PREFACE

LEAD IS A POISONOUS METAL present in a variety of commercial products, as a pollutant from industrial activities, and as an environmental contaminant in many urban and rural habitats throughout the world. When ingested or inhaled, the body "mistakes" lead for calcium and other beneficial metals, and thus transports lead into nerve cells and other vital tissues. Consequences for wildlife include neural degeneration, modification of kidney structure and bone, inhibition of blood formation and nerve transmission, and numerous other harmful manifestations (Eisler 1988). Death can occur acutely, or the individual may become emaciated as a result of digestive paralysis (Locke and Thomas 1996). Clinical symptoms associated with blood lead concentrations exceeding one microgram per gram (one part per million) may include depression, lethargy, vomiting, diarrhea, nonregenerative anemia, anorexia, blindness, and seizures (Locke and Thomas 1996, Kramer and Redig 1997).

Mankind has long known about lead as an agent of sickness and death, but medical studies published in the last five to ten years are showing pernicious effects at unexpectedly low levels of exposure. There are permanent adverse impacts upon cognitive function and growth in children with histories of blood levels averaging less than one-tenth of one microgram per gram—a level formerly considered benign (Canfield et al. 2003, Hauser et al. 2008). Other newly-discovered manifestations of lead exposure include, for example, impaired motor function, decreased brain volume (Cecil et al. 2008), behavioral dysfunction, including criminality (Wright et al. 2008), and mortality from cancer and cardiovascular disease (Menke et al. 2006).

Scientific evidence of the effects of lead on human health has brought forth large scale restrictions on its use in the United States, including the prohibition of lead in many gasolines and paints. Responses on behalf of wildlife have been less forthcoming, but consumption of lead shot by ducks and geese and secondary poisoning of Bald Eagles contributed to the 1991 ban on lead shot for waterfowl hunting in the United States (United States Department of the Interior 1986). Other countries have instituted similar measures. Evidence of lead exposure in Arctic subsistence hunters continuing to use lead shot (Dewailly et al. 2001, Johansen et al. 2004) suggests that the ban on behalf of waterfowl and eagles has benefited humans as well.

Lead ammunition is still used in North America for purposes other than waterfowl harvest, and the extent to which lead is secondarily ingested by wildlife and humans has been the subject of some recent investigations. Mourning Doves, for example, confuse shotgun pellets for grit and grain around hunted stock ponds and accordingly die in large numbers (Schulz et al. 2002). Harmata and Restani (1995) found lead in the blood of 97% of 37 Bald Eagles and 85% of 86 Golden Eagles captured as spring migrants in Montana during 1985–1993; they implicated lead bullet fragments in ground-squirrel carcasses as one source. Pattee et al. (1990) reported that among 162 free-ranging Golden Eagles captured during 1985–86 in southern California, 36% had been exposed to lead. Six of nine dead eagles in Japan died of lead poisoning, and five had lead bullet fragments in their stomachs (Iwata et al. 2000). Lead ingestion was a principal cause of recorded death in wild California Condors during the 1980s when the population was brought into captivity (Wiemeyer et al. 1988).

Field studies by The Peregrine Fund from 2000 to the present show that ingestion of lead rifle bullet fragments and shotgun pellets from animal remains is likely the only significant obstacle to the establishment of the California Condor in the wilds of Arizona and Utah. Evidence includes (1) high rates of lead exposure and required treatment, (2) the presence of lead fragments or shot in radiographs of condors and their food, and (3) temporal and spatial associations of condors with the remains of gun-killed animals (Parish et al. 2007, Hunt et al. 2006, 2007, Cade 2007). During the 2006 hunting season,

90% of 57 free-ranging condors showed evidence of lead exposure, and four died of it, including a proven breeder almost 12 years old. This represents an 11% mortality rate for birds five years old or older, a meaningful consideration given the high sensitivity of condor populations to mortality within the older age categories. The additional unknown proportion of condors that would have died without treatment renders doubtful the survival of the species in the wild without continuing, intensive management.

Close monitoring of condors by radio tracking and blood testing, together with ancillary studies of lead prevalence in gun-killed deer and other animals, have produced new insights regarding the pervasive nature of lead contamination in scavenger food webs. One must now consider, on a global scale, the scope of sickness, death, and demographic impact inflicted upon a myriad of species by a contaminant now easily substituted with less toxic alternatives. The invention of highly efficacious non-lead bullets and pellets during recent decades parallels the discovery of lead's widespread impact on wildlife and coincides with additional studies documenting lead's effects on humans at even very low levels. It is evident that conditions now favor large scale mitigation.

An important step in understanding this problem is the gathering of relevant knowledge and scientific progress on these important topics. Nowhere would such an assembly of facts and interpretation be more useful than in the proceedings of a conference of world experts. Accordingly, The Peregrine Fund and organizing partners, Boise State University, US Geological Survey, and Tufts Center for Conservation Medicine, brought such a group together in the conference "**Ingestion of Spent Lead Ammunition: Implications for Wildlife and Humans**" held in Boise, Idaho, 12–15 May 2008.

The conference was attended by over 150 experts from around the world in the fields of human health, wildlife health and conservation, policy, and shooting sports. The resulting proceedings include 25 reviewed papers, 18 reviewed extended abstracts, five program abstracts, and nine expert commentaries including the conference summary by Professor Ian Newton.

Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans, the proceedings of the conference, has been a collaborative effort. We thank our co-editors, Mark Fuller of the USGS and BSU Raptor Research Center, and Mark Pokras of Tufts University Veterinary School, Center for Conservation Medicine, for their critical partnership as peer editors of the proceedings and colleagues on the Scientific Program Committee of the conference. Their expert advice, experience in the field, and contacts over the year of work leading up to the conference were crucial for bringing together a unique diversity of professionals from fields that normally never meet. The depth, breadth, and diversity of conference participants were keys to its success.

We deliberated the choice between publishing papers in a recognized, abstracted scientific journal versus a book that may not receive the same level of readership and exposure.We chose to publish the proceedings as a book because we recognize the great value of the diversity of contributions from conference participants, and the likelihood that all would not meet the relevance criteria for inclusion in any one journal. The value of these proceedings resides in the mix of contributions that ranges from invited reviews to empirical studies, and a few anecdotal accounts. In format, contributions range from full papers to short notes, extended abstracts (with Tables, Figures, and citations), and program abstracts. Some extended abstracts have either been published elsewhere in full, or are slated for future publication with additional data. Three papers were reprinted with permission from the Wildlife Society Bulletin and PLoS ONE. The editorial team reviewed and edited all contributions for scientific and factual content. Papers beyond the technical and scientific expertise of the editorial team were sent out for external review. To expedite access to the important information in these papers, individual contributions were published separately online as soon as they were finalized, using the system of DOI numbers to permanently reference the early, online publications with the printed publication.

Readers of the vast literature on lead as an environmental contaminant encounter a confusing array of expressions pertaining to units of its concentration in blood and other tissues. Authors were asked to standardize expressions of blood concentration as µg/dL (micrograms per deciliter) and lead-in-tissue concentrations as µg/g (micrograms per gram). Where other units are used, readers can convert to these units by noting that a mass-to-volume blood lead level of 1 µg/dL is equivalent to 0.01 mg/l (milligrams per liter) or 0.048 µmol/l (micromoles per liter) or 10 ng/ml (nanograms per milliliter). For other tissues, 1 µg/g equals 1 ppm (part per million) or 1 mg/kg (milligram per kilogram). Help with other conversion issues can be obtained from http://www.onlineconversion.com/.

We thank the Conference Organizing Committee (Dominique Avery, Linda Behrman, Andrea Berkley, Kathy Bledsoe, Joell Brown, Patricia Burnham, Tom Cade, Bill Heinrich, J. Peter Jenny, Amy Siedenstrang, Rick Watson, Susan Whaley) and many volunteers and assistants for capably organizing the logistics of the conference. We especially thank David Dolton of the US Fish and Wildlife Service who took it upon himself to transcribe the comments of the expert panel, which we have included as contributions to the proceedings. We thank Amy and Mary Siedenstrang who typeset the text, tables, and graphics of the proceedings, and Terry Hunt who proofread the entire publication. We also express our sincere appreciation to the conference co-organizers, Boise State University, US Geological Survey, and Tufts Center for Conservation Medicine, and co-sponsors, the Charles Engelhard Foundation, National Park Service, Turner Foundation, and the National Aviary. Finally, we thank The Peregrine Fund, and in particular, Mr. and Mrs. Russell R. Wasendorf, Sr., for supporting the production of *Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans*, the proceedings of the conference.

Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans also would not have been possible without the enthusiastic participation of each and every contributor to the conference and proceedings. In the words of eminent scientist, Professor Ian Newton, "The meeting stands out among the many I have attended in the 45 years of my professional career as being one of a few really memorable and important ones in terms of both content and gravity of the problem discussed. I believe it could turn out, in the fullness of time, to have been a landmark conference, but this of course will be dependent on follow-up action from a range of people, including the public health delegates."

It is our hope that the findings and commentary brought forth during the conference and appearing in these proceedings will stimulate appropriate scientific and societal effort with respect to wildlife and human health.

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The Peregrine Fund
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