LEAD EXPOSURE AMONG A REINTRODUCED POPULATION OF CALIFORNIA CONDORS IN NORTHERN ARIZONA AND SOUTHERN UTAH

CHRISTOPHER N. PARISH[1], W. GRAINGER HUNT[1], EDWARD FELTES[1], RON SIEG[2], AND KATHY ORR[3]

[1]*The Peregrine Fund, 5668 West Flying Hawk Lane, Boise, ID 83709, USA.*
E-mail: cparish@peregrinefund.org

[2]*Arizona Game and Fish Department, 3500 South Lake Mary Road, Flagstaff, AZ 86004, USA.*

[3]*The Phoenix Zoo, 455 North Galvin Parkway, Phoenix, AZ 85008, USA.*

ABSTRACT.—Lead poisoning remains the leading cause of death among free-ranging California Condors released by The Peregrine Fund in Arizona from 1996 to 2007 in an ongoing effort to establish a self-sustaining population. Daily monitoring of radio-tagged condors by means of VHF and GPS telemetry shows them ranging from the Grand Canyon National Park to the Zion region of southern Utah. Increased proficiency of condors at finding carrion in the wild corresponds with a greater incidence of lead exposure. Periodic testing reveals spikes in blood lead levels during November and December commensurate with the deer hunting seasons and condor movement to deer hunting areas. These data combined with information collected on food types supports the hypothesis that lead ammunition residues in rifle- and shotgun-killed animals are the principle source of lead contamination among these scavengers in northern Arizona and southern Utah. Sustaining the population requires an intensive management regime of testing and treatment for lead exposure. Reducing or eliminating the availability of lead is essential to reestablishment of condors in the wild. *Received 15 September 2008, accepted 31 October 2008.*

PARISH, C. N., W. G. HUNT, E. FELTES, R. SIEG, AND K. ORR. 2009. Lead exposure among a reintroduced population of California Condors in northern Arizona and southern Utah. *In* R. T. Watson, M. Fuller, M. Pokras, and W. G. Hunt (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA. DOI 10.4080/ilsa.2009.0217

Key words: Bullet fragmentation, California Condor, chelation, lead exposure, lead poisoning, mortality.

THE CALIFORNIA CONDOR (*Gymnogyps californianus*) was among the first species listed on the Endangered Species Act of 1973 when only about 60 individuals remained in the wild (Snyder and Snyder 2000). The fossil record shows that condors once ranged throughout most of the southern United States, from California to Florida, but a drastic range reduction appears to have coincided with the extinction of Pleistocene megafauna about 10,000 years ago (Emslie 1987, Snyder and Snyder 2000). Evidence suggests that condors thereafter persisted along the Pacific Coast by scavenging on the remains of marine mammals and fish (Fox-Dobbs 2006), and then returned to the interior southwest in the 1700s with the introduction of livestock as a food base (Emslie 1987). But even with this probable increase in carrion availability, the species' naturally slow reproductive rate proved insufficient in offsetting human-related mortality, and the population declined. Mortality agents such as egg collecting, shooting, and poisoning, both intentional and inadvertent, were doubtless contributing factors (Koford 1953). In general, however, the difficulty of recovering dead condors for necropsy failed to reveal all the mortality agents involved and their relative contributions to the decline of condors.

Intensive monitoring by radiotelemetry in the 1980s marked the beginning of understanding, but by that time the population had dwindled to fewer than 30 birds. As extinction grew imminent, all remaining condors were removed from the wild to form a captive population. Fourteen founders among them eventually gave rise to captive-bred young in numbers sufficient to begin the reintroduction phase of a recovery effort (Grantham 2007). Condors were first reintroduced to their recent historic range in California in 1992 after a pilot experiment with Andean condors. Soon thereafter, in accordance with the federal recovery plan, efforts turned towards establishing a second, disjunct population. The U.S. Fish and Wildlife Service invited The Peregrine Fund to establish a captive breeding facility in Boise, Idaho, followed by a release program in northern Arizona. Releases began there in 1996 with an "experimental non-essential" design under Section 10(j) of the Endangered Species Act.

The area chosen for release and now occupied by free-ranging condors stretches from the Grand Canyon in northern Arizona north into the canyon lands and forests of southern Utah (Figure 1). Abrupt altitudinal differentiation, from deep red rock canyons (*ca*. 865 m msl) to uplifted mesas (3055 m msl) with immense cliffs, supports a variety of vegetational associations. Wind deflection and thermals create abundant updrafts upon which condors travel easily and rapidly. The condor's primary food consists of carcasses and partial remains of Mule Deer (*Odocoileus hemionus*), domestic cattle (*Bos taurus*), domestic sheep (*Ovis aries*), and Elk (*Cervus elaphus*). Supplementary food in the form of dairy calf carcasses is made available every three or four days at the Vermilion Cliffs Release Site (Figure 1) to which the condors periodically return.

Each condor wears a numbered patagial tag and one or two radio transmitters, either standard VHF for ground tracking and/or satellite-reporting with GPS capability. A team of biologists track the condor population on a daily basis with the goal of monitoring the movements and activity of as many individuals as possible. These locational data guide day-to-day management decisions and are used retrospectively to interpret behavior, foraging ecology, nesting activity, and potential encounters with contaminants. The current overall range (33,843 km^2) is divided into six zones based on movement patterns apparent during the first eight years of the program (Figure 1). Thus far, all condors return to the release site three or more times during the year, although the frequency of such visits for some individuals has diminished as they matured. Virtually all condors have been present at or near the release site during the coldest times of the year. Release site visits offer the opportunity to capture condors for examination, transmitter refitting, and blood sampling.

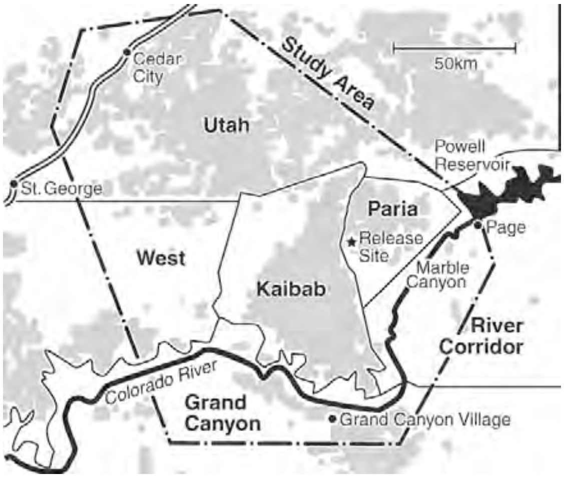

Figure 1. Study area as defined by condor movements in Arizona and Utah.

As of spring 2008, there have been 102 condors released, 40 fatalities, six birds returned to captivity, and nine wild young produced by reintroduced condors, leaving 64 condors in the wilds of southern Utah and northern Arizona. Details about the Arizona reintroduction program are given by Cade et al. 2004, Woods et al. 2007, Hunt et al. 2007, Parish et al. 2007, Sullivan et al. 2007, Osborne 2007, and Cade 2007. The present report focuses on testing, treatment, and mortality with emphasis on lead poisoning occurring since June 2005, the extent of our last published update (Parish et al. 2007).

Table 1. Information on population, reproduction, mortality, lead exposure, and treatment of California Condors in northern Arizona from 2000 through 2007.

Year	No. in Wild	No. Exposed to Lead	No. Tested for Pb	No. Treated for Pb	Blood-lead tests >15μg/dL	Blood-lead tests >65μg/dL	Deaths*	No. Birds of Breeding Age	No. Wild Young Fledged
2000	28	17 (61%)	25	9 (32%)	18	15	10(3)	7	0
2001	25	12 (48%)	25	1 (4%)	12	0	0	9	0
2002	31	23 (74%)	31	13 (42%)	29	11	4(1)	11	0
2003	40	30 (75%)	40	7 (18%)	43	7	1	14	0
2004	43	35 (81%)	43	18 (42%)	56	15	1	16	2
2005	56	29 (52%)	56	11 (20%)	40	8	6 (2)	22	2
2006	57	54 (95%)	57	40 (70%)	86	37	6 (3)	33	0
2007	61	50 (82%)	59	25 (41%)	52	18	4	40	2

*confirmed lead deaths in parentheses

LEAD POISONING

During the early years of the Arizona project, most fatalities resulted from predation and other mishaps associated with the inexperience of newly released condors (Woods et al. 2007). As the numbers of such fatalities diminished with the development of a wild flock and the application of adaptive management, lead poisoning emerged as the primary mortality factor. We first became aware of it in spring 2000 when 12 or more condors ingested shotgun pellets from an unknown source (Woods et al. 2007). This episode, which resulted in several deaths and emergency treatments, gave rise to a regular monitoring program of blood lead levels of condors periodically recaptured when they returned to the release site (Parish et al. 2007).

Condors prior to release and those subsequently feeding only upon proffered calf carcasses showed blood lead levels no higher than 12 μg/dL. Response to condors showing >30 μg/dL on a portable field analyzer (which underestimated laboratory values; see Parish et al. 2007, Green et al. 2009, this volume, Bedrosian et al. 2009, this volume) normally consisted of holding and retesting after a few days to determine if lead levels were increasing or decreasing. If increasing, or in cases of high exposure (>60 μg/dL), we administered chelation therapy, and where indicated we radiographed the condor to determine if radiodense objects existed in the digestive tract. If so, and they failed to soon pass from the stomach into the intestine, we administered phsyllium fiber or, when necessary, performed surgery to remove the object(s), the analysis of which invariably confirmed the diagnosis of lead poisoning (Sullivan et al. 2007, Chesley et al. 2009, this volume). We continued holding lead-exposed birds in captivity until a significant decrease in lead levels was apparent, at which point the birds were released (Parish et al. 2007).

These measures do not account for possible sublethal effects of lead on condors from repeated exposures, even low level exposures. In other organisms, lead is known to accumulate in soft tissue and bone where it is undetectable by blood testing (Mautino 1997). The result of that accumulation may conceivably impact adult fertility and reproduction, neural development of young, and other processes (see Gangoso et al. 2009, this volume).

We observed an abrupt increase in lead exposure in the fall of 2002, and the levels have been high each fall thereafter (Table 1). In examining the movements of condors in the weeks prior to the detection of lead exposure, we found that most had frequented the Kaibab Plateau, a popular deer hunting area nearby (Hunt et al. 2007). We hypothesized that the source might be bullet fragments in deer remains, so we studied the extent to which fragments are retained in deer gut piles and in deer lost to wounding. Hunt et al. (2006) reported that the gut piles of 18 of 20 deer killed with standard lead-based bullets contained bullet fragments, 10 showing over 100 fragments. Five whole deer carcasses contained 416–783 fragments. Other evidence, including observations of condors associated with deer remains, spikes in condor lead levels during and just after the Kaibab deer seasons (November and December), and continued correspondence between lead levels and condor occurrence on the Kaibab Plateau all supported the hypothesis of hunter-killed deer as the primary source of exposure (Hunt et al. 2007). We documented rifle-killed coyote carcasses as an additional source, but were unable to determine the source of shotgun pellet ingestion which recurs occasionally.

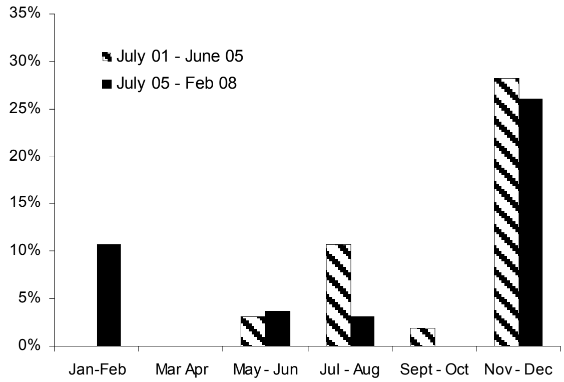

Figure 2. Annual pattern of toxic lead levels (>60 μg/dL) in condor blood from July 2001 through February 2008 in Arizona. The period July 01–June 05 was published in Parish et al. 2007. The period July 05–Feb 08 has not previously been published.

Several variables likely contributed to yearly differences in overall rates of exposure and treatment apparent in Table 1. The relatively low number of exposed condors in 2003 probably resulted from early capture and retention of condors at the release site during the hunting season. The timing and distribution of snowfall relative to hunting seasons concentrated deer, hunters, and condors in some years, presumably increasing the probability of finding and feeding on the remains of shot animals.

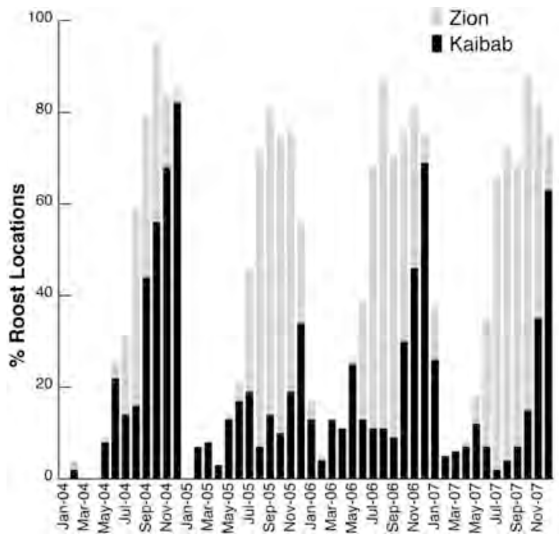

Figure 3. Percent of condor roost locations spent in the Zion and Kaibab zones.

The relationships apparent in the 2002–2004 analyses (Parish et al. 2007, Hunt et al. 2007) showing fall spikes in lead exposure (Figure 2) and their association with deer hunting areas have continued to the present (Figure 3; see Green et al. 2009, this volume). From 2002, increasing numbers of condors have summered in the Zion region of southern Utah and have remained there through much of the fall. The environment in this higher, somewhat wetter zone differs from the Arizona portion of the range in having a greater area of private ranches and abundant domestic livestock which extend to public land as well. Seasonal herds of sheep and cattle in the Zion region form a more plentiful and regular food base for condors until the livestock are removed in fall with the arrival of cold weather. Deer and Elk provide a continued source of carrion, especially with the fall hunting seasons. Condors depart the area with the arrival of snow cover and the consequent loss of food accessibility. Condors leaving Utah usually travel to the Kaibab Plateau and ultimately to the release site where proffered carcasses are continuously available.

DISCUSSION

Our findings suggest that the Kaibab Plateau and especially the Zion area are sufficient to sustain condors without reliance on food subsidies except in periods of heavy snow cover. This capability is enhanced by the ability of condors to forego eating for days at a time as they wait for favorable updrafts, and then range several hundred kilometers in a day to exploit seasonally changing food sources. One such opportunity emerges with the ungulate hunting seasons in the fall, offering sudden abundance of carrion at a time when the accessibility of food is declining with the onset of winter. The contribution of hunters in providing food during this period produces an important link in the annual cycle of food availability.

It appears on the basis of much published evidence that the occurrence of lead in gun-killed animal remains is the principal impediment to the establishment of a self-sustaining population in Arizona and Utah. The Arizona Game and Fish Department has made an effort, unprecedented in wildlife conservation, by implementing a hunter-education campaign and providing free, non-lead ammunition for hunters on the Kaibab and Paria plateaus beginning in 2005 (Sieg et al. 2009, this volume). Fortunately for condors, test reports of non-lead bullets available on today's market rate them comparable and even superior to their lead-based counterparts (see Jamison 2005). Response by hunters to Arizona's non-lead bullet program has been overwhelmingly favorable, with >80% participation in reducing the availability of ammunition lead to condors and other scavengers in fall 2007. Although lead exposure continues, its associated severity in 2007 was low, and no lead-related deaths occurred. The Utah Division of Wildlife is currently advancing a similar initiative in southern Utah, scheduled to begin in the fall 2009. According to Green et al. (2009, this volume), Utah's participation, if comparable to that in Arizona, will substantially strengthen the demography of condors and take them one step closer to establishment in the region. Meanwhile, funding permitting, The Peregrine Fund will continue monitoring condor movements and blood lead levels, and administering treatment when necessary.

ACKNOWLEDGMENTS

Funding for this project was provided by The Peregrine Fund, the U.S. Fish and Wildlife Service, the Arizona Game and Fish Department, and many other important donors. We would like to acknowledge our cooperators, and members of The Southwest Condor Working Group. We especially thank The Phoenix Zoo, Arizona Game and Fish Department, the National Park Service, and Liberty Wildlife for their help with transportation and medical attention to sick and injured condors. We thank our current team of dedicated biologists and those who have contributed in the past. Of special mention we thank Bill Burnham, Tom Cade, Bill Heinrich, Rick Watson, Lloyd Kiff, Travis Rosenberry, Kathy Sullivan, Tim Hauck, Jim Wilmarth, Eric Weis, Evan Beauchley, Mathew Podolsky, Maria Dominguez, Shaun Putz, Neil Paprocki, Marti Jenkins, Rob Gay, Thom Lord, Frank Nebenberg, Jonna Weidmaier, Sophie Osborn, Jesse Grantham, Bryan Bedrosian, and Maggie Sacher.

LITERATURE CITED

CADE, T. J. 2007. Exposure of California Condors to lead from spent ammunition. Journal of Wildlife Management 71(7): 2125–2133.

CADE, T. J., S. A. H. OSBORN, W. G. HUNT, AND C. WOODS. 2004. Commentary on released California Condors *Gymnogyps californianus* in Arizona. Pages 11–25 *in* R. D. Chancellor and B.-U. Meyburg (Eds.), Raptors Worldwide. Proceedings of the 6th World Conference on Birds of Prey and Owls. WWGBP/MME-Birdlife, Hungary.

CHESLEY, J., P. REINTHAL, C. N. PARISH, K. SULLIVAN, AND R. SIEG. 2009. Direct evidence for the source of lead contamination within the California Condor. Abstract *in* R. T. Watson, M. Fuller, M. Pokras, and W. G. Hunt (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA. DOI 10.4080/ilsa.2009. 0219

EMSLIE, S. D. 1987. Age and diet of fossil California Condors in Grand Canyon, Arizona. Science 237:768–770.

FOX-DOBBS, K., T. A. STIDHAM, G. J BOWEN, AND S. D. EMSLIE. 2006. Dietary controls on extinction versus survival among avian megafauna in the late Pleistocene. Geology 34(8):685–688.

GANGOSO, L., P. ÁLVAREZ-LLORET, A. RODRÍGUEZ-NAVARRO, R. MATEO, F. HIRALDO, AND J. ANTONIO DONÁZAR. 2009. Long-Term Effects of Lead Poisoning on Bone Mineralization in Egyptian Vulture *Neophron percnopterus.* Abstract *in* R.T. Watson, M. Fuller, M. Pokras, and W.G. Hunt, (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA. DOI 10.4080/ilsa.2009.0214

GRANTHAM, J. 2007. Reintroduction of California Condors into their historic range: The recovery program in California. Pages 123–138 *in* A. Mee, L. S. Hall and J. Grantham (Eds.). California Condors in the 21st Century. Series in Ornithology, no. 2. American Ornithologists Union, Washington, DC, and Nuttall Ornithological Club, Cambridge, Massachusetts, USA.

GREEN, R. E., W. G. HUNT, C. N. PARISH, AND I. NEWTON. 2009. Effectiveness of action to reduce exposure of free-ranging California Condors in Arizona and Utah to lead from spent ammunition. Reproduced *in* R. T. Watson, M. Fuller, M. Pokras, and W. G. Hunt (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA. DOI 10.4080/ilsa.2009.0218

HUNT, W. G., W. BURNHAM, C. N. PARISH, K. BURNHAM, B. MUTCH, AND J. L. OAKS. 2006. Bullet fragments in deer remains: implications for lead exposure in scavengers. Wildlife Society Bulletin 34:168–171.

HUNT, W. G., C. N. PARISH, S. C. FARRY, R. SEIG, AND T. G. LORD. 2007. Movements of introduced California Condors in Arizona in relation to lead exposure. Pages 79–98 *in* A. Mee, L. S. Hall and J. Grantham (Eds.). California Condors in the 21st Century. Series in Ornithology, no. 2. American Ornithologists Union, Washington, DC, and Nuttall Ornithological Club, Cambridge, Massachusetts, USA.

JAMISON, R. 2005. Premium bullet shootout: a look at ten bullets and what they can do for you. Petersen's Hunting (August): 58–61.

KOFORD, C. B. 1953. The California Condor. National Audubon Research Report No. 4:1–154.

MAUTINO, M. 1997. Lead and zinc intoxication in zoological medicine: a review. Journal of Zoo and Wildlife Medicine 28(1):28–35.

OSBORN, S. A. H. 2007. Condors in Canyon Country. Grand Canyon Association, Grand Canyon, Arizona, USA.

PARISH, C. N., W. R. HEINRICH, AND W. G. HUNT. 2007. Lead exposure, diagnosis, and treatment in California Condors released in Arizona. Pages 97–108 *in* A. Mee, L. S. Hall and J. Grantham (Eds.). California Condors in the 21st Century. Series in Ornithology, no. 2. American Ornithologists Union, Washington, DC, and Nuttall Ornithological Club, Cambridge, Massachusetts, USA.

SNYDER, N., AND H. SNYDER. 2000. The California Condor: a saga of natural history and conservation. Academic Press, San Diego, California, USA.

SULLIVAN, K., R. SIEG, AND C. PARISH. 2007. Arizona's efforts to reduce lead exposure in California Condors. Pages 109–120 *in* A. Mee, L. S. Hall and J. Grantham (Eds.). California Condors in the 21st Century. Series in Ornithology, no. 2. American Ornithologists Union, Washington, DC, and Nuttall Ornithological Club, Cambridge, Massachusetts, USA.

WOODS, C. P., W. R. HEINRICH, S. C. FARRY, C. N. PARISH, S. A. H. OSBORN, AND T. J. CADE. 2007. Survival and reproduction of California Condors released in Arizona. Pages 57–78 *in* A. Mee, L. S. Hall and J. Grantham (Eds.). California Condors in the 21st Century. Series in Ornithology, no. 2. American Ornithologists Union, Washington, DC, and Nuttall Ornithological Club, Cambridge, Massachusetts, USA.