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When a Native Predator Becomes a Pest: a Case Study

by

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INTRODUCTION

The recovery of threatened and endangered species requires that resource agencies consider several management actions to reverse the declines which are the result of increased mortality, reduced natality, or both. One important cause of increased mortality is predation by species with which the population has not coexisted until recently. These predatory populations may be either introduced species or native species that have experienced range expansions or population increases. Many management problems occur when the predator populations are subsidized by human activities; that is, when their population increases or range expansions are facilitated by resources provided by humans. These resources may include food, water, nest and perch sites, and refugia from predation and weather.

Historically, predator control primarily involved removal of individuals that were causing an economic impact (Di Silvestro 1985). Recent predator control efforts have also focused on minimizing the adverse effects native predators have on threatened or endangered species (e.g., common raven [*Corvus corax*] predation on eggs of the least tern [*Sterna antillarum browni*], Knittle 1992; and coyote [*Canis latrans*] predation on the San Joaquin kit fox [*Vulpes macrotis mutica*], Scrivner and Harris 1986). Such situations are complicated by ethical, social, and political concerns about managing native species. The program of the United States Department of Interior's Bureau of Land Management's (BLM) to reduce common raven predation on the threatened desert tortoise (*Gopherus* [=*Xerobates*] *agassizii*; BLM 1990a, 1990b) serves as an excellent example of the complications introduced by such concerns.

My primary purpose is to highlight some of the problems resource managers face when attempting to manage a native predator of a threatened or endangered animal population. I will use the BLM's evolving raven control program to illustrate these points. First, I will define the problem as it exists today by providing a history of the BLM's program and some background to the issue of raven predation on tortoises. Then, I will characterize the nature of the interaction between tortoises and ravens. Next, I will briefly discuss some of the more difficult issues that the BLM has encountered. Finally, I will conclude by emphasizing the importance of sound scientific data with the understanding that the crisis-nature of many conservation and resource management decisions (Soulé 1985) makes adherence to rigorous scientific principles sometimes difficult and unrealistic.

BACKGROUND

Tortoise Biology

The desert tortoise, a member of the Testudinidae, is a long-lived reptile that lives in the deserts of southern California and Nevada, Arizona, extreme southwest corner of Utah, and in portions of northwestern Mexico. The Mojave tortoise population, which lives west and north of the Colorado River, primarily occurs in open plains and valleys and is associated mostly with creosote bush, succulent, cheesebush, black bush, hopsage, shadscale, and Mojave saltbush-allscale scrub communities (U. S. Fish and Wildlife Service 1992). Tortoise activity corresponds to periods of water and food availability and is mediated by temperature. Inactive periods (e.g., winter, summer, and nighttime) are usually spent in subterranean burrows and small caves or crevices. Desert tortoises can live for over

100 years and reach sexual maturity at 15 to 20 years of age (Woodbury and Hardy 1948). The midline carapace length (MCL) of hatchling tortoises is approximately 35 mm, of 20-year-olds is 180 mm, and of the largest adults can be over 320 mm (Woodbury and Hardy 1948). Females lay an average of 4.5 eggs per year (Turner et al. 1987), but there is significant variability within and among individuals depending, in part on changing weather and habitat conditions.

Ravens as Subsidized Predators

Subsidized predators (after Soulé 1988) are defined as predator populations that survive and perhaps grow, in part, because of food, water, or other limiting resources provided by or associated with human activities. As a result of their association with humans, the populations grow well beyond the "natural" carrying capacity of the habitat. The subsidies may be particularly crucial in facilitating large populations by reducing mortality during only a short period of time when limiting resources are normally in low supply, as in winter.

Ravens are an excellent example of a subsidized predator. For example, they use roadkills and refuse at landfills as food (Bent 1946; Harlow et al. 1975; Knight and Call 1980; Engel and Young 1989; FaunaWest 1989; Heinrich 1989; Knight and Sherman 1991), and obtain food subsidies at sewage ponds, open dumpsters, agricultural fields, feedlots, parks, and picnic areas (Engel and Young 1989; FaunaWest 1989; Heinrich 1989). Ravens obtain water subsidies in agricultural fields, cattle troughs, sewage ponds, reservoirs, and gutters (FaunaWest 1989). In the deserts of California food and water subsidies likely facilitate increased raven populations by allowing survival during the summer and winter when prey species may be inactive and water may be scarce.

Three other forms of resource subsidies to ravens are man-made perch, nest, and roost sites. Ravens often nest and perch on power towers, telephone poles, buildings, billboards, fences, abandoned vehicles, freeway or railroad overpasses, and light posts (Knight and Call 1980; White and Tanner-White 1988) and large communal roosts are known to form on transmission towers (FaunaWest 1989; Engel et al. 1992). In some localities these man-made perch sites may allow ravens to nest or perch in areas previously inaccessible to them except short forays. It is also possible that high perches allow ravens to hunt and scavenge more effectively or with less energy expenditure than required by flight or a low perch (Knight and Kawashima 1991). Austin (1971), FaunaWest (1989), and Knight and Kawashima (1991) found significantly more ravens along powerlines and highways than along secondary roads or in areas away from linear right-of-ways. During surveys conducted in tortoise habitat in California, raven sightings were far more numerous in regions of relatively high human presence (e.g., western Mojave desert) than those of relatively low human presence (FaunaWest 1989).

Interactions between Ravens and Tortoises

Ravens obtain food in three ways: scavenging, live hunting, and pirating from other animals (Knight and Call 1980). The former two are the primary tactics used by nesting ravens during the breeding season in the deserts of California (Knight and Sherman 1991). Ravens are known to kill many types of animals for food including: invertebrates, lizards, snakes, mice, ground squirrels, weasels, lambs, and birds (Knight and Call 1980; Heinrich

1989; Camp et al. in press).

Ravens are also known to prey on juvenile desert tortoises (Berry 1985; BLM 1990a). The evidence for this comes from several direct observations and circumstantial evidence. Because tortoises are slow moving and lack aggressive defensive weapons, they are susceptible to raven predation. The primary ways ravens likely eat tortoises are by pecking a hole through the shell when it is still soft (the age of shell hardening may vary from about three to seven years and depends on many factors; D. Morafka, pers. comm.), or by pulling out the legs or head and eating the attached muscle and visceral material (Berry 1985).

In her survey of 2154 tortoise carcasses collected in California, Berry (1985) found that those showing evidence consistent with raven predation (n=279) were all juveniles less than 110 mm MCL in size (≤ 252 gm). The effect of raven predation on the survival of tortoise populations becomes clear when we consider the effect on population demography. BLM (1990a) presented data from the permanently marked tortoise population that showed the possible effect raven predation has had on the age/size class structure of the population. Significantly fewer live juveniles were found in 1988 compared to 1979. Preliminary analysis indicates that demographic trends are similar in other populations with high raven densities (Berry 1990). These data support the hypothesis that raven predation significantly reduced the numbers of juveniles present in the population, hence reducing the number of animals eventually available for recruitment into the population of breeding adults (which generally occurs when an animal reaches 180 mm MCL). Reduced recruitment can be a major conservation concern for long-lived turtle species (Congdon et al. in prep; cf. Ray et al. in press).

Ravens and tortoises co-inhabit approximately 3,000,000 ha of desert in California. Tortoise shells showing signs consistent with raven predation have been found throughout this range (Berry 1985; BLM 1990a; Boarman and Berry in prep.). The largest numbers of shells have been found in the western Mojave, followed by the eastern Mojave; the fewest have been found in the southern Colorado desert. This pattern parallels the relative distribution of ravens (FaunaWest 1989).

History of BLM Raven Management Program

In 1990, the U.S. Fish and Wildlife Service (USFWS) listed the Mojave population of the desert tortoise as a threatened species (USFWS 1990). Several factors were held responsible for the drastic population declines that resulted in the listing: disease, vandalism, illegal collecting, roadkills, and habitat destruction (Berry 1984; USFWS 1990). The problem was exacerbated by a precipitous decline in the numbers of juvenile tortoises available for recruitment into the breeding population. One of the main causes for the loss of juveniles was considered to be excessive predation by common ravens (Berry 1985). These problems are still extant today and the BLM (1988) and USFWS (1992) are implementing several actions intended to aid in the recovery of the desert tortoise.

Raven populations are rapidly increasing in the Mojave desert. Based on Breeding Bird Surveys (Robbins et al. 1986) conducted by the USFWS between 1968 and 1988, the number of ravens in the Mojave desert increased by 1528% (Fig. 1; BLM 1990a); this increase is likely much higher in the western Mojave desert. The chief reason for the population boom is arguably the increased presence of concentrated anthropogenic food and water sources

(Engel and Young 1992): such as landfills, sewage ponds, roadside rest areas, agricultural fields, and urban/suburban centers. The presence of such food and water provides year-round sustenance for ravens and likely facilitates survival of adult and hatchling ravens when natural supplies of food and water are generally low, as in summer and winter (Engel and Young 1992). The result is a larger population of ravens year round resulting in more individuals that may find and consume juvenile tortoises.

In 1989, a pilot control program was initiated by the BLM in USFWS, California Department of Fish and Game, California Department of Parks and Recreation, United States Marine Corps, and Animal Damage Control of U.S. Department of Agriculture (BLM 1989). The purpose of the pilot program was to reduce raven predation on juvenile tortoises and gain information necessary to design a long-term raven control program. The pilot program consisted primarily of poisoning ravens with hard-boiled eggs laced with the avicide DRC-1339 (Rado 1990). The pilot program was stopped by a Temporary Restraining Order filed by the Humane Society of the United States (*HSUS* v. *Manuel Lujan et al*. 1989)[1]. The Humane Society's primary concerns were that birds not responsible for taking tortoises would be killed and other species of animals may be harmed by ingesting some of the avicide. The lawsuit was subsequently settled out of court and the pilot program was terminated.

In 1990, the BLM drafted and distributed for public review a Raven Management Plan (BLM 1990a) and an associated Draft Environmental Impact Statement (BLM 1990b) that proposed a long-term strategy for reducing raven predation of desert tortoises. Such action was considered necessary to assist with the recovery of tortoise populations. The plan, which incorporated basic principles of Integrated Pest Management (Council for Agricultural Science and Technology 1982) as they are applicable to vertebrate pests (Timm 1984), included: lethal control by poison and shooting; non-lethal control such as nest destruction, hazing, sterilization, and removal of roadkills; habitat management such as changing landfill operation methods and altering perch sites; research into pertinent aspects of raven and tortoise behavior and ecology; and monitoring raven and tortoise populations. Several concerns were raised by various groups and individuals and as part of the public review process, the BLM convened a Technical Review Team composed mainly of professional, non-government biologists and conservation policy specialists. The Raven Management Plan (BLM 1990a) and Environmental Impact Statement (BLM 1990b) are presently being reviewed and rewritten by the BLM and are expected to be completed and implemented in 1993.

SPECIFIC PROBLEMS

In developing a raven control program, the BLM was confronted with several challenges. Data are not always available to address these concerns or to test various assumptions that must be formulated. Ethical and philosophical differences arise concerning the goal of resource management and the adequacy of scientific data

[1] Humane Society of the United States v. Manuel Lujan, et al., Civil Action 89-1523 (RCL), D.D.C., Settlement Agreement filed June 29, 1989.

necessary to support a predator control program. The solutions to the issues are not always obvious and they rarely satisfy all interested parties. A brief discussion follows of three areas of controversy which have complicated and frustrated the development of a raven control program within the BLM.

Goal of the Raven Control Program

The stated goals of the draft Raven Management Program are to "limit *excessive raven predation* on juvenile desert tortoises to a level that allows for *healthy recruitment* into the adult [tortoise] population" and to restore " a *balanced predator/prey relationship* between the desert tortoise and raven..." (BLM 1990a; emphases mine). The problem is that these goals use criteria that are undefined and difficult to identify unambiguously (namely, "excessive raven predation...healthy recruitment," and "balanced predator/prey relationship").

Some assumptions must be made to help fine-tune the criteria and apply available data. If it is assumed that raven predation is directly related to raven abundance (where tortoises occur), and that any amount of predation is excessive, if it is greater than what may have existed existing during early Western contact, then estimates of raven abundance made in the late 19th and early 20th centuries may be used. Apparently ravens were quite rare in the Mojave desert in the 1920's to 1940's (E. Cardiff, cited in BLM 1990a; Johnson et al. 1948). An increase in raven densities in recent years is strongly supported by USFWS data published in BLM (1990a) showing an increase in raven observations of 1528% between 1968 and 1988 in the Mojave desert. However, ravens may have been relatively common throughout the deserts of California in the latter half of the 19th century, with about 50 being seen at a slaughter house in Daggett, near Barstow, California (USDA 1893). Additional historic data are necessary before a clear picture can emerge of historic raven densities and distribution patterns. But that begs the philosophical question of whether the goal should be to return raven densities to some historic figure, to some other date or time period (see Soulé 1990; Westman 1990), or to some other "acceptable" level.

The criteria of "healthy recruitment into the adult population" is also problematic because it presupposes knowledge of what is "healthy recruitment." This may be estimated by modelling the population using the assumption that the goal is a stable population. Two somewhat contradictory models exist: Congdon et al. (in prep.) used extensive data from a demographically similar turtle species (Blanding's turtle, *Emydoidea blandingi*) and Ray et al. (in press) used limited data from one desert tortoise population. Ray et al. (in press) suggested that juvenile (<5 years old) mortality in excess of that in a stable population must be greater than 25% per year before the population's growth rate will drop below 1.0. Congdon et al. (in prep.; see also Dunham et al. 1989) suggested that, as age of first reproduction approaches 20 years, any mortality among juveniles that affects recruitment will have a major affect on the stability of the population. This is particularly true when there is increased mortality among adults.

A problem with using actual demographic parameters is that detailed studies of desert tortoise populations have been taking place only since the early 1970's, an inadequate length of time for an animal with a generation period of 32 years (Turner et al. 1987), and a life expectancy of 100 years (Woodbury and Hardy 1948). Furthermore, most populations studied show significant declines in densities (hence their threatened status), so it is difficult to develop a model using a "typical" stable population. A detailed life table is currently being prepared based on data from one relatively stable population (Berry et al. pers. comm.).

However, management decisions must be made now. Perhaps we would now have the data required if biologists at the turn of this century had had (a) the foresight to know tortoises would be endangered by ravens, and (b) the knowledge of today's principles of population and conservation biology to know that detailed population data were necessary on ravens and tortoises in California. As this is not and can not be the case, we must rely on less than perfect data to make management decisions. Because the tortoise is currently threatened, we do not have the luxury of delaying management decisions until replicated studies on an entire population cycle are conducted. The decisions must be based on the best scientific data and analyses available and, like all resource management decisions, will include considerations based on politics, ethics, and economics. These additive considerations are not necessarily pejorative; they simply reflect the diversity of thought and analysis that must be brought to bear on any decision.

Justification for Control Program

Criticisms have been lodged that the data presented by the BLM (1990a, 1990b) are inadequate to support a need to control ravens. At question are four assertions: (1) raven populations have grown substantially in recent years, (2) ravens prey on desert tortoises, (3) raven predation significantly reduces recruitment into the breeding population, and (4) excessive predation is widespread. Each of these assertions has varying levels of empirical, circumstantial, or theoretical support.

The primary data set that the BLM used to support the contention that raven populations have grown substantially in recent years is from the USFWS breeding bird surveys (Robbins et al. 1986; BLM 1990a), which shows that, between 1968 and 1988, raven populations grew by 1528% in the Mojave desert, 474% in the Colorado-Sonoran desert, and 328% in the Los Angeles-San Diego area (BLM 1990a). A potential problem with these data is that all survey routes were along roads, and ravens are clearly attracted to roads (FaunaWest 1989; Knight and Kawashima 1991), so the surveys may only represent changes in raven densities along roads. However, all of the routes surveyed by the FWS were reportedly small dirt roads that did not follow powerlines or other major attractants of ravens (K. Berry pers. comm.). Nonetheless, the numbers did show a significant increase, even if they cannot be directly extrapolated to the "open desert." Furthermore, the California deserts are criss-crossed by over 24,000 km of paved and maintained roads and nearly 34,000 km of unmaintained dirt roads (BLM 1980). Additional support for a recent increase comes from reports of Van Remsen and Cardiff (cited in BLM 1990a).

The assertion that ravens prey on desert tortoises comes from direct and circumstantial observations. There have been several direct observations of ravens attacking and eating tortoises. For example, a juvenile tortoise was found in 1991 by R. Knight (pers. comm.) beneath a raven nest. It was missing two legs, was partially eviscerated, but the tortoise was still moving. In 1992, M. Wallace (pers. comm.) observed a raven carrying in its bill a moving juvenile tortoise. Additional direct observations of predation events are cited in BLM (1990a). Because ravens are generally wary of humans (Heinrich 1989), frequent sightings of predation are not expected from casual observations.

Other evidence that ravens prey on tortoises is more circumstantial and is based on a combination of physical and associative characteristics that are consistent with raven predation on tortoises. In an analysis of shells found beneath known raven perch sites, Berry (1985) identified several characteristics of the carcasses that she used as a standard to determine that raven predation was the probable cause of death for other carcasses found. She found many shells had holes pried or torn into the carapace or plastron (Fig. 1). Some of the shells showed small holes or scratches of a diameter similar to that of the tip of a raven's bill. Often only one or two of the appendages were missing; at other times all limbs and the head were missing. She suggested that ravens pulled the legs or heads out with muscles and other organs attached and then discarded the shells. Her conclusions were supported by observations of shells found beneath active raven nests (Berry 1985; Boarman and Berry in prep.). Associative characteristics include proximity to known raven nest, perch, or roost sites, and footprints of ravens around the carcass. These characteristics have been used to ascribe raven predation as a probable cause of death for juvenile tortoises (Berry 1984, 1985, 1990; Boarman and Berry in prep.; other sources cited in BLM 1990a).

Other species of birds are potential predators on tortoises. Berry (1985) reported that 12 out of 34 nests of golden eagles (*Aquila chrysaetos*) found within tortoise habitat contained carcasses of desert tortoises. The shells ranged from 129 to 263 mm MCL; all larger than those found at raven nests and perches. The only documented evidence of greater roadrunner (*Geococcyx californianus*) predation on tortoises is a single report of a juvenile tortoise, 50 mm MCL, that was freshly killed and partially eaten with roadrunner tracks around it (Berry 1985). There is one report of two hatchling shells being found beneath a red-tailed hawk (*Buteo jamaicensis*) perch (Fusari 1982), and I observed one juvenile shell next to an active burrowing owl (*Athene cunicularia*) nest in Ivanpah Valley, California. Several hatchlings were killed by an unknown avian predator at Fort Irwin, California, and loggerhead shrike (*Lanius ludovicianus*) pellets were found nearby (pers. obs.). The pellet did not contain obvious remains of tortoises and the shells show signs consistent with raven predation.

It is reasonable to expect that some or all of the tortoise shells analyzed by Berry (1985) and Boarman and Berry (in prep) were scavenged, because ravens are known to obtain a significant amount of food from scavenging. Four arguments support the hypothesis that ravens did live hunt some of the tortoises. (1) As noted above, there are several observations of ravens actually eating tortoises, small and large. (2) Young tortoises (< 7 years) have rather soft shells; only shortly after death do the shells harden (K. Berry pers. comm; D. Morafka pers. comm). If the shell is hard when it is forced open, it is likely to crack and fracture. If the shell is still soft and pliable when it is forced open, it will tear and fold in, later hardening in that position. Many shells found associated with raven nests and perches show this latter pattern. (3) If all or most shells attributed to raven predation were actually scavenged by ravens, we would expect occasionally to find recently dead or moribund juvenile tortoises; however, this has rarely happened. The BLM has generally had field workers spend a minimum of 2400 hours per year for the past 15 years searching small areas intensively for live and dead tortoises during prime tortoise activity periods. Whereas several ill, moribund, or dead adults have been found, on only two occasions has a moribund juvenile tortoise been found; one during a BLM survey (Glenn C. Goodlett pers. comm.), and one during an independent survey (Gilbert O.

Goodlett pers. comm.). Additionally, large numbers of adult tortoises are currently dying from respiratory and shell diseases which often exhibit external symptoms and are probably a major source of non-traumatic mortality in many areas (Berry pers. comm.). No juveniles have yet been found with either disease (pers obs.; Berry pers. comm.), so there is currently no reason to expect large numbers of juveniles to be dying and becoming available for raven scavenging. (4) Ravens are very opportunistic and are likely to prey on any still or slow moving, relatively defenseless food item when they encounter it.

The assertion that raven predation has a significant impact on tortoise populations gains support from four sources. First, large numbers of dead juvenile tortoises have been found in intensive but localized searches of the desert. Since 1971 the BLM has conducted intensive surveys, generally 60-days long, for live and dead tortoises at 15 permanent study plots (each one approximately 1 mi^2 in size). Between 1971 and 1982, 143 juvenile carcasses were found that showed evidence suggesting they were killed by ravens (Berry 1985). Between 1987 and 1990, the same sites yielded approximately 150 shells that show signs consistent with raven predation over a shorter span of time. These surveys can be considered samples of shells found in the open desert, generally not associated with nests or major perch sites. Most of the shells were found alone.

Second, ravens will often take shells to perches or nest sites which consequently yield piles of shells (BLM 1990a). For instance, Woodman and Juarez (pers. comm.) found a total of 250 shells beneath one nest in two years, and Berry (1985) reported 150 shells beneath fence posts. The clumped distribution of many shells makes it difficult to estimate the impact of predation per unit area because samples from non-clumped sources (e.g., study plots) underestimate the impact while samples from clumps overestimate the impacts.

Third, as discussed above, the surveys of live tortoises at the permanent study plots yielded histograms of proportional representation among size/age classes that show significant reductions in the numbers of juveniles represented in populations coincident with high raven densities (Berry and Boarman in prep.).

Finally, the model presented by Congdon et al. (in prep.), using data mainly from Blanding turtles, showed that any loss of juveniles may be critical to long-lived populations with late age of first reproduction that is experiencing high mortality among adults.

Support for the contention that raven predation is widespread comes from evidence cited above that signs of raven predation on tortoises have been found in all major regions of the California deserts: western Mojave, eastern Mojave, and southern Colorado (Boarman and Berry in prep.; BLM 1990a). Shells have been found lying individually on the ground throughout the desert and in piles beneath known nests and known or suspected perches.

Recommended Control Actions

The most controversial action proposed in the BLM's draft management plan (1990a) is lethal control. The chief issue is whether to target "known offenders" or to effect a range-wide reduction in the raven population. Targeting known offenders is often a preferred approach because it expends limited resources on removing the actual problems and eliminates ethical concerns about needlessly killing animals. However, there is always a risk of missing offending individuals because the approach is predicated on the assumption that all offenders can be identified and controlled. An additional problem with targeting known offenders is that some mortality must occur before the offender can be identified and removed. If the prey species is sufficiently threatened or endangered, any loss to the population may be critical and should be avoided. Targeting only known offenders may be particularly effective in isolated areas, where the predators are feeding on a clumped resource, or where territorial behavior of predatory individuals prevents other conspecifics from becoming offending individuals (e.g., raven predation on least tern eggs, Knittle 1992). Targeting known offenders becomes considerably more problematic where the predator is widespread and feeds on a non-clumped resource.

A broad-scale reduction in the population level has advantages and disadvantages. First, it would likely remove many actual predators on tortoises. Second, it would eliminate the opportunity for the ravens to become offenders, thus maximally preventing loss to the endangered prey population. This assumes that many of the ravens killed would have become offenders, which is likely given that they are long-lived, highly adaptable, and range widely early in life (Knight and Call 1980; Heinrich 1989; Engel and Young 1992). Third, the major portion of the government's resources need not be spent on identifying offenders. On the other hand, such a proactive approach may result in some offenders not being removed and resources being spent on removing non-offenders. An analysis must be made of the cost to the endangered population of allowing some mortality in order to identify, *a posteriori*, and remove only known offenders versus the cost to the predator population of eliminating larger numbers of the predatory species while attempting to reduce mortality to the endangered population. This approach has the unfortunate effect of pitting one species against another. Decisions may be predicated on the costs, in terms of time and money, required to identify and eliminate known offenders versus removing many members of the offending species without adequate knowledge of individuals' behaviors.

Several factors support non-specific control of ravens to reduce predation on desert tortoises. First, desert tortoises are widespread and do not occur in tight clumps. Second, ravens are a widespread, mobile predator; juvenile ravens likely wander for the first two years of life (Heinrich 1989) and many adults probably do not defend territories outside of the breeding season (pers. obs.; FaunaWest 1989). Third, the observations of large numbers of shells at several locations indicate that one raven pair can take many tortoises in a short period, particularly if they are concentration on tortoises. Fourth, finding many shells spread independently throughout the desert indicates that many ravens may take tortoises incidentally, although they may not specialize in tortoises. Thus, the probability of removing offending individuals in a non-specific control effort is likely to be relatively high, while the probability of removing most offenders in a targeted control effort is relatively low.

On the other hand, many known offenders may likely be identified, albeit with significant effort necessary to cover 3,000,000 ha. Identification is facilitated by the fact that carcasses are left behind and the peak season of tortoise activity correspondences to the ravens' breeding season, a time when foraging activities are high and centralized. It is possible that the quantity of tortoises taken by other ravens is sufficiently low to have any significant impact on the local populations, so that the targeted removal of known offenders may be sufficient to facilitate significant recruitment into the breeding population. The other advantage to this approach is that the number of ravens killed would be minimized, thus allaying some ethical concerns about killing non-tortoise-eating birds. Such targeted removal must be on-going because every year naive birds may become tortoise-eaters.

The most equitable solution may be a hybrid approach: broad-scale removal at some localities, particularly where tortoise and raven densities are high, and selective removal of all known offenders. This could be balanced by other, non-lethal, actions that would help to facilitate lower raven population levels by removing the availability of resource subsidies used by ravens (Engel and Young 1992). If control is implemented before sufficient scientific data are available, then the BLM should also monitor the effectiveness of the program at reducing raven populations and attempt to design and implement a program to monitor the change in juvenile tortoise representation and ultimately their recruitment into the breeding population. There should also be research into raven ecology and behavior that will aid an ongoing evaluation of the control program and guide future modifications to ensure that the program is effective at its intended goal. Finally, it must be remembered that many causes are likely responsible for the threatened status of tortoise populations, and all of these factors should be addressed by the resource management agencies, not just raven predation.

CONCLUSION

Conservation is, of necessity, a crisis discipline (Soulé 1985). For political and practical reasons decisions must often be made well before sufficient information is available. A purely scientific approach to decision making requires rigorous testing of hypotheses with clearly identified assumptions and predictions. Rigorous adherence to this approach, as advocated by many scientists, may rarely lead to unambiguous conclusions from which resource managers can make sound decisions. However, violation or ignorance of the assumptions, as committed by many resource managers, may lead to inappropriate and costly actions based on faulty conclusions.

Scientists and resource managers often disagree on actions to take because of differing appreciation for each other's perspectives, but it is essential that they strive to understand each others perspectives and work together to effect sound actions. Resource managers must build science into their decisions. Where data are insufficient they must develop programs that enable them to collect and interpret sound scientific data, monitor the action, and test assumptions and conclusions. This would allow them to refine, change, or abandon the action based on the results. Scientists, on the other hand, must be willing to tolerate actions initiated in the face of uncertainty (Maguire 1991) and are needed to assist in designing actions that can yield sufficient and adequate data even though assumptions and conclusions are subject to debate. The costs of doing nothing (while waiting for more and better data) and the costs of doing something expediently (with out sufficient justification or monitoring) may both be greater than that of designing a program that generates data and promotes evaluation of the problem, and therefore increases knowledge.

To manage native predators on endangered species, resource management agencies must develop well justified rationales and goals for the control effort, both of which are based on the best scientific data available. It is essential to strive for high scientific standards in conducting studies, interpreting data, and implementing management actions. Internal and external peer review should occur at all stages of the project and results should be publishable in peer reviewed scientific publications to ensure that highest standards are met and to facilitate open discussion. This approach will help to ensure that scientifically supported actions are taken which will reduce the likelihood of making costly and incorrect decisions.

With regards to raven predation on desert tortoises, the

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FIGURE LEGENDS

Fig. 1. Photograph of juvenile tortoise shells showing signs consistent with death by raven predation.