Reducing Predation by Common Ravens on Desert Tortoises in the Mojave and Colorado Deserts

Prepared for:

Bureau of Land Management

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

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July 18, 2002

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EXECUTIVE SUMMARY

Conflicts between humans and natural populations often result from habitat fragmentation and degradation that accompanies human activities. Common raven populations in the Mojave Desert have benefited by human-provided resources; they've expanded precipitously in recent years. Because ravens prey on juveniles of the threatened desert tortoise, they have become the focus of management concerns to help recover dwindling tortoise populations. I have outlined herein a series of management recommendations designed to reduce raven predation on desert tortoises thereby facilitating juvenile tortoise recruitment into the population of reproductive adults. The recommendations are based on the best available scientific information and are intended to provide a basis for a long-term reduction in raven impacts.

The recommendations fall into four basic categories. (1) Modify anthropogenic sources of food, water, and nesting substrates to reduce their use by ravens. This includes modifying landfill operations, septage containment practices, livestock management, and other commercial and private practices that help facilitate raven survival and dispersal by providing food and water. Most of these measures are long-term actions designed to reduce the carrying capacity of the desert for ravens. This action is critical and must be done over very large areas. (2) Lethal removal of ravens by shooting or euthanizing following live trapping. Specific ravens known to prey on tortoises would be targeted as well as all ravens found foraging within specific high-priority desert tortoise management zones (e.g., Desert Tortoise Natural Area, DTNA). These actions would primarily be deployed on a short-term emergency basis to give specific tortoises populations a necessary boost until other measures become fully implemented and achieve their goals. (3) Conduct research on raven ecology, raven behavior, and methods to reduce raven predation on tortoises. Results of these studies would be used to design future phases of the raven management program. (4) All actions should be approached within an adaptive management framework. As such monitor, actions should be designed as experiments so that monitoring of actions will yield reliable and scientifically sound results. Coordinating and oversight teams should be convened to facilitate cooperation and coordination among agencies and to ensure that the actions are being implemented effectively.

Recommendations made herein were developed to help recover tortoise populations by reducing raven predation on juvenile tortoises. If the recommendations made are implemented in concert with actions reducing other causes of mortality, ill health, and lowered reproductive output, they should aid in the long-term recovery of desert tortoise populations. Many important aspects of raven population dynamics, raven predation on tortoises, and how to manage raven populations and behavior are as yet unknown. Because of this, any raven management program must be implemented within an adaptive management framework. Doing so would allow for sufficient flexibility to modify the program as new information is gained.

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INTRODUCTION

As humans increasingly populate natural areas, more conflicts between people and animal populations arise and conservation actions become more common. Vertebrate populations can decrease and increase as a result of human-induced habitat alterations and degradations. Those vertebrate populations that increase, also known as "abundant vertebrates" (Goodrich and Buskirk 1995), sometimes cause problems for other native vertebrate populations through predation, competition, disease transmission, and hybridization. Predatory species whose populations thrive on human-provided resources (i.e., subsidized predators) may have particularly acute effects on some prey species. Management actions are often needed to reduce the effects, but the most effective actions in the long term are those that alter the root cause for population increase rather than attempting to directly control the predator population (Goodrich and Buskirk 1995).

Common Ravens (*Corvus corax)* in the Mojave and Colorado Deserts of California are classic subsidized predators. Their populations in the California deserts have increased by over 1000% over a recent 25-year period (Boarman and Berry 1995). These increases are a result of human-induced alterations, which have increased and stabilized food and water sources and have increased the number of nesting sites available to ravens (Boarman 1993a). Ravens make heavy use of garbage at landfills, water from many sources, and power towers, billboards, and other anthropogenic structures for nesting. Ravens prey on myriad food items including grains, carcasses, and live animals.

Ravens are a concern to resource managers because they prey on juvenile desert tortoises (*Gopherus agassizii*), a Federally- and state-listed threatened species, and this predation has resulted in reduced survival rates of juvenile tortoises (Boarman 1993a). The long-term consequence of the loss of juveniles is lowered recruitment of new individuals into the breeding population, which likely significantly affects the stability and recovery of some tortoise populations (Fish and Wildlife Service 1994). Many populations of the desert tortoise in California have declined drastically in recent years (Berry 1990, Fish and Wildlife Service 1994, Corn 1994). Contributing factors include disease, habitat loss and fragmentation, highway mortality, and predation by ravens. While many other human activities result in adverse impacts on adult components of tortoise populations, efforts to reduce these impacts will be fruitless unless tortoise populations can recruit young (Fish and Wildlife Service 1994, Congdon et al. 1993). Conversely, if little or nothing is done to reduce adult mortality, improve reproduction, and reverse declining health of adult tortoises, raven management will have little impact on long-term tortoise recovery (Frazer 1993, Doak et al. 1994). Without action to counter the losses of young individuals in tortoise populations, declines will continue.

A comprehensive, long-term program to reduce the effects of raven predation on tortoise and other animal populations should include the following six goals. (1) Reduce mortality of juvenile desert tortoises caused by raven predation. (2) Facilitate increased recruitment (i.e., survival) of juvenile desert tortoises into breeding age classes (i.e., subadult and adult). (3) Improve understanding of the ecology and behavior of raven populations through research and monitoring. (4) Acquire additional data on means of reducing raven predation of juvenile desert tortoises. (5) Implement those measures that are found to be effective for raven management and removal. (6) Monitor raven and tortoise populations using scientifically credible methods to determine the effectiveness of program actions at reducing rates of raven predation and facilitating recruitment of tortoises to breeding age.

BACKGROUND

PREDATORY BEHAVIOR OF RAVENS ON TORTOISES

Ravens are opportunistic feeders obtaining their food in three primary ways: scavenging, live hunting, and kleptoparasitism (stealing; Boarman and Heinrich 1999, Sherman 1993). In the Mojave desert, ravens are known to eat many things including lizards, rodents, invertebrates, grains, birds, snakes, and tortoises (Camp et al. 1993, Kristan et al. in prep.).

Evidence that ravens prey on juvenile desert tortoises (<100-mm midline carapace length [MCL]) comes from several direct observations and strong circumstantial evidence (Boarman

1993a, Morafka et al. 1997, Boarman and Hamilton ms). For instance, former Bureau of Land Management (BLM) employees Ted Rado and Jim Farrell and U. S. Navy employee, Tom Campbell, have all reported observing ravens attacking tortoises (BLM 1990a). Beneath an active raven nest, Dr. Richard L. Knight (Colorado State Univ.) found a juvenile tortoise that was missing two legs and had been eviscerated, but was still alive (Boarman 1993a).

Circumstantial evidence is mostly in the form of tortoise shells found beneath active raven nests and shells that bear evidence of raven predation being found beneath likely perch sites and lying on the desert floor. The primary way ravens eat tortoises is by pulling muscle and visceral material through a hole pecked in the shell (58%) or by pulling out a leg or head (35%; Boarman and Hamilton ms.; see also Berry 1985). The remains of juvenile desert tortoises have been found in many places including: the base of transmission towers, at isolated fence posts, at mining claim stakes, next to road barricades, under Joshua trees (*Yucca brevifolia*), at the bottom of wash embankments, and on hilltops (Campbell 1983, Berry 1985, Rado 1990, BLM 1990a, Boarman and Hamilton ms.). Such remains have been found throughout the California deserts (Boarman and Hamilton ms) and in the Eldorado and Piute Valleys, Nevada (McCullough 1995, pers. obs.).

An exceptionally high concentration of tortoise shells was found beneath a raven nest near the Kramer Hills in the West Mojave. In 1987, Woodman and Juarez (1988) collected remains of 190 juveniles killed between 1984 and 1987 and concluded that ravens accounted for 185 (97%) of the deaths. In the spring of 1988, they collected additional fresh remains of juvenile desert tortoises from the nest and perch area, bringing the total number of juveniles killed between approximately 1984 and 1988 to 250. Collections of 50 to 150 shells have been found at several other sites including at a cliff nest in Chemehuevi Valley (John Wear cited in Berry 1985; Jim Farrell 1989, cited in BLM 1990a; and Boarman unpubl. data.), two to three powerline nests in Ward Valley, and one powerline nest in Fenner Valley (BLM 1990a). Tortoise populations are difficult to estimate and the method most often used (stratified Lincoln Index using mark-recapture data) is highly questionable (Corn 1994). Furthermore the juvenile component of desert tortoise populations is notoriously difficult to sample (Berry and Turner 1986, Shields 1994) so it is difficult to place these numbers in the context of overall tortoise demography.

Estimates of total tortoise population densities in the 1980s ranged from 10 - 84/ 0.5 ha and estimates for all tortoise < 140 mm (MCL) ranged from 2 - 63/ 0.5 ha (from tables presented in Berry 1990). We used 0.5 ha because Sherman (1993) showed that ravens in the eastern Mojave Desert spent 75% of their foraging time within 400 m of their nest, which, assuming a round territory centered on the nest, equals 0.5 ha. So, a loss of 10 juvenile tortoises from around a single raven nest may represent approximately 15 to 100% of the juvenile component of the immediate population.

As ravens are well known as scavengers (Boarman and Heinrich 1999), it is likely that some of the shells reported above were scavenged rather than depredated. However, several lines of evidence suggest that predation is the main source of mortality for these shells (Boarman 1993a). First, many of the shells found beneath raven nests and at other locations show evidence of being pried open while the shell was still very soft (Boarman and Hamilton ms.). The shells of live tortoises younger than approximately seven years of age are soft, but they harden rapidly after death (Morafka pers. comm.). If a shell is pecked or pried open after hardening, it would crack, but most shells found are bent, not cracked.

Second, observations are rarely made of ill, moribund, or recently dead juveniles during the thousands of person hours spent surveying for tortoises each year since the mid-1970’s. Observations of ill, moribund, and recently dead adults are relatively common in some areas. If juvenile tortoises are dying at rates high enough to be found in such large numbers beneath raven nests and perch sites, we would expect to find more ill, moribund or recently dead ones on tortoise surveys. Additionally, until 1988, very few sick or disabled tortoises were observed on 16 BLM study plots in the California deserts (Berry 1997). In 1988, two tortoise populations were discovered with diseases, one at the DTNA and the other at Chuckwalla Bench (Jacobson et al. 1991, 1994, Homer et al. 1998). These diseases may be the primary causes of mortality among those populations Berry 1997). However, large numbers of dead juvenile desert tortoises were found under raven perching and nesting sites in areas where incidence of diseased tortoises has not yet been documented (Berry 1985, Boarman ms). Thirdly, there are at least two instances of live, apparently healthy juveniles being marked as part of separate studies then being found dead one or two months later and showing typical signs of raven predation (Woodman and

Juarez 1988, Boarman unpubl.). Finally, ravens are opportunistic feeders and are unlikely to pass up a relatively defenseless food item when found.

However likely predation on juvenile tortoises is, there is no way of knowing for certain what proportion of tortoise shells found beneath raven nests were actually scavenged versus depredated. When managing a threatened or endangered species, we must rely on the best available data and, when little or no data are available, it may be best to err on the side of the threatened or endangered species rather than risk greater population declines due to inaction. Most management decisions can be reversed or relaxed as new information is obtained, but a slip to extinction or critical endangerment may be irreversible.

There is little reason to suspect that other predators are responsible for killing the large number of tortoises found. Other potential avian predators on juvenile desert tortoises in California include: golden eagles (*Aquila chrysaetos*), greater roadrunner (*Geococcyx californianus*), red-tailed hawk (*Buteo jamaicensis*), burrowing owl (*Athene cunicularia*), and loggerhead shrike (*Lanius ludovicianus*). Berry (1985) reported finding tortoise shells beneath 12 out of 34 golden eagle nests in tortoise habitat, but the shells were all larger (129 to 263 mm MCL) than those found beneath raven nests. Berry (1985) reports one freshly killed tortoise (50 mm MCL) found with roadrunner tracks around it. Jim Cornett (pers. comm.) photographed a roadrunner investigating, shaking, then leaving behind a live juvenile. Roadrunners apparently shake then swallow their prey, they do not peck at them. One tortoise shell was found beneath a red-tailed hawk nest in 1992 (Richard J. Camp, pers. comm.), and Fusari (1982) reported finding two shells beneath a probable red-tailed hawk perch. Boarman and Hamilton (ms) found no tortoise shells beneath 54 red-tailed hawk nests. Boarman (pers. obs) found an old juvenile shell, bearing signs typical of raven predation, next to an active burrowing owl nest in 1992. An unknown avian predator (based on holes poked into the shell) killed several hatchling tortoises, which were part of a study conducted by Morafka et al. (1997). Loggerhead shrike pellets were found nearby, but they did not appear to contain tortoise remains (R. Knight, pers. comm.). So, whereas other avian species may occasionally prey on tortoises, no bird species other than ravens are known to eat juvenile tortoises (<100 mm MCL) in any great quantities.

IMPACTS OF RAVEN PREDATION ON DESERT TORTOISE POPULATIONS

The best way to determine the effect raven predation has on tortoise populations is to evaluate data from actual tortoise populations. Data from permanent tortoise study plots provide a glimpse at the levels of raven predation likely occurring on juvenile desert tortoises in the California deserts (Berry 1985; BLM 1990a) and how those levels affect tortoise populations. They show apparent gaps in representation among juvenile and immature size classes in some populations, particularly in those where predation pressure from ravens is presumably high (e.g., West Mojave). Since the mid- to late 1970's and early 1980's, raven predation appears to have had significant adverse effects on desert tortoise populations. Specifically, ravens reportedly have contributed to: (1) reduced numbers of juvenile tortoises in the hatchling to eight-year classes, (2) reduced recruitment of tortoises into the larger and older size-age classes (e.g., tortoises from 9 to 20 years of age), (3) altered the size-age class composition of the population to favor adults, and (4) overall population declines from multiple sources (BLM 1990a). Examples of the degree and nature of the impacts at five permanent study plots in the Western Mojave Desert and at two study plots in the northeastern Colorado Desert are presented in BLM (1990a).

But these data have major limitations. Of greatest importance is that the methods used to survey for tortoises is best suited for larger ones (<140 mm MCL), so juveniles are underrepresented. Also of great importance, the method employed for determining tortoise density is imprecise (Corn 1994), yielding very weak estimates of age class structure, so little inference can be made from the data.

The next best way to evaluate the likely impact ravens have on tortoise populations is through modeling. When juveniles of long-lived animals such as tortoises, with delayed maturation approaching 20 years old, experience heavy mortality, the population becomes unstable (Dunham et al. 1989, Congdon et al. 1993). The problem is greatly exacerbated when mortality among adults is increased as evidenced in populations of Blanding's turtles (*Emydoidea blandingii*; Congdon et al. 1993) and snapping turtles (*Chelydra serpentina*; Brooks et al. 1991). To maintain stability, a desert tortoise population may require juvenile survivorship of approximately 75% per year. But, in populations where adult survival is depressed and the population is declining, juvenile survivorship must be about 95 to 97% for the population to recover (from figures in Congdon et al. 1993). In such populations where raven predation is high, a sufficient number of juvenile tortoises are probably not surviving to reach the larger size and older age categories. The probable lack of sufficient recruitment of young tortoises into the adult breeding population in some areas is of considerable concern.

Ray et al. (1993), presented a demographic model based on an increasing population (r=1.02) of tortoises at Goffs, California. Their stage-structured, space-structured model predicted that juvenile mortality in excess of 25% per year is required before the modeled population experiences a decline (r<1.00). If the modeled population were stable (r=1.00), excess juvenile mortality would have to be 15% or greater to maintain stability. Ray et al. (1993) concluded that ravens are not likely to be a major problem for tortoise populations. Their model as presented has limited applicability because most desert tortoise populations addressed in this plan are experiencing overall population declines (Berry 1990, Corn 1994), increased adult mortality from several sources, and juvenile mortality from causes other than just raven predation (Fish and Wildlife Service 1994). These are all factors that suggest raven predation may be an important cause for concern, one that may be both causing population declines and preventing recovery.

Finally, Doak et al. (1994) also modeled desert tortoise populations using a size-structured demographic model and incorporating important variability in demographic parameters and correlations among vital demographic rates. One of their conclusions was that conservation actions should focus on adult females rather than just juvenile tortoises. Whereas they did question the value of raven control, they state that "programs to reduce raven predation of small tortoises…are unlikely to significantly change current population trends unless combined with other, more effective, measures" (p. 458, Doak et al 1994).

These three demographic models make somewhat conflicting conclusions regarding the relative importance of reducing juvenile mortality. A critical evaluation of the three competing models using current data is needed. However, it is clear that reduction of raven predation will probably not work if efforts to increase adult survival are not implemented successfully.

RECOMMENDATIONS ACTIONS FOR REDUCING RAVEN PREDATION ON DESERT TORTOISES

The primary purpose of any comprehensive raven management program should be to increase survival of juvenile tortoises by reducing raven depredation, thereby facilitating recruitment of young tortoises into the reproductive population. Under such a program, raven management and removal should be undertaken to: (1) reduce mortality of juvenile desert tortoises caused by raven predation; (2) increase recruitment (e.g., survival) of juvenile desert tortoises into sub-adult and adult age-classes; (3) improve understanding of the ecology of the raven through research and monitoring; (4) acquire additional data on means of reducing raven predation of juvenile desert tortoises; (5) implement those measures that are found to be effective for raven management and removal; and (6) monitor tortoise and raven populations to determine the effectiveness of program actions at reducing raven predation rates. To achieve the latter, actions should be set up in an experimental fashion to compare areas with and without raven removal.

My recommendations consists of four sets of actions: alteration of raven habitat (7 proposed actions), lethal removal of individual ravens (2 proposed actions), research (6 proposed actions), and adaptive management (2 proposed actions). In a true adaptive management mode, the program would consist of multiple phases with successive phases depending on the outcome and success of earlier phases. Herein I discuss only a logical first phase.

ACTIONS TO ALTER RAVEN HABITAT

1. Reduce the population density of ravens and number of birds that may take tortoises by reducing the availability to ravens of solid wastes at sanitary landfills.—Landfills provide an important source of food year round for ravens (Boarman et al. 1995, Kristan and Boarman 2001a, b, in. prep.). This food subsidy is particularly important during times of normally low natural food availability and likely helps to increase survivorship of ravens resulting in an increased population. Landfills likely provide food for nestlings and breeding females in the spring, thus facilitating greater survival and reproductive success (Kristan and Boarman 2001a,

Webb 2001). Ravens are known to fly up to at least 65 km in a day (Engel and Young 1992, Boarman unpubl. data). Furthermore, throughout the year ravens may travel over several hundred kilometers (Stiehl 1978, Heinrich et al. 1994). Hence, any given landfill may influence raven populations over a broad area. Preliminary analysis of mtDNA data indicates that birds at Fort Irwin are genetically equivalent to those at Edwards Air Force Base (EAFB) 120-km away (Fleischer and Boarman in prep.). Because ravens move about seasonally, and individuals eat a varied diet, birds from landfills are likely to forage in tortoise habitat many miles away and may feed on juvenile tortoises. Furthermore, water is a critical resource for ravens in the desert. Any water source close to a landfill will be heavily used by ravens and may make that landfill highly attractive to ravens (Boarman et al. 1995, unpubl. data). Finally, coyotes at landfills benefit ravens in two ways, they (i) tear open otherwise inaccessible food containers (pers. obs.), and (ii) readily dig through end-of-day cover thus exposing garbage to ravens (pers. obs.).

Because of the heavy use of landfills by ravens, intense efforts must be placed on reducing raven access to organic wastes at landfills. This can best be accomplished by (i) ensuring effective cover of waste (either ≥ 6 inches cover or complete cover of garbage with tarps temporarily) multiple times each day, (ii) erecting coyote-proof fencing, (iii) rendering raven-proof all sources of standing water at the landfill, and (iv) keeping truck cleaning areas and temporary storage facilities clean and free from organic wastes and standing water. A combination of transfer stations, regional landfills, trash compaction, and alternative temporary covers (e.g., canvas tarps) may be an efficient way to manage landfills.

These recommended measures are not entirely foreign to the California deserts. California Integrated Waste Management Board and county departments of health are more strongly enforcing regulations requiring effective end of day coverage at some landfills (pers. obs.). Some counties (e.g., San Bernardino) and landfill operators (e.g., EAFB) are compacting garbage into blocks before depositing in the landfill and using alternative covers (i.e., tarps) to temporarily cover garbage until dirt can be used. This latter practice can significantly increase a landfill’s waste capacity. Some landfills appear to be greatly reducing the number of ravens present by employing these methods (pers. obs.), but no scientific data have been collected except at EAFB (Boarman unpubl. data). An additional advance currently being employed in

San Bernardino County, California, is to reduce the number of landfills by collecting garbage in well-maintained trash bins at community transfer stations. The garbage is then transported to one of three regional landfills where it is permanently deposited.

2. Reduce the availability to ravens of organic wastes outside of landfills.--In addition to landfills, ravens obtain food from many different human-sources such as dumpsters behind restaurants and grocery stores, open garbage drums and plastic bags placed on the curb for garbage pickup, excess grain dropped from trains, and livestock carcasses at dairies (pers. obs.). Additionally, some ravens subsist on pet food left out all day for pet dogs and cats and on food intentionally left out for ravens (Goodlett pers. comm., Webb pers. comm.).

A number of measures can be taken to accomplish this objective. (i) Businesses and residents should be encouraged or required to use self-closing trash bins at transfer stations and roadside rest stops, and behind restaurants, gas stations, and grocery stores; use raven-proof garbage drums at houses and other facilities; and avoid use of plastic bags for curb-side pick up in residential areas. (ii) Livestock operators should be encouraged to reduce availability of cattle feed, carcasses, afterbirths, and insects at feedlots and dairy farms. (iii) Government and non-governmental organizations should implement public education programs and other means to reduce the number of citizens who purposely feed ravens or who inadvertently do so by leaving pet food out where ravens can easily access it. (iv) BLM and county governments need to aggressively clean up illegal dumpsites that contain organic wastes. It is not known what proportion of raven forage is received from these targeted sources nor what effect their reduction would have on raven populations. However, reproductive success is higher nearer to residential areas (Kristan and Boarman 2001a, Webb 2001). In a similar study in a very different habitat (Olympic Peninsula, Washington), Marzluff and Neatherlin (ms) showed that reproduction is higher near human sources as well, but not survivorship.

3. Reduce the availability of carcasses of road-killed animals along highways in tortoise habitat.— Ravens are well known for the habit of eating road-killed animals along highway edges (Boarman and Heinrich 1999). Road kills abound along highways in the deserts (Rosen and Lowe 1994, Boarman and Sazaki 1996). It is unknown what proportion of the entire diet

this food source comprises, but it may be substantial for birds nesting near highways. This food source may not be responsible for large increases in regional raven population size, but may help to facilitate successful nesting along roads where there otherwise may not be adequate food to support a raven family (Knight and Kawashima 1993, Kristan and Boarman 2001a). These nesting birds may also prey on tortoises in the vicinity of their nest, although few tortoises are found within approximately 0.8 km of heavily traveled highways (Boarman and Sazaki 1996) and proximity to roads does not increase predation risk to tortoises from ravens (Kristan and Boarman 2001b). In spite of these points, tortoise shells bearing evidence of being depredated by ravens have been found beneath raven nests along highways (Boarman and Hamilton in prep.).

If it is shown that some ravens derive most of their food from road kills, barrier fences (3- to 6–mm mesh hardware cloth; Boarman and Sazaki 1996) should be erected along major roads and highways to prevent animals from getting killed on roads. This would thereby reduce a steady source of food for ravens away from other sources of food such as landfills. Several highways in the southwest have already been equipped with fences to reduce tortoise mortality along roads, but in many cases the mesh size is inadequate to prevent most smaller reptiles and rodents from attempting to cross and subsequently dying on roads. Boarman and Sazaki (1996) found that 6-mm mesh barrier fence reduced vertebrate mortality by 90%. The fences should be built in concert with culverts to prevent further population fragmentation of tortoise and other animal populations.

4. Reduce the availability of water to ravens.— Water is exceptionally important to ravens in the desert. In the eastern Mojave Desert, Sherman (1993) found that breeding ravens left their territories everyday to drink water several miles away. Sewage containment sites, irrigation, stock tanks, golf course ponds, leaking faucets, and other sources of standing water provide ravens with a year-round water (pers. obs.). The only ravens Knight et al. (1998) found on a study of bird use of springs and stock tanks were recorded at stock tanks; 80% of them were drinking when first sighted. The presence of these unnatural sources of water may facilitate a higher raven population by providing water during periods of normally low availability. They also allow ravens to exist farther out in parts of the desert isolated from natural sources of water.

The large movements of ravens on a daily and seasonal basis means that human-based water sources may influence raven populations over a broad area.

Reducing availability to ravens of anthropogenic sources of water could be accomplished by modifying sewage and septage containment practices in four possible ways: (i) covering the water, (ii) altering the edge of the pond with vertical walls, (iii) placing monofilament line or screening over the entire pond, or (iv) adding methyl anthranilate, or other harmless taste aversive chemicals to standing water sources. (v) Availability of other sources of water (e.g., stock tanks, dripping water faucets, golf course ponds, tamarisk irrigation lines, etc.) could also be reduced. Emphasis should be placed on reducing availability of water during the spring, when ravens are nesting, and summer, when water demands for ravens are high but natural sources are low. The needs to reduce raven populations must be balanced against the need to provide water for other forms of wildlife that depend on anthropogenic sources of water (e.g., migratory birds), so a multispecies evaluation should be made before implementing this action (e.g., Knight et al 1998).

5. <u>Reduce the impact ravens have on tortoise populations at specific locations by removing raven nests.</u>--The majority of raven predation on tortoises probably occurs in the spring (April and May) when tortoises are most active and ravens are feeding young (Boarman and Heinrich 1999, Boarman and Hamilton ms). Parent ravens spend most of their time foraging within approximately 0.8 km of their nest (Sherman 1993); hence this is probably the zone of greatest impact on the tortoise population (Kristan and Boarman 2001b). Removing raven nests with eggs in them would probably have the greatest benefit because: (i) it is likely too late for the ravens to renest in the same year, and if they do they are less likely to be successful (Kristan and Boarman 2001a, Webb 2001; cf. Marzluff et al. 1995); (ii) it is before chicks have hatched, when ravens have 3 to 7 additional mouths to feed; and (iii) it is early enough that not too many tortoises would have been eaten (as opposed to waiting until after several tortoise shells are found). Marzluff et al. (1993) showed that ravens in Idaho often re-laid within two weeks after eggs were removed, but clutches were 12% smaller and number there were 58% fewer fledglings in those re-laid broods. Removing nests outside of the breeding season is likely to have less effect on the raven populations or their predation on tortoises since they may readily rebuild at

the beginning of the next nesting season. However, recent evidence from EAFB showed that birds with no nest in their territory at the beginning of the breeding season were less likely to commence nesting than those who already had an intact nest (Kristan and Boarman 2001). Hence, if experiments show that removing nests outside of the breeding season does reduce the probability of nest initiation in the next year, then nests should also be removed then.

This objective can best be accomplished by removing raven nests (i) in specific areas where raven predation is high and tortoise populations are targeted for special management, and (ii) during the egg-laying phase of the raven's breeding cycle (any nestlings found should be euthanized using standard humane measures; Gaunt and Oring 1997). It would also be valuable to experimentally remove nests outside the breeding season to see if ravens fail to renest in the following year. If this is successful, then nest removal can occur outside the breeding season. Other species of raptors nest in raven nests (and vice versa) and raven nests often resemble other raptor nests, so caution should be taken not to greatly impact these other bird populations (e.g., great horned owls and red tail hawks).

6. <u>Avoid constructing new nesting structures and reduce the number of existing nesting structures in areas where natural or anthropogenic substrates are lacking.</u>--The majority of raven predation on tortoises takes place during the spring and is probably accomplished by breeding birds (Boarman and Hamilton ms). Because parent ravens spend most of their time foraging within approximately 0.8 km of their nests (Sherman 1993, see also Kristan and Boarman 2001a), structures that facilitate nesting in areas ravens otherwise could not nest in may pose a danger to nearby tortoise populations particularly if they are well away from other anthropogenic attractants. Whereas the majority of ravens nested in Joshua trees at and near EAFB, a significant number also nested on myriad anthropogenic structures (e.g., radar towers, high-tension power poles, telephone poles, buildings, etc.). Many of these structures can be modified to prevent raven nesting, but some cannot. Telephone and power towers of solid construction rather than lattice and with diagonal crossbars instead of horizontal ones would be harder for ravens to nest on. Because ravens hunt primarily from the wing and will readily perch on small shrubs and the ground, there is little value in modifying structures to prevent perching.

The availability of nesting sites can best be reduced by not erecting new structures (e.g., power towers, telephones, billboards, cell phone towers, open warehouses or shade towers, etc.) within tortoise management areas where alternative natural nesting substrates (e.g., Joshua trees, cliffs) do not already exist within approximately 3 km. If they must be built, structures should be designed to prevent ravens from building nests on them. Additional reductions in tortoise losses to ravens can be accomplished by removing unnecessary towers, abandoned buildings, vehicles, etc. that may serve as nesting substrates within tortoise management areas unless natural structures are in abundance.

7. <u>Modify agricultural practices to reduce availability of food and water to ravens.</u>—Ravens often make heavy use of agricultural activities for food and water (Engel and Young 1992, pers. obs.). They feed on grains at cattle feed lots and dairies, rodents and insects in alfalfa fields, and nuts and fruits in orchards and row crop fields (Boarman and Heinrich 1999). The majority of approximately 80 ravens radio tracked at EAFB spent some portion of their time at agricultural sites, which were a minimum of 20 km from where the birds were initially trapped (unpubl. data). Knight et al. (1993) found significantly more ravens in agricultural areas than in rangelands and desert controls in the Mojave Desert. Ravens also access water on farms and dairies by drinking from irrigation ditches, ponds, puddles, and sprinklers (G. C. Goodlett, pers. comm.; W. Webb pers. comm.; pers. obs.).

Facilitation of raven population growth by agricultural practices can be reduced by reducing the availability of food and water to ravens at agricultural sites. Agricultural Extension Agents should educate agricultural professionals about measures they can take to reduce raven access to crops, feed, waste, and byproducts. Effective measures need to be developed, tested, and compared in realistic settings. Possible measures that can be used include keeping unused grain covered and burying or rendering carcasses immediately. More difficult to control are sources of water.

Lethal Actions against Individual Ravens

1. Remove birds that are known to prey on tortoises.--Evidence suggests that some ravens may be responsible for taking relatively large numbers of tortoises (BLM 1990a, Boarman and Hamilton ms). These individuals can be identified by the presence of juvenile tortoise shells beneath their nests, which are generally used year after year by the same individual breeding ravens (Boarman and Heinrich 1999). By removing those birds known to prey on tortoises, survival of juvenile tortoises in that vicinity will likely increase. However, it is very difficult to identify an offending bird with absolute certainty. Furthermore, it is even more difficult to find all tortoises likely killed by a raven, because the shells may be spread over a broad area. Therefore, any territorial bird should be targeted for removal if it is found within 1.6 km of at least one tortoise shell showing evidence of being killed by a raven within the prior 15 months. 1.6 km is a reasonable estimate of the radius of larger raven territories in the California desert (based on Sherman, 1993). Because most predation probably occurs in May, shells cannot generally be found until then. Therefore, it is necessary to allow shells found in one year to be used to target birds during the following year, hence the 15-month target window.

Individual territorial ravens should be selectively shot in areas of high tortoise predation if they are found with at lease one tortoise shell bearing evidence of raven predation within 1.6 km of their nest. Under this recommendation, targeted ravens would be shot by rifle or shotgun. Ravens should be trapped and humanely euthanized where shooting is not possible (e.g., on powerlines or in residential areas) or unsuccessful. Young ravens found in nests of removed adults should be euthanized humanely if they can be captured safely. Poisoning with DRC-1339, or other appropriate agents, may be used against targeted birds in these limited areas if it is shown to be safe for other animals. Poisoned carcasses should be removed when feasible.

BLM conducted two short-term, multi-agency projects that involved lethal removal of ravens for the benefit of tortoise populations. In 1989, a pilot program was conducted to selectively reduce raven populations at two sites: the DTNA (Kern County) and the landfill at the U.S. Marine Corps Air Ground Combat Center at Twentynine Palms (San Bernardino County; Rado 1993). Raven reduction involved using a combination of poisoning with the avicide DRC-1339 and shooting. An estimated 106 to 120 individual ravens were killed over a five-day period, but no effort was made to monitor the effectiveness of this truncated program on tortoise populations.

Some success at taking this approach was demonstrated in 1993 and 1994 when the BLM and National Biological Survey conducted an experimental program to determine the efficacy of shooting as a means of removing specific offending ravens. Forty-nine ravens were shot as part of this effort (Boarman, unpubl. data). The program demonstrated that it was possible to shoot ravens, but that it was often difficult, but not impossible, to shoot both members of a nesting pair (Boarman unpubl. data). Identifying, targeting, and successfully removing individuals was time consuming. Unfortunately, no effort was made to monitor the effect this limited program had neither on tortoise populations nor on territorial replacement by other ravens.

2. Remove ravens from specific areas where tortoise mortality from several sources is high, raven predation is known to occur, and the tortoise population has a chance of benefiting from raven removal.--Some localized populations of desert tortoises are experiencing high levels of mortality from various sources, including raven predation (Fish and Wildlife Service 1994). In such populations juvenile tortoises appear to be very rare suggesting that reproductive success is low and recruitment into the breeding population will rarely happen. In these populations, survival of any juvenile tortoise may be critical to the survival and recovery of the tortoise population, so any level of mortality of juveniles greater than perhaps 3% per year may be intolerable (Congdon et al. 1993). Because it is very difficult to find the carcasses of juvenile tortoises taken by ravens in such areas, it is extremely difficult to identify offending ravens. Therefore, rather than wait to discover the death of a rare juvenile, this action plays a proactive role by attempting to prevent the deaths of many juveniles in these highly critical populations.

This objective would consist of removal of all ravens foraging within specific limited areas (e.g., Desert Wildlife Management Areas, experimental captive release and translocation areas, DTNA, etc.) with historically high tortoise mortality and raven predation, particularly where demographic analyses indicate that juvenile survivorship has been unusually low. These must be areas where significant actions are being taken to reduce other causes of tortoise mortality. Areas near anthropogenic resources (e.g., landfills and towns) that meet these criteria could be targeted because they probably tend to facilitate a high level of predation pressure on tortoise populations (Kristan and Boarman 2001b). Ravens would be shot by rifle or shotgun if they were found foraging, hunting, roosting, or nesting within approximately 0.8 km of the specific targeted area. Where shooting is not possible (e.g., on powerlines or in recreation and residential areas), ravens should be poisoned (if shown in to be safe) or trapped and humanely euthanized. Again, young ravens found in nests of removed adults should be euthanized humanely if they can be captured safely.

There is no evidence that lethal removal will have a long-lasting effect on raven populations, raven foraging behavior, or survival of juvenile tortoises. In fact, there was no measurable reduction in numbers of breeding pairs following nine years of a large scale raven removal program in Iceland (Skarphedinsson et al. 1990). An average of 4116 ravens per year were killed, this represents an estimated 87% of the annual reproductive output of ravens in Iceland. Therefore, the lethal actions can only be implemented as a short-term solution in an effort to give the local tortoise population a small window of time without predation. Long-term habitat modifications proposed above must also be implemented in order for there to be a reasonable probability of success at reducing raven predation.

In addition to removing known offending birds, the experimental program from 1993 and 1994, discussed above, attempted to remove all birds found foraging within the DTNA. The program concluded that territorial individuals could be targeted and removed with some effort, but it was extremely difficult to shoot birds in wandering flocks (unpubl. data).

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RESEARCH ACTIONS

It is recommended that a program including the above actions also contain a strong research component because there are many uncertainties about how to reduce raven predation on tortoises. The research actions are designed to yield information necessary to develop future phases of a comprehensive raven management program.

1. Determine behavior and ecology of ravens as they pertain to predation on tortoises.--Information on the ecology and behavior of ravens in the California deserts is necessary to design and modify effective long-term management actions. Over the past seven years, data have been collected in the western Mojave Desert, mostly at EAFB, on several aspects of raven ecology. Most of that research has been focused on populations in moderately to heavily human-dominated landscapes, so information is spotty on raven ecology and behavior in more natural settings. To provide a clearer picture of raven ecology in the deserts, some future research needs to focus on birds in more natural landscapes (e.g., Joshua Tree National Park and Mojave National Preserve), particularly where predation on tortoises is occurring, as well as in areas dominated by agriculture. Other research is necessary to understand better raven demography and life history to identify where the population is most vulnerable and what factors facilitate its great increase.

There are several specific objectives that still need to be met to fully understand and manage raven predation on desert tortoises. (1) Discover how and where ravens forage on tortoises by studying individuals or pairs that are known to prey on tortoises. (2) Identify the preferred food items and foraging methods employed by ravens in different parts of the desert and determine if forage choice is learned in the nest, developed after fledging, or is simply an opportunistic behavior. (3) Identify the important sources of water of water for ravens in the Mojave. (4) Determine the extent of predation by ravens on tortoises and other animals and its effect on prey populations. (5) Investigate how raven territoriality affects raven populations and predation losses from tortoise populations. (6) Evaluate how concentrated anthropogenic food and water sources influence raven populations and behavior in tortoise habitat. (7) Characterize the nesting and foraging ecology of ravens living near highways to determine the relative importance of road kills to those birds. (8) Determine if alterations to the habitat (e.g., from livestock grazing) change tortoise vulnerability to raven predation. And (9) model age-specific mortality and reproduction in raven populations to better predict the effect various management options may have on raven populations.

The U. S. Geological Survey, in cooperation with the U.S. Air Force (EAFB) and U.S. Army (Fort Irwin), has been studying raven movements and nesting ecology in an effort to better understand their population dynamics. Preliminary results indicate that ravens use landfills significantly more often than sewage ponds and the latter more often than golf courses, towns, and the open desert (Boarman unpubl. data). They also make heavy use of agricultural fields and dairy farms (pers. obs.). Nestling and fledgling survival is higher when raised closer to anthropogenic resources, and this benefit continues until the birds are at least one year old (Kristan and Boarman 2001a, Webb 2001). Nesting very close to roads and railroads can be detrimental to the entire brood. Some ravens move about very little (1-4 km diameter) during the course of a year while others move considerable amounts (60-190 km diameter). Most movements by those in human-dominated landscapes (i.e., EAFB and vicinity) are between concentrated anthropogenic resources (e.g., landfills, dairy farms). Movements are greatest during the winter. As efforts are concentrated on two relatively heavily used military bases; the data collected will be of limited value in understanding the dynamics of raven ecology in more pristine areas (e.g., Ward Valley, Piute Valley, Pinto Basin).

Between 1991 and 1996, Boarman and Hamilton (ms) collected data from 304 raven nests from throughout the California deserts. Of those, 37 (12.2%) had a total of 266 tortoise shells beneath or near them, the remaining had none. An average of 7.2 shells was found per year beneath nests with shells. Although more raven nests were found in the West Mojave, a greater proportion of the nests in the East Mojave (40%) and Southern Colorado (40%) had tortoise shells beneath them (8.5% in the West Mojave). The results may partly reflect the non-uniform methods used to search for nests and may partly reflect lower tortoise densities in the West Mojave.

2. <u>Conduct regional surveys of the California deserts to locate and map ravens and their nests and communal roosts.</u> Information on the densities and distributions of ravens and their nest, perch, and roost sites are necessary to understand the causes of their increases, to direct and modify management efforts, and to monitor the effectiveness of management efforts. Desert-wide surveys were conducted in 1988-1989 (FaunaWest Consulting 1990). Localized surveys were conducted in the vicinity of Amboy, CA, in 1995 (Knight et al. 1999), Primm, NV, in 1991-1992 (McKernan 1992), Mesquite, CA, in 1994 (McKernan, pers. comm.), Fort Irwin, CA,

in 1996-1997 (Boarman et al. ms.), Joshua Tree National Monument (Boarman and Coe, in press) and EAFB (Boarman et al. 1995). These can all serve as baselines, but continuous information is necessary to monitor raven activities.

Objectives of this effort would be to: (i) characterize distribution, behavior, and ecology of raven populations in the California deserts; (ii) monitor changes in population levels and distribution of ravens as a result of management changes; and (iii) identify causative factors for changes in raven population levels and distribution. Inventories would include private and public lands. Project proponents and other interested parties would contribute funds to a coordinated surveying program that would concentrate both on specific sites and broad regional patterns.

Surveys were conducted between 1994 and 2000 in and around EAFB with the primary goals being to monitor for changes in raven numbers as landfill management changed and to determine which resource sites were used most by ravens (Boarman et al. 1995). These and the other surveys cited above could all be used to develop a broad-based statistically sound survey protocol. GIS-based maps of over 400 nest sites have been prepared for raven nests throughout the CDCA, but nest surveys were not intensive, effort was not proportional in all areas, and funding was very limited (Boarman and Hamilton in prep.).

3. Develop, test, and implement methods for monitoring juvenile tortoises to determine effectiveness of and need for raven management efforts.--The ultimate measure of success of reduction efforts is increased survival of juvenile tortoises and recruitment into the adult population. Because of their size and cryptic behavior, juvenile tortoises are difficult to find on standard surveys of tortoise populations making estimates tenuous at best (Berry and Turner 1986, Shields 1994). Although such surveys may be useful for tracking overall trends in populations, surveys must be developed and conducted that concentrate on monitoring the juvenile component of the populations. The methods must yield statistically valid results and use sufficient sample sizes to make valid inferences about population trends. Data on tortoise populations have been collected at 16 permanent study sites throughout California deserts (Berry 1997). Although the method is biased towards larger size classes and generally provides weak estimates of density, the data need to be evaluated to determine if their continued use can yield

the data required for monitoring the juvenile component of tortoise populations. Alternative methods using distance sampling (Buckland et al. 1993) could perhaps be used, particularly if workers focused on juveniles rather than adults.

4. Develop a demographic model of raven populations to predict the effect various management alternatives might have on raven populations.--It is difficult to be certain what long-term effect any management action will have on raven populations or their predation on tortoises. Modeling, when accompanied by statistically sound data, can provide valid predictions. Such a model can be used to predict the outcomes of alternative management strategies giving us a glimpse into the probable future. A study is needed to: (i) develop and validate a computer model of the dynamics of raven populations, incorporating age-specific mortality, natality, and dispersal; (ii) apply the model to alternative management scenarios (e.g., removal of nests, selected shooting of breeding birds, broad scale removal of birds at landfills) to determine the effect the actions would have on raven populations and their overall impact on tortoise populations. No demographic modeling has been accomplished to date, but data on clutch size and nestling and fledgling survivorship that have been collected at EAFB can be used in the models.

5. Develop and test various methods for managing raven populations and behavior.--Several possibilities exist to reduce ravens' impacts on tortoise populations, but few have been tested. Aversive chemicals, anti-perch devices, and noisemakers can keep birds away from specific places (e.g., landfills). Poisons, shooting, and relocating following live trapping, are all possible ways of removing ravens from specific areas. Removal of nests both during and outside the nesting season may reduce future nesting behavior. Tests are needed to determine the effectiveness of these and other measures with ravens in the Mojave Desert.

Several aversive chemicals have been used to keep various species of birds from eating economically important crops. Studies need to be conducted on captive and wild ravens to determine their utility for achieving the goals set out herein. Methyl anthranilate is a non-toxic, grape-flavored food additive, but it is disliked by several species of birds. For instance, it has proven effective against geese on golf courses, American robins feeding on fruits, and blackbirds feeding on rice (Avery et al. 1995). An experiment should be conducted to determine if: (i) ravens are repelled by the chemical; (ii) it can be applied efficiently at landfills and other raven concentration sites, and on sources of water used by ravens (e.g., septage ponds, stock tanks, etc.); (iii) its repeated application prevents ravens from using the resource (e.g., garbage, water, etc.), (iv) methiocarb (Avery et al. 1993, Conover 1984), carbachol (Avery and Decker 1994, Nicolaus et al. 1989), or other compounds work better than methyl anthranilate. Preliminary trials conducted in spring 2001 with three captive ravens indicated that ravens find methyl anthranilate to be distasteful, but showed no conditioned taste aversion under the conditions used in the trials (Boarman et al. 2002).

Human-provided nest and perch sites in areas where tall natural substrates are lacking may facilitate hunting, roosting, and nesting in areas where tortoises may otherwise have been immune to raven predation. If the nest and perch sites are removed or made unattractive to or unusable by the ravens, then ravens may be less apt to use or benefit by the resource or prey on nearby tortoises. The only published study on effectiveness of anti-perch devices indicates that ravens will choose alternatives perches, the ground, or may even perch on the anti-perch devices when no other perches are present (Young and Engel 1988). Furthermore, as ravens do the vast majority of their hunting while in flight, and will often perch and eat on low bushes or the ground, modifying human-provided perches is not likely to greatly reduce raven predation on tortoises. If, however, new nesting substrates are introduced to an area previously devoid of adequate nesting sites, then foraging on tortoises may be facilitated. A study should be conducted to determine if: (i) raven dependence on human-provided perches and nest sites aids hunting, nesting, and overall survival; (ii) modifying raven perches, roost sites, and nest sites on a localized basis is an effective way of reducing raven predation on tortoises; and (iii) removal of raven nests early in the breeding cycle will prevent ravens from renesting in that season.

Relocation may be considered a viable control measure if three conditions are met: (i) live trapping is cost effective, (ii) appropriate resource management agencies will agree to accept relocated birds, and (iii) the ravens will not return to the California desert, and particularly to tortoise habitat. A study should be conducted to determine: (i) if live trapping is a cost effective means of catching ravens, (ii) the relative effectiveness of different live trapping techniques, (iii) where ravens can be relocated practically and legally, and (iv) if relocated ravens will return to the capture site or other desert tortoise habitat. No work has been conducted on the response of ravens to being relocated, but some work has suggested that ravens can be trapped relatively easily, at least at concentration sites such as landfills. Recent work on the genetic relatedness of common raven populations worldwide indicates that ravens in the Southwest are a genetically distinct group, perhaps a separate species from those in the rest of the world (Omland et al. 2000). These results indicate that if ravens are to be relocated, they should not be moved to an area outside of the Southwest. Preliminary results on a smaller scale suggest that there is little population structuring within the Mojave Desert, which means that ravens move around and disperse over great distances within the Mojave (Fleischer and Boarman in prep.). Thus, they are not likely to be highly adapted to their specific locale and may be adaptable to new areas, but that they may readily move away from their newly adopted homes.

One of the most effective ways of killing ravens is with the highly specific avicide DRC-1339 (Seamans and Belant 1999). The task is effected by injecting hard-boiled eggs with the poison. The measure potentially poses an adverse impact to non-target species that may also eat the avicide-laced eggs. To determine conclusively whether DRC-1339 has an impact on non-target species, an experiment should be designed and conducted to determine what other species of animals in the California deserts might eat hard-boiled eggs. No animals other than ravens approached hard-boiled eggs during the 1989 pilot raven control program (Rado 1993), but a more comprehensive study would help to obtain more conclusive results.

6. <u>Determine how humans use the desert, what practices might be amenable to change, and best to effect those changes</u>.--We need to know what will cause changes in how people living in and use the desert. For example, what can we do to help or convince dairy farmers to change certain management practices; how can we reduce the number of people who leave food and water in various forms (e.g., open garbage cans, pet food, etc.) out where ravens can access them; how can we stop people from intentionally feeding large numbers of ravens.

ADAPTIVE MANAGEMENT ACTIONS

To work within a true adaptive management framework (Walters 1986), the plan must include and a scientifically based method for determining if the program's goals and objectives are being met. This method must include control and treatment areas to properly evaluate the action's effectiveness (Marzluff and Ewing 2001). If goals are not being met, there should be a coordinating body that can evaluate and make changes to the program.

1. <u>Monitor both raven status and effectiveness of management actions at reducing predation rates on juvenile tortoises</u>.--Implementation of some of the actions may be ineffective or insufficient to accomplish the plan's goals. To determine this, raven populations must be monitored using a scientifically sound protocol that will yield sufficient power to determine if desired changes occur. Monitoring should focus on population abundance, spatial distribution, and reproductive success. Furthermore, management actions should be implemented in a way that will facilitate scientifically-sound monitoring, such as use of treatment and control sites, replications where possible, and development and implementation of specific protocols (Marzluff and Ewing 2001). Several raven surveys have been conducted (cited in Research Action No. 2, above); their results should be used to develop a biologically and statistically valid protocol. Monitoring results may indicate that modifications to existing or implementation of additional actions may be necessary. Changes to the plan may also be indicated by additional information on raven and tortoise ecology derived from research and monitoring actions or from other relevant sources. This action is central to carrying out the proposed management plan because it provides the data necessary to evaluate and modify the program to determine the nature of Phase 2. To accomplish this, an effort must be made to monitor both raven status and effectiveness of management actions at reducing predation rates on juvenile tortoises, something that was done inadequately following the pilot and experimental programs discussed above.

2. <u>Establish work groups to facilitate interagency coordination and cooperation.</u>--Design and implementation of management actions requires continuous evaluation by knowledgeable biologists and coordination between several agencies. Management actions are broad in scope and may be difficult to fund and implement. Several agencies maintain jurisdictional authorities

over lands or permitting authorities over actions that require management. Increased coordination between these agencies will facilitate plan implementation. Furthermore, because the plan is dynamic and will occur in several phases, each one depending on new information obtained from previous phases, frequent evaluation by knowledgeable biologists and resource managers is necessary.

Two work groups should be established to oversee management direction, review information, coordinate with other agencies and groups, solicit funding for implementation of specific management measures, and distribute information. The work groups should meet annually or as needed to discuss raven management actions. One work group would be an interagency task force to coordinate implementation of the program. This group would identify specific areas where lethal removal would be implemented using the criteria outlined above. The other would be a technical and policy oversight team to evaluate the progress of the plan, interpretation of data, and recommend changes in the overall program based on scientific data. This group would help to determine what thresholds of predation and recruitment are necessary to trigger implementation or cessation of lethal action. The teams would ensure that adequate data sharing occurs among agencies and bioregional plans. The goals of the work groups would be to (i) increase efficiency, effectiveness, and scientific validity of raven management in the California deserts, and (ii) ensure that future phases are developed and implemented in accordance with results of research and monitoring outlined above.

A Technical Review Team (TRT) was formed in 1991 (Boarman 1993b). Through a series of meetings in 1991 and 1992 as well as numerous conversations between the author and TRT members, the TRT provided policy- and conceptual-level advice on the development and evolution of a BLM raven management plan that has evolved into this report. The TRT consisted of national and region representatives of conservation and animal welfare organizations as well as resource management and industry representatives. The team also helped to conceptualize the experimental program to shoot ravens that was conducted in 1993 and 1994. Biologists and managers representing several Federal and State agencies also participated in the development of various plans and helped to fund and implement the 1989 pilot control program and in development of the Draft Raven Management Plan (BLM 1990a) and Draft Environmental Impact Statement (BLM 1990b).

POSSIBLE ACTIONS FOR FUTURE PHASES

Other actions that could be considered in future phases of a raven management program include: poisoning groups of birds at concentration sites; applying conditioned taste aversion methods at landfills and other food and water sources; researching and implementing other specific control measures (e.g., use of monofilament line at landfills, ponds, etc), and in the West Mojave, evaluate the utility of head starting programs at facilitating recruitment by protecting young tortoises from falling prey to ravens. If various measures suggested herein fail, it may become necessary to employ more aggressive lethal removal at various important concentration sites (e.g., landfills, dairy farms, and agricultural fields). These actions could be proposed and evaluated as part of subsequent phases of a comprehensive raven management plan.

ACKNOWLEDGMENTS

Ted Rado, Kristin Berry, and Larry Foreman were particularly instrumental in developing the earlier Plan upon which several of the current recommendations are based. Valuable input during the evolutionary process was received from many individuals. Of particularly note is advice and recommendations from members of the Raven Technical Review Team, which included John Grandy, John Borneman, Faith Campbell, James A. St. Amant, David Otis, Steve Johnson, Frank Hoover, Lenny Young, Tom Dodson, Ed Hill, and Daniel C. Pearson. Valuable comments on earlier drafts of this report were received from Larry Foreman, John Grandy, Faith Campbell, John Marzluff, William Webb, William Kristan, and Al Stein.

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