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CALIFORNIA CONDORS IN THE 21ST CENTURY

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Survival and Reproduction of California Condors Released in Arizona

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Abstract.—A drastic decline in California Condors (*Gymnogyps californianus*) resulted in their complete removal from the wild in the 1980s and subsequent establishment of captive populations to propagate offspring for reintroductions. In 1996 The Peregrine Fund began releasing captive-raised condors in the Grand Canyon region of northern Arizona. By July 2005, 77 juvenile or immature condors had been released, 26 (34%) of which had died. Eight condors perished in their first 90 days following release and 14 in total during their first year in the wild (survival rate of 79.6% as determined by days of exposure). Survivorship increased to 89.5% for condors in the second through fourth years following release, and to 97.8% from the fifth year onward. Lead poisoning from ingested shotgun pellets and bullet fragments was the greatest cause of fatalities for birds after their first 90 days free-flying, with six birds known and two suspected to have died from lead toxicity. Many surviving condors were also treated with chelation therapy at least once to reduce high blood lead levels. Under a program of intensive management, survival rates were in the range expected for wild condors, and as of December 2005 the released population had aged to include 14 adults which had laid 11 eggs and fledged 5 young. Self-sustainability, however, will require that lead in the condors' food supply be greatly reduced or eliminated.

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The ranges of the two largest extant cathartids, the Andean Condor (*Vultur gryphus*) and the slightly smaller California Condor (*Gymnogyps californianus*), have contracted greatly in historical times, and the California Condor is critically endangered (BirdLife International 2000). Few California Condors remained by the time Koford (1953) undertook the first concerted effort to study them and little is known conclusively regarding their natural mortality, whether they ever occurred at high densities, or what factors limited their numbers in the past. It is certain, however, that human-related factors, including shooting, poisoning, and encroachment into breeding and foraging areas were associated with a precipitous population decline in the last two centuries (Koford 1953; Wilbur 1973, 1978; Kiff 2000; Snyder and Snyder 2000; Fry and Maurer 2003; Snyder this volume).

In the 1980s all remaining condors were brought into captivity, and captive breeding populations were established, with the ultimate goal of restoring wild populations (see Kiff 2000, Snyder and Snyder 2000). Reintroductions began in 1992, when two condors were released at the Sespe Condor Sanctuary in southern California. Since then the magnitude of the release program has grown, and more than 100 condors now fly freely in southern and central California, northern Arizona and southern Utah, and Baja California, Mexico.

Condors seem always to have occurred in landscapes that included rugged or otherwise inaccessible terrain for nesting, open areas that allowed for extended soaring flight, and an adequate supply of medium and large mammalian carcasses. California Condors ranged across North America in prehistoric times, and formerly bred in northern Arizona along the Colorado River in what is now Grand Canyon National Park (Miller 1960, Emslie 1987). Big birds require big country, and habitat in the canyonlands of northern Arizona and southern Utah appears suitable for condor recovery because it contains extensive rugged terrain with abundant potential nesting cliffs, open areas, strong updrafts, large ungulate populations, and relatively limited human disturbance (Rea 1981).

Since 1996, condors have been released in northern Arizona along escarpments 85 to 150 km north of Grand Canyon National Park as a "nonessential experimental" population under provisions of Section 10(j) of the Endangered Species Act. As of July 2005, 50 juvenile (less than one year of age) and 27 immature (one to six years of age) condors have been released, 26 of which have died. Now, as birds from the earliest-released cohorts have begun to breed and eventual population sustainability can be contemplated, a review of mortality factors for the released birds is timely. Meretsky et al. (2000) summarized early, unpublished reports on mortality for condors in both Arizona and California; here we update and examine the factors that have led to condor deaths specifically in Arizona and Utah, and provide estimates of survival for different age groups.

Methods

California Condors were released in groups of two to eight individuals (three birds were also released singly) at two sites in northern Arizona: a primary site at Vermilion Cliffs, Coconino Co., (release years: 1996, 1997, 2000 onward; Fig. 1) and an alternate one at Hurricane Cliffs, Mohave Co., (release years: 1998, 1999; see Harting et al. [1995] and Johnson and Garrison [1996] for site description and release protocol). Condors to be released were always first maintained together at the site. Prior to 2000, condors were generally held for four to six weeks in a release pen at the cliff edge before release (Plate 7). From 2000 onward, pre-release birds were usually held in a large flight pen set back from the cliff for weeks to months before being moved to the release pen, from which they were released after a week or so. After the first release, free-flying condors had access to the exterior of the pen(s) and sometimes interacted with the pre-release birds. Interactions with humans were kept to a minimum. Nearly half (49%) of all condors were released in November or December, and 65% were less than one year old when released, having hatched the previous March, April, or May (Table 1). Four captive-reared adult condors were released experimentally in December 2000, but two quickly perished and the remaining two were consequently retrapped (see Results for further details). Owing to the unique nature and short duration of those releases, data from those birds were not included in any analyses in this paper except where stated explicitly. The earliest releases typically consisted of cohorts of six or more condors released together, although this protocol was replaced in 2002 by successive releases of birds in smaller cohorts. Condors released in Arizona were captive-reared at three facilities: 53 birds were reared at The Peregrine Fund's World Center for Birds of Prey in Boise, Idaho; 12 at the Los Angeles Zoo; and 12 at the San Diego Wild Animal Park. Five wild-reared young

Fig. 1. Condor release site at the Vermilion Cliffs, Arizona, as seen from the southwest. (Photo by C. N. Parish.)

Table 1. Release dates and numbers of California Condors released in northern Arizona between December 1996 and July 2005. All releases except those in 1998 and 1999 were at the Vermilion Cliff release site in Coconino County.

Release date	Condors released (n)	Mean age at release (days ± SD)	No. free-flying in July 2005
12 Dec 1996	6	205 ± 9	3
14 May 1997	4	771 ± 13	2
26 May 1997	5	760 ± 19	4
20 Nov 1997	4	211 ± 16	2
18 Nov 1998	9[a]	215 ± 22	3
6 Dec 1999	7[b]	246 ± 26	3
29 Dec 2000	8[c]	243 ± 10[d]	6[e]
16 Feb 2002	6	289 ± 14	3
25 Sep 2002	3	500 ± 4	2
9 Dec 2002	2	592 ± 13	2
3 Mar 2003	3	315 ± 9	3
4 Oct 2003	2	532 ± 2	2
29 Nov 2003	2	580 ± 5	2
9 Jan 2004	1	614	1
20 Mar 2004	4	338 ± 5	3
16 Oct 2004	3	559 ± 10	3
4 Feb 2005	3	651 ± 15	3
1 Mar 2005	5	298 ± 20	4
Overall	77	394 ± 205	50

[a] One bird was released singly on 23 Nov 1998. That bird was 965 days old, and is not included in average age calculation for this release.

[b] One bird was released singly on 23 Dec 1999.

[c] Four adults were also released about this time: one pair on 7 Dec 2000 and the second pair on 19 Dec 2000. These were not included in average age calculation for this release (see text for details).

[d] Not included in average age calculation for this release is one 586-day-old condor.

[e] One bird from this cohort was permanently removed from the free-flying population.

also fledged in Arizona; data from those condors, one of which later died, were not included in analyses in this paper.

All released condors were fitted with a redundant system of two radio transmitters, usually consisting of paired patagial transmitters although for a few the second transmitter was tail-mounted (Wallace et al. 1980, Meretsky and Snyder 1992). All transmitters are presently equipped with a fatality sensor, although this was not the case for birds from the earliest releases, for which death was initially inferred from lack of variation in signal strength or direction. More recently some condors have also carried GPS satellite transmitters. All birds were given large numbered patagial tags for visual identification. Condors have been monitored continually since the initial release in 1996 using radio telemetry and visual confirmation of individual identity. Whenever possible, birds have been located daily and, consequently, field data have confirmed to within a day or so the date of most deaths. For four birds that disappeared and were presumed to have perished, however, the last day of radio contact was used as the day of death, although those birds could conceivably have lived for weeks or months thereafter.

Carcasses of dead condors were removed from the field and chilled as quickly as conditions permitted, and then shipped to the San Diego Zoo, in California, where necropsies were performed. Two exceptions occurred in which law enforcement agencies were involved and took possession of the carcasses. Diagnosis of lead poisoning was based on toxicological analyses routinely performed for each fatality at the San Diego Zoo and by the presence of lead bullet fragments or shotgun pellets in some poisoned birds (determined by radiograph and/or necropsy). One condor whose carcass was unrecoverable but whose death coincided with a widespread lead-poisoning event was assumed to have succumbed to lead toxicity (see Results). Fatalities ascribed to Golden Eagles (*Aquila chrysaetos*), whether resulting from aggressive interactions or predation, were characterized by partially plucked carcasses, puncture wounds about the head consistent with large talons, and field observations of eagles in the vicinity. Deaths attributed to coyote (*Canis latrans*) predation were characterized by partially consumed carcasses, chewed feathers, fresh coyote tracks, and scat in the immediate area. Signs of struggle distinguished predation by coyotes from scavenging.

Because the daily fates of all members of the population were almost always known, survivorship of released birds could be determined precisely using days of exposure. For each bird, the day of first release was considered exposure day 1, and each subsequent day during which the bird was free-flying for any part of the day was considered an exposure day. All birds were periodically captured and re-released owing to concerns about transmitters, health, behavior, or to test for lead exposure. Complete days during which an individual was in captivity were not counted as exposure, although days of exposure were otherwise cumulative in regard to the time a condor was free-flying following its initial release. Nearly two-thirds (64%) of the birds were captive for less than 100 days in total following their release. Twenty-eight individuals, however, were held for longer than 100 days, and seven of those were held for one to three years and are thus substantially older than the number of days free-flying suggests.

To evaluate survivorship, we partitioned the number of exposure days into five stages based on annual benchmarks and our observations of apparent differences in survival rates. The stages were: initial release (the first 90 exposure days following release); remainder of the first year (91 to 365 exposure days post-release); second year (366 to 730 exposure days post-release); third through fourth years (731 to 1,460 exposure days post-release); and the fifth year onward (1,461+ exposure days post-release). We determined daily, exposure stage, and annual survivorship based on Trent and Rongstad (1974), where daily survival rate ($\hat{S}$) was calculated as the total number of exposure days within any stage, minus the number of days in the stage during which a death occurred, divided by the total number of exposure days in the stage. Survivorship throughout specific stages was $\hat{S}^n$, where n was the number of calendar days in each particular stage.

To gain an indication of what survival in the released population might have been without intensive management and chelation treatments to reduce acute blood lead levels (see Parish et al. this volume for methods), we also recalculated survival under two hypothetical scenarios: (1) all birds that were found to have blood levels of lead greater than 250 µg dL^{-1} died on the date of detection, and (2) all those with lead levels above 100 µg dL^{-1} died. For each situation, we used a standard growth rate calculation developed by Hunt (2002) to determine lambda (λ) values, which depict the direction and strength of population trajectories. For growth rate calculations, we used our calculated survival in the first year following release as a substitute for juvenile (first year) survival, our calculated survival in the second through fourth years free-flying as a substitute for immature survival, and our calculated survival from the fifth year free-flying onward to represent adult survival. We used hypothetical reproductive parameters determined by Meretsky et al. (2000).

We used chi-square analyses to evaluate differences in the number of condors that survived based on sex, rearing method (parent- vs. puppet-reared), and age when released (more or less than one year old at release). Because many condors died in the first year following their release (see Results), we also repeated those analyses but tested specifically for differences in the number of condors that survived their first year free-flying. Data for all chi-square analyses included only condors released before July 2004 (65 in total), as the more recently released birds had not yet spent a full year free-flying. Also excluded was a single bird permanently removed from the free-flying population, since it was removed less than one year after its release.

For condors that bred, the date at which egg-laying occurred was determined by changes in behavior of the adult birds, including periodic incubation exchanges at nest sites. Behavioral changes that characterized hatching, including the sudden onset of daily nest exchanges by the adults, were also used to determine laying dates, assuming an average incubation period of 57 days (Snyder and Snyder 2000). Nest sites with young were monitored carefully as the date of fledging approached, and the date and time of fledging were determined by direct observation. Where possible, nest sites were entered for close examination after the breeding effort ended.

Unless otherwise noted, all statistics are in the form of mean ± SD. The levels of lead in condors are frequently expressed in μg dL^{-1} when measured in blood and ppm when measured in the liver, and we follow those conventions here. The two measurements are easily converted, however, since 1 ppm equals 100 μg dL^{-1}.

Results

Survivorship overview.—As of July 2005, 77 young condors (43 males and 34 females) had been released in northern Arizona: 61 at the Vermilion Cliffs site and 16 at the Hurricane Cliffs site (Table 1). Of the released birds, 50 (65%) were released when less than one year of age (average age = 255 ± 46 days; range = 172–345) and 27 (35%) were released at ages ranging from 494 to 965 days (average age = 651 ± 116 days). The average age at release for all 77 birds was 394 ± 205 days. Twenty-six of the released birds died, one was removed from the free-flying population, and 50 remained in the wild in July 2005. Not included in the number of released birds or deaths are four adult birds (two breeding pairs eight to nine years old) that were released as an experimental effort to include breeders with other released birds. Coyotes killed two of the adults shortly after release (19 and 22 days), probably as a result of unsafe roosting behavior, and the other two were recaptured and permanently removed

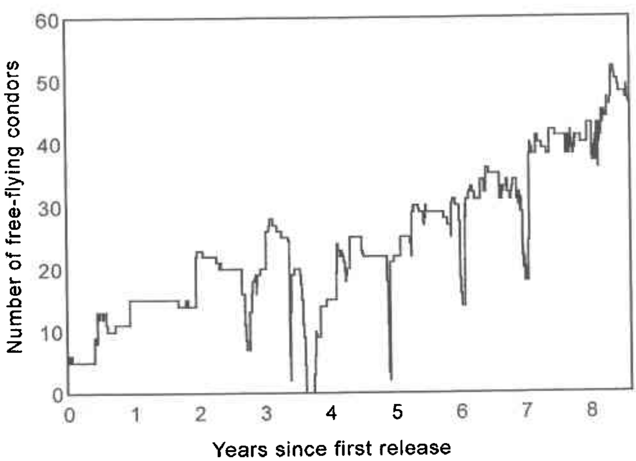

Fig. 2. Number of free-flying California Condors in northern Arizona since the first cohort was released in December 1996. Reductions in the population occurred when birds were captured and held temporarily for behavioral or health reasons. The population went to zero from mid-July through mid-August 2000 when all birds were held during a lead poisoning incident (see text).

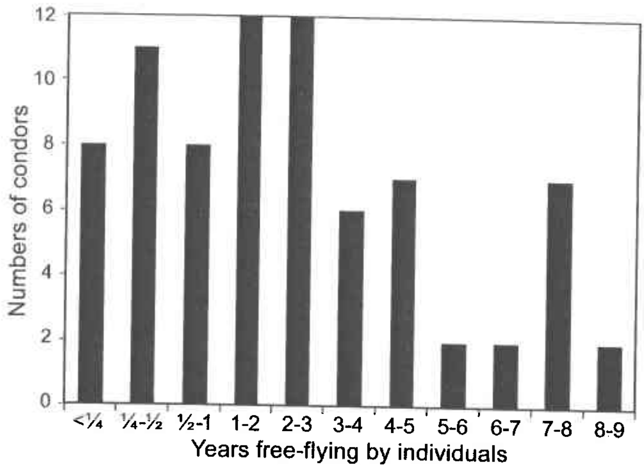

FIG. 3. Years free-flying by 77 California Condors released in northern Arizona between December 1996 and July 2005.

from the free-flying population. Since the first release in 1996, the number of birds in the wild generally increased over time, to a temporary maximum of 52 in March 2005 (Fig. 2). As of July 2005, 42 (55%) of the released birds were free-flying for 1.5 years or longer (Fig. 3), and individuals averaged 2.7 ± 2.5 years (n = 77; range = 4 days–8.2 years) in the wild.

The likelihood of survival did not differ significantly based on sex of the released birds, whether considering survival through the first year free-flying or overall ($\chi^2 = 0.84$, df = 1, $P = 0.526$; $\chi^2 = 0.06$, df = 1, $P = 0.802$, respectively). Survival also did not differ significantly based on rearing method (first year free-flying: $\chi^2 = 0.08$, df = 1, $P = 0.772$; overall: $\chi^2 = 0.15$, df = 1, $P = 0.694$). In contrast, individuals that were greater than one year of age when released were significantly more likely to survive than individuals that were released when less than one year old. Of 21 birds released when more than one year old, one (5%) perished in its first year free-flying, compared to 12 of 44 birds (27%) released when younger than one year of age ($\chi^2 = 4.94$, df = 1, $P = 0.026$). Overall, four of 21 birds (19%) released when greater than one year of age died, compared to 21 of 44 birds (48%) released when less than one year old ($\chi^2 = 4.50$, df = 1, $P = 0.034$).

We documented 75,053 exposure days in total, including 22,391 (77 birds) in the first year and 16,640 (20 birds) from the fifth year onward (Table 2). Annual survival through the first year, 79.6%, was heavily influenced by relatively high mortality of recently released birds; of the 14 that perished during their first year, eight died within the first three months. The likelihood of survival increased to 89.3% in the second year and 89.6% in the third and fourth years combined (89.5% for the second through fourth

Table 2. Survivorship based on exposure days for 77 California Condors released in northern Arizona, December 1996 through July 2005.

Stage[a]	Condors (n)	Exposure days	No. of deaths	Survivorship (%) Daily	Stage	Annual
Initial release[a]	77	6,519	8	99.877	89.5	–
Remain. 1st year[b]	69	15,872	6	99.962	90.1	–
Combined 1st year	77	22,391	14	99.937	–	79.6
2nd year	50	16,069	5	99.969	–	89.3
3rd and 4th year	38	19,953	6	99.970	–	89.6
5th year onwards	20	16,640	1	99.994	–	97.8
Overall	77	75,053	26	99.965	–	88.1

[a]Initial release is the first 90 days following release.

[b]Remain. 1st year is the remainder of first year following release (see text for further details).

years). Survival from the fifth year onward was 97.8%. Fatalities occurred sporadically throughout the release program, with the exception of four deaths in June 2000, but condor deaths were rare following four years in the wild, and by July 2005 only one bird that had been free-flying for longer than four years had perished.

Given the rates of survival found in our study, and assuming a population with a stable age distribution and a conservative reproductive rate of 0.25 for breeding age females (e.g., 50% of females breed per year with 50% breeding success), the Arizona population would be expected to grow at the rate of 2.6% per year (i.e., $\lambda = 1.026$). If the reproductive rate increased to 0.33 per year, the annual growth rate would rise to 3.7%. If, on the other hand, there were no management for lead exposure, and one assumed that all condors with acute blood levels of lead above 250 µg dL^{-1} died, resulting in an additional nine deaths, immature and adult survival would have been 81.7% and 90.9% respectively (juvenile survival would have been unaffected), and the population would have declined at 2.8% per year. With the more stringent assumption that lead levels in blood greater than 100 µg dL^{-1} were always lethal, resulting in seven deaths in addition to the nine previously mentioned, immature and adult survival would have been 72.4% and 76.9% respectively (again, there would have been no affect on juvenile survival), and the population would have declined at the greater rate of 18.6% per year.

Sources of mortality.—Fourteen condors perished in the first year following their release, mainly from predation or other experience-related factors (Table 3). Amongst those 14 deaths, predators (coyotes and Golden Eagles) killed four and possibly five condors, three birds disappeared and are

Table 3. Causes of death for 26 California condors released in northern Arizona between December 1996 and July 2005. Birds are ranked by the number of days free-flying prior to death.

Source of mortality	Sex free-flying	Days	Age at death (days)	Month/year of death
Deaths during first year free-flying				
Coyote	M	4	284	02/2002
Eagle	M	24	225	01/1997
Coyote	M	37	271	12/1998
Poor Condition [a]	M	39	326	04/2005
Septicemia [b]	M	40	256	01/2000
Poor Condition [a]	F	43	287	02/2001
Eagle	F	60	317	02/2000
Unknown–lost	F	62	817	07/1997
Unknown–lost	F	120	333	04/2000
Powerline	F	158	350	05/1997
Unknown–lost	F	173	509	09/2004
Lead	M	177	487	08/2002
Shot	M	242	508	10/2002
Coyote suspected	M	318	501	10/1998
Deaths after first year free-flying				
Lead	F	522	768	06/2000
Lead suspected	M	524	810	06/2000
Eagle	F	537	880	09/2000
Shot	M	542	1,599	08/2002
Shot	F	609	1,436	03/1999
Lead	M	816	1,355	01/2005
Lead	M	932	1,149	06/2000
Unknown [c]	M	1,021	1,634	09/2003
Lead	M	1,024	1,785	03/2000
Lead suspected	F	1,263	1,491	06/2000
Lead	F	1,345	1,700	01/2005
Unknown–lost	F	1,696	2,155	02/2004

[a] Poor body condition of unknown cause led to starvation-like deaths in these birds (see text for further details).

[b] Septicemia resulted from airsacculitis owing to aspiration.

[c] Cause of death undetermined by necropsy.

presumed to have perished, and two succumbed to starvation-like poor body condition resulting from an unknown cause or causes. In each case where coyotes appeared to kill a condor, the bird had roosted in a location that was accessible to coyotes. It is unknown whether poor body condition or other factors increased the susceptibility to predation of birds whose deaths were attributed to coyotes, but one bird appeared healthy and vigorous when captured by field personnel eight days prior to its death and another was killed