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Via email only

30 September 2020

John Forsythe (CPUC Project Manager)
California Public Utilities Commission
c/o Aspen Environmental Group
235 Montgomery Street, Suite 640
San Francisco, CA 94104-2920
Ivanpah-Control@aspeneg.com

RE: Notice of Preparation for an Environmental Impact Report (EIR) for the Ivanpah-Control Project Proposed by Southern California Edison Application No. 19-07-015

Dear Mr. Forsythe,

The Desert Tortoise Council (Council) is a non-profit organization comprised of hundreds of professionals and laypersons who share a common concern for wild desert tortoises and a commitment to advancing the public's understanding of desert tortoise species. Established in 1975 to promote conservation of tortoises in the deserts of the southwestern United States and Mexico, the Council routinely provides information and other forms of assistance to individuals, organizations, and regulatory agencies on matters potentially affecting desert tortoises within their geographic ranges.

We appreciate this opportunity to provide comments on the above-referenced project. Given the location of the proposed project in habitats likely occupied by Mojave desert tortoise (*Gopherus agassizii*) (synonymous with "Agassiz's desert tortoise"), our comments pertain to enhancing protection of this species during activities authorized by the California Public Utilities Commission (CPUC). Please accept, carefully review, and include in the relevant project file the Council's following scoping comments and attachments for the proposed project. Additionally, we ask that you respond in an email that you have received this comment letter so we can be sure our concerns have been registered with the appropriate personnel and office for this project.

On September 1, 2020, the Council received the Notice of Preparation (NOP) directly from the Ivanpah-Control Project EIR Team, which we sincerely appreciate. All references to page numbers in this letter pertain to the NOP, which is dated "September 2020." Page 1 indicates Southern California Edison Company (SCE) has filed an application for a Permit to Construct (PTC) with the CPUC for its proposed Ivanpah-Control Project (Project), which is a 115 kilovolt (kV) transmission line rebuild project. Since SCE's application and the Proponent's Environmental Assessment (PEA) were not deemed complete by CPUC (page 1), there are no formal environmental documents to review; rather, scoping comments are being solicited by the NOP.

As given on page 2, the Bureau of Land Management (BLM) will be the lead agency under the National Environmental Policy Act (NEPA), and will prepare an Environmental Impact Statement (EIS). The BLM will observe the CPUC's scoping meetings and will hold its own public scoping meetings in the future, after issuing a Notice of Intent (NOI) to prepare an EIS in the Federal Register. At the appropriate time, these same scoping comments, with pertinent revisions pending additional project information that may become available, will also be provided to the BLM.

The Council is very interested in this project, as it passes through desert tortoise critical habitat (U.S. Fish and Wildlife Service 1994) in several places. As such, we attended the virtual public scoping meeting held via Zoom on September 10, 2020. As per page 2, "SCE is proposing to rebuild components of its existing 115 kilovolt (kV) transmission lines that extend over 358 miles between the existing SCE Control and Haiwee Substations in Inyo County, the Inyokern Substation in Kern County, and the Kramer, Tortilla, Coolwater, and Ivanpah Substations in San Bernardino County, CA. The Proposed Project is located on private land, Department of Defense land, and on federal lands administered by the BLM. The Project includes re-tensioning powerlines to reduce the sag between towers; [and] installing taller poles to increase the clearance between powerlines and ground, replacing individual poles, and derating a line segment."

With regards to the following statement on page 3, "The CPUC will review SCE's conductor selection as it relates to structure height requirements and *structure spacing (span lengths)* because these factors *may have associated* visual impacts or *construction disturbance*," [*emphasis added*] we interpret this statement to mean that SCE may choose to construct new pad sites if existing spans are determined to be inadequate. We ask that in choosing such sites, insofar as engineering allows, that barren areas and other degraded habitats, as determine with input from knowledgeable biologist(s), be selected to minimize impacts to tortoises and other rare desert plants and animals.

The NOP fails to reveal if replacement, removal, and installation of new and old structures are restricted to aboveground facilities, like conductors, or if they will involve transmission poles and towers that will result in ground disturbance. For example, if the "905 new structures" identified on page 3 and in the next paragraph for Segment 1 pertain to towers, there may be considerable habitat disturbance. We expect that the estimated acreages of both temporary and permanent impacts to desert tortoise habitats, both of which are long-term impacts, will be documented in the EIR, and ask that the results also be reported in terms of their locations inside and outside tortoise critical habitat areas.

We note on page 3 for Segment 1: Control Substation (Bishop) to Inyokern, that "SCE would install approximately 905 new structures and new ACCC conductor[s] in a new right-of-way adjacent to the existing line, then remove all (approximately 1,161) existing subtransmission structures." Be advised that desert tortoises occur between Rose Valley, in the vicinity of Coso Junction south of Olancha, south to Inyokern. Throughout this area, we advise that previously disturbed areas be identified for new structures, particularly if "new structures" include new transmission towers, which is not clear from the description. It is also not clear from the description that "adjacent" will require that the new line would be on the same side of Highway 395 as the old line. In any case, we advocate the completion of U.S. Fish and Wildlife (USFWS 2019) protocol surveys for desert tortoises to help inform SCE of the best places to place new structures that would result in ground disturbance and avoid tortoises and tortoise habitats.

Similarly, all areas south of Olancha including Segments 1, 2, and the western portions of Segments 3S and 3N (west of Barstow) are in habitats that may be occupied by Mohave ground squirrels (*Xerospermophilus mohavensis*; herein "MGS"), which is listed as Threatened by the California Fish and Game Commission. We recommend that protocol trapping surveys for MGS [California Department of Fish and Game (2003; revised 2010)] be performed in all areas where ground disturbance would result in the loss of suitable habitats. Be advised that there are seasonal restrictions for these surveys, which must occur between March and mid-July of a given year; and, that results of these surveys are viable for only one year following completion of trapping surveys (e.g., if the project is not completed by July of the next year after trapping, a new trapping effort will likely be required). Alternatively, SCE may assume presence of MGS and secure a Section 2081 incidental take permit from the California Department of Fish and Wildlife (CDFW) prior to ground disturbance.

We note that work on Segments 1 and 2 would entail installation of new fiber optic cables, but there is no indication if these cables would replace existing lines. If these new cables are not replacing existing cables, we strongly recommend that they either be placed within existing roads or immediately adjacent so that as little new habitat as possible is impacted or lost to this Project. Even if SCE is replacing existing lines, we expect that knowledgeable biologist(s) will perform measurements both before and after the project to determine how many acres of tortoise and MGS habitats are temporarily and permanently lost. These data will allow SCE and the regulatory agencies to determine the levels of habitat compensation that are likely to be required by CDFW and BLM for damage to suitable habitats for these covered species.

Please be sure that acreages associated with Staging Yards and Work Areas identified on page 4 are calculated and reported in the EIR. For an accurate appraisal of these acreages, we feel it is important that each pole site, which will generate a Work Area between ¼ and ¾ acres, must be evaluated in terms of existing disturbances so that new disturbances can be calculated. Unlike pole sites that are fixed locations, there is more flexibility in determining locations of Staging Yards. We expect that all Staging Yards can occur in areas of existing disturbances (preferably barren areas), and ask that SCE commit to locating all yards in disturbed areas, with input from knowledgeable biologist(s) to determine those locations.

We note also that SCE plans to use 426 linear miles of existing roads and spur roads, and that "During road rehabilitation and preparation of staging areas, vegetation would be trimmed or removed, as needed." As given above, we expect that the EIR will identify measures that will require before and after measurements of the widths of roads that are to be improved. The difference between these measurements will allow SCE to determine how many acres of suitable tortoise and MGS habitats are lost, which can then be used by the agencies to determine appropriate habitat compensation. In the same paragraph, we appreciate that, "Tree removal would be minimized," and ask that a similar requirement be identified in the EIR that will be applied to the loss of all intact habitats, which should similarly be minimized.

As stated on page 5, we appreciate that CPUC "…will also include analysis of additional issues identified in the scoping process…" in the EIR. Certainly, one of these additional issues is the potential creation of new nesting substrates for common ravens (*Corvus corax*), which is a known predator of desert tortoises and MGS. As such, we ask that the EIR provide a summary of recent and ongoing efforts by SCE to curtail subsidizing common raven nesting on its structures. Replacing old towers with new and different towers would afford an excellent opportunity to install towers that reduce perching opportunities for ravens. We suggest exploring designs that achieve this goal.

Other questions that should be addressed in the EIR include: Is SCE contributing to the National Fish and Wildlife Foundation's Raven Management Fund for regional and cumulative impacts? Is there an existing raven management plan or a new one to be drafted for this project that meets USFWS (2010) standards as they affect construction, operation, maintenance, and decommissioning (including restoration) with monitoring and adaptive management during each project phase? For those poles that are being replaced, will new poles have design features that minimize raven nesting potential?

In this same paragraph on page 5, CPUC indicates that the EIR "…will evaluate the project's cumulative impacts (project impacts combined with other present and planned projects in the area)." In that regard, we recommend that the cumulative impacts analysis in the EIR also follow the Council on Environmental Quality (CEQ) (1997) guidance on how to analyze cumulative environmental consequences, which contains the eight principles listed below:

1. Cumulative effects are caused by the aggregate of past, present, and reasonable future actions.
The effects of a proposed action on a given resource, ecosystem, and human community, include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to the effects (past, present, and future) caused by all other actions that affect the same resource.

2. Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (federal, non-federal, or private) has taken the actions.
Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effect at one time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.

3. Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected.

Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resources, ecosystem, and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.

4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.

For cumulative effects analysis to help the decision maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to the affected parties.

5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries.

Resources are typically demarcated according to agency responsibilities, county lines, grazing allotments, or other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects analysis on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.

6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects.

Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.

7. Cumulative effects may last for many years beyond the life of the action that caused the effects.

Some actions cause damage lasting far longer than the life of the action itself (e.g., acid mine damage, radioactive waste contamination, species extinctions). Cumulative effects analysis need to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.

8. Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters.

Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.

It is unfortunate that the 30 applicant-proposed mitigation measures referenced on page 5 are not included in the NOP. When they are presented in the EIR, we ask that CPUC indicates how, if any, existing measures have been modified for this particular project, and document their effectiveness for similar projects (e.g., how effective has SCE's raven management program been in curtailing raven nesting in its transmission structures?)

There should also be a review of recent Stipulations for right-of-way grants issued by the BLM and Terms and Conditions in biological opinions issued by the USFWS to ensure that the latest protective measures are being implemented. We expect that CPUC will commit to the latest standards identified in the USFWS' (2009) Desert Tortoise (Mojave Population) Field Manual with regards to surveys, fencing, and other applicable activities. Also, we provide proposed Best Management Practices for tortoise protection during construction projects (Desert Tortoise Council 2017) for your consideration and use to supplement the 30 applicant-proposed mitigation measures, as needed.

Even if conscientiously implemented, there is the likelihood that desert tortoises and/or MGS will be adversely affected by the proposed project. In fact, Section C of the NOP on page 5 states that "The Proposed Project may result in potentially significant impacts," which we assume includes listed species. We therefore ask that the EIR document existing state and federal incidental take permits, likely issued to SCE, that will authorize foreseeable harm or mortality of listed species, including desert tortoise and MGS. Absent such programmatic permits, we expect that CPUC and/or SCE will acquire necessary state and federal take permits from CDFW and USFWS, respectively, prior to ground disturbance, and that the EIR will document the statuses of such permits.

We expect that SCE will need to rehabilitate habitats that are temporarily used resulting in long-term damage by the use of Staging Yards and Work Areas identified on page 4. As such, we submit the attached restoration guidelines (Abella and Berry 2016) for use by SCE and CPUC for this and future projects where habitats would be restored to pre-project conditions.

We appreciate this opportunity to provide input and trust that our comments will help protect tortoises during any authorized project activities. Herein, we ask that the Desert Tortoise Council be identified as an Affected Interest for this and all other CPUC projects that may affect species of desert tortoises, and that any subsequent environmental documentation for this particular project is provided to us at the contact information listed above. We also ask that you acknowledge receipt of this letter as soon as possible so we can be sure our concerns have been received by the appropriate parties.

Regards,

Edward L. LaRue, Jr., M.S.
Desert Tortoise Council, Ecosystems Advisory Committee, Chairperson

cc: California State Clearinghouse, state.clearinghouse@opr.ca.gov

Issues and Perspectives

Enhancing and Restoring Habitat for the Desert Tortoise *Gopherus agassizii*

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Abstract

Habitat has changed unfavorably during the past 150 y for the desert tortoise *Gopherus agassizii,* a federally threatened species with declining populations in the Mojave Desert and western Sonoran Desert. To support recovery efforts, we synthesized published information on relationships of desert tortoises with three habitat features (cover sites, forage, and soil) and candidate management practices for improving these features for tortoises. In addition to their role in soil health and facilitating recruitment of annual forage plants, shrubs are used by desert tortoises for cover and as sites for burrows. Outplanting greenhouse-grown seedlings, protected from herbivory, has successfully restored (>50% survival) a variety of shrubs on disturbed desert soils. Additionally, salvaging and reapplying topsoil using effective techniques is among the more ecologically beneficial ways to initiate plant recovery after severe disturbance. Through differences in biochemical composition and digestibility, some plant species provide better-quality forage than others. Desert tortoises selectively forage on particular annual and herbaceous perennial species (e.g., legumes), and forage selection shifts during the year as different plants grow or mature. Nonnative grasses provide low-quality forage and contribute fuel to spreading wildfires, which damage or kill shrubs that tortoises use for cover. Maintaining a diverse "menu" of native annual forbs and decreasing nonnative grasses are priorities for restoring most desert tortoise habitats. Reducing herbivory by nonnative animals, carefully timing herbicide applications, and strategically augmenting annual forage plants via seeding show promise for improving tortoise forage quality. Roads, another disturbance, negatively affect habitat in numerous ways (e.g., compacting soil, altering hydrology). Techniques such as recontouring road berms to reestablish drainage patterns, vertical mulching ("planting" dead plant material), and creating barriers to prevent trespasses can assist natural recovery on decommissioned backcountry roads. Most habitat enhancement efforts to date have focused on only one factor at a time (e.g., providing fencing) and have not included proactive restoration activities (e.g., planting native species on disturbed soils). A research and management priority in recovering desert tortoise habitats is implementing an integrated set of restorative habitat enhancements (e.g., reducing nonnative plants, improving forage quality, augmenting native perennial plants, and ameliorating altered hydrology) and monitoring short- and long-term indicators of habitat condition and the responses of desert tortoises to habitat restoration.

Keywords: annual plants; burrow; disturbance; forage; grazing; restoration; revegetation

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Introduction

Habitat of the desert tortoise *Gopherus agassizii* in the Mojave and bordering western Sonoran Desert in the southwestern United States has changed during the past 150 y. Beginning in earnest during the mid-1800s, thousands of nonnative animals (mainly cattle, sheep, horses, and burros) were moved through or kept in the region to support mining, ranching, and other human activities (Love 1916; Hohman and Ohmart 1978; Lovich and Bainbridge 1999). Numerous trails and roads, such as the Old Spanish Trail and the Mojave Road, originated or expanded from the 1800s through the 1900s (Keith et al. 2008). For example, within 6,000 km^2 of the central Mojave Desert, a road network of 605 km in 1885 expanded to 3,700 km by 1994 (Vogel and Hughson 2009). By the late 1800s, nonnative plant species were introduced that ubiquitously altered the composition of plant communities (Brooks and Esque 2002). In an inventory conducted from 2009 to 2011, at least one nonnative plant species inhabited 82% of 1,662 sites within 25,000 km^2 of national parks in the Mojave Desert (Abella et al. 2015c). In designated critical habitat for the desert tortoise in the western Mojave Desert, nonnative annual plants comprised 6% of the flora and 66% of the biomass in a wet year, and 27% of the flora and 91% of the biomass in a dry year (Brooks and Berry 2006). Large spreading wildfires, not known to have been common historically owing to sparse and discontinuous fuel, are now correlated with proximity to roads and annual plant productivity dominated by nonnative fuels (Brooks and Matchett 2006). Between 1992 and 2011, $>5\%$ of a 30,000-km^2 portion of the Mojave Desert burned in 1,700 lightning- and human-ignited fires (Hegeman et al. 2014). Many other land-clearing disturbances—such as agricultural fields, historical town sites, contemporary urban developments, energy transmission corridors, solar and wind energy facilities, and military training sites—have removed, altered, and fragmented habitat (Nichols and Bierman 2001; Webb et al. 2009a; Hernandez et al. 2014). Even where sources of disturbance have ceased (such as terminated livestock allotments, abandoned agricultural fields, closed roads), the legacies of altered hydrology, soil, and vegetation can continue for decades to centuries (Carpenter et al. 1986; Abella 2010; Berry et al. 2015, 2016).

The population of the desert tortoise in the Mojave and western Sonoran Desert was federally listed as threatened under the U.S. Endangered Species Act of 1973 (ESA 1973, as amended) in 1990 because of population declines, habitat alteration, and habitat loss (USFWS 1990). Population declines have continued in four of five recovery areas range-wide; the estimated decline was 32% for desert tortoises of breeding size between 2004 and 2014 in all recovery areas (USFWS 2015). Four of the five recovery areas experienced declines ranging from 27% to 67%; only one recovery area showed an increase in desert tortoise numbers.

The declines are serious for several reasons. First, studies at individual sites suggest that the recent 10-y decline continues a longer term trend (Peterson 1994; Berry and Medica 1995; Berry et al. 2006, 2014b; Medica et al. 2012). Populations of 75–140 desert tortoises/km^2 in the 1970s had decreased to $\leq 15/km^2$ by 2011–2012 (Berry et al. 2014b; Lovich et al. 2014). Second, the desert tortoise is long-lived (≥ 50 y), and persistence of adults at low densities may temporarily mask population declines at some sites (Berry et al. 2013). Third, densities of breeding adults in four of the five recovery areas with declining populations are precipitously low, ranging from only 1.5 to 15.3 tortoises/km^2 (USFWS 2015), and recruitment is poor (Berry et al. 2014b). Fourth, factors such as habitat loss and fragmentation, noted at the time of the 1990 listing, have not been curtailed and instead are expanding (Averill-Murray et al. 2013).

The Revised Recovery Plan for the desert tortoise emphasized habitat conservation, enhancement, and restoration as priority recovery actions (USFWS 2011). Habitat restoration was highly ranked, among 25 candidate recovery actions, for potential to enhance desert tortoise populations (Darst et al. 2013). This high ranking was because fundamental desert tortoise needs—food, water, and cover sites—hinge on what the habitat provides (Esque et al. 2014). Moreover, other threats perceived to limit populations, such as disease (Jacobson et al. 2014) and predation by common ravens *Corvus corax,* may also relate to habitat condition (Kristan and Boarman 2007; Averill-Murray et al. 2012). Poor forage quality and contamination of soil and food plants by mercury and arsenic, for example, are thought to increase vulnerability of desert tortoises to disease (Seltzer and Berry 2005; Chaffee and Berry 2006; Jacobson et al. 2014).

Although potential may be high for habitat management to increase the health and size of desert tortoise populations, many habitat improvement techniques are untested for their effectiveness as recovery actions for the desert tortoise. Literature has accumulated on topics such as vegetation restoration in the Mojave Desert, but this research has had diverse goals not necessarily focused on the tortoise (e.g., Wallace et al. 1980; Abella and Newton 2009; Scoles-Sciulla et al. 2014). Meanwhile, some studies have linked desert tortoise biology with habitat features, such as forage composition (Oftedal et al. 2002; Jennings and Berry 2015). The USFWS (2011) recommended integrating these types of habitat features with techniques for restoring and enhancing favorable habitat conditions, which could be followed by monitoring short- and long-term indicators of habitat condition and tortoise responses to habitat restoration.

A broad approach for enhancing habitat is essential for desert tortoise recovery (Averill-Murray et al. 2012). Elements of such an approach include conservation of specific favorable conditions and restoration of desired features designed to improve habitat in the context of contemporary and near-future environments. For example, restoring habitat on decommissioned roads to re-establish hydrological connectivity is feasible where old, previously disrupted stream channels are discernable (Nichols and Bierman 2001). In contrast, 150 y of grazing by nonnative animals and invasion by nonnative plants complicates our understanding of predisturbance forage

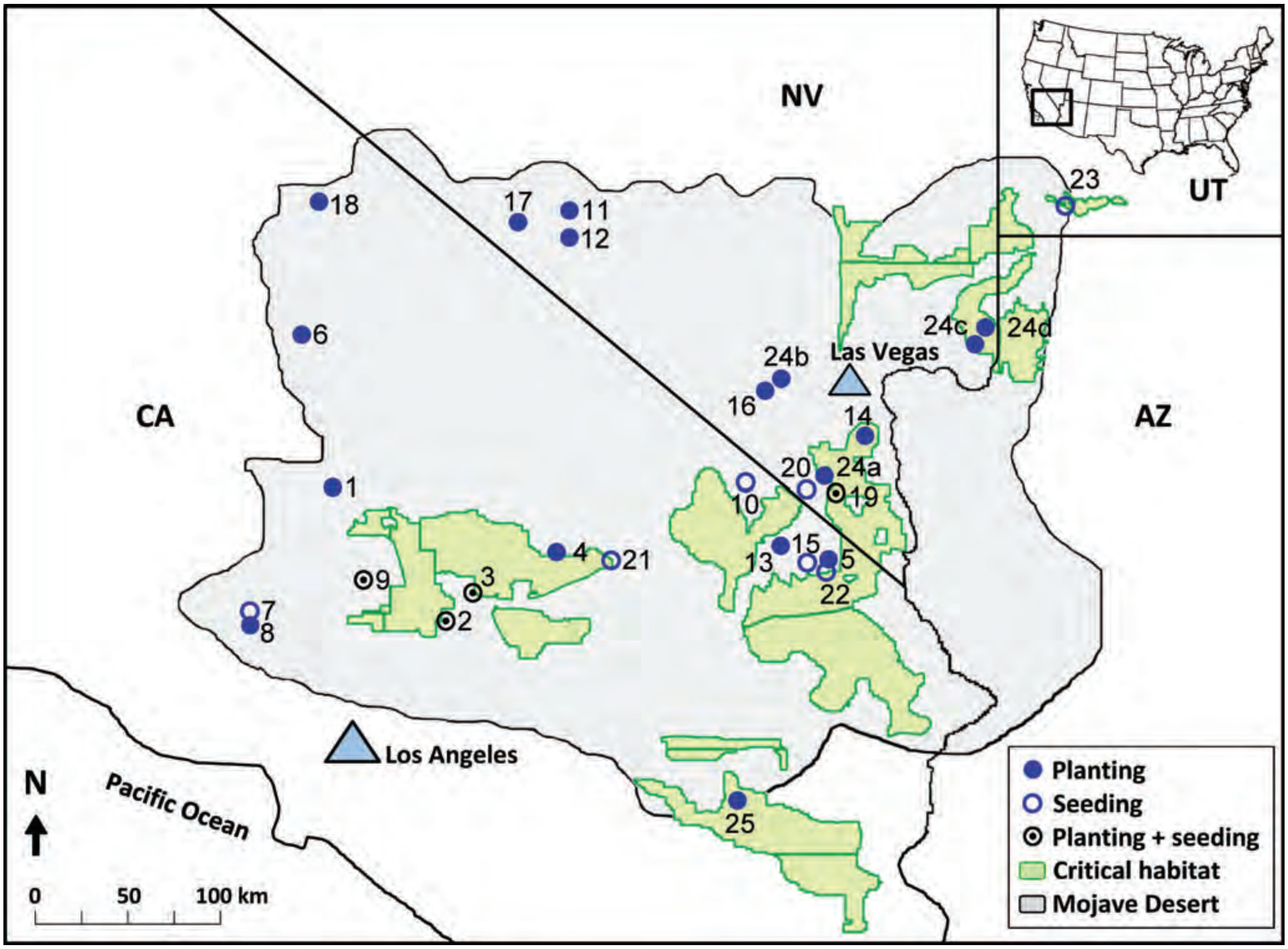

Figure 1. Distribution of critical habitat units for the desert tortoise *Gopherus agassizii* and published revegetation studies in the Mojave Desert of California, Nevada, northwestern Arizona, and Utah. The desert tortoise is distributed across much of the Mojave Desert (shown in green outline and shading). Many different maps of the boundary of the Mojave Desert are in the literature, and this map shows a combined generalization of maps in Rowlands et al. (1982), Rundel and Gibson (1996), and Webb et al. (2009b). Revegetation studies included planting nursery-grown plants and seeding. Studies numbered 1–18 correspond with 18 studies mapped in Abella and Newton (2009). Studies 19–25 are recent: 19, Abella et al. (2012b); 20, Abella et al. (2015a); 21, DeFalco et al. (2012); 22, Jones et al. (2014); 23, Ott et al. (2011); 24a–d, 4 sites in Scoles-Sciulla et al. (2014); and 25, Weigand and Rodgers (2009). Note that few of the revegetation studies are in tortoise critical habitat units. We did not find revegetation studies in the western Sonoran Desert in southeastern California that also contain a desert tortoise population.

composition, creating challenges for restoration efforts (Oldemeyer 1994). In this situation, establishing a plant composition adapted to the site and nutritionally favorable to desert tortoises may be most appropriate (Oftedal 2002; Hazard et al. 2009, 2010).

In support of recovery actions, we synthesize relationships of habitat features (vegetation and soil) with the listed Mojave and western Sonoran Desert population of the desert tortoise, and the status of knowledge for enhancing and restoring the key habitat elements of shrub cover, food, and soils. Our review has two parts: 1) requirements of the desert tortoise for shelter, food, and water; and 2) candidate practices and rationale for improving habitat condition and restoring habitats, including revegetating severe disturbances; enhancing quality of tortoise forage; removing or remediating damaged soil; salvaging topsoil; and decommissioning backcountry roads. Our focus is on habitat management practices aimed at enhancing health and growth of desert tortoise populations and for restoring damaged and deteriorated habitats within the context of past and existing recovery plans for the tortoise (USFWS 1994, 2011).

Methods

Study area

Our study area is the geographic range of the federally listed desert tortoise population, which is hot desert habitat north and west of the Colorado River. This includes most of the 124,000-km^2 Mojave Desert occupying parts of Arizona, Utah, Nevada, and California, as well as the Colorado Desert Subdivision of the western Sonoran Desert, in southeastern California (Figure 1). The study area receives much of its rainfall from November through April, during winter and spring (Rowlands et al. 1982). Annual precipitation averages 10–20 cm at low and middle elevations below 1,500 m. Topography includes mountain ranges, low hills, washes (ephemeral stream channels), and valleys. Soils include those derived from several rock types (e.g., basalt, limestone) and depositional material from erosion (Rautenstrauch and O'Farrell 1998; Berry et al. 2006; Mack et al. 2015). Geological history and soil age are key factors affecting biota, such as old surfaces of desert pavement compared with young soils in ephemeral stream channels (McDonald et al. 1995).

Dominant vegetation is desert shrubland (Rundel and Gibson 1996). Creosote bush *Larrea tridentata* and white bursage *Ambrosia dumosa* predominate across extensive low elevations, blackbrush *Coleogyne ramosissima* and succulent woodlands containing Joshua trees *Yucca brevifolia* at middle elevations from 1,300 to 1,800 m, and coniferous woodlands and forests at the higher elevations. Desert tortoises are most abundant in the low- and middle elevation creosote bush and mixed shrublands, and are sparse to absent in the higher elevation woodland and forest vegetation associations (Rautenstrauch and O'Farrell 1998; Berry et al. 2006). In years with sufficient rainfall, most annual plants in the desert shrubland germinate in winter, grow through spring, and senesce by May (Beatley 1974; Smith et al. 2014). The eastern Mojave and western Sonoran also have a component of summer annuals, stimulated by summer monsoonal storms (Jennings 2001; Wallace and Thomas 2008). Annual plants are typically most abundant below canopies of shrubs that form "fertile islands" of shaded, nutrient-enriched soil (Brooks 2009). Some annual species, however, are most abundant in interspaces between shrubs (Abella and Smith 2013). The spatial variation in the distribution of different shrub species and interspaces creates heterogeneity in the annual plant community, which may be important for diversifying the forage available to desert tortoises (Jennings and Berry 2015). The amount and timing of rainfall are also variable among years and across the landscape within a year (Hereford et al. 2006). Some years or locations have essentially no annual plants, while others support 50 species of annual plants within a single square kilometer (Brooks and Berry 2006).

Study species

The desert tortoise is distributed at elevations below 1,300 m across much of the Mojave and western Sonoran Desert, except for the Death Valley floor and other low-elevation valleys with minimal rainfall (USFWS 1994). Typical home ranges are up to 20 ha for adult females and 20–50 ha for adult males (Harless et al. 2010). Desert tortoises conduct daily and seasonal activities within these home ranges, including foraging, retreating to burrows, and reproduction. Occasionally they travel longer distances, such as 3–7 km over weeks and months, for reasons that may relate to mating, foraging, or locating new home ranges (Berry 1986). Desert tortoises spend >90% of their lives underground in burrows, thereby escaping temperature extremes, lack of moisture, and predators (Nagy and Medica 1986; Mack et al. 2015). All age classes of tortoises are active in spring during the peak spring growing season for plants. Juveniles can emerge from burrows in February and continue being active through May and June (Berry and Turner 1986), and periodically between November and February (Wilson et al. 1999). A second period of heightened activity of adults occurs during the mating season in summer and early autumn (Rostal et al. 1994). The species is primarily herbivorous (Morafka and Berry 2002; Oftedal 2002; Jennings and Berry 2015). Desert tortoises obtain moisture from succulent, green forage (Nagy et al. 1998) and drink from self-constructed catchments or puddles (Minnich 1977; Medica et al. 1980). Most desert tortoises respond to precipitation at any time of year by emerging to drink, unless they are already hydrated.

Information gathering

We focused on evaluating 1) the vegetation and soil attributes of habitat likely required by desert tortoises to survive and maintain viable populations into the foreseeable future; and 2) how these habitat features can be enhanced or restored for desert tortoises given existing habitat condition. We conducted a systematic review of information published in journal articles, book chapters, conference proceedings, and publicly available U.S. government serials (e.g., U.S. Forest Service General Technical Reports, U.S. Geological Survey Open-File Reports). We first examined review articles of the desert tortoise and disturbance and restoration in the Mojave and western Sonoran Desert (e.g., Webb and Wilshire 1983; Grover and DeFalco 1995; Abella and Newton 2009; Brooks and Lair 2009; Abella 2010). We then systematically searched the following article databases from their period of record through 2015: AGRICOLA, BioOne, GoogleScholar, JSTOR, Scopus, ScienceDirect, SpringerLink, Web of Science, and Wiley Online Library. We searched article titles, abstracts, and key words for articles containing the following terms: Mojave, Sonoran, livestock, grazing, fire, restoration, revegetation, road, right of way, corridor, desert tortoise, *Gopherus agassizii,* habitat, vegetation, forage, food, burrow, cover, perennial plant, and shrub. We also screened the 1976 to 2003 Desert Tortoise Council Proceedings for relevant papers. Nomenclature of plants follows NRCS (2016).

Relationships Between Habitat Features and Desert Tortoises

Perennial plants and protective cover

Desert tortoises predominately construct burrows in soil beneath canopies of native shrubs and under rocks; on certain sites they also use caves in cliffs or banks of ephemeral stream channels as shelters or dens (Woodbury and Hardy 1948; Burge 1978; Berry and Turner 1986; Baxter 1988; Lovich and Daniels 2000; Rautenstrauch et al. 2002; Mack et al. 2015). In three studies in natural shrubland habitat, desert tortoises constructed 72–97% of burrows beneath perennial plants (Burge 1978; Berry and Turner 1986; Baxter 1988). Furthermore, most burrows were below the largest shrubs. Burge (1978) found that the large catclaw acacia *Acacia greggii* harbored burrows at nine times that expected from its density, Mojave yucca *Yucca schidigera* seven times, and creosote bush four times. In addition to using shrubs as locations for constructing burrows, desert tortoises use shrubs as temporary resting or shelter sites during periods of activity outside burrows. In a 5-y study in the northeastern Mojave Desert, tortoises were observed beneath shrubs twice as often as in interspaces (Drake et al. 2015).

Although these studies show that desert tortoises use shrubs for protection, it is more difficult to determine how much shrub cover they need and if there are requirements for certain species and sizes of shrubs. Andersen et al. (2000), in a model of desert tortoise habitat use in the central Mojave Desert, reported that tortoises avoided areas of minimal plant cover. Berry et al. (2013) found that desert tortoise abundance was lower in areas denuded of vegetation than in adjacent undisturbed habitat. On a burned site, desert tortoises sought shelter below the skeletons of dead shrubs but frequently retreated to unburned areas with higher live perennial plant cover (Drake et al. 2015). If disturbance substantially reduces shrub density, locations for burrows and protective cover from temperature extremes and predation could limit tortoise population sizes (Andersen et al. 2000; Berry et al. 2013; Drake et al. 2015; Mack et al. 2015).

How does availability of perennial plants to desert tortoises fluctuate through time or change after anthropogenic disturbance? Severe, multiyear droughts have corresponded with die-off events in perennial plant communities. For example, some areas may still reflect effects of brief, but severe, droughts in 1989–1991 and 2002 associated with widespread mortality of some species of perennial plants (Hereford et al. 2006). In a 1-ha permanent plot remeasured between 1984 and 2004 in Joshua Tree National Park, density of mature white bursage declined from 1,600 to 523 individuals after the 2002 drought (Miriti et al. 2007). Eastern Mojave buckwheat *Eriogonum fasciculatum* dropped from 256 to 11 individuals, and desert globemallow *Sphaeralcea ambigua* from 59 to 0 individuals. Mature shrublands of creosote bush can generally be stable, but turnover can be substantial in short-lived perennial plants within creosote bush shrubland and in postdisturbance communities dominated by short-lived perennials (Webb et al. 2003). These fluctuations could affect cover as well as forage provided by herbaceous perennials such as desert globemallow (Jennings and Berry 2015).

The amount of alteration to vegetation increases with severity of disturbance and whether root systems of perennial plants remain intact (Prose et al. 1987; Scoles-Sciulla and DeFalco 2009; Webb et al. 2009a). After destruction of aboveground plant parts by off-road vehicles or low-severity wildfires, some perennial species (e.g., creosote bush) can resprout and resemble their former height within 5 y, depending on climatic conditions (Gibson et al. 2004). After wildfires, resprout frequency has varied among species and sites from 0% to near 100% (Abella 2009). Variation in resprouting can be a key influence to cover available for tortoises in postdisturbance environments because regeneration by seed of many shrubs such as creosote bush is infrequent (Esque et al. 2003; Drake et al. 2015).

Based on 30 studies of disturbance in the Mojave Desert, cover of perennial plants can reestablish to levels of nearby undisturbed areas within an average of 80 y (Abella 2010). Estimated time required for reestablishment of perennial cover varied among studies from 24 to 335 y. This variation correlated with plant community type, disturbance type and severity, site factors (e.g., soil parent material, grazing history), and weather following a disturbance (Engel and Abella 2011).

Much of the plant cover reestablishing after disturbance, however, consisted of different species than those before disturbance. Reestablishment of perennial species composition (species present and their relative abundance) was estimated to require decades to centuries after disturbance in the Mojave and Sonoran deserts (Abella 2010). These estimates assume that future conditions (e.g., climate, competition from nonnative plants) are conducive to native plant recovery. Many examples exist of town-sites and pipeline corridors cleared decades ago that remain dominated by species differing from nearby undisturbed areas (Webb et al. 2009a). The functional attributes of fertile islands, annual plant forage, and supply of large shrubs for tortoise burrows of the persistent, postdisturbance communities are poorly understood. Generally, many of the postdisturbance colonizers (e.g., desert globemallow, cheesebush *Hymenoclea salsola,* and desert trumpets *Eriogonum inflatum*) are smaller statured than those of mature shrublands and may therefore provide less protection to tortoises (Shryock et al. 2014).

Forage plants

Diet analyses and observations of foraging indicate that desert tortoises eat dozens of plant species but are selective foragers (Coombs 1979; Henen 2002; Esque et al. 2014; Jennings and Berry 2015). Diets change seasonally with variation in timing of emergence, growth, and senescence of different species of plants in spring and summer (Jennings 2002). Furthermore, juvenile and adult tortoises have access to different-sized plants (Morafka and Berry 2002).

Three sources of evidence suggest that forage quality and quantity have associations with desert tortoise

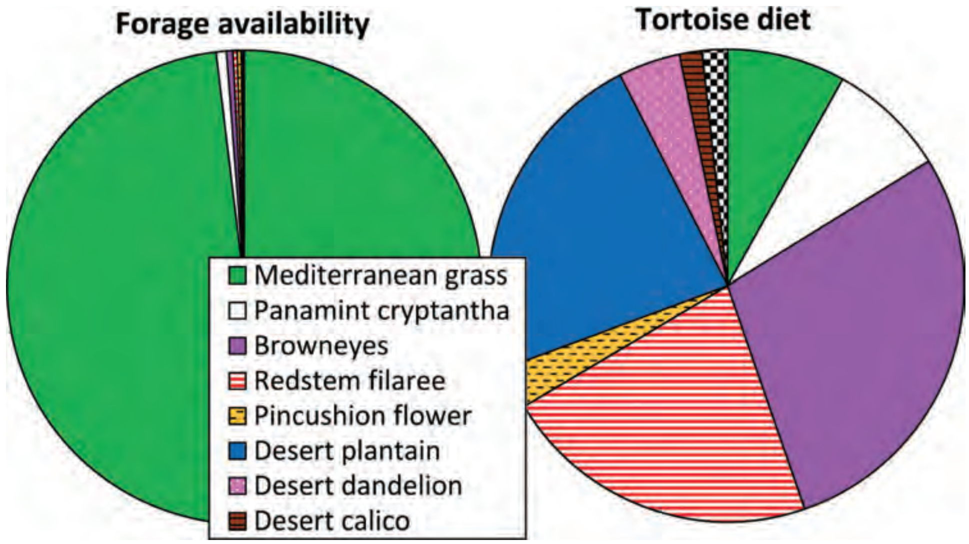

Figure 2. Availability of annual plant forage, relative to what juvenile desert tortoises *Gopherus agassizii* ate, in 1998, in an enclosure at the U.S. Army's Fort Irwin National Training Center, California. The nonnative annual Mediterranean grass dominated plant composition, but desert tortoises avoided eating them. Instead, desert tortoises preferentially ate native annual forbs, with browneyes and desert plantain constituting 52% of tortoise diets. Scientific names for species: Mediterranean grass *Schismus* spp., Panamint cryptantha *Cryptantha angustifolia,* browneyes *Camissonia claviformis,* redstem filaree *Erodium cicutarium,* pincushion flower *Chaenactis fremontii,* desert plantain *Plantago ovata,* desert dandelion *Malacothrix glabrata,* and desert calico *Loeseliastrum matthewsii*. Data from Oftedal et al. (2002).

demography: 1) links between plant productivity and health of individual tortoises, 2) experimental feeding trials, and 3) selective foraging displayed by tortoises. Between 1991 and 2011 in Joshua Tree National Park, desert tortoise survival was correlated with winter rainfall (Lovich et al. 2014). Winter rainfall in turn was correlated with biomass of native annual plants (Rao and Allen 2010) and densities of herbaceous perennial forage species such as desert globemallow (Miriti et al. 2007). At a drought-prone site in the eastern Mojave Desert, desert tortoise survival was only 33% during the 1990s (Longshore et al. 2003). High death rates corresponded with low production of annual plants and limited amounts of drinking water for tortoises in dry years (Nagy et al. 1997). In a long-term study in the northern Mojave Desert, growth of individual desert tortoises was positively correlated with annual plant production over 40 y between 1964 and 2003 (Medica et al. 2012).

Experimental feeding trials indicate that forage quality affects desert tortoise health (Barboza 1995; Nagy et al. 1998; Hazard et al. 2009, 2010). For example, Hazard et al. (2009) reported that captive, juvenile desert tortoises (0.5–1.5 y old) lost weight when fed senesced grasses low in nitrogen. In contrast, tortoises gained weight when fed the native forb desert dandelion *Malacothrix glabrata* or nonnative forb redstem filaree *Erodium cicutarium*. Similarly, in another experiment, adult desert tortoises gained weight when fed a protein- and nutrient-rich native perennial forb (desert globemallow), but lost weight when fed the nonnative grasses *Schismus* spp. (Barboza 1995). Barboza (1995) further noted the importance of a diverse "menu" of preferred food plants for long-term nutrient balances in desert tortoises.

When desert tortoises have a choice, they are selective foragers. Studies that compare what desert tortoises eat to what forage is available are rare, but two examples highlight selectivity. In a fenced enclosure in the central Mojave Desert, juvenile tortoises ate only 42 (0.02%) of the 239,000 individuals of the nonnative grasses *Schismus* spp. they encountered (Oftedal et al. 2002). In contrast, they ate 35% of 346 plants of the native forb desert plantain *Plantago ovata*. Other favored native annual forbs were desert dandelion, desert calico *Loeseliastrum matthewsii,* and browneyes *Camissonia claviformis* (Figure 2). In the particular collection of plant species analyzed, the nonfavored *Schismus* had low water and protein content, whereas the favored species were rich in water and protein (Oftedal et al. 2002).

The biochemical traits of plants thought to contribute to quality of forage for desert tortoises are similar to those for other herbivores and include water, nutrient, and fiber content and digestibility (Nagy et al. 1998; Oftedal et al. 2002; Hazard et al. 2010). Plant biochemistry fluctuates through time and across the landscape, because the chemical composition of plants varies among species, within a species during a year, and across soil types (El-Ghonemy et al. 1978; Chaffee and Berry 2006). Oftedal (2002) noted that desert tortoises are vulnerable to excess potassium, which is abundant in desert plants. Desert tortoises must excrete excess potassium to avoid toxic effects, but this requires that tortoises use water or gain sufficient nitrogen from other forage plants to excrete potassium as urates. If too much

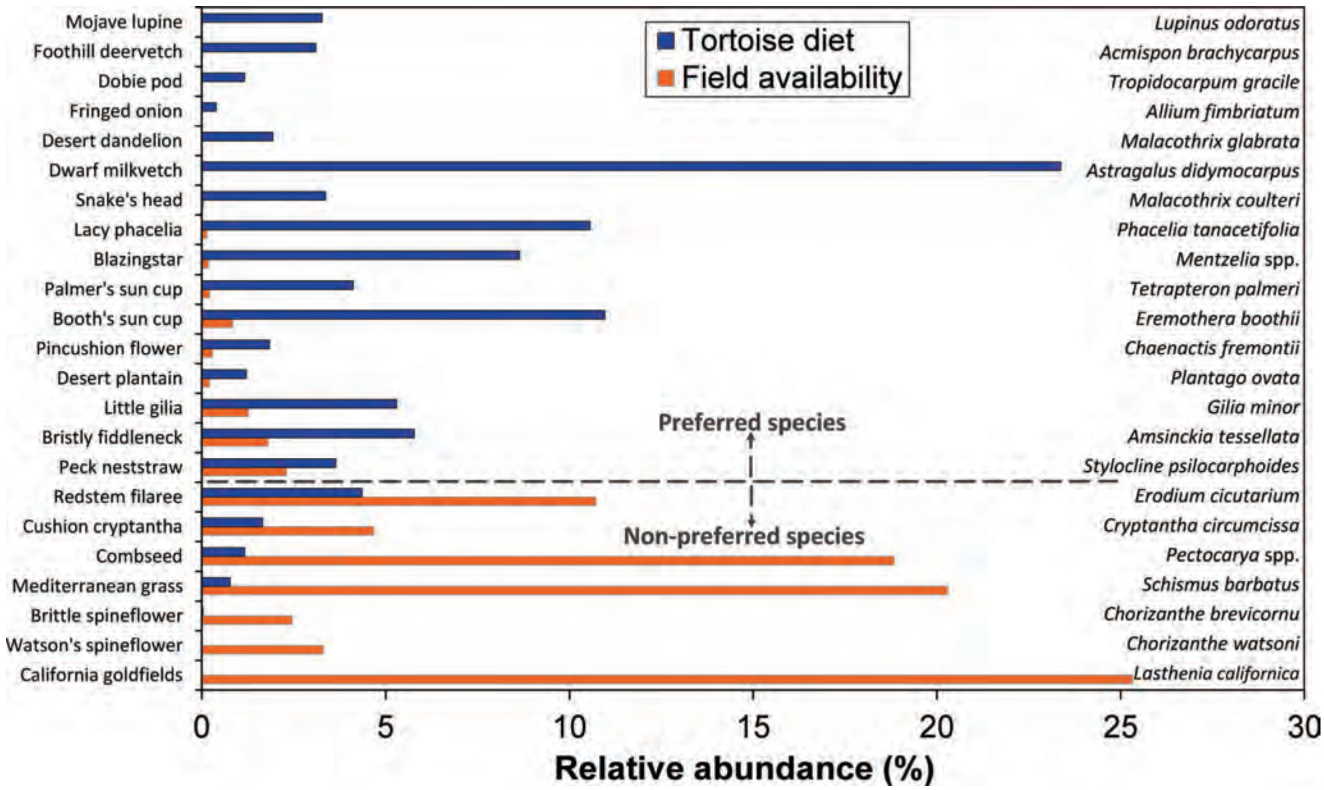

Figure 3. Comparison of availability of annual forage plants to what desert tortoises *Gopherus agassizii* ate, March and April 1992, at the Desert Tortoise Research Natural Area, California. Data from Jennings and Berry (2015).

nitrogen is required to excrete potassium, nitrogen may become limiting to tortoise growth. Oftedal et al. (2002) developed a potassium excretion potential (PEP) index that integrated potassium, water, and protein to indicate favorability of plant forage chemistry for desert tortoises to excrete potassium. Forage with high PEP was likely advantageous to tortoises compared with forage with low PEP. Plants consumed, but not preferred by tortoises (e.g., the nonnative grass *Schismus* spp.), had low PEP, whereas preferred species frequently had high PEP (e.g., plants of the Fabaceae family). Based on these biochemical traits along with field studies comparing food plant consumption to availability (Jennings and Fontenot 1992; Avery and Neibergs 1997; Oftedal et al. 2002; Jennings and Berry 2015) and feeding experiments (e.g., Barboza 1995; Hazard et al. 2009, 2010), desert tortoises favor legumes (family Fabaceae), mallows (family Malvaceae), evening primroses (family Onagraceae), and some species in the Asteraceae and Boraginaceae families. These studies further suggest that, in general, annual and herbaceous perennial forbs supply higher quality forage than nonnative annual grasses.

A study in the western Mojave Desert in southern California, at the Desert Tortoise Research Natural Area, highlighted temporal and spatial variability in tortoise foraging, which could be important to long-term tortoise behavior and nutrition balances (Jennings and Berry 2015). The authors reported seasonal variation in desert tortoise forage preferences from March to June; preferential foraging on certain herbaceous perennial forbs even though annuals were available; and that >75% of bites consumed were on a subset of 10% of the site's 80 annual and perennial species. Three herbaceous perennial forbs—desert wishbone-bush *Mirabilis laevis,* widow's milkvetch *Astragalus layneae,* and whitemargin sandmat *Chamaesyce albomarginata*—were rarely recorded in vegetation surveys but constituted significant components of desert tortoise diets. Some of the more preferred native annual forbs included Mojave lupine *Lupinus odoratus,* foothill deervetch *Acmispon brachycarpus,* dwarf milkvetch *Astragalus didymocarpus,* lacy phacelia *Phacelia tanacetifolia,* and desert dandelion (Figure 3). These favored foods were distributed unevenly within the habitat. Some favored plants were in ephemeral stream channels, and desert tortoises rarely passed by the plants without taking bites. Given how uncommon some preferred forage species are and that they also are eaten by animals other than tortoises, the possibility cannot be dismissed that availability of quality forage is a limiting factor for desert tortoise health.

Disturbance is another factor that can affect variability of annual plant forage. Effects of disturbance on annual plants appear contingent on effects to the perennial plant community and on weather conditions after disturbance, similar to temporal patterns in undisturbed desert (Abella 2010). There may be no response of annual forage plants to disturbance until a year of sufficient rainfall. Given sufficient rainfall, the cover and species richness of annual plants can attain levels found on undisturbed areas within 1–15 y after disturbance (Callison et al. 1985; Brooks and Matchett 2003; Vamstad and Rotenberry 2010). However, nonnative annual grasses—poor-quality forage for tortoises—often dominate the disturbed communities within a few years and are persistent (Callison et al. 1985; Brooks and Matchett 2003; Brooks and Berry 2006). In a study of annual plant recovery 36 y after construction of the Los Angeles Aqueduct in the western Mojave Desert, certain annual species (e.g., stiff-haired lotus *Acmispon strigosus*) known to be favored by desert tortoises had not colonized the disturbance corridor (Berry et al. 2015). These plants occurred in nearby undisturbed habitat.

Soil and topography, including the special case of roads

In addition to their effect on vegetation, soil and topography interact with desert tortoises in several ways. To create burrows, desert tortoises utilize calcic soils (caliche) in hillsides and banks of ephemeral stream channels by constructing or altering caves (Woodbury and Hardy 1948; Rautenstrauch et al. 2002; Mack et al. 2015). Burrows dug in fine sands easily collapse and do not persist (Wilson and Stager 1992). Compacted soils, including those compacted through human disturbance, are unsuitable as burrow sites because tortoises cannot dig in them. Likewise, soils contaminated with toxic wastes from mining, vehicular traffic, or other sources are unsuitable, because they can contribute to poor health of tortoises (Seltzer and Berry 2005; Jacobson et al. 2014; Kim et al. 2014). Soil type and fine-scale topography are also important for retaining rain water because tortoises drink from puddles or construct their own catchments in soil (Medica et al. 1980). Sites with slow water infiltration or depressions are likely most suitable for supplying drinking water (Henen et al. 1998).

Hazardous chemicals have been intentionally or inadvertently introduced into soils in a variety of desert tortoise habitats. In some cases, the contaminants are along roadsides from decades of vehicle traffic (e.g., leaded gasoline), and in other cases from historical mining (Chaffee and Berry 2006; Kim et al. 2014). Some contaminants are of recent origin, such as illegal dumping or drug operations. Toxic materials, whether airborne or in soil and plants, can accumulate in long-lived desert tortoises. Two examples from the western Mojave Desert illustrate potential effects. Desert tortoises ill and dying of upper respiratory disease at the Desert Tortoise Research Natural Area had 11 times the levels of mercury in their livers as did healthy tortoises from a control site (Jacobson et al. 2014). Near the Rand Mining District, elevated levels of arsenic occurred in tissues (lungs, scutes) of necropsied tortoises (Seltzer and Berry 2005). The probable sources were mining wastes and soils disturbed by mining activities and exacerbated through off-road vehicle activities. Mining wastes with mercury and arsenic from the Rand Mining District have moved tens of kilometers via transport in dust and flowing water (Chaffee and Berry 2006; Kim et al. 2012).

An important consideration in developing restoration plans is the composition of plant species existing in soil seed banks, the effects of past human activities on seed banks, and whether seed banks have been swamped by nonnative annual plants. Do adequate seeds of forage plants preferred by tortoises remain in the soil and can the seed banks support recovery of desert tortoise populations? With the arrival of settlers from the New World in the 1700s to the Southwest, native vegetation has experienced waves of impacts from human uses and the introduction of nonnative annual plants (Minnich 2008). Although we are aware of above-ground changes in cover, composition, and biomass of annual vegetation and how quickly nonnatives have become dominant (e.g., Brooks and Berry 2006; Berry et al. 2014a), we know less about the composition of soil seed banks in different desert regions and whether different types of human activities (e.g., livestock grazing, military maneuvers, off-road vehicle use) have reduced seed banks of forage plants favored by desert tortoises. Although information is limited for desert tortoise habitats, some studies illustrate effects of disturbance on soil seed banks. Brooks (1995), in a study of the benefits of protective fencing at the Desert Tortoise Research Natural Area, reported that biomass of seeds was more than twice as high inside the fence than outside. Habitat inside the fence was protected from sheep grazing and off-road vehicle use for 12–13 y. In a study in the central Mojave Desert on lands degraded by military maneuvers, DeFalco et al. (2009) found that densities of annual plant seeds in compacted soils were 33% less than on control sites. Fire temperatures during desert wildfires can alter survival of seeds (Brooks 2002) and granivores and ants can play a role in seed availability too (Suazo et al. 2013).

Roads are a special case of human alterations to soils, topography, vegetation, and wildlife not only in deserts but elsewhere (Forman et al. 2003; Brooks and Lair 2009; Vogel and Hughson 2009). Roads fragment desert tortoise habitat and can result in the deaths or losses of tortoises from collisions with vehicles, collection by visitors, and predation by predators that feed on road kills or animals crossing roads (von Seckendorff Hoff and Marlow 2002; Boarman and Sazaki 2006; Kristan and Boarman 2007; Hughson and Darby 2013; Nafus et al. 2013). The common raven is an example of a predator subsidized in part by roads and perch sites often found adjacent to roads (e.g., utility corridors; Boarman and Coe 2002). Roads, whether as highways or in the backcountry, also alter the hydrological function of desert ecosystems by changing sheet flow and water movement in drainages (Schlesinger and Jones 1984; Brooks and Lair 2009). Hydrological connectivity is often severed; instead of water flowing across soil surfaces or through multiple channels, water is diverted down the compacted surfaces of roads or through culverts into a

Table 1. Summary of three aims (in bold) for enhancing vegetation and soil habitat conditions for the desert tortoise *Gopherus agassizii* in contemporary environments of the Mojave and western Sonoran Desert. Main management actions and best practices for them are summarized below each aim.

Aims, actions, and best practices
Restore or augment perennial plants as cover or forage
Action 1: Outplanting
Carefully select species
Use good planting stock
Perform effective plant care
Action 2: Seeding
Make controllable factors favorable
Match seed treatments to species
Develop backup plans for seeding failures
Improve forage quality and quantity
Action 1: Reduce nonnative plants
Focus on comprehensively treating damaging, widespread invaders
Detect and remove new invaders early
Implement preventive measures from invasive plant science
Action 2: Manage herbivory by nonnative animals on tortoise forage plants
Monitor changes in habitats after reducing nonnative animals
Strategically deploy exclosures
Action 3: Augment native forage plants
Experimentally test forage augmentation strategies
Compare forage augmentation with other candidate actions
Restore or conserve soil health
Action 1: Salvage topsoil if large soil disturbances are planned
Carefully plan salvage operations
Carefully store soil to maximize biotic retention
Action 2: Evaluate and remediate soil potentially toxic to tortoises
Assess potential for toxic soils
Avoid or remediate toxic soils before conducting other habitat activities
Action 3: Decommission certain backcountry roads
Ameliorate topographic and soil surface alterations
Limit postrestoration vehicle incursions

few channels (Hereford 2009). This can affect the productivity of plants downstream, which is an important consideration for the desert tortoise because plants growing in small washes are important food sources (Jennings and Berry 2015).

Roads have long been implicated in contributing to the invasion and spread of nonnative plants (Frenkel 1977). Brooks and Berry (2006), in a study of nonnative annual plants in desert tortoise critical habitat, reported that density of dirt roads was correlated with abundance of nonnatives. A paved highway appeared to be the source of the invasion of another noxious, nonnative species, Sahara mustard *Brassica tournefortii* in at least one valley within desert tortoise critical habitat in the western Sonoran Desert (Berry et al. 2014a). The highway intersected a major wash, and Sahara mustard likely further spread into the desert from that source. Roads are not always correlated with the distribution of nonnative plants, especially for invasive plants already occupying most of the landscape, but they are probable entry points (Craig et al. 2010).

Habitat Management Aims, Actions, and Practices

Using the systematic literature review and our experiences, we organized actions and best practices aimed at conserving and enhancing three key elements of desert tortoise habitats: cover sites, forage, and soil (Table 1). Elements of a comprehensive, systematic approach to employing these best practices would include conducting site assessments to evaluate probable factors limiting habitat quality to guide the aims of management actions; identifying the most feasible actions with the greatest chance of success for enhancing habitat quality; and monitoring outcomes of actions to inform future projects. In the sections below, we discuss the three broad aims (improving cover, forage quality, and soil health), management actions for accomplishing each aim, and best practices for implementing each action.

Restore or augment perennial plants as cover or forage

Restoring or augmenting abundance and diversity of perennial plants can enhance protective cover and forage (in the case of herbaceous perennials) for desert tortoises. Planting nursery-grown perennials (outplanting) and seeding are the two main methods for revegetating severely disturbed soil (Bainbridge 2007). In the Mojave Desert, outplanting is more reliable than seeding for establishing perennial plants any given year (Abella et al. 2012b). Outplanting has achieved a relatively long-term ($\geq$2 y) survival of $\geq$50% for a variety of perennial species when using good planting stock and proper plant care (Abella and Newton 2009; Weigand and Rodgers 2009; Scoles-Sciulla et al. 2014). For establishing perennial plants, we discuss the actions of

Table 2. Summary of the best-performing perennial species outplanted as nursery-grown plants at revegetation sites in ≥3 studies reported in the literature in the Mojave Desert (Figure 1). Survival was monitored for ≥1 y after outplanting during studies published between 1978 and 2014. The species in the table are medium- to large-sized shrubs that provide cover or burrow sites to desert tortoises *Gopherus agassizii*.

Common name	Scientific name	Total no. of studies	No. of studies with ≥50% survival[a]
White bursage	*Ambrosia dumosa*	10	5
Fourwing saltbush	*Atriplex canescens*	5	4
Nevada jointfir	*Ephedra nevadensis*	3	3
Creosote bush	*Larrea tridentata*	8	5
Anderson thornscrub	*Lycium andersonii*	3	2

[a] In at least one treatment, with treatments including irrigation, fencing to deter herbivory, and others. Data synthesized from Abella and Newton (2009), Abella et al. (2012b), Scoles-Sciulla et al. (2014), and Weigand and Rodgers (2009).

outplanting and seeding, and three best practices for each.

Action 1: Outplanting. Because of cost and logistical challenges, outplanting can be criticized for being unable to cover as much area as seeding. However, no matter how large an area is seeded, the area revegetated is still zero if no seeded species become established, a situation not uncommon (Bainbridge 2007). Furthermore, >50% of surviving outplants have flowered and produced seed within 3 y in some projects, potentially expanding the area revegetated (Abella et al. 2012b). Given that outplanted shrubs can rapidly grow to heights of 40–50 cm within 3 y—reestablishing shaded microsites important to natural plant recruitment—it is possible that outplanting can also stimulate natural plant establishment. Therefore, a management goal using outplanting could be strategically establishing patches of native plants for stimulating recovery within the larger landscape. There are three main best practices well-supported in the literature for increasing success of outplanting: carefully select species, use good planting stock, and perform effective plant care.

1) *Carefully select species*. Species selection is critical to outplanting success because survival and ecological functions of perennial plants differ among species. Also, treatments required for plants to survive vary among species and can affect project costs and logistics. Of 45 native perennial species outplanted in the Mojave Desert, 64% have achieved ≥50% survival in at least one study (Abella and Newton 2009; Abella et al. 2012b; Scoles-Sciulla et al. 2014). Examples of the best-performing species outplanted in three or more studies are in Table 2, including shrubs beneath which desert tortoises construct burrows (Burge 1978; Berry and Turner 1986; Baxter 1988). Generally, large shrubs (e.g., creosote bush) have performed well in outplanting, forbs have performed moderately well, and grasses have struggled. Lowered overall survival in a project may be worth the benefit of diversifying plantings, by including species that do not necessarily survive at high rates but that provide important functions. Even some difficult-to-establish forbs and grasses can still achieve 10–25% survival. In an example of different functions provided by species, some native perennial species (e.g., desert globemallow) exist that can competitively reduce nonnative annuals, or at least become established on sites infested by nonnative annuals (Abella et al. 2011, 2012a). In an example of how species selection affects treatments required, planted cacti have not needed irrigation; whereas, irrigation has doubled survival of white bursage, desert globemallow, and other species (Abella et al. 2015b). The ability of cacti to become established without treatments could be important, because Medica et al. (1982) found that cacti formed >50% of tortoise diets in a dry year. Examining outplanting success and treatments required for little-studied genera, such as *Mirabilis,* that provide important herbaceous perennial forage (Jennings and Berry 2015) could increase the number of tortoise forage species available for outplanting.
2) *Use good planting stock*. Good planting stock can underpin the success of entire projects and requires advance planning. Preparing outplants typically entails ≥6–12 mo of care in nurseries to grow root systems sufficient to provide the best chance of survival in the field (Bainbridge 2007). Plants that are unhealthy leaving the greenhouse often have reduced chance of field survival.
3) *Perform effective plant care*. Treatments to enhance survival after planting at restoration sites are essential for most species. Protection from grazing by small mammals and larger herbivores can be even more important than irrigation (Scoles-Sciulla et al. 2014). It is not uncommon for outplants without protection from grazing to be all or mostly gone from restoration sites within days. An unprotected planting of 100 individuals was killed by animals in <4 h (S.R. Abella, unpublished data). This undesirable herbivory may result from outplants being nutrient-enriched from their nursery propagation (Bainbridge 2007). Enclosing plants in cages or shelters can deter herbivory and increase survival and growth (Figure 4).

Irrigation has enhanced survival in certain studies, potentially making it worth the added cost (Wallace et al. 1980). Species can respond differently to the type of irrigation. For instance, watering by hand improved survival of desert globemallow, whereas a slow-release irrigation gel did not (Abella et al. 2015b). Survival of white bursage increased with both irrigation types. It is also noteworthy that plantings on sites receiving salvaged topsoil had twice the survival of plantings on nontopsoil areas, possibly because organic matter in the salvaged topsoil retained water for gradual extraction by plants (Abella et al. 2015b).

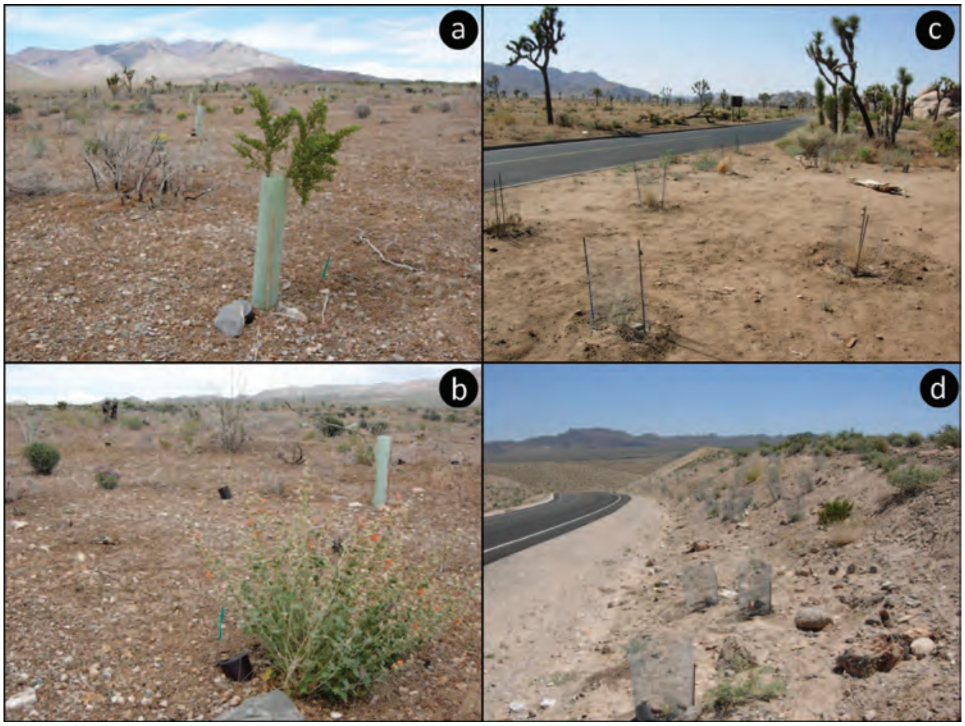

Figure 4. Examples of outplanting and care of perennial plants to revegetate disturbed habitat in the Mojave Desert. The left photos are on the 2005 Goodsprings Fire, southern Nevada, and show **(a)** an outplanted creosote bush *Larrea tridentata* protected by a shelter in the foreground, and **(b)** an outplanted desert globemallow *Sphaeralcea ambigua,* affixed with DriWater as a slow-release irrigation. Wire cages protect outplants from herbivory in roadside revegetation in **(c)** Joshua Tree National Park, California, in 2008, and **(d)** Lake Mead National Recreation Area, Nevada, in 2011. Photos by S.R. Abella.

Other treatments to enhance survival of outplants have not been extensively studied or are not necessarily recommended. Many desert species have relationships with mycorrhizae (Titus et al. 2002), but it is unclear how limiting mycorrhizae are after disturbance. Fertilizing plants in the field has not been recommended because it has not increased survival (Scoles-Sciulla et al. 2014), and augmenting soil fertility raises concerns about nonnative plant growth (Rao et al. 2010). Although nonnative annuals can compete with perennial plants (Rodríguez-Buriticá and Miriti 2009), treating nonnative plants with herbicide did not increase survival of perennial outplants in one study (Scoles-Sciulla et al. 2014).

Action 2: Seeding. Although seeding is risky during any year, it has enhanced establishment of native perennials in some projects. Short-term successes were reported in the 1970s, which was a wet decade, but it was frequently unclear how persistent seedlings were after 1–2-y, short-term studies (Abella and Newton 2009). More recently, some seeded plant establishment occurred during a 14-y monitoring period on a mine restoration site in the northeastern Mojave Desert, but the extent to which seeding improved upon natural plant establishment was uncertain (Ott et al. 2011). Another recent project resulted in no plant establishment over 3 y, despite protecting seeds from mammalian granivory and providing irrigation (Abella et al. 2012b). We emphasize three best practices for seeding in contemporary environments: make controllable factors favorable, match seed treatments to species, and have backup plans for seeding failures.

1) *Make controllable factors favorable.* Managers cannot control the weather and may also have little flexibility for attempting to time seeding with years of favorable weather because of logistical challenges, difficulty of obtaining seed, and deterioration of stored seed. Managers can control, to some extent, the quality and species of seed used, the locations for seeding, and conditions of sites receiving seed. A synthesis published in the 1970s of the phenological timing of perennial species for seed collection, seed storage procedures, and germination requirements is still among the most comprehensive reviews for optimizing seed germination in the Mojave Desert (Kay et al. 1977). Ideally, both viability and germination assays should be performed on seed lots prior to seeding. In some seeding failures, it was unclear whether seeds placed in the field were even viable (Abella and Newton 2009).

   Owing to the usual limitation of availability of native plant seed and to the potential influence of seed source on project outcomes, the question of whether to use locally collected seed (and if so, how local) is commonly raised for desert restoration projects. This issue is unresolved and the subject of ongoing research, because combined genetics and plant performance analyses are required to determine how successful particular seed sources are in different present and anticipated future environments. Given extensive evidence for local adaptation of plants, the current consensus is that seeds for restoration projects should be collected as locally as possible, unless there are specific reasons to expect that genotypes from elsewhere or other environmental site types will perform better (Johnson et al. 2010). In an example of site-type adaptation in the Mojave Desert, Shryock et al. (2015) identified genetic differentiation in desert globemallow populations along environmental gradients of water stress and temperature seasonality.

Certain sites may be more amenable to seeding than others, and conducting preliminary trials across sites is a good strategy for identifying potentially favorable locations for seeding projects (Grantz et al. 1998). If soils are degraded (e.g., erosion-affected soils), ameliorating site conditions should occur before attempting seeding. For example, roughening soil surfaces or using tackifiers to enhance soil and seed retention has potential for building soil seed banks and promoting plant establishment (DeFalco et al. 2012).

2) *Match seed treatments to species.* An important decision is whether to pretreat seeds, such as applying germination stimulants or protective coatings, because these treatments can increase project costs while sometimes being counterproductive. In a short-term project (4 mo) in the Mojave Desert, seeding bare seed resulted in 22% seedling emergence of blackbrush, whereas only 5% emergence occurred from pelletized seed (Jones et al. 2014). Seeding pelletized seed of three shrubs facilitated short-term seedling establishment (within 1 y) in another study, but the seedlings died by the second year (Abella et al. 2015a). Desert seeding projects should include preliminary assays to identify whether seed treatments are beneficial. Moreover, managers could consider "hedging bets," such as by pretreating or pelletizing a portion of seed and not treating the rest of seed.

Similarly, several options exist for treating seeds after they have been seeded on field sites or timing seeding to coincide with optimal conditions. However, effectiveness of these variations has been mixed. Irrigation has increased short-term seedling establishment in some studies but not in others, regardless of natural rainfall (Winkel et al. 1995; Grantz et al. 1998). Soil surface treatments, such as applying mulches, may only be applicable to localized areas (e.g., compacted soils) and have not consistently improved seeding success (Grantz et al. 1998). Abundant seed can be moved around or off site by mammals and invertebrates within days to weeks after seeding (DeFalco et al. 2012). Seed movement by animals does not preclude seedling establishment if some seeds escape predation and are deposited in microsites favorable for germination. Loss of seed has, however, resulted in suggestions to 1) minimize time that seeds reside on the ground before conditions conducive to germination occur, or 2) time seeding to correspond with nonpeak activity of granivores (Suazo et al. 2013). To minimize the time that dormant seeds are exposed to predation, seeds of some species can be pretreated to speed germination (Ostler et al. 2003). Although still no guarantee of success, if seeding can be timed to correspond with wet years and reduce time to germination, it may facilitate at least short-term plant establishment (Grantz et al. 1998; Ott et al. 2011).

3) *Have backup plans for seeding failures.* Even when best known practices for seeding are implemented, seeding may not be successful because of granivory, lack of germination cues, dry weather, or other factors (Bainbridge 2007). As a result, a precautionary approach would include pairing seeding with other actions for enhancing plant cover. For example, combining seeding with outplanting warrants consideration. This approach was already successful for one postburn restoration project: seeding failed completely, but outplanting successfully produced patches of perennial plants that generated their own seed within 3 y (Abella et al. 2012b).

Improve forage quality and quantity

Composition of the annual plant community across the range of the desert tortoise has changed drastically over the past century, with a major increase in nonnative species (Brooks and Esque 2002; Brooks and Berry 2006; Averill-Murray et al. 2012). Nonnative annual grasses are some of the chief increasers and, unfortunately for tortoises, these grasses provide lower quality forage than many native forbs (Oftedal et al. 2002; Medica and Eckert 2007; Hazard et al. 2009; Jennings and Berry 2015). Returning the annual plant community to primarily natives could improve forage for desert tortoises while also reducing chance of nonnative-grass-fueled fires that kill shrubs used by tortoises for cover. Additionally, protecting shrubs from fires maintains fertile islands as locations for recruitment of a diverse native annual plant community (Abella and Smith 2013) potentially important for balanced nutrition of desert tortoises. We evaluated three main actions for favorably changing forage quality and quantity provided to tortoises by the annual plant community: 1) reduce nonnative plants, 2) manage herbivory by nonnative animals on tortoise forage plants, and 3) augment native forage plants.

Action 1: Reduce nonnative plants. There are two priorities for decreasing potential impacts of nonnative plants: reducing abundance of nonnative plants already dominant across the geographic range of the desert tortoise; and limiting the establishment of new nonnative plants. Three main best practices are suggested for reducing nonnative plants in desert tortoise habitat: focus on comprehensively treating damaging, widespread invaders; detect and remove new invaders early; and implement preventive measures from invasive plant science.

1) *Focus on comprehensively treating damaging, widespread invaders.* Treatment of nonnative annual grasses is strongly supported from our synthesis because of their undesirability as desert tortoise forage and their potential to facilitate fire disturbance across large areas, in turn, creating opportunities for invasion by other nonnative plants (Brooks and Esque 2002). Other widespread invaders in desert tortoise habitat are the nonnative annual forbs redstem filaree and Sahara mustard. Although redstem filaree provides some forage value (Hazard et al. 2010), a concern with this species is that it forms monocultures that may exclude a diversity of native annuals nutritionally important to tortoises (Steers and Allen 2010; Jennings and Berry 2015). Sahara mustard has invaded desert tortoise critical habitats and often forms dense stands (Berry et al. 2014a). Sahara mustard is not a good food plant and contains oxalates, which are likely harmful to tortoise health (Jacobson et al. 2009). Nonnative grasses are the top priority for control at this time, followed by Sahara mustard, redstem filaree, and other invaders that form low-diversity stands or provide poor forage.

   When nonnative annuals are reduced, native annuals have generally responded positively. For example, Brooks (2000) found that thinning *Schismus* via cutting doubled density of native annuals in a wet year. Some of the increasing natives were bristly fiddleneck *Amsinckia tessellata* and other species that Jennings and Berry (2015) identified as forage favored by desert tortoises. Native annuals also remained green 2 wk later in spring on *Schismus*-thinned plots, which could allow tortoises to forage longer (Brooks 2000).

   Carefully timed herbicide applications have reduced nonnative plants while increasing native annuals. On a burned site in the western Mojave Desert, Steers and Allen (2010) found that applying the postemergent herbicide Fusilade early in the growing season reduced nonnative grasses as well as the forb redstem filaree. Species richness and cover of native annuals were up to three times greater in treated compared with untreated areas. Glyphosate and some other herbicides were effective in reducing or eliminating germination of Sahara mustard (Abella et al. 2013). Effects of herbicide on the desert tortoise are unclear, but early timed herbicide applications—to exploit the accelerated phenology of nonnative compared with native species (Marushia et al. 2010)—could generally occur when tortoises are inactive (Esque et al. 2014). For example, Steers and Allen (2010) applied herbicide in January. Adult tortoises remain in underground burrows until at least mid-February in some years (Burge 1977; Rautenstrauch et al. 1998), although juveniles may be active from November through February when local temperatures are warm (Wilson et al. 1999). The California Invasive Plant Council (2015) published best-management practices to reduce nontarget effects of herbicides to animals while controlling nonnative plants damaging to wildlife populations, which may be useful in desert tortoise habitats. Potential negatives of nonnative plant treatments must be balanced against the positives of curtailing deterioration of tortoise habitats by nonnative plants.

2) *Detect and remove new invaders early.* A central tenet of invasive species science is that the early detection and removal of new invaders is cheaper and more effective than managing established infestations (Davis 2009). Surveying for incipient populations of nonnative plants along roadsides is a best practice, because roads can be entry points for nonnative plants (Brooks 2009; Berry et al. 2014a). An early detection program surveyed 3,300 km of roads between 2009 and 2011 in the eastern Mojave Desert, including in desert tortoise habitat, and removed >37,000 nonnative plants (Abella et al. 2009). Prioritizing surveys in wet years may enhance detection of species and maximize benefit from limited resources for surveys and treatments. Roads should be incorporated into broader landscape strategies for nonnative plant management because many firmly established nonnative plants are not, or at least are no longer, distributed only along roadsides (Craig et al. 2010). Thus, restricting surveys only to roadsides may provide a misleading impression of the distribution of nonnative plants, because desert washes, old disturbances, and areas of seemingly undisturbed desert should also be part of detection programs. Washes in particular facilitate the spread of Sahara mustard (Berry et al. 2014a).

3) *Implement preventive measures from invasive plant science.* A concern is that desert tortoise habitats have already been invaded by several species of nonnative plants and the potential exists for transport of new invasive plants by ongoing or proposed human activities, such as renewable energy development near, or adjacent to, critical habitats (Hernandez et al. 2014). It is prudent to view desert tortoise habitats as susceptible to new invaders in the future, in addition to ongoing expansion of incipient populations of species such as Sahara mustard not yet as widespread as nonnative grasses (Berry et al. 2014a). Many best-management practices developed in invasive plant science are applicable to help forestall further invasion of desert tortoise habitats by nonnative plants (Abella 2014). For example, Lake Mead National Recreation Area, including tortoise habitat in the eastern Mojave Desert, recently developed a nonnative plant management plan detailing practices such

as cleaning vehicles to remove seeds (National Park Service 2010). Desert tortoise recovery areas may benefit from the development of similar long-term, nonnative plant management plans.

Action 2: Manage herbivory by nonnative animals on tortoise forage plants. In addition to potential for nonnative animals to affect perennial plant cover and soil in desert tortoise habitats (Webb and Stielstra 1979; Brooks et al. 2006), there may be similarity in forage consumed by nonnative animals and desert tortoises, which is important for understanding contemporary vegetation condition. Early studies comparing food habits of desert tortoises with domestic livestock and feral burros were frequently based on analysis of scats (e.g., Hansen and Martin 1973; Hansen et al. 1976; Coombs 1979; Medica et al. 1982). These studies indicated similarities in diets among tortoises, cattle, and feral burros, with overlap mainly in the grass component. This component is the one most accurately characterized by scat analysis because fibrous material from grasses is less digestible than forbs and passes through the gastrointestinal tract in greater bulk (e.g., Barboza 1995). To more thoroughly characterize diet similarity, scientists began making direct observations of tortoises foraging and counted bites consumed (Jennings and Fontenot 1992; Jennings 2002; Oftedal 2002; Oftedal et al. 2002; Jennings and Berry 2015). Through these studies, it became apparent that forbs were the major and important part of desert tortoise diets. Native forbs were also heavily utilized by nonnative animals. In seven studies across the Mojave Desert, the native annual desert plantain comprised the greatest percentage (11%) of feral burro diets (Abella 2008). Based on bite counts of juvenile desert tortoises, this forb also formed 23% of tortoise diets in the central Mojave Desert (Oftedal et al. 2002). Other forbs preferred by tortoises in at least one study (Jennings and Berry 2015), such as desert wishbone-bush, are also eaten by burros (Abella 2008). Bite counts in the Ivanpah Valley during the 1990s revealed that both cattle and tortoises consumed native annual forbs such as desert dandelion (Avery and Neibergs 1997). Similarly, domestic sheep utilized desert dandelion in a western Mojave Desert allotment (Nicholson and Humphreys 1981).

On landscapes where enhancing forage conditions for desert tortoises is a goal, a conservative approach is ensuring that tortoises do not have to alter their preferred foraging activities because nonnative animals are present (Oldemeyer 1994). This consideration partly led to the first recovery plan for the desert tortoise recommending that grazing of domestic livestock and feral horses and burros be prohibited in Desert Wildlife Management Areas, which generally became designated tortoise critical habitat units (USFWS 1994). By 2009, livestock grazing had been eliminated from 53% of 13,000 km^2 of allotments in tortoise critical habitat (USFWS 2011). Decommissioning livestock allotments remains ongoing in certain areas, though some decommissioned allotments still contain abundant feral horses and burros (Ostermann-Kelm et al. 2009). We suggest two main best practices for nonnative animals in desert tortoise habitat within the context of forage and recovery plan directives for allotment decommissioning: monitor changes in habitats after reducing nonnative animals and strategically deploy exclosures.

1) *Monitor changes in habitats after reducing nonnative animals.* Little monitoring or research has been conducted during the past 20 y to identify transitions within plant communities of desert tortoise habitats following allotment decommissioning or to compare with areas still containing livestock or feral animals. Before/after or grazed/ungrazed comparisons deserve more attention to understand if or when preferred forage plants recover or whether additional actions are needed. It should also be considered that many desert tortoise habitats were grazed by livestock and feral animals for more than a century, which could leave legacies persistent long after the animals are removed (McKnight 1958; Beever 2013; Abella 2015). A possible legacy warranting evaluation is the long-term depletion of soil seed banks of native annual and herbaceous perennial plants preferred by desert tortoises (Minnich 2008). The possibility cannot presently be dismissed that forage plants favored by tortoises remain "missing," or at low abundance, even within areas now protected from herbivory by nonnative animals. Two management implications of this uncertainty are that 1) restoration seed mixtures in priority tortoise habitats could liberally include preferred forage plants, regardless of the prerestoration presence or absence of these plants at contemporary restoration sites (while still ensuring matching species to sites where they are adapted to grow); and 2) monitoring changes in forage composition and foraging activities by tortoises after removing nonnative animals remains an important best practice that should be employed more frequently than it has been.
2) *Strategically deploy exclosures.* When high densities of nonnative animals persist within desert tortoise habitats, strategically excluding the animals from certain areas may benefit vegetation conditions for tortoises. During 3 y in the northwestern Mojave Desert, native perennial grasses were 3–9 times denser inside exclosures compared with areas outside and open to feral burros (Abella 2008). After the Desert Tortoise Research Natural Area had been fenced for 12 y (excluding large herbivores and other disturbances), perennial plant cover was twice as high inside the fence compared with outside (Brooks 1995). Furthermore, the amount and quality of annual plant forage was greater inside the fence (Figure 5).

Action 3: Augment native forage plants. Most efforts aimed at improving forage conditions for the desert tortoise are indirect, such as removing nonnative plants

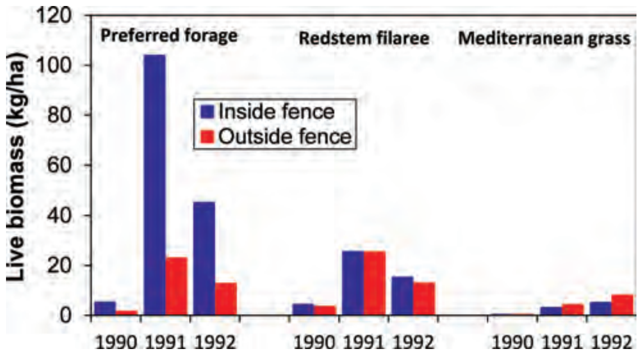

Figure 5. Comparison of the abundance of native annual forage plants with the nonnative redstem filaree *Erodium cicutarium* and Mediterranean grass *Schismus barbatus* inside and outside of fences, among 3 y, in the Desert Tortoise Research Natural Area, California. Data from Brooks (1995).

or livestock, under the assumption that forage plants will then increase naturally. Actively increasing forage plants is another option, but because research is limited to one study that showed potential (Abella et al. 2015a), the best current strategies are implementing further research and adaptive management trials. We suggest two practices: experimentally test forage augmentation strategies, and compare forage augmentation with other candidate actions.

1) *Experimentally test forage augmentation strategies.* A study at the desert tortoise Large-Scale Translocation Site in southern Nevada illustrated that actively augmenting abundance of a native annual forb—desert plantain—preferred by tortoises was feasible when effective treatments were identified (Abella et al. 2015a). Seeding bare seed without protective fencing resulted in minimal plant establishment. However, fencing and using pelletized seed produced six times the density of desert plantain relative to unseeded, unfenced controls. The seeding was followed by 2 y of average rainfall, and the one-time seeding augmented abundance of desert plantain for both years. The study showed that 0.25-ha patches of augmented forage could be established across the landscape, but it also showed that an iterative process was essential for identifying successful treatment combinations.
2) *Compare forage augmentation with other candidate actions.* The costs and benefits of actively augmenting forage remain unclear compared with other candidate actions such as treating nonnative plants or installing exclosures. For example, simply erecting fencing doubled the abundance of desert plantain in the study by Abella et al. (2015a). Yet to be tested is how fencing plus treating nonnative plants compares with the fencing plus seeding treatment. Identifying the cost- and ecological-effectiveness of a range of strategies for enhancing tortoise forage quality should be a priority.

Restore or conserve soil health

Different types of anthropogenic disturbances vary in their immediate and longer term effects on soil and vegetation. On certain soil types, such as desert pavements, even single passes of off-road vehicles leave visible scars of altered soil properties for decades (Adams et al. 1982; Belnap and Warren 2002). On nonpavement soils, several studies involving experimentally driving vehicles over soil have shown increased soil compaction, reduced water infiltration, and increased erosion compared with areas without off-road vehicles (e.g., Eckert et al. 1979; Adams et al. 1982; Webb 1982). Wildfires also can influence soil, with variable effects on different properties such as pH and total and available nutrient contents (Allen et al. 2011). Fires can increase concentrations of soil organic carbon and total nitrogen, likely by partly converting plant material to soil organic matter (Abella and Engel 2013). Elevated soil-nutrient status is not necessarily good for native ecosystems if nonnative plants usurp the additional resources (Allen et al. 2011). Wildfires also can change the structure of fertile islands, by reducing their size and killing the seeds they store (Esque et al. 2010). Severe soil disturbances—those that clear the surface layer of soil through blading or other means—can remove nutrients, biological soil crusts, and soil seed banks (Nishita and Haug 1973; Belnap and Warren 2002; Williams et al. 2013). Guo et al. (1998) reported that 97% of the viable soil seed bank was in the upper 2 cm of soil at a northern Mojave Desert site. By removing upper soil layers, land-clearing disturbances also reduce available rooting depth, which can decrease the size and productivity of perennial plants, affecting cover for desert tortoises (Bedford et al. 2009). In addition to best practices discussed in earlier sections for restoring native plant cover and reducing nonnative plant fuels to protect soils, the literature has emphasized three main actions for conserving or restoring soil health in desert tortoise habitats: 1) salvage topsoil if large soil disturbances are planned, 2) evaluate and remediate soil potentially toxic to tortoises, and 3) decommission certain backcountry roads for habitat enhancement.

Action 1: Salvage topsoil if large soil disturbances are planned. Soil formation is in constant flux, with some desert soils requiring millions of years to develop (McDonald et al. 1995). Topsoil salvage is among the most cost-effective strategies for initiating recovery on severe disturbances (Allen 1995). Salvaging and reapplying topsoil can accelerate plant colonization after disturbance because topsoil contains much of the soil organic matter, biological soil crust organisms (cyanobacteria, algae, lichens, and mosses), soil microbiota, and seed bank (Wallace et al. 1980). For example, survival of perennial plant species doubled when planted on Mojave Desert sites receiving topsoil, which was a benefit nearly equal to irrigating plants (Abella et al. 2015b). We emphasize two critical practices for effective topsoil salvage: carefully plan salvage operations, and carefully store soil to maximize biotic retention.

1) *Carefully plan salvage operations.* Several studies of salvaging desert soils have highlighted the importance of proper salvage procedures to avoid negating the benefits of salvage (e.g., Ghose 2001; Scoles-Sciulla and DeFalco 2009; Abella et al. 2015b). Present knowledge suggests that ideal salvage procedures for Mojave Desert soils include: 1) avoiding areas infested by nonnative plants or soil contaminants; 2) consistently salvaging the upper 5–10 cm; and 3) timing salvage to occur in summer from June through September (and later into autumn if it is a dry year) to capture winter annual seeds dispersed the previous spring, but before seedlings emerge in autumn–winter. Owing to concentration of live material in the upper 5–10 cm of desert soils, salvaging this depth as consistently as possible is important to avoid "diluting" the biota-rich layer with subsoil. For example, Scoles-Sciulla and DeFalco (2009) found that germinable seed density was reduced by 86% for the upper 4 cm of soil (the most important for seedling emergence) when salvaging the upper 30 cm of soil. Further research could examine benefits of strategically salvaging "fertile island" soil below the canopy driplines of shrubs to increase efficiency of nutrient and seed capture, thereby reducing space required to store soil (Abella et al. 2015b). Salvaging some interspace soil would also be wise to ensure capture of seeds of annual plants primarily growing in the open (Guo et al. 1998).
2) *Carefully store soil to maximize biotic retention.* Topsoil should be stored as briefly as possible before reapplication. Ideally, soil should not be stored at all and immediately applied to a recipient site. Practical constraints typically result in some storage being required, and this unavoidably creates some loss of biotic components. If soils must be stored, storage time ideally would not exceed 6–12 mo (Ghose 2001; Scoles-Sciulla and DeFalco 2009). For long storage durations, treatments could be used to potentially extend longevity of biotic components. Some possible treatments may include transplanting vegetation (such as native cactus pads) on top of the piles to potentially enhance longevity of soil microorganisms. These types of treatments have not been tested extensively and should be considered experimental. Also, the height of stockpiles should be as short as possible, preferably not $>$45–60 cm tall, because the deeper the pile, the more likely biotic components will be lost. If storage space limitations require deeper piles, consider periodically turning the soil. Stored soil should be protected, such as via tackifier, from wind erosion or other damage.

Action 2: Evaluate and remediate soil potentially toxic to tortoises. Toxic materials are a potentially insidious threat to desert tortoises because the presence of toxicants may not be superficially obvious and they can accumulate in the bodies of long-lived tortoises (Seltzer and Berry 2005; Jacobson et al. 2014; Kim et al. 2014). We suggest two main practices for reducing potential effects of toxicants to desert tortoises: assess potential for toxic soils, and avoid or remediate toxic soils before conducting other habitat activities.

1) *Assess potential for toxic soils.* A first step is identifying known or suspected areas with contaminants within, or adjacent to, desert tortoise critical habitats and protected areas (Chaffee and Berry 2006). For example, synthesizing records of past mining activities or identifying mine sites through remote sensing or field reconnaissance can help delineate potential locations contaminated by mining. Vectors for transport of mine wastes, such as prevailing winds or desert washes, should be evaluated (Kim et al. 2012, 2014). Other potential sources of contaminants, such as old industrial sites and associated downwind areas, should also be assessed. Ideally, soil sampling and laboratory analysis for typical contaminants, (e.g., arsenic and mercury) would be conducted to characterize areas of known or suspected contamination (Chaffee and Berry 2006).
2) *Avoid or remediate toxic soils before conducting other habitat activities.* If potential problem areas are identified, habitat enhancement actions that could draw desert tortoises to problem areas should be avoided or conducted elsewhere. Furthermore, strategies such as sealing old mines or limiting off-road vehicle use to avoid generating dust and transporting contaminants could be paramount before implementing other habitat improvements (Kim et al. 2014).

Action 3: Decommission certain backcountry roads for habitat enhancement. Strategically decommissioning and revegetating a portion of the extensive backcountry dirt road network can increase soil and plant community health (Brooks and Lair 2009). Best practices previously discussed for establishing perennial plants can also be applicable to revegetating decommissioned roads, along with practices for managing nonnative plants that can be transported along roads. Even in cases where roads have no apparent effect on adjoining vegetation, the area of the road represents a nonvegetated surface that removes an area of potential desert tortoise forage. One road 50 km long and 10 m wide, for example, occupies 50 ha of land, which is equivalent to a large home range of an adult desert tortoise (Harless et al. 2010). Practices for augmenting forage quality and quantity may be appropriate on decommissioned roads because these are already severely disturbed environments that could potentially be converted to special areas of desert tortoise forage. In addition, several studies have highlighted two main best practices for decommissioning backcountry roads: ameliorate topographic and soil surface alterations, and limit postrestoration vehicle incursions.

1) *Ameliorate topographic and soil surface alterations.* After road decommissioning, a key objective is restoring surface water flow by reconnecting severed

drainages (e.g., ephemeral stream channels) and roughening compacted road surfaces to improve water retention (Schlesinger and Jones 1984; Nichols and Bierman 2001). Recontouring road berms can be critical to restore natural water flow, whereas treatments such as ripping and constructing check dams can increase soil roughness and water infiltration (Bainbridge 2007). More work is required to understand effectiveness of mulching because the type of mulch can affect soil water and potentially erosion. For example, Walker and Powell (2001) found that straw mulch reduced soil water, likely via absorption, on a decommissioned road in the central Mojave Desert. Likewise, Caldwell et al. (2006) cautioned that additional research be directed toward developing ripping techniques for reducing soil compaction, to avoid undesirable effects like raising salts from subsoils into the rooting zone.

2) *Limit postrestoration vehicle incursions.* Another priority for road decommissioning is limiting subsequent vehicle trespasses through proper signage, traffic barriers, and camouflage (Bainbridge 2007). Investing in barriers and revegetation at road entry points can efficiently use limited resources by reducing trespasses that undermine other restoration efforts (Weigand and Rodgers 2009). Raking out vehicle tracks, applying stains for color blending, and installing live and dead plant material (vertical mulching) can blend decommissioned roads into the landscape (Bainbridge 2007; Smith et al. 2012). As DeFalco and Scoles-Sciulla (2011) noted, it is good practice to systematically document damage from unauthorized trespasses, because monetary value can be assigned to damaged public resources in court cases.

Conclusion

Changes in desert tortoise habitat during the past 150 y, including grazing by nonnative animals, invasion of nonnative plants, wildfires, proliferation of roads, urban and agricultural development, and other land-clearing disturbances, have affected habitat quantity and quality (USFWS 1994; Lovich and Bainbridge 1999; Brooks and Lair 2009; Berry et al. 2013, 2014b). Degradation of desert tortoise habitat includes lowered availability of large perennial plants as cover sites, reduced forage quality, and greater area harmful to tortoises (e.g., contaminated soil). Habitat management tools—such as actively revegetating disturbed soil and reducing nonnative plants—have potential to partly ameliorate habitat degradation. What has not been evaluated, however, is whether actively restoring habitat increases health or population sizes of desert tortoises. Short-term indicators that could provide insight into responses of desert tortoises to improved habitat may include enhanced growth or fecundity of individual tortoises, reduced evidence of mortality, or construction of new burrows by tortoises.

This review reinforces recommendations in the desert tortoise recovery plans (USFWS 1994, 2011) to implement a comprehensive suite of habitat enhancements. To date, no examples of this approach exist for the desert tortoise. Individual habitat management activities have not been related to the desert tortoise (e.g., vegetation restoration, treating nonnative plants) or have been mainly conducted in isolation as the only habitat management activity (Averill-Murray et al. 2012). To expand on the positives of individual actions such as fencing (e.g., Brooks 1995; Berry et al. 2014b), a next step is identifying priority locations to implement coordinated, integrated actions for recovery of habitat. Such actions could include mitigating roads, revegetating disturbances, enhancing forage quality, and reducing nonnative plants. It is important to ensure that these actions are not undermined by factors such as toxic soils. Sufficient science exists, including that summarized here, to identify candidate actions for implementing comprehensive habitat-enhancement trials. Improving habitat is already known to benefit other components of desert ecosystems (e.g., perennial plant communities), so implementing habitat enhancement measures is a conservative, low-risk strategy with high potential for assisting desert tortoise recovery.

Supplemental Material

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Attachments

Abella S.R. and K.H. Berry. 2016. Enhancing and restoring habitat for the desert tortoise (*Gopherus agassizii*). Journal of Fish and Wildlife Management 7(1):xx–xx; e1944-687X. doi: 10.3996/052015-JFWM-046.

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Construction Best Management Practices

Desert Tortoise Protection

August 21, 2017

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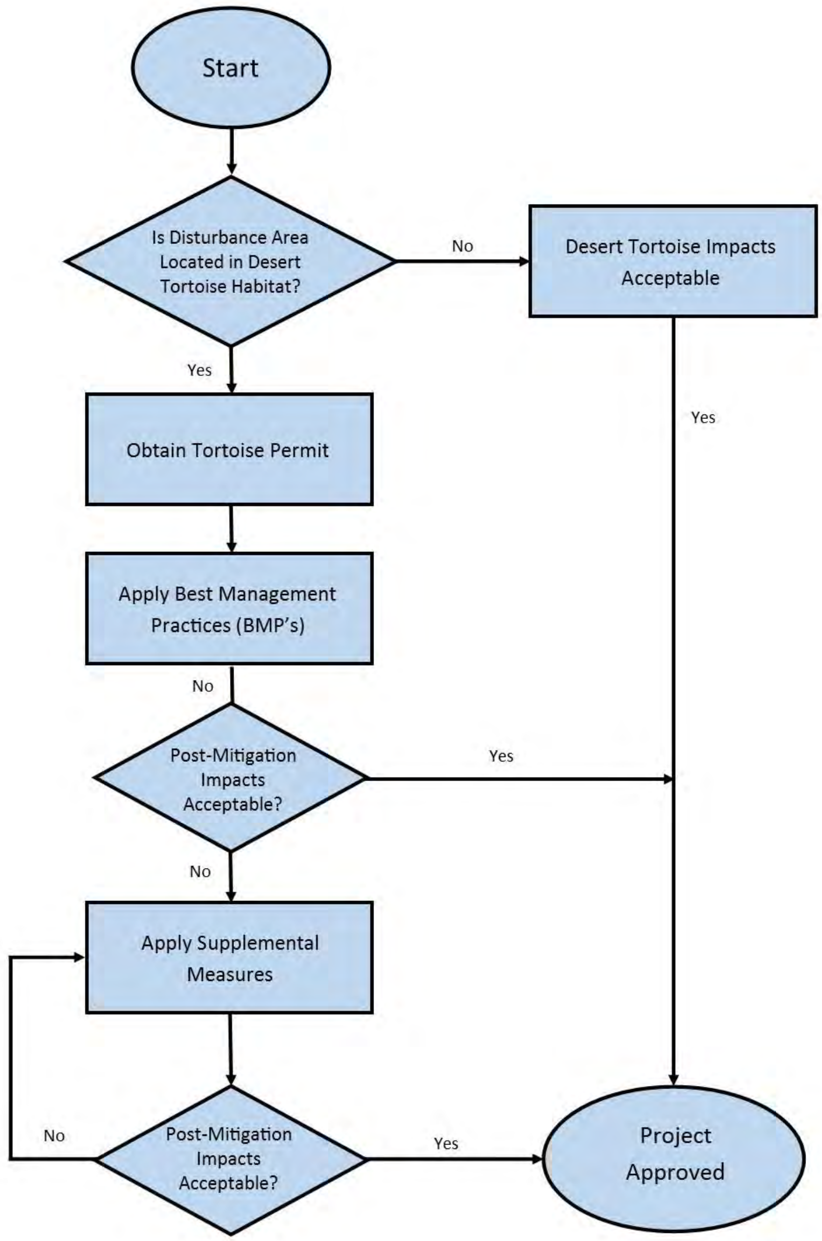
Contents

This document was prepared to provide support to the US Fish and Wildlife Service (USFWS) and land management agencies in developing Biological Opinions for projects that could affect desert tortoise (*Gopherus agassizii*). Multiple Biological Opinions were reviewed to compile this suite of consistently employed Best Management Practices (BMPs).

Project-specific BMPs adopted by the USFWS would become Terms and Conditions in a Biological Opinion and be the federal requirements for project construction. This document may also prove useful to project proponents in making their project development decisions because knowing the BMPs could allow them to minimize or avoid potential impacts to desert tortoise and its habitat. The document is organized as follows:

- **1.0 Best Management Practices Process Flowchart** – A flowchart depicting the process for application of mitigation measures and the agency decision process if provided as a summary.
- **2.0 Best Management Practices** – the BMPS are presented in this section.
- **3.0 References –** Literature reviewed for summarizing the BMPs.

1.0 Best Management Practices Process Flowchart



2.0 Best Management Practices

This compilation of BMPs was prepared to aid federal agencies by providing a suite of consistent measures and to aid project proponents in understanding the requirements needed to protect the desert tortoise in accordance with the Federal Endangered Species Act of 1973 (ESA; 16 U.S.C. § 1531 et seq.). The ESA was designed to protect critically imperiled species from extinction as a "consequence of economic growth and development untempered by adequate concern and conservation." The U.S. Supreme Court found that "the plain intent of Congress in enacting" the ESA "was to halt and reverse the trend toward species extinction, whatever the cost."

Under the ESA, USFWS had been charged with evaluation of the potential effects on species that have been federally listed as threatened or endangered with extinction including the desert tortoise. To accomplish this they consult with the federal “Action” or “Lead” agency proposing the action, resulting in a Biological Opinion that either finds the action would not jeopardize the species or that it would result in jeopardy. Examples of federal lead agencies include the Bureau of Land Management, National Park Service, Federal Highway Administration, Army Corps of Engineers, and Department of Defense. Under a jeopardy Opinion the project would be denied federal approval and the USFWS would be required to identify “Reasonable and Prudent Alternatives” that could avoid the jeopardy. A non-jeopardy Opinion typically contains a number of Terms and Conditions designed to reduce potential impacts to a non-jeopardy level. A number of recent Biological Opinions were reviewed during preparation of this document to compile a standard suite of BMPS. BMPs adopted by USFWS in a Biological Opinion become mandatory Terms and Conditions that must be implemented for project construction.

2.1 Field Contact Representative

The Applicant will designate a Field Contact Representative (FCR) who shall be responsible for overseeing compliance with the Biological Opinion. The FCR will be onsite during all active construction activities that could result in the “take” of a desert tortoise. The FCR will have the authority to briefly halt activities that are in violation of the desert tortoise protective measures until the situation is remedied.

2.2 Authorized Desert Tortoise Biologist

Authorized desert tortoise biologists shall be onsite during all construction activities to ensure compliance with this Biological Opinion. Prospective authorized desert tortoise biologists will submit their statement of qualifications to the USFWS and allow a minimum of 30 days for response. Use of authorized desert tortoise biologists will be in accordance with the most up-to-date USFWS guidance and shall required for monitoring of any pre-construction, construction, operation, or maintenance activities that may result in take of the desert tortoise. The current guidance is provided in Chapter 3 of the Desert Tortoise (Mojave Population) Field Manual (herein “USFWS 2009”).

The Applicants will employ authorized desert tortoise biologists, approved by the USFWS, to ensure compliance with protective measures for the desert tortoise. As such, all authorized desert tortoise biologists are functionally agents of the USFWS and shall report directly to the USFWS, the federal land management partner, and the proponent concurrently regarding all compliance issues and take of desert tortoises; this includes all draft and final reports of non-compliance or take.

2.3 Biological Monitors

Biological monitors shall employed and responsible for ensuring that all compliance measures in this Biological Opinion are properly implemented, including: reporting all non-compliance issues; reporting all tortoises found in harm's way; ensuring that project vehicles and equipment remain in designated areas; and minimizing the risk to tortoises on project access roads.

Working under the supervision of an authorized desert tortoise biologist, Biological Monitors would be present in all active construction locations. Biological monitors would provide oversight to ensure proper implementation of protective measures, record and report desert tortoise and desert tortoise sign observations in accordance with approved survey protocols, and report incidents of non-compliance in accordance with this Biological Opinion and other relevant project permits.

Authorized biologists will capture and handle desert tortoises in compliance with the most up-to-date guidance from the USFWS (2009). An authorized desert tortoise biologist shall be responsible for recording each observation of desert tortoise handled in the tortoise monitoring reports. This information will be provided directly to the USFWS and the federal lead agency.

2.4 Desert Tortoise Fencing

Installation of tortoise-proof fencing that is designed to protect desert tortoises by excluding them from construction zones may be warranted. Depending on the specifics of the project, USFWS will determine whether fencing is required and if so whether it is permanent, temporary, or of both types. See Chapter 8 in USFWS (2009).

2.4.1 Permanent Fencing

Permanent desert tortoise exclusionary fencing shall be installed around the boundary of the facility. An authorized desert tortoise biologist will monitor construction of exclusionary fencing in order to relocate all tortoises in harm's way to outside the fenced impact area.

Fence specifications shall be consistent with those approved in Chapter 8 of USFWS (2009) or most current version.

2.4.2 Temporary Tortoise Fencing

Should it be necessary to temporarily fence an area to exclude desert tortoises during construction, the temporary fencing would consist of: 1) portable stand-alone chain-link fence modules or plastic snow fencing supported by standard metal fencepost, and 2) desert tortoise fencing in compliance with Chapter 8 of USFWS (2009).

2.5 Desert Tortoise Site Clearance

Once desert tortoise exclusionary fencing is installed, the fenced area shall be cleared under the direction of authorized desert tortoise biologists who will survey the area to ensure that no tortoises or active burrows are present within the fenced area as per Chapter 6 in USFWS (2009).

2.5.1 Desert Tortoise Clearance Surveys and Translocation Plans

After installation of desert tortoise exclusionary fencing and prior to any surface-disturbing activities, authorized desert tortoise biologists shall conduct a clearance survey to locate and remove all desert tortoises from harm's way, including those areas to be disturbed, using techniques that provide full coverage of construction areas (see Chapter 6 in USFWS 2009).

If more than 5 desert tortoises are to be moved a distance of more than 500 meters then a separate Translocation Plan must be prepared and approved by USFWS.

Desert tortoises found during the clearance survey will either be relocated outside the project impact area or translocated to a recipient site in accordance with the Biological Opinion and Translocation Plan, if applicable. In some cases where the proponent owns contiguous lands or those lands are managed by the BLM (which would require prior approval of the BLM), tortoises may be relocated a short distance onto those lands and monitored by either the Authorized Biologist or monitor until which time the tortoise(s) is judged to be out of harm's way. In some cases, an artificial burrow will need to be constructed by qualified biologists (see Chapter 6, Subsection 7 in USFWS 2009).

Authorized desert tortoise biologists will perform desert tortoise clearance surveys of all unfenced work areas outside the main project site immediately prior to the onset of pre-construction, construction, operation, or maintenance activities for project facilities. Desert tortoise monitoring shall be conducted during all related work activities in accordance with USFWS (2009), Biological Opinion, and Translocation Plan, if applicable.

2.5.2 Worker Environmental Awareness Program

A Worker Environmental Awareness Program (WEAP) shall be presented by an authorized desert tortoise biologist to all project personnel prior to them starting work on the project site. This program will contain information concerning the biology and distribution of the desert tortoise, desert tortoise activity patterns, its legal status, and occurrence in the proposed project area. The program will also discuss the definition of "take" and its associated penalties, measures designed to minimize the effects of construction activities, the means by which employees may limit impacts, and reporting requirements to be implemented when tortoises are encountered. Personnel shall be instructed to check under vehicles before moving them as tortoises often seek shelter under parked vehicles. WEAP training shall be mandatory, and as such, workers shall be required to sign in and wear a sticker on their hard hat to signify that they have received the training and agree to comply.

2.5.3 Access Roads

Construction access would be limited to the project right-of-way (ROW) and established access roads as defined in pertinent permitting documents or as identified with the construction supervisor. The Applicants will prohibit project personnel from driving off road or performing ground-disturbing activities outside of designated areas during construction, operation, maintenance, or decommissioning.

2.5.4 Speed Limits and Signage

Until the desert tortoise exclusionary fence has been constructed (where applicable), a speed limit of 15 miles per hour shall be maintained during the periods of highest tortoise activity (March 1 through November 1), and a limit of 25 miles per hour maintained during periods of lower tortoise activity. This will reduce dust and allow for observation of tortoises in the road. Speed limit and caution signs would be installed along access roads and USFWS roads.

Where tortoise exclusionary fence is installed and desert tortoise clearance surveys have been completed, speed limits within the fenced and cleared areas shall be established by the construction contractor. Limits should be based on surface conditions and safety considerations. Vehicle travel in unfenced areas will adhere to speed limits established above.

2.5.5 Trash and Litter Control

A trash and litter control program shall be implemented and managed by the construction contractor and monitored by authorized desert tortoise biologists to reduce the attractiveness of the area to opportunistic and subsidized predators such as desert kit foxes, coyotes, badgers, and common ravens. Trash and food items shall be disposed of properly in predator-proof containers with re-sealing lids. Trash containers shall be emptied and construction waste shall be removed daily from the project area and disposed of in an approved landfill, recycling, or compost facility.

2.5.6 Dogs and Firearms

Firearms and domestic dogs shall be prohibited on the project site.

2.5.7 Raptor Control

Authorized biologists are responsible for inspecting structures annually for nesting ravens and other predatory birds and report observations of nests to the USFWS. Transmission line support structures and other facility structures shall be designed to discourage use by raptors for perching or nesting (e.g. by use of anti-perching devices) in accordance with the most current Avian Power Line Interaction Committee guidelines (APLIC 2006). BMPs to discourage the presence of ravens onsite include trash management, elimination of available water sources, designing structures to discourage potential nest sites, use of hazing to discourage raven presence, and active monitoring of the site for raven presence.

2.5.8 Habitat Compensation

Desert tortoise compensation fees will likely be required by the federal lead agency. The total acres of permanent and temporary disturbance shall be adjusted by the federal lead agency based upon final site design and disturbance acreage at the time a Notice to Proceed has been issued for the project (an increase in habitat disturbance may require re-initiation of consultation).

Compensation fees are used to support desert tortoise recovery, which may include the following actions: habitat restoration and recovery; monitoring of habitat, populations, and effectiveness of conservation and recovery actions; applied research to promote conservation/recovery; public outreach; predator management; and other actions recommended by USFWS approved Desert Tortoise Recovery Implementation Teams.

2.5.9 Overnight Hazards

An authorized desert tortoise biologist or Biological Monitor will inspect any excavations that are not within desert tortoise exclusion fencing on a regular basis (several times per day) and immediately prior to filling the excavation. If project personnel discover a desert tortoise in an open trench, an Authorized Biologist or Biological Monitor working under the supervision of an Authorized Biologist will move it to a safe location. To prevent entrapment of desert tortoises during non-work hours, the applicants will cover or temporarily fence excavations that are outside the permanently fenced project areas at the end of each day (e.g. trenches for water pipeline).

2.5.10 Checking for Tortoises Beneath Vehicles

All project personnel shall be instructed to check under vehicles before moving them as tortoises often seek shelter under parked vehicles. Vehicle door magnets or stickers that remind vehicle operators to look beneath tires before driving shall be prepared and distributed by the Authorized Biologist. If project personnel encounter a desert tortoise, they will contact an authorized desert tortoise biologist. The desert tortoise will be allowed to move a safe distance away prior to moving the vehicle. Alternatively, an authorized desert tortoise biologist or Biological Monitor may move the desert tortoise to a safe location to allow for movement of the vehicle.

2.5.11 Construction Area Flagging

Designated areas to protect desert tortoises and their habitat will be identified by an Authorized Biologist. An Authorized Biologist, Biological Monitor, of construction survey personnel, will flag boundaries of these areas for avoidance. Restricted areas may be identified and shall be monitored to ensure desert tortoises are protected during construction. ROW boundaries shall be flagged prior to beginning construction activities, and disturbance shall be confined to the ROW. In some cases, an Authorized Biologist or Biological Monitor shall escort all survey crews on site prior to construction. All survey crew vehicles will remain on existing roads and stay within flagged areas. In cases where construction vehicles are required to go off existing roads, an authorized desert tortoise biologist or Biological Monitor (on foot) would precede the vehicles and clear the area.

2.5.12 Blasting

If blasting is required in desert tortoise habitat, detonation shall only occur after the area has been surveyed and cleared by an authorized desert tortoise biologist no more than 24 hours prior. A 200-foot radius buffer area around the blasting site shall be surveyed, and all desert tortoises above ground within this 200-foot buffer shall be moved at least 500 feet from the blasting site, placed in unoccupied burrows, and temporarily penned to prevent from returning to the site. Tortoises located outside of the immediate blast zone and that are within burrows would be left in their burrows. All burrows, regardless of occupied status, will be stuffed with newspapers, flagged, and the location recorded using a GPS unit. Immediately after blasting, newspaper and flagging will be removed. If a burrow or cover site has collapsed that could be occupied, it shall be excavated to ensure no tortoises have been buried and are in danger of suffocation. Desert tortoises removed from the blast zone would be returned to their burrow if it is intact or placed in a similar unoccupied or constructed burrow.

2.5.13 Penning

Penning of desert tortoises shall be accomplished by installing a circular fence, approximately 20 feet in diameter, to enclose and surround the occupied tortoise burrow (USFWS 2009). The pen should be constructed with 1-inch horizontal by 2- inch vertical, galvanized welded 16-gauge wire. Steel T-posts or rebar should be placed every 5 to 6 feet to support the pen material. Pen material will extend 18 to 24-inches above ground. The bottom of the enclosure will be buried 6 to 12 inches or bent towards the burrow, have soils mounded along the base, and other measures implemented to ensure zero ground clearance. Care shall be taken to minimize visibility of the pen by the public. An authorized desert tortoise biologist or Biological Monitor shall check the pen at least daily to ensure the desert tortoise is secure and not stressed. No desert tortoise shall be penned for more than 48 hours without written approval by the USFWS.

Because this is a relatively new technique, all instances of penning or issues associated with penning shall be reported to the USFWS by phone and email within 24 hours by an authorized desert tortoise biologist. Desert tortoises shall not be penned when conditions are favorable for desert tortoise activity unless approved in advance by the USFWS. Pens for juvenile and hatchling-sized desert tortoises will consist of ½ inch by ¼ inch fencing with a cover to prevent predators, including smaller predators from gaining access to the tortoise (USFWS 2011).

All pens will be approved by USFWS and appropriate agencies, and the authorized desert tortoise biologist shall check pens daily to ensure all desert tortoises within the pens are present and no damage to the pens has occurred. Any impacts to penning or desert tortoises shall be reported to USFWS within one day. USFWS shall be contacted within one day of observation of desert tortoise injury or mortality.

2.5.14 Timing of Construction

The federal lead agency shall ensure that when possible, the project proponent schedules and conducts construction, operation, and maintenance activities within desert tortoise habitat during the less-active season (generally November 1 to March 1) and during periods of reduced desert tortoise activity (typically when ambient temperatures are less than 60° or greater than 95°F).

2.5.15 Confine Activity to Delineated Area

The applicants will confine all project activities, project vehicles, and equipment within designated areas or delineated boundaries of work areas that authorized desert tortoise biologists or Biological Monitors have identified and cleared of desert tortoises. The applicants will confine all work areas to previously disturbed areas, and if none is available, to the smallest practical area, considering topography, placement of facilities, location of burrows, public health and safety, and other limiting factors. During activities at the completed project site, the applicants will confine all vehicle parking, material stockpiles, and construction-related materials to the permanently fenced project sites and construction logistics areas.

2.5.16 Noise Reduction

Noise reduction devices (e.g. mufflers) will be employed to minimize impacts to tortoises and other protected species. Explosives will be used only within specified times and at specified distances from sensitive wildlife or surface waters as established by the relevant federal and state agencies. Operators will ensure that all equipment is adequately muffled and maintained in order to minimize disturbance to wildlife.

2.5.17 Installing Shade Structures and Shelters

If interior fences are in place during the active season and prior to the removal of desert tortoises from within the area, the applicants will install shade structures along these fences. Shade structures will also be installed outside tortoise exclusionary fence to protect desert tortoises that have been relocated from within the project site, as well as desert tortoises occurring in the wild outside the project perimeter. The shelters will be designed and installed to provide shelter for both small and large tortoises. The shelters will be installed at approximately 1,000-foot intervals (or as approved by the USFWS), with one smaller sized shelter placed in between each larger shelter in order to provide additional locations for subadults and juveniles.

Shelters will be made from either PVC tubes, wood, or similar material with a diameter of 14 inches or greater for the larger shelters and 6-8 inches for the smaller ones. Tubes should be cut into 2-3 foot minimum lengths and then cut horizontally to mimic a naturally occurring burrow. Each shade structure would be partially buried and covered with a minimum 4 inches of soil and rocks to keep them from being blown away and to assist with thermoregulation within the shelter. Alternatively, the PVC tubes may be wired to the exclusionary fence. During all fence monitoring, these structures will be inspected regularly for their effectiveness and adjusted as needed to increase their effectiveness. These inspections will continue until either no tortoises are found consistently walking the fence during an entire active season or until the end of the project’s construction period, whichever is earlier.

2.5.18 Moving Construction Pipes

When outside the fenced project areas, project personnel will not move construction pipes greater than 3 inches in diameter if they are stored less than 8 inches above the ground, until they have inspected the pipes to determine whether desert tortoises are present. As an alternative, the project proponent may cap all such structures before storing them outside of fenced areas.

2.5.19 Spill Prevention/Fire Management Plan

A Spill Prevention and Emergency Response Plan will be developed that considers sensitive ecological resources. Spills of any toxic substances will be promptly addressed and cleaned up before they can enter aquatic or other sensitive habitats as a result of runoff or leaching. A Fire Management Plan will be developed to implement measures that minimize the potential for a human-caused fire to affect ecological resources and that respond to natural fire situations.

2.5.20 Water Storage

Water needed for construction should be stored in tanks. If evaporation ponds are used, they will be fenced to prevent use by wildlife and treated in a manner approved by the federal lead agency partner and USFWS to prevent drowning. Wildlife escape ramps will be installed and the liner will be textured sufficiently to ensure that all wildlife can escape if they enter the pond. The ponds and fence shall be inspected at least daily. The Authorized Biologist will be responsible for monitoring for raven use and coordinate with the federal lead agency of appropriate action.

2.5.21 Non-emergency Expansion

Any non-emergency expansion of activities into areas outside of the areas considered in this Biological Opinion will require approval by the federal land management partner and USFWS, as well as necessary desert tortoise clearance surveys. These expanded activities may require re-initiation of consultation with the USFWS.

2.5.22 Geotechnical Testing

An authorized desert tortoise biologist or Biological Monitor will be at each of the geotechnical test sites for all necessary activities. Appropriate desert tortoise clearance will be conducted, and the authorized desert tortoise biologist or Biological Monitor will have the authority to micro-site the geotechnical test locations and stop work, if necessary, to avoid sensitive resources.

2.5.23 Translocation Strategy

Desert tortoises located during protocol clearance surveys of the project site may be relocated to areas outside the project site or transferred to an off-site quarantine facility (ex situ) for translocation, or monitored on the project site (in situ) via telemetry. If ex situ monitoring is selected, the off-site facility would be constructed and operated according to USFWS Translocation Guidance (2011). Transmitters and unique identifiers would be affixed to each desert tortoise following USFWS guidance.

A record of all desert tortoises encountered and translocated during project surveys and monitoring would be maintained. The record would include the following information for each desert tortoise: location (narrative, vegetation type, UTM coordinates, and maps) and dates of observations; burrow data; general conditions and health; appropriate measurements; any apparent injuries and state of healing; if moved, the location at which it was captured and the location at which it was released; voiding of the bladder and rehydration method/duration; and diagnostic markings (i.e. identification numbers).

2.5.24 Reporting

Depending on the scale of the project, agencies may require reports either at project close or quarterly during the duration of construction and annual updates after that. The federal lead agency may delegate this responsibility to the applicants. In addition, a final construction report will be submitted to the USFWS within 60 days of completion of construction of the project. All quarterly reports are due by the 10th of each of the following months (January, April, July, October), and annual reports are due February 1 of each year. If required, annual status updates shall be provided to the USFWS following completion of construction

Specifically, all reports must include information on any instances when desert tortoises were killed, injured, or handled; the circumstances of such incidents; and any actions undertaken to prevent similar incidents from reoccurring. Additionally, the reports should provide detailed information regarding each desert tortoise handled or observed, with the names of all authorized desert tortoise biologists or Biological Monitors (and the authorized desert tortoise who supervised their actions) involved in the project. Information will include the following: location (UTM), date and time of observation, whether desert tortoise was handled, general health, and whether it voided its bladder, re-hydration method and duration if applicable, location the desert tortoise was moved from and location moved to, unique physical characteristics of each tortoise, and effectiveness and compliance with the desert tortoise protection measures.

Any incident occurring during project activities that was considered by the authorized desert tortoise biologist or Biological Monitor to be in non-compliance with this Biological Opinion will be documented immediately and reported to the FCR by the authorized desert tortoise biologist.

3.0 References

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