic baseline for measuring no net loss of habitat, using available tortoise data in coordination with and approval by the Desert Tortoise Recovery Office.

Box 5. Terms related to monitoring habitat.

"Habitat loss" (evaluated under Recovery Criterion 3) is considered here as acreage subject to the complete or absolute removal of elements necessary for desert tortoise occupation (*i.e.*, grading or paving of the landscape so that no food or shelter resources are available) or other identified thresholds of habitat quality fall below that which can support desert tortoises.

"No net loss" of desert tortoise habitat refers to balancing acreage of habitat loss on public lands within tortoise conservation areas with new, restored, or enhanced acreage of habitat, such that at least the minimum conditions for desert tortoise occupation are met. No net loss of habitat may be relaxed under special circumstances in which we determine greater recovery benefits can be achieved through other means, and it will be evaluated over the expected 25-year recovery period.

"Habitat degradation" involves impacts to desert tortoise habitat, short of absolute habitat loss, that compromise its ability to support desert tortoises (*e.g.*, invasion of fire-adapted, non-native vegetation or increased incidence of unauthorized off-highway vehicle trails).

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

Given the vast amount of desert tortoise habitat already under Federal management, Criterion 3 does not apply generally to private lands. However, private or other non-Federal lands under conservation management for desert tortoises are included in tortoise conservation areas (see Box 2, page 32) and can contribute substantially to this recovery objective. In addition, habitat loss and degradation elsewhere must be minimized and mitigated, while not appreciably reducing the likelihood of survival and recovery of the tortoise, pursuant to section 10(a)(2) of the Endangered Species Act.

In order to manage desert tortoise habitat well enough to meet Objectives 1 and 2, we would also benefit from statistical models linking habitat data to tortoise demographic data (see

Recovery Action 5.2). Information from this type of model would allow us to identify minimum habitat conditions for potential tortoise occupancy and, therefore, to analyze occupancy as a function of habitat characteristics. We ultimately need to define specific parameters that relate to the quality of desert tortoise habitat (see Recovery Action 5.2) and to develop and implement a system for tracking habitat quality over time. In particular, we need to identify thresholds below which habitat degradation is so severe that the habitat fails to provide the minimum conditions for potential occupancy, due to fires for example. Measures related to habitat quality could include miles of roads and trails or the number and size of habitat fragment polygons created by roads. Incorporating a GIS "ledger" of habitat status into the range-wide recovery database, accounting for restored areas on the positive side and degraded or lost areas on the negative side, will 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, management agencies should report habitat status (particularly habitat loss/gains) on their lands (Recovery Action 1.1).

Land management agencies must work within the context of their respective land use plans, including the provisions of adaptive management such as Recovery Actions 6.2-6.3 contained within this recovery plan, to determine measures to assure no net loss and to improve quality of existing desert tortoise habitat. Until better population/habitat viability models are developed (see Recovery Action 5.2), land managers should also strive to limit the loss of desert tortoise habitat outside conservation areas as much as possible, although we reiterate that the most aggressive recovery efforts are targeted toward tortoise conservation areas. A variety of means are available to improve existing desert tortoise habitat both within and outside conservation areas. Re-establishment of native vegetation on burned landscapes may increase desert tortoise populations (see Recovery Action 2.6, especially for associated research needs). Closure of unnecessary or illegal routes of travel can create larger unfragmented blocks of habitat. Additional mitigation for habitat impacts outside conservation areas could include options such as habitat acquisition or restoration of degraded habitat in other areas or recovery units, contributions to research, or facilitating population augmentation programs within conservation areas, depending on current needs, priorities, and opportunities.

Actions or projects occurring outside tortoise conservation areas, which will be reviewed under existing State laws and the Federal section 7 and 10 processes, should seek to minimize (1) negative impacts in adjacent areas and (2) creation of edge effects (impacts within an area from projects or activities outside that area) 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.

D. RECOVERY ACTIONS

As noted previously, the recommended actions in the 1994 Recovery Plan formed a logical basis for recovery (GAO 2002), little information since 1994 contradicts these recommendations (Boarman and Kristan 2006), and insufficient time has elapsed over which detectable increases in desert tortoise populations or natural recovery of habitat could be realistically expected. Therefore, many of the specific recommendations listed below, especially under Strategic Element 2, are adapted from the 1994 Recovery Plan. However, the revised plan places a greater emphasis on solidifying partnerships across jurisdictional boundaries to maintain focus on implementing the recommended actions and conducting applied research, modeling, and effectiveness monitoring to evaluate actions in a formal adaptive management context. Table 4 identifies the listing factors and recovery objectives addressed by each major recovery action.

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

1.1. Establish regional, inter-organizational Recovery Implementation Teams to prioritize and coordinate implementation of recovery actions. 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 feasible. Therefore, regional Recovery Implementation Teams (which are exempted from the Federal Advisory Committee Act by section 4[f][2] of the Endangered Species Act) need to be established within 6 months of publication of the recovery plan to develop step-down plans and maintain focus on implementing recovery actions in coordination with the Desert Tortoise Recovery Office. The Desert Tortoise Recovery Office will work with interested managers and stakeholders to form the Recovery Implementation Teams in coordination with the Desert Tortoise Management Oversight Group. Recovery Implementation Teams 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, Recovery Implementation Teams should have broad representation by communities and the public in the recovery effort. Both technical experts and stakeholders should be represented.

Recovery Implementation Teams are the fundamental partnerships tying the adaptive management process together (Strategic Element 6; Figure 4). As a result, it is important that their regional/local efforts are productive and contribute to the range-wide effort. In order to ensure timely performance of tasks and cooperation between groups with disparate views, we recommend the following procedures:

- Each Recovery Implementation Team should have a chair to facilitate each meeting, and the Desert Tortoise Recovery Office should help organize activities through its regional recovery coordination staff. Independent facilitation should be secured, if necessary.

- Once the Recovery Implementation Team is constituted, the minimum list of participants to go forward with any meeting will be set. Unless decisions are adopted by all relevant parties, the Recovery Implementation Team is not making progress.

- The Recovery Implementation Team chair will alert participants to deadlines and ensure that all parties are aware of the need and schedule for moving the process forward.

- Recovery Implementation Teams should report annually to the Management Oversight Group and Science Advisory Committee to review progress on recovery implementation and provide any new recommendations for management or research.

Specific tasks of the Recovery Implementation Teams are described under Recovery Action 6 within the context of implementing the adaptive management program, but generally the teams should tier off the recovery plan by developing 5-year action plans and budget needs with priorities for management based on an updated decision support system (scaled to the level of local or jurisdictional levels). Priorities for studying the effectiveness of management actions (5.4) 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 Desert Tortoise Recovery Office and Recovery Implementation Teams should emphasize the collation of up-to-date information on threats and recovery action implementation into the decision support system and range-wide recovery database.

2. Protect Existing Populations and Habitat

A prototype decision support system (Strategic Element 6, Appendix C), using information provided by managers during recovery planning workshops, produced preliminary recovery action priorities relative to protecting desert tortoise populations and habitat for each recovery unit (Appendix C-7). Actions 2.1 and 2.2 below are general actions that are not included in the current decision support system. While general priorities for each recovery unit are included in the descriptions of the remaining actions below and specific rankings are listed in Appendix C-7, relative priorities for each action may change as additional information is integrated into the decision support system at local levels within each recovery unit or as new information is gained through research and monitoring. Most of the actions described below have been implemented to a greater or lesser extent in various parts of the desert tortoise's range. Inclusion in the revised plan reflects an emphasis on maintaining these actions where implemented, although general priorities may be lessened for actions that have been more broadly implemented (*e.g.*, minimize livestock grazing) and effectiveness generally needs to be more specifically evaluated. Note that other State or Federal agency policies and regulations may impose specific measures or processes to determine appropriate compensation or mitigation both within and outside of tortoise conservation areas.

At this stage, the following actions serve as guidelines, especially within tortoise conservation areas as defined in Box 2, that management agencies should implement according to their respective land-use or similar plans. For example, specific measures designed to minimize or mitigate habitat loss (*i.e.*, maintain the "no net loss" standard of Recovery Criterion

3) or habitat degradation should be implemented by each land management agency in coordination with their respective Recovery Implementation Teams according to the local situation (*e.g*., short-term or long-term impact, effect to high-quality or low-quality habitat) and governing authorities. Deviations from the following actions may be appropriate in some cases, but they should be supported by scientific rationale or justification as to how they can contribute to recovery. Again, quantifying the effectiveness of these or modified recovery actions is important, as specified under Action 5.4.

2.1. Protect intact desert tortoise habitat. Land disturbances should be precluded within tortoise conservation areas. In particular, fires should be suppressed aggressively throughout the Mojave and Colorado deserts to contain the grass-fire cycle. Minimizing the size and intensity of fires will ease subsequent restoration efforts (2.6), 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.

Development of alternative energy sources has also recently come to the forefront as a necessary and congressionally mandated use of public lands that could have large-scale impacts to desert tortoise habitat. Pursuant to the Bureau of Land Management land use plans, solar project facilities will be sited outside Desert Wildlife Management Areas and Areas of Critical Environmental Concern. Current proposals for energy projects within these land allocations should be relocated so that impacts to these areas are avoided. A cumulative impacts assessment should be conducted and appropriate areas and mitigation measures for this type of activity should be identified.

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. Specific recommendations are listed below, and additional background and details can be found in Appendix B.

- All tortoises found in the wild that may be released captives without a health check should be removed from the wild and used for breeding, adoption, or research programs unless they are determined to be uninfected and are genetically acceptable for that population.

- 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.

- 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.

Uninfected populations that have recently become infected should be carefully monitored with the removal of all individuals exhibiting acute infections. Acute infections are defined as those exhibiting a nasal or ocular discharge at an inappropriate time of year.

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 under State laws 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 is a relatively high priority in all recovery units (especially Upper Virgin River) and includes enforcing regulations pertinent to the specific recommendations to protect tortoises or their habitat listed below. This action also includes using existing officers to ensure law enforcement presence during peak recreational use periods such as weekends and holidays on a rotational basis so enforcement activity is not lost on casual users during standard work week hours. Increasing fines and establishing agreements between offices of adjacent management authorities 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 who would make contact with public land users, communicate with law enforcement officers, and conduct other activities, as necessary (*e.g.*, minor restoration or trash removal). Such personnel should be coordinated with the appropriate agencies to focus on particular issues in their respective areas. Brochures identifying and encouraging reporting of problem illegal activities could be developed and distributed to management agencies for further distribution to recreationists or others. The following is a list of illegal activities known to negatively affect the desert tortoise and warrant increased enforcement.

- Unauthorized off-road vehicle travel. Across all recovery units, this aspect of law enforcement is 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 deliberate maiming and killing of tortoises.

- Deliberate maiming and killing of tortoises. Formerly referred to as vandalism (Luke *et al.* 1991), specific examples include shooting, crushing, driving over, flipping over, and decapitating tortoises. Shooting (also called "plinking"), by far, is the most prevalent method (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 threat.

- 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, particularly in Nevada (breeding and possession of desert tortoises is prohibited in California and Washington County, Utah, respectively), 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, and (increased) fines may be warranted for the release of captive tortoises into the wild.

- Uncontrolled dogs. Domestic and feral free-roaming dogs are documented threats to captive and wild tortoises (Bjurlin and Bissonette 2001; see Boarman 2002). 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, may 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.

- Dumping and littering. Dumping and littering provide subsidies to predators, thus elevating their populations and predation pressure on tortoise populations. It can also 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. Collectively, the actions described below are of relatively high priority in all recovery units.

- Establishment of new roads should be avoided to the extent practicable within desert tortoise habitat on public lands, especially within tortoise conservation areas. Tortoise conservation areas should have a minimum goal of "no net gain" of roads.

- 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. Route designation is a particularly high priority in all recovery units except Upper Virgin River (moderate priority).

- 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. Road closures are a particularly high priority in all recovery units except Upper Virgin River (moderate priority).

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

  "Hot-spots" of road mortality should be identified and prioritized, but fencing roads is a particularly high priority in the Upper Virgin River Recovery Unit. Other areas in California in need of fencing include parts of US-395, I-40, and SR-247 in the Western Mojave Recovery Unit and 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 and Colorado Desert recovery units. 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).

- While graded roads typically need not be fenced, berms should be maintained such that tortoises do not get trapped in the roadbed. This is a particular issue in the Colorado Desert Recovery Unit, as well as throughout the Mojave National Preserve.

2.6. 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, horses and burros, invasive species, fire, environmental contaminants, and utility corridors. As such, this action is highly prioritized within the Eastern Mojave, Western Mojave, and Colorado Desert recovery units and moderately prioritized within the Northeastern Mojave and Upper Virgin River recovery units. 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. A great deal of research has been conducted on restoration and rehabilitation of habitats in arid and semi-arid ecosystems with varied results (see Roundy *et al.* 1995; Bainbridge 2007). Previous and ongoing studies should be used to inform implementation of restoration activities in desert tortoise habitats.

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 preclude land disturbance in the first place and protect remaining, intact habitats (2.1). 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.

- <u>Eradicate or suppress invasive weeds</u>. 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.

- <u>Revegetate degraded areas with native plants of high nutritive quality to desert tortoises, as well as shrubs needed for cover</u>. 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.

- 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.

2.7. Install and maintain urban or other barriers. 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 for this action include:

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

- around new developments (*e.g.*, Coyote Springs Valley) and the edges of the Las Vegas metropolitan area in the Northeastern Mojave Recovery Unit.

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

- around the town of Goffs in the Colorado Desert Recovery Unit ranked as mid-level priorities in the decision support system (Appendix C).

2.8. Sign and fence boundaries of sensitive or impacted areas. This action (relatively high priority in the Upper Virgin River Recovery Unit and moderate priority elsewhere) 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.

2.9. Secure lands/habitat for conservation. This action is of moderate priority in all recovery units. It counters habitat loss and protects tortoises, provided secured lands are suitable habitat (see Action 2.1) 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 and other private-landowner incentives 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 noted by managers 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 in the decision support system (Appendix C) 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.

2.10. Restrict off-highway vehicle events within desert tortoise habitat. This action refers to large- or small-scale competitive races or non-competitive events 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 demonstrably 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. Event planning should avoid existing tortoise conservation areas to the extent practicable.

2.11. Connect functional habitat. Connecting fragmented habitat helps to maintain gene flow between isolated populations. This action improves species fitness (ability to maintain or increase its numbers in succeeding generations) by maintaining diversity, 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 is of consistently moderate priority among recovery units. It entails connecting isolated blocks of desert tortoise habitat, particularly through corridors of natural habitat for large-scale connectivity, as well as culverts for smaller-scale connectivity across fenced roads and railroads.

2.12. Limit mining and minimize its effects. Impacts from mining can include habitat destruction and direct mortality from off-road exploratory travel; habitat loss to road and development construction, sand and gravel extraction, 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; refuse of stakes and wire from seismic testing; creation of disturbance zones for invasive plant species to establish.

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.

2.13. Limit landfills and their effects. Landfills impact tortoise populations by removing habitat, spreading garbage, introducing toxic chemicals, increasing road kills by vehicles going to and from the landfill, and facilitating proliferation of predators. 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 areas in the spring to prey upon tortoises (Boarman 2002). Proper landfill management (including dumps and sewage ponds) can help reduce several threats to tortoises, but 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 8 kilometers (5 miles) of existing tortoise conservation area boundaries.

2.14. Reduce excessive 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. Coyotes have been seen to prey upon numerous adult desert tortoises within local areas, especially in times of drought.

Several other recovery actions (2.4, 2.5, 2.13) address raven population management by limiting human subsidies (*e.g.*, food obtained at landfills and from roadkills). This action emphasizes direct predator-control programs to reduce predation on tortoises where specific problem areas are identified. Control methods can include targeted removal of known tortoise predators by shooting or trapping (live or lethal), as well as nest removal, directed at specific problem areas within tortoise conservation areas or where predation is affecting specific recovery-related research. We do not consider general, widespread predator control to be an appropriate recovery action.

2.15. Minimize impacts from horses and burros. Wild horses and burros alter desert tortoise habitat through soil compaction and vegetation change (Boarman 2002).

Tortoises and horses and burros may also compete for the same food. 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 eliminated 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 eliminated.

This action entails continued exclusion of horses and burros from desert tortoise conservation areas by fencing and/or removal. Managing for zero population levels and gathering animals to maintain this goal inside desert tortoise conservation areas is consistent with existing land use plans and the Wild Free Roaming Horses and Burros Act of 1971.

2.16. Minimize 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 competing for food (Boarman 2002).

While many cattle and sheep allotments have already been retired within desert tortoise habitat, 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. Protocols and guidelines should also draw upon recommendations by the Science Advisory Committee relative to controlling disease (Appendix B).

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. Secure facilities and obtain tortoises for use in augmentation efforts.

- 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. See also Science Advisory Committee recommendations related to desert tortoise holding facilities and the control of disease (Appendix B).

- Obtain adult tortoises for generation of progeny. Tortoises used in the head-starting program will be of known origin and of the genotype (genetic makeup) 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.

- Head-start progeny. Maintain progeny in captivity as specified in guidelines developed under 3.1.

- 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 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 individual-agency annual budgeting considerations, the Desert Tortoise Management Oversight Group should implement the GAO's recommendation (for example, through 5-year time frames) to 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.

- Monitor the number of tortoises in each recovery unit. We will estimate population change (λ) on a recovery-unit-wide scale through measures of population size, density, and/or occupancy. Refinement of range-wide monitoring techniques should continue, as recommended by USFWS (2006a).

- Use demographic rates in key areas of each recovery unit (*i.e.*, demographic study areas) to independently estimate population growth in each recovery unit. Dynamic vital-rate models should be used to provide an independent estimate of the population growth rate, λ. Some existing or prior study plots may be appropriate for inclusion in the set of demographic study areas to make use of long-term datasets.

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 population growth rate, λ. In addition, historical study-plot and sign-count data should be compared with current patterns of live and dead tortoise concentrations to provide insights into recent larger scale declines relative to those reported from some plots (USFWS 2006a).

4.3. Track changes in the quantity and quality of desert tortoise habitat. A baseline for tracking habitat quantity across each recovery unit will exist with the habitat model specified in this revised recovery plan (5.2). Trends in habitat quality over time should be integrated into the recovery database/decision support system (6.1) as conditions affecting habitat quality are identified (5.2). 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; the number and average size of habitat fragment polygons created by roaded boundaries).

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 (6.1, Appendix C), including disease and other threats that may be related to habitat quality discussed above. 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. Characterize stable age distributions of stable or increasing populations. Research on demographic study areas should document age distributions sufficiently to characterize the stable age distribution (the age distribution of a population under constant survivorship and recruitment) that distinguishes a stable or increasing population from a decreasing one, especially including the proportion of juveniles represented.

5.2. Determine factors that influence the distribution of desert tortoises.

- <u>Validate and refine the desert tortoise habitat model</u>. The draft U.S. Geological Survey desert tortoise habitat model should be completed within the first year of publication of the final revised 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.

- <u>Determine characteristics that contribute to the relative condition (*e.g.*, high, medium, or low quality) of desert tortoise habitat</u>. 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 3 relative to ensuring that habitat quality increases over the next 25 years. Research in this area should identify:

    - landscape attributes, if any, that cause clumping of desert tortoises; and

    - minimum conditions for potential desert tortoise occupancy.

- <u>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</u>. As habitat-specific demography is clarified, 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.

5.3. Conduct research on the restoration of desert tortoise habitat.

- 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 2.6.

- Identify methods to eradicate non-native, 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 2.6.

- 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 (5.2). This action may also be implemented in coordination with population augmentation (3.1-3.4) and monitoring demographic study areas (4.1).

5.4. Improve models of threats, threat mitigation, and desert tortoise demographics. The decision support system (6.1) 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.

- 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.

- 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. While the precise role of disease in desert tortoise population declines relative to other threats is unclear, disease has been a high-profile and controversial topic. Therefore, we provide specific recommendations to better understand the nature and relative importance of disease to desert 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).

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

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

- Determine whether diets high in non-native plants increase susceptibility to disease, as well as infectiousness.

- 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.

- 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.

- 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 and anti-inflammatory steroids have met with some success and could be extended.

- 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.

- Examine the implications of releasing sick tortoises into uninfected populations. Such studies should occur within enclosures at captive holding facilities.

- 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.

- 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).

5.6. Resolve population structure of the desert tortoise across its range. Additional research is needed to refine understanding of desert tortoise population structure and the extent to which recovery units conform to natural population subdivisions, as well as the importance of corridors and physical barriers to gene flow.

- 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; clarification of recovery unit boundaries) and potential distributional shifts resulting from climate change.

6. Implement an Adaptive Management Program

Recovery Implementation Teams (established under Strategic Element 1; *Partnerships* in Figure 4) will be the driving force, in coordination with the Desert Tortoise Recovery Office, behind the implementation of the adaptive management program. Here, we describe the specific steps that the Recovery Implementation Teams and Desert Tortoise Recovery Office must apply in order to fully implement the program. We refer to these steps, depicted in Figure 4, with italicized labels in the text below.

6.1. Revise and continue development of a recovery decision support system. The Recovery Implementation Teams begin the adaptive management process by *Assessing the Problem.* Toward that end, a preliminary decision support system has been developed (Appendix C) to identify and prioritize recovery actions relative to managing desert tortoise populations and habitat (see Protect Existing Populations and Habitat, above). Due to the lack of data on the effects of individual threats on tortoise demography, the 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 spatially explicit synthesis of recovery actions that have been implemented pursuant to the 1994 Recovery Plan has been completed. 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, including any new monitoring or research results, should be regularly *Evaluated* (at least biennially) by independent reviewers including the Science Advisory Committee. The decision support system should be then be *Adjusted* to achieve 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.

One of the challenges 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. Refinement of the decision support system should also continue to clarify and operationalize recovery action terminology.

Specific tasks and timelines relative to this action include:

- Within the first year after publication of the final, revised recovery plan, the Recovery Implementation Teams, Desert Tortoise Recovery Office, and other partners, should update the underlying data in the decision support system for at least two recovery units, including data on threats and current recovery-action implementation. This stage should be completed for the remaining recovery units within the second year, and regular updates to all recovery units should occur on an ongoing basis thereafter.

- Within the second year after publication of the revised recovery plan, the Desert Tortoise Recovery Office, Science Advisory Committee, and other independent reviewers should evaluate the underlying models in the decision supports system. Re-evaluation should occur at least biennially, although it is likely that different models will be in different stages of evaluation or revision within each biennium.

6.2. **Develop/revise recovery action plans.** Recovery Implementation Teams should use the decision support system to tier off the recovery plan by developing 5-year action plans and budget needs with priorities for management scaled down to local or jurisdictional levels. Five-year action plans should be coordinated with the

Management Oversight Group and completed within the first year of publication of the revised recovery plan. Initial application of the decision support system for prioritizing actions at the local or regional level will vary among recovery units according to the timeline for updating the system, as described above.

- The first step in each adaptive-management iteration includes prioritizing general actions, followed by identification of spatially and temporally explicit actions, specific enough that the action plans can be reviewed, critiqued, and adopted without confusion in relevant planning documents of the participating land management agencies. For instance, if "roads" are identified as a priority threat in a particular Recovery Implementation Team area, the general action recommended might be "road closures." The Recovery Implementation Team would then proceed to recommend specific roads for closure, so that the appropriateness of this action can be evaluated, and the action agencies have clear understanding of the Recovery Implementation Teams' recommendations.

- In conjunction with prioritizing recovery actions, the Recovery Implementation Teams must prioritize needs for effectiveness *Monitoring* or other *Research*. In order to rank monitoring priorities, a further step from the decision support system is required. Recovery Implementation Teams will need to describe conceptual models that link each threat to each of the pathways that impact tortoise health, survival, movement, population structure, recruitment, or fecundity. These models are part of *Assessing the Problem* and are the first step in describing the linkages that will be affected by management activities, so they also point to the type of *Monitoring* or *Research* that will capture the effectiveness of these activities in breaking the links. Population augmentation in conjunction with other land management, effectiveness monitoring, or research activities may also be recommended through the procedures described under Recovery Action 3. These 4 elements (Strategic Elements 2-5) will be reviewed by the Desert Tortoise Recovery Office and placed within the larger range-wide strategy.

- Once the recovery action plans, including prioritized actions, monitoring, and research, have been developed by the Recovery Implementation Teams and Desert Tortoise Recovery Office and approved by the Management Oversight Group, the relevant land management agencies will use their own processes to *Design* and *Implement* actions. By *Design*, we mean that the necessary planning processes will be engaged to formalize each agency's commitments to the adopted actions. Because all Recovery Implementation Team members should remain fully engaged, it is important that all represented land management agencies have clear tasks for each Recovery Implementation Team cycle.

- The Recovery Implementation Teams and Desert Tortoise Recovery Office should report progress on recovery implementation to the Management Oversight Group on an annual basis and revise the recovery action plans accordingly.

6.3. Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions. Federal, State, County, and City land managers should *Adjust* recovery efforts based on outcomes of the processes described above by amending planning documents as needed. 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 Area of Critical Environmental Concern plans, are an opportunity to work with stakeholders to build in detailed planning at local levels.

6.4. Incorporate scientific advice for recovery through the Science Advisory Committee. The Desert Tortoise Recovery Office should continue to work directly with the Science Advisory Committee and other independent experts, meeting at least annually to *Evaluate* progress in *Research* and *Monitoring* and other recovery plan accomplishments. The Science Advisory Committee should make new recommendations, as needed, based on progress in implementing the recovery plan. A particular need exists for vigilance in focusing on large-scale, range-wide tortoise recovery, maintaining connection to *Recovery Criteria* in the 25-year horizon, through at least 5-year evaluations of the range-wide monitoring program. Annual Science Advisory Committee meetings should include an opportunity for stakeholder and manager interaction, potentially in association with Management Oversight Group meetings, to provide direct feedback and information exchange.

Table 4. 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.	**Develop, support, and build partnerships to facilitate recovery**		
1.1	Establish regional, inter-organizational Recovery Implementation Teams to prioritize and coordinate implementation of recovery actions.	All	All
2.	**Protect existing populations and habitat**		
2.1	Protect intact desert tortoise habitat.	A,E	3
2.2	Reduce factors contributing to disease.	C	1,2
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	Restore desert tortoise habitat.	A,E	3
2.7	Install and maintain urban or other barriers.	A-C	All
2.8	Sign and fence boundaries of sensitive or impacted areas.	A,B	3
2.9	Secure lands/habitat for conservation.	A	3
2.10	Restrict off-highway vehicle events within desert tortoise habitat.	A,B	All
2.11	Connect functional habitat.	A	2
2.12	Limit mining and minimize its effects.	A,C	All
2.13	Limit landfills and their effects.	A,C	1,3
2.14	Reduce excessive predation on tortoises.	C	1
2.15	Minimize impacts from horses and horses.	A	3
2.16	Minimize livestock grazing.	A	3
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
3.3	Secure facilities and obtain tortoises for use in augmentation efforts.	All	1-2
3.4	Implement translocations in target areas to augment populations.	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.	A,D,E	3

Table 4. Continued.

	Recovery Action	Listing Factor	Recovery Objective
4.4	Quantify the presence and intensity of threats to the desert tortoise across the landscape.	All	All
5.	**Conduct applied research and modeling in support of recovery efforts within a strategic framework**		
5.1	Characterize stable age distributions of stable or increasing populations.	All	1
5.2	Determine factors that influence the distribution of desert tortoises.	All	2,3
5.3	Conduct research on the restoration of desert tortoise habitat.	A,E	3
5.4	Improve models of threats, threat mitigation, and desert tortoise demographics.	All	1,3
5.5	Conduct research on desert tortoise diseases and their effects on tortoise populations.	C	1,2
5.6	Resolve population structure of the desert tortoise across its range.	All	1,2
6.	**Implement an adaptive management program**		
6.1	Revise and continue development of a recovery decision support system.	All	All
6.2	Develop/revise recovery action plans.	All	All
6.3	Amend land use plans, habitat management plans, and other plans as needed to implement recovery actions.	All	All
6.4	Incorporate scientific advice for recovery through the Science Advisory Committee.	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.

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. *Note that no recovery actions have been assigned at the Priority 1 level based on the judgment that the desert tortoise is not on the verge of extinction or declining irreversibly at this time (reflected by its status as Threatened, rather than Endangered). Furthermore, many actions are already being implemented, so an urgent need does not exist for implementation to prevent extinction. Most actions are assigned at the Priority 2 level, described below.*

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. Recovery Implementation Teams need to be established upon publication of the final revised recovery plan (Recovery Action 1.1), and they should guide recovery action priorities and develop updated budget projections within each recovery unit through the use of an updated/improved decision support system (6.1-6.2).

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. Many tasks are listed as *Ongoing*; these are already being conducted and should continue. 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).

Abbreviations of the responsible parties identified in the Implementation Table are defined as follows:

BLM – Bureau of Land Management
CC MSHCP – Clark County, Nevada, MSHCP
CS MSHCP – Coyote Springs, Nevada, MSHCP
DOD – Department of Defense
MNP – Mojave National Preserve
NPS – National Park Service
USFWS – U.S. Fish and Wildlife Service
USGS – U.S. Geological Survey
WC HCP – Washington County, Utah, HCP

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.	**Develop, support, and build partnerships to facilitate recovery**									
1.1	Establish regional, inter-organizational RITs to coordinate implementation activities of recovery actions.	2	Continuing	USFWS (All)	500	500	500	500	500	12,500
2.	**Protect and manage existing populations and habitat**									
2.1	Protect intact desert tortoise habitat.	2	Ongoing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
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	Restore desert tortoise habitat.	2	Continuing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD
2.7	Install and maintain urban or other barriers.									
	Upper Virgin River Recovery Unit	2	2	WC HCP	0	0				0[1]
	Northeastern Mojave Recovery Unit	2	5	CC MSHCP CS MSHCP	0	0	0	0	0	0[1]
	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
2.8	Sign and fence boundaries of sensitive or impacted areas.									
	Upper Virgin River Recovery Unit	2	2	WC HCP	0	0				0[1]
	Remainder of desert tortoise range	3	Ongoing	Land Managers	600	600	600	600	600	3,500
2.9	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
2.10	Restrict off-highway vehicle events within desert tortoise habitat.	3	Ongoing	BLM	50	50	50	50	50	1,250
2.11	Connect functional habitat.	3	Ongoing	Land Managers	TBD	TBD	TBD	TBD	TBD	TBD

	Recovery Action	Priority	Duration (years)	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
					Costs (thousands of dollars)					
2.12	Limit mining and minimize its effects.	3	Ongoing	BLM	100	100	100	100	100	1,000
2.13	Limit landfills and their effects.	3	Ongoing	Counties	100	100	100	100	100	2,500
2.14	Reduce excessive predation on tortoises.	3	10	Land Managers	100	100	100	100	100	1,000
2.15	Minimize impacts from horses and horses.	3	Ongoing	BLM, NPS	500	500	500	500	500	12,500
2.16	Minimize livestock grazing.	3	Ongoing	BLM, MNP	100	100	100	100	100	2,500
3.	**Augment depleted populations through a strategic program**									
3.1	Develop protocols and guidelines for the 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	Secure facilities and obtain tortoises for use in augmentation efforts.	2	10	USFWS, DOD, MNP	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.	3	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.	3	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.	3	Continuing	USFWS (All)	TBD	TBD	TBD	TBD	TBD	TBD
4.4	Quantify the presence and intensity of threats to the desert tortoise across the landscape.	3	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	Characterize stable age distributions of stable or increasing populations.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.2	Determine factors that influence the distribution of desert tortoises.	3	TBD	USFWS, USGS (other research institutions)	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
5.3	Conduct research on the restoration of desert tortoise habitat.	3	TBD	All, research institutions	TBD	TBD	TBD	TBD	TBD	TBD
5.4	Improve models of threats, threat mitigation, and desert tortoise demographics.	3	TBD	USFWS (All; research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.5	Conduct research on desert tortoise diseases and their effects on tortoise populations.	3	TBD	USFWS (research institutions)	TBD	TBD	TBD	TBD	TBD	TBD
5.6	Resolve population structure of the desert tortoise across its range.	3	3	Research institutions	TBD	TBD	TBD			TBD
6.	**Implement an adaptive management program**									
6.1	Revise and continue development of a recovery decision support system.	2	Ongoing	USFWS (All)	50	10	5	5	5	175
6.2	Develop/revise recovery action plans.	2	Continuing	All	TBD	TBD	TBD	TBD	TBD	TBD
6.3	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
6.4	Incorporate scientific advice for recovery through the Science Advisory Committee.	3	Ongoing	USFWS (All)	5	5	5	5	5	125
FY Totals (These totals are minimum cost estimates that do not include TBD costs.)					8615	8475	8470	8470	8470	

[1]Costs for minimizing mortality and Habitat Conservation Plan activities are not included because these costs are typically required by regulatory processes, rather than as proactive recovery actions.

Total cost of recovery through 2025: $159,000,000 plus additional costs that cannot be estimated at this time.

IV. LITERATURE CITED

Abele, S., J. Bair, D.E. McIvor, L.A. Neel, R.J. Phoenix, A.E. Shaul, and J.C. Schoberg. 2006. Nevada Wildlife Action Plan. Prepared for the Nevada Department of Wildlife by the Wildlife Action Plan Team. Reno, Nevada.

Allendorf, F.W., and G. Luikart. 2007. Conservation and the genetics of populations. Blackwell, Malden, Massachusetts.

Anderson, D.R., and K.P. Burnham. 1996. A monitoring program for the desert tortoise. Report to the Desert Tortoise Management Oversight Group.

Arizona Game and Fish Department. 2006. DRAFT. Arizona's Comprehensive Wildlife Conservation Strategy: 2005-2015. Arizona Game and Fish Department, Phoenix, Arizona.

Armstrong, D.P., and P.J. Seddon. 2007. Directions in reintroduction biology. Trends in Ecology and Evolution 23:20-25.

Auffenberg, W., and R. Franz. 1978. *Gopherus agassizii* (Cooper): desert tortoise. Catalogue of American Amphibians and Reptiles 212.1-212.2.

Averill-Murray, R.C. 2002. Effects on survival of desert tortoises (*Gopherus agassizii*) urinating during handling. Chelonian Conservation and Biology 4:430-435.

Averill-Murray, R.C., and A. Averill-Murray. 2005. Regional-scale estimation of density and habitat use of the desert tortoise (*Gopherus agassizii*) in Arizona. Journal of Herpetology 39:65-72.

Avery, H.W. 1997. Effects of cattle grazing on the desert tortoise, *Gopherus agassizii*: Nutritional and behavioral interactions. Pages 13-20 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Avery, H.W. 1998. Nutritional ecology of the desert tortoise (*Gopherus agassizii*) in relation to cattle grazing in the Mojave Desert. Ph.D. Dissertation. University of California, Los Angeles.

Avise, J.C. 2004. Molecular markers, natural history, and evolution. Second edition. Sinauer, Sunderland, Massachusetts.

Bainbridge, D. 2007. A guide for desert and dryland restoration; new hope for arid lands. Island Press, Washington, D.C. 416 pp.

Berry, K.H. 1974. Desert tortoise relocation project: Status report for 1972. California Department of Transportation.

Berry, K.H. 1984. A description and comparison of field methods used in studying and censusing desert tortoises. Appendix 2, pages 1-33, *in* K.H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U.S. Fish and Wildlife Service. Order No. 11310-0083-81.

Berry, K.H. 1986. Desert tortoise (*Gopherus agassizii*) relocation: Implications of social behavior and movements. Herpetologica 42:113-125.

Berry, K.H. 1997. Demographic consequences of disease in two desert tortoise populations in California, USA. Pages 91-99 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Berry, K.H. 2003. Declining Trends in Desert Tortoise Populations at Long-term Study Plots in California between 1979 and 2002: Multiple Issues. Desert Tortoise Council Symposium. Abstract.

Berry, K.H., and B.L. Burge. 1984. The desert tortoise in Nevada. *In* K.H. Berry (ed.), The status of the desert tortoise *(Gopherus agassizii)* in the United States. Desert Tortoise Council Report to the U.S. Fish and Wildlife Service. Order No. 11310-0083-81.

Berry, K.H., and L.L. Nicholson. 1984. A summary of human activities and their impacts on desert tortoise populations and habitat in California. Chapter 3 *in* K.H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U.S. Fish and Wildlife Service. Order No. 11310-0083-81.

Berry, K.H., F.G. Hoover, and M. Walker. 1996. The effects of poaching desert tortoises in the western Mojave Desert: Evaluation of landscape and local impacts. Page 45 *in* Proceedings of the 1996 Desert Tortoise Council Symposium.

Berry, K.H., D.J. Morafka, and R.W. Murphy. 2002a. Defining the desert tortoise(s): our first priority for a coherent conservation strategy. Chelonian Conservation and Biology 4:249-262.

Berry, K.H., T. Okamoto, K. Anderson, M.B. Brown, L. Wendland, and F. Origgi. 2002b. Health assessments of captive and wild desert tortoises at 17 sites in the Mojave and Colorado deserts, California. Desert Tortoise Council Symposium. Abstract.

Bjurlin, C.D., and J.A. Bissonette. 2001. The impact of predator communities on early life history stage survival of the desert tortoise at the Marine Corps Air Ground Combat Center, Twentynine Palms, California. Report to U.S. Department of Navy. Contract N68711-97-LT-70023. UCFWRU Publication No. 00-4:1-81.

Bjurlin, C.D., and J.A. Bissonette. 2004. Survival during early life stages of the desert tortoise (*Gopherus agassizii*) in the south-central Mojave Desert. Journal of Herpetology 38:527-535.

Black, J.H. 1976. Observations on courtship behavior of the desert tortoise. Great Basin Naturalist 36:467-470.

Boarman, W.I. 1993. When a native predator becomes a pest: a case study. Pages 186-201 *in* S.K. Majumdar *et al.* (eds.), Conservation and Resource Management. Pennsylvania Academy of Science. Easton, Pennsylvania.

Boarman, W.I. 2002. Threats to desert tortoise populations: A critical review of the literature. U.S. Geological Survey, Western Ecological Research Center, Sacramento, California.

Boarman, W.I., and W.B. Kristan. 2006. Evaluation of evidence supporting the effectiveness of desert tortoise recovery actions. U.S. Geological Survey Scientific Investigations Report 2006-5143, Sacramento, California.

Boarman, W.I., and M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101.

Boarman, W.I., R.J. Camp, M. Hagan, W. Deal. 1995. Raven abundance at anthropogenic resources in the western Mojave Desert, California. Report to Edwards Air Force Base, California.

Boarman, W.I., M.A. Patten, R.J. Camp, and S.J. Collis. 2006. Ecology of a population of subsidized predators: Common ravens in the central Mojave Desert, California. Journal of Arid Environments 67 Supplement:248-261.

Brannon, R. 2000. Ownership data. National GAP Analysis Program. Moscow, Idaho. Provided to the U.S. Fish and Wildlife Service by the Redlands Institute on August 29, 2007.

Britten, H.B., B.R. Riddle, P.F. Brussard, R. Marlow, and T.E. Lee. 1997. Genetic delineation of management units for the desert tortoise, *Gopherus agassizii*, in northeastern Mojave Desert. Copeia 1997:523-530.

Brooks, M.L. 1995. Benefits of protective fencing to plant and rodent communities of the western Mojave Desert, California. Environmental Management 19:65-74.

Brooks, M.L., and T.C. Esque. 2002. Alien plants and fire in desert tortoise (*Gopherus agassizii*) habitat of the Mojave and Colorado deserts. Chelonian Conservation and Biology 4:330-340.

Brown, D.E. (ed.). 1982. Biotic communities of the American Southwest – United States and Mexico. Desert Plants 4:1-342.

Brussard, P.F., K.H. Berry, M.E. Gilpin, E.R. Jacobson, D.J. Morafka, C.R. Schwalbe, C.R. Tracy, F.C Vasek, and J. Hohman. 1994. Proposed Desert Wildlife Management Areas for recovery of the Mojave population of the desert tortoise. A companion document to the desert tortoise Recovery Plan providing detailed information on each of the 14 proposed Desert Wildlife Management Areas. U.S. Fish and Wildlife Service, Portland, Oregon.

Bunn, D., A. Mummert, R. Anderson, K. Gilardi, M. Hoshovsky, S. Shanks, and K. Stahle. 2006. California Wildlife: Conservation Challenges (California's Wildlife Action Plan). Prepared for the California Department of Fish and Game by the Wildlife Health Center, University of California, Davis.

[BLM] Bureau of Land Management. 1996. Department of Interior, Bureau of Land Management. 43 CFR Part 4100: Grazing administration, exclusive of Alaska; development and completion of standards and guidelines; implementation of fallback standards and guidelines. Federal Register 61:59834-59835.

[BLM] Bureau of Land Management. 1997. Approved Tonopah resource management plan and record of decision. October 6, 1997. Battle Mountain District; Tonopah Field Station, Tonopah, Nevada.

[BLM] Bureau of Land Management. 1998a. Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement. U.S. Department of the Interior, Bureau of Land Management, Las Vegas, Nevada.

[BLM] Bureau of Land Management. 1998b. Department of the Interior, Bureau of Land Management. Arizona: Amend the Arizona Strip Resource Management Plan. Notice to amend. Federal Register 63:39886-39887.

[BLM] Bureau of Land Management. 1999a. The California Desert Conservation Area Plan 1980, as amended. U.S. Department of the Interior, Bureau of Land Management, California.

[BLM] Bureau of Land Management. 1999b. St. George Field Office Resource Management Plan and Record of Decision. St. George, Utah.

[BLM] Bureau of Land Management. 2001. Proposed General Management Plan and Final Environmental Impact Statement for the Red Rock Canyon National Conservation Area. U.S. Department of the Interior, Bureau of Land Management, Las Vegas, Nevada.

[BLM] Bureau of Land Management. 2000. Approved Caliente management framework plan amendment and record of decision for the management of desert tortoise habitat. Ely Field Office, Nevada. June 1999.

[BLM] Bureau of Land Management. 2002a. Northern and Eastern Mojave Desert management plan, amendment to the California Desert Conservation Area Plan 1980, and final environmental impact statement. Bureau of Land Management, California Desert District, Moreno Valley, California.

[BLM] Bureau of Land Management. 2002b. Northern and Eastern Colorado Desert coordinated management plan, an amendment of the 1980 Bureau of Land Management California Desert Conservation Area Plan. Bureau of Land Management, California Desert District, Moreno Valley, California.

[BLM] Bureau of Land Management. 2002c. Proposed California Desert Conservation Area Plan Amendment for the Coachella Valley. Bureau of Land Management, California Desert District, Moreno Valley, California.

[BLM] Bureau of Land Management. 2004. Nevada Test and Training Range Resource Management Plan and Final Environmental Impact Statement. Las Vegas Field Office, Nevada.

[BLM] Bureau of Land Management. 2006. Sloan Canyon National Conservation Area Resource Management Plan/Final Environmental Impact Statement and North McCullough Wilderness Management Plan. Las Vegas Field Office, Nevada.

[BLM] Bureau of Land Management. 2007a. Biological Assessment for the Grand Canyon-Parashant National Monument, Vermillion Cliffs National Monument, and Arizona Strip Field Office Resource Management Plans and Final Environmental Impact Statement. Arizona Strip District Office. St. George, Utah.

[BLM] Bureau of Land Management. 2007b. Southern Nevada Public Lands Management Act website. Available online at <www.nv.blm.gov/snplma>. Accessed July 26, 2007.

[BLM] Bureau of Land Management, County of San Bernardino, and City of Barstow. 2005. Final environmental impact report and statement for the West Mojave Plan, a habitat conservation plan and California Desert Conservation Area Plan amendment. Bureau of Land Management, California Desert District, Moreno Valley, California.

[BLM and NPS] Bureau of Land Management and National Park Service. 2007. Proposed Resource Management Plan and Final Environmental Impact Statement for the Arizona Strip Field Office, Vermillion Cliffs National Monument, and Bureau of Land Management portion of the Grand Canyon-Parashant National Monument, and the Proposed General Management Plan for the National Park Service portion and Final Environmental Impact Statement for the National Park Service portion of the Grand Canyon-Parashant National Monument. Bureau of Land Management and National Park Service, St. George, Utah.

Burge, B.L. 1977. Daily and seasonal behavior, and areas utilized by the desert tortoise, *Gopherus agassizii*, in southern Nevada. Pages 59-94 *in* Proceedings of the Desert Tortoise Council Symposium.

Bury, R.B. 1982. An overview. Pages v-vii *in* R.B. Bury (ed.), North American Tortoises: Conservation and Ecology. U.S. Fish and Wildlife Service, Wildlife Research Report 12, Washington, D.C.

Bury, R.B. 1987. Off-road vehicles reduce tortoise numbers and well-being. U.S. Department of the Interior, Fish and Wildlife Service, National Ecology Research Center, Fort Collins, Colorado. Research Information Bulletin Number 87-6.

Bury, R.B., and D.J. Germano, (eds.). 1994. Biology of the North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

Bury, R.B., T.C. Esque, L.A. DeFalco, and P.A. Medica. 1994. Distribution, habitat use, and protection of the desert tortoise in the Eastern Mojave Desert. Pages 57-72 *in* R.B. Bury and D.J. Germano, (eds.), Biology of the North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

Campbell, F.T. 1988. The desert tortoise. Pages 567-581 *in* Audubon wildlife report 1988/1989. National Audubon Society, New York.

Caughley, G., and A.R.E. Sinclair. 1994. Wildlife Ecology and Management. Blackwell Scientific Publications, Boston, Massachusetts.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, 2007. Regional Climate Projections. Pages 847-926 *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Clark County. 2007a. Conservation Management Strategy: Coyote Springs Desert Wildlife Management Area. Las Vegas, Nevada.

Clark County. 2007b. Conservation Management Strategy: Gold Butte Desert Wildlife Management Area. Las Vegas, Nevada.

Clark County. 2007c. Conservation Management Strategy: Mormon Mesa Desert Wildlife Management Area. Las Vegas, Nevada.

Clark County. 2007d. Conservation Management Strategy: Piute-Eldorado Desert Wildlife Management Area. Las Vegas, Nevada.

Coachella Valley Association of Governments. 2007. Recirculated Coachella Valley Multiple Species Habitat Conservation Plan. Palm Desert, California.

Cook, J.C. 1983. Rehabilitation of the desert tortoise (*Gopherus* agassizii). M.S. Thesis, California State Polytechnic University, Pomona.

Cook, J.C., A.E. Weber, G.R. Stewart. 1978. Survival of captive tortoises released in California. Proceedings of the Desert Tortoise Council Symposium 1977:130-135.

Cooper, J.C. 1863. Description of *Xerobates agassizii*. Proceedings of the California Academy of Science 2:120-121.

Crumly, C.R. 1994. Phylogenetic systematics of North American tortoises (genus *Gopherus*): evidence for their classification. Pages 7-32 *in* R.B. Bury and D.J. Germano (eds.), Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

Dickson, S.D., L.S. Hillard, and K.A. Nagy. 2006. How well do head-started yearling tortoises survive after release? Desert Tortoise Council Symposium 2006:8. Abstract.

Duda, J.J., A.J. Krzysik, and J.E. Freilich. 1999. Effects of drought on desert tortoise movement and activity. Journal of Wildlife Management 63:1181-1192.

Edwards, T., E.W. Stitt, C.R. Schwalbe, and D.E. Swann. 2004a. *Gopherus agassizii* (desert tortoise). Movement. Herpetological Review 35:381-382.

Edwards, T., C.S. Goldberg, M.E. Kaplan, C.R. Schwalbe, and D.E. Swann. 2004b. Implications of anthropogenic landscape change on inter-population movements of the desert tortoise (*Gopherus agassizii*). Conservation Genetics 5:485-499.

Ernst, C.H., R.W. Barbour, and J.E. Lovich. 1994. Turtles of the United States and Canada. Smithsonian, Washington, D.C.

Esque, T.C. 1994. Diet and diet selection of the desert tortoise (*Gopherus agassizii*) in the northeastern Mojave Desert. Master's Thesis. Colorado State University, Fort Collins.

Field, K.J., C.R. Tracy, P.A. Medica, R.W. Marlow, and P.S. Corn. 2000. Translocation as a tool for conservation of the desert tortoise: Can pet tortoises be repatriated? Proceedings of the Desert Tortoise Council Symposium 2000-2001:14.

Field, K.J., C.R. Tracy, P.A. Medica, R.W. Marlow, and P.S. Corn. 2007. Return to the wild: translocation as a tool in conservation of the desert tortoise (*Gopherus agassizii*). Biological Conservation 136:232-245.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R., Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T., Winter, T.C. 2003. Road Ecology Science and Solutions. Island Press, Washington, D.C.

Fritts, T.H., and R.D. Jennings. 1994. Distribution, habitat use, and status of the desert tortoise in Mexico. Pages 49-56 *in* R.B. Bury and D.J. Germano (eds.), Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

[GAO] General Accounting Office. 2002. Endangered Species: Research Strategy and Long-Term Monitoring Needed for the Mojave Desert Tortoise Recovery Program. GAO-03-23. Washington, D.C.

Germano, D.J. 1993. Shell morphology of North American tortoises. American Midland Naturalist 129:319-335.

Germano, D.J. 1994. Comparative life histories of North American tortoises. Pages 175-185 *in* R.B. Bury and D.J. Germano (eds.), Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

Germano, D.J., R.B. Bury, T.C. Esque, T.H. Fritts, and P.A. Medica. 1994. Range and habitat of the desert tortoise. Pages 57-72 *in* R.B. Bury and D.J. Germano (eds.), Biology of the North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

Glenn, J.L., R.C. Straight, and J.W. Sites, Jr. 1990. A plasma protein marker for population genetic studies of the desert tortoise (*Xerobates agassizii*). Great Basin Naturalist 50:1-8.

Gorrell, J.V., M.E. Andersen, K.D. Bunnell, M.F. Canning, A.G. Clark, D.E. Dolsen, F. P. Howe. 2005. Utah Comprehensive Wildlife Conservation Strategy: 2005-2015. Prepared for the Utah Division of Wildlife Resources, Salt Lake City.

Hagerty, B.E., and C.R. Tracy. 2007. Follow-up report from the Scientific Advisory Committee meeting: genetic structure of the Mojave desert tortoise. Unpublished report to the U.S. Fish and Wildlife Service, Reno, Nevada.

Henen, B.T. 1997. Seasonal and annual energy budgets of female desert tortoises (Gopherus agassizii). Ecology 78:283-296.

Henen, B.T., K.A. Nagy, and L.S. Hillard. 2007. Head start mommas: preliminary assessment of reproduction. Desert Tortoise Council Symposium 2007:19. Abstract.

Henen, B.T., C.D. Peterson, I.R. Wallis, K.H. Berry, and K.A. Nagy. 1998. Effects of climatic variation on field metabolism and water relations of desert tortoises. Oecologia 117:365-373.

Homer, B.L., K.H. Berry, and E.R. Jacobson. 1996. Necropsies of eighteen desert tortoises from the Mojave and Colorado deserts of California. Final Report to the U.S. Department of the Interior, National Biological Service, Research Work Order No. 131, Riverside, California. 120 pp.

Homer, B.L., K.H. Berry, M.B. Brown, G. Ellis, E.R. Jacobson. 1998. Pathology of diseases in wild desert tortoises from California. Journal of Wildlife Diseases 34:508-523.

Homer, B.L., K.H. Berry, M.M. Christopher, M.B. Brown, E.R. Jacobson. 1994. Necropsies of desert tortoises from the Mojave and Colorado Deserts of California and the Sonoran Desert of Arizona. University of Florida, Gainesville.

Jacobson, E.R., J.M. Gaskin, M.B. Brown, R.K. Harris, C.H. Gardiner, J.L. LaPointe, H.P. Adams, and C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). Journal of Wildlife Diseases 27:296-316.

Jacobson, E.R., T.J. Wronski, J. Schumacher, C. Reggiardo, and K.H. Berry. 1994. Cutaneous dyskeratosis in free-ranging desert tortoises, *Gopherus agassizii*, in the Colorado Desert of Southern California. Journal of Zoo and Wildlife Medicine 25:68-81.

Jennings, R.D. 1985. Biochemical variation of the desert tortoise, *Gopherus agassizii*. Master's Thesis. University of New Mexico, Albuquerque.

Jennings, W.B. 1997. Habitat use and food preferences of the desert tortoise, *Gopherus agassizii*, in the western Mojave and impacts of off-road vehicles. Pages 42-45 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Kristan, W.B., and W.I. Boarman. 2003. Spatial pattern of risk of common raven predation on desert tortoises. Ecology 84:2432-2443.

Krzysik, A.J. 1998. Desert tortoise populations in the Mojave Desert and a half-century of military training activities. Pages 61-73 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Lamb, T., and C. Lydehard. 1994. A molecular phylogeny of the gopher tortoises, with comments on familial relationships within the Testudinoidea. Molecular Phylogenetics and Evolution 3:283-291.

Lamb, T., J.C. Avise, and J.W. Gibbons. 1989. Phylogeographic patterns in mitochondrial DNA of the desert tortoise (*Xerobates agassizii*), and evolutionary relationships among North American gopher tortoises. Evolution 43:76-87.

LaRue, E., and S. Dougherty. 1999. Federal biological opinion analysis for the Eagle Mountain Landfill project. Proceedings of the Desert Tortoise Council Symposium 1997-1998:52-58.

Lovich, J.E., and D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 249:309-326.

Luckenbach, R.A. 1982. Ecology and management of the desert tortoise *(Gopherus agassizii)* in California. *In* R.B. Bury (ed.). North American Tortoises: Conservation and Ecology. U.S. Fish and Wildlife Service, Wildlife Research Report 12, Washington, D.C.

Luke, C., A. Karl, and P. Garcia. 1991. A status review of the desert tortoise. Biosystems Analysis, Inc., Tiburon, California.

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Academic Press, Amsterdam.

MacMahon, J.A. 1990. Deserts. Knopf, New York.

McLuckie, A.M., and R.A. Fridell. 2002. Reproduction in a desert tortoise population on the Beaver Dam Slope, Washington County, Utah. Chelonian Conservation and Biology 4:288-294.

McLuckie, A.M., M.R.M. Bennion, and R.A. Fridell. 2006. Regional desert tortoise monitoring in the Red Cliffs Desert Reserve, 2005. Utah Division of Wildlife Resources, Publication Number 06-06. Salt Lake City.

McLuckie, A.M., D.L. Harstad, J.W. Marr, and R.A. Fridell. 2002. Regional desert tortoise monitoring in the Upper Virgin River Recovery Unit, Washington County, Utah. Chelonian Conservation and Biology 4:380-386.

Morafka, D.J., K.H. Berry, E.K. Spangenberg. 1997. Predator-proof field enclosures for enhancing hatchling success and survivorship of juvenile tortoises: a critical evaluation. Pages 147-165 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Mueller, J.M., K.R. Sharp, K.K. Zander, D.L. Rakestraw, K.R. Rautenstrauch, and P.E. Lederle. 1998. Size-specific fecundity of the desert tortoise (*Gopherus agassizii*). Journal of Herpetology 32:313-319.

Murphy, R.W., K.H. Berry, T. Edwards, and A.M. McLuckie. 2007. A genetic assessment of the recovery units for the Mojave population of the desert tortoise, *Gopherus agassizii*. Chelonian Conservation and Biology 6:229-251.

Nagy, K.A., L.S. Hillard, S.D. Dickson, and D.J. Morafka. 2007. Head-starting desert tortoises: irrigation and yearling releases at Edwards Air Force Base. Desert Tortoise Council Symposium. Abstract.

Nagy, K.A., and P.A. Medica. 1986. Physiological ecology of desert tortoises. Herpetologica 42:73-92.

[NPS] National Park Service. 2000a. Final Environmental Impact Statement, General Management Plan Amendment, Wilderness and Backcountry Management Plan for Joshua Tree National Park, Riverside and San Bernardino counties, California.

[NPS] National Park Service. 2000b. Lake Mead National Recreation Area, Arizona and California, Strategic Plan Fiscal Year 2001-2005. Boulder City, Nevada.

[NPS] National Park Service. 2002a. Death Valley National Park General Management Plan, Inyo and San Bernardino counties, California, and Esmeralda and Nye counties, Nevada.

[NPS] National Park Service. 2002b. Mojave National Preserve General Management Plan, San Bernardino County, California.

Naval Air Weapons Station, China Lake and Bureau of Land Management. 2004. Final Environmental Impact Statement for Proposed Military Operational Increases and Implementation of Associated Comprehensive Land Use and Integrated Natural Resources Management Plans. Ridgecrest, California.

Nicolson, C.R., A.M. Starfield, G.P. Kofinas, and J.A. Kruse. 2002. Ten heuristics for interdisciplinary modeling projects. Ecosystems 5:376-384.

Nussear, K.E. 2004. Mechanistic investigation of the distributional limits of the desert tortoise, *Gopherus agassizii*. Ph.D. Dissertation. University of Nevada, Reno.

O'Connor, M.P., L.C. Zimmerman, D.E. Ruby, S.J. Bulova, J.R. Spotila. 1994a. Home range size and movements by desert tortoises, *Gopherus agassizii*, in the eastern Mojave Desert. Herpetological Monographs 8:60-71.

Olson, T.E. 1996. Comparison of impacts and mitigation measures along three multi-state linear construction projects. Pages 1-9 *in* Proceedings of the 1996 Desert Tortoise Council Symposium.

Origgi, R., C.H. Romero, P.A. Klein, K.H. Berry, and E.R. Jacobson. 2002. Serological and molecular evidences of herpesvirus exposure in desert tortoises from the Mojave Desert of California. Desert Tortoise Council Symposium. Abstract.

Patterson, R. 1982. The distribution of the desert tortoise (*Gopherus agassizii*). Pages 51-55 *in* R.B. Bury (ed.), North American Tortoises: Conservation and Ecology. U.S. Fish and Wildlife Service, Wildlife Research Report 12.

Peterson, C.C. 1996a. Anhomeostasis: Seasonal water and solute relations in two populations of the threatened desert tortoise (*Gopherus agassizii*) during chronic drought. Physiological Zoology 69:1324-1358.

Peterson, C.C. 1996b. Ecological energetics of the desert tortoise (*Gopherus agassizii*): effects of rainfall and drought. Ecology 77:1831–1844.

Pulliam, H.R. 1996. Sources and sinks: empirical evidence and population consequences. Pages 45-69 *in* O.E. Rhodes, R.K. Chesser, and M.H. Smith (eds.), Population Dynamics in Ecological Space and Time. University of Chicago Press, Chicago.

Rainboth, W.J., D.G. Buth, and F.B. Turner. 1989. Allozyme variation in Mojave populations of the desert tortoise, *Gopherus agassizii*. Copeia 1989:115-125.

Ralls, K., and A.M. Starfield. 1995. Choosing a management strategy: two structured decision-making methods for evaluating the predictions of stochastic simulation models. Conservation Biology 9:175-181.

Rauscher, H.M. 1999. Ecosystem management decision support for federal forests in the United States: a review. Forest Ecology and Management 114:173-197.

Rautenstrauch, K.R., and T.P. O'Farrell. 1998. Relative abundance of desert tortoises on the Nevada Test Site. The Southwestern Naturalist 43:407-411.

RECON (Regional Environmental Consultants). 2000. Clark County Multiple Species Habitat Conservation Plan. Prepared for Clark County. Las Vegas, Nevada.

Rostal, D.C., V.A. Lance, J.S. Grumbles, and A.C. Alberts. 1994. Seasonal reproductive cycle of the desert tortoise (*Gopherus agassizii*) in the eastern Mojave Desert. Herpetological Monographs 8:72-82.

Roundy, B.A., McArthur, E.D., Haley, J.S., Mann, D.K., comps. 1995. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, Nevada. General Technical Report INT-GTR-315. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Rowlands, P.G. 1995. Regional bioclimatology of the California desert. Pages 95-134 *in* J. Latting and P.G. Rowlands (eds.), The California desert: an introduction to natural resources and man's impact. Vol. 1. June Latting Books, Riverside, California.

Rowlands, P.G., H. Johnson, E. Ritter, and A. Endo. 1982. The Mojave Desert. Pages 103-162 *in* G.L. Bender (ed.), Reference handbook on the deserts of North America. Greenwood Press, Westport, Connecticut.

Royle, J.A., J.D. Nichols, and M. Kéry. 2005. Modeling occurrence and abundance of species when detection is imperfect. Oikos 110:353-359.

Schwarz, C.J. 1998. Studies of uncontrolled events. Pages 19-39 *In* V. Sit and B. Taylor (eds.), Statistical Methods for Adaptive Management Studies. British Columbia Ministry of Forests Research Program, Handbook No. 42, Victoria, British Columbia.

Schwartz, T.S., and S.A. Karl. 2005. Population and conservation genetics of the gopher tortoise (*Gopherus polyphemus*). Conservation Genetics 6:917-928.

Scott, J.M., D.D. Goble, J.A. Wiens, D.S. Wilcove, M. Bean, and T. Male. 2005. Recovery of imperiled species under the Endangered Species Act: the need for a new approach. Frontiers in Ecology and the Environment 3:383-389.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H-P. Huang, N. Harnik, A. Leetmaa, N-C. Lau, C. Li, J. Velez, and N. Naik. 2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. Science 316:1181-1184.

Sievers, A., J.B. Aardahl, K.H. Berry, B.L. Burge, L.D. Foreman, G.E. Monesko, and J.T. St. Amant. 1988. Recommendations for management of the desert tortoise in the California Desert. Bureau of Land Management, Riverside, California, and California Department of Fish and Game, Long Beach.

Starfield, A.M. 1997. A pragmatic approach to modeling for wildlife management. Journal of Wildlife Management 61:261-270.

Starfield, A.M., and A.L. Bleloch. 1991. Building models for conservation and wildlife management. Interaction Book Company, Edina, Minnesota.

Steele, D., and R. Jones 2006. Department of Fish and Game and the desert tortoise, our state reptile. Abstract from the 31st Annual Meeting and Symposium of the Desert Tortoise Council. Tucson, Arizona.

The Wildlands Conservancy. 2007. A California nonprofit public benefit corporation focused on preservation of biodiversity and education. Oak Glen, California. Available online at <http://www.wildlandsconservancy.org/twc_projects.html>. Accessed August 12, 2007.

Tierra Data, Inc. 2005. Marine Corps Logistics Base, Barstow, Integrated Natural Resources Management Plan. Prepared for U.S. Department of the Navy, Southwest Division, Naval Facilities Engineering Command, San Diego, California. Contract No. N68711-00-D-4413/0016.

Tracy, C.R., R.C. Averill-Murray, W.I. Boarman, D. Delehanty, J.S. Heaton, E.D. McCoy, D.J. Morafka, K.E. Nussear, B.E. Hagerty, and P.A. Medica. 2004. Desert Tortoise Recovery Plan Assessment. Report to the U.S. Fish and Wildlife Service, Reno, Nevada.

Turner, R.M. 1982. Mohave desertscrub. Pages 157-168 *in* D.E. Brown (ed.), Biotic communities of the American southwest-United States and Mexico. Desert Plants 4:157-168.

Turner, R.M., and D.E. Brown. 1982. Sonoran desertscrub. Pages 181-221 *in* D.E. Brown (ed.), Biotic communities of the American southwest-United States and Mexico. Desert Plants 4:181-221.

Turner, F.B., P.A. Medica, and C.L. Lyons. 1984. Reproduction and survival of the desert tortoise *(Scaptochelys agassizii)* in Ivanpah Valley, California. Copeia 4:811-820.

Turner, F.B., P. Hayden, B.L. Burge, and J.B. Roberson. 1986. Egg production by the desert tortoise (*Gopherus agassizii*) in California. Herpetologica 42:93-104.

Turner, F.B., K.H. Berry, D.C. Randall, and G.C. White. 1987. Population ecology of the desert tortoise at Goffs, California, 1983-1986. Report to Southern California Edison Co., Rosemead, California.

U.S. Air Force. 2001. Integrated Natural Resources Management Plan for Edwards Air Force Base, California. Edwards Air Force Base 32-7064. September update. Edwards Air Force Base, California.

U.S. Air Force. 2007. Draft Environmental Assessment for the Integrated Natural Resources Management Plan for Nellis Air Force Base and the Nevada Test and Training Range. Las Vegas, Nevada.

U.S. Army. 2006. Integrated Natural Resources Management Plan and Environmental Assessment for the National Training Center and Ft. Irwin. Ft. Irwin, California.

U.S. Department of the Navy. 2001. Record of Decision for the Yuma Training Range Complex, Arizona and California. Yuma, Arizona.

[USFWS] U.S. Fish and Wildlife Service. 1980. Endangered and threatened wildlife and plants; listing as threatened with critical habitat for the Beaver Dam Slope populations of the desert tortoise in Utah. Federal Register 45:55654-55666.

[USFWS] U.S. Fish and Wildlife Service. 1983. Endangered and threatened species listing and recovery priority guidelines correction. Federal Register 48:51985.

[USFWS] U.S. Fish and Wildlife Service. 1989. Endangered and threatened wildlife and plants; emergency determination of endangered status for the Mojave population of the desert tortoise. Federal Register 54:32326-32331.

[USFWS] U.S. Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the Mojave population of the desert tortoise. Federal Register 55:12178-12191.

[USFWS] U.S. Fish and Wildlife Service. 1994a. Desert Tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

[USFWS] U.S. Fish and Wildlife Service. 1994b. Endangered and threatened wildlife and plants; determination of critical habitat for the Mojave population of the desert tortoise. Federal Register 59:5820-5866.

[USFWS] U.S. Fish and Wildlife Service. 1996. Department of the Interior, Fish and Wildlife Service; Department of Commerce, National Oceanic and Atmospheric Administration. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Notice of policy. Federal Register 61:4722-4725.

[USFWS] U.S. Fish and Wildlife Service. 2000a. Department of the Interior, Fish and Wildlife Service. Availability of Final Clark County Multiple Species Habitat Conservation Plan and Environmental Impact Statement for Clark County, Nevada. Notice of availability. Federal Register 65:57366-57367.

[USFWS] U.S. Fish and Wildlife Service. 2000b. Department of the Interior, Fish and Wildlife Service; Department of Commerce, National Oceanic and Atmospheric Administration. Policy regarding controlled propagation of species listed under the Endangered Species Act. Notice of policy. Federal Register 65:56916-56922.

[USFWS] U.S. Fish and Wildlife Service. 2005. Biological Opinion for the California Desert Conservation Area Plan [Desert Tortoise] (6840 CA930(P)) (1-8-04-F-43R). Ventura Fish and Wildlife Office, Ventura, California.

[USFWS] U.S. Fish and Wildlife Service. 2006a. Range-wide Monitoring of the Mojave Population of the Desert Tortoise: 2001-2005 Summary Report. Report by the Desert Tortoise Recovery Office, U.S. Fish and Wildlife Service, Reno, Nevada.

[USFWS] U.S. Fish and Wildlife Service. 2006b. Biological Opinion for the California Desert Conservation Area [West Mojave Plan] (6840(P) CA-063.50) (1-8-03-F-58). Ventura Fish and Wildlife Office, Ventura, California.

[USFWS] U.S. Fish and Wildlife Service. 2006c. Biological opinion for fire rehabilitation plans in Mojave Desert tortoise habitat. File Number 02-21-05-F-0772. Arizona Ecological Services Office, Phoenix, Arizona.

[USFWS] U.S. Fish and Wildlife Service, U.S. Department of Agriculture, U.S. Department of Defense, Bureau of Interior. 2008. Environmental Assessment to Implement a Desert Tortoise Recovery Plan Task: Reduce Common Raven Predation on the Desert Tortoise. Ventura Fish and Wildlife Office. Ventura, California.

U.S. Forest Service. 1996. Record of Decision for the General Management Plan for the Spring Mountains National Recreation Area, an Amendment to the Land and Resource Management Plan. Toiyabe National Forest, Las Vegas, Nevada.

U.S. Institute for Environmental Conflict Resolution and Center for Collaborative Policy. 2006. Feasibility assessment report for collaborative desert tortoise recovery planning process proposed by U.S. Fish and Wildlife Service. Report to U.S. Fish and Wildlife Service, Reno, Nevada.

U.S. Marine Corps. 2006. Integrated Natural Resources Management Plan, Fiscal Years 2007-2011. Marine Air Ground Task Force Training Command, Marine Corp Air Ground Combat Center, Twentynine Palms, California.

Van Devender, T.R. 2002a. Natural history of the Sonoran tortoise in Arizona: life in a rock pile. Pages 3-28 *in* T.R. Van Devender (ed.), The Biology of the Sonoran Desert Tortoise: Natural History, Biology, and Conservation. University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Van Devender, T.R. 2002b. Cenozoic environments and the evolution of the gopher tortoises (genus *Gopherus*). Pages 29-51 *in* T.R. Van Devender (ed.), The Biology of the Sonoran Desert Tortoise: Natural History, Biology, and Conservation. University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Van Devender, T.R. (ed.). 2002c. The Biology of the Sonoran Desert Tortoise: Natural History, Biology, and Conservation. University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Wallis, I.R., B.T. Henen, and K.A. Nagy. 1999. Egg size and annual egg production by female desert tortoises (*Gopherus agassizii*): the importance of food abundance, body size, and date of egg shelling. Journal of Herpetology 33:394-408.

Walther, G-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J-M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Weinstein, M.N., and K.H. Berry. 1987. Morphometric analysis of desert tortoise populations. Report CA950-CT7-003. Bureau of Land Management, Riverside, California.

Weltzin, J.F., M.E. Loik, S. Schwinning, D.G. Williams, P.A. Fay, B.M. Haddad, J. Harte, T.E. Huxman, A.K. Knapp, G. Lin, W.T. Pockman, M.R. Shaw, E.E. Small, M.D. Smith, S.D. Smith, D.T. Tissue, and J.C. Zak. 2003. Assessing the Response of Terrestrial Ecosystems to Potential Changes in Precipitation. Bioscience 53:942-952.

Wilcox, B.A., and D.D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. American Naturalist 125:879-887.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S., Department of the Interior, Washington, D.C.

Wolff, P.L., and U.S. Seal. 1993. Implications of infectious disease for captive propagation and reintroduction of threatened species. Journal of Zoo and Wildlife Medicine 24:229-230.

Woodbury, A.M., and R. Hardy. 1948. Studies of the desert tortoise, *Gopherus agassizii*. Ecological Monographs 18:146-200.

PERSONAL COMMUNICATIONS

Bair, Janet. 2007. U.S. Fish and Wildlife Service, Southern Nevada Field Office. Las Vegas, Nevada.

Bransfield, Ray. 2007. U.S. Fish and Wildlife Service, Ventura Fish and Wildlife Office. Ventura, California.

Brown, Jody. 2007. U.S. Fish and Wildlife Service, Nevada Fish and Wildlife Office. Reno, Nevada.

Crisp, Jim. 2007. Bureau of Land Management, St. George Field Office. St. George, Utah.

Esque, T. 2007. U.S. Geological Survey. Las Vegas, Nevada.

Hughson, Debra. 2007. National Park Service, Mojave National Preserve. Barstow, California.

Masters, Elroy. 2007. Bureau of Land Management, Nevada State Office. Reno, Nevada

McDermott, Michelle. 2006. Southern Nevada Environmental, Inc. Las Vegas, Nevada.

Nagy, Ken. 2006. University of California, Los Angeles.

APPENDIX A

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

Below is a synopsis of the threats that formed the basis for listing the tortoise as a threatened species (USFWS 1990), were further discussed in the 1994 Recovery Plan (USFWS 1994), and continue to affect the species. 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.

The vast majority of threats to the desert tortoise or its habitat are associated with human land uses. Extensive research shows that all of these individual threats directly kill or indirectly affect tortoises. Research has also clarified many mechanisms by which these threats act on tortoises. However, despite the clear demonstration that these threats impact individual tortoises, there are few data available to evaluate or quantify the effects of threats on desert tortoise populations (Boarman 2002; Tracy *et al*. 2004). While current research results can lead to predictions about how local tortoise abundance should be affected by the presence of threats, quantitative estimates of the magnitude of these threats, or of their relative importance, have not yet been developed. Thus, a particular threat or subset of threats with discernable solutions that could be targeted to the exclusion of other threats has not been identified for the desert tortoise.

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. Therefore, this revised recovery plan focuses on expanding our knowledge of individual threats and places emphasis on understanding their multiple and combined effects on tortoise populations.

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

1. Urbanization

Urban development directly affects desert tortoise populations through fragmentation and permanent loss of habitat. Areas 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). Between the years 2000 and 2005, the West experienced an 8.1 percent change in population, compared to 7.3 percent in the South, 2.4

percent in the Midwest, and 2.0 percent in the Northeast (U.S. Census Bureau 2005). During this same time period, Nevada saw a 20.8 percent increase, Arizona a 15.8 percent increase, Utah a 10.6 increase, and California a 6.7 percent increase in population growth (U.S. Census Bureau 2005).

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[3]
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
[3] Most population increase has been outside the Arizona Strip and the range of the Mojave population of the desert tortoise.

Population growth and urban development in the desert region of the Southwest continue to expand into previously undisturbed areas, putting intense pressures on the natural resources. 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 will be between 3,000 and 4,000 persons in 2010 (S. Donahue, Mohave County, pers. comm. 2007).

Increasing human populations result in corresponding increases in impacts to desert tortoise habitat not only through direct habitat loss, but also through associated human activities as more people recreate in the desert and greater infrastructure is needed to support growing communities. Lovich and Bainbridge (1999) identified various types of anthropogenic impacts from which desert ecosystems may take 50 to 300 years to recover to pre-disturbance plant cover levels. However, areas that have experienced permanent, direct 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 section C(3), Predation), and unauthorized collecting of desert tortoises may affect populations (see section B(1), Collection by Humans). 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 (see section E, Other Natural or Manmade Factors). 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 section A(2), Roads).

2. 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 also 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 unpaved roadways as well as in adjacent areas (Brooks and Lair 2005). In addition, roadside vegetation is often more robust and diverse because water that becomes concentrated along roadside berms promotes germination, which attracts tortoises and puts them at higher risk of mortality as road-kill (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 that fragment habitat and limit 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).

(a) 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 for 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 non-native species along roadways (Brooks and Lair 2005).

Near Canyonlands National Park in Utah, cover of the non-native grass *Bromus tectorum* (cheatgrass) was three times greater along paved roads than four-wheel-drive tracks, and richness (a measure of species diversity) and cover of non-native 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 non-natives (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 non-native 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 dominant role in ecosystem dynamics. For instance, increases in plant cover due to the proliferation of non-natives have altered fire regimes throughout the Mojave Desert region (Brooks 1999; Brooks and Esque 2002; Esque *et al.* 2003; Brooks *et al.* 2004) (see sections A(4)(b) and A(5) on Invasive Species and Increasing Fuel Load and Fire).

(b) 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, including roads, utility corridors, landfills, and sewage ponds (Knight and Kawashima 1993; Boarman and Berry 1995; Boarman *et al.* 1995; Knight *et al.* 1999; Boarman *et al.* 2006). See section C(3), Predation, for a detailed description of the effects of predator subsidies on the desert tortoise.

3. Off-Highway Vehicles

Off-highway vehicle activities take many forms, from organized events, small- or large-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. Nonetheless, unauthorized off-highway vehicle use continues to be of concern, for instance south of Interstate 10 in the Colorado Desert and adjacent to the Johnson Valley Open Area in the Western Mojave Recovery Unit, 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. 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). 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 number of active tortoise burrows than the area used by off-highway vehicles. The two largest tortoises in the off-highway vehicle use area weighed less than would be expected based on what is known about season-to-season 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 their 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. Because tortoises prefer washes and hills, they are more vulnerable to direct mortality from off-highway vehicles. 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 decrease 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 due to dust. Leaf and stem temperatures were also shown to be higher in plants with leaf-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 also hold true for the hot deserts that tortoises occupy. Soil crusts also appear to be an important source of water for plants, as crusts 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, non-native plants may colonize, become established, and out-compete native perennial and annual plant species (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 (see section A(4)(a), Invasive Plants and Nutrition). Increased presence of invasive plants can also contribute to increased fire frequency (see sections A(4)(b) and A(5), Increasing Fuel Load and Fire).

4. 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 non-native 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: *Erodium cicutarium* (redstem filaree), *Bassia hyssopifolia* (bassia), *Ambrosia acanthicarpa* (sand bur), *Ambrosia psilostachya* var. *californica* (western ragweed), *Hemizonia pungens* (common spikeweed), *Matricaria matricarioides* (pineapple weed), *Amsinckia intermedia* (fiddleneck), *A. tessellata* (bristly fiddleneck), *Descurania sophia* (flixweed), *Sisymbrium altissimum* (tumble mustard), *S. irio* (London rocket), *Salsola iberica* (Russian thistle), *Eremocarpus setigerus* (turkey mullein), and *Marrubium vulgare* (horehound) (Tierra Madre Consultants, Inc.1991; BLM files 2006). Annual grasses include: *Bromus rubens* (red brome), *B. tectorum*, *Hordeum glaucum* (smooth barley), *H. jubatum* (foxtail barley), *H. leporinum* (hare barley), *Schismus barbatus* (split grass), and *S. arabicus* (Arab grass). *Brassica tournefortii* (Sahara mustard) and *Hirschfeldia incana* (Mediterranean mustard) are rapidly spreading, non-native winter annuals invading the desert southwest, especially in sandy soils (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 non-native annual plant taxa in the Mojave region evolved in more fertile Mediterranean regions and benefit from increased levels of soil nitrogen, which gives 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 non-native annual plants and promote the invasion of new species in desert regions. Furthermore, increased dominance by non-native annuals may decrease the diversity of native annual plants, and increased biomass of non-native annual grasses may increase fire frequency (Brooks 2003).

(a) Nutrition. Nutritional intake affects growth rates in juvenile desert tortoises (Medica *et al.* 1975) and female reproductive output (Turner *et al.* 1986, 1987; Henen 1992). Invasion of non-native plants can 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.

As native plants are displaced by non-native invasive species in some areas of the Mojave Desert, non-native plants can be a necessary food source for some desert tortoises. However, non-native 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). Nagy *et al.* (1998), in a comparative study on the nutritional qualities of native vs. non-native grasses and forbs commonly consumed by desert tortoises (*Achnatherum hymenoides* [Indian ricegrass] vs. *Schismus barbatus*; *Malacothrix* spp. [desert dandelion] vs. *Erodium cicutarium*), found that the nutritional value of the two grasses was similar, but both grasses had much lower nutritional value than the forbs. This suggests that the proliferation of non-native grasses such as *Schismus* to the exclusion of native forbs and other plants (D'Antonio and Vitousek 1992) places desert tortoises at a nutritional disadvantage. Furthermore, if tortoises consume just enough food to satisfy their energy needs (as commonly noted in other vertebrate groups), then the native forbs provide significantly more nitrogen and water than the non-native forbs (Nagy *et al.* 1998).

Changes in the abundance and distribution of native plants also may affect desert tortoises in more subtle ways. 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) suggested that desert tortoises may be vulnerable to upper respiratory tract or other 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. Non-native, annual grasses have lower PEP indices than most native forbs (Oftedal 2002; Oftedal *et al.* 2002). 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 non-native plants, and soil disturbance) that reduce the abundance and distribution of high PEP plants may result in additional challenges for foraging desert tortoises (Oftedal *et al.* 2002).

Tracy *et al.* (2006) also quantified the rates of passage of digesta (food in the stomach) 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.* 2006). Hence, these 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 grasses) 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.* 2006).

(b) 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 inter-shrub spaces that are mostly devoid of native vegetation (Brown and Minnich 1986; USFWS 1994; Brooks 1998; Brooks and Esque 2002). Invasive, non-native annual grasses and forbs increasingly spread over the desert floor, resist decomposition, and provide flash fuel for fires. Brooks (1999) found that non-native 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 non natives increase because they regenerate on burned areas more quickly than native plants (Brown and Minnich 1986). Changes in plant communities caused by non-native plants and recurrent fire negatively affect the desert tortoise by altering habitat structure and species composition of their food plants (Brooks and Esque 2002) (see also section A(5), Fire).

Brooks and Berry (2006) found that while non-native 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 in the Mojave Desert, non-native annuals accounted for 6 percent of the flora and 66 percent of the biomass; in 1999, a low rainfall year, non-natives comprised 27 percent of the flora and 91 percent of the biomass. Annual species dominate the non-native flora, with *Bromus rubens*, *Schismus barbatus*, and *Erodium cicutarium* being the most widespread and abundant, representing up to 99 percent of the non-native biomass (Brooks and Berry 2006).

Evidence of disturbance was a more reliable indicator of non-native dominance than was native plant diversity or primary 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 *Erodium cicutarium*, as well as correlations between the size and frequency of fires and biomass of *Bromus rubens*. 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 (see section A(5), Fire).

5. 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 by 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 at that time. Fire can also compromise the quality of tortoise habitat by reducing the vegetation that provides shelter, cover, and nutrition (key forage plants) for tortoises (Brooks and Esque 2002; Esque *et al.* 2003).

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 rather than sparse cover of native species make it more likely for fire to become hot enough to damage native shrubs, which are poorly adapted to survive and/or regenerate quickly after fire and are 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). Conversion to grassland also tends to create a self-perpetuating grass/fire cycle as fuels continuously reestablish in burned areas (D'Antonio and Vitousek 1992).

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. 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 non-native 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 non-native grasses. Additionally, fires can increase the frequency and cover of non-native 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 non-native plants and frequency of fires in the future (Brooks and Esque 2002; Brooks *et al.* 2003).

The most striking changes in fire frequency in the Mojave Desert have been observed in the middle elevations dominated by *Larrea tridentata* (creosote bush), *Yucca brevifolia* (Joshua tree), and *Coleogyne ramosissima* (blackbrush), at the upper limits of desert tortoise distribution, where most of the fires 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 plant cover, whereas 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.

According to Bureau of Land Management files (2006), 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 (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, approximately 1,700 hectares (4,200 acres) of 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 likely 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 while reducing immediate and long-term tortoise mortality (Esque *et al.* 1994, 2003).

In general, as fire becomes more prevalent throughout the range of the desert tortoise, the threats to the species from mortality or injury by burning and smoke inhalation during fire events and impacts to desert habitats will also increase. Changes in habitat structure from shrub-dominated communities to non-native annual grasslands would limit the availability of cover sites for tortoises as well as alter species composition of food plants.

6. Grazing

Impacts of grazing on arid lands are well documented (Fleischner 1994; Jones 2000). Recovery from these impacts is variable, but can take decades, will likely require significant management effort beyond excluding livestock, and will be affected by other factors such as drought (GAO 1991; Friedel 1991; Laycock 1991). Livestock grazing (sheep and cattle as well as horses and burros) is known to have direct and indirect impacts on desert tortoises and their habitats through trampling that results in direct mortality either while above ground or in burrows, and 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 livestock, 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. Grazing is thought to reduce cover of shrubs and annual forbs. Studies in the eastern Mojave Desert on foraging behavior and food preferences of range cattle and desert tortoises showed that a dietary overlap (spatial and temporal) exists and that this overlap is greatest in the spring when fresh annual plants preferred by both desert tortoise and livestock are at their peak biomass and densities. Competition for these food plants 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. They noted that tortoises outside an ungrazed cattle exclosure spent more nights outside of burrows than tortoises within the exclusion area, because more burrows were destroyed in the grazed area than in the ungrazed area. In a study on translocated tortoises in the northwest Mojave Desert, one tortoise was found alive in its hibernation burrow even though the burrow had been crushed by cattle. It had skin lesions and had been parasitized by fly larvae. The tortoise was removed from the study because it was assumed that it would have died if it had been left in the crushed burrow (Nussear 2004). Tortoises with home ranges 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).

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 caused by grazing practices. Soil organic matter, carbon and nitrogen content, and microbial biomass were also lower in the 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 resulting from grazing. 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).

Studies at the Desert Tortoise Natural Area also 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 10 years (Brooks 2000). Similarly, grazing (and simulated grazing treatments) negatively impacted native plant species, while non-native species were unaffected and demonstrated superior competitive abilities, at Carrizo Plain National Monument, California (Kimball and Schiffman 2003).

7. 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).

8. Energy and Mineral Development

Exploration for and development of energy and mineral resources, as well as sand and gravel extraction, result in habitat fragmentation and permanent habitat loss due to haul roads, development of facilities necessary to support large mining operations, ancillary facilities, leachate ponds, and mine tailings. Additional impacts to the desert tortoise may result from fugitive dust and soil erosion, establishment of invasive plant species in disturbance zones, and introduction of toxins (see section C(1), Disease). Tortoises may be killed during exploration, construction and ongoing operations, and maintenance activities (USFWS 1994; Boarman 2002).

At the time the 1994 Recovery Plan was approved, 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 habitat loss from mining-related disturbances combined with increased development to support those operations may pose the most significant impact resulting from mining (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 recent public emphasis on advancing alternative energy sources. Dozens of project sites have been proposed, and the Bureau of Land Management in California has committed to excluding these projects from designated critical habitat for the desert tortoise and Desert Wildlife Management Areas. Habitat loss through energy development is also a potential threat in Nevada, where various projects have been proposed and applications have been submitted for solar power facility rights-of-way on over 53,800 hectares (133,000 acres) of suitable desert tortoise habitat. The energy development process on Bureau of Land Management lands appears to be constantly changing, with applicants submitting multiple requests to modify their projects or withdrawing their applications altogether (J. Crisp, Bureau of Land Management, pers. comm. 2007).

9. Landfills

There are more than 25 authorized sanitary landfills and waste disposal facilities known in the California deserts, with 11 of those located in the west Mojave Desert (Boarman 2002). In other urban areas throughout the range of the tortoise, all communities produce solid 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 that attracts predators, introduction of toxic chemicals, increased road kill of tortoises on access roads, and increased predator populations (Boarman 2002) (see also section C(3), Disease and Predation). 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).

10. 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, and abandonment of 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 other impacts associated with large human settlements in the desert (*i.e.*, collection of tortoises, trash dumping, increased raven populations, domestic pets as predators, off-highway vehicle use, increased exposure to disease, and increased road-kill mortality) (USFWS 1994).

The military bases and test ranges in the Mojave Desert include the Nevada Test and Training Range, Nellis Air Force Range in Nevada, Edwards Air Force Base in California, Twentynine Palms Marine Corps Air Ground Combat Center in California, Barstow Marine Corps Logistics Bases in California (includes the Yermo Annex, Main Base at Nebo, and the Marine Corps Rifle Range), Fort Irwin National Training Center in California, China Lake Naval Air Weapons Station in California, and the Mojave B and Randsburg Wash Test Ranges (in

California). The Chocolate Mountains Aerial Gunnery Range in California is the primary base affecting desert tortoise habitat in the Colorado Desert (USFWS 1994). All of these military facilities encompass desert tortoise habitat.

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 Fort Irwin National Training Center in California. 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 to minimize impacts associated with 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).

11. 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 (USFWS 1994). Disturbances associated with these corridors are usually linear in nature, and the zone of disturbance can vary in width from 15.2 to 30.5 meters (50 to 100 feet) to several hundred meters or 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) evaluated results of over 230 biological opinions issued by our southern California and Nevada offices and found that 80 percent of the tortoises reported 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, and may result in road-kills (Boarman 2002). Utility towers also provide nesting substrate and hunting perches to avian predators, such as ravens and red-tailed hawks.

12. Vandalism and Harvest of Vegetation

Vandalism and harvest of vegetation, particularly cacti and yuccas, 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). Vandalism of vegetation is considered to be 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

1. 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 (Berry and Nicholson 1984; Swingland and Klemens 1989; Schneider and Everson 1989; Ditzler 1991; BLM files 2006), 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 collecting for personal or commercial purposes was evidently significant in the past (Grant 1936; Berry and Burge 1984; Berry and Nicholson 1984; Ditzler 1991; Berry *et al.* 1996; USFWS 1994). Desert tortoises are protected from collection under both Federal and State law in all states where it occurs; 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 could possibly impact local populations, little quantitative evidence exists to support it as a significant threat causing declines in the Mojave populations (Boarman 2002). Also, information specific to this threat is limited owing to the wide distribution of the species coupled with the need for additional law enforcement officers and wardens on the ground (see section D, Inadequacy of Existing Regulatory Mechanisms).

2. Deliberate Maiming and Killing by Humans

Little additional information regarding maiming and killing 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 (Berry 1986). Evidence of gunshot was significantly higher in carcasses 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.

3. Research Activities

We permit various research activities that will inform management and recovery of the desert tortoise but may unintentionally result in infrequent injury or mortality. The following activities may be permitted with terms and conditions to minimize injury and potential mortality of individuals:

(a) Population monitoring, which involves pursuit, capture, and handling of free-ranging tortoises to determine weight, size, sex, and to mark them for recapture.

(b) Epidemiological studies, which involve general health assessments and disease-related investigations (*e.g.,* collection of blood samples and nasal lavages); moribund tortoises may be collected from the wild and occasionally euthanized.;

(c) 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 (passive integrated responders); attachment of radio transmitters or other hardware in accordance with USFWS-approved protocol; and pursuit and capture of study animals during monitoring activities.

(d) Research on impacts of grazing, road density, barriers, human-use levels, restoration, and augmentation and translocation on desert tortoise population dynamics, which may include many of the activities and associated effects described above.

(e) Research on nutritional and physiological ecology of various age classes of desert tortoises, which includes many of the types of activities and associated effects described above. In addition, captive tortoises may be injected with labeled or tritiated water in association with physiological studies.

(f) Research on reproductive behavior and physiology, which includes many of the types of activities and associated effects described above, and involve both free-ranging and captive desert tortoises.

Potential stress to desert tortoises from handling may vary depending on the time, frequency, and activity involved. Invasive procedures associated with obtaining physiological data can cause significant stress to individuals (Berry *et al.* 2002a). For example, female tortoises that void their bladders during handling may be at a reproductive disadvantage since the loss of fluid may negatively affect egg production, which requires higher total body water in reproductive females than non-reproductive females (Averill-Murray 2002). In one study, tortoises that urinated during handling had lower survival than those that did not (Averill-Murray 2002).

Despite the inherent low-level risk associated with activities covered under recovery permits, incidental injury or mortality of desert tortoises is not expected. However, if injury or mortality should occur, the permit is 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 desert tortoise research. 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.

C. Disease or Predation

1. 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 in desert tortoise populations (Boarman 2002). Likewise, only correlative studies (*i.e.,* not based on cause and effect investigations) 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, and the level of effort we should expend in disease control as compared 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 (airborne liquid droplets or solid particles). 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 also 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.* 2007), 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 virulence 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 (indicating exposure to the pathogen) were present in 82.7 percent of the tortoises tested (sample size of 179), and anti-herpesvirus antibodies were observed in 26.6 percent of the animals (sample size of 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 test positive for presence of antibodies. However, this linkage was not observed with herpesvirus exposure. These results indicate that captive tortoises released into the wild may be a source of upper respiratory infection, but not herpesvirus infection, for natural populations (Johnson *et al.* 2006).

In contrast, Jones *et al.* (2005) found that captive tortoises do not appear to serve as a reservoir for upper respiratory tract disease when released in the Sonoran population of desert tortoise. They did find higher incidence of disease in suburban areas around Tucson, Arizona, which suggests that habitat degradation associated with urbanization may be a stressor that contributes 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, which then spread to the scutes themselves. This disease has been associated with population 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 section C(2), Toxicants and Disease Susceptibility).

2. Toxicants and Disease Susceptibility

Illegal dumping of hazardous wastes that occurs in the California deserts 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 induces diseases related to toxicosis (*e.g.* liver disease) and influences the susceptibility of tortoises to infectious diseases and mortality. For example, tortoises that died of mycoplasmosis at the Desert Tortoise Natural 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 disturbances. Chaffee and Berry (2006) collected soil, stream sediment, and plant samples at six 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, to identify potential sources of toxicants in desert tortoise habitats. Some measurements of high concentrations of arsenic, mercury, and lead, were attributed to mining and vehicle exhaust. High levels of soil and plant arsenic extended more than 14 kilometers (9 miles) from some existing mine sites, and mercury was detected more than 5 kilometers (3 miles) from some mine tailings. Traces of lead were found more than 21 kilometers (13 miles) from a paved road and likely had 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).

3. Predation

Desert tortoises, particularly hatchlings and juveniles, are preyed upon by several native species of mammals, reptiles, and birds; however, the contribution of mammalian or avian predation to overall desert tortoise mortality has not been quantified. Natural predation in undisturbed, healthy ecosystems is generally not considered a threat, but under some circumstances predation comes to the forefront as a management concern, especially where landscapes have been altered and intensive human use occurs. In addition, during times of drought when typical prey species are limited, food habits of predators may shift and tortoises become more frequent components of their diets (USFWS 1994).

The best-documented predator of small tortoises is the common raven (*Corvus corax*). For example, Campbell (1986) found 136 carcasses of juvenile desert tortoises with evidence of raven predation at the base of fence posts on the perimeter of the Desert Tortoise Natural Area. Berry *et al.* (1990) reported that 30 and 45 percent, respectively, of all desert tortoise deaths at two study plots during a 6-year period were probably caused by raven predation; up to 75 percent of deaths of tortoises ≤103 mm (4.1 in) carapace length were attributed to raven predation at these plots.

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, associated food and water subsidies, and anthropogenic changes to the landscape (Boarman and Berry 1995; Boarman *et al.* 1995; 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). Particularly in the west Mojave and Coachella Valley, 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, red-tailed hawks (*Buteo jamaicensis*), and turkey vultures (*Cathartes aura*) (Knight and Kawashima 1993; Boarman *et al.* 1995; Knight *et al.* 1999). 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). The presence of roads may encourage such opportunistic species because road-killed animals are a reliable food source (Camp *et al.* 1993; Boarman and Sazaki 2006).

Raven numbers were shown to decrease with distance from urban sites in the west Mojave, placing tortoises that occur in the urban-desert 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 patterns of predation 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-desert interface experience reduced predation pressures from ravens (Boarman *et al.* 1993; Boarman 2002; Kristan and Boarman 2003).

Determining precise demographic impacts of (increased) raven predation on desert tortoise populations is complicated because of the difficulty of monitoring small, hard to find juvenile tortoises (Boarman 2002). Nevertheless, the potential impact to desert tortoise populations from raven predation is a conservation concern, especially where subsidized predators are able to persist in large numbers despite declines in their prey base. Populations of long-lived animals like the desert tortoise can sustain moderate levels of annual juvenile mortality (*e.g.*, 25 percent), but in the face of depressed adult survival, juvenile mortality must be reduced to approximately 5 percent to ensure recruitment into the breeding population (Congdon *et al*. 1993). Human-subsidized predators thus put at great disadvantage any prey species such as the desert tortoise that is unable to rebound from predation pressures (Kristan and Boarman 2003).

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 of desert tortoise (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 (Nagy *et al*. 2007).

D. Inadequacy of Existing Regulatory Mechanisms

1. Law Enforcement

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. However, State wildlife or endangered species permitting requirements do not specifically cover habitat and generally do not require mitigation of impacts to suitable, potentially occupied habitat. In addition, a great deal of effort has been dedicated to planning by the various Federal and State land management agencies whose jurisdictions include desert tortoise habitat. While 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, agency multiple-use mandates require a complex balancing of tortoise conservation and public use of Federal and State lands. Also, 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. As calculated from the data in Table A-3, current information indicates that each law enforcement officer is responsible for an average of more than 89,000 hectares (220,000 acres).

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
Total	163	23	>36,249,000

[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.

2. **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). Transactions may also 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, the 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. An additional 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. The Coyote Springs Investment (CSI) HCP is being developed to address urban development and tortoise conservation on CSI lands in Lincoln County. The plan would permit development over 8,682 hectares (21,454 acres) in Lincoln County, most of which is desert tortoise habitat (Mormon Mesa critical habitat unit). The plan would also establish a desert tortoise reserve on 5,571 hectares (13,767 acres) of the CSI leased.

Under the Bureau of Land Management’s Western Mojave Land Tenure Adjustment Program, which provides a mechanism pursuant to the Federal Land Policy and Management Act of 1976 to acquire lands within and dispose of Federal lands outside of DWMAs, approximately 21,044 hectares (52,000 acres) of land within desert tortoise critical habitat have been acquired 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 Program, for a net benefit to the amount of desert tortoise habitat protected on Federal lands (BLM 2005).

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 for 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 of the Mojave Desert relative to human occupation in the Mojave Desert wherein over 58,600 hectares (145,000 acres) of Federal land are identified for disposal and urban development.

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. These laws include 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.

E. Other Natural or Manmade Factors Affecting its Continued Existence

1. Climate Change

Climate change and drought were not regarded as threats to the desert tortoise in the 1994 Recovery Plan. Since that time it has become apparent that the combined effects of global climate change (*i.e.*, increased ambient temperatures and altered precipitation patterns) and drought may become significant factors in the long-term persistence of the species. 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 (Walther *et al.* 2002). 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 would likely 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).

The Intergovernmental Panel on Climate Change has suggested that increasingly reliable climate change projections are now available as the result of improved modeling capabilities and advanced understanding of climate systems (Christensen *et al*. 2007). The Intergovernmental Panel on Climate Change's 2007 report discussed the results of 21 Atmosphere-Ocean General Circulation Models that were run to predict regional changes in temperature and precipitation in 2080 to 2099 compared to conditions that occurred between 1980 and 1999. Generally, predictions for the geographic range of the desert tortoise's listed population suggest more frequent and/or prolonged droughts. For example, annual mean temperature is likely to increase by 3.5 to 4.0 degrees Celsius (6.3 to 7.2 degrees Fahrenheit), with the greatest increases occurring in summer (June-July-August mean up to 5 degrees Celsius [9 degrees Fahrenheit] increase) (Christensen *et al*. 2007). In summer, the highest temperatures will likely increase even more than the average temperatures. Precipitation will likely decrease by 5 to 15 percent annually in the region with winter precipitation decreasing in the range of 5 to 20 percent. More than half of the models predict that changes in summer precipitation may be more moderate (decrease by as much as 10 percent) with the possibility for a 5 percent increase (Christensen *et* *al.* 2007). This prediction for more drying in winter than in summer differs from predictions for much of the United States. Because germination of the tortoise's food plants is highly dependent on cool season rains, the forage base could be reduced due to increasing temperatures and decreasing precipitation in winter. Drought is a normal phenomenon in the Mojave Desert (Peterson 1994a; Hereford *et al.* 2006). 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.

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 many native desert plants are 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 the non-native grass *Bromus tectorum* responds to increases in CO_2 (a component required for photosynthesis) with far greater productivity than that of native plants during wet years (Smith *et al.* 2000). However, the overall response of non-native grasses to increased CO_2 is uncertain, given expected reductions in precipitation. As discussed in sections A(4)(b) and A(5), Increasing Fuel Load and Fire, colonization by non-native annual grasses is known to increase the frequency and intensity of fires, both of which have dramatic negative effects on desert water cycles and wildlife habitat (Hamerlynck *et al.* 2000).

Climatic regimes are believed to influence the distribution of plants and animals through species-specific physiological thresholds of temperature and precipitation tolerance. Warming temperatures and altered precipitation patterns may result in distributions shifting northward and/or to higher elevations, depending on resource availability (Walther *et al.* 2002). We may expect this response in the desert tortoise to reduce 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 (such as most desert regions).

Some evidence suggests, however, that desert tortoises may be capable of adapting to changes in the environment through modification of their behavior, periods of activity, and diet (Morafka and Berry 2002). The desert tortoise evolved millions of years before the formation of the North American deserts, and the species experienced both more mesic and more xeric conditions within the last several thousand year (Morafka and Berry 2002). Perhaps as the habitats they occupied changed and became more arid, the tortoise was able to adapt and succeed in desert climes and exploit a broad ecological range. The probability that the desert tortoise will be able to survive ongoing changes in vegetation and food sources or temperature and precipitation patterns remains to be seen, especially in light of continued anthropogenic alterations of the environment (Morafka and Berry 2002). Models demonstrate large shifts in plant distributions that over a long period of time may allow opportunities for migration and adaptation. Under the current scenario, however, where change may occur within a few decades, it cannot be predicted whether or not plants and animals would be able to readily migrate into new habitats (Thompson *et al.* 2003).

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). In addition, desert tortoises have temperature-dependent sex determination (*i.e.*, the sex of the hatchlings is determined by the temperatures in the nest), with 1:1 sex ratios produced at approximately 32.5º C, all males produced at 30.5º C and below, and all females produced at 32.5º C and above (Rostal *et al*. 2002). Although there has been some speculation that global temperature increases may skew sex ratios or eliminate male offspring altogether for some turtles (Janzen 1994), there is also evidence that temperature-dependent sex determination systems may be able to evolve through maternal nesting behavior if gradual changes in climate result in skewed sex ratios (Janzen and Morjan 2002). Sex ratios of reptiles may be robust to moderate temperature increases as long eggs experience daily fluctuating temperatures (Booth 2006). The heterogeneous environment in which tortoises nest does provide opportunities among diverse potential nest sites with exposure to a variety of temperature regimes. The survival of reptile species with temperature-dependent sex determination through cycles of warming and cooling over the last 100,000 years suggests that changes in climate were such that species were capable of shifting the time of nesting, choice of nest sites, the range occupied, or even temperature at which the sexes were produced (Booth 2006). Rapid changes in climate may challenge the ability of the desert tortoise to make such shifts. While it remains unclear as to how global and regional changes in climate may affect the desert tortoise, continued research and monitoring relative to behavioral and life history traits of the species under climate change will inform conservation and management decisions regarding recovery of the species in the Mojave Desert.

(a) Drought. Data do exist on some of the effects of drought on the desert tortoise. Drought is a normal phenomenon in the Mojave Desert; 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; Hereford *et al.* 2006). As noted above, extended periods of drought may affect desert tortoises through physiological effects to individuals (*i.e.*, stress) and limited forage availability. For example, unlike some other desert vertebrates, tortoises acquire much of their water and maintain overall positive energy balance by drinking free water (Peterson 1996a; Wilson *et al*. 2001).

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 many adverse effects to periods of drought, including dehydration, malnutrition, and starvation; reduced reproductive output of 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).

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 (Jacobson 1994). 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 with 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 biomass of annual plants 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 biomass production of annual plants (1996, 1997, and 1999), the survival of adult tortoises decreased. In 1996, 30 percent (15 individuals) of radio-monitored adults died following a drought that began in the summer of 1995. Although the researchers obtained no physiological evidence, they believed these deaths likely resulted from dehydration, as there was no substantial evidence of other mortality mechanisms, such as disease or predation (Longshore *et al.* 2003).

2. 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 at the urban-desert interface. However, based on current available data, garbage and litter do not appear to be a widespread or major threat to tortoise populations, except through the attraction of ravens and other predators. This indirect effect of predator subsidy may contribute to a more important problem, as discussed in section C(3), Predation (Boarman 2002).

3. 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 tortoises concluded that hearing loss and physiological changes are not likely to be dangerous during occasional short-term exposures; however, those results cannot be extrapolated to chronic exposures over a tortoise's lifetime. The authors advise that their results are "best viewed as a first-order effort to determine the effects of subsonic and supersonic aircraft noise on a desert reptile." They recommend 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).

4. 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 information 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 collection, road kill, and vandalism of tortoises; and increased raven populations (USFWS 1994; Boarman 2002). Off-trail use can degrade habitat by damaging vegetation and soil crusts (Belnap 1996) and by compacting soils.

Very few studies have been conducted 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 by 30 to 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 of cold-desert ecosystems, which may be confounded by increased levels of atmospheric pollution and nitrogen deposition associated with increased human populations (see Brooks 2003). However, soil crusts retain greater water content than bare soils, and non-native plants colonize and out-compete native species on disturbed soils (DeFalco *et al.* 2001).

5. 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 (*i.e.*, inappropriate mixing to tortoises from different parts of the range and with different genetic backgrounds). 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). Tomlinson and Hardenbrook (1993) 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.

Literature Cited: Appendix A

Aber, J.D., K.J. Nadelhoffer, P. Steudler, and J.M. Melillo. 1989. Nitrogen saturation in northern forest ecosystems. Bioscience 39:378-386.

Averill-Murray, R.C. 2002. Effects on survival of desert tortoises (*Gopherus agassizii*) urinating during handling. Chelonian Conservation and Biology 4:430-435.

Avery, H.W. 1992. Summer food habits of desert tortoises in Ivanpah Valley, California. Proceedings of the Desert Tortoise Council Symposium 1992:60.

Avery, H.W., and A.G. Neibergs. 1997. Effects of cattle grazing on the desert tortoise, *Gopherus agassizii*: Nutritional and behavioral interactions. Pages 13-20 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Avery, H.W., J.D. Congdon, and J.R. Spotila. 2002. Life history and demographic analysis of the desert tortoise at Fort Irwin and reference sites: study design and early findings. Desert Tortoise Council Symposium, March 22-25, 2002, Palm Springs, California. Abstract.

Belnap, J. 1996. Soil surface disturbance in cold deserts: effects on nitrogenase activity in cyanobacterial-lichen soil crusts. Biology and Fertility of Soils 23:362-367.

Berry, K.H. 1986. Incidence of gunshot deaths in desert tortoise populations in California. Wildlife Society Bulletin 14:127-132.

Berry, K.H. 1997. Demographic consequences of disease in two desert tortoise populations in California, USA. Pages 91-99 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Berry, K.H., and B.L. Burge. 1984. The desert tortoise in Nevada. *In* K.H. Berry (ed.), The status of the desert tortoise *(Gopherus agassizii)* in the United States. Desert Tortoise Council Report to the U.S. Fish and Wildlife Service. Order No. 11310-0083-81.

Berry, K.H., and M.M. Christopher. 2001. Guidelines for the field evaluation of desert tortoise health and disease. Journal of Wildlife Diseases 37:427-450.

Berry, K.H., and L.L. Nicholson. 1984. A summary of human activities and their impacts on desert tortoise populations and habitat in California. Chapter 3 *in* K.H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U.S. Fish and Wildlife Service. Order No. 11310-0083-81.

Berry, K.H., F.G. Hoover, and M. Walker. 1996. The effects of poaching desert tortoises in the western Mojave Desert; evaluation of landscape and local impacts. Proceedings of the Desert Tortoise Council Symposium 1996:45.

Berry, K.H., T. Shields, A.P. Woodman, T. Campbell, J. Roberson, K. Bohuski, and A. Karl. 1990. Changes in desert tortoise populations at the Desert Tortoise Research Natural Area between 1979 and 1985. Proceedings of the Desert Tortoise Council Symposium 1986:100–123.

Berry, K.H., E.K. Spangenberg, B.L. Homer, and E.R. Jacobson. 2002a. Deaths of desert tortoises following periods of drought and research manipulation. Chelonian Conservation and Biology 4:436-448.

Berry, K.H., T. Okamoto, K. Anderson, M.B. Brown, L. Wendland, and F. Origgi. 2002b. Health assessments of captive and wild desert tortoises at 17 sites in the Mojave and Colorado deserts, California. Desert Tortoise Council Symposium. Abstract.

Berry, K.H., J. Mack, R.W. Murphy, and W. Quillman. 2006. Introduction to the special issue on the changing Mojave Desert. Journal of Arid Environments 67 Supplement:5-10.

Boarman, W.I. 1993. When a native predator becomes a pest: a case study. Pages 186-201 *in* S.K. Majumdar *et al.* (eds.), Conservation and Resource Management. Pennsylvania Academy of Science. Easton, Pennsylvania.

Boarman, W.I. 2002. Threats to desert tortoise populations: A critical review of the literature. U.S. Geological Survey, Western Ecological Research Center, Sacramento, California.

Boarman, W.I., and K.H. Berry. 1995. Common ravens in the southwestern United States, 1968-92. Pages 73-75 *in* E.T. LaRoe, G.F. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (eds.), Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. National Biological Survey, Washington, D.C.

Boarman, W.I., and M. Sazaki. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. Pages 169-173 *in* G.J. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.), Trends in addressing transportation related wildlife mortality seminar. Environmental Management Office, U.S. Department of Transportation, Tallahassee, Florida.

Boarman, W.I. and M. Sazaki. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). Journal of Arid Environments 65:94-101.

Boarman, W.I., M. Sazaki, and W.B. Jennings. 1997. The effect of roads, barrier fences, and culverts on desert tortoise populations in California, USA. Pages 54-58 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York.

Boarman, W.I., R.J. Camp, M. Hagan, W. Deal. 1995. Raven abundance at anthropogenic resources in the western Mojave Desert, California. Report to Edwards Air Force Base, California.

Boarman, W.I., M.A. Patten, R.J. Camp, and S.J. Collis. 2006. Ecology of a population of subsidized predators: Common ravens in the central Mojave Desert, California. Journal of Arid Environments 67 Supplement:248-261.

Boarman, W.I., M. Sazaki, K.H. Berry, G.O. Goodlett, W.B. Jennings, and A.P. Woodman. 1993. Measuring the effectiveness of a tortoise-proof fence and culverts: status report from first field season. Proceedings of the Desert Tortoise Council Symposium 1993:126-142.

Booth, D.T. 2006. Influence of incubation temperature on hatchling phenotype in reptiles. Physiological and Biochemical Zoology 79:274-281.

Bowles, A.E., E. Eckert, L. Starke, E. Berg, L. Wolski, and J. Matesic, Jr. 1999. Effects of flight noise from jet aircraft and sonic booms on hearing, behavior, heart rate, and oxygen consumption of desert tortoise (*Gopherus agassizii*). AFRL-HE-WP-TR-1999-0170. Sea World Research Institute, Hubbs Marine Research Center, San Diego, California.

Brooks, M.L. 1998. Alien annual grass distribution, abundance, and impact on desert tortoise habitat in the western Mojave Desert. Ph.D. Dissertation. University of California, Riverside.

Brooks, M.L. 1999. Alien annual grasses and fire in the Mojave Desert. Madrono 46:13-19.

Brooks, M.L. 2000. Does protection of desert tortoise habitat generate other ecological benefits in the Mojave Desert? USDA Forest Service Proceedings RMRS-P-15 3:68-73.

Brooks, M.L. 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. Journal of Applied Ecology 40:344-353.

Brooks, M., and K. Berry. 1999. Ecology and management of alien annual plants in the California Desert. CalEPPC News, Spring 1999. Pages 4-6.

Brooks, M.L., and K.H. Berry. 2006. Dominance and environmental correlates of alien annual plants in the Mojave Desert, USA. Journal of Arid Environments 67 Supplement:100-124.

Brooks, M.L., and T.C. Esque. 2002. Alien plants and fire in desert tortoise (*Gopherus agassizii*) habitat of the Mojave and Colorado deserts. Chelonian Conservation and Biology 4:330-340.

Brooks, M.L., and B. Lair. 2005. Ecological effects of vehicular routes in a desert ecosystem. Report prepared for the U.S. Geological Survey, Recoverability and Vulnerability of Desert Ecosystems Program. Western Ecological Research Center, Henderson, Nevada.

Brooks, M.L., and J.R. Matchett. 2006. Spatial and temporal patterns of wildfires in the Mojave Desert, 1980-2004. Journal of Arid Environments 67 Supplement:148-164.

Brooks, M.L., T.C. Esque, C.R. Schwalbe. 1999. Effects of exotic grasses via wildfire on desert tortoises and their habitat. Proceedings of the Desert Tortoise Council Symposium 1999:40-41.

Brooks, M.L., T.C. Esque, and J.R. Matchett. 2003. Current status and management of alien plants and fire in desert tortoise habitat. Desert Tortoise Council Symposium, February 2003, Las Vegas, NV. Abstract.

Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. Bioscience 54:677-688.

Brown, D.E., and R.A. Minnich. 1986. Fire and changes in creosote bush scrub of the western Sonoran Desert, California. American Midland Naturalist 116:411-422.

Brown, D.R., B.C. Crenshaw, G.S. McLaughlin, I.M Schumacher, C.E. McKenna, P.A. Klein, E.R. Jacobson, and M.B. Brown. 1995. Taxonomic analysis of the tortoise Mycoplasmas *Mycoplasma agassizii* and *Mycoplasma testudinis* by 16S rRNA gene sequence comparison. International Journal of Systematic Bacteriology 45:348-350.

Brown, D.R., I.M. Schumacher, G.S. McLaughlin, L.D. Wendland, M.B. Brown, P.A. Klein, and E.R. Jacobson. 2002. Application of diagnostic tests for mycoplasmal infections of the desert and gopher tortoises, with management recommendations. Chelonian Conservation and Biology 4:497-507.

Brown, M.B., I.M. Schumacher, P.A. Klein, K. Harris, T. Correll, and E.R. Jacobson. 1994. *Mycoplasma agassizii* causes upper respiratory tract disease in the desert tortoise. Infection and Immunity 62:4580-4586.

Brown, M.B., K.H. Berry, I.M. Schumacher, K.A. Nagy, M.M. Christopher, and P.A. Klein. 1999. Seroepidemiology of upper respiratory tract disease in the desert tortoise in the western Mojave Desert of California. Journal of Wildlife Diseases 35:716-727.

Brown, M.B., D.R. Brown, P.A. Klein, G.S. McLaughlin, I.M. Schumacher, E.R. Jacobson, H.P. Adams, and J.G. Tully. 2001. *Mycoplasma agassizii* sp. nov., isolated from the upper respiratory tract of the desert tortoise (*Gopherus agassizii*) and the gopher tortoise (*Gopherus polyphemus*). International Journal of Systematic and Evolutionary Microbiology 51:413-418.

[BLM] Bureau of Land Management. 2006. Fire data compiled by the Las Vegas and Ely Field Offices, Las Vegas and Ely, Nevada.

[BLM] Bureau of Land Management, County of San Bernardino, and City of Barstow. 2005. Final environmental impact report and statement for the West Mojave Plan, a habitat conservation plan and California Desert Conservation Area Plan amendment. Bureau of Land Management, California Desert District, Moreno Valley, California.

Burge, B.L. 1977. Daily and seasonal behavior, and areas utilized by the desert tortoise, *Gopherus agassizii*, in southern Nevada. Proceedings of the Desert Tortoise Council Symposium 1977:59-94.

Burge, B.L. 1989. What goes up must come down. Massive balloon releases are a potential threat to tortoises and other wildlife. Tortoise Tracks 10(3):4.

Bury, R.B., and R.A. Luckenbach. 2002. Comparison of desert tortoise (*Gopherus agassizii*) populations in an unused and off-road vehicle area in the Mojave Desert. Chelonian Conservation and Biology 4:457-463.

Byerly, E.R., and K. Deardorff. 1995. National and State Population Estimates: 1990 to 1994, U.S. Bureau of the Census, Current Population Reports, P25-1127, U.S. Government Printing Office, Washington, D.C.

Camp, R.J., R.L. Knight, H.A.L. Knight, M.W. Sherman, and J.Y. Kawashima. 1993. Food habits of nesting common ravens in the eastern Mojave Desert. Southwestern Naturalist 38:163-165.

Campbell, T. 1986. Some natural history observations of desert tortoises and other species on and near the Desert Tortoise Natural Area, Kern County, California. Proceedings of the Desert Tortoise Council Symposium 1983:80–83.

Chafee, M.A., and K.H. Berry. 2006. Abundance and distribution of selected elements in soils, stream sediments, and selected forage plants from desert tortoise habitats in the Mojave and Colorado deserts, USA. Journal of Arid Environments 67 Supplement:35-87.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton. 2007. Regional Climate Projections. Pages 847-926 *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Clark County Department of Aviation. 2006. Project definition and justification: Proposal to construct and operate a new supplemental commercial service airport in the Ivanpah Valley. Clark County, Nevada.

Cole, K.L., K. Ironside, P. Duffy, and S. Arundel. 2005. Transient dynamics of vegetation response to past and future climatic changes in the southwestern United States. Poster presentation at U.S. Climate Change Science Program, Workshop on Climate Science in Support of Decision Making. Arlington, Virginia.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63-87.

DeFalco, L.A., J.K. Detling, C.R. Tracy, and S.D. Warren. 2001. Physiological variation among native and exotic winter annual plants associated with microbiotic crusts in the Mojave Desert. Plant and Soil 234:10-14.

Ditzler, J. 1991. Cambodians get jail for taking tortoises. The Daily Press, Barstow, California. August 23, 1991, Part A.

Duda, J.J., A.J. Krzysik, and J.E. Freilich. 1999. Effects of drought on desert tortoise movement and activity. Journal of Wildlife Management 63:1181-1192.

Edwards, T., E.W. Stitt, C.R. Schwalbe, and D.E. Swann. 2004. *Gopherus agassizii* (desert tortoise). Movement. Herpetological Review 35:381-382.

Esque, T.C. 1992. Diet selection of the desert tortoise in the northeast Mojave Desert – FY 1991 update. Proceedings of the Desert Tortoise Council Symposium 1992:64-68.

Esque, T.C. 1994. Diet and diet selection of the desert tortoise (*Gopherus agassizii*) in the northeastern Mojave Desert. Master's Thesis. Colorado State University, Fort Collins.

Esque, T.C., T. Hughes, L.A. DeFalco, B.E. Hatfield, and R.B. Duncan. 1994. Effects of wildfire on desert tortoises and their habitats. Proceedings of the Desert Tortoise Council Symposium 1994:153-154.

Esque, T.C., C.R. Schwalbe, L.A. DeFalco, R.B. Duncan, and T.J. Hughes. 2003. Effects of desert wildfires on desert tortoise (*Gopherus agassizii*) and other small vertebrates. Southwestern Naturalist 48:103-111.

Esque, T.C., K.E. Nussear, and P.A. Medica. 2005. Desert Tortoise Translocation Plan for Fort Irwin's Land Expansion Program at the U.S. Army National Training Center (NTC) and Fort Irwin. Report to the U.S. Army National Training Center, Directorate of Public Works. U.S. Geological Survey, Las Vegas, Nevada.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8:629-644.

Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: a viewpoint. Journal of Range Management 44:422-426.

[GAO] General Accounting Office. 1991. Rangeland Management: BLM's Hot Desert Grazing Program Merits Reconsideration. GAO/RCED-92-12. Washington, D.C.

Gelbard, J.L., and J. Belnap. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biology 17:420-432.

Grant, C. 1936. The southwestern desert tortoise, *Gopherus agassizii*. Zoologica 21:225-229.

Hamerlynck, E.P., T.E. Huxman, R.S. Nowak, S. Redar, M.E. Loik, D.N. Jordan, S.F. Zitzer, J.S. Coleman, J.R. Seeman, and S.D. Smith. 2000. Photosynthetic responses of *Larrea tridentata* to a step-increase in atmospheric CO_2 at the Nevada Desert FACE Facility. Journal of Arid Environments 44:425-436.

Hazard, L.C., D.R. Shemanski, and K.A. Nagy. 2002. Calcium and phosphorus availability in native and exotic food plants. Proceedings Desert Tortoise Council Symposium 2001-2002:63.

Henen, B.T. 1992. Desert tortoise diet and dietary deficiencies that may limit egg production at Goffs, California. Proceedings of the Desert Tortoise Council Symposium 1992:97.

Henen, B.T. 1997. Seasonal and annual energy budgets of female desert tortoises (*Gopherus agassizii*). Ecology 78:283-296.

Hereford, R., R.H. Webb, and C.I. Longpré. 2006. Precipitation history and ecosystem response to multidecadal precipitation variability in the Mojave Desert region, 1893-2001. Journal of Arid Environments 67 Supplement:13-34.

Hobbs, R.J. 1989. The nature and effects of disturbance relative to invasions. Pages 389-405 *in* J.A. Drake, H.A. Mooney, F. diCastri, R.H. Groves, E.J. Kruger, M. Rejmanek, and M. Williamson (eds.), Biological Invasions: A Global Perspective. John Wiley, Chichester, United Kingdom.

Hoff, K.v.S., and R.W. Marlow. 2002. Impacts of vehicle road traffic on desert tortoise populations with consideration of conservation of tortoise habitat in southern Nevada. Chelonian Conservation and Biology 4:449-456.

Homer, B.L., K.H. Berry, and E.R. Jacobson. 1996. Necropsies of eighteen desert tortoises from the Mojave and Colorado deserts of California. Final Report to the U.S. Department of the Interior, National Biological Service, Research Work Order No. 131, Riverside, California.

Homer, B.L., K.H. Berry, M.B. Brown, G. Ellis, E.R. Jacobson. 1998. Pathology of diseases in wild desert tortoises from California. Journal of Wildlife Diseases 34:508-523.

Huxman, T.E., and S.D. Smith. 2001. Photosynthesis in an invasive grass and native forb at elevated CO_2 during an El Niño year in the Mojave Desert. Oecologia 128:193–201.

Jacobson, E.R. 1994. Causes of mortality and disease in tortoises: a review. Journal of Zoo and Wildlife Medicine 25:2-17.

Jacobson, E.R., J.M. Gaskin, M.B. Brown, R.K. Harris, C.H. Gardiner, J.L. LaPointe, H.P. Adams, and C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). Journal of Wildlife Diseases 27:296-316.

Jacobson, E.R., T.J. Wronski, J. Schumacher, C. Reggiardo, and K.H. Berry. 1994. Cutaneous dyskeratosis in free-ranging desert tortoises, *Gopherus agassizii*, in the Colorado Desert of Southern California. Journal of Zoo and Wildlife Medicine 25:68-81.

Jacobson, E.R., M.B. Brown, I.M. Schumacher, B.R. Collins, R.K. Harris, and P.A. Klein. 1995. Mycoplasmosis and the desert tortoise (*Gopherus agassizii*) in Las Vegas Valley, Nevada. Chelonian Conservation and Biology 1:279-284.

Janzen, F.J. 1994. Climate change and temperature-dependent sex determination in reptiles. Proceedings of the National Academy of Sciences 91:7487-7490.

Janzen, F.J., and C.L. Morjan. 2002. Repeatability of microenvironmental-specific nesting behaviour in a turtle with environmental sex determination. Animal Behaviour 62:73-82.

Jennings, B. 1992. Observations on the feeding habits and behavior of desert tortoises at the Desert Tortoise Natural Area, California. Proceeding of the Desert Tortoise Council Symposium 1992:69-81.

Jennings, W.B. 1993. Foraging ecology of the desert tortoise (*Gopherus agassizii*) in the western Mojave Desert. M.S. Thesis. University of Texas, Arlington.

Jennings, W.B. 1997. Habitat use and food preferences of the desert tortoise, *Gopherus agassizii*, in the western Mojave and impacts of off-road vehicles. Pages 42-45 *in* J. Van Abbema (ed.), Proceedings of the International Conference on Conservation, Restoration, and Management of Tortoises and Turtles. New York Turtle and Tortoise Society, New York

Johnson, A.J., D.J. Morafka, and E.R. Jacobson. 2006. Seroprevalence of *Mycoplasma agassizii* and tortoise herpesvirus in captive desert tortoises (*Gopherus agassizii*) from the greater Barstow area, Mojave Desert, California. Journal of Arid Environments 67 Supplement:192-201.

Jones, A. 2000. Effects of cattle grazing on North American arid ecosystems: a quantitative review. Western North American Naturalist 60:155-164.

Jones, C.A., C.R. Schwalbe, D.E. Swann, D.B. Prival, and W.W. Shaw. 2005. *Mycoplasma agassizii* in Desert Tortoises: Upper Respiratory Tract Disease in Captive and Free-ranging Populations in Greater Tucson, Arizona. Final Report to the Arizona Game and Fish Department, Phoenix. Heritage Fund Urban Project No. U03005.

Kemp, P.R., and M.L. Brooks. 1998. Exotic species of California deserts. Fremontia 26:30-34.

Kimball, S., and P.M. Schiffman. 2003. Differing effects of cattle grazing on native and alien plants. Conservation Biology 17:1681-1693.

Knight, R.L., and J.Y. Kawashima. 1993. Responses of raven and red-tailed hawk populations to linear rights-of-ways. Journal of Wildlife Management 57:266-271.

Knight, R.L., R.J. Camp, W.I. Boarman, and H.A.L. Knight. 1999. Predatory bird populations in the east Mojave Desert, California. Great Basin Naturalist 59:331-338.

Knowles, C., R. Gumtow, P. Knowles, P. Frank, D. Gumtow-Farrior, and C. Gumtow Farrior. 1989a. Relative abundance and distribution of the common raven in the deserts of southern California and Nevada during spring and summer of 1989. Draft Final Report prepared by Fauna West Wildlife Consultants for the Bureau of Land Management, Riverside, California. Contract No. YA651-CT9-340035.

Knowles, C., R. Gumtow, P. Knowles, P. Houghton. 1989b. Relative abundance and distribution of the common raven in the deserts of southern California and Nevada during fall and winter of 1988-1989. Final Report prepared by Fauna West Wildlife Consultants for the Bureau of Land Management, Riverside, California. Contract No. CA950-CT8-56.

Koehler, J.H. 1977. Ground water in the Koehn Lake Area, Kern County, California. U.S. Geological Survey, Water Resources Investigations 77-66.

Kristan, W.B., and W.I. Boarman. 2003. Spatial pattern of risk of common raven predation on desert tortoises. Ecology 84:2432-2443.

LaBerteaux, D.L. 2006. Mustard removal at the Desert Tortoise Research Natural Area, Kern County, California. Report to the Desert Tortoise Preserve Committee, Inc.

LaRue, E.L., Jr. 1993. Distribution of desert tortoise sign adjacent to Highway 395, San Bernardino County, California. Proceedings of the Desert Tortoise Council Symposium 1993:190-204.

LaRue, E., and S. Dougherty. 1999. Federal biological opinion analysis for the Eagle Mountain Landfill project. Proceedings of the Desert Tortoise Council Symposium 1997-1998:52-58.

Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands: a viewpoint. Journal of Range Management 44:427-433.

Lioubimtseva, E., and J.M. Adams. 2004. Possible Implications of Increased Carbon Dioxide Levels and Climate Change for Desert Ecosystems. Environmental Management 23(Supplement 1):S388-S404.

Longshore, K.M., J.R. Jaeger, and J.M. Sappington. 2003. Desert tortoise (*Gopherus agassizii*) survival at two eastern Mojave Desert sites: death by short-term drought? Journal of Herpetology 37:169–177.

Lovich, J.E., and D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 249:309-326.

Lovich, J.E., P. Medica, H. Avery, K. Meyer, G. Bowser, and A. Brown. 1999. Studies of reproductive output of the desert tortoise at Joshua Tree National Park, the Mojave National Preserve, and comparative sites. Park Science 19:22-24.

Luke, C., A. Karl, and P. Garcia. 1991. A status review of the desert tortoise. Biosystems Analysis, Inc., Tiburon, California.

Medica, P.A., R.B. Bury, and F.B. Turner. 1975. Growth of the desert tortoise (*Gopherus agassizii*) in Nevada. Copeia 1975:639-643.

Minnich, J.E. 1970. Water and electrolyte balance of the desert iguana, *Dipsosaurus dorsalis,* in its native habitat. Comparative Biochemistry and Physiology 35:921-933.

Minnich, J.E. 1979. Comparison of maintenance electrolyte budgets of free-living desert and gopher tortoises (*Gopherus agassizi* and G. *polyphemus*). Pages 166-174 *in* Desert Tortoise Council Proceedings of the 1979 Symposium. Tucson, Arizona.

Mojave Desert.net. 2007. History of the Mojave Desert. Available online at <www.mojavedesert.net/history/early-man-01.html>. Accessed July 18, 2007.

Morafka, D.J., and K.H. Berry. 2002. Is *Gopherus agassizii* a desert-adapted tortoise, or an exaptive opportunist? Implications for tortoise conservation. Chelonian Conservation and Biology 4:263-287.

Nagy, K.A. 1972. Water and electrolyte budgets of a free-living desert lizard, *Sauromalus obesus.* Journal of Comparative Physiology 79:93-102.

Nagy, K.A., L.S. Hillard, S.D. Dickson, and D.J. Morafka. 2007. Head-starting desert tortoises: irrigation and yearling releases at Edwards Air Force Base. Desert Tortoise Council Symposium. Abstract.

Nagy, K.A., and P.A. Medica. 1986. Physiological ecology of desert tortoises. Herpetologica 42:73-92.

Nagy, K.A., B.T. Henen, and D.B. Vyas. 1998. Nutritional quality of native and introduced food plants of wild desert tortoises. Journal of Herpetology 32:260-267.

Neff, J.C., R.L. Reynolds, J. Belnap, and P. Lamothe. 2005. Multi-decadal impacts of grazing on soil physical and biogeochemical properties in southeast Utah. Ecological Applications 15:87-95

Nussear, K.E. 2004. Mechanistic investigation of the distributional limits of the desert tortoise, *Gopherus agassizii*. Ph.D. Dissertation. University of Nevada, Reno.

O'Connor, M.P., J.S. Grumbles, R.H. George, L.C. Zimmerman, and J. R. Spotila. 1994. Potential hematological and biochemical indicators of stress in free-ranging desert tortoises, *Gopherus agassizii*, in the eastern Mojave desert. Herpetological Monographs 8:60-71.

Oftedal, O.T. 2002. The nutritional ecology of the desert tortoise in the Mojave and Sonoran deserts. Pages 194-241 i*n* T.R. Van Devender (ed.), The Sonoran Desert Tortoise; Natural History, Biology and Conservation. University of Arizona Press, Tucson, Arizona.

Oftedal, O.T. and M.E. Allen. 1996. Nutrition as a major facet of reptile conservation. Zoo Biology 15:491-497.

Oftedal, O.T., S. Hillard, and D.J. Morafka. 2002. Selective spring foraging by juvenile desert tortoises (*Gopherus agassizii*) in the Mojave Desert: Evidence of an adaptive nutritional strategy. Chelonian Conservation and Biology 4:341-352.

Oldemeyer, J.L. 1994. Livestock grazing and the desert tortoise in the Mojave Desert. Pages 95-103 *in* R.B. Bury and D.J. Germano (eds.), Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13, Washington, D.C.

Origgi, R., C.H. Romero, P.A. Klein, K.H. Berry, and E.R. Jacobson. 2002. Serological and molecular evidences of herpesvirus exposure in desert tortoises from the Mojave Desert of California. Desert Tortoise Council Symposium. Abstract.

Peterson, C.C. 1994a. Different rates and causes of high mortality in two populations of the threatened desert tortoise, *Gopherus agassizii*. Biological Conservation 70:101-108.

Peterson, C.C. 1994b. Physiological ecology of the desert tortoise, *Xerobates agassizii*. Pages 213-224 *in* P.R. Brown and J.W. Wright (eds.), Herpetology of the North American Deserts, Proceedings of a Symposium. Southwestern Herpetologist Society, Van Nuys, California.

Peterson, C.C. 1996a. Ecological energetics of the desert tortoise (*Gopherus agassizii*): effects of rainfall and drought. Ecology 77:1831–1844.

Peterson, C.C. 1996b. Anhomeostasis: Seasonal water and solute relations in two populations of the threatened desert tortoise (*Gopherus agassizii*) during chronic drought. Physiological Zoology 69:1324-1358.

Rostal, D.C., T. Wibbels, J.S. Grumbles, V.A. Lance, and J.R. Spotila. 2002. Chronology of sex determination in the desert tortoise (*Gopherus agassizii*). Chelonian Conservation and Biology 4:313-318.

Schneider, J.S., and G.D. Everson. 1989. The desert tortoise (*Xerobates agassizii*) in the prehistory of the southwestern Great Basin and adjacent areas. Journal of California and Great Basin Anthropology 11:175-202.

Schumacher, I.M., M.B. Brown, E.R. Jacobson, B.R. Collins, and P.A. Klein. 1993. Detection of antibodies to a pathogenic mycoplasma in desert tortoises (*Gopherus agassizii*) with upper respiratory tract disease. Journal of Clinical Microbiology 31:1454-1460.

Schumacher, I.M., D.B. Henderson, M.B. Brown, E.R. Jacobson, and P.A. Klein. 1997. Relationship between clinical signs of upper respiratory tract disease and antibodies to *Mycoplasma agassizii* in desert tortoises from Nevada. Journal of Wildlife Diseases 33:261-266.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H-P. Huang, N. Harnik, A. Leetmaa, N-C. Lau, C. Li, J. Velez, and N. Naik. 2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. Science 316:1181-1184.

Seltzer, M.D., and K.H. Berry. 2005. Laser ablation ICP-MS profiling and semiquantitative determination of trace element concentrations in desert tortoise shells: documenting the uptake of elemental toxicants. Science of the Total Environment 339:253-265.

Sharifi, M., A.C. Gibson, and P.W. Rundel. 1997. Surface dust impacts on gas exchange in Mojave Desert shrubs. Journal of Applied Ecology 34:837-846.

Sievers, A., J.B. Aardahl, K.H. Berry, B.L. Burge, L.D. Foreman, G.E. Monesko, and J.T. St. Amant. 1988. Recommendations for management of the desert tortoise in the California Desert. Bureau of Land Management, Riverside, California, and California Department of Fish and Game, Long Beach.

Smith, S.D., T.F. Huxman, S.F. Zitzer, T.N. Charlet, D.C. Housman, J.S. Coleman, L.K. Fenstermaker, J.R. Seemann, and R.S. Nowak. 2000. Elevated CO_2 increases productivity and invasive species success in an arid ecosystem. Nature 408:79–82.

St. Amant, J. 1984. California state regulations for wild and captive desert tortoises. Chapter 7 *in* K.H. Berry (ed.), The status of the desert tortoise (*Gopherus agassizii*) in the United States. Desert Tortoise Council Report to the U.S. Fish and Wildlife Service. Order No. 11310-0083-81.

Swingland, I., and M.W. Klemens (eds.) 1989. The Conservation Biology of Tortoise. Occasional Papers of the IUCN Species Survival Commission No. 5 and The Durrell Institute of Conservation Ecology. IUCN, Gland, Switzerland.

Thompson, R.S., K.H. Anderson, and P.J. Bartlein. 2003. Assessment of potential future vegetation changes in the Southwestern United States. U.S. Geological Survey Web Conference on the Impact of Climate Change and Land Use in the Southwestern United States. July 7-25, 1997. Accessed online at http://geochange.er.usgs.gov/sw/ on December 5, 2007.

Tierra Madre Consultants, Inc. 1991. Biological assessment for Lancaster City and Planning Area: Relative density surveys for desert tortoises and cumulative human impact evaluations for Mohave ground squirrel habitat. Report to the City of Lancaster. Tierra Madre Consultants, Riverside, California.

Tomlinson, C.R., and D.B. Hardenbrook. 1993. Incidence of upper respiratory tract disease (URTD) in the Las Vegas Valley: update of results from the Desert Tortoise Lawsuit Settlement collections. Proceedings of the Desert Tortoise Council Symposium 1992:57.

Tracy, C.R., L.C. Zimmerman, C. Tracy, K. Dean-Bradley, and K. Castle. 2006. Rates of food passage in the digestive tract of young desert tortoises: Effects of body size and diet quality. Chelonian Conservation and Biology 5:269–273.

Tratz, W.M. 1978. Postfire vegetational recovery, productivity and herbivore utilization of a chaparral-desert ecotone. Master's Thesis. California State University, Los Angeles.

Tratz, W.M., and R.J. Vogl. 1977. Postfire vegetational recovery, productivity and herbivore utilization of a chaparral-desert ecotone. Pages 426-430 *in* H.A. Mooney and C.E. Conrad (eds.), Proceedings of Symposium on Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems. USDA Forest Service General Technical Report WO-3.

Turner, F.B., P.A. Medica, and C.L. Lyons. 1984. Reproduction and survival of the desert tortoise *(Scaptochelys agassizii)* in Ivanpah Valley, California. Copeia 4:811-820.

Turner, F.B., P. Hayden, B.L. Burge, and J.B. Roberson. 1986. Egg production by the desert tortoise (*Gopherus agassizii*) in California. Herpetologica 42:93-104.

Turner, F.B., K.H. Berry, D.C. Randall, and G.C. White. 1987. Population ecology of the desert tortoise at Goffs, California, 1983-1986. Report to Southern California Edison Co., Rosemead, California.

U.S. Census Bureau. 2005. Population distribution in 2005. Population Profile of the United States: Dynamic Version. Available online at http://www.census.gov/population/pop-profile/dynamic/PopDistribution.pdf. Accessed on February 13, 2008.

U.S. Census Bureau. 2007a. 50 Fastest-Growing Metro Areas Concentrated in West and South. News Press Release, April 2007. U.S. Department of Commerce, Washington, D.C.

U.S. Census Bureau. 2007b. U.S. Department of Commerce, Washington, D.C. Available online at <http://www.census.gov/popest/archives/1990s/co-99-08/99C8_49.txt>. Accessed on July 18, 2007.

U.S. Ecology. 1989. Environmental assessment for the California low-level radioactive waste disposal site. Appendices K and M, Volume II. U.S. Ecology, Beatty, Nevada.

[USFWS] U.S. Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the Mojave population of the desert tortoise. Federal Register 55:12178-12191.

[USFWS] U.S. Fish and Wildlife Service. 1994. Desert Tortoise (Mojave Population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

Walther, G-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J-M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Weltzin, J.F., M.E. Loik, S. Schwinning, D.G. Williams, P.A. Fay, B.M. Haddad, J. Harte, T.E. Huxman, A.K. Knapp, G. Lin, W.T. Pockman, M.R. Shaw, E.E. Small, M.D. Smith, S.D. Smith, D.T. Tissue, and J.C. Zak. 2003. Assessing the Response of Terrestrial Ecosystems to Potential Changes in Precipitation. Bioscience 53:942-952.

Wendland, L.D., L.A. Zacher, P.A. Klein, D.R. Brown, D. Demcovitz, R. Littell, and M.B. Brown. 2007. An improved ELISA for *Mycoplasma agassizii* exposure: a valuable tool in the management of environmentally sensitive tortoise populations. Clinical and Vaccine Immunology 14:1190-1195.

Wilshire, H.G. 1980. Human causes of accelerated wind erosion in California's desert. Pages 1-156 *in* D.R. Coates and J.D. Vitek (eds.), Thresholds in Geomorphology. George Allen and Unwin, Ltd., London.

Wilson, D.S., K.A. Nagy, C.R. Tracy, D.J. Morafka, and R.A. Yates. 2001. Water balance in neonate and juvenile desert tortoises, *Gopherus agassizii*. Herpetological Monographs 15:158–170.

Wolff, P.L., and U.S. Seal. 1993. Implications of infectious disease for captive propagation and reintroduction of threatened species. Journal of Zoo and Wildlife Medicine 24:229-230.

PERSONAL COMMUNICATIONS

Abbott, Jim. 2007. Bureau of Land Management, California State Office. Sacramento, California.

Bransfield, Ray. 2007. U.S. Fish and Wildlife Service, Ventura Fish and Wildlife Office. Ventura, California.

Conrad, Polly. 2007. Nevada Department of Wildlife. Las Vegas, Nevada.

Crisp, Jim. 2007. Bureau of Land Management, St. George Field Office. St. George, Utah.

DePrey, Paul. 2007. National Park Service, Joshua Tree National Park. Twentynine Palms, California.

Dickinson, Bill. 2007. National Park Service, Lake Mead National Recreation Area. Boulder City, Nevada.

Donahue, S. 2007. Mohave County. Kingman, Arizona.

Ek, David. 2007. National Park Service, Death Valley National Park. Death Valley, California.

Florence, Scott. 2007. Bureau of Land Management, Arizona Strip District. St. George, Utah.

Gebicke, Kirk. 2007. National Park Service, Mojave National Preserve. Barstow, California.

Harcksen, Kathleen. Bureau of Land Management, Grand Canyon-Parashant National Monument. St. George, Utah.

Henson, Fred. 2007. Nevada Department of Wildlife. Las Vegas, Nevada.

Hughson, Debra. 2007. National Park Service, Mojave National Preserve. Barstow, California.

Jones, Cristina. 2007. Arizona Game and Fish Department. Phoenix, Arizona.

Jones, Rebecca. 2007. California Department of Fish and Game. Ontario, California.

Leveille, David. U.S. Forest Service, Humboldt-Toiyabe National Forest, Supervisor's Office. Reno, Nevada.

Martinez, Cynthia. 2007. U.S. Fish and Wildlife Service, Desert National Wildlife Refuge Complex. Las Vegas, Nevada.

Masters, Elroy. 2007. Bureau of Land Management, Nevada State Office. Reno, Nevada.

McBride, Mike. 2007. California Department of Fish and Game. Ontario, California.

McDermott, Michelle. 2006. Southern Nevada Environmental, Inc. Las Vegas, Nevada.

McLuckie, Ann. 2006. Utah Division of Wildlife Resources, Washington County Field Office, St. George, Utah.

Sauer, Curt. 2007. National Park Service, Joshua Tree National Park, Twentynine Palms, California.

Thompson, Luke. 2007. Arizona Game and Fish Department. Flagstaff, Arizona.

Wainscott, Sue. 2007. Clark County. Las Vegas, Nevada.

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

A White Paper Presented to the U.S. Fish and Wildlife Service

September 2007

A. 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 (URTD), 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 URTD 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.

B. 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 URTD 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% and a specificity of 99.9%. 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 seropositivity 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%. 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% 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.

C. 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?

D. 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.

E. 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 non-native 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 with Western Blots 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. Particular care needs to be taken when the prevalence is low since we cannot rule out the possibility that individuals who exhibit a weak immune response, and thus appear ELISA-negative, are indeed highly susceptible individuals which may well die or act as important transmitters to novel infections and, as such, should not be translocated. 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 on 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. *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 desert tortoise holding facilities:

We suggest implementation of these recommendations at existing facilities (*e.g.*, Desert Tortoise Conservation Center (DTCC) in Las Vegas, Nevada, and facilities in Washington County, Utah), as well as consideration when planning future facilities.

1. Euthanizing seropositive individuals should stop immediately, unless the animals exhibit acute disease symptoms and are 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 facilities 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 a scientific oversight board to oversee and develop plans for holding facilities, research priorities, and protocols. The board would provide recommendations to facility managers each season regarding the disposition of tortoises in holding. *Our recommendations are broad, and a more focused research protocol which takes account of the logistic difficulties is required.*
4. Include the ability to hold both seropositive and seronegative tortoises at facilities as needed for key research into disease. *The ability to undertake key research at holding facilities will facilitate progress in understanding disease.*
5. The increased demands on feeding and caring for tortoises will require an increase in resources allocated to the facilities. 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.*
6. The DTCC, in particular, has great potential to function as a center for scientific research, training, and education. In support of these functions, facility upgrades will be required. *We suggest garnering range-wide support for upgrades to this facility, as benefits to desert tortoises could be far reaching.*

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, the discouragement of breeding tortoises in captivity by private citizens, and the discouragement of keeping desert tortoises as pets. 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:

Initially, it may be pertinent to recommend the implementation of terminal studies. Such studies will provide much needed data on the effects of disease that will be important to consider when proposing further research.

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*.
6. Examine the implications of releasing sick tortoises into uninfected populations. Such studies should occur within enclosures at captive holding facilities.

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.

FIELD WORKER(S):

Handler(s) ______________

Recorder(s) ______________

Observer(s) ______________

STUDY SITE Fort Irwin Translocation

UTM (WGS 84) Easting ______________

Northing ______________

County San Bernardino

State California

Date (ddmmmyyyy) ______________

Tortoise ID ______ Sex ______ Captype ______

MCL (mm) ______ Gular (mm) ______

PLN (mm) ______ Weight (g) ______

Time (PST) spent handling start ______

end ______

On a plot? yes/no

New growth? yes/no SWC ______

Photos ______________

TRANSMITTER:

Transmitter frequency? ______________

Transmitter number? ______________

Who attached transmitter? ______________

Notes ______________

LOCATION:

At cover site? Cover site type?

Tag # ______ burrow __

entering __ pallet __

exiting __ shrub __

on mound __ cave __

inside* __ rock shelter __

*specifically where ______________

TEMPERATURES (°C):

At 1.5m ______ 1cm ______ Soil ______ FWS 2″ start ______

Activity? Not at cover site? FWS 2″ end ______

resting __ in open __

basking __ other __

walking __ Interacting with another tortoise? yes/no

feeding __ sex ______ size ______ number ______

Type of interaction(s): ______________

POSTURE/BEHAVIOR:

Behavior appropriate for the time of day? yes/no If no, describe: ______________

Behavior appropriate for the season? yes/no If no, describe: ______________

Can withdraw tightly into shell? yes/no If no, describe: ______________

Alert and responsive? yes/no If no, describe: ______________

Limbs, head hanging limp or loose? yes/no If yes, describe: ______________

Lethargic? yes/no If yes, describe: ______________

FORELIMBS

Right normal/abnormal If abnormal, describe: ______________

Left normal/abnormal If abnormal, describe: ______________

HINDLIMBS

Right normal/abnormal If abnormal, describe: ______________

Left normal/abnormal If abnormal, describe: ______________

OTHER

Tail normal/abnormal If abnormal, describe: ______________

FORELEGS (adjacent to face)

Dried dirt on forelegs? yes/no/unk

Moisture on forelegs? yes/no/unk

Dried exudate on scales (glossy with dried exudate)? yes/no/unk

Scales cracking (from exudate)? yes/no/unk

Field workers(s) ______________ Date (ddmmmyyyy) ______________

Study site name ______________ Tortoise ID __________ Sex __________

CHIN GLANDS

Site	Size	Drainage	Severity (Rate 1-4)		Color of Drainage
R Gland	normal/swollen	present/absent	_____	_____	clear/cloudy/white/yellow/green
L Gland	normal/swollen	present/absent	_____	_____	clear/cloudy/white/yellow/green

INTEGUMENT

Integument dull?	yes/no	If yes, describe location:	______________
Integument glossy?	yes/no	If no, describe:	______________
Normal elasticity?	yes/no	If no, describe:	______________
Abnormal skin peeling?	yes/no	If yes, describe:	______________

Supplemental system for grading the beak, nares, eyes, and chin glands of desert tortoises. Instructions: depending on subject, circle one or more options. Rating system: 1=normal, 2=mild, 3=moderate, 4=severe

BEAK & NARES

Site	State	Severity (Rate 1-4)	Notes
Moisture (e.g. If beak is damp or wet, describe cause)			
Beak	dry/damp/wet	_____	______________
R Nare	dry/damp/wet	_____	______________
L Nare	dry/damp/wet	_____	______________
Exudate			
Beak	none/dried/wet	_____	color: clear/cloudy/white/yellow/green
R Nare	none/dried/wet	_____	color: clear/cloudy/white/yellow/green
L Nare	none/dried/wet	_____	color: clear/cloudy/white/yellow/green
Bubbles			
R Nare	yes/no	_____	______________
L Nare	yes/no	_____	______________
Occlusion			
R Nare	none/partial/complete	_____	______________
L Nare	none/partial/complete	_____	______________
Normal Foraging Stains?			
Beak	yes/no/no evidence	_____	If no, describe: ______________
Dirt on/in			
Beak	yes/no	_____	______________
R Nare	yes/no	_____	______________
L Nare	yes/no	_____	______________

ORAL CAVITY		Notes
Observed?	yes/no	______________
Discharge present?	yes/no/unk	______________
Plaques or ulcers present?	yes/no/unk	______________
Smells?	yes/no/unk	______________
Color of membranes?	unk/white, pink, yellow, other	______________

Field workers(s) ______________________ Date (ddmmmyyyy) ______________

Study site name ______________________ Tortoise ID ________ Sex ________

EYES: Palpebrae (Palp), Periocular (Perioc), Globe

Variable		State	Upper Palp	Lower Palp	Upper Perioc	Lower Perioc
			Severity (Rate 1-4)			
Discoloration						
	R Eye	yes/no/unk	______	______	______	______
	L Eye	yes/no/unk	______	______	______	______
Edema						
	R Eye	yes/no/unk	______	______	______	______
	L Eye	yes/no/unk	______	______	______	______
Crusts						
	R Eye	yes/no/unk	______	______	______	______
	L Eye	yes/no/unk	______	______	______	______

Discharge

R Eye yes/no/unk If yes, is it wet/dried ______

L Eye yes/no/unk If yes, is it wet/dried ______

Other Lesions of Palpebra and Periocular Area

R Eye yes/no/unk ______ trauma/necrosis/other: ______________

L Eye yes/no/unk ______ trauma/necrosis/other: ______________

Sunken/Recessed Eyes

R Eye yes/no/unk ______

L Eye yes/no/unk ______

Eye Swollen or Bulging in Appearance

R Eye yes/no/unk ______ dorsal ______ lateral

L Eye yes/no/unk ______ dorsal ______ lateral

Degree of Openness of Palpebra

R Eye normal (100% open)/partially closed If partially closed, ______ % is closed.

L Eye normal (100% open)/partially closed If partially closed, ______ % is closed.

Condition of Globe

R Eye clear/bright/mucus present/dull/cloudy/inflamed sclera

L Eye clear/bright/mucus present/dull/cloudy/inflamed sclera

Conjunctiva

R Eye yes/no/unk If yes, ______ % is exposed.

L Eye yes/no/unk If yes, ______ % is exposed.

Other obvious lesions

R Eye none/corneal ulcers/corneal abrasions Other: ______________

L Eye none/corneal ulcers/corneal abrasions Other: ______________

Is plant material in eye? yes/no/unk R eye/L eye ______________

Is dirt/sand in eye? yes/no/unk R eye/L eye ______________

Field workers(s) ______________________ Date (ddmmmyyyy) ______________

Study site name ______________________ Tortoise ID __________ Sex __________

RESPIRATION/BREATHING Notes

Smooth? yes/no/unk ______________________

Wheezing? yes/no/unk ______________________

Rasping or clicking? yes/no/unk ______________________

BLOOD SAMPLE*

Name of sticker(s) ______________________

Total No. of needle sticks ______ Total No. of tubes ______

Tube 1 % that is blood ______ % that is lymph ______

Location ______________ Sample size (ml) ______

Tube 2 % that is blood ______ % that is lymph ______

Location ______________ Sample size (ml) ______

Tube 3 % that is blood ______ % that is lymph ______

Location ______________ Sample size (ml) ______

Tube 4 % that is blood ______ % that is lymph ______

Location ______________ Sample size (ml) ______

NASAL LAVAGE SAMPLE

Nasal lavage sample taken: yes/no

SP4 added to sample: yes/no

Sample size (ml): ______

*** Please make sure each tube is properly labeled. For, example:**
♀ 2121, G. agassizii
Fort Irwin Translocation
San Bernardino Co., CA
21 September 2006
Blood/Plasma Mix Tube 1** of 2
****Where Tube 1 matches the information given on the left.**

URINE/URATES

Did tortoise urinate? yes/no

Urine color: ______________

Urine volume (ml): ______

Viscosity: ______________

Particulates? yes/no Particulate color: ______________

Particulate volume (ml): ______

REHYDRATION

Was tortoise rehydrated? yes/no

Amount rehydrated: ______

Amount of time in water: ______

Table 1. System for grading signs of trauma in desert tortoises. The carapace, plastron, gular, and integument on limbs and head should be rated separately.

I. Distribution: specify by plastron, carapace, gular, limbs, or head
- 1 = not present; no signs of trauma
- 2 = mild; covers ≤ 10% of plastron, carapace, gular, head, or limbs
- 3 = moderate; covers 11-40%
- 4 = severe; covers > 40%

II. Severity of lesions, both historic and present
- 1 = no trauma
- 2 = mild; minor chews or chips, no bone exposed; 1-3 damaged scales or 1 damaged toenail
- 3 = moderate; small areas of bone exposed (healed or fresh injuries); several scales damaged on one or more limbs; > 1 toenail damaged
- 4 = severe; missing large areas of scute or bone; bone exposed; soft tissue damage to limbs

III. Chronicity of trauma
- 1 = no trauma
- 2 = healed or healing injuries (state whether trauma is healed or healing)
- 3 = fresh injuries

Field workers(s) ______________________ Date (ddmmmyyyy) ________________

Study site name ______________________ Tortoise ID __________ Sex __________

PARASITES and SPINES: *show location on the diagram below

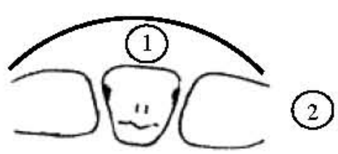
Parasite present?	yes/no	Type:	________	Number:	_____	Size(s):	________
Spine present?	yes/no	Type:	________	Number:	_____	Size(s):	________

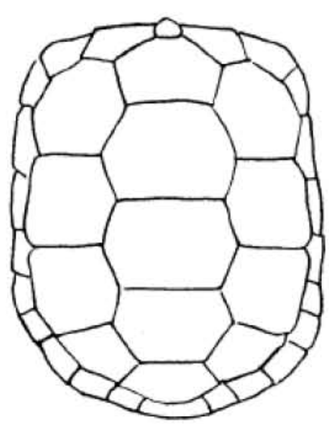
SIGNS OF TRAUMA: Severity 1 = no signs, 2 = mild, 3 = moderate, 4 = severe
Use Table 1 for definitions of mild, moderate and severe, for distribution, severity and chronicity of damage from trauma.

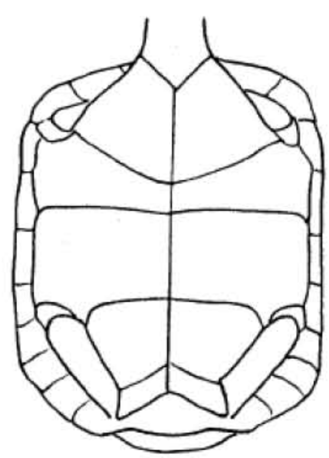
Bone/scute replacement? yes/no/unk Describe: ______________________

		Severity (Rate 1-4)	Location	Notes
HEAD	Distribution	_____	_______	______________
	Severity	_____	_______	______________
	Chronicity	_____	_______	______________
LIMBS	Distribution	_____	_______	______________
	Severity	_____	_______	______________
	Chronicity	_____	_______	______________
GULAR	Distribution	_____	_______	______________
	Severity	_____	_______	______________
	Chronicity	_____	_______	______________
CARAPACE	Distribution	_____	_______	______________
	Severity	_____	_______	______________
	Chronicity	_____	_______	______________
PLASTRON	Distribution	_____	_______	______________
	Severity	_____	_______	______________
	Chronicity	_____	_______	______________

Label all historic and recent trauma, show type in writing on form, e.g., injuries from tearing, gnawing, gnashing. Show areas of bone exposure and label as "bone exposed." Note scales removed from limbs, injuries or scars on limbs. Draw on toenails for each limb. Label each trauma as fresh, healed, or healing injuries.







1. Damage to skin? yes/no
   If yes, describe:

2. Toes normal? yes/no
   If no, describe:

Table 2. System for grading shell lesions caused by disease, such as cutaneous dyskeratosis in desert tortoises. The carapace, plastron, and integument on limbs and head should be rated separately.

I. Distribution of disease signs: specify by plastron, carapace, limbs, or head
  - 1 = not present; no signs of lesions
  - 2 = mild; lesions manifested primarily at seams, covers less than 10% of plastron (or carapace or limbs, etc.)
  - 3 = moderate; covers 11-40%
  - 4 = severe; covers > 40%

II. Severity of lesions (from disease, e.g., cutaneous dyskeratosis)
  - 1 = no lesions
  - 2 = mild; discoloration follows edges of lifting laminae, lightly discolored, flaking
  - 3 = moderate; discoloration extends over several layers of laminae, edges of laminae flaking, scutes may be thin in small areas, and potential exists for small holes and openings exposing bone
  - 4 = severe; some scutes or parts of scutes eroded away or missing and bone exposed, eroded, or damaged

III. Chronicity of trauma
  - 1 = no lesions
  - 2 = old lesions; no apparent recent activity, signs of regression or recovery; development of healthy, normal laminae is apparent at seams of scutes
  - 3 = active, current lesions

Field workers(s) ______________________ Date (ddmmmyyyy) ________________

Study site name ______________________ Tortoise ID ________ Sex ________

EVIDENCE OF SHELL/BONE DISEASE **Describe**

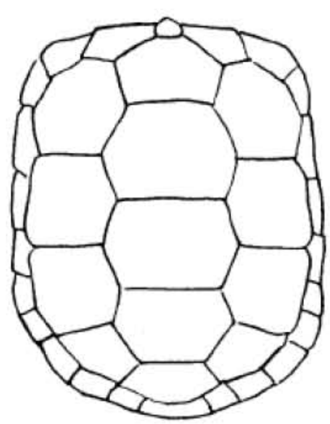
Scutes laminae peeling/missing?	yes/no/unk	____________________
Scutes depressed/concave?	yes/no/unk	____________________
Pitting?	yes/no/unk	____________________
Fungal areas? (draw onto diagram and label)	yes/no/unk	____________________

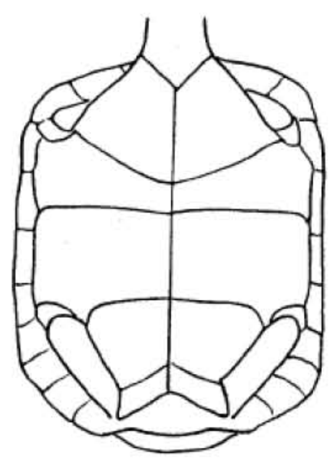
SIGNS OF LESIONS FROM DISEASE: Severity 1 = no signs, 2 = mild, 3 = moderate, 4 = severe
Use Table 2 for definitions of mild, moderate and severe for distribution, severity and chronicity.

Bone/scute replacement? yes/no/unk Describe: ____________________

		Severity (Rate 1-4)	Location	Notes
HEAD	Distribution	____	______	____________
	Severity	____	______	____________
	Chronicity	____	______	____________
LIMBS	Distribution	____	______	____________
	Severity	____	______	____________
	Chronicity	____	______	____________
GULAR	Distribution	____	______	____________
	Severity	____	______	____________
	Chronicity	____	______	____________
CARAPACE	Distribution	____	______	____________
	Severity	____	______	____________
	Chronicity	____	______	____________
PLASTRON	Distribution	____	______	____________
	Severity	____	______	____________
	Chronicity	____	______	____________

Legend: Lesions from cutaneous dyskeratosis (specifically), other lesions (enter symbols), describe in writing. Note lesions and extent on limbs.





Appendix B-2. Other Diseases of Potential Importance to Desert Tortoise Populations

Prepared by K.H. Berry for the Science Advisory Committee (September 2007)

Shell diseases, herpes viruses, and other infectious agents pose potentially significant threats to desert tortoise populations. Here, we provide a summary of what is known on shell disease and herpes virus infections.

Shell Disease

1. Shell diseases have been recorded in tortoise populations in the eastern Mojave and Colorado deserts of California, but less in the western Mojave Desert (Jacobson et al. 1994, Christopher et al. 2003).
2. The disease has been recorded in all sizes and ages of desert tortoises, but is more common and severe in adults (Jacobson et al. 1994, Homer et al. 1998).
3. The most commonly described shell disease in desert tortoises is cutaneous dyskeratosis (Jacobson et al. 1994, Homer et al. 1998), but shell necrosis has also been reported (Homer et al. 1998).
4. The cause(s) of shell disease have not been determined, and no causative infectious agent has yet been identified (Jacobson et al. 1994, Homer et al. 1998).
5. Prevalence level varies greatly; in the Mojave Desert prevalences vary from 6 percent to 79 percent.
6. There is some evidence that individuals with a positive nasal cultures for *Mycoplasma agassizii* are more likely to have severe shell disease, although whether this was cause or effect is not known.
7. Shell disease may have been a factor in population declines at some long-term study sites, and greater disease levels have been shown to covary with military maneuver areas and elevated arsenic levels in soils (Chaffee and Berry 2006).
8. The flaking and loss of scute laminae and thinning of bone observed in tortoises with cutaneous dyskeratosis may render the tortoise more vulnerable to other diseases such as fungal infections and multicentric visceral inflammation.

Herpesvirus

1. Herpesvirus infections have been reported in captive desert tortoises and have been associated with illness and mortality (Johnson et al. 2006). Herpes infections have also been recorded in other species of tortoises.
2. An ELISA test (THV-1) was developed and validated for a herpesvirus for the European tortoise (Origgi et al. 2001). This ELISA test has not been validated for *Gopherus agassizii* or other species of *Gopherus*. However, tests of captive desert tortoises living in the Mojave Desert indicated that 27 percent were seropositive for the herpes ELISA and demonstrated previous exposure to a herpesvirus (Johnson et al. 2006).

References: Appendix B

Baseman, J.B., and J.G. Tully. 1997. Mycoplasmas: sophisticated, reemerging, and hardened their notoriety. Emerging Infectious Diseases 3:21-32.

Berry, K.H. 2000. Preliminary Report on the Spring Survey of Desert Tortoises at the Goffs Permanent Study Plot and Special Project on Effects of Roads. U. S. Geological Survey, Western Ecological Research Center, Riverside, CA

Berry, K.H. 2004. Protocol- May 2004. Salvaging injured, recently dead, ill, and dying wild, free-roaming desert tortoises (*Gopherus agassizii*). Prepared for Federal Fish and Wildlife Permit TE006556-12.

Berry, K.H. 2006. The Health Status of Resident Desert Tortoises (*Gopherus agassizii*) in the Fort Irwin Translocation Area, San Bernardino County, California. Progress Report for 2005. U.S. Geological Survey, Moreno Valley, CA. Report to the U.S. Army, NTC Ft. Irwin.

Berry, K.H., and A. Demmon. 2005. Clinic and field training for desert tortoise health assessments at the Marine Corps Air Ground Combat Center, Twentynine Palms, California. May 22-28, 2004. Final Report for the Marine Air Ground Task Force Training Command at Twentynine Palms, CA. U.S. Geological Survey, Moreno Valley, CA.

Berry, K.H., and M.M. Christopher. 2001. Guidelines for the field evaluation of desert tortoise health and disease. Journal of Wildlife Diseases 34:427-450.

Berry, K.H., and R. Jones. 2004. Highlights from the November 2002 Workshop on Desert Tortoise Health and Disease. Report from the U.S. Geological Survey and California Department of Fish and Game on the Workshop held at Soda Springs, California, 14-17 November 2002.

Berry, K.H., B.L. Homer, W. Alley, M. Chaffee, and G. Haxel. 2001. Health and elevated mortality rates in desert tortoise populations: the role of arsenic and other potential toxicants. Abstract, Arsenic Group Meeting, Denver Federal Center, Denver, CO. Feb. 21-22, 2001.

Berry, K.H., E.K. Spangenberg, B.L. Homer, and E.R. Jacobson. 2002. Deaths of desert tortoises following periods of drought and research manipulation. Chelonian Conservation and Biology 4:436-448.

Berry, K.H., L.D. Wendland, A. Demmon, and M.B. Brown. 2005. A comparison of lymph and plasma sample results form ELISA tests for *Mycoplasma agassizii* in desert tortoises. Presentation and abstract from the Desert Tortoise Council Symposium, Tucson, AZ. February 2005.

Brown, D.R., B.C. Crenshaw, G.S. McLaughlin, I.M. Schumacher, C.E. McKenna, P.A. Klein, E.R. Jacobson, and M.B. Brown. 1995. Taxonomic analysis of the tortoise mycoplasmas *Mycoplasma agassizii* and *Mycoplasma testudinis* by 16S rRNA gene sequence comparison. International Journal of Systematic Bacteriology 45:348-350.

Brown, D.R., J.L. Merritt, E.R. Jacobson, P.A. Klein, J.G. Tully, and M.B. Brown. 2004. *Mycoplasma testudineum* sp. nov., from a desert tortoise (*Gopherus agassizii*) with upper respiratory tract disease. International Journal of Systematic and Evolutionary Microbiology. 45:1527-1529.

Brown, D.R., I.M. Schumacher, G.S. McLaughlin, L.D. Wendland, M.B. Brown, P.A. Klein, and E.R. Jacobson. 2002. Application of diagnostic tests for mycoplasmal infections of desert and gopher tortoises, with management recommendations. Chelonian Conservation and Biology 4:497-507.

Brown, M.B., D.R. Brown, P.A. Klein, G.S. McLaughlin, I.M. Schumacher, E.R. Jacobson, H.P. Adams, and J.G. Tully. 2001. *Mycoplasma agassizii* sp. nov., isolated from the upper respiratory tract of the desert tortoise *Gopherus agassizii*) and the gopher tortoise (*Gopherus polyphemus*). International Journal of Systematic and Evolutionary Microbiology 51:413-418.

Brown, M.B., K.H. Berry, I.M. Schumacher, K.A. Nagy, M.M. Christopher, and P.A. Klein. 1999. Seroepidemiology of upper respiratory tract disease in the desert tortoise in the western Mojave Desert of California. Journal of Wildlife Diseases 35:716-727.

Brown, M.B., K.H. Berry, C. Melendez Torres, M.A. Hasskamp, L. Wendland, F.R. Mendez de la Cruz, and M.F. Villa Andrade. 2006. Health status of wild and captive desert tortoises from the Hermosillo and Alamos areas of Mexico. Abstract from the Desert Tortoise Council Symposium, Tucson, AZ. February 2006.

Brown, M.B., G.S. McLaughlin, P.A. Klein, B.C. Crenshaw, I.M. Schumacher, D.R. Brown, and E.R. Jacobson. 1999. Upper respiratory tract disease in the gopher tortoise is caused by *Mycoplasma agassizii*. Journal of Clinical Microbiology 37:2262-2269.

Brown, M.B., I.M. Schumacher, P.A. Klein, K. Harris, T. Correll, and E.R. Jacobson. 1994. *Mycoplasma agassizii* causes upper respiratory tract disease in the desert tortoise. Infection and Immunity 62:4580-4586.

Chaffee, M.A., and K.H. Berry. 2006. Abundance and distribution of selected elements in soils, stream sediments, and selected forage plants from desert tortoise habitats in the Mojave and Colorado deserts, USA. Journal of Arid Environments 67 Supplement:35-87.

Christopher, M.M., K.H. Berry, I.R. Wallis, K.A. Nagy, B.T. Henen, and C.C. Peterson. 1999. Reference intervals and physiologic alterations in hematologic and biochemical values of free-ranging desert tortoises in the Mojave Desert. Journal of Wildlife Diseases 35:212-238.

Christopher, M.M., K.H. Berry, B.T. Henen, and K.A. Nagy. 2003. Clinical disease and laboratory abnormalities in free-ranging desert tortoises in California (1990-1995). Journal of Wildlife Diseases 39:35-56.

Domico, L. 2001. Purification of desert tortoise (*Gopherus agassizii*) metallothionein, a potential biomarker of heavy metal exposure. M.S. Thesis. University of Florida, College of Veterinary Medicine.

Gottdenker, N.L., and E.R. Jacobson. 1995. Effect of venipuncture sites on hematologic and clinical biochemical values in desert tortoises (*Gopherus agassizi*i). American Journal of Veterinary Research 56:19-21.

Henen, B.T., C.C. Peterson, I.R. Wallis, K.H. Berry, and K.A. Nagy. 1998. Effects of climatic variation on field metabolism and water relations of desert tortoises. Oecologia 117:365-373.

Hernandez-Divers, S.M., S.J. Hernandez-Divers, and J. Wyneken. 2002. Angiographic, anatomic and clinical technique descriptions of a subcarapacial venipuncture site for chelonians. Journal of Herpetological Medicine and Surgery 12:32-37.

Hill, A.C. 1985. *Mycoplasma testudinis*, a new species isolated from a tortoise. International Journal of Systematic Bacteriology 35:489-492.

Homer, B.L., K.H. Berry, M.B. Brown, and E.R. Jacobson. 1998. Pathology of spontaneously occurring diseases in free-ranging California desert tortoises (*Gopherus agassizii*). Journal of Wildlife Diseases 34:508-523.

Homer, B.L., C. Li, K.H. Berry, N.D. Denslow, E.R. Jacobson, R.H. Sawyer, and J.E. Williams. 2001. Soluble scute proteins of healthy and ill desert tortoises (*Gopherus agassizii*). American Journal of Veterinary Research 62:104-110.

Hunter, K.W., S.A. duPre, F.C. Sandmeier, and C.R. Tracy. 2007. Natural IgM antibodies to *Mycoplasma agassizii* in the desert tortoise (*Gopherus agassizii*). Report to the Desert Tortoise Scientific Advisory Committee, June 11-12, 2007.

Jacobson, E.R., and K.H. Berry. 2004. Necropsies of six desert tortoises (*Gopherus agassizii*) from California. University of Florida, Gainesville, and U.S. Geological Survey, Moreno Valley, CA.

Jacobson, E.R., M.B. Brown, I.M. Schumacher, B.R. Collins, R.K. Harris, and P.A. Klein. 1995. Mycoplasmosis and the desert tortoise (*Gopherus agassizii*) in Las Vegas Valley, Nevada. Chelonian Conservation and Biology 1:279-284.

Jacobson, E.R., J.M. Gaskin, M.B. Brown, R.K. Harris, C.H. Gardiner, J.L. LaPointe, H.P. Adams, and C. Reggiardo. 1991. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). Journal of Wildlife Diseases 27:296-316.

Johnson, A.J., D.J. Morafka, and E.R. Jacobson. 2006. Seroprevalence of *Mycoplasma agassizii* and tortoise herpesvirus in captive desert tortoises *(Gopherus agassizii*) from the Greater Barstow Area, Mojave Desert, California. Journal of Arid Environments 67 Supplement:192-201.

Johnson, A.J., A.P. Pessier, J.F.X. Wellehan, R. Brown, and E.R. Jacobson. 2005. Identification of a novel herpesvirus form a California desert tortoise (*Gopherus agassizii*). Veterinary Microbiology 111:107-116.

Lederle, P.E., K.R. Rautenstrauch, D.L. Rakestraw, K.K. Zander, and J.L. Boone. 1997. Upper respiratory tract disease and mycoplasmosis in desert tortoises from Nevada. Journal of Wildlife Diseases 33:759-765.

Marschang, R.E., C.B. Gleiser, T. Papp, A.J.P. Pfitzner, R. Böhm, and B.N. Roth. 2006. Comparison of 11 herpesvirus isolates form tortoises using partial sequences form three conserved genes. Veterinary Microbiology 117:258-266.

McLaughlin, G.S. 1997. Upper respiratory tract disease in gopher tortoises, *Gopherus polyphemus:* pathology, immune responses, transmission, and implications for conservation and management. Ph.D. Dissertation, University of Florida.

Muro, J., A. Ramis, J. Pastor, R. Velarde, J. Tarres, and S. Lavin. 1998. Chronic rhinitis associated with herpesviral infection in captive spur-thighed tortoises from Spain. Journal of Wildlife Diseases 34: 487-495.

Oli, M.K., M. Venkataraman, P.A. Klein, L.D. Wendland, and M.B. Brown. 2006. Population dynamics of infectious diseases: a discrete time model. Ecological Modeling 198:183-194.

Origgi, F.C. 2001. Development of serological and molecular diagnostic tests for herpesvirus exposure detection in tortoises. Ph.D. Dissertation, University of Florida.

Origgi, F., A. Johnson, and E.R. Jacobson. 2003. Validation of the ELISA test for herpesvirus exposure detection in desert tortoises: options and limitations. Abstract from the Desert Tortoise Council Symposium, Las Vegas, NV. February 2003.

Origgi, F.C. P.A. Klein, K. Mathes, S. Blahak, R.E. Marschang, S.J. Tucker, and E.R. Jacobson. 2001. Enzyme-linked immunosorbent assay for detecting herpesvirus exposure in Mediterranean Tortoises (Spur-Thighed Tortoise [*Testudo graeca*] and Hermann's Tortoise [*Testudo hermanni*]). Journal of Clinical Microbiology 39:3156-3163.

Origgi, F.C., P.A. Klein, S.J. Tucker, and E.R. Jacobson. 2003. Application of immunoperoxidase-based techniques to detect herpesvirus infection in tortoises. Journal of Veterinary Diagnostic Investigation 15:133-140.

Origgi, F.C., C.H. Romero, D.C. Bloom, P.A. Klein, J.M. Gaskin, S.J. Tucker, and E.R. Jacobson. 2004. Experimental transmission of a herpesvirus in Greek tortoises (*Testudo graeca*). Veterinary Pathology 41:50-61.

Pettan-Brewer, K.C.B., M.L. Drew, E. Ramsay, F.C. Mohr, and L.J. Lowenstine. 1996. Herpesvirus particles associated with oral and respiratory lesions in a California desert tortoise (*Gopherus agassizii*). Journal of Wildlife Diseases 32:521-526.

Schumacher, I.M., M.B. Brown, E.R. Jacobson, B.R. Collins, and P.A. Klein. 1993. Detection of antibodies to a pathogenic mycoplasma in desert tortoises (*Gopherus agassizii*) with upper respiratory tract disease. Journal of Clinical Microbiology 31:1454-1460.

Schumacher, I.M., D.B. Hardenbrook, M.B. Brown, E.R. Jacobson, and P.A. Klein. 1997. Relationship between clinical signs of upper respiratory tract disease and antibodies to *Mycoplasma agassizii* in desert tortoises from Nevada. Journal of Wildlife Diseases 33:261-266.

Schumacher, I.M., D.C. Rostal, R. Yates, D.R. Brown, E.R. Jacobson, and P.A. Klein. 1999. Transfer and persistence of maternal antibodies against *Mycoplasma agassizii* in desert tortoise (*Gopherus agassizii*) hatchlings. American Journal of Veterinary Research 60:826-831.

Seltzer, M.D., and K.H. Berry. 2005. Laser ablation ICP-MS profiling and semi-quantitative determination of trace element concentrations in desert tortoise shells: documenting the uptake of elemental toxicants. Science and the Total Environment 339:253-265.

Snipes, K.P., R.W. Kasten, J.M. Calagoan, and J.T. Boothby. 1995. Molecular characterization of *Pasteurella testudinis* isolated from desert tortoises (*Gopherus agassizii*) with and without upper respiratory tract disease. Journal of Wildlife Diseases 31:22-29.

Wendland, L.D., L.A. Zacher, P.A. Klein, D.R. Brown, D. Demcovitz, R. Littell, and M.B. Brown. 2007. An improved ELISA for *Mycoplasma agassizii* exposure: a valuable tool in the management of environmentally sensitive tortoise populations. Clinical and Vaccine Immunology 14:1190-1195.

Williams, E.S., T. Yuill, M. Artois, J. Fischer, and S.A. Haigh. 2002. Emerging infectious diseases in wildlife. Rev. Sci. Tech. Off. Int. Epiz. 21:139-157.

APPENDIX C

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

August 29, 2007

A. INTRODUCTION

1. 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. These workshops were conducted during March-May 2007 at which managers provided information on geographic distribution of threats, management actions, and other information described below.

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 tortoise's range. To do this, the decision support system relies primarily on GIS data of the spatial extent of threats (*i.e.*, where threats occur geographically). 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 (*i.e.*, compare ideal to current or planned management actions to identify gaps in management prescriptions for a given area) 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.

2. 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 systems were 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 was 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 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).

The development of decision support systems provides a vehicle for adaptive management through the process of developing the initial prototype, consulting it regularly, evaluating its performance, and updating it on a regular basis (Starfield and Bleloch 1991). Use of decision support systems allows different types and levels of information to be pooled, compared, weighed, and interpreted. Furthermore, arguments and discussion about the information are typically more focused in a logical, goal-oriented fashion. Also, developing and applying a decision support system makes it apparent where information is missing and where there is a need for research or monitoring programs. Irrespective of the benefits of *using* decision support systems, the process of *building* a decision support system is always stimulating and effective in better understanding the basis and limitations of existing information and its applicability for management decisions (Starfield and Bleloch 1991).

B. DECISION SUPPORT SYSTEM ROAD MAP

The remainder of this appendix describes the processing steps, data inputs, and outputs of the decision support system for desert tortoise recovery management. The following flow chart diagram (Figure 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:

- <u>Spatial Threats Model</u>: integrate threats data and associate with degrees of threat

- Tortoise mortality models
    - <u>Threat-Mortality Interaction Model</u>: estimate the contribution of each threat to mortality mechanisms
    - <u>Relative Mortality Model</u>: estimate the contribution of each mortality mechanism to overall mortality
    - <u>Demographic Impact Model</u>: 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

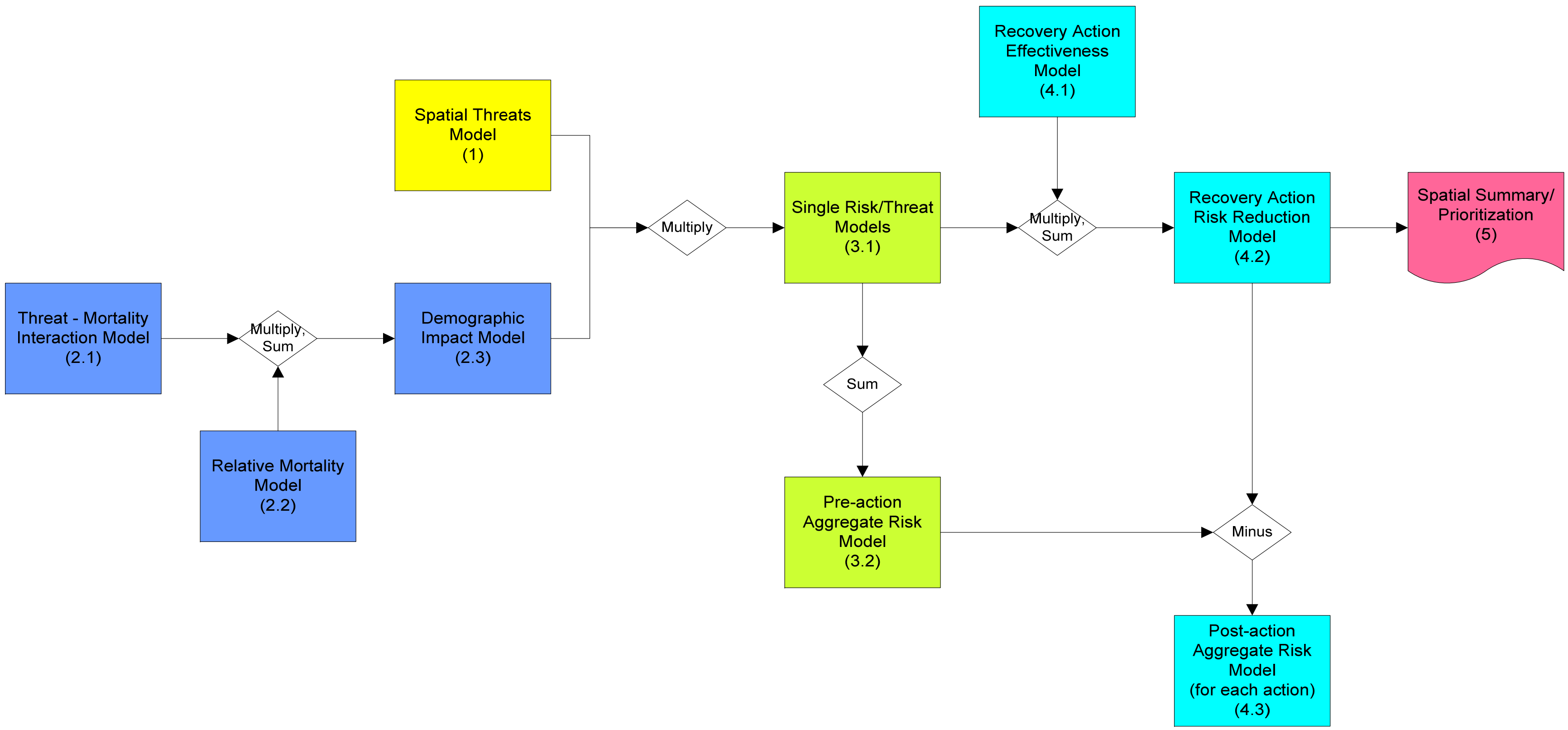


Figure C-1. Flowchart illustrating the decision support system for desert tortoise recovery. The numbers in the boxes refer to section numbers in the text.

1. INTEGRATE THREATS DATA AND ASSOCIATE WITH DEGREES OF THREAT

Spatial Threats Model (1)

The Spatial Threats Model involves two steps. The first step adds a 'degree of threat' rating to each geographic threat data layer (computerized data associating threats with specific geographic locations). This rating is derived from a threats-mapping exercise, during which land managers were asked to answer a series of questions about threats with which they were familiar (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 (*i.e.*, standardize) 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.

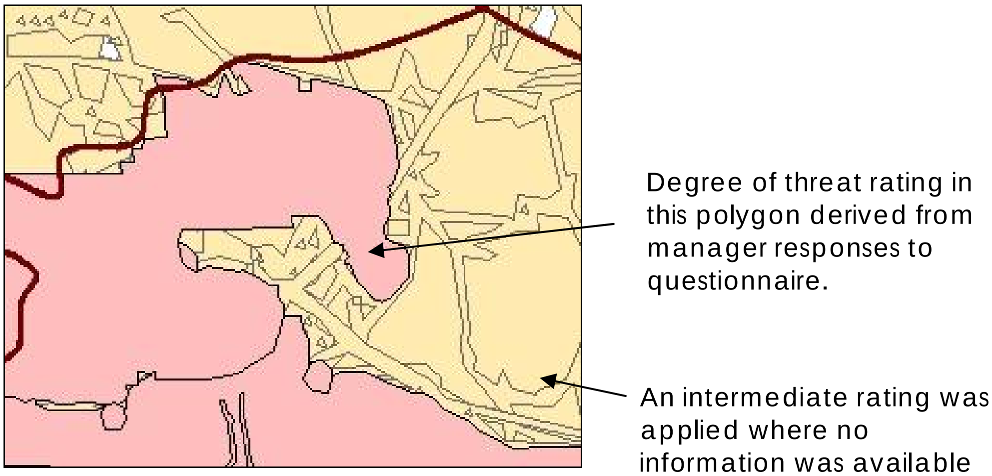
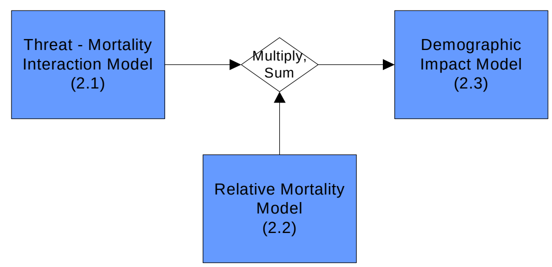


Figure C-2. Method for assigning degree of threat to threat polygons.

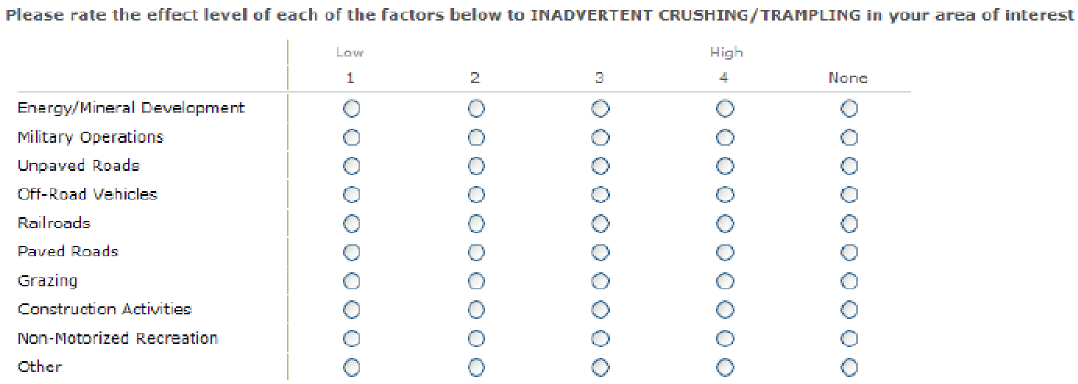
2. Estimate Contribution of Each Threat to Overall Demographic Impact



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 (Figure C-3).



Please rate the effect level of each of the factors below to INADVERTENT CRUSHING/TRAMPLING in your area of interest

	Low 1	2	3	High 4	None
Energy/Mineral Development	○	○	○	○	○
Military Operations	○	○	○	○	○
Unpaved Roads	○	○	○	○	○
Off-Road Vehicles	○	○	○	○	○
Railroads	○	○	○	○	○
Paved Roads	○	○	○	○	○
Grazing	○	○	○	○	○
Construction Activities	○	○	○	○	○
Non-Motorized Recreation	○	○	○	○	○
Other	○	○	○	○	○

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 Figure C-4. Appendix C-2 further illustrates how direct and indirect threat contributions to mortality are estimated.

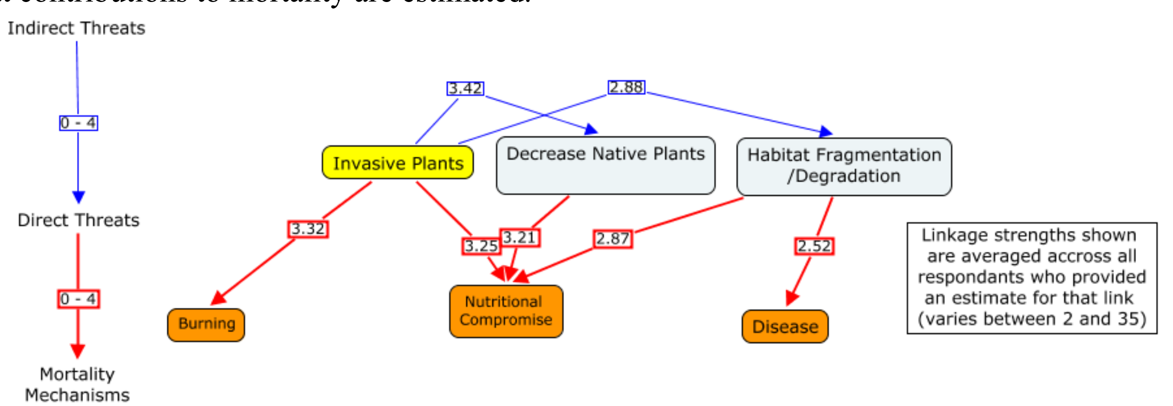


Figure C-4. Illustration of how direct and indirect threats contribute to mortality mechanisms from the perspective of the threat, Invasive Plants.

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

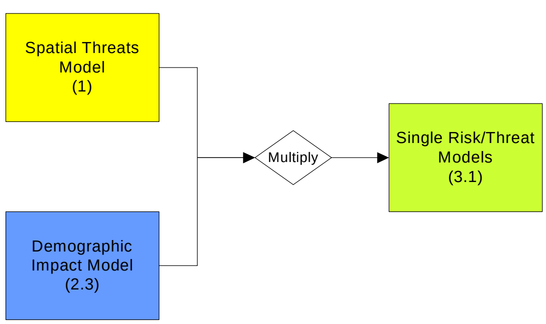
This step produces the Demographic Impact Model by combining the results from the previous steps to derive an overall weighted score for each threat. That score describes the contribution of a single threat to overall tortoise mortality. Table C-2 illustrates how each factor was combined. Appendix C-4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

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

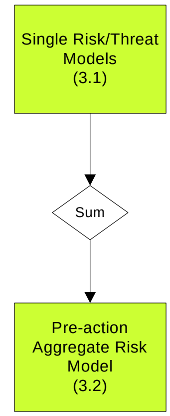
Single Threat	**Contribution to Mortality Mechanism**	**Mortality Mechanism (MM)**	**Percent Contribution of MM to overall Mortality**	**Overall Contribution of Threat to Mortality**
Invasive Plants	20.61%	Burning	9%	20.61% x 9% = 1.86%
Invasive Plants	16.93%	Nutritional Compromise	4%	16.93% x 4%= 0.68%
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 synopsis 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 the desert tortoise, reported at the spatial unit of 1 square kilometer across the tortoises' range (Figure C-5).

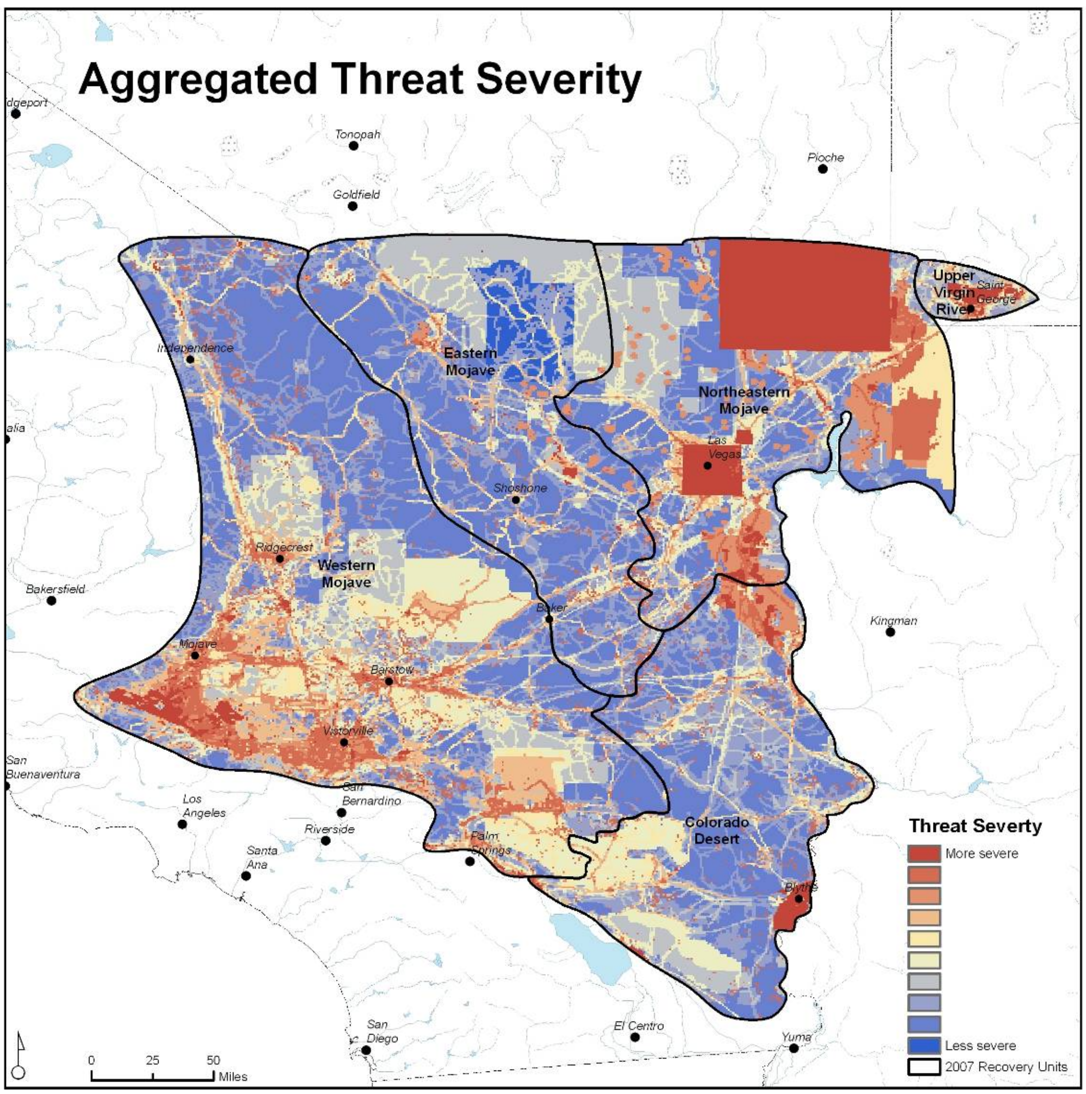
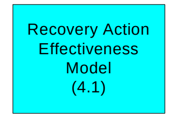


Figure C-5. Aggregated severity of threats across the range of the Mojave population of the desert tortoise estimated from the prototype decision support system. Warmer colors indicate greater severity of threats to the tortoise. *Note that this representation is preliminary and is based on incomplete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

4. Estimate Effects of Recovery Actions



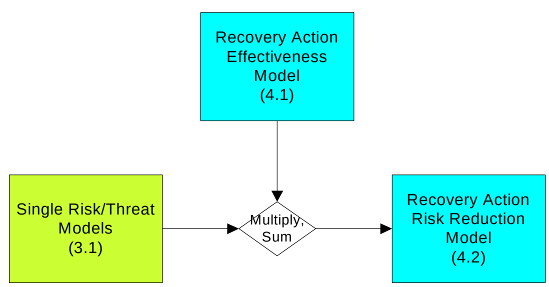
4.1 Effectiveness of Action on Threat

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.

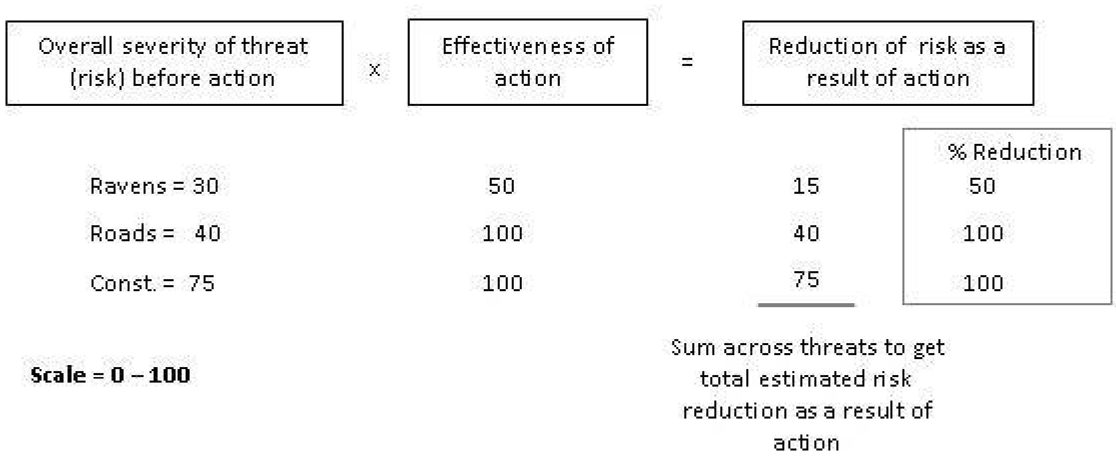
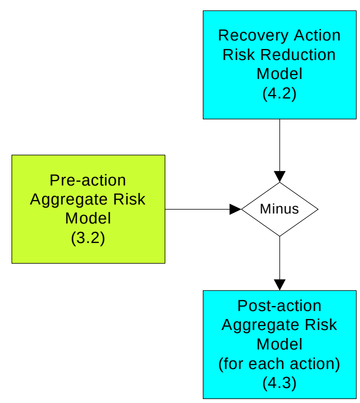


Figure C-7. Illustrative example of how the reduction in risk as a result of an action is calculated. Effectiveness of action is expressed as a percentage.

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 (Figure C-8).

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.

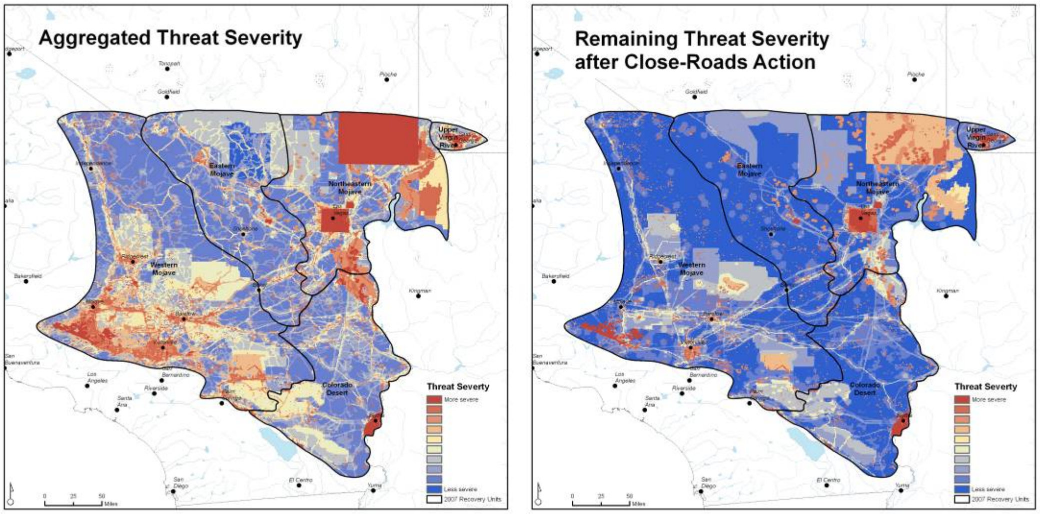
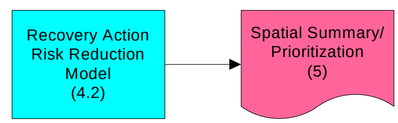


Figure C-8. Expected risk reduction as a result of the hypothetical action of closing roads across the range of the desert tortoise. The map on the left represents the aggregate threat severity (risk) from Figure C-5, and the map on the right represents post-action threat severity (risk) as a result 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.*

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 (Figure C-9).

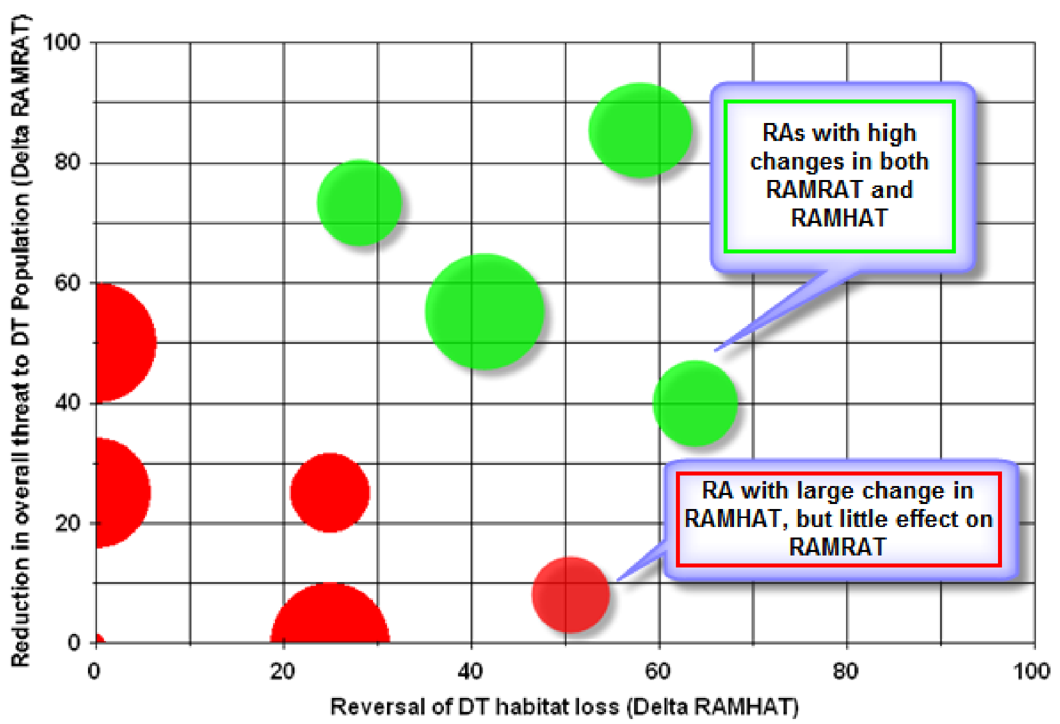


Figure C-9. Illustration of how recovery actions (RAs) can be assessed in terms of mortality risk reduction (RAMRAT) and benefit to tortoise habitat (RAMHAT). Delta RAMRAT means 'change in RAMRAT,' and Delta RAMHAT means 'change in RAMHAT.'

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 (*e.g.*, budget, available personnel, degree of controversy) 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.

Literature Cited

Ekbia, H.R. 2004. Rethinking decision support systems: lessons learned from ecosystem management. Whitepaper. The Redlands Institute, University of Redlands, Redlands, California.

Ekbia, H., and Reynolds, K. 2006. Decision support for sustainable forestry: enhancing the basic rational model. Pages 497-514 *in* A. Thompson and K.M. Reynolds (eds.), Forestry management: the past and the future. Springer Verlag.

Feick, R., and B. Hall. 2004. A method for examining the spatial dimension of multi-criteria weight sensitivity. International Journal of Geographic Information Science 18:815-840.

Keen, P.G.W., and M.S.S. Morton. 1978. Decision support systems: an organizational perspective. Addison-Wesley, Reading, Massachusetts.

Malczewski J. 2006. GIS-based multicriteria decision analysis: a survey of the literature. International Journal of Geographical Information Science 20:249-268.

Nicolson, C.R., A.M. Starfield, G.P. Kofinas, and J.A. Kruse. 2002. Ten heuristics for interdisciplinary modeling projects. Ecosystems 5:376-384.

Saaty, T.L. 1992. Multi-criteria decision making - the analytic hierarchy process. RWS Publications, Pittsburgh, Pennsylvania.

Simon, H.A. 1960. The new science of management decision (vol. 3). Harper, New York.

Starfield, A.M. 1997. A pragmatic approach to modeling for wildlife management. Journal of Wildlife Management 61:261-270.

Starfield, A.M., and A.L. Bleloch. 1991. Building models for conservation and wildlife management. Interaction Book Company, Edina, Minnesota.

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. N/A indicates data not available, but the threat is listed as a placeholder. Dates were not available for some datasets. Incorporation of additional, new, or revised data will improve the decision support system model output.

Threat Type	Dataset Title	Dataset Source	Date
Agriculture	Land Use and Land Cover for the Southwest US, Agriculture	USGS	1990
Air Pollution	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Captive Releases	Captive Release Zone	Redlands Institute, Univ. Redlands	2007
Collection	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Disease			N/A
Energy/Mineral Development	MAS/MILS mineral location	USGS	1998
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
	Locatable Minerals, AZ Strip, AZ	BLM, Arizona Strip District Office	
	Mineral Materials, AZ Strip, AZ	BLM, Arizona Strip District Office	
	Fluid Mineral Leasing (Oil and Gas), AZ Strip, AZ	BLM, Arizona Strip District Office	
	Nevada Mining Lease Potential	BLM, Nevada State Office	
	Nevada Mining Material Sites	BLM, Nevada State Office	
	NDOT Material Right-of-Way	BLM, Nevada State Office	
	Nevada Oil and Gas Lease, Ely Field Office	BLM, Nevada State Office	
	Nevada Oil and Gas Lease, Las Vegas Field Office	BLM, Nevada State Office	
Fire	Recovery Units Fire Risk Area	Redlands Institute, Univ. Redlands	2007
Free-Roaming Dogs	Feral Dog Zone	Redlands Institute, Univ. Redlands	2007
	DMG Free-roaming Dog Occurrences	Desert Managers Group	
Grazing	CA Grazing Allotments	BLM	2007
	NV Grazing Allotments	BLM, Nevada State Office	2005
	AZ Livestock Grazing Allotments	BLM, Arizona Strip District Office	2007
	CA Herd Management Area	BLM, Sacramento, CA	1999
	NV Herd Areas	BLM, Nevada State Office	
	AZ BLM wild horse and burro herd areas	Arizona BLM Field Offices	2000
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Invasive Plants	Weed Sentry 2004 infestation, *Brassica*	Clark Co., NV	2004
	Weed Sentry 2005 infestation, *Brassica*	Clark Co., NV	2005
	Brassica tournefortii locations, Lake Mead NRA	NPS, Lake Mead NRA	2006
	Prob. Finding *Brassica*, 2005 LSD Survey	Jill Heaton, UNR	2005
	Prob. Finding *Brome*, 2005 LSD Survey	Jill Heaton, UNR	2005
	Prob. Finding *Schismus*, 2005 LSD Survey	Jill Heaton, UNR	2005
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007

Military Operations	SW US Military Bases	US Army Corps of Engineers, Engineer Research & Development Center	2005
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Non-Motorized Recreation	Mohave Non-Motorized Recreation	Redlands Institute, Univ. Redlands	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Other Predators	CA, AZ, NV, UT Other Predators	Redlands Institute, Univ. Redlands	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Off-Road Vehicles	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Paved Roads	Arizona Strip Transportation	BLM, Arizona Strip District Office	2007
	Roads - Mojave Desert	Mojave Desert Ecosystem Project	1998
Railroads	Railroads of the Southwest US	USGS	1998
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Ravens	Raven Nest Field Survey, 1990-97	Bill Boarman	1997
	Raven Nest Field Survey, 2004	Redlands Institute, Univ. Redlands	2004
	Raven Nest Field Survey, 2005	Redlands Institute, Univ. Redlands	2005
	NV Raven Locations	Nevada Department of Wildlife	2003
	Clark Co. Raven Locations	USDA-ADC	2005
	Clark Co. Raven Survey	Clark County	
	Estimated Number of Ravens, 2005 LDS Survey	Jill Heaton, UNR	
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Supplemental Water Sources	Water Development Sites, Guzzlers	Nevada Department of Wildlife	2005
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Toxicant	US Toxic Release Inventory	EPA	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Unpaved Roads	Arizona Strip Transportation	BLM, Arizona Strip District Office	2007
	Roads - Mojave Desert	Mojave Desert Ecosystem Project	1998
	BLM Routes	BLM	2001
Urbanization	U.S. Census Urbanized Areas	Department of Commerce, Census Bureau, Geography Division	2004
	20 Year Urban Growth, 2020	California Resources Agency	2000
	50 Year Urban Growth, 2050	California Resources Agency	2000
	Mojave Urban Growth 2020	Desert Research Institute	2000
	Clark Co. BLM Disposal Lands – Rural	Comprehensive Planning, Clark Co., NV	2007
	Clark Co. BLM Disposal Lands	Comprehensive Planning, Clark Co., NV	2004
	Nevada Disposal Lands	BLM	2005
	Urban Land cover Areas in Clark County, NV 2001	Clark Co., NV	2001
	Urban Land cover Areas in Clark County, NV 2006	Clark Co., NV	2006
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Utility Corridors	Southern California Utility Lines	Environmental Systems Research Institute (ESRI)	1993
	SW Electrical - detailed lines	US Department of Energy	
	SW Electrical - main lines	US Department of Energy	
	US Natural Gas lines	US Department of Energy	

	US Natural Gas lines	PennWell MAPSearch	
	Energy Corridor - centerline	US Department of Energy	
	Energy Corridor - 1500ft buffer	US Department of Energy	
	Nevada Gas Lines	BLM, Nevada State Office	
	Nevada Power Lines	BLM, Nevada State Office	
	Nevada Utility Corridors	BLM, Nevada State Office	
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
Vandalism		Redlands Institute, Univ. Redlands	2007
Waste Disposal	Landfills in the West Mojave Planning Area	Redlands Institute, Univ. Redlands	2003
	AZ Landfills, Mohave Co., AZ	Mohave County Public Works, Engineering Division	2005
	DMG Dump Database	Desert Managers Group	
	California Solid Waste Information System, 2007	California Integrated Waste Management Board	2007
	Probability of Finding Trash, 2005 LDS Survey	Jill Heaton, UNR	2005
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007
	DTRO Workshop User Input Data	Redlands Institute, Univ. Redlands	2007

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

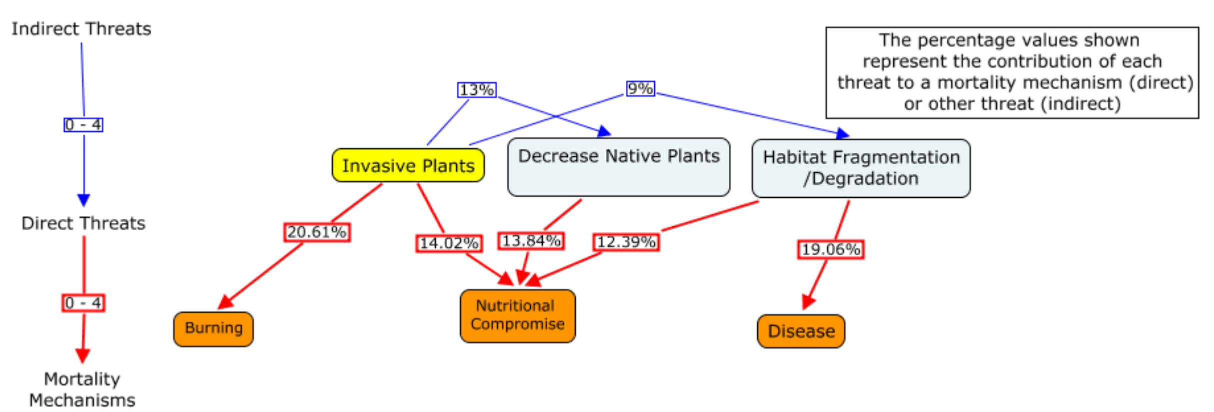


Figure C2-A: Direct and indirect contributions of the threat Invasive Species to mortality.

Indirect threats are threats that contribute 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 Figure C2-A, the contribution of the indirect link of Invasive Plants to Decrease Native Plants on the mortality mechanism Nutritional Compromise is 13 percent x 13.84 percent = 1.8 percent. We 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 (Figure C2-B).

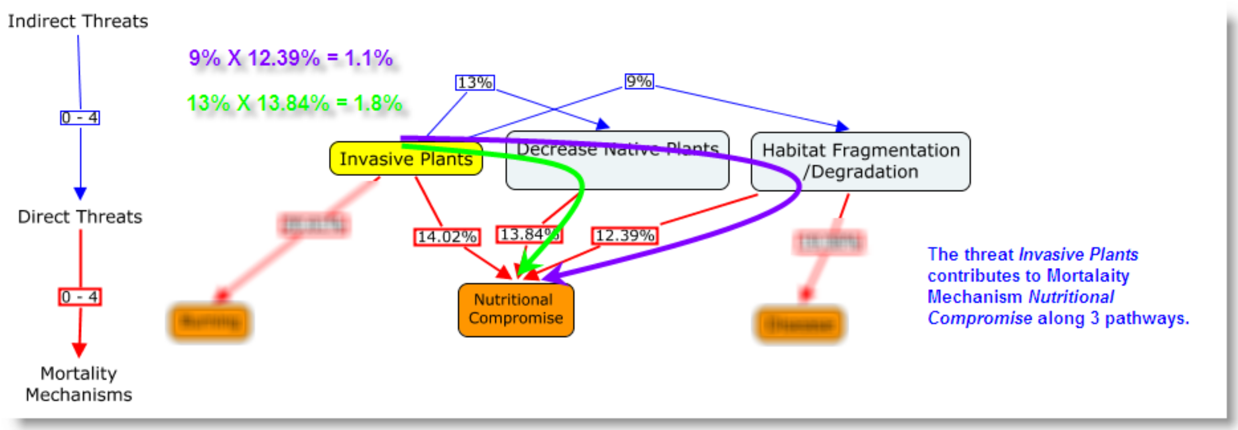


Figure C2-B. Direct and indirect contributions of the threat Invasive Species to mortality.

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 mechanism to overall mortality, calculated from Table C3-A using the principal eigenvalue method from the Analytic Hierarchy Process (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%**

Table C4-A 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						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	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										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	1			3	
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.

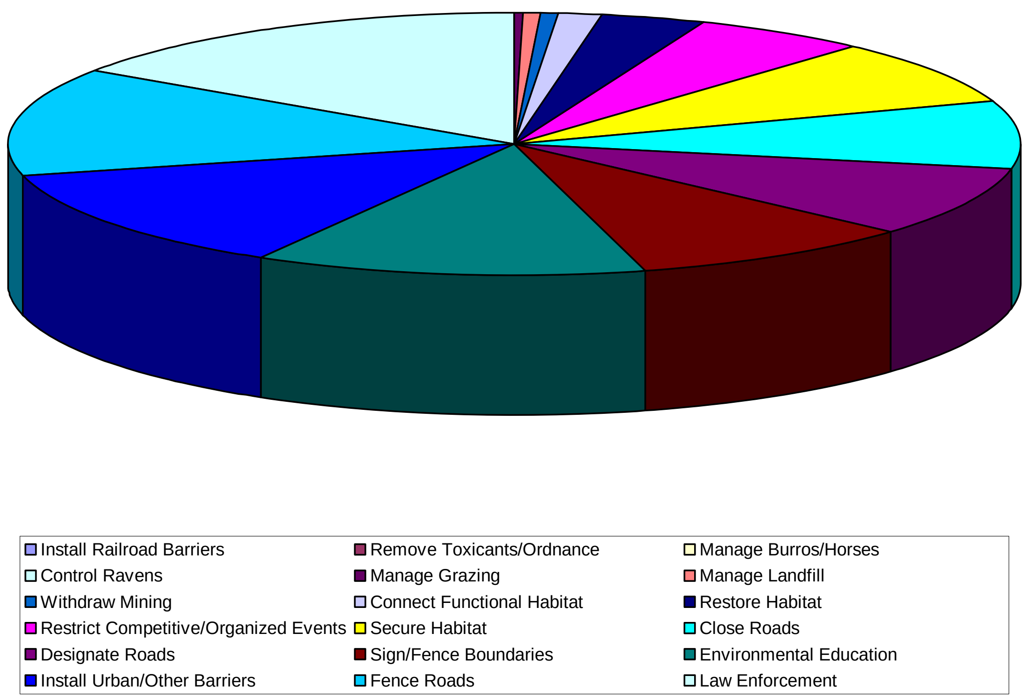
Action	Upper Virgin River	Northeastern Mojave	Eastern Mojave	Colorado Desert	Western Mojave
Close Roads	2.96	24.20	5.21	5.83	20.03
Connect Functional Habitat	0.50	7.40	0.95	1.87	4.41
Control Ravens	0.01	1.98	0.03	0.26	0.70
Designate Roads	2.96	24.20	5.21	5.83	20.03
Environmental Education	4.49	20.82	7.02	8.80	23.95
Fence Roads	4.71	5.84	2.34	2.04	9.21
Install Railroad Barriers	0.00	0.20	0.06	0.20	0.48
Install Urban/Other Barriers	4.54	21.73	0.83	2.40	5.54
Law Enforcement	5.48	16.95	4.18	5.08	12.67
Manage Burros/Horses	0.01	0.63	0.13	0.37	0.50
Manage Grazing	0.05	2.34	0.35	1.52	2.16
Manage Landfills	0.18	7.11	0.62	1.34	1.55
Remove Toxicants/Unexploded Ordnance	0.00	1.50	1.19	0.43	2.52
Restore Habitat	1.25	18.71	5.44	7.55	16.48
Restrict Competitive/Organized Events	1.91	10.11	2.56	3.40	6.61
Secure Habitat	2.91	15.77	2.29	3.77	9.58
Sign/Fence Boundaries	3.25	12.85	2.23	2.92	5.79
Withdraw Mining	0.20	4.02	1.98	3.12	7.16

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.

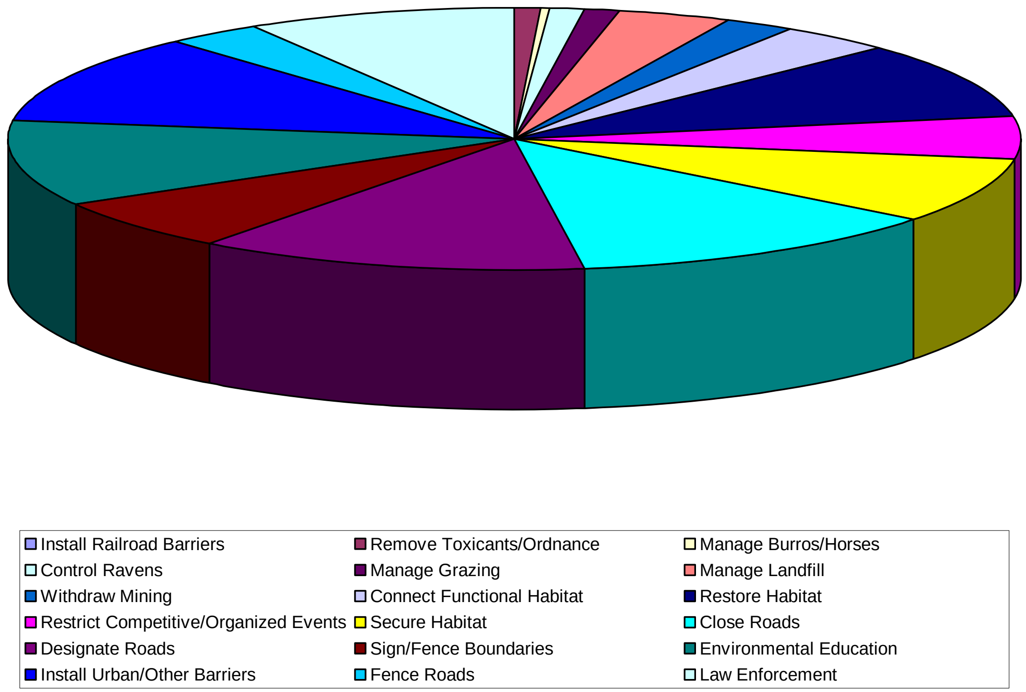
Upper Virgin River

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

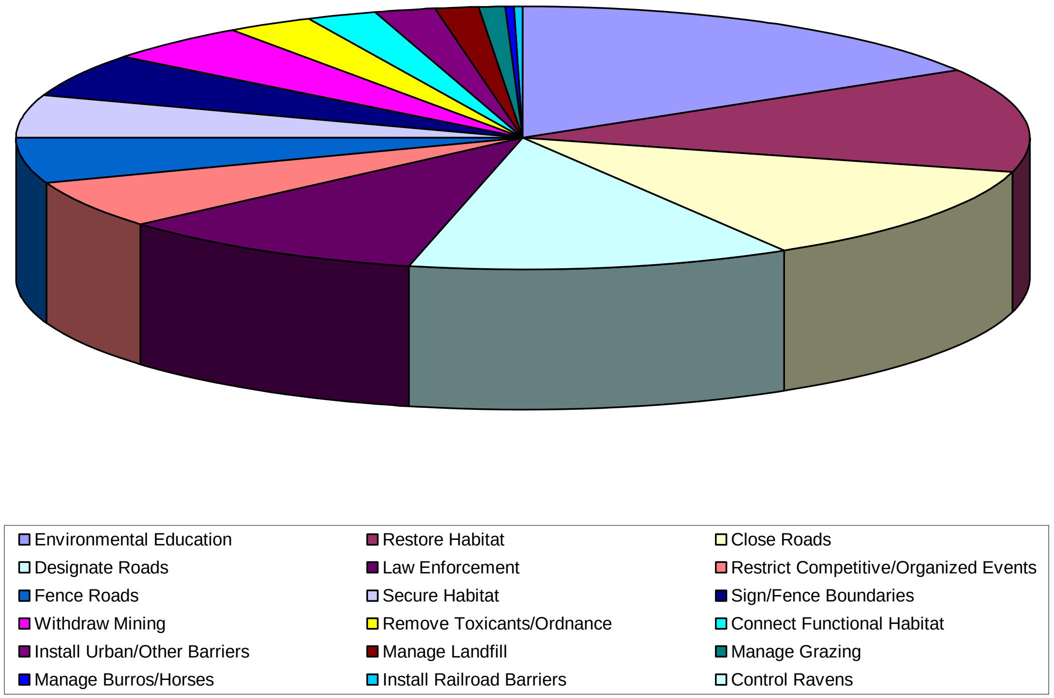


<u>Northeastern Mojave</u>

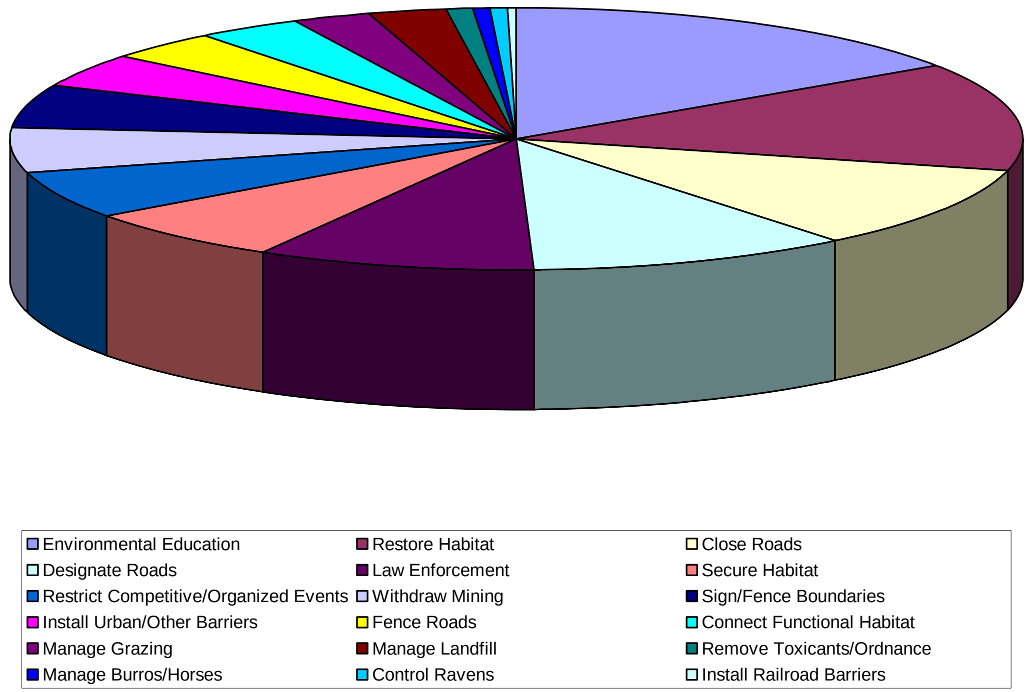
Close Roads
Designate Roads
Install Urban/Other Barriers
Environmental Education
Restore Habitat
Law Enforcement
Secure Habitat
Sign/Fence Boundaries
Restrict Competitive/Organized Events
Connect Functional Habitat
Manage Landfill
Fence Roads
Withdraw Mining
Manage Grazing
Control Ravens
Remove Toxicants/Ordnance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



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

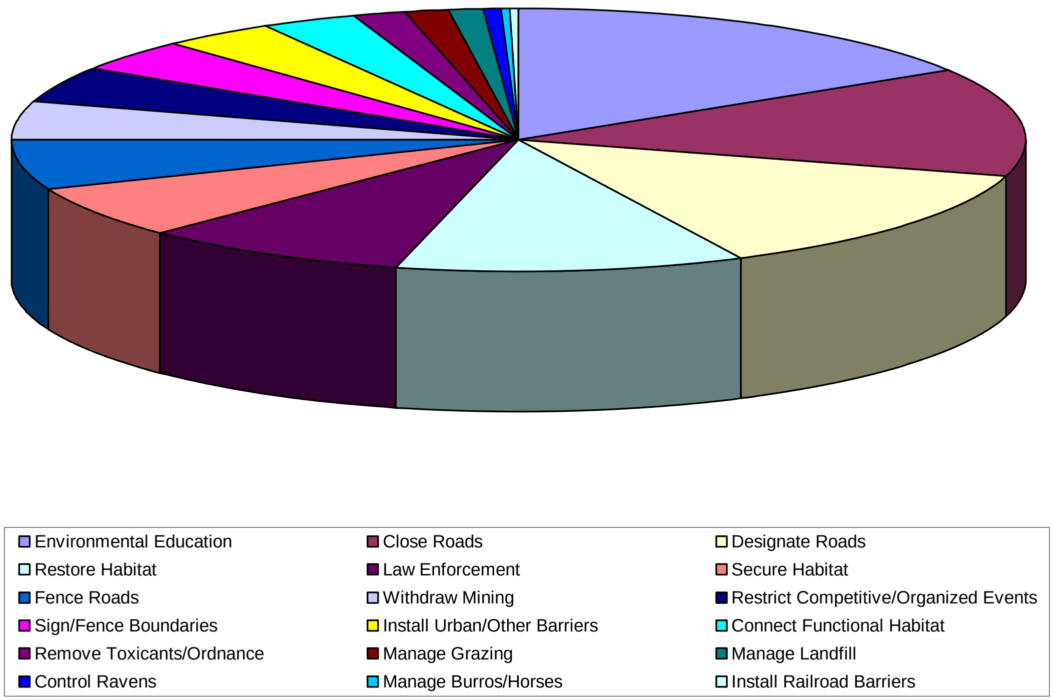


Colorado Desert
Environmental Education
Restore Habitat
Close Roads
Designate Roads
Law Enforcement
Secure Habitat
Restrict Competitive/Organized Events
Withdraw Mining
Sign/Fence Boundaries
Install Urban/Other Barriers
Fence Roads
Connect Functional Habitat
Manage Grazing
Manage Landfill
Remove Toxicants/Ordnance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



Western Mojave

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



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 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 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 cattle guards 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; cattle guards 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 cattle guard 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 cattle guards 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.

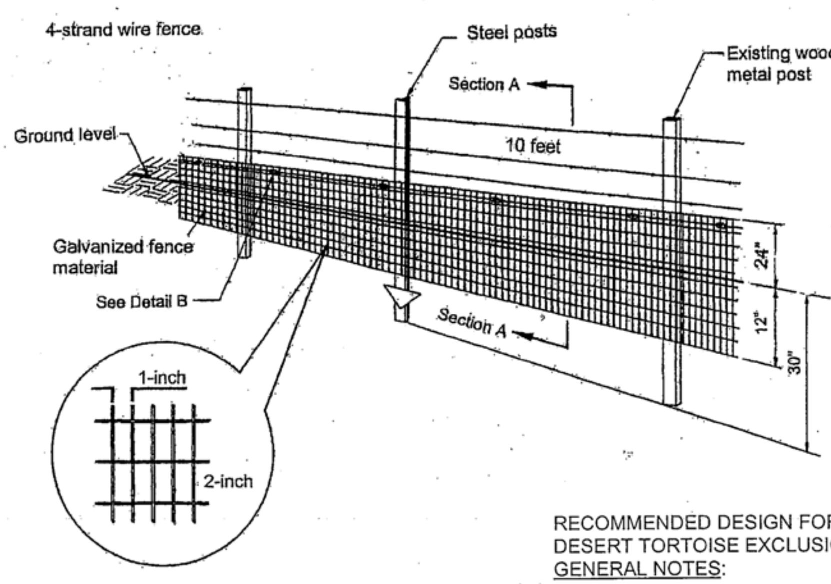
Repair and Maintenance of Desert Tortoise Barriers

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.

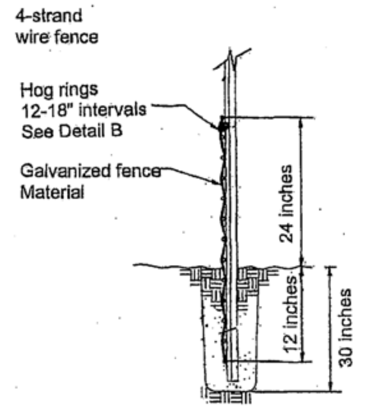
Gaps and breaks will require either: (a) repairs to the existing fence in place, with similar diameter and composition of original material, (b) replacement of the damaged section to the nearest T-post, with new fence material that original fence standards, (c) burying fence, and/or (d) restoring zero 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 cattle guards 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, cattle guards will be cleaned out of deposited material underneath them in a timely manner. In addition to periodic inspections, debris that accumulates along the fence should be removed. All cattle guards 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.

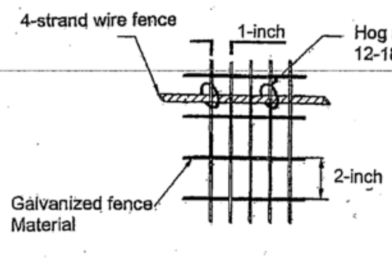
DESERT TORTOISE EXCLUSION FENCE (2005)



DETAIL A



SECTION A



DETAIL B

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.

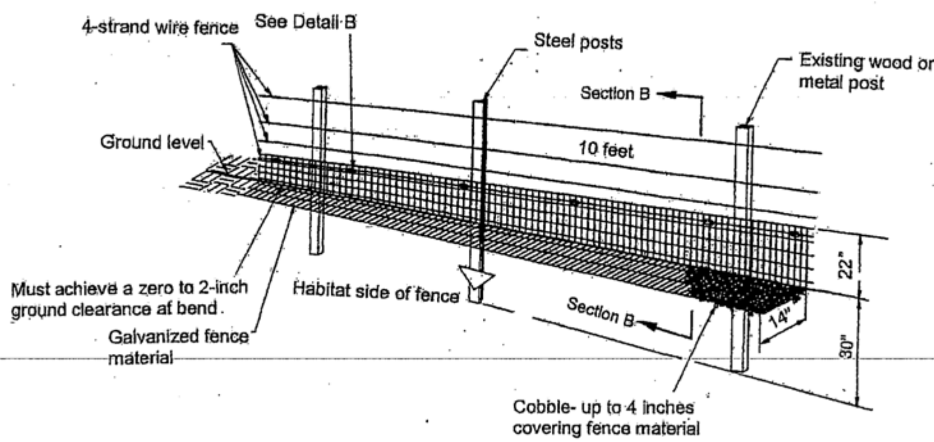
2. Ensure that the fence height above ground level is no less than 22 inches.

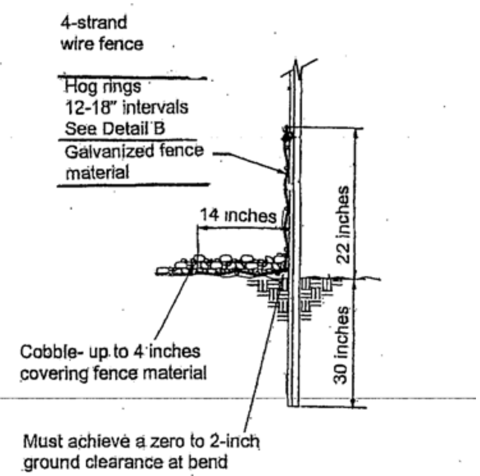
3. Ensure that there is a zero to 2-inch ground clearance at the bend.

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

U.S. Department of the Interior
U.S. Fish & Wildlife Service
Region 8, California and Nevada
Ecological Services
2800 Cottage Way, W-2606
Sacramento, California 95825

http://www.fws.gov

May 2008