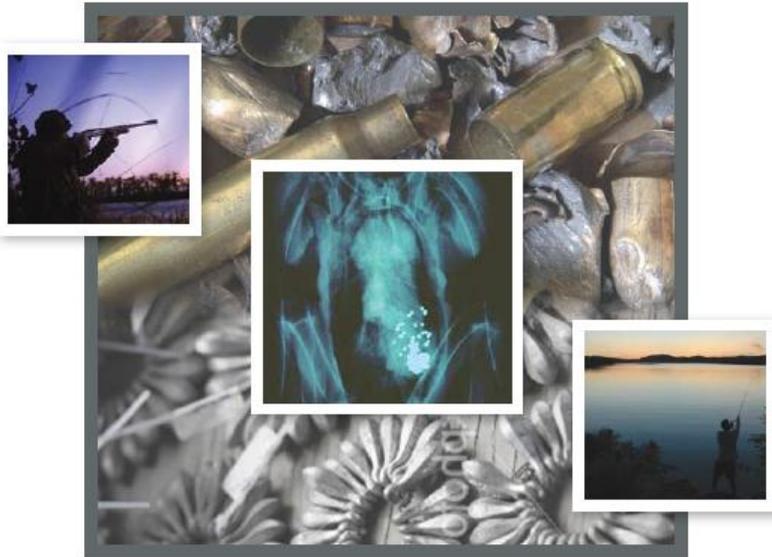


# Potential Hazards of Spent Lead Ammunition to Birds

Barnett A. Rattner, USGS

J. Christian Franson, USGS

John H. Schulz, ABC



## Sources and Implications of Lead Ammunition and Fishing Tackle on Natural Resources

Technical Review 08-01  
June 2008



### THE WILDLIFE SOCIETY

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#### Final Position Statement

#### Lead in Ammunition and Fishing Tackle

Lead has been used in ammunition and fishing tackle for centuries. It is an effective and inexpensive element for the manufacture of projectiles and weights. Although it is a naturally occurring element in the environment, lead has no functional or beneficial role in biological systems, and at very low levels of exposure it can be toxic, depending on the species and the health and age of an individual. At toxic levels lead damages the nervous system, causing paralysis and eventual death; at lower levels it is known to cause a variety of sublethal effects such as neurological damage, tissue and organ damage, and reproductive impairment.

Realization of the hazards of lead ammunition to waterfowl and some upland game birds can be traced to the late 1870s, while the hazards of lead fishing sinkers to waterfowl became apparent in the 1970s, when lead was found to poison swans in the United Kingdom (UK). In the 1970s and 1980s, the UK and some jurisdictions within the United States and Canada began placing restrictions on the use of lead ammunition and fishing tackle. Today lead from ammunition and fishing tackle provides a small fraction of total environmental releases, but it exists in a form that can be readily ingested by some species of wildlife.

Metallic lead can remain relatively stable and intact for decades, even centuries. However, under certain environmental conditions (e.g., acidic or basic water or soil) lead from shot or tackle can be readily released and taken up by plants or animals, causing a range of biochemical, physiological, and behavioral effects in some species of invertebrates, fish, amphibians, reptiles, birds, and mammals. Lead that is adsorbed or incorporated into food items through the soil, as well as lead fragments in carcasses or deposited at shooting sites, is known to be consumed by some birds and small mammals, resulting in elevated lead concentrations. Ingestion by reptiles, birds, and mammals of spent ammunition and lost fishing tackle has also been documented and can cause a range of negative effects in individuals, potentially leading to population-level consequences in some species (e.g., waterfowl, eagles, condors, mourning doves, and loons).

From a public health perspective, lead potentially can lead to a variety of human health problems, such as neurological effects and stunted growth, particularly in children. Although the extent is still unclear, recent research indicates that consumption of game taken with lead ammunition may increase blood-lead levels in humans. When lead that is imbedded in game meat becomes exposed to acid in the human stomach, lead may be absorbed into the system. Even if a lead pellet or bullet completely passes through an animal, a small amount of lead may be left in the tissue and may be absorbed by a person consuming the meat.

Lead poisoning related to spent ammunition and lost fishing tackle has been extensively studied in birds, and at least two studies indicate that the ban on the use of lead ammunition for hunting

Prepared by the USGS National Wildlife Health Center

## Lead Poisoning in Wild Birds

### Introduction

Lead in its various forms has been used for thousands of years, originally in cooking utensils and glazes and more recently in many industrial and commercial applications. However, lead is a potent, potentially deadly toxin that damages many organs in the body and can affect all animals, including humans. By the mid 1990s, lead had been removed from many products in the United States, such as paint and fuel, but it is still commonly used in ammunition for hunting upland game birds, small mammals, and large game animals, as well as in fishing tackle. Wild birds, such as mourning doves, bald eagles, California condors, and loons, can die from the ingestion of one lead shot, bullet fragment, or sinker.

According to a recent study on loon mortality, nearly half of adult loons found sick or dead during the breeding season in New England were diagnosed with confirmed or suspected lead poisoning from ingestion of lead fishing weights. Recent regulations in some states have restricted the use of lead ammunition on certain upland game hunting areas, as well as lead fishing tackle in areas frequented by common loons and trumpeter swans. A variety of alternatives to lead are available for use in hunting, shooting sports, and fishing activities.



*Radiograph showing a corroded lead fragment from a lead rifle bullet in the thoracic region of a mule deer (The Peregrine Fund).*

### Lead Ammunition Poisoning of Avian Predators and Scavengers

Lead ingestion and poisoning from ammunition sources has been documented in many avian predators and scavengers, such as bald and golden eagles, red-tailed hawks, and the California condor. These birds can be exposed to lead when they consume game birds or mammals that have been shot with lead ammunition. Lead pellets may remain intact in tissues and lead core rifle bullets may fragment into hundreds of pieces upon impact and can be found several inches from the site of the wound in large game mammals. When avian predators and scavengers consume the remains of big game in the field or animals that were shot with a lead bullet and not retrieved, the bullet or its fragments may be ingested and can result in lead poisoning.

To learn more about how lead bullets fragment, see the Minnesota Department of Natural Resources lead fragmentation study at <http://www.dnr.state.mn.us/hunting/lead/index.html>

Learn about "Ingestion of Spent Lead Ammunition: Implications for Wildlife and Humans," (The Peregrine Fund, 2008) at [http://www.peregrinefund.org/lead\\_conference/](http://www.peregrinefund.org/lead_conference/)

U.S. Department of the Interior  
U.S. Geological Survey



*Bald eagle on a deer carcass and bird eagles sick and dead from lead poisoning (Save Our Avian Resources).*



*Fact Sheet 2009-3051  
September 2009*

# Lead (Pb) Traps From the Past to Avoid in the Future

Educate, not regulate:  
compelling narrative

John H. Schulz  
Non-lead (Pb) Campaign  
Manager  
American Bird Conservancy



# Well-known facts about Pb...

- No known essential or beneficial role in biological systems
- Recognized as biocide in ancient Egypt
- Contributed to fall of Roman Empire
- Easy to mine
- Use increased in industrial revolution
- 3.6 million metric tons refined annually batteries, cable sheathing, pigments, chemicals
- Adverse human health effects (behavior, learning, physiological systems)

# Hunting, Shooting Sports: Direct Ingestion

Waterfowl, upland game birds, passerines  
Pb shot on hunting areas and clay target shooting  
areas



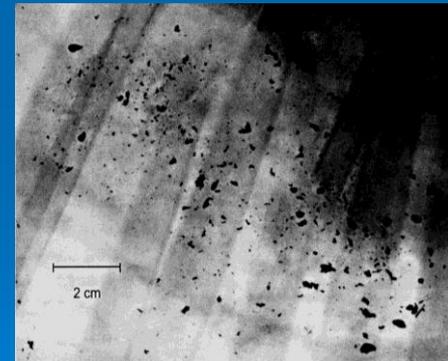


# Lead Ammunition Fragments Secondary Poisoning

- Ingested by eagles, condors, hawks, owls
- In carcasses of animals (deer, prairie dogs) killed by hunters 94% of deer killed with Pb bullets had hundreds of Pb fragments in clusters up to 30cm around wounds



Bullet jacket from bald eagle stomach



X-ray of deer carcass

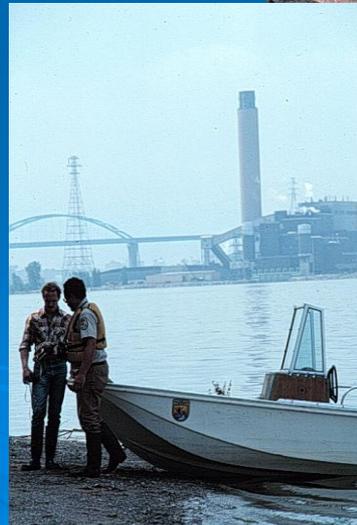
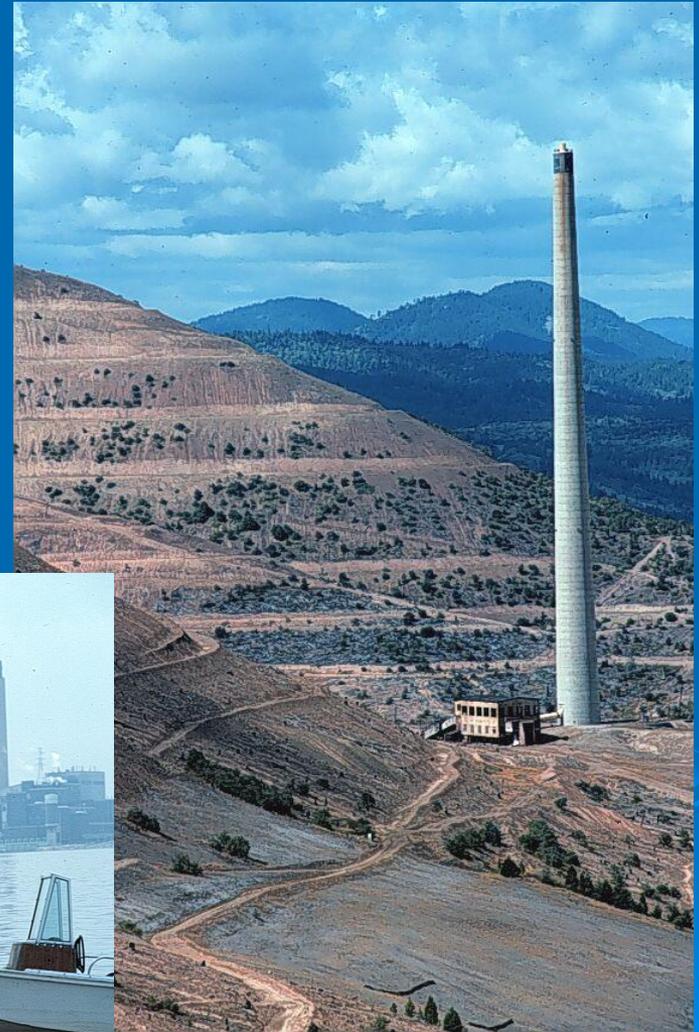
# Lead Fishing Weights in Waterbirds

Species most affected include loons, swans, pelicans, herons, cormorants



# Mining, Smelting, Industrial Sources

- Affects aquatic and terrestrial systems
- Sediment contaminated with lead
- Ingestion of sediment can poison waterfowl, other animals

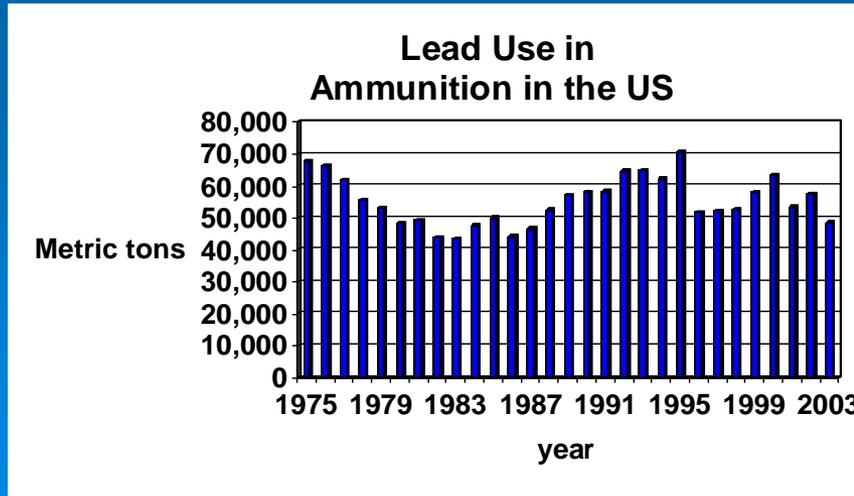


# Biogeochemistry and Physical Chemistry

- Atmospheric deposition is greatest input
- Limited quantities of  $\text{Pb}^{+2}$  in soil and water
- Elemental lead fragments are generally stable for years to decades, but...
  - acidic soft water
  - acidic sandy soil
- Pb in spent shot/lost tackle is less bioavailable than lead from atmospheric deposition and wastewater

# Lead ammunition by the numbers...

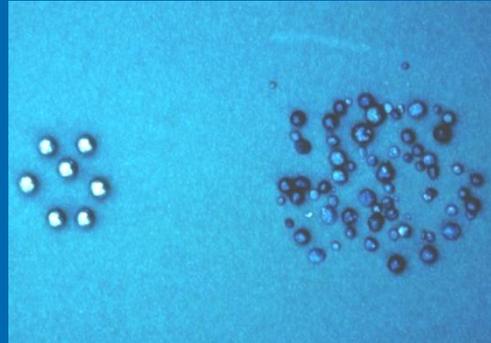
- Lead shot parallels gunpowder development
- Global Pb ammunition production ~200,000 tons
- ~2700 tons deposited US wetlands/yr prior to ban  
Up to 5,000,000 shot/ha
- ~9,000 non-military shooting ranges in US  
72,600 tons deposited in shooting ranges



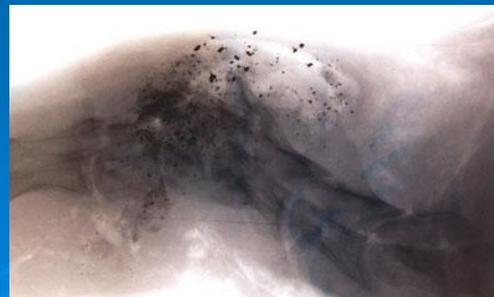
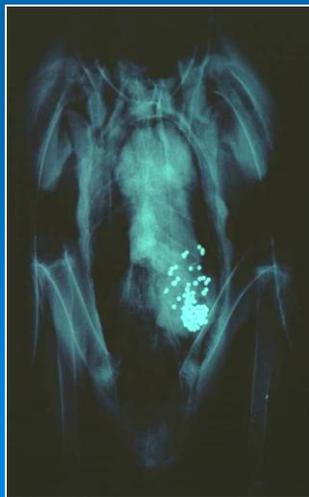
# Exposure Pathways

- Birds

-Ingestion of spent ammunition, tackle, “fragments”



-Secondary poisoning



# Some Pb shot history related to birds....

**1876** Pb-poisoning reported in pheasants on English game preserves

**1894** Pb-poisoning reported for waterfowl near Galveston *Forest and Stream*

**1919** Experimentally established the relation Pb shot ingestion-poisoning

**1950s** Illinois Nat. Hist. Survey - reports on Pb-poisoning in waterfowl

**1965** Mississippi Flyway Council recommended development nontoxic shot

**1970s** -IAFWA recommended FWS transition toward nontoxic shot for all migratory bird hunting

NWF petitioned DOI for similar regulation

-FWS publishes EIS on Pb-poisoning in waterfowl

-Polarization among states and within IAFWA - state-rights' not relevant at flyway ***Nationwide /Flyway-wide prohibition on use Pb shot is unnecessary/undesirable***

-Stevens Amendment to DOI appropriations bill prohibits USFWS implementation of nontoxic-shot regulation

**1980s** -Estimate of >2 million waterfowl dying annually from Pb-poisoning

-NWF sued FWS under the Bald Eagle Protection Act and ESA as eagles were feeding on dying Pb-poisoned waterfowl

-USFWS publishes ***Final Supplemental Environmental Impact Statement 5 Year phase out on use of Pb shot for waterfowl and coot hunting***

**>100 Years Elapsed**

# Toxicological Effects of Pb

- Neurological, neurobehavioral, development effects – humans
  - Impairs timing of cell-to-cell connection, neurotransmitter systems, inhibit Na,K-ATPase
- Peripheral Neuropathy – wristdrop, “wing droop”
  - Demyelination and axonal degeneration
- **Hematological Effects – anemia**
  - ↓RBC lifespan, impaired heme synthesis (inhibition of synthesizing enzymes, ALAD and ALA), accumulation of Zn protoporphyrin
- Nephrotoxicity
  - ↓energy dependent (mitochondrial) function in proximal tubules (glycosuria, ion transport)
- Increased Blood Pressure ( $\Delta$  sensitivity of smooth muscle)
- **Gastrointestinal Impaction**
- Reproductive Effects (gametes)
- Immunosuppression ?



# Some Clinical Signs – Lead Poisoning



Weight loss



Wing droop, weakness



Seeking cover



Green-stained feces

Often Chronic  
~3 wks to death  
(acute with large dose)

# Some Clinical Signs – Lead Poisoning



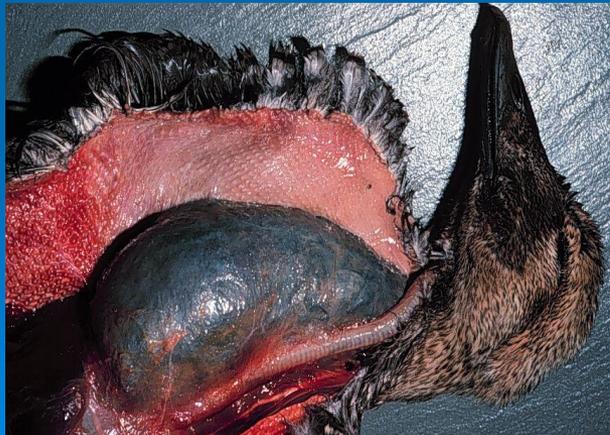
- Changes in blood measurements (within days)
- Anemia
- Low ALAD
- High protoporphyrin

# Some Gross Lesions – Lead Poisoning



Submandibular edema

Emaciation



Impacted esophagus



# Some Gross Lesions – Lead Poisoning



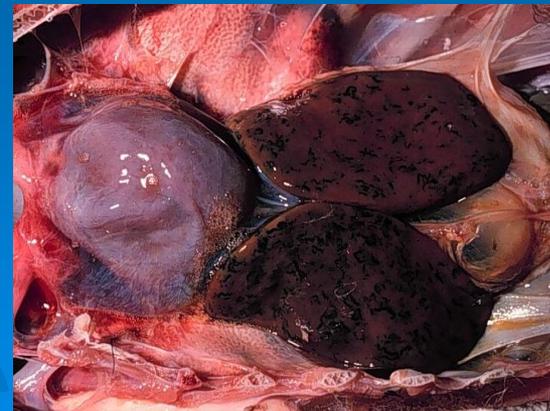
Enlarged gall bladder



Bile staining of tissues, vent



Infarctions in muscle



# Uptake of Ingested Pb fragments

- Shot retention in GI tract (and thus exposure) affected by type of food and grit
  - enhanced by grinding muscular gizzard
  - softer food with low fiber enhances passage of fragment
  - ↓pH enhances dissolution of fragments
  - ↓calcium (poor nutrition) enhances Pb absorption from GI tract
- Embedded shot or bullet fragments in muscle and skin does not generally result in Pb poisoning

# Matrices, Critical Concentrations and Biomarkers

Table 1. General criteria for lead poisoning in wild birds

	Blood		Liver		Bone
	wet weight µg/dL	wet weight µg/g or ppm	wet weight µg/g or ppm	dry weight µg/g or ppm	dry weight µg/g or ppm
Background	<20	<0.2	<2	<8	<10
Subclinical Poisoning	20 to <50	0.2 to < 0.5	2 to <6	>20	10 to 20
Clinical Poisoning	50 to 100	0.5 to 1	6 to 15		
Severe Clinical Poisoning	>100	>1	>15	>50	>20

Derived from Friend 1985, Pain 1996, and Franson and Pain 2011

Other Matrices: Kidney, Feathers

Biomarkers: RBC ALAD activity, Zn protoporphyrin

Other Measures: Pb isotope ratios (<sup>207</sup>Pb:<sup>206</sup>Pb) to discriminate ammunition vs. other sources

# Pb Poisoning: One of Many Risks for Survival and Recruitment vs. Population Effects

## Waterfowl-Bald Eagles

Pattee O.H., and S.K. Hennes. 1983. Bald eagles and waterfowl: the lead shot connection. Transactions of the 48<sup>th</sup> North American Wildlife and Natural Resources Conference. 48:230-237

-Contributed/drove ban of Pb shot for waterfowl hunting

Anderson, W.L., S.P. Havera, and B.W. Zercher. 2000. Ingestion of lead and nontoxic shotgun pellets by ducks in the Mississippi flyway. Journal of Wildlife Management 64:848-857.

-Gizzards of 16,651 ducks examined after “Nationwide conversion” to nontoxic shot

-Depending on species, 4.3% to 12.7% had ingested shot  
BUT...much of it was “Nontoxic Shot” (i.e., not Pb shot)

-Estimated that 1.4 million ducks spared from fatal Pb poisoning in the fall continental flight in 1997

# Lead Poisoning

## One of Many Risks for Survival and Recruitment

### Eagles

Kramer, J.L. and P.T. Redig. 1997. Sixteen years of lead poisoning in eagles, 1980-1995. an epizootiological review. *Journal of Raptor Research* 31:327-332

-Reduction in blood lead over time

-No change in prevalence of Pb poisoning scavenging on offal from hunter killed deer

Stauber et al. 2010. Lead poisoning of bald (*Haliaeetus leucocephalus*) and golden (*Aquila chrysaetos*) eagles in the US inland Pacific Northwest- An 18-year retrospective study: 1991-2008. *Journal of Avian Medicine and Surgery* 24:279-287.

~50% admitted had blood Pb levels considered toxic

-Most admitted at end of deer and elk hunting season

# Lead Poisoning

## One of Many Risks for Survival and Recruitment

### California Condor

Rideout, B.R. et al. 2012 Patterns of mortality in free-ranging California condors (*Gymnogyps californianus*). *Journal of Wildlife Diseases* 48:95-122.

Definitive causes of death determined in 76 of 98 cases

76 of 98 cases were anthropogenic

Nestlings: 8 of 11 instances were ingestion of trash

Juvenile: 13 of 50 instances were Pb

Adult: 10 of 15 instances were Pb

“...lead toxicosis was the primary cause of the decline of the historic California condor population through the mid- to late 20<sup>th</sup> century.”

# Lead Poisoning

## One of Many Risks for Survival and Recruitment

### California Condor

Finkelstein et al. 2012. Lead poisoning and the deceptive recovery of the critically endangered California condor. Proceedings of the National Academy of Sciences 109:11449-11454.

Even with management intervention, blood Pb levels in 30% of condors indicate subclinical poisoning ( $>20 \mu\text{g/dL}$ )

Annually 20% of the condors have blood Pb levels ( $>45 \mu\text{g/dL}$ ) that indicate the need for clinical intervention (chelation therapy)

J.H. Schulz - “If Pb exposure was removed from the range of the Condor it would still be an uphill battle...but one obstacle to recovery would be removed”

# What about other species of birds? “The Ongoing Debate over Lead”

Schulz et al. The Wildlife Professional 6:62-63, 2012

## Lead is Poison Coalition



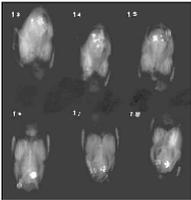
### Require non-toxic shot for dove hunting.

Protect our investments in wildlife and natural resources by keeping the non-toxic shot requirement for dove hunting.

- Wildlife and wildlife habitat are public resources.
- Lead ammunition poisons doves, pheasants, turkeys, ducks, swans, and more. 132 different wildlife species have been impacted by ingesting lead from ammunition.
- Upland game birds (like pheasants, turkey, quail, and doves), waterfowl (like ducks, geese, and swans), and songbirds can mistake lead shot for seeds or grit and eat it. One to two pieces of ingested lead shot is enough to kill a dove, duck, or cardinal.
- How much lead can be left on the ground? If five shots are taken for each of the estimated 300,000 doves harvested, and there is one ounce of lead per shot (16 ounces in one pound), there would be up to 9,375 pounds of lead left on the landscape.
- Doves are hunted over food plots. This concentrates lead shot in areas where doves and many other birds will be feeding, making them especially vulnerable to poisoning.



Lead shot mixed with seeds and grit material.



Lead shot ingested by mourning doves is apparent in these X-ray images. Note the bright areas indicating the dense lead shot. OK State University Extension Publication NR2EM-9015

- Research shows that, when lead shot is used for dove hunting, as many doves die from ingesting lead and lead poisoning as are harvested (3% of the population). Approximately, 17 million doves are harvested in the United States each year which means another 17 million die from lead poisoning.
- Non toxic shot has been required for waterfowl hunting for the last twenty years. Duck stamp sales are up 30% - a stamp is required to hunt ducks - so non-toxic requirement has not impacted the number of hunters.
- Research shows that millions of ducks have been saved from dying from lead poisoning by getting rid of lead shot. This is considered cost effective conservation, as it would be a huge dollar investment in habitat acquisition, maintenance, and management to produce one million ducks!
- National Wildlife Refuges require non-toxic shot for all hunting.

- Thirty-one states have requirements for non-toxic shot beyond the waterfowl requirement. Of these states, 24 have some form of non-toxic shot requirement for dove hunters.
- South Dakota requires non-toxic shot on most state land (totaling over 400,000 acres) and maintains the largest pheasant population in the country. Pheasants Forever says that South Dakota is the top destination for the traveling pheasant hunter.



## Mourning doves: estimates of the annual loss from Pb poisoning approximates the legal harvest (~18-24 million/yr)

Schulz et al. 2006. Will mourning dove crippling rates increase with nontoxic shot regulation? Wildlife Society Bulletin 34:861-865

# Ingested Lead **FRAGMENTS** in other Species (Ammunition and Tackle)

- **Fish**                      No evidence of spent ammunition ingestion  
                                    No evidence of mortality from lead
- **Amphibians**            No evidence of ingestion of spent lead  
                                    ammunition or lost tackle
- **Reptiles**                A few reports of ingested fishing sinker and jigs  
                                    Lead exposure and possible reproductive problems  
                                    in alligator colony fed nutria shot with lead
- **Mammals**                Captive bottlenose dolphin ingested air gun pellets  
                                    Numerous reports in man (children)

# What about....**Elemental Pb RELEASED** into the **environment** from ammunition/fishing tackle?

- **Water** Exceeds Criteria
- **Plants**  $\leq 5$  fold [Pb] elevation in roots  
reduced plant density in fall zone
- **Invertebrates** 10-100 fold [Pb] elevation
- **Fish** No data
- **Herps** Elevated tissue lead  
“may” impair development
- **Birds** Some evidence of exposure in passerines  
 $\uparrow$  protoporphyrin & bld Pb, sub-clinical effects
- **Mammals** Elevated tissue lead  
ALAD inhibition, histopathological lesions

# Regulations Lead Ammunition and Fishing Tackle

- **Lead Shot**



**Total bans on use over wetlands and for waterfowl hunting**

Canada	Denmark	Finland
Netherlands	Switzerland	US
Belgium	Cyprus	France
Hungary	Norway	Spain
Sweden	England	Scotland

Many countries have partial/voluntary bans

- **Lead Sinkers**

**Some restrictions on sale and use**

Canada	Denmark	Great Britain	US
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Monday  
December 1, 1997

## Part II

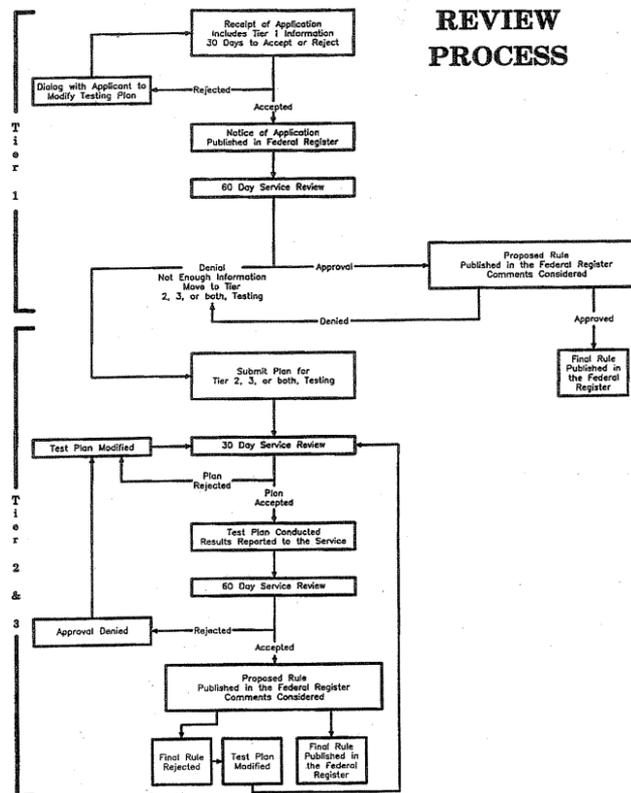
### Department of the Interior

Fish and Wildlife Service

50 CFR Part 20  
Migratory Bird Hunting: Revised Test  
Protocol for Nontoxic Approval  
Procedures for Shot and Shot Coating;  
Final Rule

63607

## REVIEW PROCESS



6

BILLING CODE 4310-66-C

# Alternatives to lead

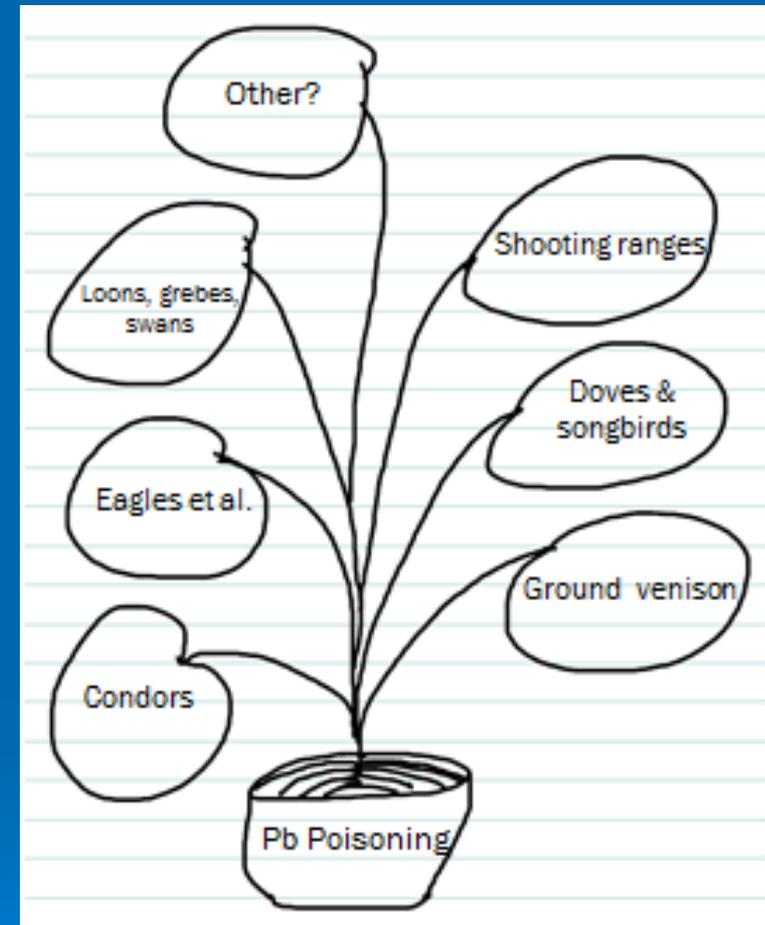
- **Shot**
  - steel
  - tungsten-bronze
  - tungsten-matrix
  - tungsten-polymer
  - tungsten-tin-iron
  - zinc
  - bismuth-tin
  - tungsten-iron
  - tungsten-nickel-iron
  - tungsten-tin-bismuth
  - tungsten-tin-iron-nickel
- **Bullets**
  - copper
  - tungsten core
  - copper-tin
- **Sinker/jigs**
  - stainless steel
  - tin
  - ceramic
  - pewter
  - brass
  - carbon steel
  - tin-bismuth
  - glass
  - tungsten composite
  - zinc

# Some recommendations...

- **Alternative Materials – Ongoing but slow**  
Test the “safety” (i.e., determine toxicity) of candidate materials  
Advocate the use of safe alternatives
- **Education and Outreach – Ongoing !**  
Communicate hazards of lead ammunition and fishing tackle  
Communicate availability & ecological benefits of alternatives

# The Big Picture of Pb Poisoning

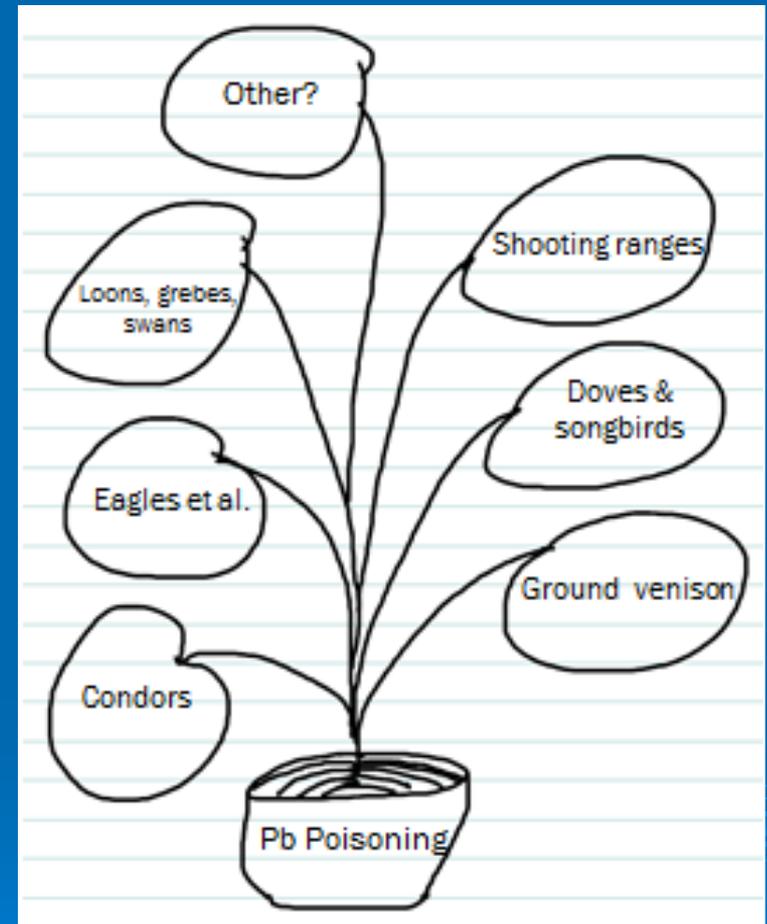
- ✓ Pb-poisoning resulting from traditional Pb-based hunting ammunition and fishing tackle is a complex and multifaceted problem.
- ✓ Each sub-problem is difficult by itself; together they appear unsolvable if not impossible (put yourself in the position of state director or high level federal policy maker faced with this problem).
- ✓ Using reductionist thinking, we can parse issues apart and think about each element individually, and begin solving the problem one element at a time.



Graciously provided by John H. Schulz,  
Non-lead (Pb) Campaign Manager, ABC

# Multiple Problems

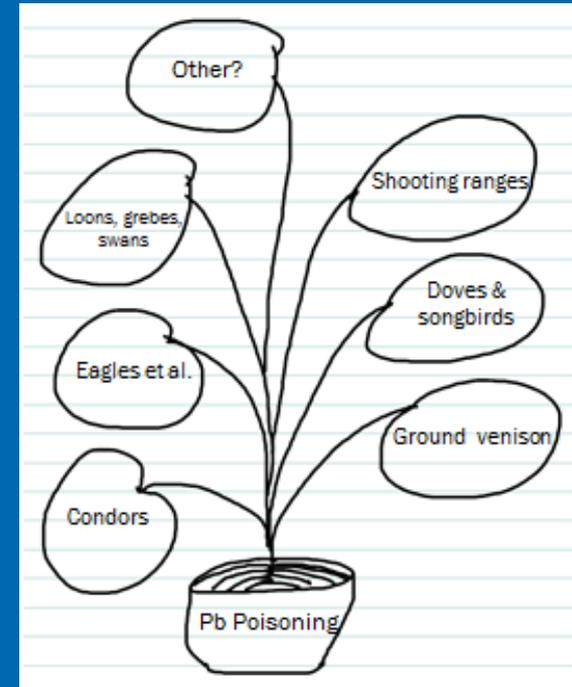
- ✓ **Condor** range and gut-piles laced with Pb-fragments. Non-Pb ammunition regulation in CA and AZ has a voluntary program; problems continue because the far-ranging birds don't follow state boundaries.
- ✓ Other avian scavengers and raptor species (e.g. bald eagles, turkey vultures, and ravens) also feed on big-game gut-piles all across the country. Small animal carcasses laced with Pb-bullet fragments resulting from varmint hunting are eaten by these same birds.
- ✓ Exposure is an issue for hunters, their families, friends, and recipients of wild-game meat at food pantries.



Graciously provided by John H. Schulz,  
Non-lead (Pb) Campaign Manager, ABC

# Multiple Problems

- ✓ Mourning doves and surface-feeding songbirds using managed shooting fields, and legacy concerns on public lands due to the volume of shot deposited (up to 52,000 Pb pellets/acre has been estimated on some fields; ~18–24 million mourning doves poisoned annually)
- ✓ Lost Pb-based fishing tackle and ingestion by loons, grebes, cormorants, and other fish eating birds in Great Lakes region and northeastern states. Trumpeter and tundra swans exposed to lost tackle and legacy Pb-shot from historical waterfowl hunting.
- ✓ Pb on rifle ranges can be “recycled” but costs are high. However, shotgun ranges with trap, skeet, and sporting-clay shooting are often located near attractive wildlife habitats (e.g., wetlands, or forest edge).



Graciously provided by John H. Schulz,  
Non-lead (Pb) Campaign Manager, ABC

# Policy-Making & Additional Research

- ✓ Sufficient reliable information exists to explicitly **define the big-picture problem and each sub-problem**, and sufficient information exists to **begin dialogs** about identifying possible solutions and policy strategies (with implementation several years away if necessary).
- ✓ It is critical for all stakeholders to understand that the need for additional research should not be used as a ***stalling tactic*** or ***displacement behavior***.
- ✓ Future research should help inform policy development and implementation, not to further substantiate if a problem exists (a favorite stalling tactic by some stakeholders claiming ***unsettled science***).

Graciously provided by John H. Schulz,  
Non-lead (Pb) Campaign Manager, ABC

Questions?

Discussion