DOI: 10.1007/s00267-003-2982-x

Managing a Subsidized Predator Population: Reducing Common Raven Predation on Desert Tortoises

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ABSTRACT / Human communities often are an inadvertent source of food, water, and other resources to native species of wildlife. Because these resources are more stable and predictable than those in a natural environment, animals that subsist on them are able to increase in numbers and expand their range, much to the detriment of their competitors and species they prey upon. In the Mojave Desert, common ravens (*Corvus corax*) have benefited from human-provided resources to increase in population size precipitously in recent years. This trend has caused concern because ravens prey on juvenile desert tortoises (*Gopherus agassizii*), a federally threatened species. In this paper, I discuss management strategies to reduce raven predation on desert tortoises. The recommendations fall into three categories: (1) managing raven populations by reducing access to anthropogenic resources; (2) removing offending ravens or other birds in specially targeted tortoise management zones; and (3) continuing research on raven ecology, raven behavior, and methods of reducing raven predation on tortoises. I also recommend approaching the problem within an adaptive management framework: management efforts should first be employed as scientific experiments—with replicates and controls—to yield an unbiased assessment of their effectiveness. Furthermore, these strategies should be implemented in concert with actions that reduce other causes of desert tortoise mortality to aid the long-term recovery of their populations. Overall, the approaches outlined in this paper are widely applicable to the management of subsidized predators, particularly where they present a threat to a declining species of prey.

Humans have the unique ability to modify landscapes and alter the distribution of habitats and resources. The effects of landscape changes become more widespread and pronounced as humans increasingly populate natural areas. Such changes often are detrimental to native species, but can be beneficial to generalists that not only make use of disturbed habitats but also may subsist on anthropogenic resources. Such species—termed "abundant vertebrates" by Goodrich and Buskirk (1995)—can create problems for habitat specialists through predation, competition, disease transmission, and hybridization. The effect is not limited to the disturbed areas. "Spillover predation" (Schneider 2001, Kristan and Boarman 2003) occurs when predator populations are maintained by some abundant, often introduced, prey, but depredate rare native prey when they come across them in the same habitat. In many cases, active management is necessary to overcome the imbalance that favors subsidized species.

In the Mojave and Colorado deserts of California, USA, common ravens (*Corvus corax*) are a classic subsidized predator. They have a varied diet, including grains and scavenged carcasses, as well as live prey—a versatility that allows them to benefit from garbage at landfills and dumpsters. They are able to travel long distances to take advantage of anthropogenic food and water sources, and they make use of power towers, billboards, and other structures as nest substrate (Boar-

both a daily and a seasonal basis, human-provided water sources may affect 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: (1) covering the water, (2) altering the edge of the pond with vertical walls, (3) placing monofilament line or screening over the entire pond, or (4) adding methyl anthranilate or other harmless taste aversive chemicals to standing water sources. 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 need 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 and others 1998).

Agricultural practices also make food and water available to ravens (Engel and Young 1992, personal observation). Grains at cattle feed lots and dairies, rodents and insects in alfalfa fields, and nuts and fruits in orchards and row crop fields all are eaten by ravens (Boarman and Heinrich 1999). Water is accessible on farms and dairies at irrigation ditches, ponds, puddles, and sprinklers (G. C. Goodlett, personal communication, W. Webb personal communication, personal observation). The majority of approximately 80 ravens radio tracked at EAFB spent some portion of their time at a agricultural sites, which were a minimum of 20 km from where the birds were initially trapped (unpublished data). Knight and others (1993) found significantly more ravens in agricultural areas than in rangelands and desert controls in the Mojave Desert. Controlling raven access to subsidies in an agricultural setting presents a challenge, as food and water are ubiquitous; however, doing so is an important step in reducing the abundance of ravens. Education will play a critical role, as extension agents can encourage agricultural professionals to cover unused grain containers, bury or render carcasses immediately, and dispose of other wastes and byproducts in secure containers.

Discourage nesting behavior. Efforts to discourage ravens from nesting also will help reduce raven populations and local raven predation on tortoises. 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 in preparation). Parent ravens spend most of their time foraging within approximately 0.4 km of their nest (Sherman 1993); hence this is probably the zone of greatest impact on the tortoise population (Kristan and Boarman 2003). Removing raven nests with eggs in them would probably have the greatest benefit because they are not likely to renest, and if they do, they are less likely to be successful (Kristan and Boarman 2001, Webb 2001, cf. Marzluff and others 1995). In addition, it is best to remove nests before chicks have hatched, when the pressure to feed 3–7 juveniles may increase the frequency of tortoise predation. Dipping bird eggs into corn oil prevents hatching and causes the parents to continue incubating rather than renesting that year (Wildlife Services 2001). Although labor intensive, this is an alternative way to reduce reproduction and brood-related foraging. Recent evidence from EAFB indicates that fledging success is significantly reduced in late broods. Thus, if destroying nests or oiling eggs causes initiation clutches to be delayed sufficiently, then these reproduction efforts would probably fail.

Removing nests outside of the breeding season probably would 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 that 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. 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-tailed hawks).

In addition, the construction of new nesting structures (e.g., power towers, telephone poles, billboards, etc) should be avoided in tortoise habitat, and, if possible, existing nesting structures should be removed in areas where natural substrates are lacking. 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. At EAFB, a significant number of ravens nested on myriad anthropogenic structures (e.g., radar towers, high-tension power poles, telephone poles, buildings, etc.) (Webb 2001, Boarman personal observation). 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 are harder for ravens to nest on (Boarman personal observation). 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. 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.

Lethal actions against individual ravens. There is no evidence that lethal removal will have a long-lasting effect on raven population levels, raven foraging behavior, or survival of juvenile tortoises. In Iceland, a large-scale raven removal program found that there was no measurable reduction in numbers of breeding pairs following nine years of removal (Skarphedinsson and others 1990). Still, a relaxation from predation pressure in specific areas for several years may help tortoise recruitment. The BLM conducted two short-term, multiagency projects that involved lethal removal of ravens for the benefit of tortoise populations. In 1989, a pilot program poisoned and shot 106–120 birds at the Desert Tortoise Natural Area (DTNA) (Kern County, California) and the landfill at the US Marine Corps Air Ground Combat Center at Twentynine Palms (San Bernardino County) (Rado 1993). No effort was made to monitor the effectiveness of this aborted program on tortoise populations (Boarman 1993b). Some success at taking this approach was demonstrated in 1993 and 1994 in an experimental program in which 49 ravens were shot (Boarman unpublished data). Unfortunately, no effort was made to monitor the effect this limited program had on either tortoise populations or territorial replacement by other ravens. I recommend that lethal actions should only be implemented as a short-term solution in an effort to give the local tortoise population a small window of time with minimal predation. The nonlethal raven management measures proposed above must also be implemented for there to be a reasonable probability of success at reducing raven predation (Schneider 2001).

One case in which lethal removal may be particularly effective is for ravens that are known to prey on tortoise. Evidence suggests that some ravens may be responsible for taking relatively large numbers of tortoises (US BLM 1990a, Boarman and Hamilton in preparation). 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 may increase locally. However, it is very difficult to identify an offending bird with absolute certainty. Furthermore, it is even harder to find tortoises killed by a raven, because the shells may be spread over a broad area. Territorial ravens should be selectively shot in areas of high tortoise predation if they are found with at least one tortoise shell bearing evidence of raven predation within 1.6 km of their nest, a reasonable estimate of the radius of their territories in the California desert (based on Sherman 1993). Under this recommendation, targeted ravens would be shot by rifle or shotgun or trapped and humanely killed where shooting is not possible (e.g., on power lines or in residential areas) or successful. Young ravens found in nests of removed adults should be killed euthanized humanely if they can be captured. Poisoning with DRC-1339, or other appropriate agents, could 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.

Lethal removal of ravens also may be a useful tool in situations where critical tortoise populations face threats from several sources, including raven predation. In this case, ravens would be removed from specific areas (e.g., limited portions of 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. Areas near anthropogenic resources (e.g., landfills and towns) that meet these criteria could be targeted because they probably facilitate a high level of predation pressure through spillover predation (Kristan and Boarman 2003) . None of these actions should be implemented without being accompanied by nonlethal, long-term actions.

Research and Monitoring

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.

The first objective of research efforts should be to determine the 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 eight years, data have been collected in the western Mojave Desert, mostly at EAFB, on several aspects of raven ecology.

Most of that research was 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 better understand 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 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 US Geological Survey, in cooperation with the US Air Force (EAFB) and US Army (Fort Irwin), studied raven movements and nesting ecology for six years in an effort to better understand their population dynamics (Boarman and others 1995, Kristin and Boarman 2001, Kristan and Boarman 2003, Webb 2001). Studies concentrated on the use of anthropogenic habitats and resources, nestling and fledgling survival relative to proximity to anthropogenic resources, natal dispersal, adult movements, and spatial aspects of predation risk posed by ravens. For six years, Boarman and Hamilton (in preparation) collected data from 304 raven nests throughout the California deserts to determine the geographic extent of raven predation.

In addition, regional surveys should be conducted of the California deserts to locate and map ravens and their nests and communal roosts. 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. These can all serve as baselines, but continuous information is necessary to monitor raven activities. Objectives of this effort would be to characterize distribution, behavior, and ecology of raven populations in the California deserts; monitor changes in population levels and distribution of ravens as a result of management changes; and identify potential causative factors for changes in raven population levels and distribution. Inventories should include private and public lands. Project proponents and other interested parties could 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 changes in raven numbers as landfill management changed and to determine which resource sites were used most by ravens (Boarman and others 1995). These and the other less extensive surveys throughout the Mojave Desert, California (Fauna West Wildlife Consultants 1990), Amboy, California (Knight and others 1999), Primm, Nevada, Mesquite, California (McKernan, personal communication), Fort Irwin, California (Boarman and others in preparation), Joshua Tree National Monument, California (Boarman and Coe 2002), EAFB (Boarman and others 1995), and Marine Corps Air Ground Combat Center, California (Chamblin and Boarman, unpublished data) could be used to develop a broad-based statistically sound survey protocol. GIS maps of over 400 nest sites in the California deserts have been prepared, but nest surveys were ad hoc, the effort was disproportional in some areas, and funding was very limited (Boarman and Hamilton in preparation).

An effort should also be made to 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 to monitor the juvenile component of tortoise populations. Alternative methods using distance sampling (Buckland and others 1993) or removal rate of tortoise models (Kristan and Boarman 2003) could perhaps be used.

Another important goal is to 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 develop and validate a computer model of the dynamics of raven populations, incorporating age-specific mortality, natality, and dispersal and to 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 has been collected at EAFB can be used in the models (Kristan and Boarman 2001, Webb 2001).

A fifth research objective is to develop and test specific methods to directly manage raven populations and behavior. Several possibilities exist to reduce raven impact on tortoise populations, but few have been tested. Aversive chemicals, antiperch devices, and noisemakers can keep birds away from specific resource sites that may facilitate increasing raven populations (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 [e.g., methyl anthranilate (Avery and others 1995), methio-carb (Conover 1984), carbachol (Avery and Decker 1994, Nicolaus and others 1989)]. However, they do have limitations. Methyl anthranilate is highly volatile and breaks down readily under exposure to ultraviolet light; it has limited utility in natural settings. Perhaps it could be sprayed over garbage to repel ravens for a few hours until the garbage can be covered. Methio-carb has been used to condition ravens against eating bird eggs (Avery and others 1993). Maybe it could be applied to model tortoises and deployed at sites where nursery-bred juvenile tortoises are to be bred and released (Morafka and others 1997). Studies need to be conducted on captive and wild ravens to determine their utility for achieving the goals set out herein. 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 and others 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. However, as ravens likely 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 probably will not 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 definitively if: (1) raven dependence on human-provided perches and nest sites aids hunting, nesting, and overall survival; (2) modifying raven perches, roost sites, and nest sites on a localized basis is an effective way of reducing raven predation on tortoises; (3) removal of raven nests early in the breeding cycle will prevent ravens from renesting in that season; and (4) oiling of eggs inhibits egg hatching while discouraging parents from laying another clutch (Wildlife Services 2001).

One of the most effective ways of killing ravens is with the 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 nontarget species that may also eat the avicide-laced eggs. To determine conclusively whether DRC-1339 has an impact on nontarget 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.

Lastly, an effort should be made to determine how humans use the desert, what practices might be amenable to change, and how best to effect those changes. We need to know what will cause changes in how people live in and use the desert. For example, what can we do to help or convince dairy farmers to change management practices? How can we reduce the number of people who leave out food and water in various forms (e.g., open garbage cans, pet food, etc.) where ravens can access them? How can we stop people from intentionally feeding large numbers of ravens?

Adaptive Management Approach

I recommend that the management of ravens to reduce predation on desert tortoises should take an adaptive management approach, with feedback on successes and failures guiding a process that is constantly evolving. To work within a true adaptive management framework (Walters 1986), the plan must include 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.

To assess effectiveness of management techniques at reducing raven predation on tortoises, monitoring of raven status and predation rates on juvenile tortoises should be conducted. Implementation of some of the actions may be ineffective or insufficient to accomplish the plan's goals. To determine this, tortoise and raven populations must be monitored using a scientifically sound protocol that will yield sufficient power to determine if desired changes occur. Raven 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 and Monitoring, above); their results should be used to develop a biologically and statistically valid protocol. Tortoise monitoring is problematic and was discussed, above. 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 or from other relevant sources. This action is central to carrying out the recommended management actions because it provides the data necessary to evaluate and modify the program to determine the nature of phase 2.

Another adaptive management strategy that I recommend is to establish work groups to facilitate interagency coordination and cooperation. 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.

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. 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.

As an example, a technical review team (TRT) was formed in 1991 (Boarman 1993b). Through a series of meetings in 1991 and 1992, the TRT provided policy- and conceptual-level advice on the development and evolution of a US BLM raven management plan that has evolved into this manuscript. The TRT consisted of national and regional representatives of conservation and animal welfare organizations as well as resource management and industry representatives.

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 to reintroduce and protect 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.

Acknowledgements

Larry Foreman, Ted Rado, and Kristin Berry 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 particular note is advice and recommendations from members of the Raven Technical Review Team, which included John Borneman, Faith Campbell, Tom Dodson, John Grandy, Ed Hill, Frank Hoover, Steve Johnson, David Otis, Daniel C. Pearson, James A. St. Amant, and Lenny Young. Valuable comments on earlier drafts of this manuscript were received from Michael Avery, Faith Campbell, Doug Chamblin, Steve Corn, Larry Foreman, John Grandy, William Kristan, John Marzluff, Al Stein, and William Webb.

References

Avery, M. L., and D. G. Decker. 1994. Responses of captive fish crows to eggs treated with chemical repellents. *Journal of Wildlife Management* 58:261–266.

Avery, M. L., Bergman D. L., Decker D. G., Flynt R. D., Knittle C. E., Pavelka M. A., Tope K. L. 1993. Evaluation of aversive conditioning for reducing raven predation on eggs of California least terns, Camp Pendelton, California—1992. US Department of the Interior, Denver Wildlife Research Center, Florida Field Station. Gainesville, Florida, 92 pp.

Avery, M. L., D. G. Decker, J. S. Humphrey, E. Aronov, S. D. Linscombe, and M. O. Way. 1995. Methyl anthranilate as a rice seed treatment to deter birds. *Journal of Wildlife Management* 59:50–56.

Berry, K. H., 1985. Avian predation on the desert tortoise (Gopherus agassizii) in California. US Bureau of Land Management, Riverside, California. Report to Southern Edison Company, Rosemead, California.

Berry, K. 1990. The status of the desert tortoise in California in 1989. Draft report. US Bureau of Land Management, Riverside, California.

Berry, K. H. 1997. Demographic consequences of disease in two desert tortoise populations in California, USA. Proceedings: conservation, restoration, and management of tortoises and turtles—an international conference, pp. 91–99.

Berry, K. H., and F. B. Turner. 1986. Spring activities and habitats of juvenile desert tortoises, *Gopherus agassizii,* in California. *Copeia* 1986:1010–1012.

Boarman, W. I. 1993a. When a native predator becomes a pest: a case study. Pages 191–206 *in* S. K. Majumdar, E. W. Miller, D. E. Miller, E. K. Brown, J. R. Pratt, and R. F. Schmalz. Eds, Conservation and resource management. Pennsylvania Academy of Sciences, Philadelphia, Pennsylvania.

Boarman, W. I. 1993b. The raven management program of the Bureau of Land Management: status as of 1992. Pages 113–116 *in* Proceedings of the Desert Tortoise Council Symposium, 1992.

Boarman, W. I., and K. H. Berry. 1995. Common Ravens in the Southwestern United States, 1968–92. Pages 73–75 *in* E. T. Laroe Eds, Our living resources: a report to the nation on the distribution, abundance, and health of US plants, animals, and ecosystems. US Department of the Interior–National Biological Service, Washington, DC.

Boarman, W. I., and B. Heinrich. 1999. Common Raven. *in* A. Poole, and F. Gill. Eds, The birds of North America, No. 476. The Birds of North America, Inc, Philadelphia, Pennsylvania.

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

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

Boarman, W. I., Coe, S.J. and Webb, W. (2002) Development of aversion techniques to prevent equipment damage by common ravens (*Corvus corax*) at China Lake Air Warfare Station. Report to China Lake Naval Air Warfare Station. U.S. Geological Survey, San Diego, California.

Boarman, W. I., Coe, S.J. 2002. An evaluation of the distribution and abundance of common ravens at Joshua Tree National Monument. *Bulletin of the Southern California Academy of Sciences* 101:86–102.

Brooks, R. J., G. P. Brown, and D. A. Galbraith. 1991. Effects of a sudden increase in natural mortality of adults on a population of the common snapping turtle (*Chelydra serpentina*). *Canadian Journal of Zoology* 69:1314–1320.

Buckland, S. T., K. Burnham, and D. Anderson. 1993. Distance sampling: estimating abundance of biological populations. Chapman & Hall, London, 446 pp.

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

Campbell, T. 1983. Some natural history observations of desert tortoises and other species on and near the Desert Tortoise Natural Area, Kern County, California. Pages

80–88 *in* M. Trotter (ed.), Proceedings of the Desert Tortoise Council symposium, 1983.

Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. *Conservation Biology* 7:826–833.

Conover, M. R. 1984. Response of birds to different types of food repellents. *Journal of Applied Ecology* 21:437–443.

Corn, P. S. 1994. Recent trends of desert tortoise populations in the Mojave Desert. Pages 85–93 *in* R. B. Bury, and D. J. Germano. Eds, The biology of North American tortoises. National Biological Service, Washington, DC.

Doak, D., P. Karieva, and B. Klepetka. 1994. Modeling population variability for the desert tortoise in the western Mojave Desert. *Ecological Applications* 4:446–460.

Dunham, A. E., K. L. Overall, W. P. Porter, and C. A. Forster. 1989. Implications of ecological energetics and biophysical and developmental constraints for life-history variation in dinosaurs. Pages 1–19 *in* J.O. Farlow Eds, Paleobiology of the dinosaurs. Paper 238. Geological Society of America, Boulder, Colorado.

Engel, K. A., and L.S. Young. 1992. Movements and habitat use by common ravens from roost sites in southwestern Idaho. *Journal of Wildlife Management* 56:596–602.

Fauna West Wildlife Consultants. 1990. Relative abundance and distribution of the common raven in the deserts of southern California and Nevada during spring and summer of 1989. Report to US Bureau of Land Management, Contract No. YA651-CT9-340035. Riverside, CA, 60 pp. + appendixes.

Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) Recovery Plan. US Fish and Wildlife Service, Portland, OR, 73 pp. + appendix.

Frazer, N. B. 1993. Sea turtle conservation and halfway technology. *Conservation Biology* 6:179–184.

Fusari, M. 1982. Feasibility of a highway crossing system for desert tortoises. Report to California Department of Transportation. Report No. FHWA/CA/TP-8/1. Sacramento, CA.

Goodrich, J. M., and S. W. Buskirk. 1995. Control of abundant native vertebrates for conservation of endangered species. *Conservation Biology* 9:1357–1364.

Heinrich, B., D. Kaye, T. Knight, and K. Schaumburg. 1994. Dispersal and association among common ravens. *Condor* 96:545–551.

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

Hughes, J. M. 1996. Greater Roadrunner. *in* A. Poole, and F. Gill. Eds, The birds of North America, No. 244. The Birds of North America, Inc, Philadelphia, Pennsylvania.

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

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

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

Knight, R. L, H. A. L. Knight, and R. J. Camp. 1993. Raven populations and land-use patterns in the Mojave Desert, California. *Wildlife Society Bulletin* 22:469–471.

Knight, R. L., R. J. Camp, and H. A. L. Knight. 1998. Ravens, cowbirds, and starlings at springs and stock tanks, Mojave National Preserve, California. *Great Basin Naturalist* 58:393–395.

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

Kristan, III, W. B., and W. I. Boarman. 2001. Effects of anthropogenic developments on raven nesting biology in the west Mojave Desert. *in* W. B. Kristan, III Eds, Effects of habitat selection on avian population ecology in urbanizing landscapes. PhD Dissertation. University of California, Riverside, Riverside, CA.

Kristan, III, W. B., and Boarman, W.I. 2003. The spatial distribution of risk of desert tortoise (*Gopherus agassizii*) predation by common ravens (*Corvus corax*). *Ecology* (in press).

Marzluff, J. M., and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: A general framework and specific recommendations for urbanizing landscapes. *Restoration Ecology* 9:280–292.

Marzluff, J. M., Whitmore, K., Valutis, L. 1995. Captive propagation, nest manipulation, and nesting behavior of common ravens in the Snake River Birds of Prey National Conservation Area. Pages 305–312. *in* Snake River Birds of Prey National Conservation Area research and monitoring annual report, 1994. Bureau of Land Management, Boise.

McKernan, R. L. 1992. Field observations of common ravens at Whiskey Pete's California Nevada Stateline. Spring 1992. Report to US Department of the Interior, Bureau of Land Management, Needles, CA.

Morafka, D. J., Berry K. H., and Spangenberg, E. K. 1997. Predator-proof field enclosures for enhancing hatching success and survivorship of juvenile tortoises: a critical evaluation. Proceedings: conservation, restoration, and management of tortoises and turtles—an international conference, pp. 147–165.

Nicolaus, L. K., J. Herrera, J. C. Nicolaus, and C. R. Dimmick. 1989. Carbachol as a conditioned taste aversion agent to control avian depredation. *Agriculture, Ecosystems & Environment.* 1989:13–21.

Rado, T. 1993. Results of the 1989 pilot raven control program. Pages 266–272 *in* Proceedings of the Desert Tortoise Council symposia, 1987–1991.

Ray, C., Gilpin, M., Biehl, C., and Philippi, T. 1993. Modeling raven predation on the desert tortoise: An age and space structured approach. Pages 118–124 *in* Proceedings of the Desert Tortoise Council symposium, 1992.

Rosen, P. C., and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. *Biological Conservation* 68:143–148.

Schneider, M. F. 2001. Habitat loss, fragmentation and predator impact: spatial implications for prey conservation. *Journal of Applied Ecology* 38:720–735.

Seamans, T. W., and J. L. Belant. 1999. Comparison of DRC-1339 and alpha-chloralose to reduce herring gull populations. *Wildlife Society Bulletin* 27:729–733.

Sherman, M.W. 1993. Activity patterns and foraging ecology of nesting common ravens in the Mojave Desert, California. M.S. Thesis, Colorado State University, Fort Collins Colorado.

Shields, T. 1994. Field sampling of small tortoises: three experiments. Page 374 *in* Proceedings of the Desert Tortoise Council symposia, 1987–1991.

Skarphedinsson, K. H., O. Nielsen, S. Thorisson, S. Thorstensen, and S. A. Temple. 1990. Breeding biology, movements, and persecution of ravens in Iceland. *Acta Naturalia Islandica* 33:1–45.

Smith, A. P., and D. G. Quin. 1996. Patterns and causes of extinction and decline in conilurine rodents. *Biological Conservation* 77:243–267.

Soulé, M. E. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. *Conservation Biology* 2:75–92.

Stiehl, R.B. 1978. Aspects of the ecology of the common raven in Harney Basin, Oregon. PhD dissertation, Portland State University, Portland, Oregon.

US BLM (Bureau of Land Management). 1990a. Draft raven management plan for the California Desert Conservation Area. US Bureau of Land Management, Riverside, California, 59 pp

US BLM (Bureau of Land Management). 1990b. Draft environmental impact statement for the management of ravens in the California Desert Conservation Area. US Bureau of Land Management, Riverside, California, 73 pp + appendices.

Walters, C.J. (1986) Adaptive management of renewable resources. Macmillan, New York, pp 374.

Webb, W. C. 2001. Common raven (*Corvus corax*) juvenile survival and movements in a human augmented landscape. M.S. Thesis. University of California, Riverside, California.

Wildlife Services. 2001. Egg oil: an avian population control tool. Technical bulletin. US Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

Woodman, A. P., and Juarez, S. M. 1988. Juvenile desert tortoises utilized as primary prey of nesting common ravens near Kramer, California. Paper presented at the 13th annual meeting and symposium of the Desert Tortoise Council, 26–27, March 1988, Laughlin, Nevada.