HB23- 1036 - Summary of Information Contained in this Packet

Lead poisoning in eagles on the rise due to hunting, fishing gear

Takeaway: Forty to fifty percent of bald and golden eagles in the United States are carrying chronic levels of lead.

Lead Exposure Through Eating Wild Game - The American Journal of Medicine

Takeaway: "As many as 7.7% of children that eat wild game harvested with lead bullets will experience a reduction of one IQ point."

Health Risks from Lead-Based Ammunition in the Environment – Consensus Statement of 30 Scientists

Takeaway: "Based on the overwhelming evidence for the toxic effects of lead in humans and wildlife, even at very low exposure levels, convincing data that the discharge of lead ammunition into the environment poses significant risk of lead exposure to humans and wildlife."

Environmental Research **- Hunting with lead: Association between blood lead levels and wild game consumption**

Takeaway: "(P)ersons who consumed wild game had 0.30 µg/dl (95% confidence interval: 0.16–0.44 µg/dl) higher PbB than persons who did not."

Colorado Department of Health & Environment -Lead in wild Harvested game

Takeaway: "Children and pregnant people are more vulnerable to lead poisoning and should not eat any game harvested with lead bullets. The number one thing hunters can do to protect themselves and their families is to only use lead-free ammunition."

Science of the Total Environment **- Are lead-free hunting rifle bullets as effective at killing wildlife as conventional lead bullets? A comparison based on wound size and morphology**

Takeaways: "This study demonstrates that lead-free bullets are equal to conventional hunting bullets in terms of killing effectiveness and thus equally meet the welfare requirements of killing wildlife as painlessly as possible. The widespread introduction and use of lead-free bullets should be encouraged as it prevents environmental contamination with a seriously toxic pollutant and contributes to the conservation of a wide variety of threatened or endangered raptors and other members of the guild of scavengers."

Lead poisoning in eagles on the rise due to hunting, fishing gear

by Miya Ingle

Monday, February 6th 2023

Sixteen years after America's national was removed from the endangered species list, the population of eagles is once again being affected. (Janice Johnson)

GRAND TRAVERSE COUNTY, Mich., (WPBN/WGTU) -- 16 years after America's national bird was removed from the endangered species list, the population of eagles is once again at risk.

Increased exposure to a toxic material is posing a threat to the magnificent creature.

"Forty to fifty percent of bald and golden eagles in the United States are carrying chronic levels of lead," Skegemog Raptor Center Executive Director James Manley said.

In 2022, the Skegemog Raptor Center in Traverse City began testing eagles that were admitted for rehabilitation.

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Lead Exposure Through Eating Wild Game

People generally reject the idea of injecting toxic substances into food, except when it involves hunting wild game. Perhaps surprising to nonhunters, up to 95% of hunters use lead projectiles,[1] despite nonlead projectiles offering a suitable alternative (**Figure**).[2] The use of nonlead projectiles eliminates lead exposure experienced through eating wild game. Hunters are not averse to using lead-free projectiles: when hunters were given free copper projectiles, 77% used these nontoxic projectiles.[3] Physicians are in a unique position to explain the risks of lead exposure to hunting patients and their families and also explain the option of using nonlead projectiles.

Eighty percent of ground meat packages of wild-harvested deer contain lead[4] and this lead is bioavailable.[5] Eating meat harvested with lead projectiles increases serum lead levels,[6,7] and while it has been suggested that the tissue from around the wound channel can be discarded to reduce lead exposure,[8] there are an average of 356 metal fragments in a deer carcass after being shot with a lead projectile from a rifle.[9] This is an impossible number of fragments to pick out by hand, especially because some of these fragments are microscopic.[9] Regularly eating game birds harvested with lead shot may exceed World Health Organization lead intake limits,[10] and regular consumption of large game shot with lead bullets using a rifle is likely to exceed World Health Organization lead intake limits.[1] It is important to keep in mind that the California condor nearly went extinct largely from lead poisoning as a result of scavenging lead-shot carrion.[11] Medically, it is clear that eating wild game harvested with lead projectiles increases lead serum levels.

As lead is one of the few substances that does not have a safe level of exposure, it is important to prevent all lead exposure. Lead has negative consequences for nearly every major physiologic system, with the central nervous system being the system classically impacted. Very low levels of lead exposure result in neurologic impairments,[12] and as many as 7.7% of children that eat wild game harvested with lead bullets will experience a reduction of one IQ point.[13] That magnitude of a reduction in IQ translates into a decreased lifetime earnings value of between £1319 (2042 USD) and £11,967 (18,528 USD).[14]

Particularly because there are readily available suitable projectile alternatives to lead, such as copper,[2] limiting the use of lead projectiles for hunting is reasonable, and California has moved to ban all lead projectiles for hunting by 2019.[15] Physicians need to be proactive in sharing with their patients the risks of potential lead exposure through eating wild game. Often when I explain to hunters the risks associated with lead exposure, especially when considering their

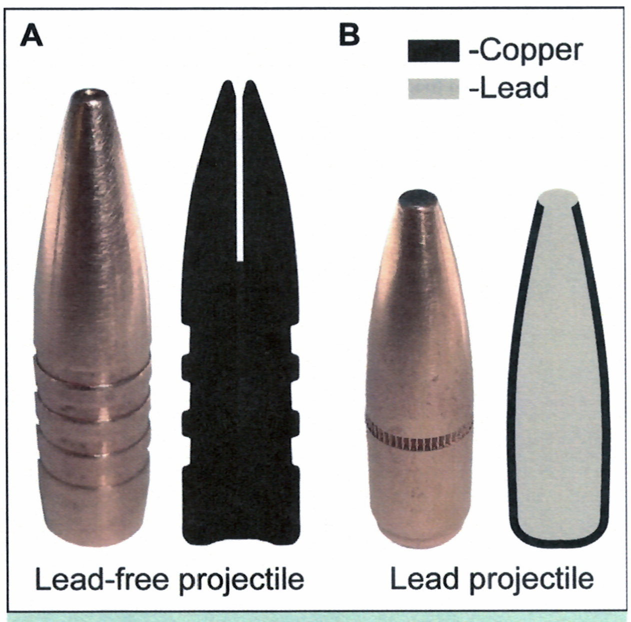

Figure Examples of 0.30-caliber, 165-grain lead and lead-free rifle projectiles and illustrations of projectile cross-section. A typical solid-copper projectile (**A**) is longer than a copper-jacketed lead projectile (**B**) for the same caliber because of the greater density of lead than copper. Both projectiles are designed to expand on impact; however, the lead projectile typically disintegrates into hundreds of fragments while the copper projectile retains nearly all of its mass. These lead fragments are the source of lead ingested when eating wild game. Nearly all lead hunting projectiles have a copper jacket to reduce lead fouling of the firearm barrel, which occurs with pure lead projectiles.

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Requests for reprints should be addressed to Eric J. Buenz, PhD, Nelson Marlborough Institute of Technology, 322 Hardy Street, Nelson 7010, New Zealand.
E-mail address: Eric.Buenz@nmit.ac.nz

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Health Risks from Lead-Based Ammunition in the Environment

A Consensus Statement of Scientists

March 22, 2013

We, the undersigned, with scientific expertise in lead and environmental health, endorse the overwhelming scientific evidence on the toxic effects of lead on human and wildlife health. In light of this evidence, we support the reduction and eventual elimination of lead released to the environment through the discharge of lead-based ammunition, in order to protect human and environmental health.

1) Lead is one of the most well-studied of all anthropogenic toxins and there is overwhelming scientific evidence that demonstrates:
   a) Lead is toxic to multiple physiological systems in vertebrate organisms, including the central and peripheral nervous, renal, cardiovascular, reproductive, immune, and hematologic systems. Lead is also potentially carcinogenic; lead is officially recognized as a carcinogen and reproductive toxin in California, and the International Agency for Research on Cancer, the National Toxicology Program, and the US Environmental Protection Agency have identified lead as likely to be carcinogenic to humans.
   b) There is no level of lead exposure to children known to be without deleterious effects (CDC, 2012). Exposure in childhood to even slightly elevated levels of lead produce lasting neurological deficits in intelligence and behavior.
   c) Lead is also known to be toxic across different vertebrate organisms, including mammalian and avian species.

2) Lead-based ammunition is likely the greatest, largely unregulated source of lead knowingly discharged into the environment in the United States. In contrast, other significant sources of lead in the environment, such as leaded gasoline, lead-based paint, and lead-based solder, are recognized as harmful and have been significantly reduced or eliminated over the past 50 years.
   a) Lead-based ammunition production is the second largest annual use of lead in the United States, accounting for over 60,000 metric tons consumed in 2012, second only to the consumption of lead in the manufacture of storage batteries (USGS, 2013).
   b) The release of toxic lead into the environment via the discharge of lead-based ammunition is largely unregulated. Other major categories of lead consumption, such as leaded batteries and sheet lead/lead pipes, are regulated in their environmental discharge/disposal.

3) The discharge of lead-based ammunition and accumulation of spent lead-based ammunition in the environment poses significant health risks to humans and wildlife. The best available scientific evidence demonstrates:
   a) The discharge of lead-based ammunition substantially increases environmental lead levels, especially in areas of concentrated shooting activity (USEPA ISA for Lead draft report, 2012).
   b) The discharge of lead-based ammunition is known to pose risks of elevated lead exposure to gun users (NRC, 2012).
   c) Lead-based bullets used to shoot wildlife can fragment into hundreds of small pieces, with a large proportion being sufficiently small to be easily ingested by scavenging animals or incorporated into processed meat for human consumption (Pauli and Burkirk, 2007; Hunt *et al.*, 2009; Knott *et al.*, 2010).

Michael Fry, PhD
Research Physiologist (retired)
Department of Avian Sciences
University of California, Davis
Davis, CA 95616

Rhys E. Green, PhD
Professor of Conservation Science
University of Cambridge
Department of Zoology
Downing Street
Cambridge CB2 3EJ
United Kingdom

Howard Hu, MD, MPH, ScD
Director & Professor
Dalla Lana School of Public Health
University of Toronto
Toronto, ON M5T 3M7
Canada

David E. Jacobs, PhD, CIH
Research Director, National Center for Healthy Housing
Adjunct Associate Professor, University of Illinois at Chicago School of Public Health
Washington DC 20016

Christine Johnson, DVM, PhD
Associate Professor of Ecosystem Health and Epidemiology
School of Veterinary Medicine, Wildlife Health Center
University of California, Davis
Davis, CA 95616

Terra Kelly, DVM, PhD, Dipl. ACZM
Wildlife Veterinarian and Epidemiologist
School of Veterinary Medicine, Wildlife Health Center
University of California, Davis
Davis, CA 95616

Michael Kosnett, MD, MPH
Associate Clinical Professor
Division of Clinical Pharmacology & Toxicology
Department of Medicine, University of Colorado School of Medicine
Department of Environmental and Occupational Health,
Colorado School of Public Health
Aurora, CO 80045

Philip J. Landrigan, MD, MSc
Dean for Global Health
Ethel H. Wise Professor and Chairman
Department of Preventive Medicine
Professor of Pediatrics
Director, Children's Environmental Health Center
Mount Sinai School of Medicine
New York, NY 10029

Bruce Lanphear, MD, MPH
Clinician Scientist, Child & Family Research Institute
BC Children's Hospital Professor
Simon Fraser University
Vancouver, BC V6H 3N1
Canada

Howard W. Mielke, PhD
Professor
Department of Pharmacology
Tulane University School of Medicine
New Orleans, LA 70112

Ian Newton, D.Sc, OBE, FRS, FRSE
Emeritus Fellow,
Centre for Ecology & Hydrology
Benson Lane, Crowmarsh Gifford
Wallingford, Oxon OX10 8BB
United Kingdom

Mark A. Pokras, DVM
Associate Professor
Wildlife Clinic & Center for Conservation Medicine Tufts University
Cummings School of Veterinary Medicine
N. Grafton, MA 01536

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Hunting with lead: Association between blood lead levels and wild game consumption

Shahed Iqbal [a,b,*], Wendy Blumenthal [c], Chinaro Kennedy [c], Fuyuen Y. Yip [b], Stephen Pickard [d,e], W. Dana Flanders [f,h], Kelly Loringer [a], Kirby Kruger [e], Kathleen L. Caldwell [g], Mary Jean Brown [c]

[a] Epidemic Intelligence Service, Office of Workforce and Career Development, Centers for Disease Control and Prevention, USA
[b] Air Pollution and Respiratory Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, USA
[c] Lead Poisoning Prevention Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, USA
[d] Office of Science and Public Health Practice, Coordinating Office of Terrorism Preparedness and Emergency Response, Centers for Disease Control and Prevention, USA
[e] North Dakota Department of Health, USA
[f] Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention, USA
[g] Division of Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention, USA
[h] Emory University, Atlanta, GA

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ABSTRACT

Background: Wild game hunting is a popular activity in many regions of the United States. Recently, the presence of lead fragments in wild game meat, presumably from the bullets or shot used for hunting, has raised concerns about health risks from meat consumption.
Objective: This study examined the association between blood lead levels (PbB) and wild game consumption.
Methods: We recruited 742 participants, aged 2–92 years, from six North Dakota cities. Blood lead samples were collected from 736 persons. Information on socio-demographic background, housing, lead exposure source, and types of wild game consumption (i.e., venison, other game such as moose, birds) was also collected. Generalized estimating equations (GEE) were used to determine the association between PbB and wild game consumption.
Results: Most participants reported consuming wild game (80.8%) obtained from hunting (98.8%). The geometric mean PbB were 1.27 and 0.84 μg/dl among persons who did and did not consume wild game, respectively. After adjusting for potential confounders, persons who consumed wild game had 0.30 μg/dl (95% confidence interval: 0.16–0.44 μg/dl) higher PbB than persons who did not. For all game types, recent (<1 month) wild game consumption was associated with higher PbB. PbB was also higher among those who consumed a larger serving size (≥2 oz vs. <2 oz); however, this association was significant for 'other game' consumption only.
Conclusions: Participants who consumed wild game had higher PbB than those who did not consume wild game. Careful review of butchering practices and monitoring of meat-packing processes may decrease lead exposure from wild game consumption.

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1. Introduction

Wild game hunting is a popular leisure time activity with substantial economic impact in many regions of the country. There are 18.6 million hunters 16 years or older in the United States, 12.5 million of whom were engaged in hunting activities in 2006. In 2006 alone, expenditures associated with hunting were estimated to be approximately $23 billion (US Department of Interior, Fish and Wildlife Service (FWS), 2006). Nationally, the West North Central region (Kansas, Iowa, Minnesota, Missouri, Nebraska, North Dakota, South Dakota) has the highest rate of participation in hunting activities among those ≥16 years of age (12%) compared to any other regions (2–8%) in the United States or the overall national rate (5%) (FWS, 2006). Although the wild game is predominantly consumed by hunters and their families, a large amount is also donated to the local charitable organizations, serving as a source of protein for many low-income families through the *Sportsmen*

Abbreviations: PbB, blood lead levels; FWS, Fish and Wildlife Services; ATSDR, Agency for Toxic Substance and Disease Registry; MN DNR, Minnesota Department of Natural Resources; CDC, Centers for Disease Control and Prevention; GEE, generalized estimating equations

* Corresponding author at: Air Pollution and Respiratory Health Branch, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Chamblee, GA 30341, USA. Fax: +1 770 488 1540.
E-mail addresses:
SIqbal@cdc.gov, iqbalshahed@yahoo.com (S. Iqbal).

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(Perkin-Elmer SCIEX, Concord, Ontario, Canada) equipped with a Minehart nebulizer and cyclonic spray chamber. During analysis of whole blood samples, two bench quality control pools were analyzed along with 'blind' quality control pools interspersed among the participant samples. Accuracy of analysis results was verified by the analysis of standard reference material (SRM 955 c) from the National Institute of Standards Technology (National Institute of Standards Technology, 2009). The minimum detection level for blood lead was 0.25 µg/dl. For persons with no detectable levels of blood lead ($n = 5$), a value calculated as the detection limit divided by the square root of 2 was assigned (National Center for Environmental Health, 2001).

2.4. Statistical analysis

Frequencies and proportions were reported for all variables: socio-demographic and housing characteristics; lead-related occupations and hobbies; and wild game consumption, including type, frequency, and average serving size. Geometric mean lead levels and frequency for PbB ≥5 µg/dl were reported. To account for potential clustering within families, generalized estimating equation (GEE) methods were used to determine unadjusted and adjusted associations between PbB and other variables using SAS software (version 9.1, Copyright © SAS Institute, Inc., 2002–2003, Cary, NC, USA). Separate GEE models were developed by types of wild game (i.e., venison, other game, birds) to determine the association between frequency, duration, average food serving size, and PbB. Age, sex, race, and income, commonly reported predictors of elevated PbB, were included in the multivariate model based on a priori considerations. Additional variables were included in the multivariate model only if those variables were significant (p-value <0.05) in unadjusted models. Parameter estimates with 95% confidence intervals and significance levels were reported for all models. Two-way interactions with the exposure variable (e.g., consumption of wild game) were considered in multivariate models.

3. Results

3.1. Study population

Almost half of the participants (48.2%) were ≥55 years of age. Participation among males (54.3%) was higher than among females (Table 1). Participants were almost exclusively white (98.4%). The majority of the study participants (65.5%) had at least college degrees and most participants (78%) reported an annual household income of at least $40,000.

In addition to socio-demographic information, we also collected information on housing characteristics. Most of the residences of the participants were built in or after 1950 (83.9%). More than half of the participants reported living in the same household for >10 years (53.5%) and had some renovation done on the home while they were living there (54%). Most participants did not observe any peeling paint inside or outside their homes (85.8%).

Exposure to lead can also occur as a result of particular occupations or hobbies. Approximately 13% of the participants reported that they were currently engaged in at least one lead-related occupation, while another 36.6% reported that they previously had such an occupation (Table 1). Most of the participants (64%) reported currently having at least one lead-related hobby, and 56.3% reported previously having lead-related hobbies. Approximately 22.4% of participants had family members with at least one lead-related occupation, and most (55.5%) reported at least one family member with lead-related hobbies.

3.2. Laboratory results

Among all participants, the geometric mean PbB was 1.17 µg/dl (Table 1); 1.1% ($n = 8$) had PbB ≥5 µg/dl, and none exceeded the Centers for Disease Control and Prevention's level of concern of 10 µg/dl (PbB range of participants: 0.18–9.82 µg/dl). The geometric mean PbB were 1.27 µg/dl (range: 0.18–9.82 µg/dl) and 0.84 µg/dl (range: 0.18–3.92 µg/dl) among persons who did and did not consume wild game, respectively.

Table 1
Characteristics of the study participants ($N = 736$).

Variables	n (%)
Age (years)	
2–5	5 (0.7)
6–14	11 (1.5)
15–24	21 (2.9)
25–34	78 (10.6)
35–44	89 (12.1)
45–54	177 (24.0)
55–64	202 (27.4)
65 or more	153 (20.8)
Male sex	400 (54.3)
White race	723 (98.4)
Education	
Less than high school	12 (1.6)
High school graduate or equivalent	75 (10.2)
Some college	167 (22.7)
College grad or more	482 (65.5)
Income	
Less than $15,000	10 (1.5)
$15,000–$24,999	38 (5.5)
$25,000–$39,999	104 (15.0)
$40,000 or more	540 (78.0)
House construction year	
1949 or before	118 (16.1)
1950 to 1977	296 (40.6)
1978 or after	316 (43.3)
Duration of living in current residence	
2 months or less	7 (0.9)
3 months to a year	37 (5.0)
≥1–5 years	164 (22.2)
≥5–10 years	135 (18.2)
>10 years	396 (53.5)
House renovation/remodeling	
No renovation done	336 (46.0)
Currently undergoing renovation	42 (5.7)
Done within the last 12 months	75 (10.3)
Done beyond the last 12 months	278 (38.0)
House has peeling paint or paint chips	**104 (14.2)**
Have lead-related occupations[a]	**93 (13.0)**
Had lead-related occupations	**262 (36.6)**
Household members with any lead-related occupations	**164 (22.4)**
Have lead-related hobbies[b]	**471 (64.0)**
Had lead-related hobbies	**414 (56.3)**
Household members with any lead-related hobbies	**408 (55.5)**
Geometric mean PbB (µg/dl)	**1.17**

[a] Auto repair, battery manufacture/repair, construction, home construction/painting, working in lead smelter/refinery/mine, plumbing or pipe fitting, radiator repair, welding, working in brass/copper foundry, gas station attendant, military/police officer, etc.

[b] Car/boat repair, casting (bullets, fishing weights, etc.), casting lead figures (toys, soldiers), furniture finishing, home remodeling/paint job, hunting, jewelry making, lead soldering, pottery/stained glass making, reloading, target shooting, welding, etc.

3.3. Wild game consumption

Approximately 80.8% ($n = 594$) of the participants reported consuming at least one type of wild game (i.e., venison, other game, birds), of whom 86.4% ($n = 513$) reported consuming more than one type (Table 2). Among those who consumed wild game, almost all reported consuming venison (98.8%), and 64.7% and 84.3% reported consuming other game and birds, respectively. Study participants indicated that they primarily hunted the wild game they consumed, or else that it was hunted by family members or by friends (98.8%). Most of these participants (81.8%) reported that the meat was processed by themselves or family members. Some of the participants also reported having some of wild game consumption and other variables were considered in the model (data not shown). For all three game types, participants with more recent (<1 month) wild game consumption had higher PbB (Table 5). Among those who reported consuming other game, a 0.40 μg/dl increase in PbB was associated with having an average serving size of ≥2 oz, compared with those who consumed a lesser amount (Table 5).

Table 4
Geometric mean (μg/dl) and associations between PbB and other variables in multivariate generalized estimating equations (GEE) model[a] ($N = 736$).

Variables	Geometric mean (μg/dl) (95% CI)	Parameter estimates (95% CI)
Age		
2–5 years	0.88 (0.66, 1.11)	−0.84 (−1.12, −0.56)††
6–24 years	0.60 (0.41, 0.79)	−1.11 (−1.52, −0.71)††
25–44 years	0.75 (0.65, 0.85)	−1.05 (−1.30, −0.80)††
45–65 years	1.29 (1.23, 1.35)	−0.44 (−0.68, −0.20)†
65 years or more	1.77 (1.69, 1.85)	Ref.
Sex		
Male	1.49 (1.43, 1.54)	0.28 (0.08, 0.48)*
Female	0.89 (0.81, 0.96)	Ref.
House construction year		
1978 or after	1.00 (0.93, 1.07)	Ref.
1950–1977	1.31 (1.24, 1.38)	0.19 (0.02, 0.37)*
1949 or before	1.39 (1.27, 1.50)	0.43 (0.16, 0.70)*
Current lead-related hobbies		
No	0.88 (0.81, 0.96)	Ref.
Yes	1.38 (1.32, 1.44)	0.34 (0.17, 0.50)††
Consumes wild game		
No	0.84 (0.74, 0.94)	Ref.
Yes	1.27 (1.22, 1.33)	0.30 (0.16, 0.44)††

*p-value<0.05; †p-value<0.001; ††p-value<0.0001.

[a] After adjusting for race, education, income, home renovation/remodeling, duration of living in the current home, current and previous lead-related occupations, previous lead-related hobbies, household members with lead-related hobbies or occupations.

4. Discussion

In this study, the consumption of wild game was significantly associated with an increase (0.30 μg/dl) in PbB. Another study reported a similar increase for adults consuming two game meat meals per week containing 1 μg/g lead using a lead biokinetic model (Kosnett, 2008). The observed increase in our study could not be attributed to one single game type, since there was substantial overlap in the types of wild game that the participants reported consuming. Previous studies have also reported difficulty in teasing out the effects of any single type of game due to diet habits of participants and collinearity between consumption of different kinds of game (Kosatsky et al., 2001; Tsuji et al., 2008b). However, no linear increase in PbB was observed with an increase in the number of wild game types consumed. Nevertheless, after adjusting for other factors, the associated increase in PbB was significant ($p<0.05$) and highest among participants who consumed all three game types (i.e., venison, other game, and birds) (data not shown).

Recent lead isotope ratio studies reported that wild game meat can be contaminated by lead fragments from ammunition sources, which can contribute significantly to PbB (Tsuji et al., 2008a, 2008b, 2009). Hunt et al. (2009) reported that in venison-fed pigs, lead fragments in contaminated meat were present in bioavailable form and significantly increased blood lead concentration. This has important public health implications as previous studies have consistently reported wild game birds as a significant source of population PbB (Scheuhammer et al., 1998; Odland et al., 1999;

Table 5
Multivariate-adjusted association between PbB and frequency, proportion, and duration of wild game consumption by game type[a]

Variables	Parameter estimates (95% CI)		
	Venison ($N = 584$)	Other game ($N = 378$)	Birds ($N = 494$)
Consumption in a given year			
Occasionally	Ref.	Ref.	Ref.
Hunting season only	−0.01 (−0.54, 0.51)	0.07 (−0.28, 0.42)	0.16 (−0.06, 0.38)
All year round	0.01 (−0.27, 0.28)	−0.01 (−0.33, 0.31)	0.15 (−0.12, 0.42)
Consumption in a given month			
<1 time/week	Ref.	Ref.	Ref.
1–3 times/week	0.08 (−0.14, 0.30)	−0.07 (−0.38, 0.23)	0.05 (−0.21, 0.32)
>3 times/week	0.15 (−0.13, 0.43)	−0.19 (−0.71, 0.32)	0.02 (−0.64, 0.67)
Most recent consumption			
<1 month ago	Ref.	Ref.	Ref.
1–6 months ago	−0.18 (−0.48, 0.11)	−0.46 (−0.79, −0.13)*	−0.28 (−0.52, −0.04)*
>6 months ago	−0.34 (−0.66, −0.01)*	−0.38 (−0.73, −0.03)*	−0.36 (−0.64, −0.08)*
Most often processed			
Ground	Ref.	Ref.	Ref.
Not ground	0.05 (−0.21, 0.30)	0.12 (−0.14, 0.39)	0.14 (−0.35, 0.63)
Both	−0.03 (−0.22, 0.17)	0.08 (−0.25, 0.41)	0.08 (−0.61, 0.77)
Average serving			
<2 oz	Ref.	Ref.	Ref.
≥2 oz	0.10 (−0.15, 0.35)	0.40 (0.07, 0.74)*	0.23 (−0.01, 0.48)
Years of consumption			
<1 year	Ref.	Ref.	Ref.
1–3 years	−0.08 (−0.95, 0.80)	0.51 (−0.13, 1.16)	0.02 (−0.50, 0.54)
4–10 years	−0.07 (−0.99, 0.85)	0.13 (−0.38, 0.65)	0.18 (−0.40, 0.75)
>10 years	−0.11 (−1.02, 0.79)	0.15 (−0.27, 0.56)	0.18 (−0.28, 0.65)

*p-value <0.05; †p-value <0.001; ††p-value <0.0001.

[a] After adjusting for age, sex, race, age of housing, current and previous lead-related hobbies, current and previous lead-related occupations, household members with lead-related hobbies or occupation.

low-velocity bullets or shot) may reduce an individual's risk of exposure to lead (MN DNR, 2008). Additionally, review and monitoring of meat packing processes may be warranted, since meat from different hunters is typically mixed together during grinding (MN DNR, 2008). These findings have population-wide implications, since a substantial proportion of the population in the United States, including hunters and their families as well as low-income families, consume wild game as a major source of protein and may be exposed to this environmental source of lead.

Disclaimer

The findings and conclusions in this article are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Lead in wild harvested game

Eating game meat harvested with lead bullets increases the risk of lead poisoning. Lead bullets easily fragment when they strike an animal, and people can unintentionally eat them in processed game meat.

Children and pregnant people are more vulnerable to lead poisoning and should not eat any game harvested with lead bullets. The number one thing hunters can do to protect themselves and their families is to only use lead-free ammunition.

Lead poisoning

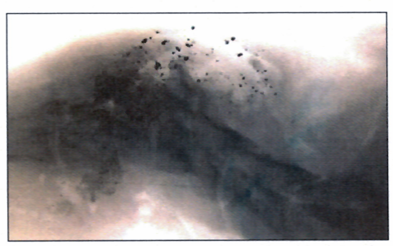
- Lead poisoning in children happens when they eat or inhale small amounts of lead for a long time. There may be no signs or symptoms until dangerous amounts have accumulated in the body.
- Does your child need to be tested for lead? Talk to your health care provider or use this checklist to find out (https://rb.gy/3yognq)

More information

- Health and environmental risks from lead-based ammunition: Science versus socio-politics (doi.org/10.1007/s10393-016-1177-x)
- Health risks from lead-based ammunition in the environment—A consensus statement of scientists. (doi.org/10.1289/ehp.1306945)
- Learn about the risk of lead in indoor shooting and fire ranges (https://rb.gy/hmkk0o
- CDPHE Lead and Health web page (cdphe.colorado.gov/lead-health)

Tips for hunters

- For big game, use monolithic copper projectiles for centerfire rifles. These options provide for little to no fragmentation and controlled expansion. Example brands include Barnes TTSX, Hornady GMX, Nosler Etip, and Federal Trophy Copper. Lead-free bullet options for muzzleloaders include Federal BOR Lok and THOR bullets.
- For turkey and small game, commonly available lead-free shotshell options include steel, bismuth, and tungsten. There are a number of shot options that do not cause toxicity when birds or wildlife swallow or absorb them. (fws.gov/birds/bird-enthusiasts/hunting/nontoxic.php)
- Hunters who use lead ammunition should choose quality hunting-grade ammunition with a "bonded" or "partition" construction. Avoid frangible bullet types such as "cup and core" or "match" bullets, which fragment more easily.
- Ensure commercial meat processors properly clean equipment between animals to avoid lead contamination. All tools and surfaces should be cleaned with hot, soapy water and disinfected with a 10% chlorine bleach solution.



National Park Service

X-ray image showing lead bullet fragments (dark spots) in a mule deer's neck.

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Are lead-free hunting rifle bullets as effective at killing wildlife as conventional lead bullets? A comparison based on wound size and morphology

Anna Trinogga *, Guido Fritsch, Heribert Hofer, Oliver Krone

Leibniz Institute for Zoo and Wildlife Research, P.O. 601103, D-10252 Berlin, Germany

HIGHLIGHTS

- ► Wound diameters do not differ between lead-free and lead-based hunting rifle bullets.
- ► The size of the wound's maximum cross-sectional area does not depend on bullet material.
- ► Lead-free rifle bullets represent a suitable alternative to conventional bullets.
- ► The use of non lead bullets is appropriate to prevent lead deposit in the ecosystem.

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ABSTRACT

Fragmentation of the lead core of conventional wildlife hunting rifle bullets causes contamination of the target with lead. The community of scavenger species which feed on carcasses or viscera discarded by hunters are regularly exposed to these lead fragments and may die by acute or chronic lead intoxication, as demonstrated for numerous species such as white-tailed eagles (*Haliaeetus albicilla*) where it is among the most important sources of mortality. Not only does hunting with conventional ammunition deposit lead in considerable quantities in the environment, it also significantly delays or threatens the recovery of endangered raptor populations. Although lead-free bullets might be considered a suitable alternative that addresses the source of these problems, serious reservations have been expressed as to their ability to quickly and effectively kill a hunted animal. To assess the suitability of lead-free projectiles for hunting practice, the wounding potential of conventional bullets was compared with lead-free bullets under real life hunting conditions. Wound dimensions were regarded as good markers of the projectiles' killing potential. Wound channels in 34 killed wild ungulates were evaluated using computed tomography and post-mortem macroscopical examination. Wound diameters caused by conventional bullets did not differ significantly to those created by lead-free bullets. Similarly, the size of the maximum cross-sectional area of the wound was similar for both bullet types. Injury patterns suggested that all animals died by exsanguination. This study demonstrates that lead-free bullets are equal to conventional hunting bullets in terms of killing effectiveness and thus equally meet the welfare requirements of killing wildlife as painlessly as possible. The widespread introduction and use of lead-free bullets should be encouraged as it prevents environmental contamination with a seriously toxic pollutant and contributes to the conservation of a wide variety of threatened or endangered raptors and other members of the guild of scavengers.

1. Introduction

1.1. Lead intoxications in birds of prey

The impact of lead on the ecosystem represents an important challenge in terms of nature conservation. As lead is a highly toxic heavy metal, efforts have been made for years in order to eliminate it from the environment. Nevertheless, considerable quantities of lead are deposited in the ecosystem by hunting. Conventional hunting rifle bullets contain a lead core partially enclosed by a copper or brass jacket, a type of bullet that is called semi-jacketed. These projectiles fragment on impact on a body, leaving behind a large number of small lead particles (Cornicelli and Grund, 2008; Hunt et al., 2006, 2009b). The oral uptake of such lead fragments may result in severe and often fatal lead poisoning in raptors (Fisher et al., 2006; Hunt et al., 2006; Kenntner et al., 2001; Kramer and Redig, 1997; Krone et al., 2009; Scheuhammer and Templeton, 1998). It is a common practice among hunters to eviscerate hunted wildlife in the field, leaving

* Corresponding author at: Food and Feed Control Authority of the county of Havelland (Landkreis Havelland, Amt für Landwirtschaft, Veterinär- und Lebensmittelüberwachung), Goethestr. 59/60, D-14641 Nauen, Germany. Tel.: +49 3321 4035516; fax: +49 3321 40335516.
E-mail address: anna_trinogga@gmx.de (A. Trinogga).

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Table 1
Bullets employed by hunters in the present study.

Manufacturer and brand name	Bullet type	N
Barnes XLC or TSX	Lead-free deforming bullet	5
Lapua Naturalis	Lead-free deforming bullet	5
RWS Bionic Yellow	Lead-free partially fragmenting bullet	4
Moeller KJG	Lead-free partially fragmenting bullet	2
Reichenberg HDBoH	Lead-free partially fragmenting bullet	5
Norma Vulkan	Bullet with one or two lead-core(s)	1
RWS Evolution	Bullet with one or two lead-core(s)	5
RWS UNI classic	Bullet with one or two lead-core(s)	2
Semi-jacketed	Bullet with one or two lead-core(s)	5

placement, the length of the wound channel (with units mm) and the number of bones crossed by the wound channel. The diameter of identifiable tissue damage was measured at a penetration depth of 0 mm (entry wound) and at distances of every 50 mm along the wound channel (Fig. 1) in units of mm. The size of the maximum diameter (with units mm) of damaged tissue was also determined. The maximum cross-sectional area of the wound channel A_{max} was calculated using the formula for the area of an ellipsis as πab, with a and b being the major and minor axes (with units mm) of the ellipsis, respectively.

2.4. Necropsy

After CT, the animals were thawed and a necropsy was conducted. The locations of entry and exit wounds were noted, the wound channel was examined macroscopically; and injuries were described and documented by photographs (Figs. 2 and 3). We measured the diametres of entry and exit wounds in proximodistal and craniocaudal directions. To calculate the cross-sectional areas A_{entry} and A_{exit} of the wounds we treated them as being elliptic and calculated them as πab with a and b denoting, as before, the major and minor axes of the ellipsis (measured in units of mm). During the preparation of the wound channel, special attention was paid to the colour of mucous membranes and inner organs as well as to the degree to which hypostasis had occurred. These criteria were regarded as markers of the intensity of blood loss (Betz, 2004). We refrained from estimating the angle of bullet entry or grouping cases according to angles of bullet entry as we wanted to evaluate whether lead-free bullet types work well in those situations in which German hunters normally decide to shoot. We also did not expect the angle of the shot to systematically vary with bullet type, so neglecting this factor would not have introduced any kind of bias to the subsequent data analysis.

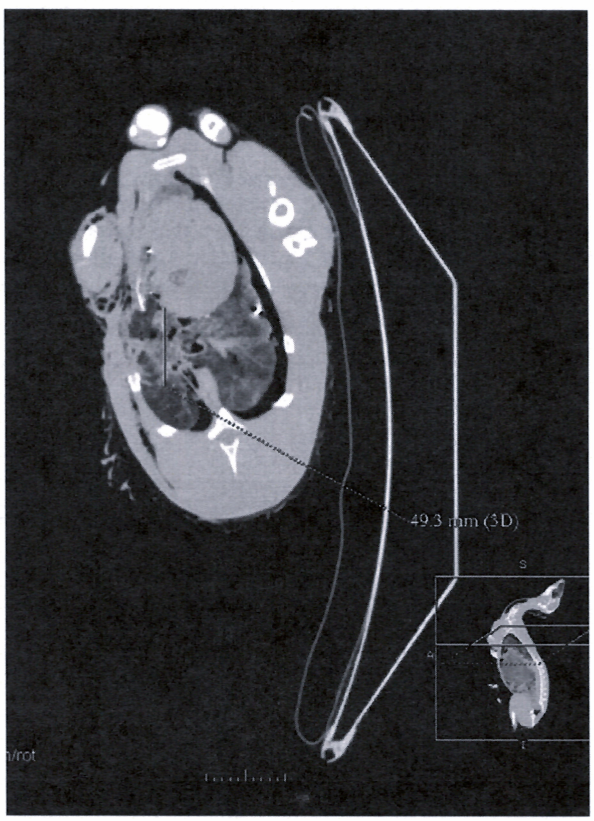

Fig. 1. Axial CT image of a roe deer with measurement of destroyed lung tissue (see inset for orientation).

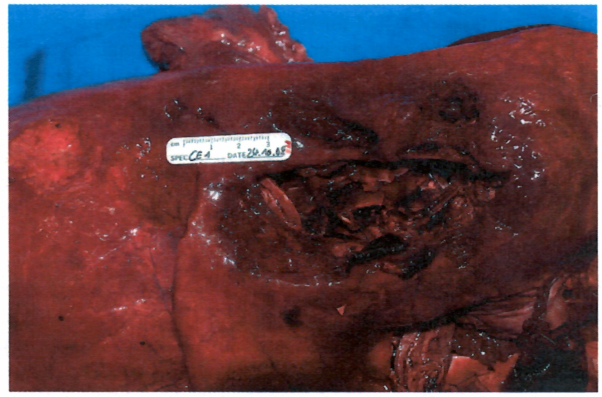

Fig. 2. Lateral view of the lung of a red deer (*Cervus elaphus*) wounded by a conventional lead-core bullet (RWS UNI Classic).

2.5. Statistical analyses

Statistical analyses were conducted in SPSS 18 (SPSS Inc., Chicago, Illinois) and SYSTAT 13 (Systat Inc., Chicago, Illinois). Descriptive statistics are reported as means ± S.E.M, the median, the range of values and the coefficient of variation, a measure of the relative spread of variation as it is estimated as the standard deviation divided by the mean. The significance threshold was set at 0.05 and all tests were two-tailed. Variation between bullet types in terms of sectional density and impact energy were tested with the nonparametric Kruskal–Wallis test, post hoc multiple comparisons performed using the Dwass–Steel–Critchlow–Fligner test. To assess the question whether the type of bullet influences A_{max} we analysed tissue damage measurements with a general linear model (GLM) with A_{max} as the dependent variable and bullet type and the number of bones in the wound tract as independent variables. With regard to wound diameters measured at several defined

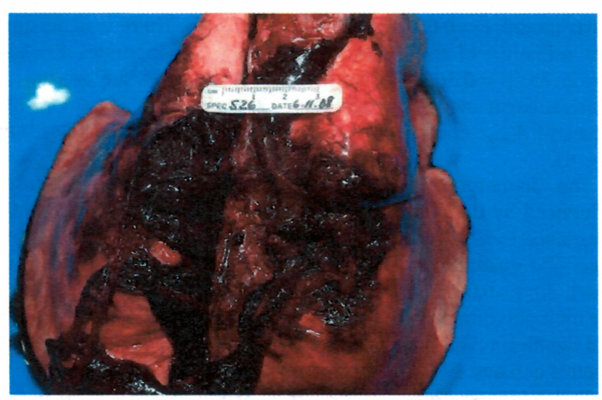

Fig. 3. Lacerations in the lung of a wild boar killed by a lead-free deforming copper bullet (Barnes XLC) (wound channel in laterolateral direction).

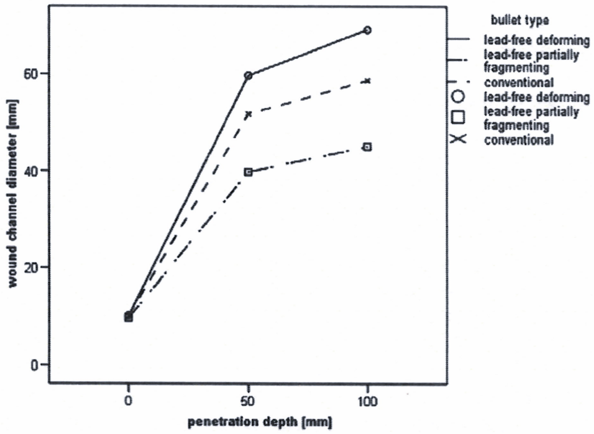

Fig. 5. Estimated marginal means of the wound diameters at three different penetration depths. Wound diameters are significantly larger after 5 and 10 cm penetration than at the entry point. Differences between lead-free types and conventional bullets are not significant.

wound channel was torn and bloody at distances of several centimetres from the wound cavity (Figs. 2 and 3). All animals had injuries to the lungs, 16 had additional injuries to major blood vessels such as the aorta or the *Truncus pulmonalis* and in 17 cases the heart was injured. Eight animals were injured in all three locations.

Except for one case – a wild boar shot with a partially fragmenting lead-free bullet – all bullets exited the bodies. There were no significant differences of the size of entry wounds (Kruskal–Wallis test, $H=1.087$, $df=2$, $p=0.581$) or exit wounds (Kruskal–Wallis test, $H=2.876$, $df=2$, $p=0.237$) between bullet types (Table 2).

4. Discussion

4.1. Wound dimensions and morphology

Our findings show that under real life normal German hunting conditions, with bullets having an impact energy of 1500 to 3500 J, the decision whether a conventional lead-core bullet or a lead-free variety is used does not significantly influence the wounding potential of the shot. According to Spencer (1908), the wounding potential of a projectile depends on its kinetic energy and on its ability to transfer this energy onto the target. The latter is strongly influenced by the sectional density of a bullet which is given by the ratio of its mass to its cross-sectional area. Kneubuehl (2004) states that sectional density is the crucial parameter in ballistics and more important than bullet mass or calibre. As sectional density decreases, wounds become wider and shorter (Sellier and Kneubuehl, 2001). The initial sectional density is lower in lead-free partially-fragmenting bullets than in the other types. As lower sectional density results in wider wounds this might mask the effect of the lower kinetic energy. On the other hand, sectional density changes during the interaction of the bullet with the tissue. In this study it was not possible to assess the shape of the residual bullet. The extent to which sectional density changed in the actual shots could therefore not be evaluated. Data obtained by simulation experiments with ballistic soap (Trinogga et al. unpublished), however, suggest that sectional density in lead-free partially-fragmenting bullets often does not decrease as much by the interaction with the target as in the other bullet types. This may be reflected by the smaller wound diameters caused by this type of projectile. This hypothesis is further supported by the fact that despite of intermediate-sized entry wound surfaces the exit wound surfaces caused by lead-free partially fragmenting bullets tended to be the smallest of all three bullet types, although the differences between bullet types were not significant. The non-significant difference in tissue damage between the lead-free deforming bullets (type 1) and conventional bullets (type 3) – slightly larger diameters with type 1 – may also be a consequence of their different sectional densities.

As our results show, the maximum cross-sectional area of the wound channel is not affected by the choice of bullet type. Wound morphology also does not depend on projectile type, as no significant interaction effect between penetration depth and bullet type could be detected. The diameter of tissue destruction significantly increased between the point of entry and a depth of 5 and 10 cm, respectively. We conclude that each of the three missile types starts dissolving its kinetic energy on target quickly after first contact. These kinetic properties are desirable for hunting small to medium-sized wildlife because wound channels are likely to be short in these animals as body dimensions are small.

Bullets with a lead core did not cause wider wounds at 0, 5 and 10 cm penetration depth than their lead-free counterparts. The only significant difference in this respect concerned the two types of lead-free projectiles. Wounds caused by deforming bullets (type 1) had a larger diameter than those created by partially fragmenting varieties (type 2). Although the difference in impact energy between lead-free deforming bullets (type 1) and lead-free partially fragmenting bullets (type 2) was not statistically significant, the higher energy of the deforming projectiles might be reflected in larger wounds. In contrast, the significantly higher impact energy of conventional lead core bullets (type 3) than lead-free bullets (types 1 and 2) did not induce a significant difference in tissue damage.

4.2. Temporary cavitation and hit placement

The interaction between a bullet and a body is characterised by the phenomenon of the temporary wound cavity (Karger, 2004; Kneubuehl et al., 2008; Sellier and Kneubuehl, 2001). The penetrating bullet causes a radial acceleration of body tissue which is displaced as a consequence and subjected to elongation and shearing forces. The amount of tissue destruction caused by the temporary cavity depends on the elasticity of the organs which are struck — less elastic tissue such as liver (Amato et al., 1974a, 1974b) or brain (Oehmichen et al., 2000) is more severely damaged than muscle or lung, for example, which have a higher elasticity. For this reason we restricted the analysis to shots through the chest. Owing to its high elasticity, the lung is relatively insensitive to damage by the temporary cavity (Karger, 2004). As it collapses when air enters the thorax, measurements in lung tissue are difficult to compare with measurements made in other organs.

An unambiguous differential diagnosis separating the direct impact of the shot from putrefaction and autolysis which arose because of the unavoidable delay between the death of the animal and its freezing can be difficult in abdominal organs (Jackowski et al., 2006) and often was impossible in our study. We therefore refrained from conducting measurements on abdominal viscera. Other shot placements such as the head or the neck were not represented as frequently as would have been necessary for statistical evaluation. We consider that the value of the current study was not restricted by this constraint. A comparison of the wounding potential of bullet types should be based on the analysis of thorax shots because hunters normally aim at the chest since this shot placement allows a rapid killing of the animal and at the same time implies a considerably lower risk of missing and wounding than a shot through the head or neck which theoretically is even more potent. As our study was meant to evaluate real life hunting situations it seems legitimate to confine the analysis to the desired hit placement.

4.3. Cause of death

Schmidt and Madea (1994) report cases of death via vaso-vagal reflexes caused by contusion of the cervical spinal cord through the formation of the temporary cavity. Sellier and Kneubuehl (2001) also mention the theoretical possibility of baroreceptor-mediated reflex

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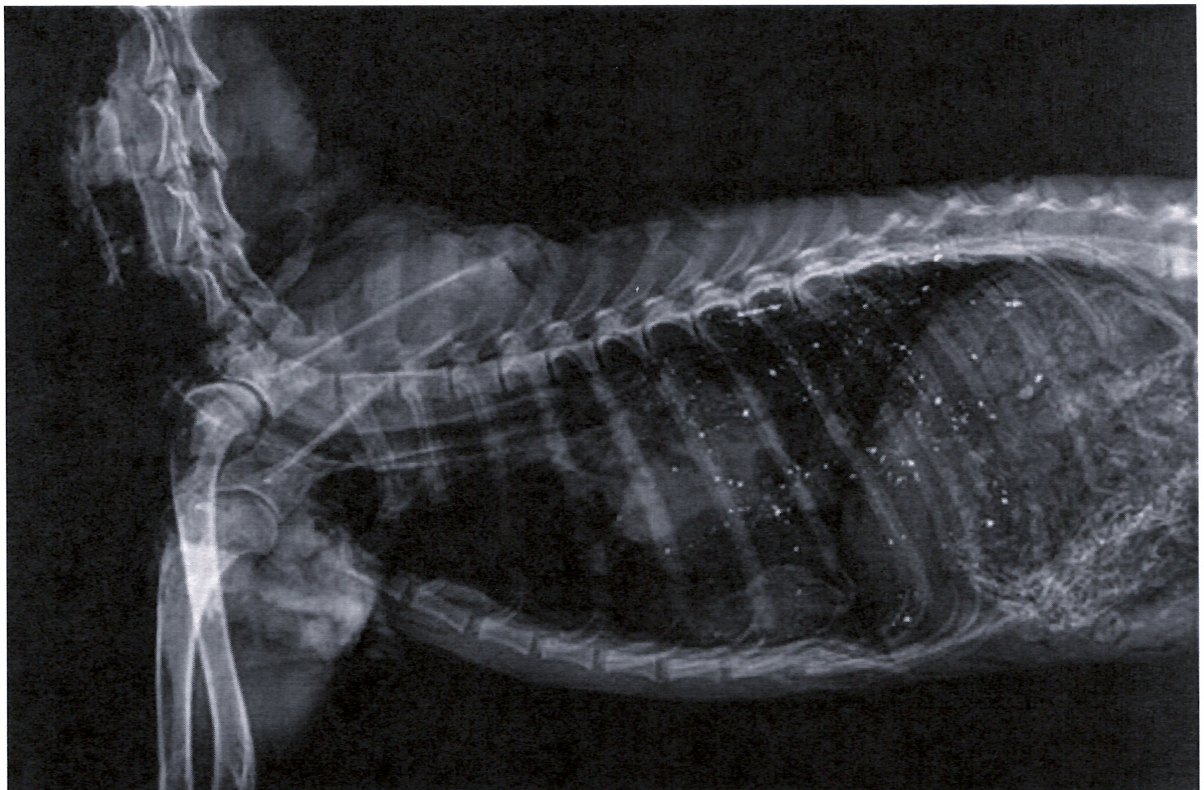
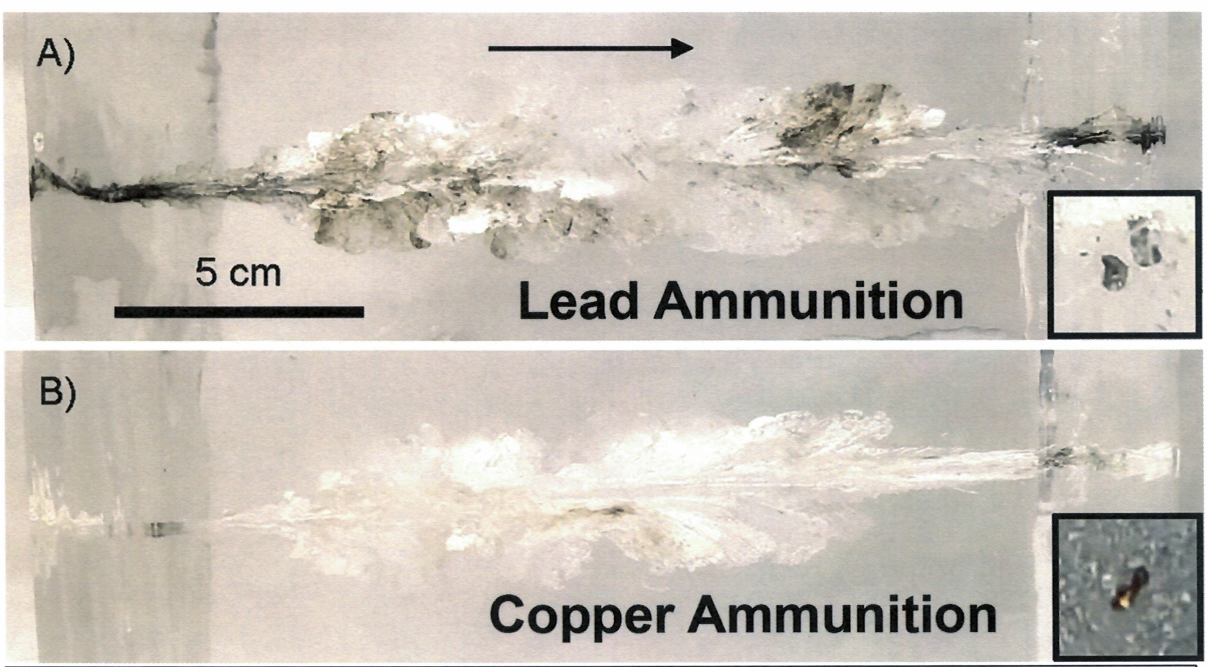


X-Ray showing how lead ammunition can fragment after hitting a game animal.



Comparison of lead and copper ammunition fired through a gel that simulates animal flesh. Note debris from lead versus that of copper.

HOUSE BILL 23-1060:
Updates to State Forest Service Nursery

Colorado needs trees. Reforestation is critical for the state's future.

The Colorado State Forest Service Nursery is the state's leader in producing low-cost, Colorado-grown seedling trees and shrubs for conservation.

The demand is rapidly growing for nursery-grown seedling trees and shrubs to meet several needs:

- Reforest burned areas
- Build climate-resilient watersheds and forests
- Enhance carbon storage to meet the state's climate mitigation goals

The CSFS Nursery needs to update and expand operations to meet this increasing demand for seedlings.

2.66 MILLION ACRES in Colorado could be reforested to mitigate climate change.

Reforesting these areas with approximately 795 million trees could capture 1.77 million tons of CO_2 per year, equivalent to removing 382,000 cars from the road.

SOURCE: The Nature Conservancy and American Forests *(www.reforestationhub.org/state/colorado)*

The East Troublesome Fire and other record-breaking wildfires in Colorado have burned hundreds of thousands of acres of forests. Some may not recover without reforestation.

Seedling trees grown by the CSFS Nursery are critical for restoring forests after floods and wildfires, especially in important watersheds.

The Colorado State Forest Service Nursery has started making upgrades thanks to HB22-1323, but more funds are needed to get the job done.

House Bill 22-1323 provided $5 million to the CSFS Nursery. These funds are being put to good use:

- **Greenhouse upgrades and expansion ($2.7 million)**
- **Shade house structures upgrades and expansion ($2 million)**
- **Growing containers ($70,000)**
- **Capacity, expertise and infrastructure analysis ($40,000)**
- **Temporary staffing to oversee capital improvements and increase production ($190K)**

The assessment funded through HB22-1323 identified over $14 million in needs at the CSFS Nursery. Additional funding would allow the CSFS to address more of those needs:

- **Completion of upgrade and expansion to shade house structures**
- **Bare root field upgrades**
- **Bare root equipment repair and replacement**
- **Seed storage and seedling processing improvements**
- **Delivery trucks**
- **Staffing increase to produce high-quality seedlings and meet production targets**

UP TO 2 MILLION

seedlings a year could be grown at the CSFS Nursery if improvements are made

COLORADO STATE FOREST SERVICE
5060 Campus Delivery
Fort Collins, CO 80523-5060
970•491•6303

csfs.colostate.edu