Mojave Desert Tortoise
(Gopherus agassizii)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Desert Tortoise Recovery Office
Southern Nevada Fish and Wildlife Service
Las Vegas, Nevada

May, 2022

5-YEAR REVIEW

Mojave Desert Tortoise (*Gopherus agassizii*)

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5-YEAR REVIEW
Mojave Desert Tortoise/*Gopherus agassizii*

GENERAL INFORMATION

Species: Mojave desert tortoise

Original Listing
Federal Register (FR) Notice: 45 FR 55654
Date of Final Listing Rule: August 20, 1980
Entity Listed: Beaver Dam Slope population of the desert tortoise in Utah
Classification: Threatened with Critical Habitat

Revised Listing
FR Notice: 54 FR 32326
Date Listed: August 4, 1989
Entity Listed: Mojave population of desert tortoise
Classification: Emergency listing as endangered

No emergency action was taken under this rule to reclassify the Beaver Dam Slope subpopulation in Utah as endangered because it was already protected under the Act (Service 1980: 45 FR 55654).

Revised Listing
FR Notice: 55 FR 12178
Date Listed: April 2, 1990
Entity Listed: Mojave population of desert tortoise
Classification: Threatened

Associated Rulemakings:
Similarity of appearance
FR Notice: 55 FR 12178
Date Listed: April 2, 1990
Entity Listed: Sonoran population of desert tortoise found outside its natural range in Arizona (south and east of the Colorado River) and Mexico
Classification: Threatened

Proposed determination of Critical Habitat
FR Notice: 58 FR 45748
Date: August 30, 1993

Determination of Critical Habitat
FR Notice: 59 FR 5820
Date: August 8, 1994

Critical Habitat was designated on over 6,000,000 acres in portions of the Mojave and Colorado deserts. The Colorado Desert is a subdivision of the Sonoran Desert and is located in California west of the Colorado River. This designation includes primarily Federal lands in southwestern Utah, northwestern Arizona, southern Nevada, and southern California.

Methodology used to complete the review
This review was prepared by the Desert Tortoise Recovery Office and coordinated with field offices within Regions 8, 2, and 6. We used information from the 2010 5-year review (Service 2010a), 2011 Recovery Plan (Service 2011a), and survey information and research results from published literature by experts who have been monitoring and studying various aspects of this species. We received three letters in response to our FR notice initiating this 5-year review (from one individual and three non-governmental organizations). These sources together with personal communications with experts were our primary sources of information used to update the species' status and threats. This 5-year review contains updated information on the species' biology and threats and an assessment of that information compared to that known at the time of publication of the revised recovery plan in 2011.

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FR Notice citation announcing the species is under active review
FR Notice: 86 FR 27462

REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) policy

We concluded in the 2010 5-year review that the currently listed Mojave population of the desert tortoise was a valid distinct population segment under the 1996 DPS policy, but individual subunits of the Mojave DPS do not qualify as distinct population segments (Service 2010a). In summary, habitat occupied by the Mojave DPS is relatively continuously distributed, and genetic differentiation within the DPS is consistent with isolation-by-distance in a continuous-distribution model of gene flow. In addition, observed variation in behavioral and physiological characteristics across the DPS was likely related to environmental gradations between the described subdivisions of the Mojave and Colorado deserts. In 2010 we concluded that these factors disqualified subunits of the Mojave DPS under the discreteness criterion of the policy.

Since the revised recovery plan was published, the Mojave DPS was taxonomically elevated to species status as *Gopherus agassizii*, and most tortoises east of the Colorado River are now recognized by the scientific community as *G. morafkai* (Murphy *et al.* 2011). However, the Colorado River has been a porous genetic barrier through time for multiple species, including desert tortoises (Dolby *et al*. 2019). To date, nine local populations that include *G. agassizii* or hybrids with *G. morafkai* have been genetically identified east of the Colorado River in Arizona (Fig. 1; McLuckie *et al.* 1999; Edwards *et al*. 2015; Dolby 2020). Herein, we keep with historical common usage by referring to *G. agassizii* as the Mojave Desert Tortoise and *G. morafkai* as the Sonoran Desert Tortoise. We formally recognized *G. morafkai* taxonomically in 2012 (77 FR 69997), and we recommend that the listing status of *G. agassizii* under the Act also be evaluated relative to its current taxonomy and distribution. Further consideration of DPSs within a taxonomically revised listed entity could be made at that time.

Recovery Criteria

Recovery Objective 1 (Demography)

Maintain self-sustaining populations of desert tortoises within each recovery unit into the future.

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

Recovery Objective 2 (Distribution)

Maintain well-distributed populations of desert tortoises throughout each recovery unit.

> **Recovery Criterion 2.** Distribution of desert tortoises throughout each tortoise conservation area is increasing over at least 25 years (*i.e.*, ψ [occupancy] > 0).

Recovery Objective 3 (Habitat)

Ensure that habitat within each recovery unit is protected and managed to support long-term viability of desert tortoise populations.

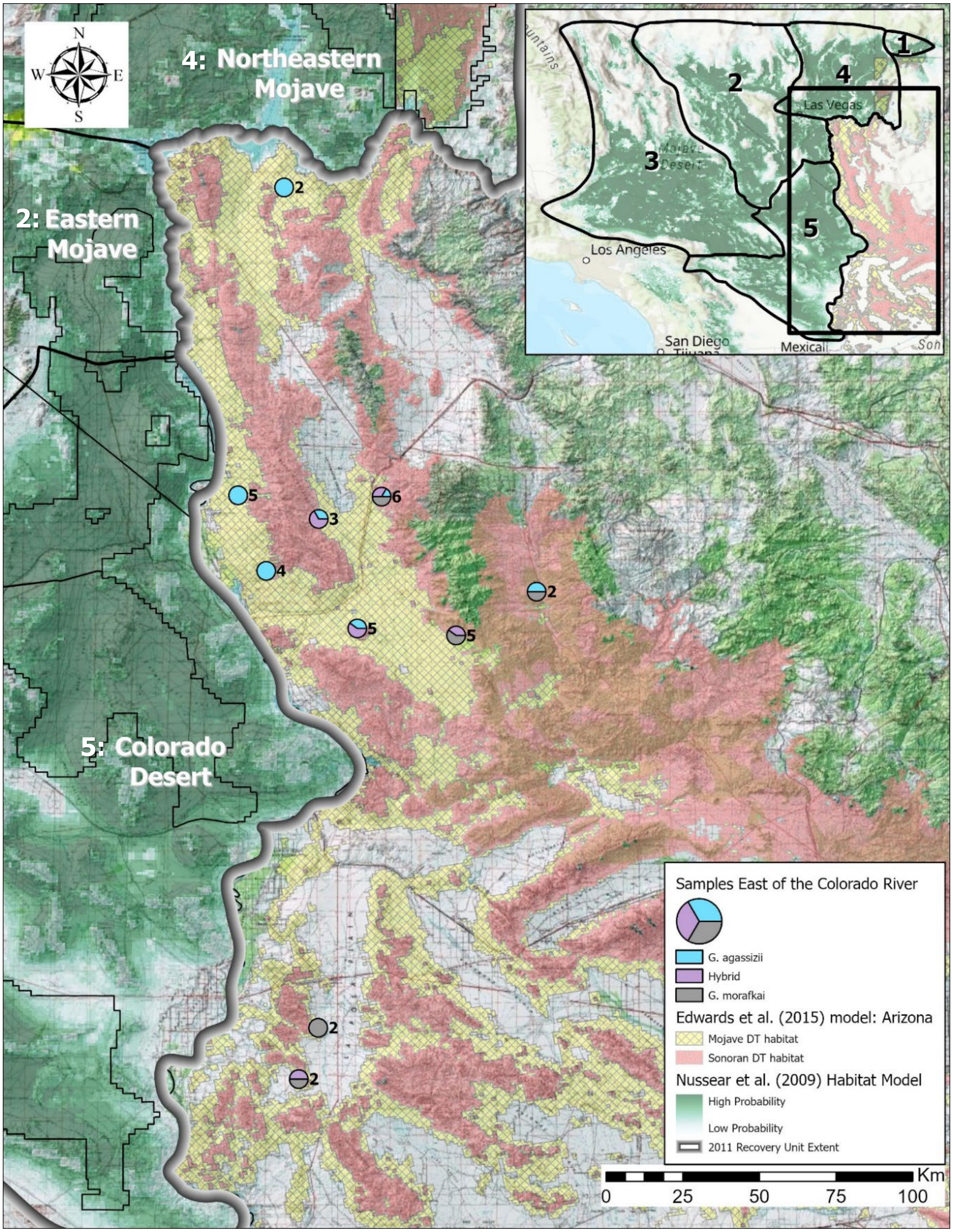

Figure 1. Genetic samples collected from desert tortoises east of the Colorado River (Edwards *et al*. 2015; Dolby 2020). Bold numbers indicate sample sizes at each site. EB = East Bajada monitoring plot; HF = Hualapai Foothills plot; BUCK = Buck Mountains plot. Recovery units in inset not labeled in main map: 1 = Upper Virgin River; 3 = Western Mojave.

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

Recovery Plan: U.S. Fish and Wildlife Service. 2011. Revised recovery plan for the Mojave population of the desert tortoise (*Gopherus agassizii*). U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, California. 222 pp.

Desert tortoise populations and habitat have not been monitored long enough for recovery criteria to have been met. However, declining trends in tortoise density (Recovery Criterion 1) need to be reversed in most areas (see below).

Updated Information and Current Species Status

This section summarizes new information since the last status review and the revised recovery plan (Service 2010a; Service 2011a). This does not constitute a comprehensive literature review of the great deal of research that has been published on desert tortoises since 2011, but provides on overview of substantial new information that pertains directly to the species' status. A bibliography of literature published since 2011, organized by research recommendations in the revised recovery plan, is provided in Appendix A.

Biology and Habitat

Genetics

Genomic analysis indicates that *G. agassizii* populations east of the Colorado River are not genetically diverged from populations west of the Colorado, but the known eastern populations are relatively small and isolated (Dolby 2020). Two additional studies published more detailed genetic analyses of Mojave Desert Tortoises since 2011. Shaffer *et al*. (2017) found evidence of genetic differentiation between tortoise populations in a northern group that corresponds with the Eastern Mojave Recovery Unit and recovery units to the north and a southern group that corresponds with the Western Mojave and Colorado Desert recovery units. This division is consistent with previous mitochondrial and nuclear genetic analyses (Lamb *et al*. 1989; Murphy *et al*. 2007; Hagerty and Tracy 2010). Also consistent with past studies, relatedness between tortoises was predicted by geographic distance both within and between the major north/south groups, but the divergence of populations between the two major groups was greater than the divergence at comparable distances within each group (Shaffer *et al*. 2017). Shaffer *et al*. also found secondary differentiation that separates populations between the Western Mojave and Colorado Desert recovery units. Sánchez-Ramírez *et al*. (2018) found the same differentiation as above, additional minor differentiation within the Western Mojave Recovery Unit, and levels of admixture between populations consistent with isolation by distance.

Spatial Distribution

Our knowledge of the precise distribution of tortoises in the Upper Virgin River Recovery Unit outside the Red Cliffs Desert Reserve is limited, but we continue to work with our partners to acquire distribution information throughout Washington County, Utah. For example, a population assessment of the desert tortoise in the recovery unit applied analytical units that recognized the extent of contiguous potential habitat beyond the recovery units drawn in 2011 and which extends from Utah into Arizona (Fig. 2; Service 2021a).

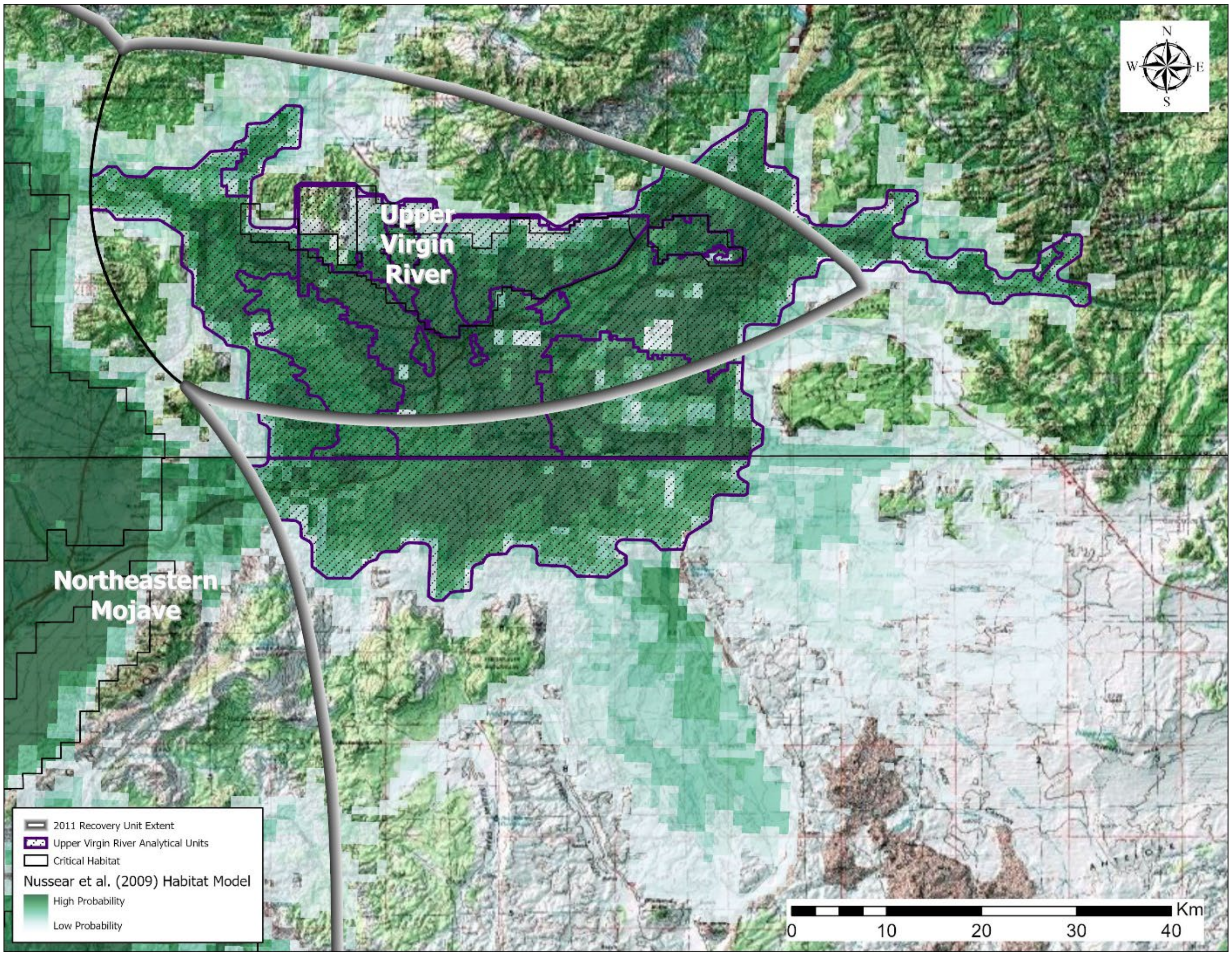

Figure 2. Boundary of the Upper Virgin River Recovery Unit relative to contiguous modeled habitat across the Utah-Arizona state line and population analytical units (Service 2021a). The black-and-white gradient lines around the periphery of the range indicate the potential for tortoises to be found outside mapped recovery unit boundaries, in which case those tortoises naturally would be assigned to the adjacent recovery unit.

Desert tortoise observations south of Palm Springs, California, and into Anza Borrego Desert State Park (ABDSP) have long been considered to be from captive releases (Luckenbach 1976, 1982). Recent records include at least five localities from the vicinity of the Philip L. Boyd Deep Canyon Desert Research Center on the northeastern flank of the Santa Rosa Mountains to central ABDSP, and observations of juvenile tortoises indicate that these populations are naturally reproducing (Fig. 3; Manning 2018; Puffer *et al*. 2018). Genetic analysis of samples collected in 2018 found that all sampled tortoises are *G. agassizii*, but resolution of source populations to determine whether the tortoises originate from near to or distant from ABDSP is ongoing (Manning 2018). Nevertheless, this information extends the distribution of reproducing Mojave Desert Tortoises greater than 60 km south of Palm Springs and beyond the southern edge of the Colorado Desert Recovery Unit boundary depicted in the recovery plan (Service 2011a).

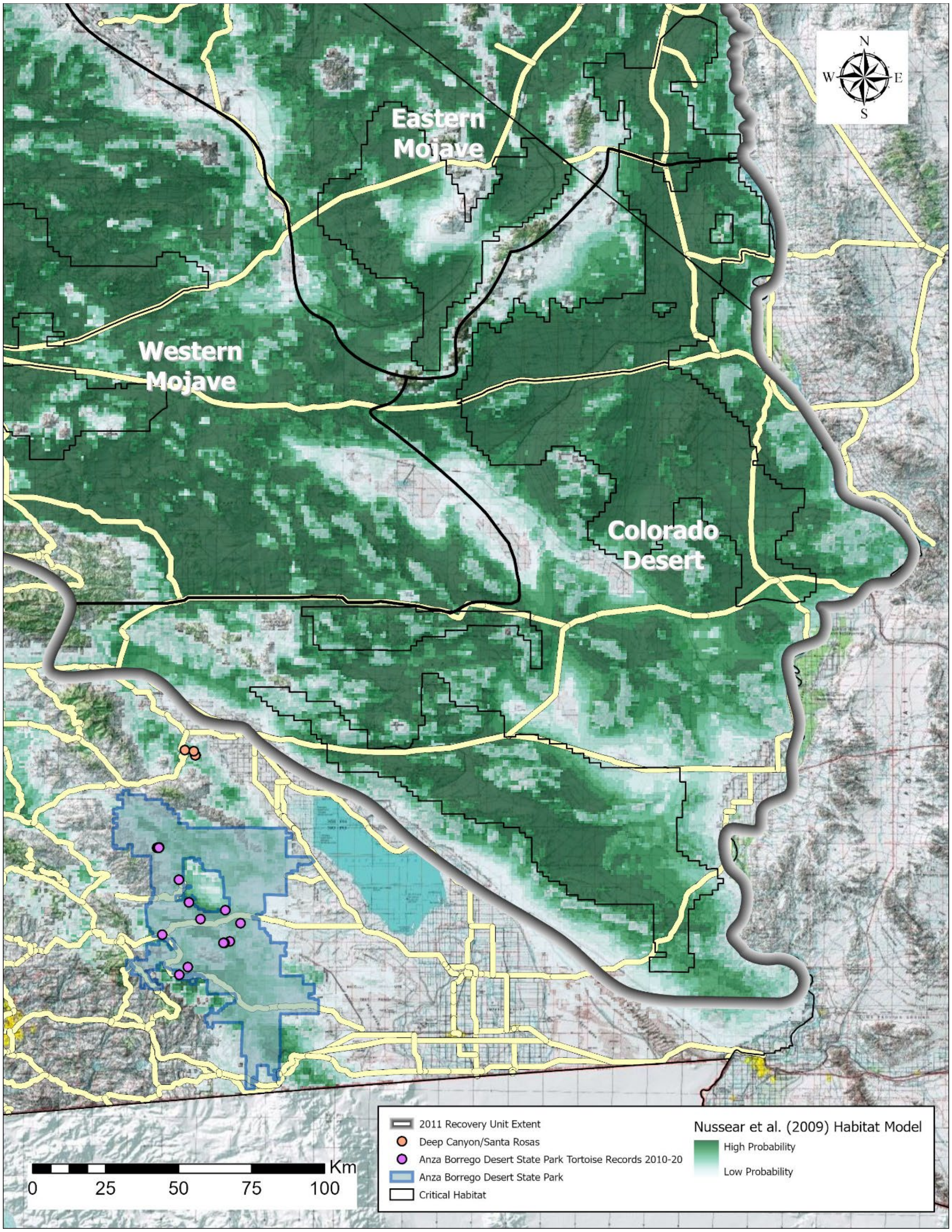

Figure 3. The Colorado Desert Recovery Unit relative to Mojave Desert Tortoise localities from the northern flank of the Santa Rosa Mountains through Anza Borrego Desert State Park. The black-and-white gradient lines around the periphery of the range indicate the potential for tortoises to be found outside mapped recovery unit boundaries, in which case those tortoises naturally would be assigned to the adjacent recovery unit.

Documented populations of Mojave Desert Tortoises east of the Colorado River in Arizona occur as far north as the vicinity of Temple Bar on Lake Mead National Recreation Area (Fig. 1). Additional populations, some including hybrids with Sonoran Desert Tortoises, encircle the western, southern, and eastern flanks of the Black Mountains west of Kingman; south at least to the Buck Mountains; and east to the western foothills of the Hualapai Mountains (Fig. 1). A single individual genetically diagnosed as a hybrid was found among four sampled individuals (the other three were *G. morafkai*) on the U.S. Army Yuma Proving Ground (Fig. 1). A single Mojave Desert Tortoise also was documented near a Sonoran Desert Tortoise near Wickieup, Arizona (the farthest east point in Fig. 1); the genotype of this tortoise suggests it is closely related to those tortoises found in the Black Mountains, particularly on their eastern bajada (Dolby 2020). We suspect that this tortoise was illegally translocated by people given its proximity to both Interstate 40 and Highway 93.

Abundance, Density, and Population Viability

With several exceptions, populations monitored within Tortoise Conservation Areas (TCAs; Service 2011a) continued to decline between 2004 and 2014 (Allison and McLuckie 2018). Populations declined on average in every TCA except those in the Northeastern Mojave Recovery Unit and in Joshua Tree and Piute Valley in the Colorado Desert Recovery Unit (Table 1). Extrapolating densities across modeled habitat in all the recovery units, the total number of adult tortoises declined by an estimated 124,050 (37%) during that time period (Table 1). Mean density of adult tortoises in 11 of the 17 TCAs was below 3.9/km^2, which is thought to be this species' minimum viable density (Table 1; Service 1994a). Updated trend analysis scheduled following the 2020 field season was postponed due to cancellation of field work and collection of necessary data in much of the range as a result of the COVID-19 pandemic. In the meantime and as expected, some annual density estimates in TCAs since 2014 have been higher and some lower than projected from past trends (McLuckie *et al*. 2018; Service 2016, 2018a, 2019, 2020a). An upcoming analysis of trends (with at least three more years of annual data in each TCA) is expected to refine our current working understanding of trends in each TCA and recovery unit but not to substantively change patterns described in the previous analysis because population growth in this long-lived species will be slow (Service 1994a).

Spatial population viability analysis using data from 12 capture-recapture plots in Nevada, Arizona, and Utah found negative population growth and higher probabilities of local extinction in the vicinity and north of Eldorado Valley between 1977 and 2003 (Harju 2019). This regional negative trend has continued since 2004 (Table 1). Unfortunately, data that would allow a more comprehensive spatial analysis including California have not been made available, but recent analyses of local or regional populations in California show that population levels and trends can vary markedly within TCAs and over time. For example, following declines in the 1990s, tortoise density within the Desert Tortoise Research Natural Area (DTRNA) on the northwestern edge of Fremont-Kramer had increased to roughly 2.5 times densities outside the DTRNA by 2012 (Berry *et al*. 2020). This difference was associated with a greater degree of protection inside the DTRNA than in adjacent critical habitat and private lands (Berry *et al*. 2014). Meanwhile, estimated tortoise numbers declined by over 75% on a 2.59-km^2 plot within Joshua Tree National Park between 1996 and 2012, largely as a result of reduced survival from 1997 to 2002 that was concurrent with persistent drought (Lovich *et al*. 2014). Increases in annual survival of tortoises on the plot following 2002 coincide with increasing trends in average density across the park between 2004 and 2014 (Table 1).

Table 1. Annual trends in adult (≥180 mm midline carapace length) tortoise density (km^{-2}) within each recovery unit and monitored Tortoise Conservation Area (TCA) and estimated changes in total adult tortoise abundance within each recovery unit between 2004 and 2014 (Allison and McLuckie 2018). Superscripts in TCA names represent label codes used in Figure 8.

Recovery Unit / TCA	Annual Trend	Modeled Habitat (km^2)	2004 Abundance	2014 Abundance	Change in Abundance, 2004–2014	Mean Density in 2014 from Trend
Western Mojave RU	–7.1%	23,139	131,540	64,871	–66,668	
Fremont-Kramer[FK]	–6.8%			6,196		2.6
Ord-Rodman[OR]	–8.2%			3,064		3.6
Superior-Cronese[SC]	–9.3%			7,398		2.4
Colorado Desert RU	–4.5%	18,024	103,675	66,097	–37,578	
Chocolate Mountain[AG]	–3.3%			5,146		2.8
Chuckwalla[CK]	–4.1%			9,304		3.3
Chemehuevi[CM]	–10.8%			10,469		2.8
Fenner[FE]	–7.3%			8,517		4.8
Joshua Tree[JT]	6.2%			4,319		3.7
Pinto Mountains[PT]	–8.3%			1,241		2.4
Piute Valley[PV]	4.4%			4,874		5.3
Eastern Mojave RU	–11.2%	16,061	75,342	24,664	–50,679	
Eldorado Valley[EV]	–9.2%			1,543		1.5
Ivanpah[IV]	–7.4%			5,578		2.3
Northeastern Mojave RU	13.1%	10,664	12,610	46,701	34,091	
Beaver Dam Slope[BD]	22.2%			18,220		6.2
Coyote Springs Valley[CS]	10.2%			3,801		4.0
Gold Butte-Pakoon[GB]	14.4%			4,278		2.7
Mormon Mesa[MM]	8.2%			5,432		6.4
Upper Virgin River RU	–3.2%	613	13,226	10,010	–3,216	
Red Cliffs Desert Reserve[RC]	–3.2%			1,760		15.3
Total		68,501	336,393	212,343	–124,050	

Most Mojave Desert Tortoise populations east of the Colorado River have not been monitored extensively. However, a 1-mi^2 mark-recapture plot on the eastern bajada of the Black Mountains (EB) was surveyed six times between 1990 and 2017, and a similar plot in the foothills of the Hualapai Mountains (HF) was surveyed five times between 1991 and 2016. Most genotyped tortoises at EB were identified as *G. agassizii* with some hybrids, while genotyped tortoises at HF were a mix of hybrids and *G. morafkai* (Fig. 1; Edwards *et al*. 2015; Dolby 2020).

The average adult survival rate through 2007 at EB and HF were among the lowest (0.87 and 0.89, respectively) across 15 plots in Arizona, the rest of which are populated by Sonoran Desert Tortoises (Zylstra *et al*. 2013). The period of lowest survival coincided with extreme drought, and cumulative survival of adult tortoises during the drought period (0.30 and 0.34 at EB and HF, respectively) indicated that abundance of adults was reduced by over 50% during that time (Zylstra *et al*. 2013). Estimated abundance at EB dropped from about 60–70 adult tortoises during the 1990s to 9 adults in 2002 (Woodman *et al*. 2008); since then, abundance has increased to ~35 adults (Rubke and O'Donnell 2019). Abundance at HF in 2005 (estimated 12 adults) had dropped from estimates of greater than 30 adult tortoises in the 1990s (Woodman *et al*. 2006) before increasing back to ~25 adults in 2016 (Rubke *et al*. 2017). The most recent density estimates were 10.3 adults/km^2 and 7.3 adults/km^2 at EB and HF, respectively (Rubke *et al*. 2017; Rubke and O'Donnell 2019). These densities are substantially greater than mean 2014 densities in the adjacent TCAs to the west (Eldorado, Fenner, Chemehuevi; Table 1), although densities on the plots are not necessarily representative of broader, regional densities because the plots were selected largely due to the relative ease of finding tortoises (Averill-Murray 2000).

Another 1-mi^2 mark-recapture plot in the Buck Mountains was surveyed in 2002, 2005, and 2010 (EcoPlan Associates 2011). Most genotyped tortoises on this plot were identified as hybrids with some *G. agassizii* (Fig. 1; Edwards *et al*. 2015; Dolby 2020). Fewer tortoises occupy this plot than EB or HF, and abundance appears to have declined between each survey, from 21 to 17 to 13 adult tortoises, respectively; the estimates are imprecise, so interpretations of a trend from these three data points should be made with caution (EcoPlan Associates 2011).

Threats Analysis

The 2010 status review noted that the approach of focusing on individual threats may not have produced expected gains toward desert tortoise recovery because multiple threats act simultaneously to suppress tortoise populations at any given location within the species' range. The 2011 revised recovery plan emphasized expanding the understanding of multiple and combined effects of threats on tortoise populations. A model of these inter-relationships was developed as the basis of a spatial decision support system to help prioritize implementation of management actions that would provide the greatest benefit to recovery (Darst *et al*. 2013).

The decision support system produced rankings of threats that affect—and recovery actions that would benefit—each TCA across the range (Service 2014a, b, c). Individual threats vary widely among each of the TCAs, which is apparent in the number of threats that rank within the top five within one or more TCAs despite having an average rank in the bottom half of threats across all TCAs (Fig. 4). However, the types of recovery actions that would have the greatest effect in reducing or eliminating the cumulative risk from threats across the desert tortoise's range fall within a relatively narrow set (Fig. 5). As a result, the Desert Tortoise Management Oversight Group (MOG) endorsed the top five range-wide recovery actions (i.e., restore habitat, education, decrease human subsidies, targeted predator control, and installing barrier fencing along highways) as the highest priorities for implementation (Lohoefener 2015). The MOG subsequently added fire management planning and implementation to their list of priorities given its preventative relationship with the need for habitat restoration (Souza 2017).

The condition of most threats is similar to that described in the previous status review, but the spatial decision support system provided a better understanding of the relative importance of threats and recovery actions to desert tortoise populations. The following review describes substantive new information since 2011 relative to changes in threats, conservation measures, and regulatory mechanisms that pertain to the five listing factors outlined in section 4(a)(1) of the Act. Each section begins with the extracted summary of threats from the previous status review for reference.

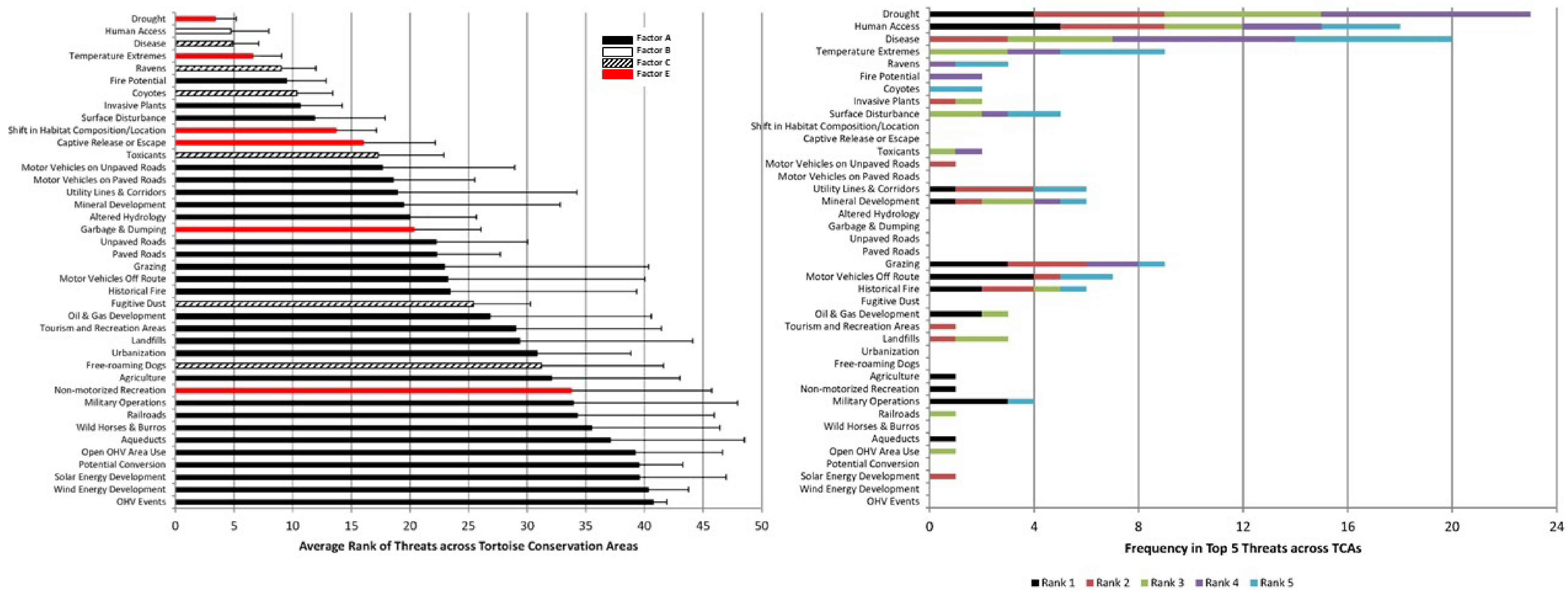

Figure 4. Mean rank plus one standard deviation of threats to desert tortoise populations (left) and the frequency that each threat appears in the top-five ranking (right) across 28 Tortoise Conservation Areas (TCAs), as modeled in the desert tortoise spatial decision support system (from Service 2014a, b, c).

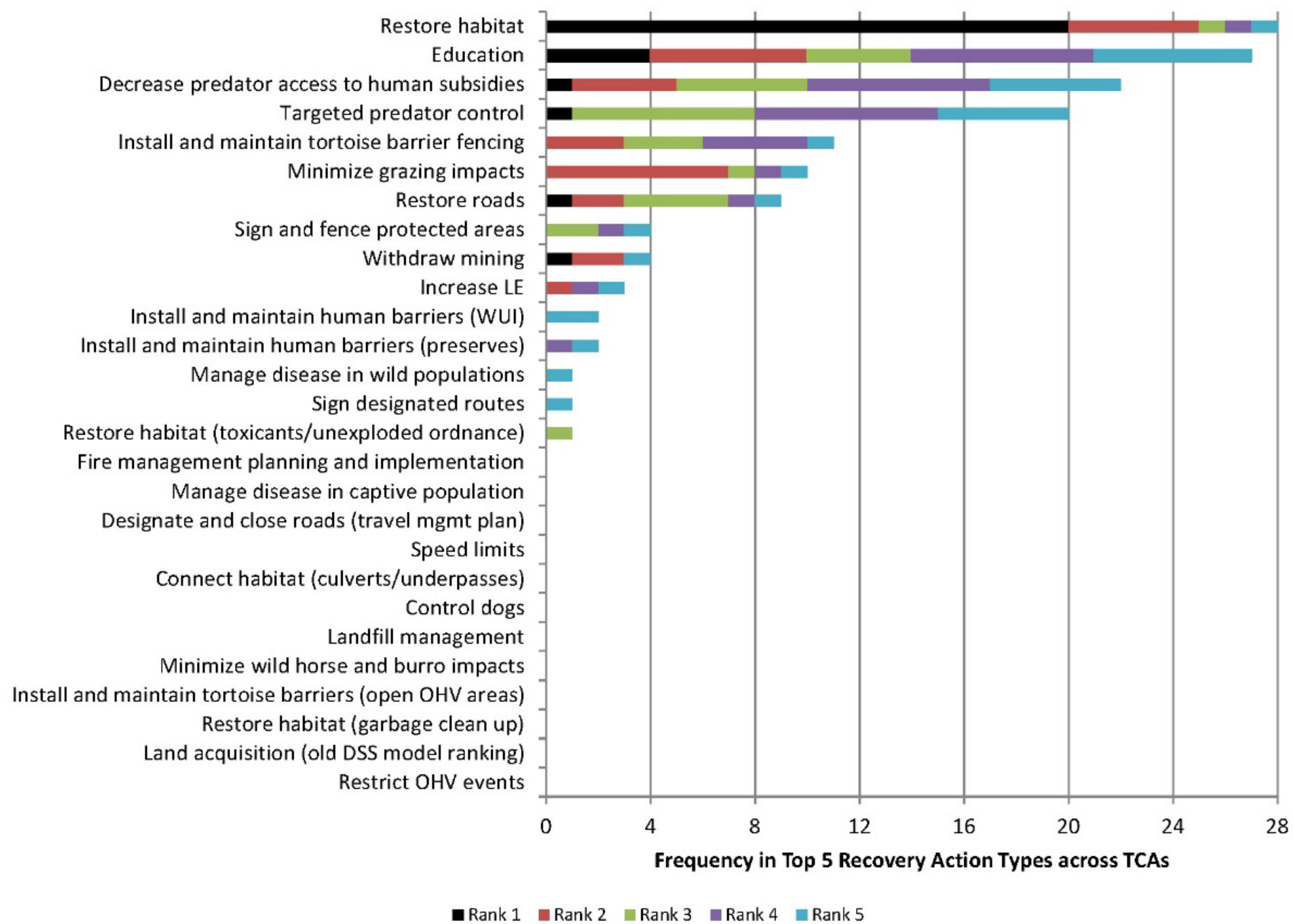

Figure 5. Frequency that each recovery action type appears in the top-five ranking across 28 Tortoise Conservation Areas (TCAs), as modeled in the desert tortoise spatial decision support system (from Service 2014a, b, c).

Factor A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range
Summary from Service (2010a)*: Since the time of listing, many threats associated with Factor A continue to impact the desert tortoise. In particular, human populations, paved and unpaved roads, non-native invasive plants and the associated threat of wildfire, and prospective energy development (especially renewable energy development and associated utility corridors) have increased. These threats result in continued habitat loss, population fragmentation, nutritional compromise, soil erosion, and indirect impacts associated with increased human presence, including illegal dumping, human-subsidies for predators, and introduction of toxins. Since the time of listing, off-highway vehicle areas and trails have been formally designated, but unauthorized use continues to be a significant source of habitat degradation. Many grazing allotments within Critical Habitat have been retired; however large areas are also still grazed.*

Range-wide, the absolute amount of desert tortoise habitat lost (north and west of the Colorado River) decreased from 93,071 acres lost in the six years prior to publication of the revised recovery plan (2005–2010) to 70,671 acres lost in the six years following publication of the revised recovery plan (2012–2017; calculated from data from Eichenwald *et al*. [2020] who estimated habitat loss from LandSat imagery by sudden changes in the trend of the normalized difference vegetation index [NDVI] at image pixels over time). Only three of the top 12 ranked threats within TCAs are directly related to Factor A (Fig. 4; Service 2014a, b, c). However, the cumulative importance of habitat-related threats is demonstrated by the fact that most recovery action types that are ranked in the top five in any TCA directly address habitat (Fig. 5). In addition, threats under this factor remain important because large expanses of high-quality habitat are necessary to provide resilience to populations as they fluctuate due to threats under the other listing factors, such as variability in precipitation patterns; localized declines attributed to drought, disease, or predation events; or stochastic population dynamics (Averill-Murray *et al*. 2021). As habitat is lost and fragmented, habitat patches become smaller, patch populations (e.g., clusters of tortoises) have fewer tortoises and become more disjunct, extinction probabilities within patches increase, and the number of occupied patches decreases (Fahrig 2002; Ovaskainen *et al*. 2002).

Of particular note since the completion of the previous 5-year review, large areas of desert tortoise habitat have been developed or approved for development for utility-scale solar energy. These developments are located outside of TCAs, but in aggregate they would result in development of approximately 74,000 acres of desert tortoise habitat (Table 2; Fig. 6). In fact, solar energy development is the second-ranked threat in the Boulder City Conservation Easement, and it is the top threat outside of TCAs within the Northeast Mojave Recovery Implementation Team's Southeastern Nevada Workgroup area (Service 2014b). Solar development has increased dramatically within the Northeastern Mojave Recovery Unit in the last three years (Fig. 6). To minimize the impacts of such developments, construction of projects in Nevada increasingly have allowed native vegetation to regrow and desert tortoises to reoccupy the sites (approximately 13,000 acres), although the success of this approach in maintaining functional habitat remains to be determined.

Table 2. List of solar projects and impacted acreage that have received biological opinions or incidental take permits, 2010–2021. Asterisks indicate projects allowing vegetation to regrow and desert tortoises to reoccupy the sites.

Recovery Unit	Project	Habitat (acres)	Citation
Eastern Mojave			
	Ivanpah Solar Electric Generating System	3,582	Service 2011b
	Stateline	1,685	Service 2013a
	Silver State North	685	Service 2010b
	Silver State South	2,427	Service 2013a
	Nevada Solar One	400	Burroughs 2012
	Copper Mountain North	1,400	Burroughs 2012
	Copper Mountain	380	Burroughs 2012
	Townsite	885	Service 2014d
	Techren Boulder City	2,200	Service 2012b
	Valley Electric Association*	80	Service 2015a
	Canyon Mesa*	123	Service 2019b
	Yellow Pine	4,285	Service 2020b
Subtotal		**18,132**	
Western Mojave			
	Mojave	0[a]	Service 2011c
	Cinco	500	Service 2015b
	Soda Mountain	1,726	Service 2015c
	High Desert	547	Service 2019c
Subtotal		**2,773**	
Northeastern Mojave			
	Res Americas Moapa Solar Energy Center	951	Service 2014e
	Moapa K Road	2,141	Service 2012c
	Playa	1,538	Service 2015d
	Invenergy Harry Allen	594	Service 2015d
	NV Energy Dry Lake Solar Energy Center	751	Service 2015d
	NV Energy Dry Lake Solar Energy Center at Harry Allen	55	Service 2015d
	Aiya	672	Service 2015e
	Mountainview	146	Wise 2018
	Gemini*[65%]	7,113	Service 2019d
	Eagle Shadow Mountain*	2,285	Service 2019e
	Arrow Canyon Solar Project*	2,124	Service 2020c
	Southern Bighorn Solar 1 Project*	2,642	Service 2021b
	Southern Bighorn Solar 2 Project*	1,025	Service 2021c
Subtotal		**22,037**	
Colorado Desert			
	Genesis	1,774	Service 2010c
	Blythe	6,958	Service 2010d
	Desert Sunlight	4,004	Service 2011d
	McCoy	4,533	Service 2013b
	Desert Harvest	1,300	Service 2013c
	Rice	1,368	Service 2011e
	Palen	3,140	Service 2018b
	Desert Quartzite	2,831	Service 2019f
	IP Athos	3,440	Service 2019g
	Crimson	2,201	Service 2020d
Subtotal		**31,549**	
Grand Total		**74,491**	

[a]Primarily in abandoned agricultural fields

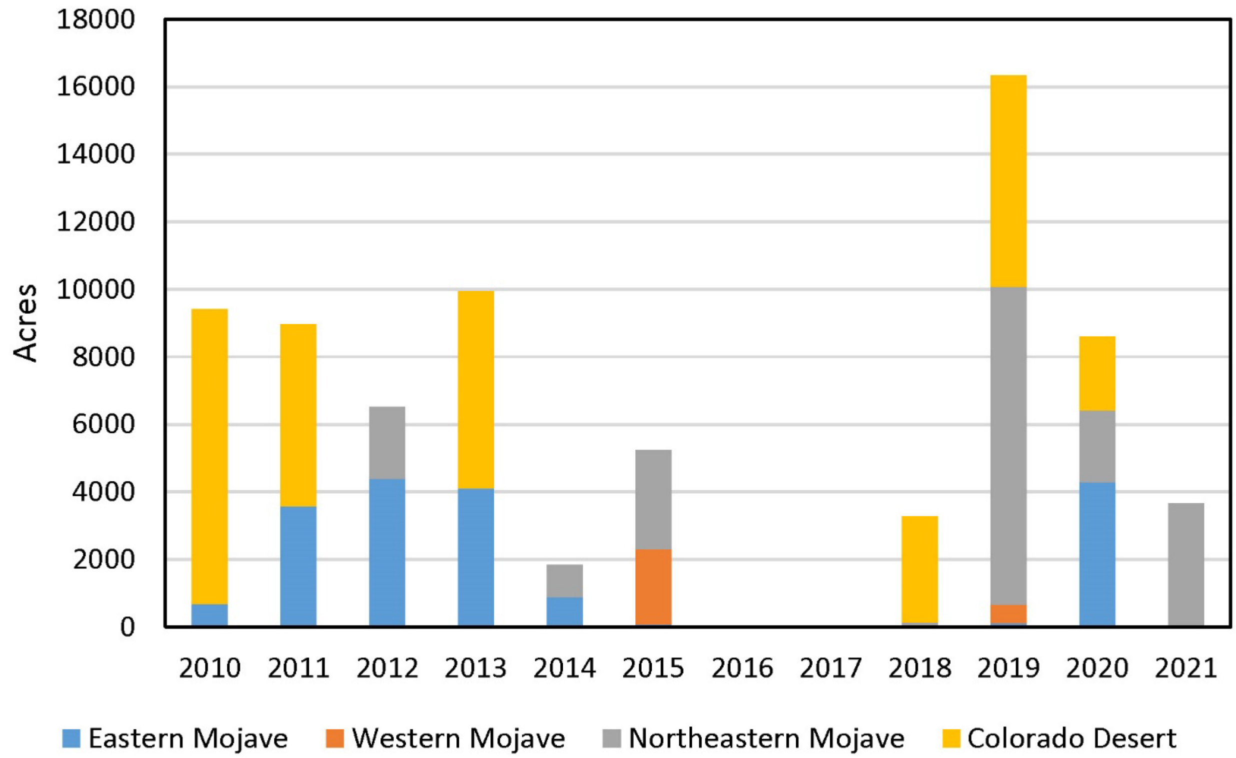

Figure 6. Acreage for solar projects within each recovery unit that have received biological opinions or incidental take permits, 2010–2021.

The Desert Renewable Energy and Conversation Plan (DRECP) Land Use Plan Amendment to the California Desert Conservation Act Plan of 1980 resulted in the designation of approximately 388,000 acres of development focus areas where the Bureau of Land Management would apply a streamlined review process to applications for projects that generate renewable energy; the Bureau estimated that approximately 11,290 acres of modeled desert tortoise habitat within the development focus areas would eventually be developed for renewable energy (U.S. Bureau of Land Management 2016). The Bureau also adopted numerous conservation and management actions as part of the plan amendment. Chief among these was the establishment of new limits on ground-disturbance activities (past, present, and future) of 0.1–1.0% relative to total Bureau of Land Management lands within TCAs and mapped linkages between TCAs. In addition, all activities, except transmission, that will result in the long-term removal of habitat supporting more than five tortoises at least 160 mm carapace length per square mile, or more than 35 individuals in total, are prohibited; the upper limit is five total individuals for projects within TCAs or mapped population linkages. The number of desert tortoises on a site will be based on estimates derived from the protocol surveys described previously using the USFWS's pre-activity survey protocol. The land-use plan amendment also increased the amount of land that the Bureau manages for conservation in California (e.g., areas of critical environmental concern, California Desert National Conservation Lands, etc.) from 6,118,135 to 8,689,669 acres, although not all of the areas subject to increased protection are within desert tortoise habitat (U.S. Bureau of Land Management 2016a). The Bureau will also manage lands outside of development focus areas according to numerous conservation and management actions that are more protective of desert tortoises than direction contained in the previous land use plan.

Additional military training-land expansions have also occurred or have been approved. The Department of the Army (Army) expanded training onto 18,197 acres of designated critical habitat on the southern area of Fort Irwin that had previously been off-limits to training, thus requiring the translocation of approximately 650 adult desert tortoises (Service 2012a). To help offset the effects of this habitat loss, the Army acquired approximately 100,000 acres of non-federal land within the Superior-Cronese Critical Habitat Unit for conservation management of desert tortoises. It also purchased the base property of three cattle allotments on which the Bureau subsequently re-allotted the forage to wildlife. The Army also funded several other activities aimed at conserving desert tortoises in the Western Mojave Recovery Unit. In addition, the Army plans to expand activities onto and displace tortoises from up to 62,045 acres of its western training area in the near future, which is designated critical habitat and currently off-limits to training.

The Department of the Navy (Navy) expanded training for the Marine Corps Air Ground Combat Center (MCAGCC) at Twentynine Palms into approximately 167,982 acres of public and private land, which required translocating approximately 1,000 adult tortoises (Service 2017). Most of the expansion area lies within the Johnson Valley Off-highway Vehicle Recreation Area. To help offset the effects of habitat loss, the Navy committed to funding several activities aimed at conserving desert tortoises, particularly within the Ord-Rodman Critical Habitat Unit into which many tortoises from the expansion area were translocated. These measures include establishment of special use areas on MCAGCC with limited surface-disturbing military activities, increased law enforcement in the Ord-Rodman Critical Habitat Unit, predator monitoring and targeted control within translocation sites, rehabilitation of closed routes, and installation of off-highway-vehicle barriers and desert tortoise exclusion fencing, among other activities.

The 26,509-acre Cuddeback Range expansion area on the Naval Air Weapons Station at China Lake includes approximately 2,777 acres of tortoise habitat. The Cuddeback Range lies within the Superior-Cronese Critical Habitat Unit, but all of the disturbance would occur in a previously disturbed area that the U.S. Air Force historically used as a target zone. The Navy will include the entire Cuddeback Range in its Integrated Natural Resource Management Plan and construct a perimeter fence around the range to prevent trespass by the public. These actions will provide conservation benefits for plants, fish, and wildlife within the area, including the desert tortoise. Because the Navy will not disturb most of the area, it did not translocate any desert tortoises as part of this action (Service 2019h).

Invasive grass-fueled wildfires remain a concern across much of the tortoise's range. For example, the Meadow Valley Fire burned approximately 23,500 acres of desert tortoise habitat (none in designated critical habitat) in the Bureau of Land Management's Caliente Field Office jurisdiction in July 2020. Most of this overlapped habitat that burned in 2005, further complicating recovery of that area, and about 800 acres of previously unburned habitat were affected by the new fire (A. Delcalzo, personal communication, 2021). In addition, multiple fires burned over 11,000 acres and killed at least 25 tortoises in the Red Cliffs Desert Reserve (Upper Virgin River Recovery Unit) in July 2020 (McLuckie *et al*. 2021). These fires represent approximately 20% of the Upper Virgin River Critical Habitat Unit. About 1/3 of the area had been previously unburned (McLuckie *et al*. 2021 [from oral presentation]). In California, the August 2020 Dome Fire in Mojave National Preserve burned 43,273 acres of peripheral (higher elevation) tortoise habitat (National Park Service 2020). All of these fires were fueled at least in part by invasive annual *Bromus* grasses. While the distribution of *Bromus rubens* is expected to increase under a warming climate, drier winters may weaken the *Bromus*-fire cycle (Bradley *et al*. 2016).

In addition to the well-publicized trespass grazing that continues in the Gold Butte-Pakoon TCA, livestock grazing continues to be authorized in the Grand Canyon-Parashant National Monument, Arizona; Beaver Dam Wash National Conservation Area, Utah; Mojave National Preserve, California; and other TCAs across the range, including Bureau of Land Management-managed lands outside of the national monuments in Arizona, California, and Utah (e.g., U.S. Bureau of Land Management 2008, 2016b, 2019a; U.S. Bureau of Land Management and National Park Service 2008). East of the Colorado River, livestock grazing occurs in tortoise habitat managed by both the Bureau of Land Management and the Arizona State Land Department. Additionally, invasive grass-fueled wildfires are a concern in this area, similar to the rest of the tortoise's range. Threat simulations for tortoises in the Gold Butte-Pakoon area indicated that the combined effect of legal and illegal livestock grazing and feral burro disturbances caused the more severe declines in tortoise abundance relative to human presence, subsidized predators, and wildfire (Tuma *et al*. 2016).

A new threat is the recent and rapid increase in illegal cannabis farms in the Mojave Desert, primarily since 2016 in southern California (Cosgrove and Sahagún 2021). For example, San Bernardino sheriff's deputies recently documented 860 illegal farms in that county alone. Many of these occur within or adjacent to designated critical habitat. Bulldozers typically scrape the vegetation and topsoil into berms to prepare the sites for greenhouses, and water is often stolen from agricultural wells, aqueducts, or hydrants for irrigation. The problem has become so severe that the California Department of Fish and Wildlife recently solicited grant proposals for cleanup and remediation of environmental damage in watersheds affected by illicit cannabis cultivation on government lands (California Department of Fish and Wildlife 2021).

Overall, desert tortoises do not coexist well with human development and disturbances; tortoises are essentially absent from habitat within 1 km of areas with greater than 10% development (including urban development, cultivated agriculture, energy development, surface mines and quarries, pipelines and transmission lines, and roads and railroads; Carter *et al*. 2020). Across both sides of the Colorado River, only 5% of modeled Mojave Desert Tortoise habitat had levels of development exceeding this threshold (Carter *et al*. 2020), so space does not appear to be a limiting factor to tortoise recovery. Parsing these data by recovery unit shows that at least 39% of tortoise habitat in each recovery unit has almost no development within 1 km (Table 3; Fig. 7). The Upper Virgin River Recovery Unit has the highest proportion of developed tortoise habitat with 14% of habitat occurring within 1 km of lands that have been developed more than 10% (Table 3; Fig. 7), and habitat affected by development is only likely to increase further with ongoing urban growth in Washington County.

Specific to roads, all tortoise populations declined in TCAs with route densities (paved and unpaved) above 0.75 km/km^2, although there was much variation in tortoise population trends at lower route densities (Fig. 8). Potential construction of approximately 6.9 km of multi-lane highway near the southern boundary of the Red Cliffs Desert Reserve (U.S. Bureau of Land Management 2021) is an example of development that would encroach on quality tortoise habitat if constructed. Managing development and habitat disturbances is primarily important relative to maintaining connectivity of inter-connected blocks of tortoise habitat (Averill-Murray *et al*. 2021), while improving tortoise survival and recruitment requires managing the threats that affect tortoise mortality and the quality of habitat within those blocks. We note that the national roads database used in the analyses mentioned here lacks the accuracy of smaller-scaled local datasets, especially under-representing unauthorized, unpaved routes (Carr *et al*. 2017). However, unpaved routes typically pose problems of mitigating habitat degradation rather than absolute habitat loss, although some degree of absolute habitat loss ultimately will be associated with the expansion of the Spangler, El Mirage, and Johnson Valley off-highway vehicle (OHV) recreation areas under the 2019 John D. Dingell, Jr. Conservation, Management, and Recreation Act as OHV use and trails increase in those areas.

Table 3. Proportion of Mojave Desert Tortoise habitat with ≤1% or >10% human development within 1 km. Proportions are given for each recovery unit overall, within protected areas[1], and within habitat outside the protected areas (Unprotected) as calculated from the development index of Carter *et al*. (2020).

Recovery Unit	<1% (within overall unit)	>10% (within overall unit)	<1% (within protected areas1)	>10% (within protected areas1)	<1% (within unprotected areas)	>10% (within unprotected areas)
Upper Virgin River	0.39	0.14	0.45	0.07	0.38	0.15
Northeastern Mojave	0.66	0.05	0.79	0.00	0.57	0.09
Eastern Mojave	0.58	0.05	0.74	0.00	0.45	0.09
Western Mojave	0.47	0.05	0.81	0.01	0.39	0.07
Colorado Desert	0.65	0.04	0.74	0.01	0.54	0.09
Mohave County, AZ[2]	0.58	0.04	0.84	0.01	0.51	0.05

[1] Includes wilderness areas, national parks, national monuments, and national conservation areas designated as GAP Analysis Project status 1 and 2 protected areas (U.S. Geological Survey 2020).

[2] Includes habitat for both Mojave Desert Tortoises and Sonoran Desert Tortoises south and east of the Colorado River (i.e., outside the current range listed under the Act).

Counter to the threats documented above, President Obama designated the 1.6 million-acre Mojave Trails National Monument in 2016 (Obama 2016). Much of the monument includes designated wilderness or other lands managed for conservation (e.g., parts of the Fenner and Chemehuevi critical habitat units), but it also includes almost 267,000 acres of lands that had previously been acquired by The Wildlands Conservancy and donated to the Bureau of Land Management (The Wildlands Conservancy 2021). The monument also adds a layer of protection to much of the modeled tortoise habitat linkage between the Superior-Cronese and Ord-Rodman critical habitat units in the Western Mojave Recovery Unit and the Mojave National Preserve in the Eastern Mojave Recovery Unit (*cf.* Averill-Murray *et al*. 2013).

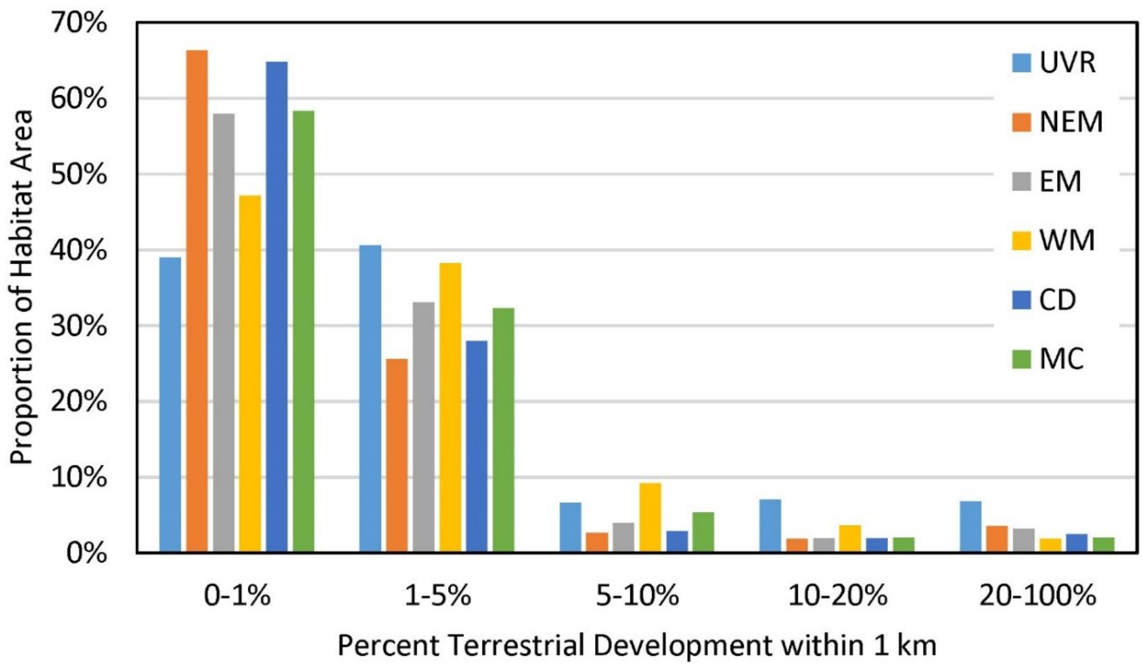

Figure 7. Frequency distribution of development levels for Mojave Desert Tortoise habitat within each recovery unit and Mohave County as calculated from the development index of Carter *et al*. (2020). UVR = Upper Virgin River, NEM = Northeastern Mojave Desert, EM = Eastern Mojave Desert, WM = Western Mojave Desert, CD = Colorado Desert, MC = Mohave County, Arizona (including habitat modeled for both Mojave Desert Tortoises and Sonoran Desert Tortoises south and east of the Colorado River).

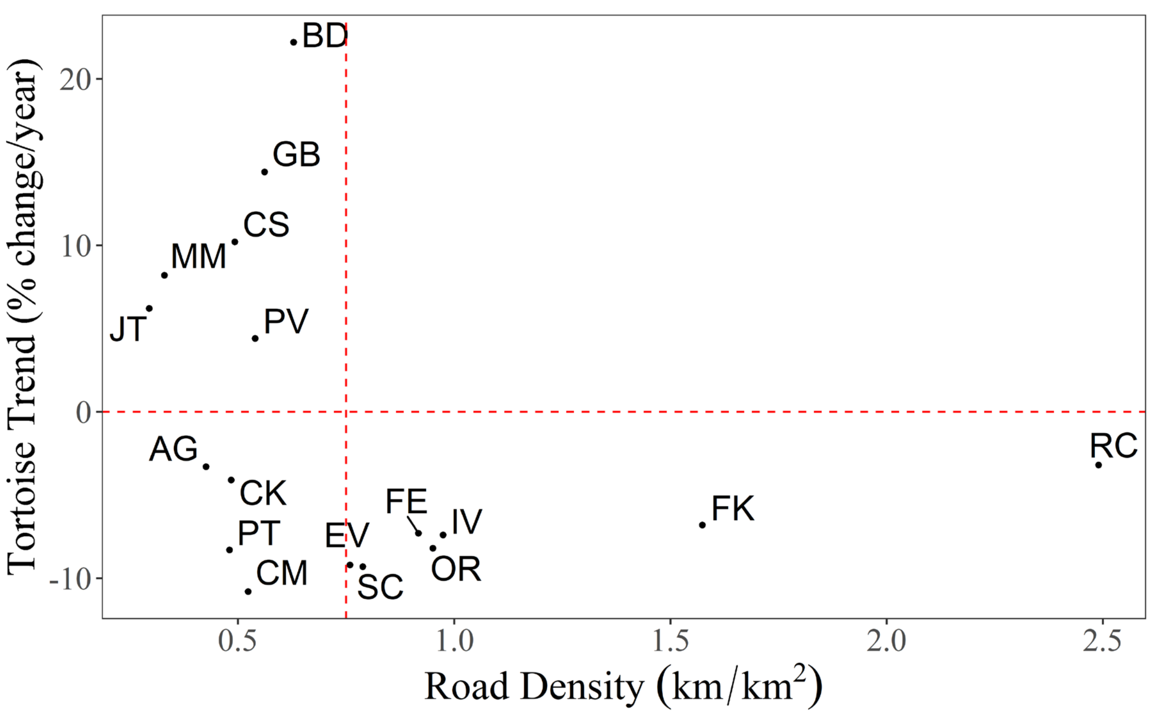

Figure 8. Population trends of Mojave Desert Tortoises plotted against density of paved and unpaved roads within Tortoise Conservation Areas. Codes are given in Table 1.

Much work also is ongoing to address the MOG's priorities related to habitat restoration and reduction of roadkill via installation of tortoise barrier fencing along highways. Numerous habitat restoration projects by State and federal agencies, local governments, and non-governmental organizations are in progress or planned in every recovery unit. These projects address threats including invasive plants, fire potential, unpaved roads, and surface disturbance, although the range-wide scale of the threats still outweighs the cumulative scope of the current projects. Through 2011 approximately 1,660 km of highway roadside (including both sides of roads for those fenced on each side) had tortoise exclusion fencing installed to prevent road mortalities. Unfortunately, only approximately 43 km of roadside have been fenced in the decade since 2011. Almost 500 km of roadside have been identified as priorities for fencing based on our current understanding of road-effect zone area, relative habitat potential, and locations of extant populations (Holcomb 2019). Finally, the Department of Defense and Department of the Interior recently initiated a Recovery and Sustainment Partnership (DOD and DOI 2018). In this partnership, DOD and DOI developed an action plan for the Mojave Desert Tortoise with the goal to implement actions that would accelerate recovery of the tortoise while reducing the regulatory burden on DOD installations (DOD and DOI 2019). An implementation plan is in development which focuses on identifying ways to accelerate habitat restoration, fencing conservation areas and roadways, and addressing unauthorized routes in the Western Mojave Desert Recovery Unit.

Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes
Summary from Service (2010a): *Little quantitative evidence regarding collection and deliberate maiming and killing of desert tortoise by humans has been obtained since time of listing, and the relative significance of this threat remains unknown.*

Little new information on threats under Factor B has become available since the most recent status review. However, the potential for negative impacts to desert tortoise populations on either side of the Colorado River exists from collection and deliberate maiming/killing as a result of human access, vehicles on paved/unpaved roads, and non-motorized recreation (Fig. 4; Grandmaison and Frary 2012). Various research activities are permitted for purposes of enhancing the recovery and conservation of the desert tortoise. These activities provide valuable information that can be used to recover and improve management of the desert tortoise, resulting in few cases of unintentional injury or mortality based on past experience and the protective measures imposed upon all permittees (Service 2013d).

Factor C: Disease or Predation
Summary from Service (2010a): *The available evidence indicates that upper respiratory tract disease is probably the most important infectious disease for desert tortoises, and external factors, such as environmental contaminants and drought, may increase susceptibility. However, additional research is needed to clarify the role of disease in desert tortoise population dynamics relative to other threats. Ravens and coyotes have dramatically increased in the desert southwest over the past 25 years due to anthropogenic subsidization and have been commonly implicated in tortoise predation. Instances of isolated, very intense predation suggest predation comes to the forefront as a management concern, especially where landscapes have been altered and intensive human use occurs or in times of extreme drought. The population-level effects of these or other predators, however, are unknown.*

Disease was the third-ranked threat across TCAs (Fig. 4), and much has been published since 2011 (Appendix). The most common pathogen (*Mycoplasma agassizii*) and cause of upper respiratory tract disease (URTD) has been found in populations across the desert tortoise's range north and west of the Colorado River (Sandmeier *et al*. 2013; Weitzman *et al*. 2017). Less sampling of Mojave Desert Tortoises east of the Colorado River has been done, but visual signs of URTD have been rare on the EB, HF, and Buck Mountains plots, although one tortoise at HF had antibodies to *M. agassizii* in 2005 (EcoPlan Associates 2011; Rubke *et al*. 2017; Rubke and O'Donnell 2019). The host-disease relationship is complex: high transmission rates usually require extensive contact between tortoises over multiple days (Aiello *et al*. 2016); responses to infection and infection patterns over time can be highly variable, including recurrence of disease from subclinical infections (Sandmeier *et al*. 2017; Aiello *et al*. 2018); and multiple factors may contribute to outbreaks of URTD include environmental stress, human impacts, exposure to heavy metals and other toxicants, and the escape or release of captive tortoises (Jacobson *et al*. 2014). Collectively, current research suggests that direct disease management of wild tortoise populations is less important (other than in translocations of tortoises between populations) than managing factors that affect their habitat and its capacity to support healthy tortoises (i.e., under Factor A). For example, *Bromus rubens* negatively affects health and survival of juvenile desert tortoises (Drake *et al*. 2016).

Since 2011, badgers have emerged as a predator that can exert severe effects at the local level (Embledge *et al*. 2015). Also, a study of coyote diets suggested that tortoises are opportunistically consumed consistently at low levels over time and under variable environmental conditions (Cypher *et al*. 2018). Population impacts may be higher near human settlements where coyotes are subsidized by human food items, however (Esque *et al*. 2010; Cypher *et al*. 2018). The proportion of predator (coyote, kit fox, raven, dog, red-tailed hawk) scats containing tortoise DNA suggests that tortoises could be consumed at higher rates than previously estimated through morphological analysis of scat (Boarman and Kristan 2018). As mentioned under Factor A, habitat fragmentation can exacerbate local declines caused by elevated predation because as tortoise populations become more disjunct, extinction probabilities within patches increase due to the lack of immigration from adjacent populations (Averill-Murray *et al*. 2021). Meanwhile, scientists continue to attribute predation by tremendously inflated raven populations, subsidized by human food and water sources, to unsustainable pressure on tortoise recruitment (Holcomb *et al. accepted*), and raven control recently has been expanded within designated critical habitat in California to focus on broad-scale removal of ravens. New tools also are now being applied to address this threat, including oiling raven eggs to prevent hatching and applying demographic models to guide efforts in reducing raven numbers (Shields *et al*. 2019; Hanley *et al. accepted;* Holcomb *et al. accepted*). Predation has not been a substantial mortality factor for tortoises at the HF or Buck Mountains plots (EcoPlan Associates 2011; Rubke *et al*. 2017). Evidence of attacks by free-roaming dogs or other canids at EB were common during the 1990s, but such predation has been less apparent since at least 2007 (Woodman *et al*. 2008; Rubke and O'Donnell 2019).

<u>Factor D: Inadequacy of Existing Regulatory Mechanisms</u>
Summary from Service (2010a): *There are Federal and State regulatory mechanisms which provide discretionary protections for the desert tortoise based on current management direction,*

but with the exception of the California Fish and Game Code, none guarantee protection absent the Endangered Species Act. While many land use plans completed since time of listing include language specific to protection of the tortoise, land management agencies frequently do not have sufficient funding to enforce their land use regulations, and personnel are often spread across vast landscapes with multiple resource responsibilities.

In October 2020, the California Fish and Game Commission designated the Mojave Desert Tortoise a candidate species for Endangered status under the California Endangered Species Act in response to a petition to uplist the species from Threatened status. A final decision on the listing status was expected by 21 October 2021 (California Fish and Game Commission 2020). However, an uplisted status designation will not carry any additional regulatory protections under the California Endangered Species Act (L. Patterson, personal communication, 2021).

As noted under Factor A, the DRECP in California established more restrictive caps and other limitations on new surface disturbance on public lands within TCAs and desert tortoise linkages. However, the summary from the previous status review remains generally applicable today, including for populations east of the Colorado River. Law enforcement has an average ranking of 7.1 among 27 recovery action types across TCAs (calculated from Service 2014a, b, c). The shortage in law enforcement is exemplified by a number of examples:

- Difficulties in improving compliance with off-highway-vehicle travel have led to 24,518 km of ground transportation linear features in the western Mojave planning area, which is greater than 2.5 times the 9,651 km currently designated as open/limited (U.S. Bureau of Land Management 2019a, b).
- Unauthorized and unregulated development is occurring in occupied tortoise habitat on private lands in northwest Mohave County, Arizona (Service 2019i).
- The Bureau of Land Management has been unable to remove trespass cattle from the Gold Butte National Monument and adjacent areas for over two decades, leading to the well-publicized armed stand-off during an attempted roundup in April 2014.
- Authorities have warned the public to avoid all the illegal cannabis farms across the Mojave Desert because resources are insufficient to deal with them (Cosgrove and Sahagún 2021). Illegal cannabis farms have already led to the cessation of raven monitoring and management efforts in the Fremont-Kramer Critical Habitat Unit in 2021, with the likelihood that tortoise monitoring in the same unit scheduled for 2022 will be cancelled due to safety concerns for field workers.

Factor E: Other Natural or Manmade Factors Affecting its Continued Existence

Summary from Service (2010a): *Captive releases continue to have the potential to introduce disease and genetic contamination into wild populations of desert tortoises, although the magnitude of such releases and their effects on tortoise populations remains unknown. Since the time of listing, it has become apparent that the combined effects of global climate change (i.e., increased ambient temperatures and altered precipitation patterns) and drought may become significant factors in the long-term persistence of the species. Little is known regarding direct effects of climate change on the desert tortoise and its habitat, although increased drought will likely affect desert tortoises, directly through habitat loss and indirectly through decreased availability/quality of food and increased predation and possibly disease. Little information is available on the actual or relative impacts of other potential threats documented under Factor E.*

Three of the top 10-ranked threats are associated with Factor E, specifically climate change (Fig. 4). The climate in the southwestern U.S. from 2000 through 2021 was the driest 22-year period in over 1200 years and is predicted to continue through 2022 and likely beyond (Williams *et al.* 2022). Questions remain about the effect of increased temperatures on hatchling sex ratios and about the effect of decreased precipitation or increased drought frequency on tortoise egg production and survival of all age classes (Service 2010a, 2011). Research suggests that desert tortoises will produce and lay eggs earlier in a warming climate (Lovich *et al*. 2012), which could lead to increased annual egg production by providing more time for females to lay additional clutches in a year (Wallis *et al*. 1999). Shifts in egg production and nesting still might not compensate for changes in the environment depending on factors such as the time nests spend above the critical thermal maximum temperature for eggs and whether the availability of forage necessary to provide the nutrients for egg production synchronizes with shifts in tortoise activity (Lovich *et al*. 2017). In addition, declining reproductive output across much of the Mojave desert tortoise's range, as estimated between 1990 and 2018, could have a negative population-level effect, especially if precipitation is significantly reduced across the species' range as predicted under some climate models (Mitchell *et al*. 2021). Effects of any reduction in reproductive output will be compounded by the failure to reduce human-subsidized predation pressure on juvenile tortoises, especially by ravens.

Several local-level models projected substantial reductions in and movement upslope of suitable desert tortoise habitat under the anticipated effects of climate change. For example, at moderate predictions of climate change (+2°C maximum July temperature, –50 mm annual precipitation), modeled desert tortoise habitat at Joshua Tree National Park shrank by nearly 66% in the Mojave Desert portion and nearly 88% in the Sonoran Desert portion of the park (Barrows 2011). Similarly, projections of 1°C to 3°C warmer maximum July temperatures resulted in modeled habitat reductions of 24% and 55%, respectively, in the vicinity of MCAGCC (Barrows *et al*. 2016). Likewise, models of the region surrounding Lake Mead National Recreation Area using a similar range of climate projections as those above predicted habitat reductions of up to 77% (Barrows and Murphy 2011). Much of the predicted habitat east of the Colorado River shifted upslope away from LMNRA onto adjacent BLM lands under the warmer and drier scenarios (Barrows and Murphy 2011).

Currently, two projects are investigating implications of climate change across the Mojave desert tortoise's range. One is investigating how both land use and climate change will impact tortoise gene flow and corridor functionality using present and future habitat models (Heaton 2020). The second began with the premise that reliance on standard habitat models for performing climate vulnerability assessments may overestimate the risk from climate change because such assessments place more focus on the nature and magnitude of exposure to change than species' adaptive capacity to change; this project is using data collected across the broadest possible range of environmental conditions to estimate tortoise population growth rates as a function of inter-correlated vital rates, body condition, and spatiotemporally varying environmental conditions and then to assess metapopulation viability under multiple plausible future scenarios (Shoemaker 2020). Both projects are scheduled to be completed in mid-2022.

Synthesis

Allison and McLuckie (2018): *The negative population trends in most of the TCAs for Mojave Desert Tortoises indicate that this species is on the path to extinction under current conditions. This may reflect inadequate recovery action implementation, slow response by tortoises and their habitat to implemented actions, or new and ongoing human activities in the desert that have not been mitigated appropriately. It may also be a result of stochastic or directional climatic events that impact large expanses of tortoise habitat (e.g., drought, fire, climate change) and are largely beyond the realm of local land management activities. Our results are a call to action to remove ongoing threats to tortoises from TCAs, and possibly to contemplate the role of human activities outside TCAs and their impact on tortoise populations inside them.*

As documented by Allison and McLuckie (2018), the status of the Mojave Desert Tortoise had not improved by 2014 and most threats to the species persist at or above 2010–2011 levels. These conditions portend further status deterioration in the absence of concerted efforts by land managers to meaningfully reduce predator subsidies, vehicle-caused tortoise mortalities, and invasive annual plants in important tortoise habitats. The magnitude of population trends and status of current threats led the International Union for the Conservation of Nature and Natural Resources to reclassify the species as Critically Endangered under their unique Red List criteria (Berry *et al*. 2021).

Despite being in a more precarious overall situation than at the time of publication of the revised recovery plan, recognition of *G. agassizii* populations east of the Colorado River makes the range of the species slightly larger than the currently listed entity, and the total range-wide population consisted of hundreds of thousands of individuals (all size classes) at last estimation. In addition, the MOG has taken steps to prioritize and implement actions that would be most effective at facilitating recovery across the range. Although sufficient time has not yet passed to see substantial population improvements of a species with such a slow life history, we expect those efforts to result in positive impacts over time. Those efforts, combined with the total estimated population size, and increasing population trends in parts of the range, suggest that the species is not in imminent danger of extinction in the foreseeable future, so we do not recommend a change in status under the Endangered Species Act at this time. An updated analysis of population trends is in preparation, and new models of the effects of land use and climate change on the Mojave Desert Tortoise will also soon be available for a more informed status recommendation in the next five-year review. Basing an updated status recommendation on upcoming models of future scenarios and trends will also allow an assessment of progress of large-scale conservation initiatives such as more concerted raven monitoring and management and the Recovery and Sustainment Partnership between the Department of Defense and Department of Interior.

RESULTS

Recommended Classification: No change is needed

Recovery Priority Number: 11C (no change)

Brief Rationale: The RPN is based on a) ongoing population declines and threats; b) a low potential for recovery, based on current uncertainties about various threats and our ability to manage them; c) listed at species level; and d) potential conflict with development or other forms of economic activity.

RECOMMENDATIONS FOR FUTURE ACTIONS

In light of declining trends across much of the Mojave Desert Tortoise's range and the status of threats across the range, the highest-priority actions over the next five years are listed below. Recommended actions in the 2011 recovery plan are identified by recovery action number.

1. Most importantly, the top recovery actions endorsed by the Desert Tortoise MOG require more aggressive implementation (Fig. 5).
   a. Habitat restoration (Recovery Action 2.6): Define habitat status and desired conditions relative to desert tortoise fitness (5.1 and 5.2, in part) and target restoration or protection efforts to meet those conditions. Habitat restoration should address invasive weeds, native forage plants, and recovery of unpaved roads and routes.
   b. Minimize excessive predation on tortoises by decreasing predator access to human subsidies and with targeted predator control (2.14). Demographic models should guide efforts to reduce raven abundance and predation rates on tortoises via tools such as oiling raven eggs to prevent hatching as well as efforts to remove targeted numbers of breeding and non-breeding adults in areas that exceed 0.89 ravens/km^2 or other thresholds derived from updated modeling. All active raven nests within approximately 1–2 km, depending on local raven density, of TCAs should be oiled or removed.
   c. Install and maintain tortoise barrier fencing (2.5, in part) along priority stretches of highways (see Holcomb 2019).
   d. Fire management planning and implementation (2.1, in part): Fire prevention and management should be pursued throughout the Mojave and Colorado deserts to contain the grass-fire cycle. Minimizing the size and intensity of fires will ease subsequent restoration efforts, even in previously burned areas. Identifying and mapping priority areas and developing a fire plan for habitat protection, fire-crew access, and the use of natural or created fuel breaks could help limit response time and fire spread.
   e. Environmental education (2.3): Coordinated, consistent messaging should increase awareness on how targeted user groups, such as off-highway-vehicle enthusiasts, and the general public can recreate responsibly to minimize their impacts on desert tortoise populations and should include subjects such as adoption programs for captive tortoises, the importance of discouraging unauthorized breeding of desert tortoises in captivity, and the illegality of releasing captive tortoises into wildlands.

2. Maintain landscape connectivity and the resilience of TCAs (2.11) via actions described by Averill-Murray *et al*. (2021).
   a. Manage all desert tortoise habitat for persistence and connectivity. For example, managing the entire remaining matrix of desert tortoise habitat outside TCAs for permeability may be better than delineating fixed corridors between TCAs.
   b. Limit landscape-level disturbance across habitat managed for the desert tortoise (2.1) by extending surface-disturbance caps similar to those enacted by the DRECP in California to the rest of the Mojave Desert Tortoise's range.
   c. In addition to minimizing mortality from roads as per 1.c, above, maximize passage under roads, e.g., by filling eroded drop-offs or by modifying erosion-control features such as rip-rap at culvert entrances to make them safer and more passable for tortoises.
   d. Adapt management based on information from research (5.5) on i) the effects of climate change on desert tortoise habitat, distribution, and population connectivity; ii) the effects of large-scale fires, especially within repeatedly burned habitat, on desert tortoise distribution and population connectivity; iii) the ability of solar energy facilities or similar developments to support tortoise movement and presence by leaving washes and native vegetation intact; and iv) the design and frequency of underpasses necessary to maintain functional demographic and genetic connectivity across roads and highways.

3. Increase law enforcement efforts across the range of the desert tortoise (2.4), especially within TCAs, to minimize impacts of habitat destruction and degradation as a result of unauthorized OHV use, unpermitted cannabis farms, and trespass grazing.

4. Use population augmentation to help achieve recovery criteria in each of the five recovery units according to the Fish and Wildlife Service's population augmentation strategy (3.2–3.4). Individual augmentation plans should include design, feasibility and risk assessment, implementation, monitoring, and evaluation and adjustment elements (Service 2021d).

5. Update the taxonomy, distribution, and listed status of *Gopherus agassizii* under the Endangered Species Act to include populations east of the Colorado River (Fig. 1). A "similarity of appearance" rule may be necessary for *G. morafkai* populations or individuals that occur within the range of the Mojave Desert Tortoise.

6. Incorporate updated population trend analysis (Service, in progress) and climate change/land-use modeling (5.5: Heaton 2020; Shoemaker 2020) into the next 5-year review. These climate-change models should be used to inform management strategies under the Resist-Accept-Direct framework for ecological adaptation (Schuurman *et al.* 2021; Williams 2021).

7. Range-wide monitoring efforts continue to fluctuate at suboptimal levels due to inconsistent funding (Allison and McLuckie 2018). Therefore, we reiterate the 2002 recommendation "that the Secretary of the Interior work with the Secretary of Defense and other agencies and organizations involved in tortoise recovery to identify and assess options for securing continued funding for rangewide population monitoring" to ensure that long-term monitoring of the desert tortoise is sustained (General Accounting Office [GAO] 2002). Estimation of trends within TCAs also would be improved by streamlining individual-agency access

processes. For example, access has been difficult to obtain for certain parcels of critical habitat during the primary tortoise active season.

8. Develop a revised spatial decision support system to improve models of threats, recovery actions, and tortoise demographics (5.3, 6.1). Development should include up-to-date underlying geospatial data, evaluation of prior conceptual models, and improved operationalization of recovery action terminology.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Mojave Desert Tortoise (*Gopherus agassizii*)

Current Classification: Threatened

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (Indicate reasons for delisting per 50 CFR 424.11):
 ____ Extinction
 ____ Recovery
 ____ Original data for classification in error
_X__ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: 11C

APPROVAL:

Assistant Regional Director, Pacific Southwest Region, Fish and Wildlife Service

Approve MICHAEL SENN Digitally signed by MICHAEL SENN Date: 2022.05.20 14:40:37 -07'00' Date May 20, 2022

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

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U.S. Bureau of Land Management. 2019b. Record of Decision: West Mojave Route Network Project Decision to Amend California Desert Conservation Area Plan and Implement Nine Travel Management Plans. Bureau of Land Management, California Desert District.

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Weitzman, C.L., F.C. Sandmeier, and C.R. Tracy. 2017. Prevalence and diversity of the upper respiratory pathogen *Mycoplasma agassizii* in Mojave Desert Tortoises (*Gopherus agassizii*). Herpetologica 73:113–120.

Williams, A.P., B.I. Cook, and J.E. Smerdon. 2022. Rapid intensification of the emerging southwestern North American megadrought in 2020–2021. Nature Climate Change.

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PERSONAL COMMUNICATIONS

Delcalzo, A. 10 March 2021 email re: Meadow Valley Fire.

Patterson, L. 26 July 2021 email re: California Endangered Species Act.

APPENDIX: Published Research Since 2011

This appendix lists research on Mojave Desert Tortoises that has been published since the 2011 recovery plan. Sections are organized by numbered recommendations in the recovery plan.

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

<u>Translocation</u>

Aiello *et al*. 2014. Disease dynamics during wildlife translocations: disruptions to the host population and potential consequences for transmission in desert tortoise contact networks. Animal Conservation 17(Suppl. 1):27–39.

Averill-Murray and Hagerty. 2014. Translocation relative to spatial genetic structure of the Mojave Desert Tortoise, *Gopherus agassizii*. Chelonian Conservation and Biology 13:35–41.

Brand *et al*. 2016. Mitigation-driven translocation effects on temperature, condition, growth, and mortality of Mojave desert tortoise (*Gopherus agassizii*) in the face of solar energy development. Biological Conservation 200:104–111.

Dickson *et al*. 2019. Multiyear monitoring of survival following mitigation-driven translocation of a long-lived threatened reptile. Conservation Biology 5:1094–1105.

Drake *et al*. 2012. Does translocation influence physiological stress in the desert tortoise? Animal Conservation 15:560–570.

Edwards and Berry. 2013. Are captive tortoises a reservoir for conservation? An assessment of genealogical affiliation of captive *Gopherus agassizii* to local, wild populations. Conservation Genetics doi:10.1007/s10592–013–0458–y.

Farnsworth *et al*. 2015. Short-term space-use patterns of translocated Mojave Desert Tortoise in southern California. PLoS One 10(9):e0134250.doi:10.1371/journal.pone.0134250.

Germano *et al*. 2015. Mitigation-driven translocations: are we moving wildlife in the right directions? Frontiers in Ecology and the Environment 13:100–105. doi:10.1890/140137.

Germano *et al*. 2017. Predicting translocation outcomes with personality for desert tortoises. Behavioral Ecology doi:10.1093/beheco/arx064.

Harju *et al*. 2020. Using incidental mark-encounter data to improve survival estimation. Ecology and Evolution 10:360–370. (*includes results of translocation to the Boulder City Conservation Easement, Nevada*)

Hedrick. 2021. Comment on “Individual heterozygosity predicts translocation success in threatened desert tortoises.” Science 10.1126/science.abg2673.

Hansson *et al*. 2021. Comment on “Individual heterozygosity predicts translocation success in threatened desert tortoises.” Science 10.1126/science.abh1105.

Hinderle *et al*. 2015. The effects of homing and movement behaviors on translocation: desert tortoises in the western Mojave Desert. Journal of Wildlife Management 79:137–147.

Mulder *et al*. 2017. No paternal genetic integration in desert tortoises (*Gopherus agassizii*) following translocation into an existing population. Biological Conservation 210:318–324.

Nafus *et al*. 2017. Habitat drives dispersal and survival of translocated juvenile desert tortoises. Journal of Applied Ecology 54:430–438.

Nussear *et al*. 2012. Translocation as a conservation tool for Agassiz’s desert tortoise: survivorship, reproduction, and movements. Journal of Wildlife Management 76:1341–1353.

Sadoti *et al*. 2017. Discriminating patterns and drivers of multiscale movement in herpetofauna: the dynamic and changing environment of the Mojave desert tortoise. Ecology and Evolution doi:10.1002/ece3.3235.

Sah *et al*. 2016. Inferring social structure and its drivers from refuge use in the desert tortoise, a relatively solitary species. Behavioral Ecology and Sociobiology doi:10.1007/s00265–016–2316–9.

Scott *et al*. 2020. Individual heterozygosity predicts translocation success in threatened desert tortoises. Science 370:1086–1089.

Scott *et al*. 2021. Response to comment on "Individual heterozygosity predicts translocation success in threatened desert tortoises." Science 10.1126/science.abg3199.

Scott *et al*. 2021. Response to comment on "Individual heterozygosity predicts translocation success in threatened desert tortoises." Science 10.1126/science.abh2633.

Head-starting

Daly *et al*. 2018. Comparing growth and body condition of indoor-reared, outdoor-reared, and direct-released juvenile Mojave Desert Tortoises. Herpetological Conservation and Biology 13:622–633.

Daly *et al*. 2019. Survival and movements of head-started Mojave Desert Tortoises. Journal of Wildlife Management 83:1700–1710.

Hazard *et al*. 2015. Post-release dispersal and predation of head-started juvenile desert tortoises (*Gopherus agassizii*): effect of release site distance on homing behavior. Herpetological Conservation and Biology 10:504–515.

Mack *et al*. 2018. Crowding affects health, growth, and behavior in headstart pens for Agassiz's Desert Tortoise. Chelonian Conservation and Biology 17:14–26.

McGovern *et al*. 2020. Comparing husbandry techniques for optimal head-starting of the Mojave Desert Tortoise (*Gopherus agassizii*). Herpetological Conservation and Biology 15:626–641.

McGovern *et al*. 2020. The effect of size on postrelease survival of head-started Mojave Desert Tortoises. Journal of Fish and Wildlife Management 11:494–506.

McGovern *et al*. 2021. Comparing post-release cover and burrow use by differentially head-started Mojave Desert Tortoises in southern California. Conservation Evidence Journal 18:37–43.

Nagy *et al*. 2015. Head-started desert tortoises (*Gopherus agassizii*): movements, survivorship and mortality causes following their release. Herpetological Conservation and Biology 10:203–215.

Nagy *et al*. 2015. Effects of artificial rain on survivorship, body condition, and growth of head-started desert tortoises (*Gopherus agassizii*) released to the open desert. Herpetological Conservation and Biology 10:535–549.

Nagy *et al*. 2016. Weather and sex ratios of head-started Agassiz's desert tortoise *Gopherus agassizii* juveniles hatched in natural habitat enclosures. Endangered Species Research 30:145–155.

Nagy *et al*. 2020. Head-started Agassiz's Desert Tortoises *Gopherus agassizii* achieve high survival, growth, and body condition in natural field enclosures. Endangered Species Research 43:305–321.

Tuberville *et al*. 2019. Effects of short-term, outdoor head-starting on growth and survival in the Mojave Desert Tortoise (*Gopherus agassizii*). Herpetological Conservation and Biology 14:171–184.

5.1 Determine factors that influence the distribution of desert tortoises.

- Validate and refine the desert tortoise habitat model. Expand to model potential effects of global climate change on existing desert tortoise habitat.
- Determine characteristics that contribute to the relative condition (*e.g.*, high or low quality) of desert tortoise habitat.

Harju and Cambrin. 2019. Identifying habitat correlates of latent occupancy when apparent annual occupancy is confounded with availability for detection. Biological Conservation DOI: 10.1016/j.biocon.2019.108246.

Inman *et al*. 2019. Local niche differences predict genotype associations in sister taxa of desert tortoise. Diversity and Distributions. DOI: 10.1111/ddi.12927

Todd *et al*. 2016. Habitat selection by juvenile Mojave Desert Tortoises. Journal of Wildlife Management. DOI:10.1002/jwmg.1054.

5.2 Conduct research on the restoration of desert tortoise habitat. Papers loosely categorized according to topics identified in the recovery plan:

a) Evaluate the effectiveness of different restoration methods.
b) Identify methods to eradicate non-native, invasive plants within desert tortoise habitat.
c) Assess the ecological consequences of climate change on future vegetation communities within the range of the desert tortoise.
d) Correlate habitat restoration with desert tortoise population status.
e) Other restoration-related papers since 2011.

[b]Abella. 2014. Effectiveness of exotic plant treatments on National Park Service lands in the United States. Invasive Plant Science and Management 7:147–163.

[a]Abella. 2017. Persistent establishment of outplanted seedlings in the Mojave Desert. Ecological Restoration 35(1):16–19.

[a]Abella and Berry. 2016. Enhancing and restoring habitat for the desert tortoise *Gopherus agassizii*. Journal of Fish and Wildlife Management doi:10.3996/052015–JFWM–046.

[e]Abella, S.R., and L.P. Chiquoine. 2019. The good with the bad: when ecological restoration facilitates native and non-native species. Restoration Ecology 27:343–351.

[a]Abella and Smith. 2013. Annual-perennial plant relationships and species selection for desert restoration. Journal of Arid Land 5:298–309.

[b]Abella *et al*. 2011. Relationships of native desert plants with red brome (*Bromus rubens*): toward identifying invasion-reducing species. Invasive Plant Science and Management 4:115–124.

[a]Abella *et al*. 2012. Outplanting but not seeding establishes native desert perennials. Native Plants 13:81–89.

[b]Abella *et al*. 2012. Identifying native vegetation for reducing exotic species during the restoration of desert ecosystems. Restoration Ecology 20:781–787.

[a]Abella *et al*. 2015. Restoring a desert ecosystem using soil salvage, revegetation, and irrigation. Journal of Arid Environments 115:44–52.

[a]Abella *et al*. 2015. Enhancing quality of desert tortoise habitat: augmenting native forage and cover plants. Journal of Fish and Wildlife Management 6:278–289.

[c]Bachelet *et al*. 2016. Climate change effects on southern California deserts. Journal of Arid Environments 127:17–29.
[a]Berry *et al*. 2015. Bidirectional recovery patterns of Mojave Desert vegetation in an aqueduct pipeline corridor after 36 years: I. Perennial shrubs and grasses. Journal of Arid Environments http://dx.doi.org/10.1016/j.jaridenv.2015.03.004.
[a]Berry *et al*. 2015. Bidirectional recovery patterns of Mojave Desert vegetation in an aqueduct pipeline corridor after 36 years: II. Annual plants. Journal of Arid Environments 122: 141–153. https://doi.org/10.1016/j.jaridenv.2015.06.016.
[a]Chiquoine *et al*. 2016. Rapidly restoring biological soil crusts and ecosystem functions in a severely disturbed desert ecosystem. Ecological Applications 26:1260–1272.
[a]DeFalco and Esque. 2014. Soil seed banks: preserving native biodiversity and repairing damaged desert shrublands. California's Deserts, Part 2: threats and conservation strategies. Fremontia 42:20–23.
[a]DeFalco *et al*. 2012. Supplementing seed banks to rehabilitate disturbed Mojave Desert shrublands: Where do all the seeds go? Restoration Ecology 20:85–94.
[a]Devitt *et al*. 2020. Post burn restoration response of *Encelia virginensis* within a small wash system in the Mojave Desert. Ecological Restoration 38:169–179.
[e]Esque *et al*. 2021. Priority species lists to restore desert tortoise and pollinator habitats in Mojave Desert shrublands. Natural Areas Journal 41:145–158.
[a]Jones *et al*. 2014. Seedling ecology and restoration of blackbrush (*Coleogyne ramosissima*) in the Mojave Desert, United States. Restoration Ecology doi: 10.1111/rec.12128.
[c]Munson *et al*. 2015. Long-term plant responses to climate are moderated by biophysical attributes in a North American desert. Journal of Ecology 103:657–668.
[c]Munson *et al*. 2016. Cumulative drought and land-use impacts on perennial vegetation across a North American dryland region. Applied Vegetation Science doi:10.1111/avsc.12228.
[a]Scoles-Sciulla *et al*. 2014. Contrasting long-term survival of two outplanted Mojave Desert perennials for post-fire restoration. Arid Land Research and Management 29:110–124.
[a]Scoles-Sciulla *et al*. 2015. Contrasting long-term survival of two outplanted Mojave Desert perennials for post-fire revegetation. Arid Land Research and Management 29:110–124.
[e]Shryock *et al*. 2015. Landscape genomics of *Sphaeralcea ambigua* in the Mojave Desert: a multivariate, spatially-explicit approach to guide ecological restoration. Conservation Genetics 16:1303–1317.
[e]Shryock *et al*. 2017. Landscape genetic approaches to guide native plant restoration in the Mojave Desert. Ecological Applications 27:429–445.
[e]Shryock *et al*. 2020. Harnessing landscape genomics to identify future climate resilient genotypes in a desert annual. Molecular Ecology 2020:00:1-20.

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

Papers loosely categorized according to topics identified in the recovery plan:

a) Develop conceptual and quantitative models of threats to clarify interactive relationships between threats and to identify critical synergies that contribute to population declines. Demographic effects of individual threats and suites of threats on tortoise populations should be determined experimentally.
b) Develop and test models of the effectiveness of management actions.
c) Model desert tortoise demography relative to habitat condition to determine the proportion of habitat that needs to be occupied (or is available to be occupied) for

recovery. Models should incorporate predicted effects of climate change on desert tortoise demography as well as on the current composition of tortoise habitat.

d) Update population viability analyses.

e) Other publications since 2011 directly related to particular threats and demographics

  i. Invasive plants
  ii. Fire and burned habitat
  iii. Wind energy development
  iv. Predation
  v. Climate
  vi. Other

[e.ii]Abella and Engel. 2013. Influences of wildfires on organic carbon, total nitrogen, and other properties of desert soils. Soil Science Society of America Journal 77:1806–1817.

[e.i]Abella *et al*. 2012. Biophysical correlates with the distribution of the invasive annual red brome (*Bromus rubens*) on a Mojave Desert landscape. Invasive Plant Science and Management 5:47–56.

[e.iii]Agha *et al*. 2015. Turbines and terrestrial vertebrates: variation in tortoise survivorship between a wind energy facility and an adjacent undisturbed wildland area in the desert Southwest (USA). Environmental Management doi:10.1007/s00267–015–0498–9.

[e.vi]Agha *et al*. 2015. The effect of research activities and winter precipitation on voiding behaviour of Agassiz's desert tortoises (*Gopherus agassizii*). Wildlife Research 41:641–649.

[e.vi]Agha *et al*. 2015. Nelson's Big Horn Sheep (*Ovis canadensis nelson*) trample Agassiz's Desert Tortoise (*Gopherus agassizii*) burrow at a California wind energy facility. Bulletin of the Southern California Academy of Sciences 114:58–62.

[e.vi]Agha *et al*. 2017. Mammalian mesocarnivore visitation at tortoise burrows in a wind farm. Journal of Wildlife Management 81:1117–1124.

[e.iv]Anderson and Berry. 2019. *Gopherus agassizii* (Agassiz's Desert Tortoise). Predation. Herpetological Review 50:351.

[e.v]Barrows *et al*. 2016. Identifying climate refugia: a framework to inform conservation strategies for Agassiz's Desert Tortoise in a warmer future. Chelonian Conservation and Biology 15:2–11.

[a]Berry *et al*. 2013. Multiple factors affect a population of Agassiz's desert tortoise (*Gopherus agassizii*) in the northwestern Mojave Desert. Herpetological Monographs 27:87–109.

[a]Berry *et al*. 2014. Protection benefits desert tortoise (*Gopherus agassizii*) abundance: the influence of three management strategies on a threatened species. Herpetological Monographs 28:66–92.

[e.i]Berry *et al*. 2014. Models of invasion and establishment for African mustard (*Brassica tournefortii*). Invasive Plant Science and Management 7:599–616.

[e.vi]Berry *et al*. 2020. Feral burros and other influences of desert tortoise presence in the western Sonoran Desert. Herpetologica 76:403–413.

[a]Berry *et al*. 2020. The catastrophic decline of tortoises at a fenced natural area. Wildlife Monographs 205:1–53.

[a]Berry *et al*. 2020. An uncertain future for a population of desert tortoises experiencing human impacts. Herpetologica 76:1–11.

[e.iv]Boarman and Kristan. 2018. Boulder City Conservation Easement desert tortoise predation study: predator assessment report. Clark County Desert Conservation Program. Las Vegas, Nevada.

[e.ii]Brooks. 2012. Effects of high fire frequency in creosote bush scrub vegetation of the Mojave Desert. International Journal of Wildland Fire 21:61–68.
[a]Carter *et al*. 2020. Quantifying development to inform management of Mojave and Sonoran desert tortoise habitat in the American southwest. Endangered Species Research 42:167–184.
[e.vi]Cohn *et al*. 2021. Heavy metal concentrations in Mojave Desert Tortoises (*Gopherus agassizii*) related to a mitigation translocation project, Ivanpah Valley, California, USA. Herpetological Conservation and Biology 16:128–141.
[b]Custer *et al*. 2017. Drawing a line in the sand: effectiveness of off-highway vehicle management in California's Sonoran desert. Journal of Environmental Management http://dx.doi.org/10.1016/j.jenvman.2017.02.033.
[e.iv]Cypher *et al*. 2018. Coyote diet patterns in the Mojave Desert: implications for threatened desert tortoises. Pacific Conservation Biology https://doi.org/10.1071/PC17039.
[a]Darst *et al*. 2013. A strategy for prioritizing threats and recovery actions for at-risk species. Environmental Management 51:786–800.
[e.ii]Drake *et al*. 2015. Desert tortoise use of burned habitat in the eastern Mojave Desert. Journal of Wildlife Management doi:10.1002/jwmg.874.
[e.i]Drake *et al*. 2016. Negative impacts of invasive plants on conservation of sensitive desert wildlife. Ecosphere 7(10):e01531.10.1002/ecs2.1531.
[e.iv]Emblidge, *et al*. 2015. Severe predation on a population of threatened desert tortoises: the American Badger as a novel predator. Endangered Species Research 28:109–116.
[e.iii]Ennen *et al*. 2012. Nesting ecology of a population of *Gopherus agassizii* at a utility-scale wind energy facility in southern California. Copeia 2012:222–228.
[e.v]Ennen *et al*. 2012. Female Agassiz's desert tortoise activity at a wind energy facility in southern California: the influence of an El Niño event. Natural Science 4:30–37.
[e.i]Germino *et al*. 2016. Exotic Brome-Grasses in Arid and Semiarid Ecosystems of the Western U.S.: Causes, Consequences, and Management Implications. Springer, Cham, Switzerland.
[e.ii]Gray and Dickson. 2016. Applying fire connectivity and centrality measures to mitigate the cheatgrass-fire cycle in the arid West, USA. Landscape Ecology 31:1681–1696.
[e.ii]Hegeman *et al*. 2014. Probabilistic models of fire occurrence across National Park Service units within the Mojave Desert network, USA. Landscape Ecology 29:1587–1600.
[e.iv]Henderson *et al*. 2016. *Gopherus agassizii* (Mohave Desert Tortoise). Nest depredation. Herpetological Review 47:446–447.
[e.i]Jurand and Abella. 2013. Soil seed banks of the exotic annual grass *Bromus rubens* on a burned desert landscape. Rangeland Ecology and Management 66:157–163.
[e.iv]Kelly *et al*. 2019. Temporal variation in foraging patterns in Desert Kit Foxes (*Vulpes macrotis arsipus*) in the Mojave Desert, California, USA. Journal of Arid Environments 167:1–7.
[e.iv]Kelly *et al*. 2021. Predation on desert tortoises (*Gopherus agassizii*) by desert canids. Journal of Arid Environments 189:104476. https://doi.org/10.1016/j.jaridenv.2021.104476.
[e.vi]Loughran *et al*. 2011. *Gopherus agassizii* (Desert Tortoise). Burrow collapse. Herpetological Review 42:593.
[e.vi]Lovich *et al*. 2011. Turtles, culverts, and alternative energy development: an unreported but potentially significant mortality threat to the desert tortoise (*Gopherus agassizii*). Chelonian Conservation and Biology 10:124–129.
[e.v]Lovich *et al*. 2012. Climatic variation affects clutch phenology in Agassiz's desert tortoise *Gopherus agassizii*. Endangered Species Research 19:63–74.

[e.iii]Lovich *et al*. 2014. Nest site characteristics, nesting movements, and lack of long-term nest site fidelity in Agassiz's desert tortoises at a wind energy facility in southern California. California Fish and Game 100:404–416.
[e.iv]Lovich *et al*. 2014. Black bears (*Ursus americanus*) as a novel potential predator of Agassiz's Desert Tortoises (*Gopherus agassizii*) at a California wind energy facility. Bulletin of the Southern California Academy of Sciences 113:34–41.
[e.v]Lovich *et al*. 2014. Climatic variation and tortoise survival: has a desert species met its match? Biological Conservation 169:214–224.
[e.ii]Lovich *et al*. 2018. Agassiz's desert tortoise (*Gopherus agassizii*) activity areas are little changed after wind turbine-induced fires in California. International Journal of Wildland Fire 27:851–856.
[e.v]Mack *et al*. 2015. Factors affecting the thermal environment of Agassizi's desert tortoise (*Gopherus agassizii*) cover sites in the central Mojave Desert during periods of temperature extremes. Journal of Herpetology 49:405–414.
[e.v]Mitchell *et al*. 2021. 'Unscrambling' the drivers of egg production in Agassiz's Desert Tortoise: climate and individual attributes predict reproductive output. Endangered Species Research 44:217–230.
[e.vi]Nafus *et al*. 2013. Relative abundance and demographic structure of Agassiz's desert tortoise (*Gopherus agassizii*) along roads of varying size and traffic volume. Biological Conservation 162:100–106.
[e.iv]Nafus *et al*. 2017. Cues from a common predator cause survival-linked behavioral adjustments in Mojave Desert tortoises (*Gopherus agassizii*). Behavioral Ecology and Sociobiology doi:10.1007/s00265–017–2387–0.
[e.v]Nafus *et al*. 2017. Precipitation quantity and timing affect native plant production and growth of a key herbivore, the desert tortoise, in the Mojave Desert. Climate Change Responses doi:10.1186/s40665–017–0032–9.
[e.v]Nowakowski *et al*. 2020. Thermal performance curves based on field movements reveal context-dependence of thermal traits in a desert ectotherm. Landscape Ecology 35:893–906.
[b, e.vi]Peaden. 2017. Habitat use and behavior of Agassiz's Desert Tortoise (*Gopherus agassizii*): outpacing development to achieve long standing conservation goals. PhD Dissertation. University of California, Davis.
[e.vi]Peaden *et al*. 2015. Delimiting road-effect zones for threatened species: implications for mitigation fencing. Wildlife Research 42:650–659.
[a]Peaden *et al*. 2017. Effects of roads and roadside fencing on movements, space use, and carapace temperatures of a threatened tortoise. Biological Conservation 214:13–22.
[a]Shields *et al*. 2019. Novel management tools for subsidized avian predators and a case study in the conservation of a threatened species. Ecosphere 10:e02895.
[e.ii]Shyrock *et al*. 2014. Life-history traits predict perennial species response to fire in a desert ecosystem. Ecology and Evolution 4:3046–3059.
[e.v]Sieg *et al*. 2015. Mojave desert tortoise (*Gopherus agassizii*) thermal ecology and reproductive success along a rainfall cline. Integrative Zoology 10:282–294.
[e.vi]Smith *et al*. 2015. *Gopherus agassizii* (Agassiz's Desert Tortoise). Mechanical injury. Herpetological Review 46:423–424.
[e.iv]Smith *et al*. 2016. A potential predator-prey interaction of an American Badger and an Agassiz's Desert Tortoise with a review of badger predation on turtles. California Fish and Game 102:131–144.
[e.iv]Spenceley *et al*. 2015. *Gopherus agassizii* (Agassiz's Desert Tortoise). Attempted predation. Herpetological Review 46:422–423.

[e.ii]Soulard *et al*. 2013. The role of fire on soil mounds and surface roughness in the Mojave Desert. Earth Surf. Process. Landforms 38:111–121.
[e.ii]Syphard *et al*. 2017. Trends and drivers of fire activity vary across California aridland ecosystems. Journal of Arid Environments 144:110–122.
[a]Tuma *et al*. 2016. Modeling Agassiz's Desert Tortoise population response to anthropogenic stressors. Journal of Wildlife Management doi:10.1002/jwmg.1044.
[e.ii]Van Linn *et al*. 2013. Estimating wildfire risk on a Mojave Desert landscape using remote sensing and field sampling. International Journal of Wildland Fire http://dx.doi.org/10.1071/WF12158.

5.4 Conduct research on desert tortoise diseases and their effects on tortoise populations. *Papers loosely categorized according to topics identified in the recovery plan:*

a) Determine whether population declines through environmental stress are less severe when *Mycoplasma* is absent.
b) Determine if desert tortoises exposed to simulated drought conditions become more susceptible to infection and more infectious.
c) Determine whether diets high in plants of low nutritional value increase susceptibility to disease, as well as infectiousness.
d) Identify virulent and less virulent strains of *Mycoplasma* in wild and captive populations and monitor temporal and spatial change in prevalence in relation to host genetic status and environmental stressors.
e) Identify genes expressing toxin production and the circumstances when these genes are expressed.
f) Examine the level of cross immunity between strains and variation in resistance in relation to the plane of nutrition and availability of water.
g) Identify which individual tortoises are shedding, how they shed, when they shed, and for how long they shed infectious *Mycoplasma* particles.
h) Identify whether individuals removed from drought-stressed areas or areas with severely deteriorated habitats continue to shed *Mycoplasma* and for how long. This research will identify in more detail seasonal forces of infection, the period of infectiousness, and how infectiousness varies under different circumstances.
i) Undertake trials to determine if it is possible to cure individuals with *Mycoplasma* infections, even if only feasible in captive individuals.
j) Examine the behavior of infectious tortoises in comparison to uninfected tortoises in the wild. Obtain estimates of contact rate according to sex, age, and season. This research will help us understand the most critical epidemiological parameters associated with transmission and, with other data, allow us to produce a predictive model of outbreak.
k) Examine the implications of releasing sick tortoises into uninfected populations.
l) Further explore natural antibodies in desert tortoises.
m) Create a comprehensive disease-tortoise population model that incorporates the above information.
n) Evaluate other known or emerging diseases for effects on desert tortoise populations.
o) Other health- or disease-related publications since 2011

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