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STATUS OF THE CALIFORNIA CONDOR (*GYMNOGYPS CALIFORNIANUS*) AND EFFORTS TO ACHIEVE ITS RECOVERY

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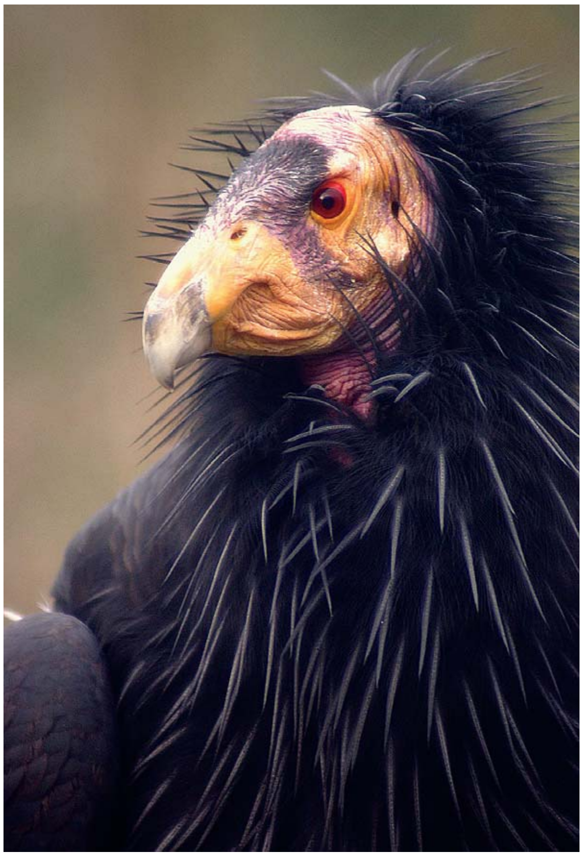

Fig. 1. Adult California Condor. (Photograph by S. Haig, U.S. Geological Survey.)

The California Condor (*Gymnogyps californianus*; hereafter "condor"; Fig. 1) has long been symbolic of avian conservation in the United States. Its large size, inquisitiveness, and association with remote places make it highly charismatic, and its decline to the brink of extinction aroused a continuing public interest in its plight. By 1982, only 22 individuals remained of this species whose range once encompassed much of North America. The last wild bird was trapped and brought into captivity in 1987, which rendered the species extinct in the wild (Snyder and Snyder 1989). In the 1980s, some questioned whether viable populations could ever again exist in the natural environment, and whether limited conservation funds should be expended on what they viewed as a hopeless cause (Pitelka 1981). Nevertheless, since that low point, a captive-breeding and release program has increased the total population by an order of magnitude, and condors fly free again in California, Arizona, Utah, and Baja California, Mexico (Fig. 2). At this writing (summer 2009), more than 350 condors exist, 180 of which are in the wild (J. Grantham pers. comm.). The free-living birds face severe challenges, however, and receive constant human assistance. The intensive management applied to the free-living populations, as well as the ongoing monitoring and captive-breeding programs, are tremendously expensive and become more so as the population grows. Thus, the program has reached a crossroads, caught between the financial and logistical pressures required to maintain an increasing number of condors in the wild and the environmental problems that preclude establishment of naturally sustainable, free-ranging populations.

Recognizing this dilemma, in November 2006, Audubon California requested that the American Ornithologists' Union (AOU) convene an independent panel to evaluate the California Condor Recovery Program. The National Audubon Society (NAS) and the AOU have a long history of interest and involvement in condor

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Fig. 2. Free-flying California Condor in southern California. (Photograph by A. Fuentes, courtesy of U.S. Fish and Wildlife Service.)

recovery. The NAS helped fund Carl Koford's pioneering studies of condor biology in the 1940s (Koford 1953). A previous panel jointly appointed by the NAS and AOU examined the plight of the condor in the late 1970s, and their report (Ricklefs 1978) laid the groundwork for the current conservation program. The NAS was a full partner with the U.S. Fish and Wildlife Service (USFWS) in the early days of the program, from 1980 through 1988. Ricklefs (1978) recommended that the program "be reviewed periodically by an impartial panel of scientists," and this was done annually by an AOU committee for several years after the release of the report, but the condor program has not been formally and thoroughly reviewed since the mid-1980s. Audubon California believed that the recovery program was operating with a recovery plan (USFWS 1996) widely acknowledged to be outdated, and that issues that were impeding progress toward recovery needed outside evaluation in order for the USFWS, which administers the program, and other policy makers to make the best decisions about the direction of the program (G. Chisholm pers. comm.). Such an evaluation would also help funding organizations better invest in the program.

This review falls within the charge of the AOU Committee on Conservation, which is to evaluate science relevant to avian conservation. The AOU therefore agreed to establish a Blue Ribbon Panel (the authors) as a subcommittee of the Committee on Conservation. Audubon California obtained funding from the National Fish and Wildlife Foundation, the Morgan Family Foundation, and other private donors to support the work of the panel. Our charge was to evaluate and synthesize the accumulated knowledge and experience in order to reassess the recovery program's fundamental goals and recommend needed changes. Specifically, we were charged with the following tasks:

- To collect, review, and synthesize knowledge and experience about condor reproduction, rearing, foraging, mortality, and other aspects of the species' life history and ecology with the goal of characterizing the relative degrees of consensus and uncertainty about each;
- To assess and prioritize the relative importance of physiological, behavioral, and ecological factors in terms of their potential to limit the species' recovery and sustainability;
- To recommend scientific research, including controlled field experiments and population dynamics modeling, needed to resolve or bound remaining key uncertainties about factors affecting the condor's recovery;
- To review key operational aspects of the recovery program and recommend changes needed to improve the effectiveness, value, quality, and validity of the practices employed and the data generated by research and monitoring;
- To assess the organizational and funding structure and the management function of the recovery program and the California Condor Recovery Team, and to recommend changes needed to improve the program's overall effectiveness and value; and
- On the basis of all of the above, to reassess the program's fundamental goals and recommend needed changes.

To fulfill this charge, we reviewed the condor recovery program from September 2007 through July 2008 by visiting captive-breeding facilities in Los Angeles, San Diego, Boise, and Portland; visiting release sites in southern California, central California, and Arizona; reading the published literature and unpublished reports; conducting interviews with program participants in person during site visits and via telephone conference calls; and soliciting written comments from those with whom we were unable to speak personally. Our findings are based on the available science, and in many instances the science is sufficient to support strong inferences. Where the science is sparse or equivocal, we offer consensus opinions based on the available facts and experiences of those in the condor program. In developing these opinions, we relied especially on the collective knowledge of those who work directly with the birds in the field and in captivity.

We presented our findings, conclusions, and recommendations in a report released at the AOU meeting in Portland in August 2008. That report served as the foundation for the present publication, augmented by comments, suggestions, and further information provided by individuals within and outside of the condor program in response to the report. The following is not a thorough review of the literature on condors, but rather an assessment of the current state of the species and its recovery program. Accordingly, we rely heavily on recent publications that summarize the literature, especially the volume that resulted from the 2005 AOU symposium on condors (Mee and Hall 2007). We hope that we have provided a new vision of the program for the next 10–25 years, as the previous AOU report (Ricklefs 1978) did for the past 30 years.

Condor Biology

The condor is by far the largest soaring bird in North America, with a wingspan of 2.8 m and body weight of 8.5 kg (Snyder and Schmitt 2002). The species had a wide distribution in North America before the late Pleistocene megafaunal extinctions

(Emslie 1987), but by the 19th century it was largely restricted to the West Coast, from British Columbia to Baja California. By the middle of the 20th century, the species was confined to southern California (Koford 1953, Wilbur 1978). In modern times, condors inhabited a variety of western landscapes from coasts to deserts to high mountain ranges that included beaches, shrublands, and forests. Modern records of nest sites of wild condors are all from California and include rugged cliffs and ancient trees.

Condors feed exclusively on carrion, primarily medium- to large-sized mammal carcasses. Prehistoric condors evidently fed on carcasses of (now extinct) megafaunal species and marine mammals, and the diet of modern condors includes domestic livestock as well as native terrestrial and marine species (Chamberlain et al. 2005). Condors use their exceptional soaring abilities to cover large distances in search of food. Meretsky and Snyder (1992) reported nesting birds traveling up to 180 km from the nest in a single trip in search of food, and foraging ranges of nonbreeding birds of 7,000 km^2. Condors are highly gregarious in feeding and most other activities, with the exception of nesting, which occurs in caves in cliffs or natural cavities on nesting territories defended by pairs (Snyder and Schmitt 2002). Theirs is a textbook example of a long-lived life history (Mertz 1971), characterized by high survival rates and exceedingly low reproductive rates, with breeding pairs producing, if all goes well, two fledglings in a 3-year period (Meretsky et al. 2000). For further details of condor biology, see Koford (1953), Wilbur (1978), Snyder and Snyder (2000), and Snyder and Schmitt (2002).

HISTORY OF THE CONDOR RECOVERY PROGRAM

Condors were first protected nationally in 1967 under the auspices of the U.S. Endangered Species Preservation Act, and the birds were formally listed and protected as endangered with the signing of the U.S. Endangered Species Act (ESA) in 1972. The California Condor Recovery Team was formed in 1973, and it produced the first recovery plan for an endangered species in the United States in 1975 (USFWS 1975). The program initially followed a noninterventionist course, but given the continuing decline of the wild population, a pessimistic assessment by Verner (1978), and their own analysis, the AOU–NAS panel recommended an immediate intensive research program that included captive breeding, radiotelemetry, and field investigations of the causes of the species' decline (Ricklefs 1978). This highly publicized and, to some, highly controversial program was initiated in 1980 by a joint partnership between the USFWS and NAS. The species continued to decline over the next 6 years despite intensive field work, and by 1986, with only three birds remaining in the wild, the decision was made (following the recommendation of the Recovery Team) to bring the last birds into captivity (Fig. 3). By that time, eggs, chicks, and unmated adults had been removed from the wild to begin a captive-breeding program.

The condors were initially housed at the Los Angeles Zoo and San Diego Wild Animal Park. In 1993, The Peregrine Fund joined the effort as an additional partner and began breeding birds at their Boise, Idaho, facility (Fig. 3). Successful reproduction in captivity was first achieved in San Diego in 1988 (by two wild-trapped

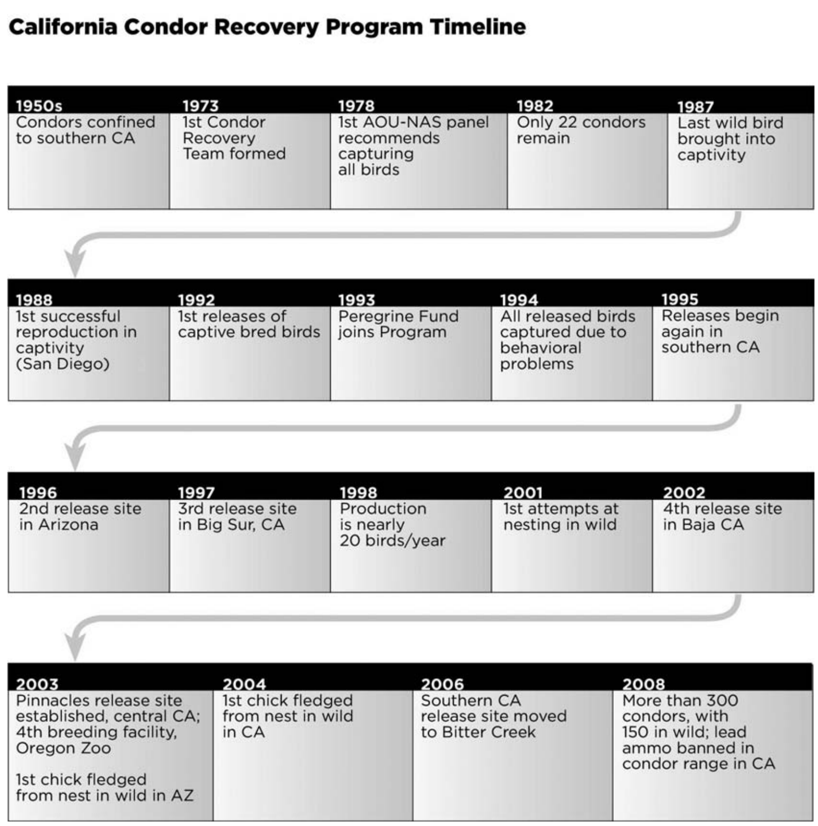

FIG. 3. California Condor Recovery Program timeline.

adults), and by the late 1990s, the program was producing 20 offspring per year and all of the birds originally removed from the wild were breeding successfully in captivity (Snyder and Schmitt 2002). The Oregon Zoo in Portland was added as a fourth captive-breeding facility in 2003.

The first releases of captive-reared birds occurred in 1992 in southern California, but recurring issues with the birds' attraction to human-built structures led to a decision to return the initial cohort of released condors to captivity in 1994. Releases were reinitiated in southern California in 1995 and have continued since. A second release site was established in Arizona in 1996, and a third in central California in the Big Sur area in 1997 (Fig. 3). In 2002, a fourth release site was added in Baja California, Mexico, and the following year marked the debut of Pinnacles National Monument as a second location from which to release birds in central California. Reintroduced birds first attempted to nest in southern California and Arizona in 2001. The first fledging of a chick by reintroduced birds occurred in Arizona in 2003 (Woods et al. 2007), followed by the first successful fledging in California the next year (Grantham 2007).

THE CONDOR PROGRAM TODAY

The condor recovery program has achieved success beyond what many believed possible when the last few birds were brought into captivity. Numbers have increased steadily (Fig. 4). Managers are routinely releasing birds raised in captivity that exhibit desirable and socially appropriate behavior in the wild, and further additions to the free-living population come from chicks fledged from natural nests by breeding pairs that formed on their own after release. In Arizona, birds subsist on food they find themselves for much of the year, and in central California they feed on carcasses of marine mammals, including several whales that have washed ashore. Millions of hectares of nesting and foraging habitat for condors are protected to some degree. A large number of highly committed partners contribute substantially to the program, and new partners continue to join the effort. Recovery of the condor, once almost inconceivable, has become imaginable, and the public believes the condor program to be a success.

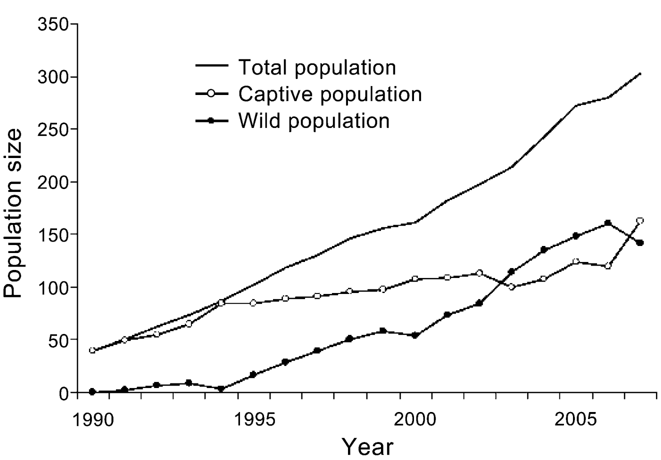

FIG. 4. Population size over time for the captive, free-living, and total populations of California Condors (from Wallace et al. 2007a).

Yet enormous obstacles to recovery still exist, so much so that the possibility that condors could once again be extirpated in the wild is as conceivable as recovery. In our opinion, the free-living populations would disappear were the current enormous investment in intense monitoring and management of adults and subadults—and, at some locations, nestlings—to cease. Lead poisoning from ingestion of ammunition fragments in carcasses is so severe and chronic a problem at all release sites (Cade 2007) that the program partners are unified in the belief that condor recovery cannot be achieved so long as such lead exposure continues. Although relatively few birds have actually died from lead poisoning, deaths almost certainly would occur were the birds not regularly trapped, tested, and treated for lead. Several individuals have been treated for lead exposure multiple times. The free-living birds are induced to depend on carcasses provided by humans at feeding stations so that they can easily be trapped and treated for lead poisoning, and to reduce the ingestion of lead that occurs when they forage on their own. This likely detracts from their development of foraging skills. Feeding, trapping, and chelation treatment reduce deaths from ingestion of lead, but the effects of repeated, sublethal exposure to lead are as yet unknown. Effects on behavior and demography are likely, given the current levels of exposure (Pokras and Kneeland 2009).

Similarly, nesting success in southern California was negligible until intensive management of nests was instituted in 2007. It is likely that fledging success would be reduced to near zero again if chicks were not examined monthly for ingestion of microtrash (i.e., small bits of refuse of human origin, including items such as rags, nuts, bolts, washers, plastic, bottle caps, chunks of pipe, spent cartridges, and pieces of copper wire; see Mee et al. 2007a) and treated on site by veterinarians and field biologists. Chicks are also vaccinated for West Nile virus. Condors are maintained in the wild only with great effort and, hence, are the epitome of a conservation-reliant species (Scott et al. 2005). Partners cannot be expected to expend funds indefinitely to maintain condors in nature, especially when additions to the free-living population increase management requirements and annual costs. Population growth is limited not by capacity to produce captive-bred birds suitable for release, but by the willingness of partners to spend more money to keep more birds alive in the wild. The program is indeed at a crossroads, its success on its current path limited by tradeoffs among demography, management intensity, and population size.

Program Partners

The California Condor Recovery Program is one of America's oldest and most complex efforts to recover an endangered species. The large and physiographically imposing geographic range of the species, the need for captive-rearing, release, and monitoring expertise, and the uncertain response of free-ranging condors to known and yet-to-be-discovered limiting factors have spawned a complex mix of nongovernmental and international, federal, and state governmental organizations cooperating to restore the species at four release sites in two countries (Table 1).

The birds are managed to meet demographic and genetic objectives following a Species Survival Plan under the auspices of the American Zoo and Aquarium Association (e.g., M. P. Wallace et al. unpubl. report). Managed as a single population, the birds

Table 1. Annual financial contributions to the California Condor Recovery Program by major partners in 2007. Budget figures were provided by each partner. Participants maintain captive-rearing facilities, release sites, or both.

Partner	Annual expenditure	Rearing facility	Release site
U.S. Fish and Wildlife Service	$857,000[a]	No	Bitter Creek, Hopper Mountain
Los Angeles Zoo	$573,000	Yes	None
San Diego Wild Animal Park	$1,479,000	Yes	Baja
The Peregrine Fund	$1,520,000[b]	Yes	Arizona
Ventana Wildlife Society	$244,000	No	Big Sur
Pinnacles National Monument (National Park Service)	$500,000	No	Pinnacles
Oregon Zoo	$172,000	Yes	None

[a]Includes $186,000 for refuge operations.
[b]Includes $394,000 in earmarked funds through USFWS.

are exchanged between breeding facilities such that a bird raised at any captive-breeding facility might be released at any release site. Still, individual breeding facilities are associated with particular release sites because of geographic and programmatic linkages. In southern California, the USFWS operates release sites at Hopper Mountain and Bitter Creek National Wildlife Refuges, and these sites are linked with the captive-breeding operation at the Los Angeles Zoo. Veterinary staff and keepers from the Los Angeles Zoo provide field support at the southern and central California release sites, and birds from these release sites in need of medical attention are brought to the zoo for treatment. The captive-breeding program at the San Diego Wild Animal Park also has strong linkages with the southern and central California release sites, and in addition operates the Baja California release site in collaboration with the Instituto Nacional de Ecología in Mexico. The Mexican National Zoo currently has two condors on display and is a likely location for an additional captive-breeding program to be associated with this release site in the future. The Peregrine Fund links the captive-breeding facility in Boise with the Arizona release site, as it operates both. The Oregon Zoo provides birds to multiple release sites. In central California there is a strong relationship between two partners, the Ventana Wildlife Society and the National Park Service, which run the release sites in Big Sur and Pinnacles National Monument, respectively. The birds released at these two sites function as a single flock, and accordingly these two partners have integrated their monitoring and field-support activities.

This recovery effort is costly. Pitelka's (1982) projections have proved accurate: tens of millions of dollars have been spent on condor recovery over the past two to three decades. Currently, over $5 million is spent per year, and one of the key features of the condor program is the large proportion of this funding contributed by private partners. The Los Angeles Zoo funds their captive-breeding program and provides field support at the southern California release sites, expending $575,000 annually (Table 1). The San Diego Wild Animal Park expends $1.5 million annually on their contributions to the condor program. The USFWS provides The Peregrine Fund with congressionally earmarked funds ($394,000 in 2007 and $633,000 in 2008; we follow the U.S. Office of Management and Budget's definition of earmarks as appropriated funds, including add-ons, that specify location or recipient of funds) to operate the Boise captive-breeding facility and Arizona release site, and The Peregrine Fund contributes another $1.1 million of their own funds annually toward these operations. The Ventana Wildlife Society raises $250,000 annually from nongovernment sources for its operations in central California, and the National Park Service recently received a $500,000 increase in their permanent base funding that represents their contribution to the condor program. The Oregon Zoo currently spends $175,000 annually on their captive-breeding program, and their contribution will no doubt grow if establishing a new release site in the Pacific Northwest becomes a possibility (see below). The USFWS expends $850,000 annually in directing the program and operating the southern California release sites. The relatively modest funding that the USFWS has devoted to condor recovery compared with that from private partners (Restani and Marzluff 2001) likely reflects a general lack of political will to fund conservation (Miller et al. 2002, Restani and Marzluff 2002a), competition for scarce dollars throughout the Endangered Species Program and Refuge System, overregulation of USFWS budgets through the earmarking process (U.S. General Accounting Office 1988), and the necessity to commit scarce funds and personnel to respond to litigation (Restani and Marzluff 2002b).

Several other partners besides those involved in running the captive-breeding programs and release sites mentioned above make important contributions to the condor program. Personnel from the San Diego Zoo make major contributions to the program. The Santa Barbara Zoo is a new partner with a focus on outreach and studies of breeding ecology of wild birds in southern California and also helps with nest monitoring. Also in California, a lead awareness campaign is underway in the central and southern parts of the state under the auspices of the Institute for Wildlife Studies. The Arizona Game and Fish Department is an active partner in the condor program, contributing a full-time condor biologist whose primary responsibility is outreach. Birds released in Arizona range into Utah, and the Utah Division of Wildlife Resources has become involved in the consortium of partners concerned with that population (known as the California Condor Southwest Working Group). The California Department of Fish and Game has had relatively little involvement in the condor program, but that is changing with the advent of new state regulations to protect condors (see below). The agency plans to add a full-time condor biologist to their staff (D. Steele pers. comm.). The Oregon Department of Fish and Wildlife has recently become involved with investigating the potential for a release site in the Pacific Northwest (D. Shepherdson pers. comm.).

The business community has cooperated in the recovery effort. A private ranch in Baja California contributes to operations at the release site there. In southern California, the Tejon Ranch recently signed an agreement with several conservation organizations to set aside nearly 100,000 ha of habitat for condors. At Big Sur, Pacific Gas and Electric has spent hundreds of thousands of dollars, and may end up spending millions, to reduce condor deaths caused by collisions with power lines in this region (M. Best pers. comm.).

Currently, the contributions to condor recovery of federal agencies, other than the USFWS, that operate in the range of the free-living birds are relatively small. The Bureau of Land Management (BLM) provides a feeding site near Pinnacles National Park, has provided funds for monitoring equipment, and is funding trash removal in specific areas. The BLM and the U.S. Forest Service (USFS) manage important condor habitat, and some of their lands in Arizona and California are extensively used by condors. Future recovery efforts could benefit from more formal involvement by, and contributions from, these agencies.

Protection of habitat for nesting and foraging is a critical aspect of the condor program, and achievements in this aspect have been considerable. Most of the current condor nesting range is on public land, and in Arizona much of the foraging range is as well (Hunt et al. 2007). Some historical foraging habitat in southern California is no longer suitable, but historical grassland foraging habitat around the base of the San Joaquin Valley remains viable, and large swaths have been protected since about 1984, including the Bitter Creek National Wildlife Refuge (NWR) (5,867 ha), the private Wind Wolves Preserve (39,000 ha), and the Carrizo Plains National Monument (121,405 ha). The Tejon Ranch conservation agreement protects large swaths of foraging and roosting habitat in an area that is a critical gateway to historical foraging areas in the Sierra Nevadas (Wilbur 1978). Grassland and oak savanna remain critical foraging habitat for condors, as relatively little foraging takes place in densely forested or chaparral habitat.

BIOLOGICAL ISSUES AND STATE OF THE RELEVANT SCIENCE

The biological challenges of establishing viable populations of a large, wide-ranging species with a low population growth rate are daunting, and there are serious obstacles to achieving that objective for condors. Below, we evaluate the major biological issues, the solutions to which lie in existing science and in research yet to be conducted.

Lead Exposure

Any discussion of the biological challenges confronting the condor program must begin with the issue of lead. A basic tenet of conservation biology is that reintroductions will inevitably fail if the factors that caused the species to decline in the first place have not been addressed (Meretsky et al. 2000). Reintroduction of condors may illustrate this principle, lead exposure being the recurring factor. Habitat loss and direct persecution through shooting and poisoning of carcasses were certainly involved in the decline of the condor through the 19th and into the 20th century (Snyder 2007), but there is compelling evidence that elevated mortality attributable to lead poisoning was a major cause of continuing decline at the time the birds were brought into captivity (Meretsky et al. 2000, Snyder 2007). Although the significance and source of lead exposure in reintroduced condors were debated just a few years ago (Beissinger 2002, Risebrough 2002), there is now widespread consensus and considerable evidence that poisoning from ingestion of lead ammunition fragments in carcasses currently precludes the establishment of viable populations in the wild (Cade 2007, Watson et al. 2009).

The condor is a long-lived species with a low reproductive rate (Mertz 1971), such that adult mortality rates certainly must be <10% (Meretsky et al. 2000), and likely <5% (Cade et al. 2004, Cade 2007, Woods et al. 2007), for populations to be self-sustaining. We conclude that condors are exposed to lead through ingestion of ammunition fragments frequently enough that, were the birds not treated, mortality rates would rise above those required for sustainability (see also Woods et al. 2007). There is risk of lead exposure from virtually every type of carcass on which condors feed: big game, small mammals, coyotes, domestic livestock, feral hogs, even (albeit rarely) marine mammals—all are sometimes shot with lead ammunition. Alternative views about the threat posed by lead and sources of lead exposure, which were plausible only a few years ago, are no longer credible (Newton 2009).

Reintroductions that have limited success because of failure to remove limiting factors can still be informative. Such is the case for condors. Although there has been some awareness that predatory and scavenging birds could be poisoned by lead in their food (Fisher et al. 2006), the plight of the condors has brought attention to the lead issue, resulting in a much better understanding of the dynamics of lead exposure, the pervasiveness of the problem, and the actions required to solve it. The lead ammunition issue goes well beyond condors, affecting other terrestrial scavengers and potentially even human health (Fisher et al. 2006, Watson et al. 2009; see below). Thus, condors have functioned as sentinels of an environmental problem that has yet to be adequately addressed in the western ecosystems they inhabit.

Some condors have died from lead poisoning. The first condor mortalities definitively linked to lead were in the 1980s (Janssen et al. 1986, Wiemeyer et al. 1988b). Among birds released since the mid-1990s, Fry and Maurer (2003), Woods et al. (2007), and Parish et al. (2007) documented six known and two suspected lead deaths in Arizona, and Dr. Cynthia Stringfield (2007, unpublished report to California Condor Recovery Team) documented 12 suspected cases of lead-caused mortalities in California (see also Hall et al. 2007). Unpublished information suggests that mortalities from lead exposure have occurred at all release sites, including three deaths (one confirmed to have been caused by lead, two suspected) in Baja California. Of course, not all of the 97 captive-reared condors that have died across all release programs since releases began in 1992 (J. Grantham pers. comm.) have been analyzed for lead exposure. In our opinion, trying to determine the exact number of condors that have died from lead poisoning is a fruitless exercise, because whatever this number is, it will be small in relation to the number of deaths that would have occurred were the birds not monitored intensively for exposure to lead and provided with clean carcasses to reduce exposure.

The frequency with which the field crews detect high, often debilitating and potentially lethal levels in the blood of free-living condors is alarming. For example, Parrish et al. (2007) detected such levels in 9% of 437 blood samples taken in Arizona during 2000–2004, and 40% of the samples indicated some degree of exposure to lead. In southern California, 8% of 214 blood samples taken during 1997–2004 indicated clinical exposure to lead, and 32% of 44 individual condors tested experienced at least one such exposure during the study period (Hall et al. 2007). The majority of the birds with clinical levels of lead exposure are treated successfully and returned to the wild. It is because of these many instances in which, without human intervention, condors likely would have died that we conclude, as have others (Cade 2007, Mee and Snyder 2007, Woods et al. 2007, Green et al. 2008, Newton 2009), that condor populations would not be stable in the absence of intensive management, and instead would decline to extirpation, as the original wild populations did.

Besides the potential for ingesting lethal doses of lead, condors may also suffer from repeated exposure to sublethal doses (Pokras and Kneeland 2009). Chronic exposure resulting in blood lead levels <10 μg dL^{-1} has been shown to cause subtle but permanent adverse neurological effects in human children (Canfield et al. 2003, Hunt et al. 2009), and it is probable that repeated exposures of condors at similar levels will also cause neurological impairment. In California, 82% of 469 condors tested had blood lead levels >10 μg dL^{-1} (data supplied by USFWS and Ventana Wildlife Society). In Arizona, 40% of 437 condors tested had levels >15 μg dL^{-1} (Parish et al. 2007). No formal behavioral evaluation has been conducted with lead-exposed condors to determine whether sublethal effects can be detected in exposed birds.

Exposure to lead in the field.—The working assumption of those in the condor program is that condors are exposed to lead through feeding on carcasses or gut piles of animals shot with lead bullets or shotgun ammunition (Mee and Hall 2007, Watson et al. 2009). Sources of exposure may include not only game species, but also varmints (e.g., ground squirrels, coyotes, and prairie dogs) and even livestock killed with lead bullets (R. Jurek pers. comm.). Whatever the species, one carcass can contain enough lead to kill many condors via the "snowstorm" effect (Fig. 5), when lead rifle bullets shatter into hundreds of fragments as they enter an animal (Hunt et al. 2006). Fry and Maurer (2003) estimated the lethal dose of lead to a condor to be 33–65 mg, approximately 0.3–0.6% of the mass of a 9,700-mg rifle bullet (150 grains). When a rifle bullet fragments into a lead snowstorm, there may be more than 200 fragments of this size produced that remain within the carcass or viscera left in the field (Hunt et al. 2006).

Bird species other than condors, especially Common Ravens (*Corvus corax*), Turkey Vultures (*Cathartes aura*), and Golden Eagles (*Aquila chrysaetos*), have been used to document the pattern of lead exposure in the environment. The surveillance studies of Wiemeyer et al. (1986) and Pattee et al. (1990) documented lead exposures in several species of avian and mammalian scavengers within the condor range in California. A similar study by Craighead and Bedrosian (2008) documented exposure in Common Ravens in Wyoming that fed on offal left in the field by elk hunters; blood measurements showed significant exposure in these birds, highly correlated with the fall elk-hunting season. The California Fish and Game Commission contracted a study in December 2007 with the University of California at Davis Wildlife Health Center to document the extent of lead exposure in avian and mammalian

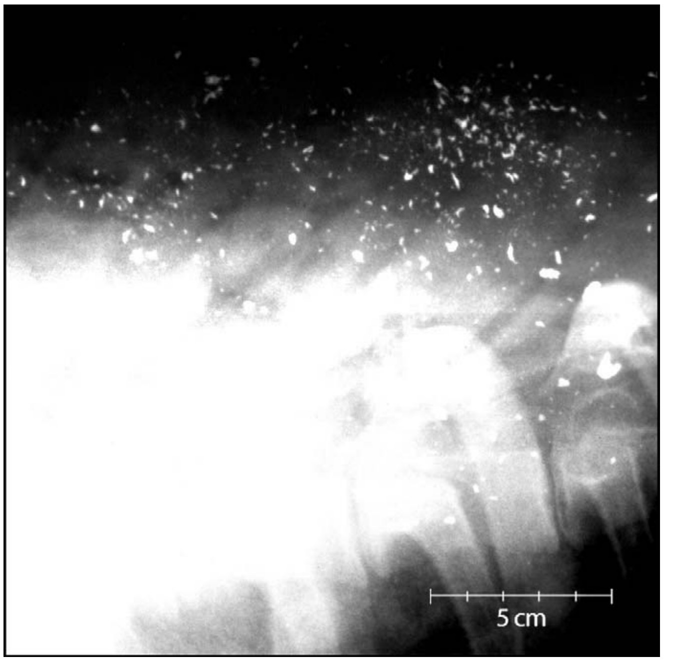

Fig. 5. Radiograph of lead fragment "snowstorm" in a deer carcass. (Photograph courtesy of The Peregrine Fund.)

scavengers within condor range and in other selected regions of California to determine whether the lead exposure problem is widespread. Results of this study are due in 2011.

Lead is monitored in condors in the field and confirmed with duplicate samples submitted to clinical reference labs in California and Arizona. Field blood testing of all condors occurs at least once a year, but generally more often. Field monitoring is done with portable LeadCare machines (ESA, Chelmsford, Massachusetts), which produce rapid readouts of blood lead levels, with a detection range of 3–65 μg dL^{-1}. Correlations between LeadCare data and data from clinical laboratories indicate that the field tests underestimate the actual blood lead levels by about 20–30% (Fry and Maurer 2003, Parish et al. 2007, Sorenson and Burnett 2007). Field crews in Arizona have access to a portable X-ray machine, which enables them to radiograph condors suspected of ingesting lead. Lack of such equipment hinders the ability to diagnose lead exposure at other field sites.

Identification of the sources of lead that are affecting condors is being undertaken by Donald Smith and his students at the University of California at Santa Cruz and by John Chesley at the University of Arizona. Both laboratories are using mass spectrometry to separate and quantify the natural isotopes of lead, which are found in varying proportions in metallic lead from mines throughout the world (Church et al. 2006, Chesley et al. 2009). There are four natural isotopes of lead (atomic weights: 204, 206, 207, and 208), each composing 1% to 56% of metallic lead. Lead from a single source often has a distinctive isotope pattern, and lead from different geographic regions is usually distinctive. Metallic lead objects made from a single source can frequently be identified, whereas lead from recycled sources, such as batteries or electronic parts, has less distinctive patterns that reflect mixing of different sources.

When a condor ingests lead, the metal is slowly dissolved by stomach acid, enters the blood stream, and is distributed to other tissues, including liver, muscle, kidney, brain, bone, and growing feathers. The isotope pattern of the lead in these tissues reflects the isotope pattern of the lead in the ingested lead object or lead-contaminated food. In an effort to identify sources of lead exposure in condors, the laboratories have been characterizing the lead isotope patterns in blood and feather samples and comparing them to ingested fragments of lead, commercial lead bullets, environmental lead background sources, and published data listing known lead-source isotope patterns.

The lead isotope patterns in blood or feathers have matched lead bullet fragments recovered from carcasses on which the birds were feeding (Church et al. 2006), and isotopes in blood and feathers match lead isotopes of fragments recovered from the gastrointestinal tracts of exposed birds (Chesley et al. 2009, Parmentier et al. 2009). These data implicate ammunition as a significant source of lead, but the data are far from complete, and the isotopic composition of some blood samples does not match the isotope patterns of the few ammunition samples that have been analyzed by Church et al. (2006) or reported in the literature. However, Chesley et al. (2009) recently provided convincing evidence that lead fragments in carcasses and gut piles match the isotope patterns found in condors feeding on that carrion. The scientists doing the identification have gone to great lengths to document exposures and match them to sources, and the data are convincing. Nonetheless, many individuals criticized the data at public hearings in California on the grounds that all potential sources of lead in the condor range have not been characterized. These critics argued that other materials besides ammunition fragments, including microtrash, may be significant sources of lead. We agree that there are many potential sources of lead in western ecosystems but are convinced that ammunition fragments are the major source of lead exposure for condors in the wild.

Determining baseline lead levels.—To assess lead exposure, one must know the baseline level of lead concentration in the blood. A background or baseline level of 20 μg dL^{-1} lead in blood of wild scavengers was proposed by Redig (1984) on the basis of an analysis of Bald Eagles (*Haliaeetus leucocephalus*) and other raptors (Redig et al. 1980). Many authors have used this figure since (Wiemeyer et al. 1986, Patee et al. 1990, Fry and Maurer 2003). However, this baseline appears to be unrealistically high and reflective of lead contamination from ammunition fragments and other sources, including environmental contamination by leaded gasoline in the 1980s. A more realistic baseline for lead should be the levels measured in captive condors prior to release. Captive-reared condors tested at zoos before transfer and release from holding pens have blood lead levels ≤4 μg dL^{-1}, with a few exceptions when blood lead levels of 7 and 8 μg dL^{-1} were reported (C. Stringfield pers. comm.). These exceptions indicate that some condors may have access to unknown lead sources at zoos or holding facilities, such as lead paint, or possibly lead in zinc galvanized wire, solder joints, or other electrical wiring. By contrast, as discussed above, lead levels in free-living condors are typically ≥10 μg dL^{-1}. Fry and Maurer (2003) and Fry et al. (2009) have used 10 μg dL^{-1} as the background limit, with values above that interpreted as representing acute or chronic lead exposure.

Lead exposure and kinetics of lead clearance.—Fry and Maurer (2003) calculated the half-life of lead in the blood of condors as 13.3 ± 6.5 days, from a limited number of pairs of blood samples of birds held in captivity without chelation. Additional analysis has shown a shorter half-life of about 9 ± 6 days, with considerable variation among individual birds (Fry et al. 2009). This indicates that after an acute exposure event, blood lead levels decrease rapidly, and an acute exposure as high as 100 μg dL^{-1} will fall to ~10 μg dL^{-1} within 30–45 days. The field data (see above) thus suggest that condors are frequently exposed to lead while feeding in the wild, given that a high proportion of condors exhibit elevated blood lead levels when tested at random, despite the fact that blood levels drop rapidly back to background levels when birds are no longer exposed to lead. The data from the captive birds indicate that condors can recover quickly if sources of lead exposure are removed.

Condors discovered to be exposed to high levels of lead in the wild are generally held in captivity, treated to reduce the amount of lead in blood, and evaluated as to whether lead fragments are present in the gastrointestinal tract. Treatments include purging the gut with oral slurry doses of psyllium husks to physically push particles through the gastrointestinal tract or removing fragments by endoscopic or other surgical procedures. Birds with high blood lead levels, generally >50 μg dL^{-1} but occasionally lower, are treated with chelating agents to chemically bind the lead and remove it by excretion via the kidneys (Parish et al. 2007, Sorenson and Burnett 2007).

Chelation therapy provides a temporary lowering of lead levels in acutely exposed birds, but blood lead levels may rise again within weeks as lead slowly reequilibrates back into blood from soft tissues such as liver, kidney, and muscle, causing a rebound in blood lead levels after chelation (Marcus 1985). Birds that are chronically exposed will also have lead slowly deposited in bone (Schutz et al. 1987). The sublethal consequences of this chronic, moderate to high blood lead level are unknown in condors and other birds but are recognized as a debilitating neurotoxic response in humans (Canfield et al. 2003, Kosnett 2009, Pokras and Kneeland 2009, Watson and Avery 2009).

In Arizona, as of 2007, condors exhibiting high lead levels have been chelated on an emergency basis on 124 occasions, including multiple treatments of the same individuals in some cases (C. Parish pers. comm.). There are likely long-term consequences of repeated sublethal lead exposure, and probably consequences of repeated exposure to chelation drugs (primarily calcium EDTA and/or succimer [2, 3-dimercaptosuccinic acid]), as well as the stress and trauma risks of capture, handling, and treatment. The drastic steps taken in trapping and veterinary intervention on a recurring basis for birds in Arizona and California require a high investment of time and effort on the part of the field teams and significantly alter the "wild" status of the birds. An examination of behavior and demography of condors as a function of the number of times they have been chelated, as well as studies of sublethal and developmental effects of lead, are critical research needs.

The issue of condors being able to feed on their own rather than sustained by carcasses put out for them at feeding stations (see below) is also tied to the lead issue. Managers must feed birds to be able to trap them to treat for lead poisoning.

Efforts to eliminate lead from the food sources of condors.— There are various approaches for eliminating exposure of condors to lead ammunition fragments. The actions of other nations offer several possibilities as lead ammunition is increasingly recognized as potentially deadly to fish and wildlife (Avery and Watson 2009, Mateo 2009, Thomas 2009). A federally mandated, national switch to nonlead ammunition such as Japan has adopted to protect White-tailed Eagles (*H. albicilla*) and Steller's Sea-Eagles (*H. pelagicus*) is one example. In the United States, the National Park Service has indicated that it will begin to phase out the use of lead ammunition on its lands by 2010 to avoid both harm to wildlife and the danger of dissolved lead contaminating groundwater. Working through local hunters and national organizations for a voluntary conversion to nonlead ammunition is another approach. Arizona's Game and Fish Department has developed a successful voluntary program to replace lead with nonlead ammunition in an important condor foraging area in that state (Sullivan et al. 2007, Green et al. 2008, Sieg et al. 2009; see below).

Copper or other nonlead bullets can be a solution to the lead problem (Oltrogge 2009). Copper is much less toxic than lead, and copper bullets do not fragment into small pieces as lead bullets do. Although large pieces of copper could pose a risk, we believe that the risk will be small compared with the current risks of lead exposure. Those we interviewed indicated that the ballistics of copper bullets match or exceed those of lead (see also Schulz et al. 2009). The only issues with substitution of copper for lead bullets raised in our interviews are that the former are currently more expensive and are not readily available in some calibers.

A growing awareness of the adverse environmental effects resulting from use of lead ammunition is reflected in the variety of recent actions, some mandatory and some voluntary, designed to replace lead with nonlead ammunition (Thomas 2009). The most significant of these is legislation passed in California in 2007 (the Ridley-Tree Condor Preservation Act, AB 821) requiring the use of nonlead ammunition in big-game hunting within the range of the condor in California. In addition, the California Fish and Game Commission adopted regulations in December 2007 to require the use of "lead-free" ammunition, including .22 rimfire cartridges, for all forms of hunting (excepting upland game-bird hunting) within the condor range as of 1 July 2008. California Fish and Game also requires copper ammunition for killing pigs and deer in agricultural areas.

The Tejon Ranch, which has a major hunting program for pigs, deer, elk, bears, pronghorn, upland game birds, and varmints including coyotes, bobcats, badgers, gray foxes, and ground squirrels, switched to the use of nonlead ammunition, including .22 rimfire ammunition, in January 2008 (Hill 2009). This action is part of a Habitat Conservation Plan that is the result of a long negotiation with the USFWS. Two military installations with hunting programs within the foraging range of the condor, Camp Roberts and Fort Hunter Liggett, also require nonlead ammunition.

These are very important steps toward reducing exposure of condors to lead, but their effectiveness will depend on education and enforcement. Enforcement of lead-free hunting regulations may be problematic because of the lack of enforcement personnel to apprehend violators, and the difficulty for enforcement officers of distinguishing between lead and nonlead ammunition in the field and documenting any illegal shooting with lead ammunition. Thus, it will be critical to assess the effectiveness of these regulatory actions in eliminating lead ammunition. Ensuring that nonlead ammunition is used in recreational shooting of ground squirrels and other small animals is another enforcement issue (Schulz et al. 2009).

The impact of the actions taken in California remains to be seen, but until their efficacy is demonstrated we are not convinced that they will reduce incidences of lead poisoning of condors sufficiently to enable self-sustaining populations as long as lead ammunition is freely available, because of issues with compliance and enforcement. Tejon Ranch's new policy was implemented through notification by word-of-mouth and letters to all hunters, followed up later by spot checks in the field (Hill 2009). Yet, in the spring of 2008, high lead levels were detected in seven condors in southern California, and global positioning system (GPS) data indicated that condors carrying transmitters had been feeding on Tejon Ranch in addition to using provisioned carcasses at Bitter Creek NWR. These birds were taken to the Los Angeles Zoo for treatment, and one subsequently died. There was speculation that the birds may have ingested lead in carcasses available through Tejon's year-round pig-hunting program. This possible exposure event caused Tejon to close down their hunting program for a 1-month review and resulted in tightening of their enforcement program. The possibility that condors were exposed to lead-contaminated pig carcasses on the Tejon Ranch despite the prohibition of lead ammunition points to the necessity of enforcement to ensure compliance with nonlead regulations and to the difficulty of achieving 100% compliance even in highly controlled hunting programs.

Enforcing the statewide prohibition on lead ammunition in California could be similarly problematic. The Ridley-Tree Condor Preservation Act provides for subsidies to hunters for nonlead ammunition, but California has not provided any funding for the program. Still, early indications are that compliance may be sufficiently high that enforcement may not be an issue: in February 2009, California Department of Fish and Game reported that a survey of hunters indicated that 99% complied with the nonlead ammunition requirement in 2008. One problem is that poachers take large numbers of animals in California and are unlikely to comply with the nonlead requirement, as long as lead bullets are easily purchased.

Because the Arizona condors are considered an experimental population (see below), in the Southwest the lead issue has been addressed through voluntary programs rather than mandatory regulations. The Peregrine Fund has teamed with the Arizona Department of Game and Fish to encourage hunters to use copper bullets in areas where condors feed (Sullivan et al. 2007). Having identified the deer hunt on the Kaibab Plateau as the primary source of lead exposure in Arizona, they initiated a public education program for all hunters drawing permits for that hunt and provided them with lead-free ammunition at no charge. Outreach efforts have been highly successful, with voluntary compliance by >80% of hunters (K. Sullivan pers. comm.). Despite this success, condors continue to be exposed to lead while foraging on the Kaibab and when ranging beyond the Arizona border. The failure of the Arizona program to significantly reduce exposure of condors to lead is one of the reasons we are skeptical about the effectiveness of voluntary, and even mandatory, local prohibitions of lead ammunition.

In Arizona and Utah, birds have access to a large supply of their preferred food, deer, during the late summer, fall, and early winter. Green et al. (2008) modeled exposure and cleansing of the population during the hunting season and concluded that without trapping and intervention, sufficient mortality would occur in the population to prevent sustainability, even at the current high rate of compliance in use of lead-free ammunition by deer hunters in the Kaibab Plateau. Previously, Woods et al. (2007) reached the same conclusion on the basis of an assessment of field data. In future years, as more birds move into Utah during the hunting season, the problem will become worse unless a very successful hunter-education program is undertaken and hunters widely accept the use of lead-free ammunition (Sullivan et al. 2007). Even so, Green et al. (2008) hypothesized that only a few lead-exposed carcasses would be sufficient to cause mass mortalities of condors if there is not a successful way of trapping birds during the hunting season in Arizona and Utah.

Exposure of condors to lead fragments in carcasses is analogous to die-offs of Asian vultures in which populations of several species have been reduced nearly to extinction because of feeding on cattle carcasses that contained the veterinary drug diclofenac (Oaks et al. 2004). Diclofenac is a very effective nonsteroidal anti-inflammatory drug, but if a treated animal dies, a single carcass may contain multiple lethal doses of toxicant and can poison multiple birds feeding communally. Green et al. (2004) created models of exposure scenarios to determine the proportion of carcasses that needed to be contaminated to adversely affect the population of Asian vultures feeding on carcasses and found that if as few as 1% of the carcasses contained diclofenac, they would intoxicate so many individuals that the vulture population would not be sustainable.

Lead and condor recovery.—We are convinced that condor recovery cannot be achieved unless exposure to lead from ingesting ammunition fragments while feeding on carcasses and gut piles is eliminated. On the other hand, we also believe it is quite possible that wild populations that did not require human intervention to be self-sustaining could be established were this threat removed. We are skeptical that, even with excellent compliance, voluntary programs promoting the use of nonlead ammunition can reduce lethal exposure to lead sufficiently to wean condor populations from constant veterinary care. Similarly, the efficacy of area-specific requirements for nonlead ammunition such as the local regulations on the Tejon Ranch or even the state regulations in California remains uncertain, especially when some legal uses of lead ammunition are retained in those areas. Replacement of lead with nonlead ammunition needs to be achieved on an ecologically relevant scale and thereby positively affect survival rates over all or a significant portion of the condor's range if self-sustainability is to be achieved. We predict that if lead ammunition remains available, some of it will find its way into carcasses on which condors feed, sometimes in unanticipated ways. In Baja California, 11 birds, constituting half of the population, had to be treated for lead poisoning because the cows used for their supplemental food supply apparently had previously been shot with .22 caliber lead ammunition by vandals (E. Peters pers. comm.).

We submit that condor recovery will not be possible until exposure to lead in their food sources is totally eliminated. The effectiveness of voluntary programs and regulations targeted toward particular types of ammunition in particular areas will soon become apparent. If such partial regulation proves insufficient, some will likely suggest a national ban on lead ammunition, similar to the ban on lead shot for waterfowl hunting (Friend et al. 2009). Progress toward recovery is not sustainable under current conditions because reintroduction of more condors simply increases the costs required to keep free-living birds alive rather than improving the ability of the free-living populations to persist without human assistance. The program thus has reached an impasse involving tradeoffs between number of birds, mortality rates, and program costs. As more condors enter the population, partners may be unable or unwilling to sustain the increased level of support required to prevent mortality rates from lead ingestion from rising. The ultimate goal of many of the partners is to be involved in lower-intensity monitoring of populations that are not reliant on human intervention to be self-sustaining, or to exit the program entirely when populations reach this point, not to continue increasing expenditures indefinitely. That goal is unattainable as long as the lead threat remains, and the longer the lead issue continues to impede progress, the more difficult it will be to sustain the support of existing partners or secure additional support for the recovery program.

The USFWS is the agency responsible for achieving recovery, including resolving the lead issue. However, neither the USFWS nor any of the other federal recovery partners has the statutory authority to regulate the use of lead ammunition outside of their lands. Coordination among land management and regulatory agencies could provide a means of addressing lead exposure of condors over a meaningful spatial scale. This could also assist federal land managers in meeting their recovery obligations under the ESA (see below). Also, the USFWS can make the case for eliminating lead ammunition to those agencies that have authority to bring about such action, and to the public. State wildlife agencies play a critical role because of their jurisdiction over hunting regulations, and in California, Arizona, Utah, and Oregon these agencies are already fully engaged with the lead issue.

Replacement of lead ammunition with nonlead alternatives will take some time, as it did when lead shot was eliminated from waterfowl hunting (Friend et al. 2009). It will be essential to rally public support for such a change, and a gradual transition will impose fewer hardships on hunters, state wildlife agencies attempting to implement new regulations, and ammunition manufacturers and distributors (Thomas 2009). During this transition, much can be learned about the degree of compliance, enforcement capability, and effectiveness in reducing lead exposure in condors of various types of regulations. There is no danger that condors will disappear from the wild if it takes some time to complete the transition to nonlead ammunition, because managers are able to maintain populations, provided that adequate funding and personnel remain available to sustain the current intensity of intervention.

We conclude that a reduction in hunting, depredation permits, or other types of shooting would not promote condor recovery. Such actions might effectively reduce lead in the environment, but they would also result in a significant reduction in the condors' food supply. Humans are the dominant predators in most of the condor's range, and carcasses and gut piles resulting from hunting and other types of shooting are important food sources for condors. It is essential that humans continue to harvest deer, pigs, and other wildlife throughout the condor range—but using nonlead rather than lead ammunition, so that a clean source of wild food is available to condors beyond food subsidies. It is unlikely that condors could be sustained in the wild after food subsidies are reduced without this source of food. Emphasizing the importance of hunting to condors might be an effective means to gain support from the hunting community for conversion from lead to nonlead ammunition. It is also important that hunters be made aware of the potential for adverse effects of lead exposure from spent ammunition on other species, including humans (Thomas 2009).

The mortality risk to condors posed by lead ammunition is such that, under some circumstances, use of such ammunition could be considered "take" of condors under the ESA. The birds reintroduced in Arizona are classified as a nonessential experimental population under ESA section 10(j). Hence, they are treated legally as proposed for listing rather than endangered, except in national parks and national wildlife refuges where they are treated as threatened under the 10(j) rules. Condors in California and parts of Utah outside of the experimental population boundaries receive the full benefits of protection against incidental take provided by ESA sections 7 and 9. The USFWS and land management agencies may benefit from development of policy and guidelines that integrate current knowledge of lead impacts into management programs and ESA consultations. Such guidance could clarify whether the use of lead in hunting programs and depredation programs, considered individually and cumulatively, reach the regulatory and consultation thresholds under section 7 of the ESA and, if so, how these types of actions should be addressed.

A similar approach might be applied to "take" of condors attributable to microtrash ingestion (see below), whereby federal agencies would consider the impacts of microtrash in their land-use plans, issuing of oil and gas lease permits, and consultations with the USFWS. One possible outcome might be that the BLM and USFS would make removal of trash a requirement for lease and permit holders on public lands when activities conducted under such permits would create a source of microtrash (e.g., Hopper Mountain).

Foraging and Supplemental Feeding

Lead-free carcasses are provided at all condor release sites as a possible means of reducing exposure to lead. The potential effectiveness of this food subsidy as a means of keeping condors from consuming contaminated food was, in fact, a justification for initiating releases in the 1990s (USFWS 1996). At the time, it was believed that captive-reared condors might become strongly dependent on subsidies, as was observed in similar releases of Eurasian Griffon Vultures (*Gyps fulvus*) in France (Terrasse 1985) and Andean Condors (*Vultur gryphus*) in Peru (Wallace and Temple 1987, 1988). However, California Condors have not become strongly dependent on clean food subsidies at release sites, which parallels the findings from earlier feeding programs for the original wild population (Wilbur 1977, Snyder and Snyder 1989). Moreover, proffered foods have been provided at multiple locations at all release sites, especially in the 1990s, when efforts were made to lure the birds away from human activity. As the birds became more mobile and more adept at keying in on other scavengers, especially ravens, they quickly adapted to feeding at nonproffered sites. As released condors strayed from food subsidies, the incidence of lead poisoning increased, although the level of adherence to subsidies and the incidence of lead poisoning vary among sites. For example, adherence to subsidies has been strongest in southern California, where feeding stations have been few and nonproffered food sources appear to be limited (Snyder and Snyder 2000, Grantham 2007, Hall et al. 2007). By contrast, sites where adherence to subsidies has been weaker had multiple feeding stations to encourage exploration and more abundant nonproffered food, such as hunter-killed game in Arizona and dead marine mammals at Big Sur (Hunt et al. 2007, Sorenson and Burnett 2007, Woods et al. 2007). Overall, providing food subsidies has not proved to be an effective means to prevent condors from being exposed to lead.

Still, released condors make extensive use of subsidies, which are usually offered on a regular schedule (e.g., every 3 days) at a site or several sites relatively close together. Stillborn calves from dairies are the most common food, although other species are sometimes offered, depending on availability (Grantham 2007, Wallace et al. 2007). Although its effectiveness in achieving its original objective of reducing lead exposure is arguable, luring captive-reared condors to feeding stations has clearly been invaluable for flock management. For instance, releasing young, captive-reared condors near feeding stations promotes their socialization through interactions with older, experienced conspecifics and facilitates their integration into the free-living flock (Grantham 2007, Woods et al. 2007). Additionally, feeding stations allow for routine retrapping of condors to replace transmitters, conduct health checks (e.g., blood tests for lead or West Nile virus postvaccination antibody titers), and, when warranted, provide chelation treatment for lead exposure (W. Austin et al. unpubl. data). Thus, even in Arizona, where feeding on "natural" food has been especially emphasized for some time, managers still must offer food subsidies in order to trap, test, and treat birds once or twice each fall and winter when the birds return to the holding pen area after feeding on deer carcasses during the hunting season on the Kaibab Plateau. Recently, providing food at multiple, widely dispersed locations has been used to stimulate expansion of the birds' foraging range. Finally, attraction of condors to fixed feeding stations allows for routine observation and provides opportunities for experiments related to food choice or nutrition, such as providing bone chips to test the hypothesis that microtrash ingestion is related to calcium deficiency (Mee et al. 2007a).

Although feeding condors at fixed sites and fixed time intervals has been useful, it likely retards development of normal wide-ranging foraging behavior, alters time and energy budgets, and may adversely affect other natural behaviors (Mee and Snyder 2007). For instance, food subsidy has been hypothesized to disrupt the normal pattern and rate of food delivery to nestling condors by their parents (Mee et al. 2007a). Possible effects include increased synchrony in food deliveries to the chick, more frequent periods of food deprivation, and inability of subordinate pairs to secure a full crop or the more nutritious parts of a carcass. Also, as discussed more fully below, condors that rely on food subsidies may use some of their "excess" time that normally would be devoted to extensive searches for carrion to engage in unnatural or inappropriate behaviors, such as the exploration of human-developed sites and ingestion of trash (Mee and Snyder 2007).

FIG. 6. California Condors and a Golden Eagle at a protected feeding site. (Photograph courtesy of U.S. Fish and Wildlife Service.)

As food subsidies have become predictable in space and time, feeding stations have attracted not only condors but also other scavengers and predators (e.g., feral pigs, coyotes, cougars, bears, bobcats, and Golden Eagles), thereby increasing competition and predation risk for condors. To deter food loss and interactions with mammalian predators and scavengers, "permanent" feeding stations have been protected with electric fences at two sites in southern California and similar protected feeding stations have been established in central California (Fig. 6). Although these protected feeding stations have reduced food loss to mammalian scavengers, risk of predation by Golden Eagles may still exist (Mee and Snyder 2007). Furthermore, these feeding stations can promote a high level of sociality among condors, as observed in southern California, where it is possible to find the entire reintroduced population of that area together at a feeding site (Mee and Snyder 2007). Such concentrations of condors at a single site were never observed in the wild population before its extirpation, because much of the condors' time was occupied in searching for food, leaving little time for aggregating at a site (Meretsky and Snyder 1992). The effects of high levels of sociality at feeding sites are unknown, but it is likely that dominant birds control the food source, making it difficult for young birds and less dominant condors to obtain food. High levels of sociality may also increase the risk of disease transmission.

Given that food subsidy at a fixed site or a few fixed sites near the release site is required to trap and treat birds for lead exposure, most problems that arise from subsidy cannot be alleviated until the lead problem is solved. Increased linkage of monitoring with foraging patterns and lead exposure would be useful in developing a feeding strategy. Once the lead issue is solved, problems associated with food subsidy will likely diminish, and those that remain may become more tractable to management intervention. Continued food subsidy may be required at sites with inadequate food supplies or seasonal shortages of carrion, such as in Arizona, where condors may continue to require subsidized food during the winter (Hunt et al. 2007). In fact, it is not yet clear whether condors could subsist without food subsidies at any of the reintroduction sites. The impact of feral hogs as scavengers on the condor's food base is one concern, and all the changes in the landscape wrought by humans over the last 200 years is another. Investigation of this issue, including experimentation, could help prevent this from becoming the next impediment to condor recovery once the lead problem is solved.

Foraging habitats at reintroduction sites vary considerably and include beaches and coastal redwood forests at Big Sur, oak savannas, grasslands, and chaparral at Pinnacles National Monument, grasslands and oak savannas in southern California, high desert and forested plateaus in Arizona and Utah, and arid scrub habitats of Baja California. This variety provides a rich context for studies of the foraging abilities and requirements of condors on current landscapes. Their ability to feed on marine mammals is an encouraging development with respect to the potential food base in central California and farther north. At this point, southern California appears to be the most problematic area as far as natural foraging potential is concerned, but the recent protection of habitat on Tejon Ranch, the gateway between historical foraging ranges of the southern California population in the coastal ranges and the southern Sierra Nevada (Wilbur 1978), provides opportunities for this area.

We recommend continuing research on the capacity of condors to become self-sufficient foragers within the extant landscapes where they are being released, and we endorse recent efforts in southern California and elsewhere to encourage condors to forage more widely and rely less on proffered food. The condors currently on the landscape are pioneers. We learn much from them, albeit at some cost to the birds and the partners involved in the condor program. Although encouraging condors to explore a larger landscape may increase the risk of lead exposure, it provides benefits in learning opportunities.

Undesirable Behavior of Released Birds

From the first releases of captive condors back into the wild, the behavior of released birds, specifically their attraction to humans and human-built structures (Fig. 7), has been an issue (Snyder and Snyder 2000). The inquisitiveness of condors makes tame birds unusually prone to interact with humans, and because of their large size and gregariousness such interaction is inevitably problematic. As a consequence of the condor's social nature, undesirable behavior can be contagious: well-behaved birds can learn undesirable behaviors from other condors. The survivors among the first birds released in 1992 and 1993 were recaptured and returned to captivity because of their tameness, general attraction to human activity, and tendency to engage in the high-risk behavior of perching on utility poles (USFWS 1996). Subsequent examples of undesirable behavior range from mundane destruction of property to the truly fantastic. In southern California, a cohort of birds reared and released together began associating with hang-gliding enthusiasts on weekends, roosting on a communication tower at the launch site, mingling with the humans on the ground to pick through food wrappers and other trash, and soaring with the hang-gliders when they took to the air (Mee and Snyder 2007, J. Grantham pers. comm.). Another group of condors descended on the Pine Mountain Club property near Mt. Pinos in 1999, destroying satellite dishes, roof shingles, and a screen door, and entering the bedroom of one home to take bites out of a mattress (Snyder and Snyder 2000).

Fig. 7. California Condors attracted to a human-built structure. (Photograph courtesy of U.S. Fish and Wildlife Service.)

Many in the condor program believe that supplemental feeding promotes development of undesirable behavior involving attraction to humans and human-built structures because it provides birds with more time for activities other than foraging (Mee and Snyder 2007). This is debatable, whereas it is clear that captive-rearing and socialization techniques affect the expression of undesirable postrelease behavior (Bukowinski et al. 2007, Clark et al. 2007, Wallace et al. 2007). Since the first releases, development of rearing and release techniques that produce well-behaved birds has been a major issue and an important focus of research, conducted largely through trial and error. Much progress has been made, especially in recent years (Clark et al. 2007, Wallace et al. 2007). In general, two rearing methods are used, parent-rearing and puppet-rearing (Wallace et al. 2007). Condors learn survival skills and appropriate social behavior through interaction with other condors (Wallace 2000, Alagona 2004), and in the wild, young birds learn from their parents during a long period of dependence (Snyder and Snyder 2000). In the early years of the program, puppet-reared birds were raised in cohorts and thus lacked adult mentors (Bukowinski et al. 2007). These birds were prone to undesirable behavior (Meretsky et al. 2000, 2001; Snyder and Snyder 2000) and were seemingly lacking in social skills (Cade et al. 2004) and wariness of humans (Meretsky et al. 2001). The puppet-rearing procedure has subsequently evolved to include interaction with older mentors as an important component of the rearing routine (Clark et al. 2007). In addition, birds are now held in outdoor pens at release sites for a considerable period and have further opportunities to learn from mentors placed within the pen, as well as through interactions with free-living birds that visit the pen. Thus, birds are integrated with the existing flock to some extent before they are released. Both puppet-rearing and parent-rearing are currently producing birds that behave appropriately, and there is no difference in postrelease survival between birds raised by these two methods (Woods et al. 2007).

Rearing-and-release now involves close integration between captive and field facilities geared toward releasing a well-behaved bird and managing subsequent behavior in the field. Managers have learned to recognize appropriate and undesirable behavior and monitor individuals closely to decide if and when a bird is suitable for release. Such monitoring continues after release, and problem birds are caught and returned to captivity for a "time-out" period of months or years during which they undergo behavioral rehabilitation or are moved to another release site. Intensive monitoring is also required so that managers know when to apply negative reinforcement (i.e., hazing) in response to undesirable behavior. This may be effective in deterring young condors from approaching humans or their structures; it was effective in Arizona (Hunt et al. 2007), but not in southern California (Grantham 2007). Similarly, managers in Arizona employ hazing to deter newly released condors (including older birds) from roosting on the ground, where they are vulnerable to predators (Woods et al. 2007). Negative reinforcement in the form of aversion training of young birds prior to their release has also been effective in discouraging condors from landing on utility poles, contributing to a reduction in power-line-related mortalities (Mee and Snyder 2007). Undesirable behavior is much less an issue today than it was previously, but occasional problem individuals that interact inappropriately with humans or other condors still occur, and one pervasive behavioral problem, microtrash ingestion in southern California, still exists. Perhaps the biggest change is that managers have gotten much better at recognizing undesirable behavior earlier and removing individuals that exhibit it from the free-living populations before they cause problems.

There is widespread belief among the program's biologists that parent-rearing is superior to puppet-rearing in producing desired behavior (Meretsky et al. 2000, Wallace et al. 2007). Although unequivocal evidence that this is so is lacking, we support a preference for parent-rearing on the general principle that reducing reliance on humans is desirable. However, because breeding pairs will renest when their eggs are removed and sometimes fail in raising young, puppet-rearing results in considerably higher productivity than parent-rearing (Wallace et al. 2007). Hence, there may be tradeoffs between producing a better bird for release versus producing a greater number of birds. The current emphasis on parent-rearing is facilitated by the fact that some release sites, for example the one in Arizona, are at or near capacity in terms of the number of birds that they can handle given the intense postrelease monitoring and treatment requirements. Use of puppet-rearing will increase if demand for birds for release increases in the future, and, hence, further research designed to improve the puppet-rearing technique, such as the current study in Baja California (Wallace et al. 2007), is warranted. Carefully designed experiments such as this one, as opposed to the trial-and-error approaches of the past, will provide the most definitive results (Meretsky et al. 2000). Designing experiments that will produce clear interpretations is challenging, however, because of the influence of the existing free-living flock on the behavior of newly released birds. Indeed, one of the current issues is the extent to which improved behavior in recent years is attributable to more use of parent-rearing versus the presence of older free-living mentors. This issue was avoided in the Baja California experiment because there was no previously existing flock there. We encourage others to conduct a similar experiment with parent-reared and parent-socialized birds if such an opportunity arises in a new and separate release area.

There is good coordination between rearing methods and demands at release sites among partners that work closely (e.g., Boise-Arizona, San Diego-Baja, Los Angeles Zoo-Bitter Creek), and this is reflected in the emphasis on parent-rearing in Boise and the Los Angeles Zoo, and in greater use of puppet-rearing at San Diego. However, matching overall demand with overall production across the program may need some attention. In particular, the central California release site (Big Sur and Pinnacles) would like more birds than they are currently receiving. At the program level, genetic and demographic considerations drive decisions about how many and which birds are available for release (Ralls et al. 2000, Ralls and Ballou 2004). Currently, an age structure skewed toward the older age classes in the captive population is a particular concern (M. P. Wallace et al. unpubl. report, K. Ralls pers. comm.). To correct this problem will require that some of the young birds produced be retained in captivity, thereby reducing the number available for release. Therefore, decisions will need to be made on the basis of prioritization among the competing needs for retaining more birds for breeding, reducing the incidence of undesirable behavior (parent-rearing), and producing more birds (puppet-rearing) for release. In our opinion, reducing the incidence of undesirable behavior is the most important of these needs. Annual breeding and transfer recommendations should follow established procedures for Species Survival Plans in coordination with the Population Management Center at the Lincoln Park Zoo.

Despite the great progress that has been made in developing rearing techniques that produce well-behaved birds, concerns about undesirable behavior remain. For example, in central California, program managers are concerned that condors have frequent opportunities to interact with people in Pinnacles National Monument and on the coast along Highway 1, where birds roost immediately adjacent to the highway above the coastal colonies of sea lions. Thus, there is a continuing need for postrelease monitoring and behavioral management of released birds.

There is room for further experimentation with rearing techniques as well. In general, the improvements that have been made represent shifts toward procedures that more closely resemble natural processes of rearing and socialization, the emphasis on parent-rearing being the most obvious example. Rearing techniques could be shifted further in this direction (Mee and Snyder 2007). Leaving chicks with their parents for a prolonged period and delaying mixing of young birds until the age when they naturally would separate from their parents represent such shifts. There is some concern that exposing young birds to one another at an early age could trigger incest-avoidance mechanisms and thereby affect pair bonding (Hartt et al. 1994, Mee and Snyder 2007). Once the lead problem is solved, we recommend the release of established breeding pairs from the captive population. Old birds from the original free-living population should be included in these releases because their knowledge could be invaluable in reestablishing traditional seasonal movements and foraging patterns (Mee and Snyder 2007). For example, older birds might lead younger condors back to historical foraging grounds in the Sierras.

We conclude that undesirable behavior is no longer an impediment to reestablishment of free-living condor populations. Sufficient progress has been made in refining captive-rearing and release techniques to produce appropriate behavior, and in managing behavior after release, that undesirable behavior is confined to individual cases that are quickly addressed. Still, more work is needed to reach the point where it is no longer necessary to manage the behavior of free-living condors. In the meantime, the close integration between captive and field facilities in managing behavior should continue, with continued emphasis on parent-rearing while demand for birds for release remains relatively low. Until the lead problem is solved, the quality of the birds produced, not their quantity, is paramount.

Microtrash ingestion.—Condor parents feeding nestlings small items of trash has been the major cause of nest failure in southern California. While hatching success in this reintroduced population compares well with that documented in the historical condor population and other vulture species, fledging success has been substantially lower than expected (Mee et al. 2007a, b; Snyder 2007).

Of 12 nestlings hatched in the wild in southern California between 2001 and 2006, eight died before fledging (Table 2). Although only two deaths (nestlings SB#285 and SB#308) can be directly attributed to trash, trash ingestion was probably a contributing factor in the deaths of five additional nestlings. Between 2001 and 2006, only a single nestling (SB#326) successfully fledged without assistance, although three other nestlings (SB#328, SB#370, and SB#412) were removed from the wild for medical treatment and were either returned to the nest or rereleased into the wild following their recovery. Nestling SB#328 had 222 g of foreign material removed by surgery yet appeared to be healthy, whereas nestling SB#370 had 200 g of microtrash removed by surgery and was clearly debilitated. Ingested items are diverse and have included rags, nuts, bolts, washers, plastic, chunks of pipe, bottle caps, spent cartridges, and pieces of copper wire. Mee et al. (2007a) examined 650 trash items recovered from condor nests and nestlings and determined that 226 (34.8%) were plastic, 223 (34.3%) were glass, 148 (22.8%) were metallic, and 53 (8.1%) were other materials (Fig. 8). They found that trash items were significantly more numerous, larger, and of greater mass in reintroduced condors' nests than in historical nests.

Because of the problems posed by microtrash ingestion, and following a successful intervention in 2006 in which a chick from which microtrash was surgically removed subsequently fledged, the USFWS initiated an intensive nest-monitoring program in southern California in 2007. Nestling feather growth and development are carefully monitored because trash ingestion can cause distention of the crop and gizzard and interfere with food uptake and processing. During nest visits, nestlings are palpated and checked with a metal detector to ascertain the presence of metallic trash. Trash items are removed from the floor of the nest

TABLE 2. Causes of posthatching nest failure of California Condors in California, 2001–2006 (modified from Mee et al. 2007a).

	Effect			
Primary cause	Dead	Removed	Percentage	Additional data (number of nestlings affected)
Ingested trash	2[a]	2[b]	36	Zinc toxicosis (1), retarded growth (2), elevated copper (2), anemia (1), pneumonia (1), perforated gut (1)
Undetermined	3		27	Elevated copper (2), ingested trash (2)
Trauma	1[c]		10	Head and neck wounds
Dehydration		1[d]	9	Visceral gout, ingested trash, elevated copper
Fall from nest	1[e]		9	Ingested trash, broken wing
West Nile virus	1		9	Aspergillosis, ingested trash, retarded growth

[a] Chick SB#308 was removed from the wild on 11 September 2003 (~133 days of age) and was subsequently euthanized at Los Angeles Zoo on 24 September 2003.
[b] Chick SB#370 (116 days of age) was rescued from the wild in 2005 for surgery and treatment and was rereleased to the wild in 2006. Chick SB#412 (~130 days of age) was removed from its nest to Los Angeles Zoo in 2006 for emergency surgery for impaction at Los Angeles Zoo, was returned to its nest the next day, and survived to fledge.
[c] Chick SB#263 died at ~2 days of age in 2001. The chick was derived from a captive-produced egg placed in the nest of a "trio" (1 male, 2 females) of adults when their two eggs were not viable. Wounds possibly resulted from adult aggression. Adult female SB#108 was subsequently removed from the wild.
[d] Chick SB#288 died at 145 days of age and had gone at least 6–8 days without food during hot weather.
[e] Chick SB#328 was found below the nest cave with a broken wing. The 131-day-old chick was taken to the Los Angeles Zoo for surgery to repair the wing and remove trash. The chick recovered and was subsequently rereleased to the wild in 2006.

cavity, and bone fragments are provided. Nestlings are also vaccinated for West Nile virus during these examinations. During the 2007 breeding season, all six breeding attempts were successful, although two fledglings were subsequently lost (SB#434 to a wildfire and SB#444 to an unknown cause). As of July 2008, microtrash had been found in four of five nests in southern California, and some chicks had microtrash in their digestive tracts (J. Grantham pers. comm.). We conclude that successful nesting in southern California is currently contingent upon intensive nest monitoring and corrective intervention when needed, and we recommend that this monitoring, although it is time- and labor-intensive and costly, be continued until the behavior of feeding microtrash to chicks ends. In our opinion, the rationale for such monitoring is reasonable: it is more desirable to have a chick fledged naturally into the wild by free-living parents than to raise and release a captive-reared chick, and a wild-reared chick will likely adopt natural behaviors more quickly than a captive-reared one.

FIG. 8. Microtrash from a California Condor nest in southern California. (Photograph courtesy of U.S. Fish and Wildlife Service.)

Although areas with abundant trash (e.g., oil platforms and visitor overlooks) that are frequented by adult condors are being identified and cleaned up, it seems unlikely that this effort alone will solve the trash ingestion problem, given the scale and diversity of these sites (Mee et al. 2007a, J. Grantham pers. comm.). The question as to why condors feed trash items to their chicks remains unresolved and clearly merits additional investigation. Trash ingestion may represent a misdirected search for calcium and food sources needed for egg laying and chick growth and development, as documented in other large vultures (Mundy and Ledger 1976, Richardson et al. 1986, Benson et al. 2004, Houston et al. 2007). Although provisioning of calcium sources (i.e., bone fragments and small mammals) at feeding sites in southern California did not seem to reduce the quantity of trash delivered to nestlings, these items were provided irregularly and in inadequate amounts to rigorously test this hypothesis (Mee and Snyder 2007; Mee et al. 2007a, b). Additional efforts to test this hypothesis are warranted, and we agree with Mee and Snyder (2007) that studies on pellet formation and regurgitation in adults and chicks as well as on the timing and rate of bone mineralization in nestlings could provide valuable supplemental information.

Microtrash ingestion has been especially common in the southern California release population, where trash ingestion has caused chick mortality (Mee et al. 2007a, b). Incidence of microtrash is not as well documented in Arizona as it is in southern California because nests are visited less frequently in Arizona. However, reasonable nest success rates (Woods et al. 2007) and observations when nests are visited indicate that trash ingestion by chicks is not nearly as common in Arizona as in southern California and is not an important factor in chick mortality. Some site differences in the frequency of trash ingestion by chicks are attributable to differences in the availability of trash—the southern California site has an abundance of trash (especially along roadsides and oil drilling pads) in the vicinity of nest sites, in contrast to the more pristine environment of northern Arizona. It also has been suggested that the Arizona condors have a lower propensity to bring trash to the nest because they forage more widely on a variety of natural carrion and display less reliance on subsidized food (Mee et al. 2007a). Moreover, in the past, the Arizona nests were farther from the provisioning site (some are up to 80 km away) than southern California nests, all of which were in the vicinity of the provisioning site (1.5–12 km) until recently. Therefore, it has been hypothesized that regardless of the food source, breeding pairs in Arizona foraged more widely and had less time available to search for trash (Mee et al. 2007a, b; Mee and Snyder 2007). As of July 2008, however, feeding sites are now 72 km from nest sites in southern California, yet GPS telemetry data indicate that some breeding adults continue to make stops at prospective trash sites on their way to or from feeding sites, and microtrash continues to appear in nests (J. Grantham pers. comm.). Thus, the microtrash issue continues to defy simple solutions.

Nest observations in southern California suggest that nestlings now receive more irregular feedings than historically, a feature that may be related to the timing of food availability at feeding stations and may also influence trash ingestion behavior (Mee et al. 2007a). We agree with Mee and Snyder (2007) that experimental and observational examination of relationships between the regularity and spacing of feedings and the frequency of trash ingestion would be of considerable value. It was during periods of food deprivation that nestling Cape Vultures (*Gyps coprotheres*) were most likely to ingest foreign materials, including human artifacts and nest material (Benson et al. 2004).

The recent requirements for nonlead ammunition within condor habitat in California opens up the possibility of eventually reestablishing more natural foraging patterns in this population by providing a larger number of more widely distributed feeding stations, thereby inducing birds to travel much greater distances. Relocation of the release site and primary feeding station in southern California from Hopper Mountain NWR to Bitter Creek NWR in 2006 (Fig. 3), a distance of 72 km, was the first step in this direction. Establishment of additional feeding stations at Tejon Ranch and Wind Wolves Preserve in 2008 following adoption of the nonlead requirement represents a further attempt to alter adult movements and activity budgets and recreate historical geographic foraging patterns. Whether these changes will eventually reduce the incidence of microtrash ingestion remains to be seen, but clearly altered foraging and activity patterns did not immediately extinguish such behavior in the individuals that had a tradition of picking up trash (see above). Extant foraging patterns are still far less extensive than those documented historically, however, and we recommend that additional experiments designed to increase parental foraging time and effort be undertaken as soon as lead risks can be minimized and addressed. Perhaps development of more natural foraging patterns will prevent new breeders from acquiring the microtrash habit.

Adult condors also seem to vary considerably in their propensity to feed trash to chicks and may not visit trash sites until they are feeding nestlings (J. Grantham pers. comm.). Suggestions on how to deal with individuals that habitually pick up trash range from aversive training to relocating the birds to reestablished populations in Arizona or Baja California, where trash is much less available. One breeding pair that regularly fed microtrash to their nestlings were returned to captivity and subjected to aversive training, but they quickly resumed the behavior when they were returned to the wild in southern California. To date, there have been no attempts to transfer "problem" birds or pairs from southern California to other release locations. Whether microtrash ingestion can be modified or extinguished through aversive training is uncertain. No quantitative results were obtained from the one pair subjected to aversive training because the video recordings of the training sessions were lost as a result of equipment failure (M. Mace pers. comm.). We recommend that experiments with aversive training be undertaken in captivity as soon as practicable. Experiments involving young birds before their release and adults that have exhibited this behavior in the wild would be useful.

Early indications are that microtrash will not be as large an issue at the central California release sites as it has been in southern California. The first nesting in central California occurred in 2007, and only one of two nests contained any microtrash. Identifying the source and cleaning it up quickly eliminated the microtrash problem at that nest. This provides some hope that microtrash can be managed. The most promising avenues to pursue in reducing the microtrash problem appear to be (1) eliminating microtrash at sites frequented by condors; (2) returning adults that pick up microtrash to captivity for aversive training, as has been done for other undesirable behaviors; and (3) promoting more natural foraging patterns in nesting adults.

Exposure to Organochlorines

Of greater concern in central California is the possibility that contaminants accumulated through feeding on marine mammals could have adverse effects on survival and, especially, reproduction. These possibilities include long-term health effects associated with toxicants such as PCBs and eggshell thinning caused by exposure to DDE, to which condors and other raptors are purported to be sensitive (Kiff et al. 1979; Wiemeyer et al. 1984, 1988a; but see Snyder and Meretsky 2003). Iwata et al. (2000) showed that sea eagles feeding on marine mammals are exposed to DDE. Because breeding is just beginning in central California and the new breeders are young, it is currently difficult to evaluate this possibility, and early observations are equivocal. Initially no problems were evident, but in 2008 two eggs contained embryos that died during development from excessive moisture loss that may have resulted from thin-shelled eggs (J. Burnett pers. comm.). We recommend vigorous and timely investigation of the possibility that contaminants acquired by feeding on marine mammals interfere with reproduction in the central California birds. It is tempting to view carcasses of marine mammals as a panacea for condors living in coastal areas, but it is essential to make sure there are no issues with this food source. Specialized protocols need to be developed for collecting eggs and tissues of condors in central California in order to assess and monitor contaminants. Testing of samples and dissemination of test results in a timely manner has been a recurring issue with this work.

PROGRAMMATIC ISSUES

Program Organization and Administration

Condor recovery partners are currently self-organized into a diffuse network (Fig. 9). The central elements of the recovery program are a large and diverse Recovery Team, a Field Working Group,

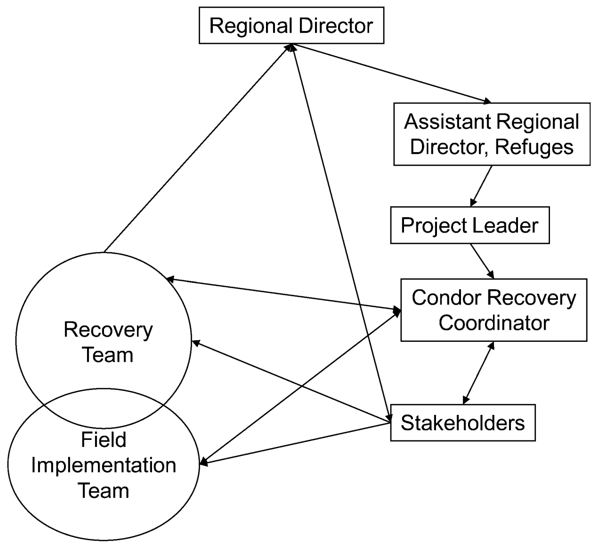

FIG. 9. Organization of the current California Condor Recovery Program.

and a USFWS condor recovery coordinator. The latter is housed near the southern California release site in Ventura, California, and is supervised by the Hopper Mountain NWR project leader. The 19-person Recovery Team is led by and primarily comprises active participants in the condor rearing, release, and monitoring programs and is weighted toward personnel from captive-breeding facilities. Meeting frequency has declined from semiannual to irregular. The Field Working Group, which was established several years ago, includes all technicians from the captive-propagation and release-management programs who are actively involved in restoring condors. They meet twice each year. There is also a veterinary coordinator charged with ensuring standardized care (e.g., vaccination policies), a pathology coordinator charged with conducting postmortem examinations and evaluating causes of mortality, and a Genetics Group (associated with the American Zoo and Aquarium Association and consisting of personnel from the Smithsonian's National Zoo and the Lincoln Park Zoo) that makes recommendations about pairings and transfers to optimize the genetic structure of the population.

Issues with current structure.—Efficient recovery programs require effective, adaptive, and typically task-oriented organizational structures (Clark and Cragun 2002). Except for the newly formed Field Working Group, which exhibits all these qualities, we rarely found these characteristics in the condor program. The position of condor recovery coordinator highlights many of the inefficiencies we discovered. The coordinator must monitor and lead a large program that involves two countries, three USFWS regions, and many state and private partners. However, because this position is located in a local refuge office, the coordinator must report to a supervisor in that office rather than directly to a senior manager in the regional office. This unnecessarily long hierarchy of authority and overuse of bureaucracy is characteristic of problematic implementation of the ESA (Yaffee 1982). Problems with long hierarchies certainly depend on the resources, desires, personalities, and leadership skills of the various supervisors. Multiple supervisors that are dedicated to a program could articulate a strong, unified voice for that program, but in practice this outcome is seldom realized, particularly when many of the supervisors have tight budgets and many competing demands besides the program in question. We conclude that placing the condor recovery coordinator in a refuge office unnecessarily links the coordinator to a single release site, reduces the coordinator's authority, and stifles the "virtuoso talents" needed by effective recovery-program leaders (Westrum 1994). Potentially, the long hierarchy of authority could also make it difficult for the coordinator to keep regional and national staff abreast of ever-changing and controversial issues affecting condors, to find program funding usually acquired at the national and regional level, and to work effectively with leaders of partner organizations who hold much higher-level positions within their own hierarchies. When condor recovery efforts were focused on reestablishment of the southern California breeding population, housing the coordinator at nearby refuges established for the condor made sense. But given the expanse of the condor program today, this structure no longer seems appropriate.

Housing the condor recovery coordinator at a local refuge office is not typical of national recovery programs. Most coordinators, especially for wide-ranging species like condors (e.g., Whooping Crane [*Grus americana*], Northern Spotted Owl [*Strix occidentalis occidentalis*], Gray Wolf [*Canis lupus*], and Grizzly Bear [*Ursus arctos horribilis*]), are assigned to USFWS Ecological Services field offices or regional offices. The coordinator for the Red Wolf (*C. l. rufus*) is an exception, being under the USFWS Refuges chain of command. But the Red Wolf has a narrow distribution in the southeastern United States and occurs almost exclusively on Alligator River NWR, where the coordinator is assigned. It makes sense to have the coordinator at the refuge in the case of the Red Wolf, but not in the case of the condor, whose refuge use constitutes such a small portion of the geographic range.

If the lead issue is resolved, new partners will certainly be needed to expand the program to new locations. In our opinion, the current program structure is not conducive to recruiting new partners. Program inequity and lack of shared and effective leadership make new partners feel uninformed and undervalued. They often feel out-of-sight and out-of-mind when it comes to programmatic decision-making and coordination. Similarly, stakeholders outside the program must navigate a confusing programmatic structure to voice concerns and remain informed about recovery. Increasing the profile of the condor recovery coordinator would provide stakeholders and new partners more effective entry to the recovery program. This would also enable the coordinator to better inform others that are not active partners, such as the BLM, USFS, and California Fish and Game, of program activities, especially when selecting new release sites. In the past, those affected by condors have not always been informed that birds were going to be released and would likely use their lands. It would be advisable to coordinate with other affected parties (e.g., utility companies) as well to avoid predictable problems.

The lack of funding for permanent field staff at the southern California release sites run by the USFWS is an issue. The success of the field program at Hopper Mountain and Bitter Creek depends on the dedication of interns and temporary employees who have little or no experience in working with such a highly visible, critically endangered species. There has been high turnover in the temporary positions, which has resulted in a lack of long-term continuity and familiarity with the species and strategies and techniques developed from working with large birds. When more experienced individuals fill these positions, operations tend to be more successful: the tremendous nesting success achieved at Hopper Mountain NWR in 2007 was heavily dependent on the efforts of two temporary USFWS employees who had the experience, passion, and commitment to make the program work. Results might decline dramatically with new, less experienced personnel in these key positions. Also, there needs to be someone above the field-supervisor level who has the bigger picture in focus. That individual should guide research and management, find funding, and have a direct connection with the field program.

By contrast, the Arizona site is staffed by a crew of 11, and with the base funding increase in the National Park Service budget, the central California release site will be staffed by two biologists and two or three interns from the Ventana Wildlife Society, plus five permanent biologists, two temporary biologists, and two interns from the National Park Service. This compares to one supervisory biologist, two GS-7 temporary biologists, two GS-5 temporary biologists, and interns in southern California, where the work load is heavier because of intensive nest monitoring. There is a critical need for additional funding from either the USFWS or program partners to adequately staff the southern California release sites. We question whether this release site can remain viable as currently operated.

The modest level of USFWS funding complicates general program administration, in that private partners must place their own budgetary needs before those of the cooperative recovery program. The level of investment by private partners also poses difficulties for program administration, in that the partners' need for autonomy in raising funds must be balanced with program coordination. A diverse partnership is essential in the condor program, and although this is bound to lead to some inefficiencies, the situation could be improved.

Finally, the Recovery Team is not fulfilling its role of providing leadership in implementing recovery. It has become overwhelmed by its many responsibilities as the program has grown ever larger. Its large size and a membership drawn mostly from program participants limit its effectiveness in providing a vision for the program, making recommendations to the USFWS, and coordinating new scientific investigations of key issues (e.g., foraging patterns, contaminants, land-use patterns and changes, and human demographics). The team has become a stakeholder group to some extent and receives relatively little input from independent scientists outside the program.

Proposed reorganization: A new approach to condor recovery.—That the current condor program has enjoyed as much success as it has is a tribute to the determination of all who have been, and are, involved with the program. However, continued realization that conservation-dependent species like condors require long-term, active management (Scott et al. 2005) demands that we do better. We conclude that the current structure of the program reflects past rather than current or future conditions and that a reorganization of this structure is overdue. We offer one possible reorganization that illustrates the kind of change that we believe is needed to enable the condor program to better adapt to existing and new challenges. Of course, our proposal does not represent the only possible effective structure, but rather is intended to convey the kinds of changes that could improve the program. The USFWS and its partners may be able to devise other structures that achieve the same ends.

(1) At the center of condor recovery would be a Condor Recovery Office (CRO) that works seamlessly with a Recovery Implementation Team (RIT) comprising those organizations that rear, release, and monitor condors (Fig. 10). Basic programmatic coordination would be the duty of the condor recovery coordinator. An additional, senior-level staff scientist would join the CRO as the condor research and monitoring coordinator. This senior endangered-species scientist would report to the recovery coordinator and would be reported to by the site-specific field supervisors. This arrangement would increase the ability of the CRO to coordinate recovery and the research on which it depends. Although coordination would be led by the CRO, all members of the RIT would share leadership of on-the-ground restoration efforts in a dynamic, problem-specific manner. The RIT would report directly to the recovery coordinator and interact directly with the Scientific Advisory Team (see part 3 below).

Interactions between individuals at the same level in different programs and organizations (e.g., keepers at zoos and field personnel at release locations) are useful, as evidenced by the effectiveness of the Field Working Group. Our suggested reorganization includes holding semiannual meetings of the RIT and CRO, modeled on the current and productive "field team meetings," thereby formalizing the current Field Working Group as the Recovery Implementation Team. These meetings enable communication and interaction between isolated field workers, and participation of staff from California, Arizona, Baja California, and Oregon has been excellent. Certainly, this team may continue to be organized around release sites and captive populations, but we envision a much more dynamic formation of subgroups as issues arise, perhaps in collaboration with the Scientific Advisory Team. As issues change, leadership would shift among team members, allowing those who best understand and can solve the problem to lead (Westrum 1994). For example, once the program gets beyond the lead issue, new groups will likely be needed to address land-use changes, human demographics, and new release sites. This structure is fundamentally different from the current organization-specific, fixed leadership positions.

(2) To reduce the chain of command between the regional director and the CRO, the condor recovery coordinator and research and monitoring coordinator would report directly to a deputy regional director or assistant regional director rather than being placed within the hierarchy of a field office. It matters less whether this director is in the NWR system or Ecological Services than that the director be in a regional office rather than in a field office, where the personalities and directives of additional supervisors must be navigated by the CRO on behalf of the condor. As pointed out above, to coordinate a species that crosses USFWS jurisdictional boundaries, spends considerable time on private (rather than refuge) land, and ranges across international borders requires access to the regional director in the lead office for the listed species (in this case, Sacramento). It might be effective to physically locate the CRO in a field rather than regional office in order to maintain contact between the condor recovery and research and monitoring coordinators and personnel working with condors in the field.

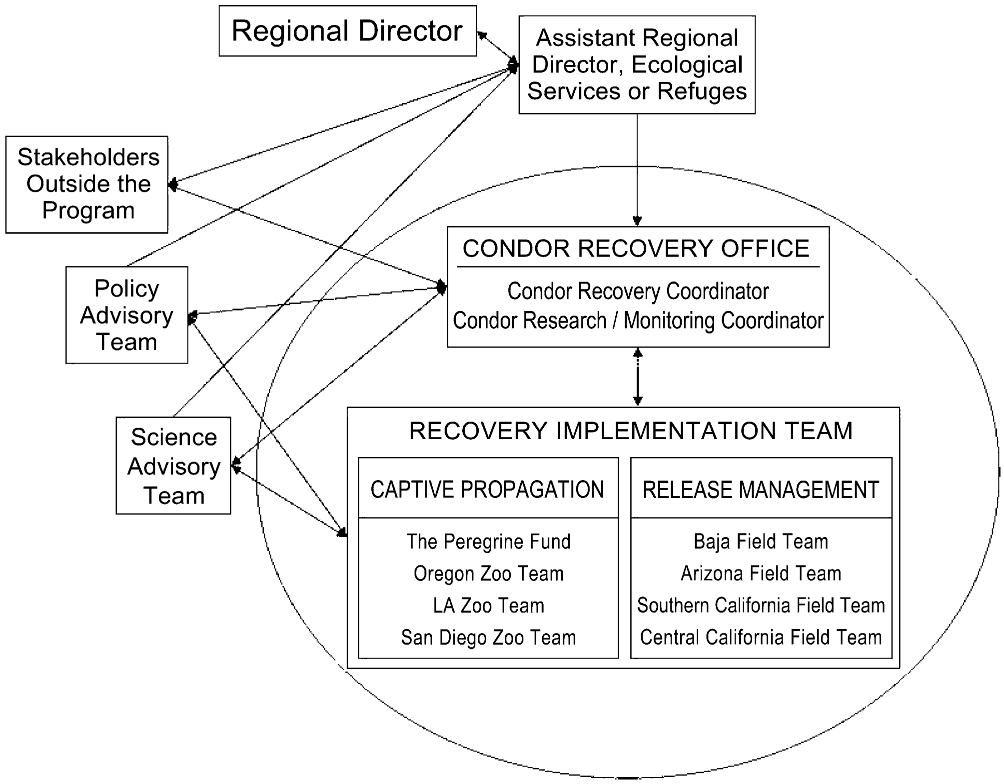

Fig. 10. Proposed reorganization of the California Condor Recovery Program. We suggest creating a new Condor Recovery Office, which would report directly to a U.S. Fish and Wildlife Service regional office, and an independent Science Advisory Team. The science team's autonomy would be enhanced by the creation of a separate Policy Advisory Team and a practical Recovery Implementation Team.

(3) The function and composition of the Recovery Team needs to be reconsidered. Our suggested reorganization involves disbanding the current team and dividing its duties between two new entities. The first is a small, scientifically focused advisory team. This Science Advisory Team (Fig. 10) would comprise 7 to 10 scientists with appropriate expertise (e.g., avian ecology and conservation, captive management, conservation genetics, contaminants, analysis of animal movements) and excellent interpersonal skills from a variety of institutions (academic, private, and governmental). Team members would interact with the CRO and RIT at biannual meetings, provide an objective scientific framework for the recovery process, review research results, and reassess future research needs. This group would take on some of the responsibilities of the current Recovery Team and associated research working group but would differ in having greater involvement of scientists outside the program. Independent advisory teams are increasingly common and effective (Stoskopf et al. 2005) as recovery teams transition from planning to implementation. The team would have clear rules and expectations that encourage creativity rather than suppression of novel ideas (Stoskopf et al. 2005), and team members would be independent of financial ties to condor recovery. The team might strive to prioritize short-term activities (tasks) or long-term activities (projects) and encourage publication of results at each meeting (Stoskopf et al. 2005). Working groups, led by team members and involving other scientists and managers within and outside the RIT, might be effective in addressing specific issues (e.g., lead poisoning, captive breeding, survival of released birds, land-cover change, veterinary care). By listening carefully to the CRO and RIT and applying broad scientific thought, priorities needed by the recovery program would be arrived at by consensus and conveyed to the USFWS regional director by the team. These priorities would include research rather than focusing exclusively on management.

(4) Leaders of organizations that are involved in the condor recovery effort would not be part of the Scientific Advisory Team, but their insights into program management and involvement in recovery implementation are critical to success. Therefore, we include in our suggested reorganization a Policy Advisory Team (Fig. 10), consisting of these participants and the condor recovery coordinator, that would meet as needed to set policy direction for the program and help coordinate communication and management among the various cooperating organizations. The Policy Advisory Team would furnish the partner organizations with a vehicle for providing input on important decisions that affect them, such as addition of new release sites, captive-breeding facilities, and partners and major shifts in program direction. Team members, and especially the leader (e.g., a CEO of an involved nongovernmental organization), would be expected to be visible, dynamic, technically savvy, high-energy, hands-on managers who ask key questions of the program and effectively voice the needs of the condor to the political world that ultimately will decide its fate.

The Role of Research and Science in the Condor Program

Ideally, endangered species programs should integrate management, monitoring, and research in an adaptive management framework, making research a component of the management mission (Walters and Holling 1990, Gosselin 2009). The adaptive management process developed for the ongoing Everglades restoration provides an excellent example of this process (National Research Council 2003, 2007; RECOVER 2006). Although there is effective feedback between monitoring and management in the condor program, for example in managing condor behavior, an adaptive management framework that includes research is not evident. Research occurs, but it is not coordinated and integrated into program operations as management and monitoring are. This hinders progress in understanding condor biology and addressing critical research and management needs. We believe that including a research and monitoring coordinator and Science Advisory Team (Fig. 10) will result in more effective use of research in the condor program.

Inside and outside the condor program, there is widespread concern that the role of research is insufficient and widespread support for making more use of a hypothesis-testing approach to research. Many partners perceive that the current condor program is run as a management and monitoring operation, and explicitly not as a research operation. Funding for research is extremely limited, and currently relatively little research is being conducted on free-living condors. There is a research working group associated with the Recovery Team, but no organized research structure to coordinate and take advantage of the research opportunities and data streams emerging from the operations of the program. The program could benefit from more involvement of U.S. Geological Survey (USGS) scientists, whose mission includes research in support of USFWS programs, as well as more involvement of the academic and zoo research communities. The recently formed Pacific Northwest California Condor Scientific Working Group—a consortium of USGS, USFWS, USFS, Oregon State University, and Oregon Zoo researchers who have outlined and prioritized research needs to evaluate the possibility that condors can be released back into the Pacific Northwest—illustrates the integration of research into the program that we recommend. The Santa Barbara Zoo, as a new partner, is an excellent resource for increasing the role of science in the program as well.

Behavioral issues, including the microtrash problem, are particularly well suited to an adaptive management approach. Active adaptive management involving experimentation provides the greatest opportunities for learning, but even a passive approach that formally relates management and monitoring to key questions would be far superior to the current situation. Data collected on free-living and captive birds need to be question-oriented (Meretsky et al. 2000). For example, the microtrash issue has not been addressed in a systematic way, yet it could be approached via a series of food-preference experiments involving microtrash-aversion conditioning of captive birds before their release. Examining food preference and nutritional value of domestic versus wild carcasses would be a simple yet critical experiment to conduct on free-living and captive birds. We recommend adoption of a formal adaptive management process that includes research to address these and other issues, in which hypotheses about the outcome of management actions based on current understanding of biology are stated explicitly and collection of monitoring data is designed to test these hypotheses.

Standardization and Management of Data

Considerable concern about standardization, management, and ownership of data exists throughout the condor recovery program. These issues encompass a wide array of topics, including access to historical records, responses to requests for data from individuals outside the program, dispersed storage of information, incomplete inventories of samples and specimens, absence of summary reports, delayed access to GPS movement data, incomplete information concerning law enforcement actions, and a general lack of standardization (e.g., multiple IDs for the same bird and multiple reporting formats). Personnel at one site do not always have access to the latest information from another and, as a result, sometimes repeat mistakes made elsewhere or fail to make use of new understanding of biology or management. The task of assembling all data relevant to a particular question, collected and stored in various, nonstandardized ways by the various partners, is sufficiently daunting to seriously impede research. Even Ventana and the National Park Service, though managing the central California birds as a single flock, are unable to merge much of their data. Some databases that would be extremely valuable (e.g., reproductive performance of individual breeding pairs, and blood lead levels recorded in free-living birds at each recapture) simply do not exist or are incomplete and have not been systematically examined.

That data-management concerns exist is not surprising given the long history of the recovery program; its expansion to include multiple reintroduction sites, organizations, and individuals; and rapidly evolving technologies. We conclude, however, that these problems have reached the point that they seriously impede the effectiveness of the program. Furthermore, there is a great deal of information gathered on condors over the years that needs to be reviewed and organized. As an interim measure, we recommend hiring a data manager–statistician to work with the proposed research and monitoring coordinator to oversee the existing data and assist in future standardization of data collection, reporting, and storage. Although postdoctoral researchers, students, interns, and volunteers should also be used in this effort, the data manager position needs secure funding to prevent turnover and provide consistency. Two important initial tasks for this position are to summarize the extant data for critical review and evaluation and to develop standardized databases for record keeping for all program participants.

Data management is a difficult but critical issue for long-term programs. Computerization is obviously required for effective management, but access to stored information can be hampered when computerized systems and programs become obsolete. Similarly, data stored in various programs or formats at multiple locations may not be readily accessible to program participants or other potential users. The condor recovery program clearly faces all these challenges. The zoos presently involved in the condor program maintain electronic information on each captive specimen using two independent database systems: (1) an Animal Records Keeping System (ARKS), which records information on location, behavior, molt, diet, breeding, transfers, etc.; and (2) a Medical Records Keeping System (MedARKS), which contains a record of all health-related issues, medical examinations, treatments, and so forth. Additionally, Mike Mace at the San Diego Wild Animal Park maintains the condor studbook (Mace 2007) using a third database program called Species Animal Records Keeping System (SPARKS), which contains an inventory of all living and dead condors and can be used to complete basic demographic and genetic analyses of the living population. Unfortunately, all these systems must be independently maintained and accessed, which impedes the timely sharing of information. The International Species Inventory System (ISIS) is presently developing a unified global database system called the Zoological Information Management System (ZIMS), which will combine the independent functions of the ARKS, MedARKS, and SPARKS systems (see Acknowledgments). This flexible, web-based system will use high-quality code and will allow authorized institutions to enter, search, and retrieve data directly. We recommend that participants in the condor program follow the development, testing, and deployment of the ZIMS system closely, because the benefits of applying this system to store, manage, and access information on captive and free-living condors are potentially huge.

Data ownership is a serious issue because it is not clear who owns collected data, research samples, or specimens. This situation has precipitated unnecessary conflict in the past and, unless effectively addressed, will continue to inhibit cooperation among partners and across release areas and captive-breeding facilities. Being derived from a federally organized endangered species program, data pertaining to the condor belong in the public domain. We encourage program partners to make more data more available and more accessible to others in the program and to the public at large. Internally, data should be shared freely among partners, while adhering to standard courtesies and protocols with respect to publication and proprietary information. We believe addition of a research and monitoring coordinator and data manager to the program and standardization of data collection will facilitate cooperation and promote sharing of data and testing of ideas among partners.

Field, veterinary, and pathology protocols should be evaluated with standardization in mind, although we recognize the need for partners to retain flexibility as appropriate to each program. Current program reporting schemes should also be evaluated in order to secure standardized contents, formats, and submission frequencies among cooperators. Feedback loops also need to be examined to make certain that important findings are translated into appropriate research and management actions.

Monitoring Released Birds

It is critical to continue long-term demographic monitoring and evaluation of birds in the wild. Currently, intensive monitoring of released birds is essential to reduce mortality caused by lead poisoning and to detect and treat undesirable behavior. Once the lead issue is resolved, continued monitoring will be needed to track population dynamics and key aspects of biology such as foraging patterns and dispersal.

Several methods, such as photographic identification of individual condors (Snyder and Johnson 1985) and radiotelemetry (Meretsky and Snyder 1992), were developed and used successfully in the 1980s to monitor various aspects of wild condor demography, ecology, and movements (Snyder and Snyder 2000).

FIG. 11. California Condor with patagial tag and VHF transmitter. (Photograph by S. Haig, U.S. Geological Survey.)

There was no evidence in these early studies that radiotransmitters, their attachment, and associated trapping and handling contributed to condor mortality. Since then, radiotelemetry has become the most important and frequently used method for monitoring released condors, as summarized for specific sites by Mee and Hall (2007). All released condors are fitted with a VHF transmitter mounted on the patagium (Wallace et al. 1994) or, occasionally, on the tail (Hunt et al. 2007) and fitted with vinyl tags attached at the patagium (Fig. 11) for visual identification. Despite these standard attachment methods, some have suggested that better methods for attaching or implanting transmitters should be explored, given that transmitters have caused injury to some birds. Some condors also receive GPS satellite-reporting transmitters designed to provide hourly position fixes with an accuracy of 50 m during daylight hours. Most tracking of VHF radiotagged condors is done by observers in motor vehicles or on foot at various high points, but fixed-wing aircraft are sometimes used to search for missing birds. Both GPS and VHF transmitters are needed to collect the data required for the monitoring program. Thus, we see great benefit in ensuring that each bird has one of each transmitter type. GPS transmitters will become increasingly important as the need to monitor foraging movements and dispersal increases. We recognize that funding issues may limit the use of GPS transmitters. However, managers should be able to do better than 5-month transmitter life, considering the technology now available.

Monitoring individual condors with radiotelemetry is essential for evaluating the success of releases, determining survival rates and range use, identifying sources of mortality, and alerting managers to situations that require active intervention or management changes. In addition, scientifically designed monitoring programs based on telemetry are required to identify reasons for failure or success of releases so that future releases can correct problems of the past and replicate successful releases. Currently, monitoring of released condors is required to reduce mortality from lead poisoning because it indicates where (geographic locations), when (season), and from which food sources condors are obtaining lead at various release sites (Hall et al. 2007, Hunt et al. 2007, Sorenson and Burnett 2007) and can identify birds weakened by lead poisoning (Mee and Snyder 2007). For example, monitoring has indicated that the relatively low incidence of lead poisoning in Big Sur condors is associated with their reliance on marine mammals, which limits their exposure to lead (Sorenson and Burnett 2007).

Monitoring is also required to detect undesirable behavior of released condors to determine underlying causes so that corrective actions can be taken. For instance, the effectiveness of different captive-rearing methods (e.g., puppet-rearing and parent-rearing) in reducing or eliminating unnatural tameness or attraction to humans and human structures can be evaluated only by close monitoring of released birds (Clark et al. 2007, Mee and Snyder 2007, Wallace et al. 2007). Monitoring of parental movements has identified some sources of microtrash delivered to nestlings (Grantham 2007, Mee et al. 2007a), which has led to cleaning efforts at these sources (Mee et al. 2007b, J. Grantham pers. comm.). Further reductions in power-line mortalities or injuries may be possible by sharing condor movement data and coordinating with the electric utility companies. In central California, the Ventana Wildlife Society is working with the electric company PG&E to modify lines by making them more visible (e.g., insulated lines and diverters) or even relocating them to eliminate condor accidents.

There are more radiotagged condors now than in the free-living population of the past, so that more and better data are accumulating on mortality factors (Hall et al. 2007, Snyder 2007, Woods et al. 2007). Identification of mortality factors was one of the justifications for initiating the early releases in the 1990s (Snyder and Snyder 2000). Nevertheless, the cause of mortality is unknown for about a third of the deaths since releases began (Snyder 2007). Improved monitoring has improved the ability to document mortality events, and increased use of VHF and GPS transmitters would result in further improvements. Future monitoring should also focus on tracking population dynamics and key aspects of biology such as foraging patterns and resource use (Marzluff et al. 2004) rather than functioning as a form of triage with respect to lead exposure and bird behavior. However, fully implementing these high-priority studies requires solving the lead problem. Costs will escalate as condor numbers grow; hence, sustaining the intense level of current monitoring may not be possible. Once the major stresses on condor populations that now exist have been ameliorated, some routine population-monitoring activities could be conducted by photographic identification of individual condors (Snyder and Johnson 1985). With the advent of digital photography, photographic identification of individuals has become more cost effective, and digital methods eliminate many of the earlier problems associated with film (e.g., Meretsky and Snyder 1992).

Monitoring of reproductive effort and success is also necessary to identify factors that contribute to reproductive failures so that ameliorative actions can be instituted, if needed, to ensure population stability or growth. Although successful breeding has occurred at all release sites except Baja California, the presence of breeding trios and divorce of breeding pairs at some sites interferes with reproductive success and may represent unnatural behaviors derived from captive-rearing methods, given that such behaviors were unknown in the original wild population (Snyder and Snyder 2000, Mee and Snyder 2007). Whatever the cause of this aberrant breeding behavior, monitoring is needed to determine whether the behaviors disappear with breeding experience or with changes in rearing methods as advocated by Mee and Snyder (2007). The intensity of monitoring and frequency of management intervention will vary among sites, depending on nesting success. For instance, at one extreme is intensive nest monitoring and frequent intervention in southern California to counter chick mortality caused by ingestion of microtrash and the threat of West Nile virus. This contrasts with Arizona, where nest success has been relatively high (45%), nest monitoring less intensive, and nest visits infrequent (Woods et al. 2007). These nest success rates at release sites can be combined with reproductive effort and survivorship data in demographic models (e.g., Meretsky et al. 2000) to indicate the likelihood of successful reestablishment of condors at a site.

Managing Population Structure

Although the genetic structure of the reintroduced populations is carefully managed (Mace 2007), the condor program lacks an overall vision of the geographic structure of a range-wide, self-sustaining population. Such a vision is needed to evaluate the efficacy of current and future release sites. Thus, some species-wide population modeling needs to take place in a risk-assessment venue so that various hypotheses regarding translocation and reintroduction may be evaluated with multiple stakeholder interests in mind. In essence, a detailed recovery target is needed, specifying locations of and movement rates between populations, demographic parameters, numbers and age structure of individuals within those populations, and sustainable and expected amounts of variation.

The existing release sites for condors represent remote locations in areas of appropriate habitat within the historical range. Initially, the birds released at different locations, tied to their nearby supplemental feeding sites, were effectively separate populations. As numbers grow and birds begin to forage more on their own and thus range more widely, the structure of the overall population becomes an important question. As noted above, managers quickly realized that the birds reintroduced at the two release sites in central California, Big Sur, and Pinnacles National Monument functioned as a single population and have adjusted their management accordingly. There have been interactions between the southern and central California populations as well, but on this larger scale there has not yet been an assessment of the birds' home range, dispersal tendencies, and potential links to release sites other than their own. Therefore, there is no plan for metapopulation development and conservation of the species at the range-wide level. However, detailed movement data, collected via attachment of various types of transmitters, have been collected at each release site and are currently being analyzed with the ultimate goal of providing perspective on how to better link existing populations and on where future reintroductions should occur to ensure healthy within- and among-population structure. Experience with the Eurasian Griffon Vulture illustrates the importance of having a network of populations (Le Gouar et al. 2008).

We recommend that the utility of current and future release sites be assessed on a metapopulation scale: the distribution of release sites should be based on desired geographic structure of a viable, self-sustaining range-wide population. Developing a range-wide plan to manage population structure and viability will involve evaluation of historical, current, and future habitat availability and connectivity. For example, establishment of breeding territories near release sites can necessitate identifying new release sites for existing populations. This was a factor in the decision to open a second release site in central California (i.e., Pinnacles). On a larger scale, it may be important to condor recovery to develop new release sites in the Pacific Northwest or elsewhere in order to increase asynchrony in environmental stochasticity among the component populations and thereby increase the stability of the overall metapopulation. It may become necessary to develop a more formal process for making such decisions as the program grows and the stakes (i.e., revenue for partners) become greater.

Until the lead problem is resolved, we cannot recommend opening additional release sites. If any new sites are opened in areas where lead ammunition is used, the birds will have to be induced to use supplemental food, monitored intensively for evidence of undesirable behavior and lead exposure, and regularly trapped and treated for lead poisoning, as they are elsewhere. However, once the lead issue is resolved, additional release sites should be considered. Currently, condors are not dispersing into their historical range in the southern Sierra Nevada from the southern California release sites. A Sierra release site previously identified as a good geographic location was rejected because of excessive lead exposure. With the new lead regulations in California and the recent setting aside of habitat on the Tejon Ranch that links the foraging habitat where the birds are now and the historical foraging areas in the Sierras, this and possibly other sites in the Sierras may become prime locations for a new release site. We suggest that a site in California's Sierra Nevada be considered as an alternative or additional release site for southern California. However, candidate release sites in the Sierras are distant from abundant nest sites. Perhaps the best goal for these sites is to resolve the lead issue expediently so that the four remaining condors originally captured from the wild in this region could be released there. Additional disjunct sites should be considered as appropriate.

The ability of condors released at Big Sur to locate and feed on marine mammals provides optimism about the viability of additional coastal release sites in similar habitat in northern California and Oregon, once the lead issue is resolved. However, the contaminant load in these carcasses must be evaluated before sites are selected, because marine mammals are known to bioaccumulate toxins that could be passed on to condors (see above).

Successful expansion of the range of condors may benefit from formal protection of future release sites and associated habitat. This provides incentive to identify future sites now, even if none will be opened soon. Development is occurring at a rapid pace, and the longer it takes to identify and protect potential future release sites and foraging areas, the fewer locations with sufficient, well-connected habitat will be available. Large parcels of land associated with current release sites have been protected, which indicates that it is possible (although difficult) to protect habitat for new release sites. The USFS, BLM, USFWS, and a number of tribal groups will likely be important partners in such efforts. In northern California, the Yurok Tribe is negotiating with Green Diamond Timber Company (formerly Simpson Timber) to purchase 40,000 acres near the Oregon border as a tribal park where condors could be released. This property would link inland forests (and food sources such as elk and deer) with coastal areas, thus providing a foraging corridor for condors. The tribe is hoping that habitat can also be secured close to their tribal park on the Oregon side of the border to provide a wider swath of habitat and better protection for the birds. The Yurok Tribe recently received funds from the tribal wildlife program of USFWS to carry out a prerelease assessment of habitat needs, food availability, potential lead exposure, and stakeholder interests within the Yurok ancestral territory. A Bureau of Indian Affairs interagency task force and the Tribal Park Task Force will help guide this effort.

Farther north, in Portland, the Oregon Zoo is interested in participating in a future release of condors in Oregon. To that end, historical records of condors in the state have been evaluated, current potential habitat has been documented, and modeling work to determine optimal release sites has been conducted. As described previously, the Pacific Northwest California Condor Scientific Working Group is assessing research to be undertaken prior to release of birds in Oregon.

Disease and Health Management

Effective procedures have been developed for monitoring and managing the health of condors in captivity and in the wild, and veterinarians within the program have prepared written protocols for managing health. Monitoring and treatment of birds for lead exposure has been especially impressive, albeit expensive and laborious. Each zoo maintains a dedicated staff for condor health. The Peregrine Fund utilizes a local veterinarian in Boise as well as long-term relationships with veterinarians at Washington State University and the Phoenix Zoo. Field teams have contracts with veterinarians and clinical diagnostic laboratories to monitor health and analyze blood samples for lead and clinical chemistry parameters.

Pathologists at the San Diego Zoo have prepared written protocols for the handling, shipment, and evaluation of dead condors for program participants. Although detailed pathology reports are available for most condors that have died in captivity or in the wild, we discern two gaps in information. The first involves dead condors that have been seized by USFWS Law Enforcement personnel as part of ongoing criminal investigations. The second involves examination of unhatched eggs of both captive and wild origin. These deficits in information need to be corrected. We recommend that the pathology coordinator develop a standardized protocol for submission and evaluation of all unhatched eggs. We also suggest close coordination between USFWS Law Enforcement and the pathologists at the San Diego Zoo to ensure consistency in all aspects of postmortem analyses, including histological examinations and tissue collections. Veterinary and pathology protocols should be reviewed, appropriately revised, and distributed to all program participants annually.

Condors have shown good resilience in captivity and do not have many health problems in the captive environment. In the wild, one free-flying Arizona juvenile and one California chick suffered broken wings, which were repaired. Both birds were eventually returned to the wild. Two chicks that suffered from trash impaction were taken from nests, treated surgically to remove the trash, and replaced in the nest the following day. Both ultimately fledged successfully. Few health problems other than lead poisoning and West Nile virus have plagued the program.

We recommend continuing the existing veterinary coordinator position to facilitate information transfer on topics such as vaccines and procedures. The Field Working Group meetings have assisted greatly in this information exchange and should be continued as well, reformed as the Recovery Implementation Team (see above). Addition of a research and monitoring coordinator and data manager to the program will make the veterinary coordinator more effective. We also recommend that the veterinary coordinator oversee development of general health protocols for the program. These should be carefully reviewed by participating veterinary representatives and updated appropriately.

West Nile virus.—The condor program appointed Dr. Cynthia Stringfield, then a veterinarian at the Los Angeles Zoo, to coordinate the vaccination program for West Nile virus when this threat hit bird populations on the East Coast in 1999. Dr. Stringfield worked with the Centers for Disease Control to identify the best vaccine to use for condors and other zoo birds (Chang et al. 2007). All captive condors have been vaccinated for West Nile virus, and protocols are in place to vaccinate all free-living chicks before 30 days after hatching and to administer a booster before fledging. The effectiveness of the vaccine has been demonstrated by complete protection of the captive flock. The only condors that have succumbed to West Nile virus were seven birds, including four chicks, at The Peregrine Fund's facility in Boise that were not vaccinated. Other birds at the facility became ill, but they recovered. Since that event in 2006, all adults and new chicks have been vaccinated at all facilities and all chicks have been vaccinated in accessible nests or when first captured in the wild. One free-living chick died in August 2005 in southern California before being vaccinated, which indicates that parentally transferred immunity will not protect a chick for long and that chicks must be vaccinated as early as possible.

Other threats.—The potential for high-pathogenicity avian influenza (HP H5N1) in condors could be significant if the avian flu virus gets imported into the United States and infects wild birds and poultry. Vaccines have been produced to immunize avian populations, especially captive zoo collections and endangered species such as condors. The vaccine protocols are managed by the U.S. Department of Agriculture and require federal permits to be employed. To date, no poultry or zoo birds have been vaccinated in the United States, and no vaccinations are planned unless H5N1 enters the country. More information on avian influenza can be found online (see Acknowledgments).

Outreach

Overall, most Americans consider the California Condor Recovery Program to be a success, rather than a work in progress. The public needs to be apprised of the reality of the situation, so that the resources essential for recovery can be secured. Effective outreach builds public support for returning the birds to the wild and helps partners raise the funds that they need to continue their contributions to condor recovery. Toward those ends, all major partners in the condor program are involved in outreach programs that educate the public about condors and highlight issues of concern such as littering (i.e., microtrash) and use of lead ammunition. These programs have produced materials ranging from informational websites to children's craft projects (for examples, see Acknowledgments). Although all partners are active in outreach, at least locally, they look to the USFWS for assistance and leadership at the national level. Currently, USFWS outreach activities are limited. If the USFWS is to provide effective leadership in outreach activities, this situation must be corrected, and indeed the USFWS is seeking to fill a staff position dedicated to outreach. It will also be important to engage the Santa Barbara Zoo in program-wide outreach activities, as this new partner has considerable capability and is willing to commit to a major role in outreach activities.

The prime example of where a national outreach program is needed is the lead issue. In our opinion, condor recovery is unlikely unless hunters adopt nonlead ammunition universally, and, therefore, gaining the support of the hunting community for such a change and increasing the appreciation within that community of their important role as providers of food for condors are key steps toward recovery. Those involved in the hunting industry must take the necessary steps to make nonlead ammunition widely and readily available as well. An important step toward rallying public support for replacement of lead ammunition was taken with The Peregrine Fund's 2008 conference on "Ingestion of Spent Lead Ammunition: Implications for Humans and Wildlife" (see Acknowledgments; Watson et al. 2009).

The Arizona Department of Game and Fish outreach program has been highly successful in illustrating the negative effects of lead ammunition and convincing hunters to use copper bullets for deer and elk hunting (Sieg et al. 2009). We recommend that state wildlife agencies in California and Utah, as well as in states such as Oregon where condors may exist in the future, participate actively in outreach and encourage hunting with nontoxic ammunition using programs similar to those in Arizona. Subsidies to hunters for nontoxic ammunition could be implemented in each state. Currently, the Cooperative North American Shotgun Education Program in Klamath Falls, Oregon, is promoting use of nonlead ammunition and investigating requirements for nonlead ammunition in various states.

A Look to the Future

The goal of the condor program is to establish a wild population that can maintain itself with minimal human intervention. If that goal is achieved, the zoos, veterinarians, and release-site field crews, and most of the current partners, would happily leave the condor business. The intense management, food subsidies, and triage activities of today would, hopefully, become a thing of the past. In fact, many of the partners have acknowledged that this is indeed their long-term vision. That vision may be a while in arriving.

In our opinion, the primary focus today must be on solving the lead problem, and secondarily the microtrash problem, as currently these are impenetrable barriers between the heavily subsidized populations of today and the self-sustaining populations envisioned for the future (Fig. 12). If these problems are solved, in the heady aftermath of that event it will be easy to be overly optimistic and imagine that recovery is imminent. But once past the current barriers, the condors will likely discover new, though probably less formidable, ones. Wind energy and gas and oil development loom as future threats. Emerging diseases and global climate change are other possible future issues. The genetic and

FIG. 12. Hopefully, these heavily managed birds of today will become the self-sustaining population of tomorrow. (Photograph courtesy of U.S. Fish and Wildlife Service.)

demographic stability of the captive and free-living populations may be another. Still, our review of the condor program leaves us optimistic. We believe that recovery of the condor, once almost inconceivable, is possible. Perhaps that is the greatest achievement of the condor recovery program over the past 25 years: to demonstrate the possibility of recovery. But this potential cannot be realized until the lead problem is solved.

Some will disagree with our assessment. There are many skeptics who believe that the landscape has changed so much that it can no longer support condors. Certainly, habitat has changed greatly and many formerly remote areas are now heavily affected by anthropogenic influences. The mammal community that was the basis of the condor food supply has changed greatly, as has the community of scavengers in which they compete, the addition of feral hogs being a particularly worrisome change in the latter. It is because of this that it will be critical to encourage and maintain hunting and controlled depredation shooting throughout the condor range, using nontoxic ammunition, to provide a source of food for the free-living birds. There are still wild places that appear to be able to support condors, and interest among many in expanding the free-living population. We believe that adaptive management provides the means to address whatever new issues arise and that there is great hope for recovery of these magnificent creatures.

CONCLUSIONS AND RECOMMENDATIONS

In the following section, we provide a summary of the present review for the convenience of the reader, in the form of our most important conclusions and recommendations. All of these are presented in the body of the paper above, along with their respective bases.

The condor has long been symbolic of avian conservation in the United States. Following their extirpation from the wild in 1987, many questioned whether condors could ever be returned to the natural environment. Yet the California Condor Recovery Program, one of the oldest and most complex efforts of its kind in the United States, has achieved success beyond what many imagined possible. As of the summer of 2009, there were more than 350 condors, more than 180 of which were free-living, soaring in the skies of southern and central California, Arizona, Utah, and Baja California, Mexico. The free-living birds face severe challenges, however, and receive constant and costly human assistance. Thus, the program has reached a crossroads, caught between the financial and logistical pressures required to maintain an increasing number of condors in the wild and environmental problems that preclude establishment of wild populations that can sustain themselves without human intervention.

Recognizing this, Audubon California requested that the AOU conduct an evaluation of the recovery program. The AOU agreed to establish a Blue Ribbon Panel, consisting of the authors of the present review, as a subcommittee of their Committee on Conservation. We collected information through site visits to captive-breeding facilities and release sites, a review of the literature, interviews in person and by telephone of those involved in the condor program, and solicitation of comments from other interested parties. The following are our primary conclusions and recommendations.

Conclusion 1

Because the condor is a long-lived species with a low reproductive rate, annual mortality rates of adults certainly must be <10%, and likely <5%, for populations to be self-sustaining. We conclude that condors are exposed to lead through ingestion of ammunition fragments frequently enough that, were the birds not treated, mortality rates would rise above those required for sustainability. The evidence on this point is overwhelming and includes radiographs of lead fragments in sick condors and the carcasses on which they feed, direct linkages of illnesses and deaths to feeding on contaminated carcasses, and direct measurements of blood levels that indicated acute lead exposure in an alarming number of condors. In our opinion, progress toward recovery is not sustainable under current conditions because reintroduction of more condors simply increases the costs required to keep free-living birds alive rather than improving the ability of the free-living population to maintain itself. We concur with nearly all of those involved in the condor program that condor recovery will not be possible until exposure to lead in their food sources is totally eliminated. Replacement of lead with nonlead ammunition needs to be achieved on an ecologically relevant scale and thereby positively affect survival rates over all or a significant portion of the condor's range if self-sustainability in the absence of human intervention is to be achieved. We are skeptical that, even with excellent compliance, voluntary programs promoting the use of nonlead ammunition can achieve this goal. Similarly, the efficacy of area-specific requirements for nonlead ammunition, such as the local regulations on the Tejon Ranch or even the state regulations in California, remains uncertain when some legal uses of lead ammunition are retained in those areas. The effectiveness of voluntary programs and regulations targeted toward particular types of ammunition in particular areas in eliminating exposure of condors to lead will soon become apparent. If such partial regulation proves insufficient, some will likely suggest a national ban on lead ammunition, similar to the ban on lead shot for waterfowl hunting.

Recommendation.—The USFWS is the agency responsible for achieving recovery, including resolving the lead issue. However, neither the USFWS nor any of the other federal recovery partners have the statutory authority to regulate the use of lead ammunition outside of their lands. Thus, their role might be to make the case for eliminating lead ammunition to those agencies that have such authority and to the public in the context of promoting condor recovery. Coordination among land-management and regulatory agencies could provide a means of addressing lead exposure of condors over a meaningful spatial scale. State wildlife agencies are critical because of their jurisdiction over hunting regulations. We recognize that replacement of lead ammunition with nonlead alternatives will take some time and that a gradual transition will impose fewer hardships on hunters, state wildlife agencies attempting to implement new regulations, and ammunition manufacturers and distributors. In the meantime, we recommend that portable X-ray equipment be provided to all field crews to facilitate lead monitoring until a successful transition to nonlead ammunition is accomplished.

Conclusion 2

A reduction in hunting, depredation permits, or other types of shooting would not promote condor recovery. Such actions might effectively reduce lead in the environment, but they would also result in a significant reduction in the condors' food supply. Humans are the dominant predators in most of the condor's range, and carcasses and gut piles that result from hunting and other types of shooting are important food sources for condors. It is essential that hunters continue to harvest deer, pigs, and other wildlife throughout the condor range using nonlead ammunition, so that a clean source of wild food is available to condors beyond food subsidies. It is unlikely that condors could be sustained in the wild after food subsidies are reduced without this source of food. The lead-ammunition issue goes well beyond condors, affecting other terrestrial scavengers and potentially even human health.

Recommendation.—Hunters should be made aware of the importance of hunting to condors in order to gain their support for conversion from lead to nonlead ammunition. Hunters should also be made aware of the potential adverse effects of lead exposure from spent ammunition on other species, including humans.

Conclusion 3

Condors are provided with supplemental food at fixed sites to reduce their exposure to lead while foraging on their own and to enable managers to trap, test, and treat the birds for lead exposure. Although its effectiveness in achieving the objective of reducing lead exposure is arguable, luring captive-reared condors to feeding stations has clearly been invaluable for flock management. However, use of food subsidies likely retards development of normal wide-ranging foraging behavior, alters time and energy budgets, and may adversely affect other natural behaviors. Because of the widespread use of supplemental feeding, it is not yet clear whether condors could subsist without subsidies in modern landscapes, and this could become the next impediment to recovery beyond lead.

Recommendation.—Supplemental feeding must continue until the lead problem is solved, but we endorse efforts to encourage the birds to forage more widely by use of multiple feeding sites at strategic locations. We recommend further research to ascertain the capacity of condors to become self-sufficient foragers within the landscapes where they are being released.

Conclusion 4

Many in the condor program believe that supplemental feeding promotes development of undesirable behavior involving attraction to humans and human-built structures because it provides birds with more time for activities other than foraging. This is debatable, whereas it is quite clear that captive-rearing and socialization techniques affect the expression of undesirable postrelease behavior. Considerable progress has been made in refining these techniques to produce desired behavior, such that undesirable behavior is no longer an impediment to reestablishment of wild condor populations. Adult mentors and interaction with free-living condors at release sites prior to release have been especially positive innovations. That parent-rearing is more effective than puppet-rearing in bringing about more desirable juvenile and subadult behavior is a widely held belief, but evidence on this point is equivocal and could be further researched.

Recommendation.—We recommend continued emphasis on parent-rearing while demand for birds for release remains relatively low, on the premise that reducing reliance on humans is desirable. However, because puppet-rearing increases the productivity of breeding pairs, development of that technique should continue in order to satisfy increased demand for birds for release once the lead problem is solved. The close integration between captive-breeding and field facilities in managing behavior should continue. We also recommend attempting to improve rearing and release techniques further by making them more closely resemble natural processes of rearing and socialization.

Conclusion 5

The most significant behavioral problem at present is adults feeding small items of trash to chicks in southern California, which has significantly reduced breeding success there but has not been a major issue elsewhere. We conclude that currently, given the microtrash problem, successful nesting in southern California is contingent upon intensive nest monitoring and corrective intervention as needed. The causes of this behavior are not yet understood. We suggest that the most promising avenues to pursue in reducing this problem are (1) eliminating mictrotrash at sites frequented by condors; (2) returning adults that exhibit such behavior to captivity for aversive training, as has been done for other undesirable behaviors; and (3) promoting more natural foraging patterns in nesting adults. Although recent data suggest that this last avenue may not reduce the frequency of feeding of microtrash by breeders with a tradition of such behavior, current foraging patterns still fall far short of those documented historically.

Recommendation.—Ongoing efforts to document and clean up microtrash sites need to be continued. We recommend that experiments with aversive training involving young birds prior to their release and adults that have exhibited feeding of microtrash in the wild be undertaken in captivity as soon as practicable. Additional experiments designed to increase parental foraging time and effort should be undertaken as soon as lead risks can be minimized and addressed. Additional research into the cause of such behavior should be conducted.

Conclusion 6

That condors readily feed on marine mammals in central California is a positive development, but it is critical to make sure that there are no deleterious issues associated with this food source. Of particular concern are the possibilities of eggshell thinning caused by exposure to DDE and long-term health effects associated with other toxicants, such as PCBs.

Recommendation.—We recommend vigorous and timely investigation of the possibility that contaminants acquired by feeding on marine mammals interfere with condor reproduction. Specialized protocols need to be developed for collection of eggs and tissues of condors in central California in order to assess and monitor contaminants. Testing of samples and analyses of results must be completed in a timely manner.

Conclusion 7

The condor program includes federal, state, and private partners that collectively expend more than $5 million annually. The major partners are the USFWS, National Park Service, Los Angeles Zoo, San Diego Wild Animal Park, Oregon Zoo, The Peregrine Fund, Ventana Wildlife Society, and Arizona Department of Game and Fish. These partners have developed an effective captive-breeding and release program that has produced impressive results and, through valiant effort, are maintaining growing populations in the wild. Recovery partners are self-organized into a diffuse network, the central elements of which are a large and diverse Recovery Team, a Field Working Group, and a USFWS condor recovery coordinator. In our opinion, the current structure of the program reflects past rather than current or future conditions. Specifically, within the USFWS, the program is housed in a field office at the refuge associated with the site of the first releases of captive-bred condors in southern California, and the condor recovery coordinator reports to a project leader within that office. This unnecessarily increases the chain of command concerning condors, and today, the refuges associated with this office represent only a small fraction of the range of the southern California birds, whereas the coordinator needs to monitor and lead a large program that spans two countries and three USFWS regions. The overly large Recovery Team has too many responsibilities and has come to resemble a stakeholder group in being composed primarily of active participants in the condor rearing, release, and monitoring programs. There is relatively little input from independent scientists outside the program that could bring new vision to the recovery effort.

Recommendation.—We recommend that the structure of the program be overhauled to better reflect current and future circumstances. The one possible reorganization we have outlined as an example includes establishment of a Condor Recovery Office that works with a Recovery Implementation Team comprising those organizations that rear, release, and monitor condors. The Recovery Implementation Team is modeled after the current Field Working Group, which has been very successful. In our suggested reorganization, the Condor Recovery Office would report to a USFWS deputy regional director or an assistant regional director, and basic programmatic coordination would be the duty of the condor recovery coordinator. The Condor Recovery Office would include an additional senior-level USFWS or USGS staff scientist designated as condor research and monitoring coordinator. The proposed structure also includes a Science Advisory Team, a small, scientifically focused advisory group composed largely of independent scientists outside of the condor program. Leaders of organizations that are involved in the condor recovery effort would not be part of the Scientific Advisory Team, but their insights into program management and involvement in recovery implementation would be critical to success. These participants and the condor recovery coordinator would form a Policy Advisory Team. Under our proposed structure, the existing Recovery Team would be disbanded and its functions assumed by the Scientific Advisory and Policy Advisory teams.

Conclusion 8

Field staffing at the southern California release sites operated by the USFWS is insufficient. Although monitoring requirements there exceed those at other release sites because of the microtrash problem, many of these responsibilities fall to a small number of temporary employees. Elsewhere they are performed by a larger number of permanent staff.

Recommendation.—We recommend that additional funding be obtained from either the USFWS or program partners to adequately staff the southern California release sites.

Conclusion 9

Adaptive management requires an effective and continuous integration of research, monitoring, and management. Although there is effective feedback between monitoring and management in the condor program, for example in managing behavior, an adaptive management framework that includes research is not evident. Research occurs, but it is not coordinated and integrated into program operations as are management and monitoring. In our opinion, this hinders the ability to improve understanding of condor biology and address critical research and management needs.

Recommendation.—The condor program should be reorganized to enable more effective use of research. In our suggested reorganization, this is accomplished by the addition of a research and monitoring coordinator and formation of a Science Advisory Team. We further recommend adoption of a formal adaptive management process that includes research in addressing important issues in the condor program.

Conclusion 10

Considerable concern about standardization, management, and ownership of data exists throughout the condor recovery program. That data management concerns exist is not surprising given the long history of the recovery program, its expansion to include multiple reintroduction sites, organizations, and individuals, and rapidly evolving technologies. We conclude, however, that these problems have reached the point where they seriously impede the effectiveness of the program. Furthermore, there is a great deal of information gathered on condors over the years that needs to be reviewed and organized.

Recommendation.—We recommend hiring a data manager–statistician to oversee the existing data and assist in future standardization of data collection, reporting, and storage. In our suggested reorganization, the data manager would work with the research and monitoring coordinator. Two important initial tasks for this position are to summarize extant data for critical review and evaluation and to develop standardized databases for record keeping for all program participants. We encourage program partners to make more data more available and more accessible, both to others in the program and to the public at large.

Conclusion 11

Currently, intensive monitoring of released birds is essential to reduce mortality caused by lead poisoning and to detect and manage undesirable behavior. Once the lead problem is resolved, continued monitoring will be needed to track population dynamics and key aspects of biology such as foraging patterns and dispersal.

Recommendation.—We recommend that demographic monitoring and evaluation of the health and behavior of free-living birds be continued. As the birds range more widely, it will be increasingly important to integrate monitoring into the adaptive management framework to learn about emerging issues such as foraging capabilities, connections between populations, and contaminant levels. We also recommend that intensive nest monitoring be continued in southern California until the behavior of feeding microtrash to chicks is extinguished.

Conclusion 12

As the number of free-living condors grows and the birds begin to range more widely, the geographic structure of the overall population becomes an important question. Currently, there is no plan for metapopulation development and conservation of the species at the range-wide level.

Recommendation.—We recommend that the utility of current and future release sites be assessed on a metapopulation scale such that the distribution of release sites is based on the desired geographic structure of a range-wide population. We cannot recommend releasing condors at new sites at this time because of the lead issue; however, once this issue is resolved, additional release sites should be considered. We recommend that a site in California's Sierra Nevada be considered as an alternative to Bitter Creek NWR or an additional site in southern California. It may be important to develop new release sites in the Pacific Northwest or elsewhere in order to increase asynchrony in environmental stochasticity among the component populations and thereby increase the stability of the overall metapopulation.

Conclusion 13

Condors have proved adaptable to captivity and do not have many health problems in the captive environment. Effective procedures to monitor and manage the health of the birds in captivity and in the wild have been developed, and veterinarians within the program have prepared written protocols. Although thorough protocols for processing dead condors exist, there are two gaps in information: (1) dead condors that have been seized by USFWS Law Enforcement as part of ongoing criminal investigations and (2) examination of unhatched eggs.

Recommendation.—We recommend continuing the existing veterinary coordinator position to facilitate information transfer on topics such as vaccines and procedures. Addition of a research and monitoring coordinator and data manager would make the veterinary coordinator more effective. We also recommend that the veterinary coordinator oversee development of general health protocols for the program. We recommend that the pathology coordinator develop a standardized protocol for the submission and evaluation of all unhatched eggs of wild or captive origin, and closer coordination between USFWS Law Enforcement and the pathologists at the San Diego Zoo, to ensure consistency of postmortem analyses.

Conclusion 14

Effective outreach programs are a necessity for condor recovery. Program partners are active in outreach, but they look to the USFWS for assistance and leadership at the national level. There is an urgent need for an extensive outreach effort to rally public support for replacement of lead ammunition.

Recommendation.—Leadership in outreach at the national and state levels is necessary, especially with regard to the lead issue. Other states could participate more actively in outreach and encourage hunting with nontoxic ammunition using programs similar to those in Arizona. Subsidies to hunters for nontoxic ammunition could be implemented in each state. As already noted, most Americans consider the recovery program a success, rather than a work in progress, and the public needs to be apprised of the reality of the situation so that the resources essential for recovery can be secured.

Conclusion 15

Our review of the condor program leaves us optimistic. We believe that recovery of the condor, once almost inconceivable, is possible. Perhaps that is the greatest achievement of the condor recovery program over the past 25 years: to demonstrate the possibility of recovery. But this potential cannot be realized until the lead problem is solved.

Recommendation.—Resolve the lead issue and move forward.

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For information on the Zoological Information Management System, go to www.isis.org/Pages/default.aspx. Information on avian influenza is available from the University of Minnesota Center for Infectious Disease Research and Policy website at www.cidrap.umn.edu/cidrap/content/influenza/avianflu/biofacts/avflu.html#_Hosts or from the Wildlife Disease Information Node of National Biological Information Infrastructure at wildlifedisease.nbii.gov/diseasehome.jsp?disease=Avian%20Influenza&pagemode=submit. Examples of outreach programs by partners in the condor recovery effort can be found at www.sandiegozoo.org/animalbytes/t-condor.html, www.azgfd.gov/w_c/california_condor_lead.shtml, and www.sandiegozoo.org/kids/craft_condor.html. Information and proceedings from The Peregrine Fund's 2008 conference on "Ingestion of Spent Lead Ammunition: Implications for Humans and Wildlife" is at www.peregrinefund.org/lead_conference/default.htm.

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