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Desert Tortoise

Gopherus agassizii

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Legal Status: Federal - Threatened
State - Threatened

General Distribution: The desert tortoise is widely distributed throughout major portions of the Mojave and Sonoran deserts of California, Nevada, Utah, Arizona, Sonora, and Sinaloa. Genetic, morphological, ecological, and behavioral features suggest an evolutionary divergence between the tortoises found south and east of the Colorado River ("Sonoran population"), and those found north and west of the river ("Mojave population;" Lamb et al. 1989). The latter is the population Federally and State-listed as threatened. This population will be referred to in the remainder of this account. The majority of animals in the Mojave population occur at variable densities in six distinct population segments (i.e., evolutionarily significant units), each identified in the Recovery Plan for desert tortoises as separate Recovery Units (USFWS 1994).

Distribution in the WMPA: One major segment of the Mojave population of the desert tortoise occurs almost entirely within the WMPA and is called the West Mojave Recovery Unit (USFWS 1994). Tortoises in the West Mojave Desert are divided into four not entirely separate subpopulations: Ord-Rodman, Superior-Cronese, Fremont-Kramer, Joshua Tree (see USFWS 1994 for detailed descriptions). Population densities within these areas are variable and patchy varying from 0-250/mi^2 (0-155/km^2; Berry and Nicholson 1984). Within each subsegment, tortoise density is highly heterogeneous with clusters of high densities (perhaps several hundred hectares in size) surrounded by areas of rather low densities in seemingly suitable habitat. Tortoises occur outside of these four subsegments, but at very low densities (i.e., 0-20/mi^2 (0–12/km^2; Berry and Nicholson 1984).

Natural History: The desert tortoise is a medium-sized, terrestrial turtle in the family Testudinidae. The shell is light brown to very dark brown with brown to orange or yellow in the centers of scutes, particularly in young animals. The skin is dry and scaly with thick, stumpy, elephantine hind legs. A strong projection, the gular horn, located at the anterior end of the plastron, is most pronounced in adult males. Adult males also have shorter claws, longer, thicker tails, a concave plastron, and pronounced chin glands. They weigh 0.04-10+ lbs (20-5000+ g) and range in size from about 1.4 inches (35 mm; carapace length) at hatching to 11-16 inches (280-400 mm; carapace length) as adults. No other terrestrial turtle occurs within the range of the desert tortoise.

Desert tortoises are long lived with delayed sexual maturity. Some individuals begin reproducing when 7.4 inches (180 mm) long (median carapace length, MCL), which they attain when about 12-15 years old. The majority do not begin reproducing until they reach 8.2 inches (208 mm; approximately 12-20 years old; Turner and Berry 1984, Turner et al. 1986). Maximum longevity in the wild is likely to be about 50 to 70 years, the norm being 25 to 35 years (Germano 1992, 1994). The average clutch size is 4.5 eggs (range 1-8), with 0-3 clutches deposited per year (Turner et al. 1986). Clutch size and number probably depend on female size, water, and annual productivity of forage plants in the current and previous year (Turner et al. 1984, 1986; Henen 1997). The ability to alter reproductive output in response to resource availability may allow individuals more options to ensure higher lifetime reproductive success. The interaction of longevity, late maturation, and relatively low annual reproductive output causes tortoise populations to recover slowly from natural or anthropogenic decreases in density. To ensure population stability or increase, these factors also require relatively high juvenile survivorship (75-98% per year), particularly when adult mortality is elevated (Congdon et al. 1993).

Most eggs are laid in spring (Apr -Jun) and occasionally in fall (Sept-Oct). Eggs are laid in sandy or friable soil, often at the mouths of burrows. Hatching occurs 90-120 days later, mostly in late summer and fall (mid Aug-Oct). Eggs and young are untended by the parents. Tortoise sex determination is environmentally controlled during incubation (Spotila et al. 1994). Hatchlings develop into females when the incubation (i.e., soil) temperature is greater than 89.3° F (31.8° C) and males when the temperature is below that (Spotila et al. 1994). Mortality is higher when incubation temperatures are greater than 95.5° F (35.3° C) or less than 78.8° F (26.0° C). The sensitivity of embryonic tortoises to incubation temperature may make populations vulnerable to unusual changes in soil temperature (e.g., from changes in vegetation cover), but there are no data available from the field that can be used to test this hypothesis.

Tortoise activity patterns are primarily controlled by ambient temperature and precipitation (Nagy and Medica 1986, Zimmerman et al. 1994). In the East Mojave and Colorado Deserts, annual precipitation occurs in both summer and winter, providing food and water to tortoises throughout much of the summer and fall. Most precipitation occurs in winter in the West Mojave Desert resulting in an abundance of annual spring vegetation, which dries up by late May or June. Tortoises in this region are primarily active between May and June, with a secondary activity period from September through October. Tortoises may also be active during periods of mild or rainy weather in summer and winter. During inactive periods, tortoises hibernate, aestivate, or rest in subterranean burrows or caliche caves, and spend approximately 98% of the time in these cover sites (Marlow 1979, Nagy and Medica 1986). During active periods, they usually spend nights and the hotter part of the day in their burrow; they may also rest under shrubs or in shallow burrows (called pallets). Tortoises use an average of 7-12 burrows at any given time (Barrett 1990, Bulova 1994, TRW Environmental Safety Systems Inc. 1997); some burrows may be used for relatively short periods of time and then are replaced by other burrows. Tortoises sometimes share a burrow with several other tortoises (Bulova 1994).

Tortoises eat primarily annual forbs, but also perennials (e.g., cacti and grasses). Forage species selected by tortoises in the west Mojave Desert include: *Astragalus didymocarpus*. *Astragalus layneae*, *Camissonia boothii*, *Euphorbia albomarginatus*, *Lotus humistratus*, and *Mirabilis bigelovii* (Jennings 1993). In the east Mojave Desert, tortoises showed a preference for *Camissonia boothii*, *Cryptantha angustifolia*, *Malacothrix glabrata*, *Opuntia basilaris*, *Rafinesquia neomexicana*, *Schismus barbata*, *Stephanomeria exigua* and other species (Avery 1998). On rare occasions they have been observed eating other items such as caterpillars, lizards, and cow dung, but these make up a very small proportion of their diets (Jennings 1993, Esque 1994, Avery 1998). Although they will eat exotic plants, tortoises generally prefer native forbs when available (Jennings 1993, Avery 1998, cf. Esque 1994). The dietary preference may place them at a nitrogen and water deficit. Droughts frequently occur in the desert, resulting in extended periods of low water availability. Periods of extended drought place tortoises at even greater water and nitrogen deficit than during moderate or high rainfall years (Peterson 1996, Henen 1997). During a drought, more nitrogen than normal is required to excrete nitrogenous wastes, thus more rapidly depleting nitrogen stored in body tissues. Plants also play important roles in stabilizing soil and providing cover for protection from predators and heat.

The tortoise mating system is probably polygynous, and may be polyandrous, although DNA fingerprinting to analyze patterns of paternity has not been conducted. Choice of mate is mediated by aggressive male-male interactions and possibly by female choice (Niblick et al.

1994). Recent findings indicate that tortoises in the West Mojave Desert may exhibit pre-breeding dispersal movements, typical of other vertebrates, ranging from 1 to 10 miles (0.6-16 km) away in a single season (Sazaki et al. 1995). The advantage of pre-breeding dispersal may be to find a more favorable environment (physical, biotic, social) in which to reproduce. However, the risk is increased mortality from predation, exposure, starvation, or anthropogenic factors (e.g., motor vehicle mortality).

Tortoise activities are concentrated in core areas, known as home ranges. These home ranges overlap; because tortoises do not defend a specific, exclusive area, they do not maintain territories. Home range sizes have been measured at 10-450 acres (4-180 hectares) and vary with sex, age, season, and density or availability of resources (USFWS 1994). Whereas home range sizes may vary from year to year, it is not known at what rate tortoises change their home range location and size over the course of their life. Over their entire life span, an individual tortoise may require considerably larger areas than that used in individual years.

There are many natural causes of mortality, but their extents are difficult to evaluate and vary from location to location. Several native predators are known to prey on tortoise eggs, hatchlings, juveniles, and adults including: coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), badger (*Taxidea taxus*), skunks (*Spilogale putorius*), common ravens (*Corvus corax*), golden eagles (*Aquila chrysaetos*), and Gila monsters (*Heloderma suspectum*). Additional natural sources of mortality to eggs, juvenile, and adults may include desiccation, starvation, being crushed (including in burrows), internal parasites, disease, and being turned over onto their backs during fights or courtship (Luckenbach 1982, Turner et al. 1987, pers. obs.). There are little data available to evaluate the relative contributions any of these factors make to natural mortality in undisturbed tortoise populations. Population models indicate that for a stable population to maintain its stability, on average, no more than 25% of the juveniles and 2% of the adults can die each year (Congdon et al. 1993, USFWS 1994). However, adult mortality at one site in the West Mojave was 90% over a 13-year period (Berry 1997). Morafka et al. (1997) reported 32% mortality over five years among free-ranging and semi-captive hatchling and juvenile tortoises (up to 5 years old) in the West Mojave. When the 26 that were known to have been preyed on by ravens were removed from the analysis, mortality dropped to 24%. Turner et al. (1987) reported an average annual mortality rate of 19 - 22% among juveniles over a nine year period in the East Mojave.

Habitat Requirements: Vegetation and topography in tortoise habitat within the WMPA are variable. The greatest population densities in the WMPA are found in creosote bush scrub with lower densities occurring in Joshua tree woodland and Mojave-saltbush-allscale scrub. Major topographical features used by tortoises include flats, valleys, bajadas, and rolling hills generally from 2000-3300 ft (600-1000 m) in elevation and occasionally above 4100 ft (1250 m; Weinstein 1989). Tortoises typically avoid plateaus, playas, sand dunes, steep slopes (>20%) and areas with many obstacles to free movement. They prefer surfaces covered with sand and fine gravel versus course gravel, pebbles, and desert pavement (Weinstein 1989). Friable soil is important for digging burrows, but when friability (e.g., diggability) is similar, productivity of plants is more important (Wilson and Stager 1992).

In an attempt to quantify the relationship between tortoise abundance and habitat characteristics, Weinstein (Weinstein et al. 1987, Weinstein 1989) found habitat to be difficult and complex to characterize with any accuracy. Food availability, soil diggability, longitude (higher densities in West Mojave Desert), and degree of stream-washing were the habitat characteristics that were most useful in discriminating between areas with high densities of tortoises and those with no tortoises. However, the model was quite poor at classifying into correct density categories data that were not used in developing the model.

Population Status: It is commonly claimed that tortoise populations have suffered drastic declines throughout much of the species' range, but a thorough presentation of these data has never been published (Bury and Corn 1995). Nonetheless, the cursory published accounts of tortoise populations in the West Mojave Desert do show significant reductions, at least in that region (Corn 1994, Berry and Medica 1995). At one site in the Desert Tortoise Natural Area, north of California City, a loss of approximately 76% was estimated to occur between 1979 and 1992 followed by no apparent change in 1996 (Berry 1997, Brown et al. 1999). A complete analysis of the existing data is needed. Most of the deaths were thought to be caused by a respiratory disease (see below).

Threats Analysis: Direct threats to desert tortoise populations are those that immediately affect survival and reproduction and are much easier to document. Indirect threats are those that may affect individuals in some less immediate way, such as by reducing food or altering the soil temperature, which then may affect tortoise reproduction or survival. Indirect threats are often very difficult to substantiate. Examples of direct threats include: collisions with motorized vehicles, illegal collecting, and disease. Indirect threats likely affecting tortoise populations include: habitat loss from construction and agricultural development; habitat alterations from livestock grazing, recreational activities, atmospheric pollution, global warming, and invasions of exotic plants.

Two general phenomena are particularly critical to understanding trends in tortoise populations. Their life history characteristics (e.g., delayed maturation, longevity, low average annual reproductive output, and highly variable nest success) make them susceptible to increased mortality and long delays in recovering from catastrophic losses. Additionally, as populations become increasingly fragmented, the probability of population persistence becomes more tenuous. When population size is low, inbreeding becomes a potential problem. Smaller populations also are at an increased risk of extinction from catastrophes (e.g., fires and disease) and random variation in population parameters, like sex ratio, age class structure, fecundity, and mortality. Populations can reach non-recoverable levels through fragmentation into smaller populations (e.g., from highways, utility corridors, and development) and exacerbated mortality within these fragmented populations.

The relative importance of different threat factors is difficult to rate. First, the cause of death of animals and how much decline is really attributable to the various indirect causes of mortality (e.g., habitat alteration) is difficult to determine. Second, too little is known about several potential threats to evaluate their absolute or relative impacts. Third, determining which factors cause mortality is very site specific. The following evaluation of the relative importance of each factor in terms of threat to tortoise population viability in the West Mojave Desert is based on the available scientific evidence, which is often incomplete. More complete discussions can be found in Lovich and Bainbridge (1999) and Boarman (2002).

The greatest threats to tortoise populations in the WMPA are probably: disease; the cummulative effects of habitat loss, degradation, and fragmentation from construction, urbanization, and development; and a high level of human access to tortoise habitat. Disease, specifically Upper Respiratory Tract Disease (URTD), may have caused dramatic declines in some populations (Berry 1997). The causative agent of URTD is the bacterium *Mycoplasma agassizii*, which causes lesions in the respiratory tract (Jacobson 1994). Clinical signs of the disease (e.g., swollen eye lids, nasal discharge, wheezy breath, and in extreme cases, lethargy) have been found in many animals within populations experiencing high mortality rates and has been found in some animals prior to death. The introduction, or at least the spread of the disease in some populations, has been attributed to the release of infected captive animals. Little is known about the epidemiology of the disease. It is also unclear if the disease is actually lethal and some apparent recovery has been observed (Brown et al. 1994a,b). Other than preventing the spread by proper handling of animals by trained workers, nothing is known about how to reduce the effects of the disease in wild populations. A shell disease, cutaneous dyskeratosis, has also been identified within tortoise populations. Cutaneous dyskeratosis has been associated with high mortalities in the Chuckwalla Bench area of the Colorado Desert and may be caused by a vitamin or mineral deficiency or contact with a natural or anthropogenic toxicant in the environment (Jacobson et al. 1994, Homer et al. 1998). Little is known about the cause, epidemiology, or treatment of this shell disease, and its incidence appears to be low in the West Mojave Desert.

Habitat loss, degradation, and fragmentation are major problems in the WMPA because of the high level of human activity. The West Mojave Desert is a growing suburban area, with an increase in housing, industry, and commercial development in major municipal areas, rural areas, and along major transportation corridors. The loss of habitat, mortality from increased traffic, reduced quality of habitat altered by human presence and activity, fragmentation of populations, and the cumulative effects of other problems associated with humans (e.g., dogs, recreation, utility corridors, etc.) pose a significant and increasing problem for the viability of tortoise populations within the WMPA.

Many of the individual threats discussed below relate to the level of access to tortoise habitat afforded to people. For instance, illegal collecting of tortoises for food or cultural ceremonies has been documented on a few occasions by law enforcement officials (USFWS 1994). There is ample evidence that driving off of roads compacts soil and damages vegetation (see "ORV" section, below). The possibility also exists that tortoises or their burrows may be crushed. Even though off-road rehicle (ORV) activity on roads may pose little such direct impact to tortoises or their habitat, the presence of a road poses potential harm to tortoises and their habitat, and the more roads there are the greater is the proportion of the tortoise population that is under the threat of harmful off-road activity. Other potentially harmful activities that likely occur in greater numbers near roads include: mineral exploration, illegal dumping of garbage and toxic wastes, release of ill tortoises, anthropogenic fire, handling and harassing of tortoises, spread of invasive weeds, and trailing of sheep (Berry and Nicholson 1984). The threat posed to tortoise populations by each of these activities likely increases with increased access afforded by the proliferation of roads, even very lightly traveled ones. Furthermore, some of these individual threats may be relatively low, but their cumulative impact may be great.

Several activities may be considered "moderate threats" to tortoise populations in the WMPA because they cause less direct mortality, are less widespread, are not likely to increase, probably pose a relatively low to moderate level of risk to tortoises or tortoise populations, or little is known about their impacts. The importance of each threat varies from place to place.

Also, individually, these threats may be of moderate importance, but their overall cumulative effects are probably of extreme importance.

Agriculture. The effect of agriculture on tortoise populations is primarily through the loss of habitat. When tortoise habitat is converted to agricultural use, it becomes largely unsuitable to tortoises. Other impacts include the introduction of invasive weeds, facilitation of increases in raven population, lowering of the water table, production of dust, and possible introduction of toxic chemicals.

Fire. Fire is an ever increasing threat to tortoises and their habitat in the WMPA. Fire was previously rare in the Mojave Desert, but has increased with the proliferation of introduced plants, particularly the grass red brome (*Bromus rubens*), which provide fuel for fires. Red brome helps to spread fire because it is common, tends to grow in large relatively dense mats, and fills the intershrub spaces, which are largely devoid of much native vegetation (Brooks 1998). Fires can cause direct mortality when tortoises are burned, which can happen both inside and out of burrows. There are a few documented examples of tortoises being burned by fires (Homer et al. 1988, Esque et al. in press). Other indirect impacts fires may have on tortoise populations include: 1) short-term effect of removing dry and some living forage plants (but this effect is likely short-term); 2) long-term effects of facilitating proliferation of non-native plants, which are of lower nutrient value to tortoises (Avery 1995), and may be avoided by them; 3) short-term fragmentation of tortoise habitat by creating patches of unsuitable habitat, at least on the short term; 4) alteration of temperature profile from removal shade; 5) loss of shrubs used as daytime or night time cover sites; and 6) decreased soil stability and increased erosion.

Landfills. In the West Mojave Desert, there are 13 county-run solid-waste landfills and an unknown number of unauthorized dumpsites. The potential impacts of landfills on tortoise populations include: loss of habitat, spread of garbage, introduction of toxic chemicals, increased road mortality, and proliferation of predatory species. The loss of habitat from landfill presence and expansion is relatively minor except when viewed in the context of habitat degradation and fragmentation caused by the myriad human developments that are proliferating in the desert. The greatest potential impact from landfills is their probable role in facilitating the increase in populations of predators such as common ravens, and perhaps coyotes. Ravens make extensive use of landfills for food (Boarman 1993). The food eaten probably supports raven populations through the summer and winter, when natural resources are in low abundance. As a result, large numbers of ravens are present at the beginning of the breeding season (Feb-Jun). Some then move into tortoise habitat, and then nest, raise young, and potentially feed on tortoises. Predation by ravens is probably relatively low within the immediate vicinity of landfills because of the low density of tortoises in the vicinity, but predation may increase as ravens disperse to nest farther from the landfills (Kristan 2001).

Grazing. Grazing by cattle and sheep has several potential direct and indirect effects on tortoise populations. These include: mortality from crushing of animals or their burrows, destruction of vegetation, alteration of soil, augmentation of forage (e.g., presence of livestock droppings, and stimulation of vegetative growth or nutritive value of forage plants), and competition for food. There is weak evidence for declines in tortoise density directly associated with grazing, but its evaluation is complicated by the presence of multiple factors affecting tortoises at most sites and the difficulty of being able to measure accurately tortoise densities to assay direct effects (Luke et al. 1991, Oldemeyer 1994). There are observations of sheep or cattle stepping on tortoises or their burrows (Berry 1978, Nicholson and Humphreys 1981, Avery 1998). Cattle may out compete tortoises for some seasonally important forage species (i.e., desert dandelions, *Malacothrix glabrata;* Avery 1998), but the few studies testing for it do not show strong effects of competition (Tracy 1996). Past studies have shown dietary overlap, a condition necessary, but not sufficient, to show competition (Avery 1998). There are only two studies showing sheep and tortoises eat some of the same food items (Hansen et al. 1976, Nicholson and Humphreys 1981). However, there are no studies that tested if sheep compete with tortoises for food. If livestock significantly affect tortoise populations, it is most likely through habitat alteration. Sheep and cattle are known to compact soil, trample vegetation, and cause observable changes in the composition and structure of the plant and animal communities (Nicholson and Humphreys 1981, Webb and Stielstra 1979, Berry 1978, Brooks 1995, Avery et al. in prep.). No evidence is available to indicate that sheep or cattle benefit tortoises by providing food or improving habitat condition in the Mojave Desert (cf. Bostick 1990).

Military. There are five military bases located within the WMPA. Impacts of military activities on tortoises vary from base to base, but generally fall into four categories. Four of the five facilities have large internal support communities, while all five have large operations areas. Both of these factors result in loss, degradation, and fragmentation of habitat. Each one of the bases also support local communities (e.g., Barstow, Ridgecrest, Twenty-nine Palms), which also destroy, degrade, and fragment habitat. Four of the five bases conduct substantial field maneuvers (e.g., tank operations, detonation of air and ground based explosives) that can result in direct mortality for tortoises and destruction and degradation of tortoise habitat. The proposed expansion of Fort Irwin southward will degrade a portion of tortoise habitat used by the Superior-Cronese population; this proposed expansion may pose the greatest single threat to the

West Mojave tortoise population. An additional, but unexplored, possible impact of military activity is contamination by toxic chemicals.

By virtue of the restrictive, secret, or hazardous nature of much of their activities, military bases sometimes offer a great level of protection to tortoise populations. For example, restrictions on access to the Precision Impact Range Area at Edwards Air Force Base reduces the amount of human traffic in the area, which is designated critical habitat. All bases, to some extent, prohibit public access, which likely results in less ORV activity, shooting, dumping, etc., than on adjacent private lands. The 44 square miles (71 km^2) of NASA's Goldstone Deep Space installation on Fort Irwin is a good example of relatively protected habitat where dog tracks, shotgun shells, sheep scat, etc. are scarce (LaRue pers. comm.). Furthermore, each of the bases is required to develop a Natural Resource Plan, which must comply with the Endangered Species Act.

Off-road Vehicles. Off-road vehicle (ORV) activities have caused a substantial loss of tortoise habitat and a reduction in its quality. Competitive events and free play activities cause destruction and degradation of vegetation, compaction of soil, a reduction in tortoise densities, and likely crush tortoises and burrows (Davidson and Fox 1974, Vollmer et al. 1976, Adams et al. 1982, Webb 1983, Bury and Luckenback 1986, Berry 1990 as amended). Some designated Open (free-play) Areas are in formerly high tortoise density areas, so current ORV activities may prevent recolonization of former tortoise habitat. Little data are available to evaluate the effects of light OHV activity on tortoise populations or their habitat, but the direct effects are likely to be minor if vehicles use designated routes of travel and stay on the roads. Indirect impacts, which may be substantial, probably occur wherever vehicle access is allowed in tortoise habitat. These impacts potentially include: soil compaction, vegetation destruction, significant disturbance of biotic soil crusts (i.e. cryptogams), increased soil destabilization and erosion, proliferation of non-native weeds, crushing of tortoise and burrows when vehicle leave the road, shooting and vandalism of tortoises, harming of tortoises or their burrows by dogs, deposition of garbage, providing food for ravens, and the handling, collecting, or disturbance of tortoises. Data necessary to evaluate the extent of these effects are not available, although each of these impacts is to some degree more prevalent in areas with roads than in roadless areas. Berry et al. (1994) found a negative correlation between off-road vehicle trails and tortoise sign (an index of tortoise density), although that may be because tortoise sign were obliterated by vehicles or covered by dust.

Predation. Predation is a naturally-occurring phenomenon. Predation by common ravens has become a major problem for some tortoise populations. Raven populations are increasing at a precipitous rate because of resource subsidies (food, water, nesting substrate) that are provided by increasing human populations (Boarman 1993). Ravens prey on juvenile tortoise (mean size = 2.7 inches [68.4 mm; range = 1.3-4.9 inches; 33-124 mm]). The remains of juveniles killed by ravens have been found throughout the WMPA (Berry 1985, Boarman unpubl. data). Between 1968 and 1992, raven populations in the Mojave Desert have increased by over 1000% (Boarman and Berry 1995), with the highest increases probably occurring in the West Mojave Desert. This means that every year there are more ravens present in tortoise habitat, thus increasing the predation pressure on tortoise populations. Predation by domestic dogs (*Canis familiaris*) and coyotes are likely depleting some tortoise populations (Berry 1990, as amended, Bjurlin and Bissonette 2001). Few data are available to evaluate the nature of the problem caused by these two species, which also benefit from human-based resource subsidies.

Road Mortality. Roads and highways have several impacts on desert tortoise populations and their habitat (Boarman and Sazaki 1996). Direct impacts include mortality through road kills and destruction of habitat (including burrows). On a series of annual surveys, Boarman and Sazaki (1996) found an average of one dead tortoise (mostly adults and subadults) per year for every two miles of highway. This was a conservative estimate of the incidence of road kill along California State Highway 395. Indirect effects include degradation of habitat because the roads serve as corridors for dispersal of invasive weeds, predators, development, recreation, and other anthropogenic sources of impact. They also fragment the habitat and populations and alter the sheet flow dynamics of rain water runoff. Tortoise and other animal road kills are also an important source of food for ravens, probably facilitating raven survival and population increases, and as such, roads are another indirect source of mortality to tortoises.

Utility Corridors. Corridors formed by utility and energy rights-of-way cause linear impacts to tortoise populations and may have far reaching impacts well beyond those of many point sources of impacts (e.g., developments). Far more tortoise home ranges are traversed by a narrow linear corridor than by a more condensed non-linear project of similar acreage. Further, Olson (1996) reported that the construction of a natural gas pipeline had the greatest impact on tortoises and habitat, construction of a transmission line had intermediate impacts, and a fiber optic line was the most benign. Of 53 tortoises reported accidentally killed during implementation of 171 biological opinions in California and Nevada between 1989 and 1995, 41 of them (77%) were found dead on two linear projects, including the Mojave-Kern Pipeline and Meade-Adelanto Transmission Line (Circle Mountain Biological Consultants. 1996).

Considerable habitat destruction or alteration occurs when pipelines and power lines are constructed, and the impacts are repeated as maintenance operations, new pipelines, or new power lines are placed along existing corridors. Pits left open for pipe installation or maintenance may serve as traps for tortoises and other animals (Olson et al. 1993). The habitat conversions during early stages of post-construction succession not only preclude use by tortoises, but may function to inhibit or reduce dispersal across the corridor, thus effectively fragmenting a previously intact population. Furthermore, the presence of utility towers in areas otherwise devoid of other raven nesting substrates (e.g., joshua trees, palo verdes, cliffs), may introduce heavy predation to an area previously largely immune to this activity.

Low-level Impacts. Several additional anthropogenic activities also impact tortoise populations, but may be of lesser concern because the amount of area (hence, number of tortoises) impacted is small, total effect or probability of effect on impacted animals is low, our knowledge of the potential effects is low, or our ability to control them is largely non-existent. These include: illegal collecting, energy and mineral development, uncontained refuse, handling and manipulating tortoises, noise, non-motorized recreation, and vandalism. Although many tortoises probably die from it (Peterson 1994, 1996) drought is also considered a low level of threat because, although it may confound the effects of anthropogenic factors, it is a natural phenomenon and there is virtually nothing that can be done directly to minimize its effects.

Biological Standards: Based on a series of Population Viability Analyses (PVA), the recovery plan for the desert tortoise (USFWS 1994) recommended that several areas of approximately 1000 mi^2 (1610 km^2) of tortoise habitat be conserved and managed for tortoise recovery. A PVA is a process that uses information on the special genetic and demographic traits of small populations to predict the probability of extinction over a given period of time. It is wise to set recovery goals (target number of individuals) that have relatively low probabilities of extinction. These analyses resulted in a series of conditions for the viability of populations for a period of 500 years (20 tortoise generations), and were based on several conditional assumptions.

Condition 1. A genetically viable population of desert tortoises must be composed of at least 5000 adults. This condition is based on two major assumptions: 1) 500 individuals (adults) of any species must actively and successfully reproduce and pass genes onto the next generation to maintain sufficient genetic heterogeneity (Franklin 1980, USFWS 1994; cf. Dawson et al. 1986, Lande and Barrowclough 1987) and 2) only 10% of the adult population actually contributes to future generations (Ryman et al. 1981, Shull and Tipton 1987, USFWS 1994).

Condition 2. A demographically viable population of desert tortoises must be composed of at least 50,000 adults to cushion it against environmental stochasticity (variation in population growth rates). This condition is based on several assumptions (USFWS 1994): 1) the average growth rate for tortoise populations is 0.985 (which actually represents an overall decline and is based on data collected between 1979 and 1989 from 13 tortoise populations throughout the Mojave Desert), 2) standard deviation in annual growth rate is 0.096 (20% higher than measured between 1979 and 1989 to account for greater observed and hypothesized variation than existed during those ten years), 3) environmental and population conditions (other than variance in population growth rates) between 1979 and 1989 are applicable for the next 500 years. It should be noted that catastrophes (e.g., disease, drought, major habitat destruction) were not included, the 20% increase in variation in population growth rate resulted in 250% increase in the minimum viable population size estimated, and two of the PVAs indicated that increasing population growth rates (by reducing mortality or increasing reproduction) to near 1.0 are very important for raising the probability of population persistence.

Condition 3. A viable population of desert tortoises must maintain an average minimum density of 10 adults per mi^2 (6 per km^2). This minimum number ensures that adults have ample opportunity to encounter likely mates. This condition assumes that 1) space requirements for finding a mate can be based on years of greatest home range sizes (years with low forage production) and is approximately 125 acres (50 hectares), 2) male home ranges show little overlap with neighboring males, and 3) adult male to adult female ratio is 1:1. If these assumptions are met, every female is likely to encounter a male at least in years of low forage production.

Condition 4. Each reserve should contain a minimum of 1000 mi^2 (1610km^2) of tortoise habitat. This condition assumes that 1) 5000 adult tortoises are required to maintain a genetically viable population (Condition 1, above), 2) adult tortoises must exist at an average density of 10/mi^2 (6/km^2; Condition 3, above), and 3) tortoise habitat and presence are patchy, thus some areas would contain lower densities of tortoises. This space requirement is inadequate to ensure viability based on demographic considerations (Condition 2, above), which requires 5000 - 10,000 mi^2 (8050-16,100 km^2) of tortoise habitat and as such is optimistic and makes recovery dependent on Condition 5, below.

Condition 5. Modern principles of preserve design should be employed when developing reserves. This condition assumes that populations are at a lower risk of extinction when: 1) reserves have low perimeter relative to area (i.e., approaching circular shape), 2) there is low fragmentation of reserves (hence, populations), 3) dispersal occurs among multiple reserves, and 4) there are two or more reserves for the species. The Recovery Plan recommends that there be three reserves (Desert Wildlife Management Areas, DWMAs) in the West Mojave Desert, each containing approximately 1000 mi^2 (1610 km^2) of tortoise habitat and that areas of suitable habitat be maintained between the three DWMAs to facilitate dispersal, thereby reducing the probability of extinction of any one population. If 1000 mi^2 (1610 km^2) of contiguous tortoise habitat cannot be included in a single reserve, then smaller segments, the sum of each should total at least 1000 mi^2 (1610 km^2), should be connected by corridors of usable tortoise habitat. Reserves that adhere less to these principles should be more strictly managed to reduce mortality and increase reproduction.

Condition 6. Population growth rates of 1.0 (stable population) should be achieved and maintained by reducing levels of mortality. This is particularly important in reserves where total population sizes are less than 10,000 - 20,000 animals. This condition assumes that: 1) starting populations are sufficiently large (e.g., much larger than 2,000 and probably closer to 20,000 adults), 2) variation in population growth rates does not increase greatly, and 3) no catastrophes occur. The more mortality is reduced through strict management, the greater will be the population growth rate and will be the required space of reserves. The converse is also true, the less mortality is reduced, the larger the reserves have to be to maintain the same probability of persistence. However, if population growth rates are 0.975 or less, it becomes highly unlikely that the population will persist for more than 400 years.

The assumptions made above concerning number of tortoises or amount of space are estimates based on the best available data. Actual numbers and areas necessary to establish and maintain viability are unknown, but the PVAs provide the only realistic means available for determining quantifiable targets for management areas.

Mortality can be reduced and reproduction increased through maintenance and implementation of several measures designed to reduce the effects of the threats listed above. Following is a list of actions recommended in the Recovery Plan (USFWS 1994). Most actions are oriented towards reserve-level management within DWMAs, but some apply to activities outside of the DWMAs. Activities that should be prohibited within DWMAs include: vehicles driving off of designated routes, competitive and organized ORV activities, habitat-destructive military maneuvers, clearing for agriculture, clearing for new landfills, surface disturbances that diminish habitat, livestock grazing (but perhaps allow experimental grazing in some non-core areas), feral burros and horses, vegetation harvest (w/o permit), collecting of biological specimens (w/o permit), dumping and littering, deposition of captive or displaced tortoise & other animals (w/o permit), uncontrolled dogs, discharge of firearms (except for hunting between Sept. and Feb.). Some of these activities could possibly be reintroduced once scientific research provides hard evidence that specific activities, when properly managed, have minimal impact on tortoise population viability.

The following additional actions should be implemented: erect barrier fences and passageways along selected roads and highways, sign and in some cases fence boundaries near communities and Open Areas, reduce raven predation on juvenile tortoises, implement translocations from adjacent areas, designate Ord-Rodman DWMA as an Ecological Reserve and Research Natural Area, establish drop-off site in Barstow for adopting captive tortoises, remove of feral dog packs, initiate semi-wild breeding program once it has been shown with scientific evidence that captive release can be successful and is necessary, establish visitor and resident education center and programs.

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