

Commentary on Released California Condors *Gymnogyps californianus* in Arizona

Tom J. Cade, Sophie A. H. Osborn, W. Grainger Hunt and
Christopher P. Woods

ABSTRACT

Critics of the California Condor recovery program have advocated the removal of all released condors from the wild until problems they consider insurmountable by currently used methods are replaced by new procedures. We examine the criticisms on which this conclusion is based and argue that it is not supported by results of the release project in Arizona.

Between 1996 and 2002, 54 immature California Condors were released in northern Arizona, and 20 died. The main cause of death was lead poisoning, but predation by eagles and coyotes was also high. Other condors might have died of lead poisoning without chelation treatments to remove lead from their systems. Under current conditions continued hands-on management and chelation will be necessary. In the absence of lead-induced fatalities adult condor mortality should drop below 5% per year, allowing for a self-sustaining population. About 20% of released condors showed little initial fear of humans, and some even made physical contact with people. Methods to correct inappropriate behaviour included: pre-release electrical shocking of birds when they landed on mock utility poles; hazing birds when they landed near people or on manmade structures, and detention in confinement followed by re-release. Case histories of condors show that over time nearly all birds decreased close contact with humans and began to act more like wild condors, especially when they became reproductively active. It is not yet clear to what extent the observed changes resulted from management or from the slow maturation of intrinsic condor behaviour. Differences between puppet-reared and parent-reared condors in behaviour, survival, and development of reproductive competence were ultimately insignificant.

INTRODUCTION

“Time and time again, the view of condors from the armchair proved wrong when confronted with data...” (Beissinger 2001, p. 1197).

Intensive “hands-on” management of the California Condor *Gymnogyps californianus* began in the field in 1980 and was subsequently extended to the breeding of condors in captivity and the release of their progeny back to nature beginning in 1992 (see Kiff 2000 for a succinct and impartial summary through 1998). Currently condors are propagated at three facilities: the San Diego Wild Animal Park, the Los Angeles Zoo, and the World Center for Birds of Prey in Boise, Idaho. There are four release and reintroduction projects, two in California, one in Baja California, Mexico, and one in northern Arizona. By the end of 2002, about 157 condors had been released, and there had been nine breeding attempts in the wild.

Some scientists view the demographic and behavioural characteristics of released California Condors as so appalling that they advocate the removal of all condors from the wild until the problems they consider insurmountable by current practices can be overcome with new procedures they espouse (Meretsky *et al.* 2000, 2001; Snyder & Snyder 2000; Beissinger 2001, 2002). Their main complaints are: 1) Fatalities among the released condors are too frequent to allow for the establishment of a self-sustaining population in nature. 2) Poisoning by lead from spent ammunition in carcasses is the pervasive and overriding cause of death among condors, and until this mortality factor is eliminated, all efforts to re-establish free-ranging condors are doomed to failure. 3) The human-focused behaviour of some released condors is unacceptable, uncorrectable, and potentially dangerous both to condors and to human beings and their property, and this “bad” behaviour has continued to be expressed by breeding-age condors (Beissinger 2002). 4) Puppet-reared condors more frequently show unacceptable behaviour than parent-reared birds, and puppet-reared birds in mixed flocks corrupt the acceptable behaviour of parent-reared birds. 5) The current groups of managers who are working to restore the condor are unwilling to change their ways, because they have “vested interests” in continuing their programs as long as possible, a situation that leads “repeatedly to poor decisions” (Beissinger 2002). 6) The several condor projects also suffer from a lack of scientific supervision and method, resulting in uninformed, inefficient and unjustified procedures.

These critics recommend the following actions to correct what they see as a failed effort to restore wild condor populations by the release of birds produced in captivity: 1) There should be a comprehensive, independent “peer review” by a panel of experts appointed by some authority such as the U. S. Fish and Wildlife Service or the National Academy of Sciences to examine the current condor recovery program, identify its failings, and then to prescribe a list of preferred methodologies that will produce better results (Meretsky *et al.* 2000; Snyder & Snyder 2000). 2) Foremost among these prescriptions would be a campaign to ban the use of lead ammunition in the range of the condor (currently California, Arizona, Utah, and Baja California). Ideally, the use of lead bullets and shot would be phased out on a continent-wide scale. 3) Until such time as lead-contaminated carcasses can be eliminated from the

environment, if condors are released they should be fed on lead-free food as much as possible ("food subsidy") and encouraged not to forage widely for natural carcasses. 4) All puppet-reared birds and human-focused individuals should be removed permanently from the wild and placed in captive breeding projects, and only parent-reared birds should be released. 5) To encourage wildness and further improve the quality of young produced in captivity, pairs of captive condors should be housed in large, outdoor flight pens in the natural areas where their young are to be established.

In the following sections we examine some of these criticisms from the perspective of The Peregrine Fund's involvement in the captive breeding of California Condors and their release into the wilds of northern Arizona and southern Utah, refuting some and qualifying others. Occasional comparisons are also made with the results of other release projects in California.

STAFF AND INSTITUTIONAL QUALIFICATIONS

The Peregrine Fund has been engaged in breeding birds of prey in captivity and using produced birds to establish self-sustaining populations in nature for more than 30 years. We have successfully established breeding populations of Peregrine Falcons *Falco peregrinus* in the eastern and western United States, Aplomado Falcons *Falco femoralis* in south Texas, and helped substantially with the establishment of Bald Eagles *Haliaeetus leucocephalus* in New York State, and reintroduction of the Mauritius Kestrel *Falco punctatus* on its island home in the Indian Ocean. No other organization has more experience or been more successful in such endeavors (Cade 2000), and the successful methods we employed for re-establishment of the Peregrine Falcon have strongly influenced those adopted for the condor program.

Although the main functions of The Peregrine Fund are in the applied areas of conservation and wildlife management, we have always incorporated a strong element of scientific research and overview in our projects. Our condor project is no exception. While none of our condor field workers has a Ph. D. degree, several have Master's degrees, and all have had experience in the scientific collection of information. These field workers and their efforts also receive regular scientific review by three Ph.D. level staff members of The Peregrine Fund, as well as by frequent outside scientific consultants brought in to help with specific problems.

Meretsky *et al.* (2000) implicitly recognized the scientific merit of our field work by using unpublished data of The Peregrine Fund in their own, peer-reviewed publication, but these scientists have never contacted any member of The Peregrine Fund directly to learn about our work. Since 2001 we have also employed a full time, senior research biologist to supervise and coordinate study design and data collection for both the condor and the Aplomado Falcon, and the Zoological Society of San Diego has a full time behavioural scientist to support condor reintroduction, contrary to the latest armchair pronouncement that the condor program still "lacks a research component" (Beissinger 2002).

CAUSES OF DEATH AND SURVIVAL RATES OF RELEASED CONDORS

Since December of 1996 The Peregrine Fund has released 54 juvenile and subadult condors for varying periods of time, and 20 (37.0%) have died from a variety of causes (Table 1). In addition, one bird was returned to captivity for breeding. At the end of 2002, the free-flying population of 33 birds included six 7-year-olds, four 6-year-olds, two 5-year-olds, three 4-year-olds, five 3-year-olds, five 2-year-olds, and eight 1-year-olds, with a sex ratio of 1.2:1 (18 males to 15 females). One pair in 2001 and two pairs in 2002 attempted to nest but failed before or soon after hatching their eggs.

Table 1. Mortality of California Condors in Arizona

Causes of death	Number
Illegal shooting	3
Eagle predation	3
Coyote predation	3
Lead poisoning	4
Possible lead poisoning	1
Unknown	3
Power line collision	1
Septicemia*	1
Starvation	1
Total	20

* Resulting from aspiration and airsacculitis.

We used the Trent & Rongstad (1974) method to calculate annual survival for three groupings of released condors: first year following release, second year following release, and all subsequent years following release (C. Woods *et al.* in prep.). Condors were first released at ages ranging from >six to >24 months. We considered survival based on 1) the number of days that birds have been in the wild, and 2) the total number of days since they were initially released (i.e., including days held in captivity following initial release). As expected, mortality was highest (> 25%) during the first year after release but rapidly improved as birds aged and gained experience, so that annual survival for birds in the wild for more than two years was above 93% (Table 2). Thus, overall mortality of released condors in Arizona does not appear to be "increasing rapidly" as predicted by Meretsky *et al.* (2000) and repeated by Snyder & Schmitt (2002).

It should be noted that these figures do not represent true survival values under normal wild conditions with little or no management, since all of the birds were taken into captivity for various periods of time. Moreover, many of the older birds underwent chelation therapy for high blood levels of lead (>50 µg/dl) at least once, and some of those birds might have died without such treatment. If the five likely deaths from lead poisoning had not occurred, then second year survival would have been 86.5 to 88.3%, and there would have been no deaths in the after-second-year birds for the past four years. The reduced mortality of the older condors does indicate that an encouraging level of survival can be achieved under a carefully managed regime with birds free-flying most of the time.

Table 2. Survival estimates for California Condors in Arizona.

Years since release	Population variables	Data limited to days in wild	Data for all days since release
<1	Number of birds	54	54
	Deaths	12	12
	Exposure days	14,321	14,996
	Annual survival	73.6%	74.7%
1 to 2	Number of birds	32	34
	Deaths	5	5
	Exposure days	10,108	11,709
	Annual survival	83.5%	85.6%
>2	Number of birds	20	29
	Deaths	3	3
	Exposure days	15,886	21,027
	Annual survival	93.3%	94.9%

As Mertz (1971) and Verner (1978) first emphasized, the slow maturation and low reproductive rates of condors (about 0.3 young/breeding female/year) require high adult survival rates for population stability. Verner (1978) and Meretsky *et al.* (2000) modelled population parameters for condors, and both generally concluded that annual survival for adults and subadults must exceed 90% in a stable condor population (Verner: 91% adult and 89% subadult; Meretsky *et al.*: 90.1% for both adult and subadult), and that adult survival should approach 95% annually to compensate for subadult survival of about 85%. First-year survival in the Arizona population remains about 10% lower than those models require, but second-year survival is comparable, and after-second-year survival is as high or higher than their models require for stability.

The Arizona population still consists of young birds by condor standards, as they first breed at 6 to 7 years and live for at least 45 years (Snyder & Schmitt 2002). Survival so far indicates that breeding age condors should be able to replace themselves if they can reproduce at the historically known rate for wild condors in California, and as long as hands-on management continues, including periodic monitoring of blood lead levels and chelation treatment for lead exposure. In fact, if the current observed mortality continues to hold in the Arizona population at 25% for the first year, 15% for the second, and 5% thereafter, the population will have a slightly positive growth rate, contrary to Snyder and Schmitt (2002) who stated without reference to data that "Overall mortality rates of the releases in Arizona and s. California now closely approximate the unsustainable mortality rates of the historic wild population of the 1980s (about 24% annual mortality) and have been increasing rapidly...." Moreover, later generations of naturally produced young can be expected to have higher juvenile and subadult survival rates (e.g., Griffon Vulture [*Gyps fulvus*], Sarrazin *et al.* 1994), and for that reason population viability estimates based on the performance of released birds before they have become fully established and have produced a new generation in the wild (Meretsky *et al.* 2000, 2001). are rather meaningless (Beres & Starfield 2001).

THE LEAD PROBLEM

During studies in the 1980s on wild condors in California, Noel Snyder came to the conclusion that lead poisoning from spent ammunition was the primary cause of death in condors. In all 15 birds were known to have died between 1982 and 1986, but only four were necropsied, and three contained lead residues high enough to indicate lethal poisoning (Snyder & Snyder 2000). Based on these limited data, he and others concluded that reintroduction cannot be expected to result in viable populations of condors until sources of lead contamination in the environment are effectively reduced (Meretsky *et al.* 2000, 2001; Snyder & Snyder 2000; Beissinger 2001, 2002, Snyder & Schmitt 2002).

In Arizona, we did not encounter problems with lead until the fourth year of releases. Two lead poisoning incidents occurred in 2000. The first lead-associated fatality was found on 3 March along the Colorado River in the Grand Canyon. All remaining condors were trapped and tested for lead in late April, and one had an acute blood level of 109 µg/dl, which was reduced to background level by chelation before the bird was re-released. In the second incident later in the year, three birds died under suspicious circumstances, and 10 condors had elevated blood levels of lead greater than 50 µg/dl and underwent chelation in captivity before return to the wild. All of these other fatalities and individuals with elevated lead levels were found during a span of 20 days in June, suggesting that most of them had been contaminated from a single source. This conclusion is further supported by radio telemetry tracking that showed the birds had frequented a location on the south rim of the canyon west of the national park boundary, on private land where investigators were not allowed, and by the fact that five of these condors had shotgun pellets in their gastro-intestinal tracts, an unusual source of lead contamination for condors, made even more anomalous by the co-occurrence of two or more sizes of lead shot in the same bird.

Only two of those three deaths can be ascribed with confidence specifically to lead. The carcass of the third condor was unrecoverable, but owing to the time of its death, the bird may well have succumbed to lead poisoning.

The condors have been periodically monitored for lead since then, and if blood levels are above 50 µg/dl the birds are held for chelation. This procedure is lengthy and stressful to the birds, involving capture and manual injection of calcium versenate or CaEDTA twice daily until blood concentrations drop to background levels (about 10 µg/dl in Arizona, although Fry [2003] gives 20 µg/dl for condors in California). The CaEDTA binds to lead and then is excreted from the body. The long-term side effects of this treatment are unknown.

Only one condor required chelation between August 2000 and August 2002; but in August 2002 a condor was found dead in southern Utah with lead fragments in its digestive tract. In November 2002 11 birds were treated with blood levels of >65 µg/dl, and in this period many condors spent time on the Kaibab Plateau during the hunting season and were seen at deer carcasses. In December 2002 another condor had to be treated for a lead fragment in its gut. In summary, over the six-year period, four condors were clinically diagnosed

as lead fatalities, one or two others may have succumbed to lead, and individual condors had to be treated for high lead levels in blood a total of 24 times.

There is no question that lead poisoning is a serious and unnatural cause of both morbidity and fatality in released California Condors. At the same time, it needs to be emphasized that the assignment of a cause of death to a bird found in the wild is not always easy or precise and depends on how much information can be obtained from the carcass and the circumstances associated with it. Finding a dead condor with lead fragments in its gut is not conclusive evidence of death by lead poisoning, but in the absence of any other signs of death, it can be used as strong presumptive evidence.

Blood levels of lead in condors are equally difficult to interpret, because there is no clear understanding about how they relate to death from lead toxicity or, for that matter, how lead causes death in condors. Presumably birds found dead in good body condition die quickly of acute toxicity, while emaciated birds die slowly of starvation from lead-induced paralysis of the gastro-intestinal tract. Nor do we have information about how long-term, chronic exposure to sublethal levels of lead may affect vision, neuromuscular coordination, cardiac function, reproductive processes, or digestive processes, to name a few of the physiological functions known to be affected by lead in other organisms including human beings. Veterinarians have arbitrarily established 60 µg/dl as the blood level at which birds should undergo chelation as a precaution, but condors with acute blood levels of >100 µg/dl have been trapped in the field with no evident signs of morbidity (see Fry 2003 for discussion of these issues).

We know that blood levels of lead rise and fall in condors without treatment and mainly reflect recent exposure to lead, as the half time for elimination of lead from condor blood is only 13-14 days; how blood levels relate to lead levels in other tissues and organs, or to total body burden of lead, is poorly known (Fry 2003). Until these relationships are better understood, it should not be assumed that all birds with elevated lead levels will die and should be counted as fatalities in calculations of population dynamics, as others have done (Meretsky *et al.* 2000; Beissinger 2002).

BEHAVIOUR OF RELEASED CONDORS

Condors have been released at two locations in northern Arizona, but the site at Vermilion Cliffs, a few miles north and west of the Colorado River and Grand Canyon, is where most birds have been released and is the only location continually operated as a release and feeding station. When first turned out the condors remain close to the release site, as they practice flying, develop strength, and learn to feed on calf carcasses laid out for them on top of the cliff. They slowly extend their movements farther away and develop habitual routes to locations for perching, roosting, loafing, and searching for food. The canyonlands of northern Arizona and southern Utah comprise an immense region of many tens of thousands of square kilometres of suitable-looking habitat. While some condors have ranged hundreds of kilometres from the release site, they eventually return to it.

Two frequently used areas are the South Rim of Grand Canyon National Park where the main park headquarters and tourist facilities are located and at the Navajo Bridge across the Colorado River a few miles below the Glen Canyon Dam. The condors come into contact with people at these locations, and also at the North Rim of Grand Canyon, the Pipe Spring National Monument, Zion and Bryce National Parks in Utah, river camps along the Colorado, and hunting camps on the Kaibab Plateau.

Condors are extremely inquisitive and exploratory in their behaviour, constantly examining even minute details of their environment. Any object that looks different or conspicuous is immediately eyed and nibbled at or picked up in the beak, and some are swallowed. Some of the young condors are also quite unwary of human beings and will approach them closely to pull at shoestrings and even allow themselves to be touched. This combination of inquisitiveness and approachability has caused some condors to come into conflicting situations with humans and human property, requiring intervention and capture of persistent offenders.

Although we expected that this undesirable or "bad" behaviour would disappear as the birds matured, it was soon obvious that some special management procedures would be needed to speed modification of behaviour toward acceptable norms and to prevent possible harm to the birds and to people and their property. We wanted the birds to stay away from people and manmade structures as much as possible, even though historically condors were not particularly wary of humans. J. K. Townsend, for example, noted condors foraging for fish offal around Indian villages along the Columbia River in the 1830s (Townsend & Jobanek 1999), and there are other examples of "unwariness" toward humans (Snyder 1988; Snyder & Snyder 2000).

The behaviour of released condors has been modified in a variety of ways. Collisions and electrocutions were the leading cause of death in early California releases, and a condor from the first release in Arizona also died after colliding with power lines. As a result, all release projects instituted negative conditioning of condors in pre-release pens with electrified, mock power poles, which gave an electric shock whenever a bird attempted to land on the structure. Such conditioning worked quickly in captivity, and since introducing this form of aversion training in Arizona, no condor has died or been injured as the result of a power line collision or electrocution. After release, condors that landed near people or on buildings were hazed and frightened away. Lastly, we removed particularly unwary and assertive birds from the field and placed them in detention for periods ranging from a few days to more than two years before re-releasing them. In California such "problem" birds were at first returned permanently to captivity, but we chose to verify whether or not their behaviour might change with additional time to mature.

In order to determine whether or not there has been change in the behaviour of individual birds over time, we prepared detailed case history studies of each bird based on recorded field data (S. Osborn *et al.* in prep.). Three categories of behaviour were recognized: Type I and Type II behaviour were considered to be acceptable, normal exploratory and play activities that may be adaptive,

while Type III behaviour represented unacceptable, aberrant activity. Type I behaviour is characterized by birds landing no closer than 15 metres from people, by investigative fly-bys no closer than 15 metres, occasional investigation of manmade objects, perching on manmade structures that resemble natural objects or provide safe vantage points, and not repeating undesirable behaviour after being hazed once or twice. Type II behaviour is an intermediate category that represents tolerable though not ideal behaviour toward humans. It is characterized by birds landing or flying closer than 15 metres to humans, but maintaining an "individual distance" when approaching or being approached by humans and circumventing humans when investigating their belongings, allowing close human approach only when a clear escape route is present, and fleeing when hazed. Type III behaviour is dysgenic and consists of birds allowing close human approach when no escape route is present (no fear of being boxed in), seeking out and initiating contact with humans, allowing touching and handling (including capture), not responding to hazing, and showing no fear of humans.

Eleven of the 54 released birds showed Type III behaviour initially. Their occurrence in the general population has ranged between one and three individuals per year. Case histories of individual birds revealed that, after hazing and detentions ranging from seven to 24 months, six of the Type III birds, including the two worst offenders, changed their behaviour to Type I or infrequently Type II, one was shot after seven months of Type I behaviour, one was returned permanently to captivity for breeding, and three are recent cases for which an outcome cannot yet be determined. One of 12 breeding-age condors was a Type III bird, but it currently exhibits Type I and Type II behaviour and has successfully engaged in courtship and nesting.

The frequency of Type I birds in the Arizona population has increased from two of 11 condors (18%) in 1998 to 19 of 34 (56%) in 2002. This obvious change has resulted in part from the change in behaviour of Type II and III birds and in part from the higher percentage of recently released condors that entered the population as Type I birds in the last two to three years. This improvement may be related to mentoring by older condors placed in pre-release pens with the naïve birds, and especially to the social conditioning and survival training that the free-flying adult condors now provide to new recruits into the population. It is still unclear to what extent our management procedures have influenced this progressive improvement in the behaviour of the condors and to what degree it may result from the slow maturation of intrinsic behaviour in these long-lived birds, but it is clear that the prediction that "bad" behaviour would persist and increase in frequency in the population was at best premature (see Meretsky *et al.* 2000, 2001).

PUPPET-REARED VERSUS PARENT-REARED CONDORS

A sharp, categorical distinction between the "good" (more or less normal) behaviour of parent-reared condors and the "bad" (abnormally tame and assertive) behaviour of puppet-reared ones has become entrenched in recent publications on condors (Meretsky *et al.* 2000, 2001; Snyder & Snyder 2000; Beysinger 2001, 2002; Snyder & Schmidt 2002). Although no data were ever

presented in any of these accounts, this idea apparently arose from impressions of second-hand information about the first two groups of condors released by the Ventana Wilderness Society in the Big Sur region of central California. In the first release, four puppet-reared condors had to be trapped and returned permanently to captivity because of their frequent close interactions with humans and their property and the birds' total lack of intraspecific socialization. These condors had been reared in isolation from each other, and from other condors, at a "naturalistic" facility in Hopper Canyon during a pre-release period; they arrived at Ventana with dysfunctional, anti-social behaviour already ingrained, perhaps as a result of their treatment at Hopper Canyon (K. Sorenson, pers. comm.). Five parent-reared birds released subsequently were said to have shown virtually no inclination to interact with humans, although details of their actual behaviour are lacking from published accounts. All five were still alive at the end of 2002 (R. Jurek, Condor Recovery Team records).

In Arizona 16 of the 54 released condors were parent-reared (Table 3). Although no parent-reared condors have shown Type III behaviour in the wild, they have not survived better than puppet-reared ones: seven deaths in six years or 43.8% mortality for the former ($n = 16$) and 13 deaths or 34.2% for the latter ($n = 38$). Among the nesting condors in Arizona (as of 2003), two were parent-reared and four puppet-reared; and also among other birds showing pre-breeding courtship and mating, two were parent-reared and four puppet-reared. In California all but one of eight breeders have been puppet-reared (R. Jurek, Condor Recovery Team records). The exception was a parent-reared male that showed extreme Type III behaviour initially but, after a year in captivity, changed to Type I behaviour and began breeding in 2003 (G. Austin, pers. comm.).

Table 3. Puppet-reared and Parent-reared Condors Released in Arizona, 1996-2002.

	Puppet-reared	Parent-reared
Total number	38	16
Fatalities, all causes	13	7
% Annual survival after 2 yrs	93.4-95.3	93.1-93.9
Breeding birds	4	2
Type III behavior	11	0

Although parent-reared condors appear to be more wary of people than puppet-reared birds when first released, the puppet-reared individuals are able to catch up within a year or two, and as adults they behave and survive at least as well as parent-reared birds. The idea that "bad" behaving juvenile condors permanently corrupt the behaviour of more wary condors is not supported by the overall population trend toward an increasing percentage of Type I birds with time; if anything, the converse is true. Releasing at an older age those condors that appear particularly unwary or human-focused and the increased presence of "mentoring" subadult and adult condors in the population appear to have reduced the incidence of unacceptable behaviour in newly released, naïve young condors.

It should also be emphasized that variables other than parent- or puppet-rearing can influence the behaviour of birds released to the wild and that the methods of artificial rearing have changed as breeders learned more about the behaviour of young condors. For example, in some of the first rearing attempts in California, young condors were put together in small groups at three to four months of age and reared together from that point on. This procedure promoted abnormal socialization and highly assertive and exploratory “gang” behaviour when the birds were released (M. J. Wallace pers. comm.). Also, “sibling imprinting” and reproductive incompatibility between unrelated condors appear to have resulted when condors were paired at too early an age in captivity (Hartt *et al.* 1994). The Hopper Canyon experiment mentioned previously went to the opposite extreme, producing abnormally behaved birds that would not associate with one another (although one later re-released in Arizona, no. 134, is now a Type I bird at seven years of age).

Now most puppet-reared birds are raised in isolation from other young until they are fledged, as in nature; in addition to being fed by a puppet, the young also have close visual contact with a subadult or adult condor housed in an adjacent cage. Prior to release most young are also kept in holding pens with one or more older condors until a social organization and hierarchy have been established. These youngsters are usually more wary and less focused on human beings. Other variables influencing the behaviour of released condors include the extent to which they were exposed to humans prior to release and whether or not those experiences were positive or negative, and, perhaps most importantly, the age at which they are released.

So far, 14 of 26 breeding age condors have paired up and become breeders (California and Arizona combined as of spring 2003): all five 9-year-olds, six of seven 8-year-olds, two of four 7-year-olds (one died in 2002), and one of nine 6-year-olds (first laid at five years). Three (33.3%) of nine parent-reared adults alive in 2003 have bred one or more times, while 10 (62.5%) of 16 puppet-reared birds have done so (R. Jurek, Condor Recovery Team records). Despite whatever behavioural handicaps they suffer from artificial rearing, it is remarkable to observe these birds functioning like wild condors as they mature into full adulthood. The nest sites they have chosen are historical locations in California and typical condor sites in Arizona; and they search for food, observing vultures, ravens, and eagles, and find naturally occurring carcasses with apparent ease while still remaining faithful to their original release site as a permanent feeding station.

CONCLUSION

We agree that lead residues are a major threat to California Condors, as they are to many other animals, including human beings (see resolution of The Cooper Ornithological Society, Condor 105:171, 2003). For condors and other scavengers lead fragments and particles in animal carcasses appear to be the main source of contact. Each case of poisoning for which we have established the source of lead has been shooting-related, involving the presence of lead shot or bullet fragments, although lead fishing tackle and other sources, including mining wastes and atmospheric pollutants, could also be involved

(Fry 2003). There is every reason to believe that if lead ammunition were replaced by non-toxic substitutes, the condors in Arizona could easily maintain an adult survival rate exceeding 95% per year and could thereby become a self-sustaining, viable population with considerable potential for growth.

Under current conditions sustainability appears to be achievable only by continued, intrusive monitoring of the whole population for lead poisoning and chelation treatment of individuals showing high blood levels of lead. So far it has proved to be operationally feasible to re-trap all the birds whenever examination and treatment are required, at an approximate cost of \$20,000 in 2002 (C. Parish pers. comm.), but the long-term consequences to the birds of repeated handling are questionable, as are the effects of chronic, sublethal levels of lead in their bodies.

The degree and consequence of lead exposure to condors in northern Arizona and southern Utah were unknown when the release project started in 1996. There was no *a priori* basis for thinking that lead would be a problem or that there would be a need for the public to adopt the use of non-toxic ammunition to protect the welfare of wildlife in the region. The Peregrine Fund opted to determine what a closely monitored population of released condors would reveal and to use adaptive management when needed.

The landscape was clearly rich for condors, both physically and biotically, and there was reasonable expectation that the population would sustain itself mainly on uncontaminated carcasses, both artificially supplied and naturally occurring. Even with the anticipated occurrence of some lead contamination, it was reasonable to assume that the low incidence of other harmful agents might collectively hold mortality to a level at which the condor population could grow without continual augmentation.

These expectations appeared justified until the autumn of 2002, when 11 condors showed lead levels of $>65 \mu\text{g}/\text{dl}$ in their blood, and two others, including a fatality, had lead fragments in their stomachs. Although the extent to which feeding on hunter-killed deer resulted in lead ingestion and whether this exposure would have caused additional fatalities without treatment are unknown, this series of poisonings and the one in the summer of 2000, combined with persistent lead levels in blood above $20 \mu\text{g}/\text{dl}$ in many individuals, strongly indicate that a shift to the use of non-toxic ammunition would greatly favour the long-term success of this population, a conclusion that is only now factually tenable. Ironically, the release projects that Noel Snyder has criticized so persistently have provided the bulk of data that support his conclusion about the significance of lead poisoning.

Adaptive management has to proceed in steps, each based on sound information. Although we are limited by what can be done to control illegal shooting, natural predation, and collisions, lead contamination of the environment from spent ammunition is the one, major mortality factor affecting condors that could be reduced to insignificance. A solution exists but has not yet been adopted. The U. S. military establishment has recognized the serious nature of environmental pollution from spent lead ammunition and has supported vigorous research at the Oak Ridge National Laboratory (DOE) to produce non-toxic alternatives now in use (Mikko 1999), and the Department

of Defense is said to be on schedule for a complete conversion to non-toxic small arms ammunition by 2005. Private companies have also produced good, non-toxic substitutes for lead ammunition with superior ballistics; and some are being commercially manufactured (McMurphy 2003), but they are not yet popular or widely available. If hunters and shooters, firearms and ammunition manufacturers, and their advocacy groups, and state and federal wildlife agencies could somehow become imbued with the same sense of urgency that has motivated the U. S. military to adopt non-lead ammunition, it would be a great day for condors and wildlife generally.

Stark differences in behaviour between parent- and puppet-reared condors do not exist, and condor workers in the four current reintroduction projects agree that both types of young are suitable for release, although parent-reared birds do have some initial advantages in terms of behaviour. The proposal to remove all puppet-reared birds and behaviourally difficult individuals permanently from the wild was based on the incorrect assumption that their behaviour was unchangeable and contagious. Following a regime of conditioning procedures and, especially, detentions in captivity and re-release, even the most recalcitrant individuals adopted more normal and acceptable behaviour in relation to human beings.

How removal from the wild and detention in captivity result in improved behaviour on re-release is still unclear. It may in some way refocus the bird's attention away from its former activities associated with humans, or it may be a matter of behavioural maturation with motivations shifting more toward sexual and other intraspecific activities with increasing age. We suspect, however, that maturation is at least a part of the answer, and there is some indication that the release of condors around one and a half years of age may be more successful than releasing younger birds, a perception that has gained credence among the California projects as well.

The idea that breeding condors should be caged under natural conditions in the areas where their young are to be released and established, patterned after the successful reintroduction project for the Griffon Vulture in France (Sarrazin *et al* 1994), is attractive. It would, however, require tremendous labour and cost per bird released, and it would take an indeterminable amount of time to establish a self-sustaining population by this procedure. In a situation where time and cost are no concern, it might be interesting to try.

The reintroduction of a species with delayed sexual maturity and a low rate of reproduction is a slow process. Patience is a virtue in any recovery effort, but every successful reintroduction (e.g., Peregrine Falcon, Bald Eagle, Mauritius Kestrel, Aplomado Falcon) has had impatient critics who expounded on reasons why the project would fail. Successful projects typically require 10-15 years or more, even for species that mature sexually in 2-3 years (Cade 2000). In the case of the California Condor we should expect a long period for recovery.

The minimum requirement of the condor recovery plan calls for two separate wild populations each with 15 breeding pairs and 150 individuals, although the latter is demographically unrealistic, before downlisting to the threatened category. If a feasible cohort of 10 young birds were released each year and assuming 75% survival the first year, 85% the second, and 95% after

second year to breeding age at seven years, it would take at least 13 years and the release of 70 condors to obtain 15 pairs, assuming a sex ratio of 1:1. If, as so far indicated, condors are like albatrosses (Fisher 1976) and typically fail in their first reproductive attempts, then the effective age of first breeding may be more like nine to 10 years, in which case it would take considerably longer to reach a goal of 15 productive pairs.

Viewed from that perspective, the slightly more than six-year-old Arizona project is on schedule. An increasing number of adults now constitute a sizeable contingent of breeders and pre-breeders, at least 12 birds in 2003, and breeding activities, none yet successful, have been under way for three years. If we can continue monitoring the birds for lead and chelating those individuals that require treatment, and barring some reproductive malfunction associated with chronic lead exposure or other human-caused problems, we should be able to maintain a self-reproducing population of condors in Arizona. The population will not be self-sustaining, however, until lead contamination of the condors' food decreases to safe levels.

Added Note: In 2003, three pairs laid eggs, and one of them fledged a chick in early November. Only one fatality occurred, an after-second year bird; but even so the annual survival rate of this age group increased to >95%, averaged over a five year period.

ACKNOWLEDGEMENTS

The Peregrine Fund manages the condor project in Arizona in co-operation with the U. S. Fish and Wildlife Service, Bureau of Land Management, National Park Service, Arizona Game and Fish Department, the Los Angeles Zoo, the Zoological Society of San Diego, and the Ventana Wilderness Society. We thank Mark Vekasy and Shawn Farry for conducting and supervising field work in the early years; Shawn also devised a preliminary categorization of condor behaviour on which our system is based. Bill Heinrich and Chris Parish of The Peregrine Fund provided important information as well as overview of the project. The Superintendent of Grand Canyon National Park, Joseph Alston, and his staff provided important care and monitoring of the condors in the park; Chad Olson has worked closely with The Peregrine Fund in that regard. Greg Austin, Lloyd Kiff, Kelly Sorenson and Mike Wallace shared information and insights about the condor recovery program in California. G. Austin, B. Burnham, B. Heinrich, L. Kiff, M. Mace, K. Ralls, K. Sorensen, M. Wallace, and two anonymous reviewers provided helpful comments on an earlier draft of this paper.

The work in Arizona is supported by federal contracts as well as by numerous private sources, which are listed in The Peregrine Fund's Annual Report for 2002.

REFERENCES

- BEISSINGER, S. R. 2001. The California Condor: A flagship adrift. *Conservation Biology* 13: 1197- 1199.
- BEISSINGER, S. R. 2002. Unresolved problems in the condor recovery program: Response to Risebrough. *Conservation Biology* 16:1158-1159.
- BERES, D. L. & A. M. STARFIELD 2001. "Demography of the California Condor" and management decisions based on modeling: a reply to Meretsky et al. *Conservation Biology* 15:1445-1448.

- CADE, T. J. 2000.** Progress in the translocation of diurnal raptors. Pp. 342-372 in R. D. Chancellor & B.-U. Meyburg (Eds.), *Raptors at Risk*. WWGBP/Hancock House, Surrey, British Columbia.
- FISHER, H. I. 1976.** Some dynamics of a breeding colony of Laysan Albatrosses. *Wilson Bulletin* 88:121-142.
- FRY, D. M. 2003.** Assessment of lead contamination sources exposing California Condors. Final Report: California Department of Fish and Game, Habitat Conservation Branch, 1416 Ninth Street, Sacramento, CA., 85pp.
- HARTT, E., W. N. C. HARVEY, A. J. LEETE & K. PRESTON 1994.** Effects of age at pairing on reproduction in captive California Condors. *Zoo Biology* 13:3-11.
- KIFF, L. 2000.** The California Condor Programme. Pp. 307-319 in Chancellor R. D. & B.U. Meyburg, (Eds.), *Raptors at Risk*. WWGBP/Hancock House, Surrey, British Columbia.
- McMURCHY, I. 2003.** Barnes XLC bullets. American Hunter, National Rifle Association, January 2003, pp. 70-71.
- MERETSKY, V. J., N. F. R. SNYDER, S. R. BEISSINGER, D. A. CLENDENEN & J. W. WILEY 2000.** Demography of the California Condor: Implications for reestablishment. *Conservation Biology* 14:957-967.
- MERETSKY, V. J., N. F. R. SNYDER, S. R. BEISSINGER, D. A. CLENDENEN & J. W. WILEY 2001.** Quantity versus quality in California Condor reintroduction: Reply to Beres and Starfield. *Conservation Biology* 15:1449-1451.
- MERTZ, D. B. 1971.** The mathematical demography of the California Condor population. *American Naturalist* 105:437-453.
- MIKKO, D. 1999.** U. S. military "green bullets." *Association of Firearms and Tool Mark Examiners Journal* 31(4):493.
- SARRAZIN, F., C. BAGNOLINI, J. I. PENNA, E. DANCHIN & J. CLOBERT 1994.** High survival estimates of Griffon Vultures (*Gyps fulvus fulvus*) in a reintroduced population. *Auk* 111:853-862.
- SNYDER, N. F. R. 1988.** California Condor *Gymnogyps californianus* (Shaw). P. 61 in Palmer, R. S., ed., *Handbook of North American birds, vol. 4, Diurnal Raptors (Part I)*. Yale University Press, New Haven, CT.
- SNYDER, N. F. R. & J. SCHMITT 2002.** California Condor (*Gymnogyps californianus*). In *The Birds of North America, No. 610* (A. Poole & F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.
- SNYDER, N. F. R. & H. SNYDER 2000.** *The California Condor: A saga of natural history and conservation*. Academic Press, San Diego, California.
- TOWNSEND, J. K.** (introduction and annotation by G. Jobanek). 1999. *Narrative of a journey across the Rocky Mountains to the Columbia River, and a visit to the Sandwich Islands, Chili &c., with a scientific appendix*. Oregon State University Press, Corvallis, OR.
- TRENT, T. T. & O. J. RONGSTAD 1974.** Home range and survival of cottontail rabbits in southwestern Wisconsin. *Journal of Wildlife Management* 38:459-472.
- VERNER, J. 1978.** California Condor: Status of the recovery effort. General technical report PSW-28. U.S. Forest Service, Washington, D.C.

Tom J. Cade, Sophie A. H. Osborn, W. Grainger Hunt, and Christopher P. Woods.
 The Peregrine Fund
 5668 West Flying Hawk Lane
 Boise, ID 83709, U.S.A.
 tcade@peregrinefund.org